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INA14 Reston, USA 2013

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INA14 Program

Sunday September 15th

8:00am-4:00pm
Pre-Conference Field Trip - Leave from the main entrance of the Sheraton Reston

4:00pm-6:30pm
Early Registration at the Sheraton Reston

6:30pm-8:30pm
Ice Breaker Reception at the Sheraton Reston

Monday September 16th

7:00am-8:30am - ***Registration Open***

8:30am-9:00am - ***Welcome Speakers***

SESSION I - Taxonomy and Evolution
Chairs: Marie-Pierre Aubry and Jeremy Young

9:00am
Jordan, R.W., McCartney, K., and Witkowski, J., The Melbourne Code: implications for nannofossil and silicoflagellate taxonomy

9:15am
Young, J.R., Bown, P.R., and Lees, J.A., Nannotax-creating a web directory of nannofossil taxonomy

9:30am
Thomsen, H.A., Østergaard, J.B., and Heldal, M., Weakly calcified polar coccolithophorids: the genus Pappomonas revisted

9:45am
McCartney, K., Witkowski, J., *et al*., Fossil and Recent silicoflagellate double skeletons: clues to evolutionary history, taxonomy, and the formation of skeletons

10:00am
de Kaenel, E., A revision of reticulofenestrid taxonomy and biostratigraphy

10:15am-10:45pm – Morning Coffee Break

10:45am-12:00pm
Taxonomy cont'd

10:45am
Henderiks, J., Reitan, T., *et al*., Phenotypic evolution of the "planktic superspecies" Coccolithus pelagicus

11:00am
Bord, D.*, and Aubry, M.-P., Patterns of morphological evolution in the Tribrachiatus lineage: a geometric morphometric study

11:15am
Hagino, K., Onuma, R., *et al*., Relationships among Braarudosphaera bigelowii, Chrysochlomulina parkeae, and the prymnesiophyte host of the cyanobacterium UCYN-A

11:30am
Aubry, M.-P., and Bord, D.*, The Order Discoasterales—taxonomy and phylogenetic reconstruction

SESSION II -
Biostratigraphy and Boundary Events (part I)
Chairs: Richard Howe and David Watkins

11:45am
Erba, E., Da-Yong, J., *et al*., The oldest calcareous nannofossils: Middle Triassic coccoliths from China

12:00pm-1:30pm - ***Lunch Break***

1:30pm- 3:15pm
Biostratigraphy and Boundary Events (part I) cont'd

1:30pm
Fraguas, Á., Herrle, J.O., *et al*., Biostratigraphy of Lower Jurassic calcareous nannofossils from the Schandelah core (NW Germany)

1:45pm
Mattioli, E., Recent advances in calcareous nannofossil biostratigraphy across the Pleinsbachian-Toarcian boundary in the Peniche section, the GSSP candidate, and comparisons with other Tethyan settings

2:00pm
Ferreira, J., Mattioli, E., *et al*., Advances on calcareous nannofossil biostratigraphy based on Toarcian-Aalenian sections from the Lusitanian Basin (Portugal)

2:15pm
Rai, J., When did the Jurrassic Sea date the western Indian craton: revelations by nannofossils

2:30pm
Stoykova, K., Ivanov, M., and Idakieva, V., Calibration of calcareous nannofossil and ammonite bio-events across the Jurassic-Cretaceous boundary: a case study from Bulgaria

2:45pm
Russo, F.*, Erba, E., and Bottini, C., The calcareous nannofossil record in the Cenomanian-Turonian boundary interval: implications for regional and global correlations

3:00pm
Corbett, M.J., Watkins, D.K., and Pospichal, J.J., Quantitative analysis of calcareous nannofossil bioevents of the Late Cretaceous (late Cenomanian-Coniacian) Western Interior Seaway and their relative reliability

3:15pm-3:45pm - ***Afternoon Coffee Break***

3:45pm-4:30pm
Biostratigraphy and Boundary Events (part II)
Chairs: Eric de Kaenel and Mike Styzen

3:45pm
Wagreich, M., Nannofossil biostratigraphy in the Campanian – a Tethyan perspective

4:00pm
Garg, R., Rai, J., and Singh, A., Calcareous nannofossils across the K-T boundary at Um Sohryngkew, Meghalaya, northeastern India

4:15pm
Dunkley Jones, T., Moore, T., *et al*., Integrated microplankton records of equatorial Pacific ecosystem perturbations across the Eocene-Oligocene transition

4:30pm-5:15pm
Keynote Talk: Dr. Brian Huber, Datum chasing toward an improved Cretaceous time scale

5:30pm-7:00pm
Evening Poster Session

Tuesday September 17th

8:15am-10:15am **SESSION II -**
Biostratigraphy and Boundary Events (part II) cont'd

8:15am
Alqudah, M.*, Mutterlose, J., *et al*., Calcareous nannofossil biostratigraphy of oil shales from central Jordan

8:30am
Fernando, A.G.S., Fernandez, A.R.C., *et al*., Calcareous nannofossil biostratigraphic studies in the Visayan Basin (central Philippines)

8:45am
Aljahdali, M.*, Alsuwailem, A., *et al*., Pliocene-Pleistocene calcareous nannofossil biostratigraphy of IODP Hole 1396C (adjacent to Montserrat Island in the Lesser Antilles) and experimentally induced diagenesis

9:00am
Flores, J.-A., Balestra, B., *et al*., Preliminary Pleistocene calcareous nannofossil biostratgraphy for IODP Site 1385 (Shackleton Site)

9:15am
Barbarin, N., Beaufort, L., *et al*., Automated recognition of calcareous nannofossils: an application for quantitative biostratigraphy

SESSION III – Biogeography and Ecology
Chairs: Barbara Balestra and Jose Abel-Flores

9:30am
Villarosa Garcia, M. and Porter, J.J., The effect of coccolith shape on coccolithophore fluid dynamics

9:45am
Agbali, A., Avery, A., *et al*., Reconstruction of calcareous nannoplankton assemblages present along the Florida Continental Margin during the 2010 Macondo Oil Spill in the Gulf of Mexico

10:00am
Luan, O., Sun, J., and Want, J., Composition and distribution of living coccolithophores in the Yellow Sea and East China Sea

*10:15am-10:45pm - **Morning Coffee Break***

10:45am-12:00pm
Biogeography and Ecology cont'd

10:45am
Malinverno, E., Cerino, F., *et al*., Seasonal patterns of coccolithophores, silicoflagellates, and ebridians from a coastal time series in the Gulf of Trieste (North Adriatic Sea)

11:00am
Saavedra-Pellitero, M., Baumann, K.-H., *et al*., Biogeographic distribution of living coccolithophores in the Pacific sector of the Southern Ocean

11:15am
Jin, X.*, Liu, C., and Liang, D.,* Distribution and malformation of extant coccolithophores in the East China Sea in summer, 2011

11:30am
Peleo-Alampay, A.M., Marquez-Ardiente, D.J.D.*, *et al*., Coccolithophore flux in sediment traps from northern South China Sea

11:45am
Cabarcos, E.*, Flores, J.-A., and Sierro, F.J., What governs the productivity of coccolithophores in the Eastern Equatorial Pacific?

*12:00pm-1:30pm - **Lunch Break***

1:30pm- 3:15pm
Biogeography and Ecology cont'd

1:30pm
Ausín, B., Flores, J.-A., *et al*., High-resolution analysis of coccolithophore assemblages and SST-Mg/Ca- derived records in the western Mediterranean Sea during the Holocene: productivity reconstruction in an upwelling region

1:45pm
López-Otálvaro, G.-E., Flores, J.-A., *et al*., Patterns and mechanisms of calcareous nannoplankton productivity and upwelling in the western Tropical Atlantic: interplay between the Intertropical Convergence Zone and the Northern Hemisphere

2:00pm
Liang, D.*, Chuanlian, L., and Beaufort, L., Upper water structure and primary productivity variations

of the central West Pacific Warm Pool in the last ~380kyr

SESSION IV – Industry and Techniques
Chairs: Alicia Kahn and Jamie Shamrock

2:15pm
Kadar, A.P., Crespo, S., and Karam, K.A., Middle to Upper Jurassic calcareous nannofossil biostratigraphy, onshore North Kuwait

2:30pm
Fuertes, M.A.*, Flores, J.-A., and Sierro, F.J., A new technique for observing calcareous nannofossils: Methodology and applications

2:45pm
Blaj, T., Cole, S., *et al*., An industrial revolution: a comparison of industry and research nannofossil quatitative counting techniques

3:00pm
Shamrock, J.L., Munoz, E., and Carter, J.H., An improved sample preparation technique for calcareous nannofossils in organic-rich mudstones

*3:15pm-3:45pm - **Afternoon Coffee Break***

3:45pm-5:00pm
Industry and Techniques cont'd

3:45pm
Weber, R.D., Febo, L., *et al*., Integrated geochronology: how microscopic fossils influence the design of deepwater production facilities

4:00pm
Scheuth, J.*, Keller, K., *et al*., The Probable Datum Method (PDM): a statistical technique for determining the true age of nannoplankton origination or extinction

4:15pm
Sheldon, E., Ineson, J., *et al*., Nannofossil biostratigraphy and paleoecology of the Danish Lower Cretaceous reservoir chalks (Tuxen and Sola Formations)

4:30pm
Cachão, M., Robust biostratigraphers's "feeling": multivariate ecostratigraphy biosteering (MEB)

4:45pm
de Gama, R., A review of late Oligocene to mid-Miocene sphenolithids from DSDP Leg 94, Site 608 and DSDP Leg 25, Site 242

Wednesday September 18th

WORKSHOPS AND PLENARY TALK AT THE US GEOLOGICAL SURVEY

9:00am-11:30am
Perspectives in Coccolithophore Biogeography: From Coastal to Deep Sea Organizers: Barbara Balestra and José Abel-Flores (Ric Jordan = alternate)

9:00am-11:30am
Nannoconus/Polycostella/Micrantholithus/ Braarudosphaera Group in the Tithonian and Berriasian
Organizer: Richard Howe

*11:30am-1:00pm - **Lunch Break (USGS Cafeteria)***

1:00pm-3:15pm
The Collection and Interpretation of Coccolithophore-derived Geochemical Data
Organizer: Tom Dunkley Jones

1:00pm-3:15pm
Reticulofenestrid Taxonomy
Organizer: Eric de Kaenel

3:30pm-4:15pm
Plenary Talk: Dr. Barney Balch, The Great Calcite Belt-Read My Liths!

6:30pm-10:30pm
Conference Dinner: Sunset Hills Winery, catered by Magnolia's at the Mill **Buses leave at 5:30pm from the Sheraton Hotel**

Thursday September 19th

8:15am-10:15am **SESSION V - Environmental Controls on Coccolithophore Calcification**
Chairs: Tom Dunkley Jones and Baptiste Suchéras-Marx

8:15am
Cachão, M., Coccolithophore response to cadmium – preliminary results from Project Cd-ToxCoN

8:30am
Šupraha, L.*, Gerecht, A., *et al*., Is phosphate availability significant to the morphological diversity within Helicosphaera carteri?

8:45am
Gerecht, A., Šupraha, L.*, *et al*., Phosphorus limitation does not change the ratio of calcite to organic carbon in Coccolithus spp.

9:00am
Young, J.R., and Tyrell, T., Cruise-based multi-factorial investigation of the impact of ocean acidification on the pelagic biosphere

9:15am
Beaufort, L., de Garidel-Thoron, T., *et al*., Recent decline in pelagic calcification offshore of the Sepik River in the Western Pacific Warm Pool

9:30am
Meier, K.J.S., Bauke, C., and Kinkel, H., Coccolith

calcification changes during glacial terminations in the North Atlantic Ocean

9:45am
Bordiga, M., Cobianchi, M., *et al*., Calcareous nannofossil contribution to carbonate export during the last 450 ka in the NW Pacific Ocean (Shatsky Rise)

10:00am
O'Dea, S.A., Gibbs, S.J., *et al*., A cellular perspective on coccolithophore growth and biomineralization at the Paleocene-Eocene Thermal Maximum

*10:15am-10:45pm - **Morning Coffee Break***

10:45am-12:15pm
Environmental Controls on Coccolithophore Calcification cont'd

10:45am
Faucher, G.*, Erba, E., and Bottini, C., Life in extreme oceans: calcareous nannoplankton adaptations and strategies during Oceanic Anoxic Event 2

11:00am
Suchéras-Marx, B., Mattioli, E., *et al*., History of the oceanic carbonate cycle based on calcareous nannofossil absolute abundance and flux in the past 190 Myr

SESSION VI - Enivironments, Climate and Oceans
Chairs: Mario Cachão and Karl-Heinz Baumann

11:15am
Bottini, C., Erba, E., *et al*., Climatic and ecological changes during the Aptian traced by calcareous nannofossils and oxygen isotopes

11:30am
Hassanein, W.*, Giraud, F., *et al*., Paleoenvironmental conditions during the late Aptian-early Albian in the Essaouira-Agadir Basin (Morocco): evidence from sedimentology, calcareous nannofossils, and carbon and oxygen isotope records

11:45am
Giraud, F., Reboulet, S., *et al*., The mid-Cenomanian event in a Tethyan section (Blieux, SE France): integrated stratigraphy and paleoenvironmental conditions

12:00 noon
Linnert, C., Lees, J., *et al*., Calcareous nannofossils and Late Cretaceous climate cooling: Campanian through Maastrichtian assemblages from the Evans-Shuqualak borehole (Mississippi)

*12:15pm-1:30pm - **Lunch Break***

1:30pm-3:15pm
SESSION VI -
Enivironments, Climate and Oceans cont'd

1:30pm
Singh, A., and Rai, J., A Late Cretaceous cocktail of cold and warm water nannoflora from Jaisalmer, western India and its paleobiogeographic implications

1:45pm
Bralower, T.J., Schueth, J., and Jiang, S., Extinction risk of phytoplankton species to potential killing mechanisms at the Cretaceous-Paleogene boundary

2:00pm
Kulhanek, D.K., Taylor, M.J.S., *et al*., Calcareous nannofossils tie organic-rich sedimentation in the SW Pacific to an early late Paleocene climatic event

2:15pm
Prentice, K.*, Dunkley Jones, T., *et al*., The effects of climate change on coccolithophore productivity over the Eocene-Oligocene transition

2:30pm
Martinez-Sanchez, M.*, Flores, J.-A., Sierro, F.J. *et al*., Reconstruction of surface-water dynamics at IODP Site U1314 during the MPT (MISs, 30-19) based on coccolithphore analyses

2:45pm
Amore, F.O., Palumbo, E., *et al*., High-resolution coccolithophore analyses in the Atlantic Ocean and in the Tyrrhenian Sea: paleoenvironmental and paleoclimatic changes during the middle Pleistocene and Holocene

3:00pm
Álvarez, C.M., Cros, L., and Alonso, B., Pleistocene and Holocene climatic events in the Alboran Sea (western Mediterranean Sea)

3:15pm
Triantaphyllou, M.V., Coccolithophore assemblages during sapropel S1 deposition in the NE Mediterranean Sea: paleoceanographic and paleoclimatic implications

*3:30pm-4:00pm - **Afternoon Coffee Break***

4:00pm-5:00pm
INA Biannual Business Meeting

Friday September 20th

7:30am
Leave for Post-Conference Field Trip from Sheraton Hotel

Saturday September 21st

5:00pm
Return from Post-Conference Field Trip to Sheraton Hotel

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* - *denotes student*

KEYNOTE ADDRESS

Datum Chasing Toward an Improved Cretaceous Time Scale

Brian T. Huber
Department of Paleobiology, Smithsonian Institution, Washington, DC 20013 USA

The Cretaceous is the longest Period of the Mesozoic Era (ca. 80 million years) and includes 12 stages that are correlated worldwide. However, only three GSSPs (Global Stratotypes, Sections and Points) have been ratified (Maastrichtian, Turonian, and Cenomanian bases), one is awaiting final ratification by the IUGS (Santonian base; Olazagutia, N. Spain), one is in review (Coniacian base; Salzgitter-Vistula, N. Germany-Poland), and one proposal was rejected (Albian base, Tartonne section, France). There are currently no proposals being considered for the remaining six stage boundaries. The main shortcomings of the unratified Cretaceous stage boundaries include the traditional use of macrofossils as key defining criteria, despite their frequently limited paleogeographic distribution, and emphasis of sections proposed from northern Europe in epicontinental sea settings. While the goal for correlating stratotype sections globally by integrating micro- and macrofossil biostratigraphies with magneto- and chemostratigraphic events is now widely supported, progress has been hampered by poor coordination of research efforts and the need for better quality and higher resolution bio- and chemostratigraphic data.

The greatest refinements to Cretaceous chronostratigraphy have been achieved for the Campanian and Maastrichtian intervals with development of well calibrated age-depth curves from multiple deep-sea sites, restudy of planktic foraminiferal ranges in the classic magnetostratigraphy section at Gubbio, Italy, and orbital tuning of high-resolution carbon isotope records from a number of important pelagic chalk sections. Detailed taxonomic and biostratigraphic studies of exceptionally well-preserved foraminiferal assemblages from land-based Cenomanian-Campanian boreholes drilled in coastal Tanzania and deep-sea sites on Blake Plateau (North Atlantic), Falkland Plateau (South Atlantic), and Shatsky Rise (North Pacific) have been particularly valuable for recognition of new Aptian-Campanian foraminiferal bioevents that can be globally correlated. Careful integration of planktic foraminiferal and calcareous nannofossil events at these and other Cretaceous sections, and evaluation of their reliability for global correlation, is essential to further improvements in the Cretaceous time scale and establishment of a new basis for defining GSSPs for the remaining unratified Cretaceous stage boundaries.

PLENARY ADDRESS

The Great Calcite Belt – "Read my liths!"

William M. Balch
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We have surveyed half the region of the Southern Ocean known as the Great Calcite Belt (GCB) in the Atlantic and Indian sectors. The GCB has been known for its elevated satellite-derived reflectance, but there has been little information about the coccolithophores that live in it, controls on growth, or consequences to the carbon cycle and biogeochemical pump. Microscopy performed on water samples revealed abundant *Emiliania huxleyi* off the Patagonian shelf, with increasing numbers of other coccolithophore species going eastward. GCB coccolithophore features were typically associated with frontal boundaries, showing seawater pCO^2 50-150µatm higher than non-GCB regions of the Southern Ocean. GCB waters were usually high-nutrient-low-chlorophyll and coccolithophore-rich waters of the GCB had increased calcification rates (>10% of integrated primary production). Three-quarters of shipboard ocean acidification experiments showed significant declines in coccolith concentration following exposure to increasing pCO^2 (up to 1200 ppm). Dilution experiments hint to a more complex community response to ocean acidification. The implications of these results will be discussed relative to the greater problem of ocean acidification.

INA14 attendees are eligible for 10% discount. Sign up at registration desk.

Reconstruction of calcareous nannoplankton assemblages present along the Florida Continental Margin during the 2010 Macondo Oil Spill in the Gulf of Mexico

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Calcareous nannoplankton are important protist constituents of the base of the food chain along the continental margin off the Florida Panhandle. However, no quantitative studies have been published on their abundance and seasonal variability in this region. Thus, the effects of the BP Macondo Oil Spill on these skeletal-bearing phytoplankton can only be determined by after-the-fact measurements and comparisons with unpublished data. We report here preliminary results of a study in progress: the first step in the reconstruction of nannoplankton populations at the time of the spill. We began monthly sampling in January 2011, along three transects across the shelf of the Florida Panhandle. We have taken over 1000 samples through the photic zone, via Niskin-bottle rosettes, from which quantitative nannoplankton census data are being taken via scanning electron microscopy. Our goal is to use these data to predict the effects of any future oil spills in the Gulf of Mexico on calcareous nannoplankton.

Pliocene–Pleistocene calcareous nannofossil biostratigraphy for IODP Site 1396C (adjacent to Montserrat Island in the Lesser Antilles) and experimentally induced diagenesis

Mohammed Aljahdali*
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Integrated Ocean Drilling Program (IODP) Site 1396C, adjacent to Montserrat Island in the Lesser Antilles, provides a lower Pliocene to Pleistocene record of calcareous nannofossil assemblages (Zones CN11 to CN15). The nannofossil assemblages are generally common to abundant with moderate preservation in upper Pleistocene sediments, and very abundant with good preservation in lower Pleistocene to Pliocene sediments. The sequence was zoned via the Gartner (1977) scheme for the Pleistocene and the Okada & Bukry (1980) zonation for the Pliocene, using the recent age updates from Backman *et al*. (2012).

Nannofossil biostratigraphy suggests that there were low sedimentation rates in the Pleistocene and high sedimentation rates during the Pliocene. This sedimentation pattern was also observed at Site 1000 from Ocean Drilling Program Leg 165 in the central Caribbean Sea, which indicates that there was a regional event caused by the closure of the Central American Seaway.

During the expedition (IODP 340), selected samples from Sites 1396A and 1396C were used to determine sediment water content by heating them to 105°C at room pressure for 24 hours. This process produced an abnormal "late diagenesis" effect with severe overgrowth features on the nannofossils. Further examination of these samples should provide a better understanding of the progression in carbonate diagenesis in cases of high temperatures.

References

Backman, J., Raffi, I., Rio, D., Fornaciari, E., & Palike, H. 2012. Biozonation and biochronology of Miocene through Pleistocene calcareous nannofossils from low and middle latitudes. *Newsletters on Stratigraphy*, **45**: 221-224.

Gartner, S. 1977. Calcareous nannofossil biostratigraphy and revised zonation of the Pleistocene. *Marine Micropaleontology*, **2**: 1-25.

Okada, H. & Bukry, D. 1980. Supplementary modification and introduction of code numbers to the low-latitude coccolith biostratigraphic zonation (Bukry, 1973; 1975). *Marine Micropaleontology*, **5**(3): 321-325.

Calcareous nannofossil biostratigraphy of oil shales from central Jordan

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Total organic carbon (TOC) -rich marls of Cretaceous age are widespread throughout Jordan and adjoining areas. Based on foraminifera (Futyan, 1976; Yassini, 1979), these oil shales have previously been assigned a late Campanian-Paleocene age. A total of 214 smear slides from two sections in central Jordan were investigated for calcareous nannofossil biostratigraphy by using light microscopy. These new findings suggest a much more restricted age range for deposition of the oil shales than was previously thought. The oil shales that were studied contain abundant calcareous nannofossils of Maastrichtian age, but also contain taxa of Eocene age. The occurrence of *Discoaster sublodoensis*, *Nannotetrina quadrata*, and *Discoaster bifax* gives these strata an early to middle Eocene age, while the Cretaceous forms indicate major reworking. The Cretaceous taxa reflect either subaerial erosive input from the hinterland or submarine reworking of Cretaceous strata within the basin itself.

References

Futyan, A.I. 1976. Late Mesozoic and Early Cainozoic benthic foraminifera from Jordan. *Paleontology*, **19**(3): 517-537.

Yassini, I. 1979. Maestrichtian-lower Eocene biostratigraphy and the planktonic foraminiferal biozonation in Jordan. *Revista Española de Micropaleontología*, **11**, 5-57.

Pleistocene and Holocene climatic events in the Alboran Sea (western Mediterranean Sea)

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Coccolith abundance, stratigraphy, and geophysical data from the ALM6 gravity core, located in the Alboran Sea (Almeria margin, 36.35°N 2.61°W, 1456 m), were analyzed in order to observe possible climate variability during the last 20 ka. Five turbidite events were identified in the ALM6 core. Four turbidites were located in the Pleistocene part of the core, and the most recent turbidite was at the top of the core. No clear correlation was observed between coccolith abundance and the presence of the turbidites.

We recognized some climatic events, primarily based on the total abundance of the coccolith assemblage and the abundance of *Oolithotus fragilis*, which was reported as a warm-water and oligotrophic taxa (Okada & McIntyre, 1979). The most significant events were the cold Younger Dryas (YD) event and an additional cool event at 8.2 ka. Among the warm events, deglaciation terminations, the Holocene hypsithermal period, and the event at 3.2 ka were recognized.

The most significant occurrences of high coccolith abundances were observed at 7.5 ka and 3.2 ka. The 7.5 ka occurrences could be related to the "Hypsithermal" period in the Holocene (Boudreau *et al*., 2001), and the 3.2 ka occurrences could be indicative of drier and cooler conditions (Lee-Thorp *et al*., 2001). Two other periods of high nannofossil abundances occurred in the lower part of the core and could be related to earlier warm periods associated with deglaciation terminations.

The lowest values in total abundance occurred during the Pleistocene. Moreover, two other low abundance intervals could be identified using the abundance of *O. fragilis*. One of them was located at 11.5 ka, which coincides with the Younger Dryas, and the other was at 8.2 ka (de Menorcal *et al*., 2000).

References

Boudreau, R.E.A., Patterson, R.T., Dalby, A.P. & McKillop, W.B. 2001. Non-marine occurrence of the foraminifer Cribroelphidium gunteri in northern Lake Winnipegosis, Manitoba, Canada. *Journal of Foraminiferal Research*, **31**(2): 108-119.

de Menorcal, P., Ortiz, J., Guilderson, T. & Sarnthein, M. 2000. Coherent high- and low-latitude climate variability during the Holocene Warm Period. *Science*, **228**: 2198-2202.

Lee-Thorp, J.A., Holmgren, K., Lauritzen, S.E., Linge, H., Moberg, A., Partridge, T.C., Stevenson, C. & Tyson, P.D. 2001. Rapid climate shifts in the southern African interior throughout the mid to late Holocene. *Geophysical Research Letters*, **28**(23): 4507-4510.

Okada, H. & McIntyre, A. 1979. Seasonal distribution of modern coccolithophores in the western North Atlantic Ocean. *Marine Biology*, **54**: 319-328.

High-resolution coccolithophore analyses in the Atlantic Ocean and in the Tyrrhenian Sea: paleoenvironmental and paleoclimatic changes during the middle Pleistocene and Holocene

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High-resolution coccolithophore analyses of sediment cores in the Atlantic Ocean (Amore *et al*., 2012; Palumbo *et al*., 2013a, b) and the Mediterranean Sea (Amore *et al*., 2004) have been carried out. Comparison between these areas improves the knowledge of global and local climate change that occurred at different time scales during the middle Pleistocene to Holocene. Reconstructions of water mass variability and paleoproductivity patterns were performed in order to identify paleoenvironmental and paleoclimatic changes. In the time interval from 535 to 300 ka (Marine Isotope Stage (MIS) 13/14 boundary to MIS 9), analyses highlighted the occurrence of climatic and paleoceanographic variability on precessional timescales that are superimposed on well-known long-term changes. These climatic variations are related to changes in regional surface-water circulation patterns and to the migration of the Intertropical Convergence Zone and the Azores High Pressure System. A similar evolution was also observed during MIS 18/19 and in the last 24 ka. Furthermore, millennial-scale oscillations and changes in paleoproductivity were also recognized during MIS 19, MIS 11, and MIS 1. Comparison of these interglacial events improved the understanding of global climatic dynamics, thus providing new insights on future climate evolution.

References

Amore, F.O., Caffau, M., Massa, B. & Morabito, S. 2004. Late Pleistocene-Holocene paleoclimate and related paleoenvironmental changes as recorded by calcareous nannofossils and planktonic foraminifera assemblages in the southern Tyrrhenian Sea (Cape Palinuro, Italy). *Marine Micropaleontolgy*, **52**: 255-276.

Amore, F.O., Flores, J.A., Voelker, A.H.L., Lebreiro, S.M., Palumbo, E. & Sierro, F.J. 2012. A middle Pleistocene Northeast Atlantic coccolithophore record: paleoclimatology and paleoproductivity aspects. *Marine Micropaleontology*, **90-91**: 44–59.

Palumbo, E., Flores, J.A., Perugia, C., Emanuele, D., Petrillo, Z., Rodrigues, T., Voelker, A.H.L. & Amore, F.O. 2013a. Abrupt variability of the last 24 ka BP recorded by coccolithophore assemblages off the Iberian Margin (core MD03-2699). *Journal of Quaternary Science*, **28**(3): 320–328.

Palumbo, E., Flores, J.A., Perugia, C., Petrillo, Z., Voelker, A.H.L. & Amore, F.O. 2013b. Millennial scale coccolithophore paleoproductivity and surface water changes between 445 and 360 ka (Marine Isotope Stages 12/11) in the Northeast Atlantic. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **383–384**: 27–41.

Climate variability at the North Aegean Sea (eastern Mediterranean Sea) during the last two millennia: coccolithophore evidence

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We present the first high-resolution record of climate variability and ecosystem response in the sensitive area of the North Aegean (eastern Mediterranean Sea) for the last two millennia. A core that was retrieved from the North Aegean Sea (M2: 40º05'N 24º32'E, 1018 m) was sectioned at 0.5-cm intervals and dated using 210Pb and radiocarbon techniques. Past sea surface temperatures (SSTs) were reconstructed using the alkenone unsaturation index (Uk'37), while water column stratification and net primary production were evaluated from coccolithophore indices.

During the Medieval Climate Anomaly (MCA; 900-1250 AD), higher values of *Florisphaera profunda* and *Braarudosphaera bigelowii* supported the establishment of low-salinity, stratified waters and the onset of a nutrient-rich environment in the deep photic zone. The onset of the MCA is characterized by a marked increase in SST (1.1ºC) that averages 16.3º C during this period. The SST record reveals significant variability with marked cool and warm intervals. Interestingly, the onset of the Little Ice Age (LIA) (~1250 AD) is marked by an incremental increase in SST, and values reached as high as 19.5ºC in approximately the mid 1600's. In agreement with SST trends, the increased coccolithophore stratification (S) index between ~1350-1650 AD points to increased development of the Deep Chlorophyll Maximum and a subsequent increase in *Florisphaera profunda*.

After a sharp decrease in the SST at approximately 1700 AD, the last three centuries indicate rising SST by about 0.6ºC/100 yrs. This trend is accompanied by a prominent increase in warm coccolithophore species (*Discosphaera tubifera*, *Rhabdosphaera clavigera*, *Calciosolenia* spp., *Umbellosphaera tenuis*, *Pontosphaera* spp., and *Syracosphaera* spp.). In the colder phase of the LIA (~1700 AD, Maunder solar minimum), stratification decreased, and productivity increased due probably to enhanced winter mixing conditions, following SST minima. Finally, during the Instrumental Period (IP; 1850-2010 AD), SST rose significantly, drastically impacting algal productivity in the euphotic zone, primarily represented by *Emiliania huxleyi* and *Rhabdosphaera* spp.

The Order Discoasterales—taxonomy and phylogenetic reconstruction

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Coccolithophores play a determinant role in our quest for understanding the modes, tempo, and causes of the major events that have punctuated Earth history. This understanding necessitates a sound documentation of evolutionary patterns, which can only be achieved via a sound approach to taxonomy. Molecular biology has validated the morphostructural approach to coccolithophore taxonomy, which lends strong support to the classification of the Cenozoic coccolithophores into five extant and five extinct orders, and 46 families (including *Incertae Sedis*) (Aubry, 2013-2015). We are extending this approach to the Mesozoic coccolithophores, which shows that, contrary to current understanding, all Cenozoic orders originated in the early Mesozoic whereas several Mesozoic orders became extinct in the Late Cretaceous. We discuss here the Order Discoasterales that has regrouped a myriad of unrelated genera since its introduction by Hay (1977) and despite Prins' earlier determination (1971) of the Mesozoic origin of the order and his documentation of the Paleocene diversification of the most prominent genera of the order (e.g., *Sphenolithus*, *Fasciculithus* [s.l.], and *Discoaster* [s.l.]). *Biantholithus* is a pivotal genus in the evolutionary history of the Discoasterales, from which the Cenozoic lineages can be seen to sequentially evolve at the same time as the Mesozoic lineages can be reconstructed backward in time. The term *coccolith* has rarely been used in reference to the Discoasterales although it is easy to determine how a typical Mesozoic coccolith was transformed into a *nannolith* (a superfluous term, at least with reference to the Order Discoasterales). This, plus the *Biantholithus* coccosphere, firmly places the Discoasterales among the coccolithophores. Their coccoliths are heterococcoliths, consisting of up to three structural units composed of elements arranged in cycles. Mesozoic Discoasterales diversified along several lines, producing generally short-lived lineages. In contrast, Cenozoic Discoasterales diversified into two long-lived major lineages that diverged across the early-middle Paleocene boundary, beginning in the latest Danian. The forcing mechanisms that resulted in generic and species diversification are explained in terms of mixotrophic physiology (Aubry, 2009; Aubry *et al*., 2012).

References

Aubry, M.-P. 2009. A sea of Lilliputians. *Palaeogeography*, *Palaeoclimatology*, *Palaeoecology*. **284**(1-2): 88-113. 10.1016/j.palaeo.2009.08.020.

Aubry, M.-P. 2013-2015. *Cenozoic coccolithophores*. New York: Micropaleontology Press. Atlas of Micropaleontology series. CC-D: Braarudosphaerales, 2013 (published), 327pp.

Aubry, M.-P., Rodriguez, O., Bord, D.*, Godfrey, L., Schmitz, B. and Knox, R.W.O'. B. 2012. The first radiation of the fasciculiths: morphologic adaptations of the coccolithophores to oligotrophy. *Austrian Journal of Earth Sciences*, **105**(1): 29-38.

Hay, W.W. 1977. Calcareous nannofossils. *In:* A.T.S. Ramsay (Ed). *Oceanic micropaleontology*. Academic Press, London: **2**: 1055-1200.

Prins, B. 1971. Speculations on relations, evolution, and stratigraphic distribution of discoasters. *In:* A. Farinacci (Ed). *Proceedings of the II Planktonic Conference, Roma*, 1970, **1**: 1017-1037. Rome: Edizione Tecnoscienza.

High-resolution reconstruction of productivity using coccolithophores in two sites in the Alboran Sea (Western Mediterranean Sea) during the last 25 kyr

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North Atlantic Surface Water (NASW) entering the Alboran Sea (western Mediterranean Sea) promotes the formation of two anticyclonic gyres. On the northern edges of these gyres are semi-permanent areas of upwelling (Sarhan *et al*., 2000). Outside these productive cells, the western Mediterranean is generally characterized by oligotrophy.

A high-resolution analysis of the coccolithophore assemblages in 450 samples from the last 25 kyr was performed on two marine cores located at both sides (N and S) of the Alboran Basin. This study reconstructed the paleoproductivity record in two strategic locations, which then could be compared to well-known present productivity: core HER-GC-T1 off the coast of Malaga and core CEUTA10-PC8 off the coast of Ceuta. The first study area is currently in the productive cell associated with the Western Anticyclone Gyre (WAG) called the Malaga upwelling (Bárcena & Abrantes, 1998). The second core is further south, outside of this productive area.

Comparison between the nannofossil accumulation rates (NAR) in these two areas reveals that productivity was lower in Malaga than in Ceuta from 25 kyr until the Heinrich Event 1. This difference occurs at two intervals in both cores: the first one centered at 18.8 ka cal. BP, and the second one, which was centered at 16 ka cal. BP, was colder. From this time to the mid-to late-Holocene, both sites approached present conditions: HER-GC-T1 core location became a semi-permanent productive cell, while oligotrophy affected the CEUTA10-PC8 study area. This general pattern was interrupted by an abrupt increase in the total NAR in both cores that peaked at 9.3 ka cal. BP in CEUTA10-PC8 and at 7.4 ka cal. BP in HER-GC-T1, indicating periods of higher productivity. The forcing mechanisms for these two events remain unclear. Interestingly, every taxon records these conspicuous changes in their NAR, independently of their paleoecological requirements. This fact suggests that further research is needed in order to unravel the mechanisms involved in these short-term productivity variations.

References

Bárcena, M.A. & Abrantes, F. 1998. Evidence of a high-productivity area off the coast of Malaga from studies of diatoms in surface sediments. *Marine Micropaleontology*, **35**: 91-103.

Sarhan, T., Garcia Lafuente, J., Vargas, M., Vargas, J. & Plaza, F. 2000. Upwelling mechanisms in the northwestern Alboran Sea. *Journal of Marine Systems*, **23**: 317-331.

High-resolution analysis of coccolithophore assemblages and SST-Mg/Ca-derived records in the western Mediterranean Sea during the Holocene: productivity reconstruction in an upwelling region

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Gravity core HER-GC-T1 was recovered in coastal upwelling off Malaga, a productive cell associated with the Western Anticyclonic Gyre in the Alboran Sea. The core is located where there is a direct influence from North Atlantic Surface Water (NASW) entering the area, the Atlantic Jet (AJ), while Western Mediterranean Deep Waters (WMDW) flow underneath in the opposite direction. Holocene productivity at this location was reconstructed by studying the coccolithophore assemblage in 93 samples with a time resolution of ~130 years. From this record, a drastic hydrographic reorganization in the Alboran Sea was inferred at 7.7 ka cal BP and linked to the establishment of anticyclonic gyres. From that time, the Nannofossil Accumulation Rate (NAR) of *Florisphaera profunda* and *Gephyrocapsa oceanica* has been linked to the volume of AJ water entering the Alboran Sea. In addition, the N ratio (relationship between the upper photic and lower photic zone coccolithophore taxa) and the NAR of the species *Florisphaera profunda* show an alternation between upwelling pulses and stratification episodes of hundreds of years in the mid-to late-Holocene. The relative abundance of reworked coccoliths, used here as an indicator of terrigenous input from exposed continental margins, points to more arid conditions when upwelling events occurred. Along with these records, the sea surface temperature (SST)-Mg/Ca-derived record shows a positive relationship between drops in SST and upwelling pulses. Finally, comparisons between these short-term episodes in the study area with those of WMDW formation (Frigola *et al*., 2007) in the Gulf of Lion are in good agreement. This fact shows that an increase in WMDW formation, which is promoted by stronger westerlies blowing in the Gulf of Lion, could be related to upwelling pulses off the coast of Malaga. An as yet unknown mechanism akin to the present North Atlantic Oscillation could have been operating over the western Mediterranean Sea, influencing its past productivity on a millennial-centennial time scale. Two potential climatic and oceanographic scenarios are proposed to explain these variations in productivity during the mid-to late Holocene in the study area:

A) A one-to-one match between increasing N index trends, low NAR of *Florisphaera profunda*, high relative abundance of reworked coccoliths, and drops in SST-Mg/Ca is interpreted as follows: a positive NAO-like index (higher pressure gradient between Icelandic-low and Azores-high) led to strong westerlies, increasing the formation of WMDW in the Gulf of Lion, which was then associated with shoaling of the nutricline. This, along with a major AJ, would favor vertical mixing and long-term upwelling events in the study area.

B) The positive correlation among decreasing N index trends, high NAR of *Florisphaera profunda*, low relative abundance of reworked coccoliths, and rises in SST-Mg/Ca was linked to a negative NAO-like index (lower pressure gradient). This would correspond to weaker westerlies that promoted a weakening of WMDW formation. This, along with a lesser and warmer AJ influx, led to a deepening of the nutricline and long-term stratification events.

Reference

Frigola, J., Moreno, A., Cacho, I., Canals, M., Sierro, F.J., Flores, J.-A., Grimalt, J.O., Hodell, D.A. & Curtis, J.H. 2007. Holocene climate variability in the western Mediterranean region from a deepwater sediment record. *Paleoceanography*, **22**: PA2209.

Living and fossil coccolithophore communities in the West Iberia margin and Gulf of Cadiz (IODP Expedition 339): oceanographic and environmental controls

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For the first time during an IODP Expedition (Exp. 339, Mediterranean Outflow), water samples were collected to examine living coccolithophore distributions, and mudline samples were collected to determine coccolith assemblages in the underlying surface sediments. The idea was to provide additional information about living coccolithophores as potential proxies in paleoceanographic studies. Expedition IODP 339 was conducted in the Gulf of Cadiz and coastal areas off West Iberia (Northeast Atlantic) to explore the effects of Mediterranean Outflow Water (MOW) on North Atlantic circulation and climate from November 2011 to January 2012. Fourteen water samples were gathered from seven cored sites at two depths (5 and 20 m), immediately filtered onboard through cellulose acetate filters, and then oven-dried and stored in petri dishes. Temperature and salinity data were simultaneously collected, as well as water samples for oxygen isotope analysis. Mudline samples were prepared onboard for both relative and absolute coccolith counts. Additionally, reworked coccoliths were also considered in order to analyze the potential relationship with deep- and bottom-water dynamics. Coccolithophore absolute abundances ranged from $1.87x10^4$ to $1.04x10^5$ cell/l. Species richness was consistently high, and assemblages were dominated by *Emiliania huxleyi*, *Gephyrocapsa* small, and *Gephyrocapsa oceanica*. However, coccolithophore distributions showed spatial variations, as well as variable species diversity, in the different site locations. In particular, the assemblages that characterize the West Iberia Margin differ from that of the Gulf of Cadiz, showing the existence of oceanographic and environmental controls on the distribution of the communities. Comparison of the living assemblage with surface sediment records showed significant differences in the presence and abundance of some species, especially at sites U1390 and U1391. In particular, *Coccolithus pelagicus* was common in the sediment at those sites but absent in all the water stations. In the other site locations, the fossil record matches the water column assemblages, suggesting more open-sea conditions where inorganic input and reworked species are less important. Surprisingly, in one site, U1388, there were no coccoliths in the sediment, but abundant coccolithophores in the water column. This could indicate different sedimentary processes, related to both the Atlantic water masses or the MOW, which is characterized here by a higher velocity current (up to 280 cm /s), and thus may have prevented sedimentation of the coccoliths at this location. However, loss of specimens during the drilling due to instrumental effects cannot be excluded.

Future work will include the integration of the coccolithophore results with the benthic foraminifer communities in the mudline samples, the Mg/Ca-Sr/Ca ratios, and the geochemical signal of the pore water. Integration of these data will lead to a better understanding of the surface and deep-water dynamics for the most recent climatic cycle in the Expedition 339 investigation area.

Automated recognition of calcareous nannofossils: an application for quantitative biostratigraphy

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Calcareous nannofossils are excellent biomarkers because they are well diversified through geologic time and sensitive to climatic changes. Their rapid evolution and abundance variations make them ideal for biostratigraphy and paleoceanographic reconstructions. This work is usually tedious, but this can be conducted in a much shorter period of time through the use of automated recognition software that can detect relevant specimens in a large number of non-coccolith microscopic objects. The new automated system SYRACO (SYstème de Reconnaissance Automatisée des Coccolithes) (Dollfus & Beaufort, 1999; Beaufort & Dollfus, 2004) is now able to detect most of the coccoliths belonging to thousands of species that have evolved since the upper Eocene. The system is able to filter out approximately 90% of non-nannofossils and keep between 75-90% of the nannofossils. It is able to lump detected images and measurements in about 30 classes. After showing the potential and limits of this method, we will present two examples of biostratigraphic applications to the upper Pleistocene and two covering the last 3 Ma: the MD052930 core from the last 800 kyr in the Gulf of Papua, the GOLODRILL core from the last 500 kyr in the Mediterranean Sea east of Corsica, and the MD972125 and MD962066 cores from the last 3 Ma in the Tasmanian Sea and the Mozambique Channel, respectively. The results give a good estimation of abundances of the main taxonomic groups that are used to highlight evolution and paleoecologic and climatic events. They quickly produce a biozonation and datums that constrain the temporal resolution of the cores.

References

Beaufort, L. & Dollfus, D. 2004. Automatic recognition of coccoliths by dynamical neural networks. *Marine Micropaleontology*, **51**(1-2): 57-73.

Dollfus, D. & Beaufort, L. 1999. Fat neural network for recognition of position-normalised objects. *Neural Networks*, **12**(3): 553-560.

The Badenian-Sarmatian boundary in the Getic Depression: preliminary results of integrating biostratigraphy and magnetostratigraphy

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At present, the stratigraphic correlation of middle Miocene regional Central Paratethys chronostratigraphic stages with standard chronostratigraphic stages, magnetostratigraphic polarity units, and biostratigraphic zonations is imprecise and needs to be refined. Here, we present the preliminary results of an integrated stratigraphic study (calcareous nannoplankton, planktonic and benthic foraminifera, and magnetostratigraphy) of middle Miocene sediments that crop out in four land sections in the Getic Depression in Romania. Specifically, we are aiming to determine the biostratigraphic and magnetostratigraphic events at the boundary between the regional chronostratigraphic stages of the Badenian and Sarmatian (early Serravallian). Combining micropaleontological analyses of foraminifera and nannoplankton will refine the biostratigraphic resolution. It will also allow us to associate the changes observed in nannoplankton assemblages with definite environmental changes, which will improve our understanding of the paleoecological preferences of individual taxa.

The four land sections considered (Tisei, Salcia, Morilor, and Cosmina Valleys) are successions of primarily marlstones with lesser amounts of claystones and siltstones and a few intercalated tuff layers that allow lithostratigraphic correlation. The foraminiferal associations indicate a deep-water environment with short periods of restricted water circulation in the late Badenian, significant environmental changes at the Badenian-Sarmatian boundary, and anoxic conditions in the early Sarmatian. The nannoplankton assemblages underwent considerable changes at the Badenian-Sarmatian boundary, particularly in terms of abundances of individual taxa. A transitional increase in the proportion of redeposited coccoliths can be detected at the boundary level, and slightly above this there is a distinct peak in abundance of *Calcidiscus pataecus*, which increases from being less than 1% to about 10% of the assemblage.

The species composition of the studied nannoplankton assemblages is similar to that reported for the same time period by Mărunţeanu (1999) and Galović (2009). However, the biostratigraphic ranges of certain species appear to be somewhat different.

In the current state of our research, it appears that the most reliable nannoplankton event at the base of the Sarmatian is the peak in abundance of *Calcidiscus pataecus*. The shifts in abundance of other coccolith species observed in the study material and reported in literature (Galović, 2009) are consistent with significant environmental changes taking place during this time interval, so they appear to be linked to particular environments and probably cannot be used as reliable biostratigraphic markers over long distances.

References

Mărunţeanu, M. 1999. Litho- and biostratigraphy (calcareous nannoplankton) of the Miocene deposits from the Outer Moldavides. *Geologica Carpathica*, **50**: 313-324.

Galović, I. 2009. *Middle Miocene (Sarmatian) calcareous nannoplankton, silicoflagellates and diatoms of the southwestern part of the Paratethys*. PhD thesis, University of Ljubljana, Ljubljana: 210pp.

Biogeography and ecology of Calcidiscus and Umbilicosphaera in the South Atlantic

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Research based on genetic divergences, life cycles, and morphometrics (Sáez *et al*., 2003; Geisen *et al*., 2004; Quinn *et al*., 2004) has indicated that some coccolithophore species with apparent global distribution are composed of two or more discrete species with subtle morphological differences. However, their discrete ecological adaptations and distributions are still only partly known. We present here the biogeographic distribution patterns and ecological information for five coccolithophorid species (*Calcidiscus leptoporus*, *C. leptoporus* small, *C. quadriperforatus*, *Umbilicosphaera foliosa*, and *U. sibogae*). The mapping is entirely based on surface sediments from the South Atlantic, and sediment trap data from this region are added for morphometric evaluation of the species.

The three *Calcidiscus* species can easily be distinguished by a combination of size and qualitative characters of the distal shield. Primarily encountered in the temperate to sub-polar regions, *Calcidiscus leptoporus* exhibited a negative correlation to temperature and to salinity. However, a positive response to nitrate and phosphate concentrations was detected. Its strong preference for highly dynamic environments is therefore emphasized by the canonical correspondence analysis (CCA). In contrast, both *C. leptoporus* small and large *C. quadriperforatus* were mainly found in warm, more oligotrophic South Atlantic waters.

Two round *Umbilicosphaera* species were distinguished, largely based on coccosphere characters. However, the two species do exhibit significant differences in coccolith morphology and show only little overlap in size. The highest numbers in the South Atlantic were encountered mainly in subtropical latitudes and were due primarily to *U. sibogae*. In contrast, abundances of *U. foliosa* were only significant in the cold and nutrient-enriched Benguela upwelling. The distribution pattern of *U. foliosa* confirms the results of earlier studies that show a weak trend towards higher proportions in environments with greater availability of nutrients. In contrast, the more common *U. sibogae* primarily occurs under rather oligotrophic conditions.

References

Geisen, M., Young, J.R., Probert, I., Garcia Sáez, A., Baumann, K.-H., Bollmann, J., Cros, L., De Vargas, C., Medlin, L.K. & Sprengel, C. 2004. Species level variation in coccolithophores. *In:* H.R. Thierstein & J.R. Young (Eds). *Coccolithophores – from molecular processes to global impact*. Springer-Verlag, Heidelberg: 327-366.

Quinn, P.S., Garcia Sáez, A., Baumann, K.-H., Steel, B.A., Sprengel, C. & Geisen, M. 2004. Coccolithophorid biodiversity: evidence from the cosmopolitan species Calcidiscus leptoporus. *In:* H.R. Thierstein & J.R. Young (Eds). *Coccolithophores – from molecular processes to global impact*. Springer-Verlag, Heidelberg: 299-326.

Sáez, A.G., Probert, I., Geisen, M., Quinn, P., Young, J.R. & Medlin, L.K. 2003. Pseudo-cryptic speciation in coccolithophores. *Proceedings of the National Academy of Sciences of the USA*, **100**: 7163–7168.

Coccolithophores in the Eastern Boundary Current System off NW Africa: response to abrupt climate events during the last 45,000 years

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The Eastern Boundary Current region off NW Africa is characterized by southward transport of comparatively cold surface water within the Canary Current. In addition, coastal upwelling of cold and nutrient-enriched central water occurred seasonally. High production of biogenic particles off the capes, in combination with a huge supply of terrestrial particles (dust due to present arid conditions), resulted in rapid sediment accumulation on the upper continental slope, which makes these sites suitable for high resolution climate reconstructions. We present the coccolithophore data from an 8.5-m long piston core (GeoB 5546) that was recovered off Cape Yubi (27.5ºN, 1072 m). Correlation of the coccolithophore records with other proxy records (total organic carbon, carbonate, isotopes, and alkenones) from the same site were carried out in order to assess the sensitivity of coccolithophores to short-term climatic changes.

The study has produced a high-resolution record for the last 45,000 years with a sampling resolution of less than 500 years and where short-term climatic events (Heinrich Events (HE) and Dansgaard-Oeschger Cycles) were identified. In general, absolute coccolith numbers were relatively constant throughout most of the time interval investigated. Surprisingly, the numbers of total coccoliths did not increase significantly before the middle Holocene. *Emiliania huxleyi* and *Gephyrocapsa* species were the main contributors to the coccolith assemblage. Whereas E. huxleyi was abundant throughout the studied interval, a considerable change in dominance of *G. muellerae* to *G. oceanica* occurred near the last glacial maximum, and *G. oceanica* was dominant in the Holocene. Glacial sea-surface temperatures showed marked millennial oscillations around a mean of 15-17ºC. These phases were characterized by the circulation of fresh and turbulent surface-water masses as indicated by high abundances of *E. huxleyi*, *G. muellerae*, *Calcidiscus leptoporus*, and reworked coccoliths. The coldest events off Cape Yubi occurred abruptly during the last glacial, which is coincident with large iceberg transports in the North Atlantic Heinrich Events and the Younger Dryas cooling. These events were characterized by peaks in the abundance of the deep-dwelling *Florisphaera profunda* (especially during HE1 and HE3), which, in concordance with the general Atlantic signal, indicate water column stratification and possibly a stabilized water column with no upwelling influence.

Recent decline in pelagic calcification offshore of the Sepik River in the western Pacific warm pool

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Because of their minute size, we can use the degree of calcification of coccolithophores as an early marker of acidification. Thus, from a previous extensive survey of diverse chemical conditions in the present and past oceans, we can show that the mass of coccolithophores in the class of the Isochrysidales increases with carbonate ion concentration except in the most acidic conditions (Beaufort *et al*., 2011). Using new technical developments to measure coccolith thickness, we have produced a 400-year record of coccolith mass from the western Pacific north of Papua (25 km from the mouth of the Sepik River) with a one-year resolution. The chronology, based on Pb210 and 14C dates, indicates a regular sedimentation rate in the order of 6 mm/1000 years. We sampled the top 6 m of the core at one-centimeter spacing.

The high sedimentation rates in this core imply important dilution of coccoliths in the sediments, but with the help of an automated technique it was possible to get a sufficient number of coccoliths to obtain robust statistics. The mass of *Emiliania huxleyi* remained constant between 1580 and 1940 AD and since then has decreased by half. The flux of coccoliths also has decreased dramatically in recent years. However, the flux of alkenone has increased in recent years, and this is indicative of increased production of Isochrysidales since 1950. We sampled the surface water at the site location in February 2012, for chemistry and morphologic analysis. We observed an absence of coccoliths of *E. huxleyi* and the rare presence of coccospheres of *Gephyrocapsa oceanica*. The absence of *E. huxleyi* coccoliths could be the result of its actual absence at that time or the fact that it was naked (not producing coccoliths). The pH was measured at about 7.97. We estimate that pH was above 8 before the industrial revolution based on changes in pCO2 recorded in Antarctic ice cores (Etheridge *et al*., 1996). Coral records of temperature and salinity determined near the coring site indicate no recent changes in those parameters (Tudhope *et al*., 1995). These measurements and observations point to an important ecological impact of acidification in this coastal environment.

References

Beaufort, L., Probert, I., de Garidel-Thoron, T., Bendif, E.M., Ruiz-Pino, D., Metzl, N., Goyet, C., Buchet, N., Coupel, P., Grelaud, M., Rost, B., Rickaby, R.E.M. & de Vargas, C. 2011. Sensitivity of coccolithophores to carbonate chemistry and ocean acidification. *Nature*, **476**: 80-84.

Etheridge, D.M., Steele, L.P., Langenfelds, R.L., Francey, R.J., Barnola, J.M. & Morgan, V.I. 1996. Natural and anthropogenic changes in atmospheric CO2 over the last 1000 years from air in Antarctic ice and firn: *Journal of Geophysical Research: Atmospheres*, **101**: 4115-4128.

Tudhope, A.W., Shimmield, G.B., Chilcott, C.P., Jebb, M., Fallick, A.E. & Dalgleish, A.N. 1995. Recent changes in climate in the far western equatorial Pacific and their relationship to the Southern Oscillation: oxygen isotope records from massive corals, Papua New Guinea. *Earth and Planetary Science Letters*, **136**: 575-590.

An industrial revolution: a comparison of industry and research nannofossil quantitative counting techniques

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A variety of techniques are being utilized to examine calcareous nannofossils. In terms of sample preparation, various specialized techniques are used by research, but preparing simple smear slides is the most popular technique. These smear slides have been the basis of most nannofossil research over the past decades. Smear slide preparation is quick and easy and ideal for industrial applications, particularly well-site biostratigraphy. Counting methods for quantitative nannofossil data vary considerably, but broadly speaking there are two distinct schools of thought: (1) industrial where everything is counted along a fixed traverse length, and (2) research where a fixed number of specimens (e.g., 300) is counted. Comparison of quantitative data generated by the different methods is difficult and often limits the utility of published data. The purpose of this presentation is to promote an understanding of well-proven industrial methods among researchers, in the hope that counting methods can eventually be standardized.

Based on a review of nannofossil articles published over the last 60 years, there is no single and consistent counting method adopted by researchers. For the researchers who counted a fixed number of individual nannofossil specimens per slide, various numbers were counted, although 300 specimens were frequently regarded as statistically significant in micropaleontological research (Phleger, 1960; Fatela & Taborda, 2002). Other inconsistencies may hamper the utility of this technique. For example, (1) fixed count data can be presented as % abundance or specimens per square mm, (2) counts may be conducted in either XPL or PPL, the latter excluding identification of many species, (3) counts may be conducted at various magnifications, (4) some research projects focus on a particular group and 'lump' or do not record any secondary species such as small placoliths and (5) some authors employ semi-quantitative approaches and estimate the abundance of individual species.

Industrial nannofossil analyses generally involve counting all specimens within a standard traverse (e.g., 60 fields of view [FOV] or 10 mm at x1,000 magnification), then scanning of the remainder of the slide for rare species. In richly nannofossiliferous samples, a 'cascading count' procedure similar to that proposed by Styzen (1997) can be applied. With this method, abundant species are quickly eliminated from the count because their abundance is factored up to equate with a full 60 FOV traverse. In this way, these slides can be counted in a reasonable amount of time, which is industrially practical. We propose that this industrial method of counting is a more robust method that could be adopted as a standard by the research community. It is favored over counting a fixed number of specimens (e.g., 300) for a variety of reasons. First, in poor material it can be impossible to find 300 specimens. Second, and most importantly, in rich material 300 specimens might be counted in only two or three fields of view. In a typical Cretaceous-Paleogene sample, 95% of counted specimens will be long-ranging placoliths and counting will cease before many useful species have been found. The 300-count technique precludes identification of certain important nannofossil acme events (e.g., *Eprolithus eptapetalus* in the early-middle Turonian), which are easily detected via counting 60 FOV. In comparison, a 60 FOV traverse can yield counts from zero (barren) to >5,000 specimens, enabling accurate quantification of the abundance of non-dominant (but important) marker species. This method also provides a good indication of variation in total nannofossil abundance without any calculation.

Having re-examined a variety of well sections, we are able to present comparisons between "industrial" and "research" datasets. We hope this demonstrates that the industrial method produces more realistic and reproducible diversity and abundance figures, facilitating comparison and correlation of wells or outcrops. Counting a fixed number of specimens may be useful for foraminiferal research, but we consider this methodology inappropriate for nannofossil analyses.

References

Fatela, F. & Taborda, R. 2002. Confidence limits of species proportions in microfossil assemblages. *Marine Micropaleontology*, **45**: 169-174.

Phleger, F.B. 1960. *Ecology and distribution of Recent foraminifera*. Johns Hopkins Press, Baltimore.

Styzen, M.J. 1997. Cascading counts of nannofossil abundance. *Journal of Nannoplankton Research*, **19**(1): 49.

Patterns of morphological evolution in the Tribrachiatus lineage: a geometric morphometric study

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A detailed morphometric analysis was conducted on the early Eocene *Tribrachiatus* linage to characterize morphological evolution of shape and form during speciation. This study incorporated outline-based and landmark-based geometric morphometric analyses, as well as traditional morphometrics. This lineage is one of the only undeniable and uninterrupted lineages in coccolithophores. It consists of three morphologically successive species that have evolved through rotation of two stacked equilateral triplets. The radially symmetrical hexaradiate form, *T. bramlettei* (the stem species) evolves into an asymmetric form (*T. contortus*), which itself evolves into a triradiate form (*T. orthostylus*). This is well expressed at North Atlantic DSDP Site 550 where the lineage occurs over a 12-m interval (from the upper range of *T. bramlettei*, through the range of *T. contortus*, and up to the lower range of *T. orthostylus*). The transition from *T. bramlettei* to *T. contortus* is well documented at this site where it occurs over a thin stratigraphic interval (0.5 m), representing a few thousand years. Previously documented transitional forms suggest that this lineage is a prime example of gradual (anagenesis) evolution.

Eigenshape outline analysis and partial Procrustes superimpositions were conducted to complement the traditional approach of measuring the angles between triplet arms for a full analysis of shape and form. Geometric morphometrics decompose measurements to a minimum set of dimensions for analysis of shape within and between samples. The geometric morphometric analysis during the speciation between *T. bramlettei* and *T. contortus* shows, unexpectedly, morphologic stasis within each species. Additionally, an abrupt morphologic shift during speciation indicates rapid evolution of an intermediate morphotype. This intermediate form disappears once *T. contortus* is established (i.e., once fixation of the latter morphology has occurred). The abruptness in this transition might be best described as punctuated equilibrium, though the duration does not meet the criteria (<1% of the total duration) arbitrarily set by Gould (1982). This pattern is best described as punctuated anagenesis, similar to the speciation pattern described by Malmgren *et al*. (1983) in the *Globorotalia tumida* lineage. However, and of particular interest, morphotypes similar to *T. bramlettei* co-occur with *T. contortus* morphotypes throughout most of the range of T. contortus, albeit decreasing in abundance. This does not fully agree with Malmgren's concept. This suggests there was more than the straightforward replacement of an ancestral morphotype by a descendant morphotype. The patterns in this uninterrupted lineage grant us access to the tempo and direction of morphologic evolution during coccolithophore speciation.

References

Gould, S.J. 1982. The meaning of punctuated equilibrium and its role in validating a hierarchical approach to macroevolution. *In:* R. Milkman (Ed). *Perspectives on Evolution*. Sinauer, Sunderland, Massachusetts: 83-104.

Malmgren, B.A., Berggren, W.A. & Lohmann, G. 1983. Evidence for punctuated gradualism in the Late Neogene *Globorotalia tumida* lineage of planktonic foraminifera. *Paleobiology*, **9**: 377-389.

Calcareous nannofossil contribution to carbonate export during the last 450 ka in the NW Pacific Ocean (Shatsky Rise)

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Many processes influence the ocean-atmosphere CO_2 exchange, including physical, biological, and carbonate pumps. Coccolithophores are able to export carbonate to the deep sea and contribute to the biological pump through photosynthesis. They have been the major pelagic carbonate producers in the NW Pacific over the last 450 ka, possibly playing a significant role in regulating the ocean CO_2 chemistry on timescales >1-100 ka. We present micropaleontological and geochemical analyses from the Pleistocene succession in ODP core 198-1209B (Shatsky Rise, NW Pacific) and evaluate the calcareous nannoplankton contribution to the organic and inorganic carbon pumps.

Calcareous nannofossil assemblages were analyzed in 59 samples to determine total coccolith carbonate accumulation rates (CAR), nannofossil preservation (NDI), and paleoproductivity indices (N). Stable isotopic composition ($\delta^{18}O$ and $\delta^{13}C$) and Sr/Ca in the 2-20 μm carbonate fraction (coccolith-derived component), as well $CaCO_3$ content (wt%) on bulk and the <20 μm fraction, were measured. Spectral and wavelet analyses were applied to the time series to evaluate periodicities, particularly Milankovitch-type frequencies.

On the basis of coccolithophore paleoecology and coccolith (N and Sr/Ca) and foraminiferal geochemical ($\Delta\delta^{13}C_{p\text{-}b}$) proxies, high paleoproductivity from MIS 12 to MIS 8 was derived. From MIS 6 upwards, Sr/Ca-derived coccolithophore productivity shows low values during glacials. This contrasts with the high primary productivity recorded during glacials by N and $\Delta\delta^{13}C_{p\text{-}b}$. A possible explanation is a dominance of siliceous organisms during these periods due to the presence of eolian dust rich in iron from Asia, also documented by Zhang *et al*. (2007).

Coccolith preservation and CAR can be used to discuss the dynamics of carbonate production and export to the deep sea. Good preservation during glacials and intense dissolution episodes at glacial onsets were recorded and CAR showed major coccolith-carbonate fluxes during deglaciations. Our data show that nannofossils have been the major pelagic carbonate producers, constituting 50-80% of the total carbonate buried in the sediments at this site. Speculating about the coccolithophore role in the CO_{2atm} balance, we conclude that nannoplankton contributed to the CO_{2atm} regulation through the biological pump, particularly during interglacials. High carbonate burial fluxes during deglaciations may point to a different balance towards minimum efficiency of CO_{2atm} uptake. Conversely, increased coccolith-carbonate accumulation in deep-sea sediments would favor CO_2 buffering during high carbonate dissolution episodes.

At site 1209B, the physical pump was primarily driven by shallow circulation and vertical mixing from the Kuroshio Current. We assume that climate and oceanographic forcing (local currents, oceanic fronts, monsoons, and orbital reorganization) could influence the nannofossil assemblages, and thus carbonate dynamics over the last 450 ka.

This study demonstrates how coccolithophore carbonate export and sedimentation strongly interact with ocean and atmosphere chemistry for more than time scales >100 ka. At a glacial-interglacial scale, changes in coccolith production were able to influence the saturation of deep waters, as demonstrated also by spectral and wavelet analyses.

Although based only on one site, our study suggests that calcareous nannoplankton pumps and sedimentation can influence the ocean carbon inventory and that its dynamics operate at different time scales. Changes in the strength of the pumps can lead to shifts in vertical distribution of the ocean CO_2 and alkalinity, while not affecting their inventories. This process is possibly important to understand changes in surface-ocean chemistry and CO_{2atm} on glacial-interglacial time scales.

Reference

Zhang, J., Wang, P., Li, Q., Cheng, X., Jin, H. & Zhang, S. 2007. Western equatorial Pacific productivity and carbonate dissolution over the last 550 kyr: foraminiferal and nannofossil evidence from ODP Hole 807A. *Marine Micropaleontology*, **64**: 121-140.

Paleoceanographic changes in the NW Pacific Ocean over the last 450 ka: evidence from statistical analysis of calcareous nannofossil assemblages

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This work investigated Pleistocene sediments from ODP Site 1209B, located on the Shatsky Rise (NW Pacific). Calcareous nannofossil assemblages, a nannofossil-derived paleoproductivity index (N ratio), and a Warm Water Taxa (WWT) proxy were employed to investigate the paleoceanographic changes in the NW Pacific mid-latitudes over the last 450 ka, i.e., Marine Isotope Stages (MIS) 1-12. Multivariate statistical analyses on our quantitative micropaleontological data clarified the relationships between coccolith distribution and paleoenvironmental variables. We analyzed the calcareous nannofossil content of 59 samples, and all data were processed using the software PAST (Paleontological Statistics of Hammer *et al*., 2001) to perform Principal Component Analysis (PCA) and Cluster Analysis.

At Site 1209B, calcareous nannofossils were abundant and well diversified. The PCA retained two principal components, accounting for 66.8% and 11.8% of the variance, respectively. Principal component 1 (PC1) was negatively loaded by *Gephyrocapsa caribbeanica* and *G. ericsonii* and positively loaded by *G. aperta*, species driven mainly by temperature. In addition, PC1 had a high correlation value with the WWT proxy (r = 0.83). Thus, PC1 is linked to temperature variations and records a warming SST trend over 450 ka. Principal component 2 (PC2) was positively loaded by *G. caribbeanica*, a cosmopolitan species, and negatively loaded by *G. aperta* and *G. ericsonii*, species typical of subtropical and tropical regions. Thus, PC2 could be related to the proximity of a subtropical front at the site. Cluster analysis allowed for identification of five different clusters, and their distributions confirmed the interpretation of PC1 and PC2.

A number of paleoceanographic and paleoclimatic interpretations were derived from our multivariate statistical analyses for the last 450 ka, and four time intervals, characterized by different paleoceanographic scenarios, are proposed here. From MIS 12 to MIS 8, eutrophic/mesotrophic conditions (high N ratio values), cold-temperate SST, and a minor influence of the subtropical waters on the site, recorded both by calcareous nannofossil assemblages and by PCA, may be linked to a southern position of the oceanic front and to a major influence of the cold-eutrophic Oyashio Current. This configuration could also be related to the El Niño-Southern Oscillation (ENSO) - like events, which were able to influence both currents and paleoclimate in the western Pacific region. During MIS 7, decreasing productivity and warming documented a major influence of the warm-oligotrophic Kuroshio Extension and the onset of El Niño-like conditions. At the beginning of MIS 6, the increased abundance of subtropical species and PC2 confirmed a northward shift of the oceanic front due to the end of the Mid-Brunhes Event (MBE). Moreover, the recorded high productivity may reflect a Kuroshio Extension in a contracted state and a major dust input linked to boreal monsoon dynamics (Zhang *et al*., 2007). Finally, from MIS 5 to MIS 1, higher temperature and a slightly decreasing trend in paleoproductivity could be linked to the influence of the prevalent and more intense Kuroshio Extension, which probably reflects more frequent El Niño-like events.

Through a statistical approach, we have documented that the main changes in nannofossil distribution were driven by ENSO patterns and boreal monsoons associated with local currents and oceanic front position.

References

Hammer, Ø., Harper, D.A.T. & Ryan, P.D. 2001. PAST: Paleontological Statistics software package for education and data analysis. *Palaeontologia Electronica*, **4**(1): 9pp.

Zhang, J., Wang, P., Li, Q., Cheng, X., Jin, H. & Zhang, S. 2007. Western Equatorial Pacific productivity and carbonate dissolution over the last 550 kyr: foraminiferal and nannofossil evidence from ODP Hole 807A. *Marine Micropaleontology*, **64**: 121-140.

Climatic and ecological changes during the Aptian traced by calcareous nannofossils and oxygen isotopes

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The Lower Cretaceous was marked by the emplacement of large igneous provinces (LIPs) that formed gigantic oceanic plateaus, thus affecting ecosystems at a global scale. Biota were forced to face excess CO_2 and climatic and global perturbations in the ocean-atmosphere system. In particular, Ontong Java Plateau (OJP) volcanism was coeval with an episode of oxygen depletion in the oceans that resulted in burial of massive amounts of organic matter, coinciding with the early Aptian Oceanic Anoxic Event (OAE)1a.

Several studies have been conducted to reconstruct temperature variations across the Aptian, especially during OAE1a. There is a general consensus that a major warming characterized OAE1a, although some authors have provided evidence for transient cooling intervals. In contrast, the climatic conditions in the late Aptian are less constrained, and a complete record is not yet available.

We present a reconstruction of surface-water paleotemperature and fertility based on calcareous nannofossil records from the Tethys and Pacific Oceans. The data, integrated with oxygen-isotope records and datasets from other latitudes, provide a detailed picture of climatic and ecological changes during the Aptian, showing variations never highlighted before.

The collected dataset indicates that maximum warming characterized the early phase of anoxia under the intense volcanic activity of the OJP. A short-lived (~35ky) cooling, following a rapid increase in weathering, interrupted the major warming. A generally warm and humid climate was probably the promoter of continental runoff and consequent nutrient supply to the oceans. Peaks in trace metal concentrations suggest that biolimiting metals may have additionally fertilized the oceans. Nannofossils suggest meso- to eutrophic conditions were reached under the highest temperatures and during the maximum amount of OJP volcanism. The rest of OAE1a was characterized by subsequent cooling events, probably promoted by CO2 sequestration during burial of organic matter. In this phase, high productivity was probably maintained by N2-fixing cyanobacteria, while nannofossil indicators of high fertility were rare. The end of anoxia coincides with the end of volcanism and a pronounced cooling. The mid Aptian was characterized by high surface-water fertility and progressively decreasing temperatures, probably suggestive of intense continental weathering that supplied nutrients to the oceans and maintained low pCO_2. The lowest temperatures, combined with low fertility, were reached in the late Aptian across the interval characterized by blooming of *Nannoconus truittii*. A stasis in volcanism and less humid climate are proposed for this interval.

Our data indicate that OJP activity played a direct role in inducing global warming during the early Aptian, and while other mechanisms acted as feedback processes that favored temporary cold interludes, persisting volcanism eventually led to the end of anoxia.

North American Middle and Late Cretaceous paleoceanographic trends evidenced by Biscutum

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The abundance of *Biscutum* spp. is frequently used as a paleoceanographic proxy for surface-water fertility. Examination of relative abundance fluctuations, coupled with timing of evolutionary events, provides insight into wider paleoceanographic and evolutionary patterns. This study presents a detailed record of the relative abundance of *Biscutum* spp. with respect to major evolutionary and paleoceanographic events from a composite section of mid- to Late Cretaceous sites from North America, encompassing OAE1d, OAE2, OAE3, and the Mid-Maastrichtian Event. During OAE1d, a pattern of increasingly higher minima and maxima is recorded, leading up to the event where values rapidly decrease. After the rapid drop in relative abundance, values quickly recover to pre-event levels. These data suggest that the period of time leading up to OAE1d was associated with increasingly fertile, and perhaps increasingly unstable, surface-water conditions. The origin of a new, relatively short-ranging species of *Biscutum* is also recorded during OAE1d. During OAE2, a rapid decrease in the abundance of *Biscutum* spp. was observed as values dropped from approximately 30% of the assemblage to <15%. These data indicate that OAE2 was likely associated with decreasing surface-water fertility leading into the event in the WIS (Western Interior Seaway) from where the OAE2 data are derived. Although only one extinction and one origination were documented with *Biscutum* near OAE2, the origin of three new species was recorded during the mid Cenomanian leading up to the event. The appearance of these forms is concomitant with high relative abundance values of *Biscutum* spp. (>40%), suggesting that increased surface water fertility may have been conducive to diversification. Abundance patterns during OAE3 vary between the GOM (Gulf of Mexico) and the WIS. The average relative abundance of *Biscutum* spp. was 10% higher in the WIS than in the GOM during this interval. The total range of a new species of *Biscutum*, which has only been observed in the GOM, is documented during the Santonian/Campanian. No further evolutionary first occurrences were recorded for the remainder of the Cretaceous. Two distinct trends were visible in the Maastrichtian. First, no species turnover occurred in *Biscutum* subsequent to the Campanian in mid-latitudes, and all evolutionary activity appeared to be concentrated at high latitudes. Second, the interval of time in the Maastrichtian in which five high-latitude species undergo extinction coincides with a drop in *Biscutum* abundance in mid-latitudes. Changes in ocean circulation at this time (e.g., the Mid-Maastrichtian Event) may have disrupted evolution of this lineage.

Extinction risk of phytoplankton species to potential killing mechanisms at the Cretaceous-Paleogene boundary

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The impact at Chicxulub caused catastrophic changes in marine habitats, including extended darkness, ocean acidification, and eutrophication. These changes were devastating to some groups of phytoplankton at the base of the marine food chain while others escaped virtually unscathed. For example, diatoms had ~85% survival across the boundary, and dinoflagellates actually increased in diversity. These non-calcareous plankton most likely survived due to their adaptation to high-stress environments and their ability to form spores and resting cysts. The calcareous nannoplankton, however, were decimated, and approximately 85% of genera and 93% of species went extinct. Nannoplankton generally lack the ability to encyst and thus, as a group, would have been susceptible to darkness, ocean acidification, and eutrophication. However, we still do not fully understand why certain nannofossil taxa survived while others went extinct. Extinction risk, the projected susceptibility of a taxon to extinction based on its ecology and ability to adapt, is a concept that is widely applied to extant species and higher order fossil groups, but not to phytoplankton. This concept is useful for probing the selectivity of ancient species to mass extinction. Determining the extinction risk of late Maastrichtian nannoplankton species would be a step towards understanding the selection of survivors.

The deep-sea record contains a remarkable archive of nannoplankton extinction and recovery across the Cretaceous-Paleogene boundary. The recovery was geologically extended, enabling detailed comparisons among the ocean basins. A large global database of assemblages has led to the discovery that the Northern Hemisphere oceans suffered higher nannoplankton extinction rates than the Southern Hemisphere with an ecological "crisis" that lasted for approximately 350 thousand years after the impact. In addition, incumbency played a major role in the origination of new species. Since extinction almost certainly occurred over durations far shorter than can be resolved in the stratigraphic record, determining their ultimate causes is challenging and far more speculative. In our presentation, we discuss the extinction risk of latest Maastrichtian nannoplankton species by comparing our understanding of their ecology with the biological effects of each potential killing mechanism. Our results show that no one mechanism can explain the extinction of nannoplankton as a group, while also explaining the selection of survivors. We show how acidification and eutrophication amplified extinction risk of species, as did the cessation of photosynthesis caused by darkness.

Calcareous nannofossils and water dynamics in the eastern Pacific and Caribbean (western Atlantic) during the final phase of the emersion of Central America

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The modern configuration of the earth's crust is the result of continuous tectonic modifications through geologic time. These processes control the shape of the ocean basins and influence the distribution, weakening, or reinforcement of the oceanic currents. The last known global events were the closure of the Indonesian Gateway and the emersion of Central America. The closure of the Central American Seaway was a stepwise tectonic event that began at ~16.1-15.1 Ma (Duque-Caro, 1990), and its final phase lasted from 4.6 to 1.9 Ma (Keigwin, 1982; Lundelius, 1987; Keller *et al*., 1989; Coates *et al*., 1992; Haug *et al*., 2001; among others). The main aim of this work was to (1) evaluate how the calcareous nannofossils (CN) responded to the appearance of this land barrier and the intensification of Northern Hemisphere glaciations (NHG)(~2.75 Ma), and (2) elucidate how these events affected the surface ocean dynamics of the Equatorial Eastern Pacific Ocean (EEPO) and the Caribbean Sea (western Atlantic Ocean). We selected samples from the early Pliocene to early Pleistocene (~4.0 to ~1.9 Ma) that were recovered during the ODP Leg 138 (Site 846: 3°5.802'S 90°49.074'W; 849: 0°10.993'N 110°31.167'W; 852: 5°17.550'N 110°4.537'W)(Mayer *et al*., 1992) and Leg 165 (Site 999: 12°44.639'N, 78°44.360'W) (Sigurdsson *et al*., 1997). With an opened gateway, we observed slight fluctuations and very low abundances (e.g., *Pseudoemiliania lacunosa*) of almost every species, except for the <5μm reticulofenestrids. This suggests that there was intensification of the California Current, the North Equatorial Countercurrent, and the Equatorial Undercurrent. After the emergence of Central America, and as a response to the intensification of the NHG, there were high amplitude fluctuations in every species, and the extinction process of the genus *Discoaster* was accelerated, indicating that the South Equatorial Current (SEC) and the Peru Current (PC) were strengthened.

References

Coates, A.G., Jackson, J.B.C., Collins, L.S., Cronin, T.M., Dowsett, H.J., Bybell, L.M., Jung, P. & Obando, J.A. 1992. Closure of the Isthmus of Panama: the near-shore marine record of Costa Rica and western Panama. *Geological Society of America Bulletin*, **104**: 814-828.

Duque-Caro, H. 1990. Neogene stratigraphy, paleoceanography and paleobiogeography in northwest South America and the evolution of the Panama Seaway. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **77**: 203-234.

Haug, G.H., Tiedemann, R., Zahn, R. & Ravelo, A.C. 2001. Role of Panama uplift on oceanic freshwater balance. *Geology*, **29**: 207-210.

Keigwin, L.D. 1982. Isotopic paleoceanography of the Caribbean and east Pacific: role of Panama uplift in late Neogene time. *Science*, **217**: 350-352.

Keller, G., Zenker, C.E. & Stone, S.M. 1989. Late Neogene history of the Pacific-Caribbean gateway. *Journal of South American Earth Sciences*, **2**: 73-108.

Lundelius, E.L., Jr. 1987. The North American Quaternary sequence. *In:* M.O. Woodburne (Ed). *Cenozoic Mammals of North America*. University of California Press, Berkeley: 211-235.

Mayer, L., Pisias, N., Janecek, T. *et al*. 1992. Initial Reports, *Proceedings of the Ocean Drilling Program*, **138**.

Sigurdsson, H., Leckie, R.M., Acton, G.D. *et al*. 1997. Shipboard Scientific Party, Site 999. *Proceedings of the Ocean Drilling Program*, **165**: 131-230

Are Indian Ocean dynamics controlled by the Pacific Ocean or vice versa: ENSO versus monsoon dynamics at a suborbital scale

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Coccolithophores were studied from ODP Site 1240 (0º01.31'N, 86º27.76'W at 2921 m) in the Eastern Equatorial Pacific (EEP) and from the SK-17 core (15º5'N, 72º58'E at 840 m) in the Eastern Arabian Sea (EAS). The Pacific and Indian Oceans are connected by the Indonesian Passageway, with flow generally moving from the Pacific into the Indian Ocean and passing through the Indonesian Archipelago. Productivity in the EEP is primarily determined by variations in the trade winds and El Niño-Southern Oscillation (ENSO) dynamics. Productivity in the EAS is controlled mainly by changes in the Asian monsoon intensity. Productivity in both regions was greater during Termination 1 in the Holocene. This suggests the presence of La Niña-like conditions over the EEP and intensified winter monsoon winds over the EAS during Termination 1. Under these conditions, upwelling occurs in the EEP and in the EAS due to the divergence, which is the result of intense dominant trade winds in both areas. A significant decline in the productivity of both areas occurred in the early Holocene, and productivity was relatively low during the middle and late Holocene, suggesting a weakening of the dominant Trade Winds. EEP productivity showed large fluctuations during the middle and late Holocene, suggesting an alternation of La Niña-like and El Niño-like conditions. To a lesser extent, EAS productivity showed continued significant fluctuations during the middle and late Holocene, likely related to changes in the wind intensity during the winter monsoon. Antarctic waters (e.g., Subantarctic Mode Water) played a crucial role in productivity in the entire Southern Hemisphere because these waters are the main source of nutrients for the thermocline. Our data suggest that thermohaline circulation and Southern Ocean dynamics had a major influence on the productivity of tropical areas of the Pacific and Indian Oceans. Furthermore, we observed a strong parallelism between the productivity of the EEP and the EAS, which suggests a connection between the Pacific and Indian Oceans at this time.

What governs the productivity of coccolithophores in the eastern Equatorial Pacific?

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We provide high-resolution paleoproductivity data for the Holocene in the Eastern Equatorial Pacific and describe the coccolithophore assemblages at Ocean Drilling Project (ODP) Site 1240 in the Panama Basin. Coccolithophores are proposed as a proxy for estimating paleoproductivity and nutricline position in the tropical Pacific Ocean. Our proxies can be used as an indirect tool to reconstruct the El Niño-Southern Oscillation (ENSO), the main factor controlling the climate variability in the Eastern Equatorial Pacific. Equatorial upwelling intensity and the influence of waters with a subantarctic origin controlled the productivity and the phytoplankton composition during the Holocene, and this has been strongly controlled by ENSO dynamics and, as our data suggest, by Southern Hemisphere dynamics. Our results reveal a clear prevalence of dominant La Niña conditions during the early Holocene, with intense upwelling and high primary productivity in the Eastern Equatorial Pacific. La Niña conditions also prevailed during the middle Holocene, although important fluctuations were observed in paleoproductivity, and some intervals with a low primary productivity were recognizable (between 8.2 and 8 ka and around 7 and 6.5 ka), which indicates a weakened upwelling pulse, as occurs during El Niño events. A strong decrease in paleoproductivity occurred between 5 and 4.3 ka, suggesting an increase in stratification of the water column as a result of a shift towards dominant El Niño conditions. Alternations between El Niño- and La Niña-dominant conditions occurred during the late Holocene, with El Niño conditions and low primary productivity clearly prevailing. In addition, we suggest that solar forcing over the Eastern Equatorial Pacific influenced productivity during the Holocene, which generated decadal variability.

Coccolithophore response to cadmium - preliminary results from Project Cd-ToxCoN

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Certain coccolithophores are reported to have some of the highest Cd:P (cadmium to phosphorus) ratios among phytoplankton (*Emiliania huxleyi*: 0.36; *Gephyrocapsa oceanica*: 0.31 mmol:mol) (Finkel *et al*., 2007) and the highest cellular concentration of Cd (*E. huxleyi*: 48; *G. oceanica*: 43 μmol/L of cell volume) (Ho *et al*., 2003). The question remains whether these high Cd ratios and concentrations also reflect a high tolerance to Cd-enrichment conditions with possible implications for toxicity amplification along the trophic food web.

In the present work, controlled laboratory experiments, using a Cd-enriched seawater medium, were performed with coccolithophore strains isolated from Portuguese offshore waters during opportunity cruises. Several species of coccolithophores were isolated and cultured (*Coccolithus pelagicus*, *Calcidiscus leptoporus*, *E. huxleyi*, *G. oceanica*, and *Umbilicosphaera hulburtiana*), but only *E. huxleyi* and *G. oceanica* were able to attain high cell densities during scale-up culture implementation, a necessary step to obtain enough coccolith-driven calcium carbonate to allow Cd analysis.

Two parameters were investigated: (1) Cd partition in the cell (intracellular versus exoskeleton coccosphere) and (2) the effect of increasing Cd concentrations in the physiology of *E. huxleyi* and *G. oceanica*.

The following four Cd concentration thresholds were postulated and examined:

TL1 – above which there is a drop in photosynthetic efficiency

TL2 – above which there is coccolith malformation

TL3 – above which a change into the haploid stage is induced

TL4 – above which cell lysis occurs

Even at the highest Cd concentration tested (8.9 x 10^{-8} M), no evident negative physiological effects were observed. Cells remained viable, photosynthetic efficiency remained high, no gross malformations were observed, and life cycle transitions were not induced. Higher Cd concentrations in the medium led to higher Cd uptake, which was preferentially located inside the cells. Cadmium concentrations higher than present day ocean concentrations seem to favor calcium incorporation into coccospheres.

The very high Cd uptake capacity of the studied ubiquitous coccolithophores raises questions regarding the consequences of these high ratios to marine plankton toxicity.

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References

Finkel, Z.V., Quigg, A.S., Chiampi, R.K., Schofield, O.E. & Falkowski, P.G. 2007. Phylogenetic diversity in cadmium: phosphorus ratio regulation by marine phytoplankton: *Limnology and Oceanography*, **52**(3): 1131-1138.

Ho, T.-Y., Quigg, A.S., Finkel, Z.V., Milligan, A.J., Wyman, K., Falkowski, P.G. & Morel, F.M.M. 2003. Elemental composition of some marine phytoplankton. *Journal of Phycology*, **39**: 1145-1159.

Robust biostratigrapher's "feeling": multivariate ecostratigraphy biosteering (MEB)

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Biosteering uses microfossils to help "guide well trajectory back into a reservoir, boosting access to reserves... particularly when features like sub-seismic faults can throw a well way out of the reservoir package" (Payne *in* Shirley, 2002).

Biosteering normally operates inside a single biostratigraphic unit, i.e., essentially within the same microfossil assemblage. This prevents the use of traditional approaches like FAD/LAD, and the biostratigrapher must use his/her experience based only on subtle assemblage variations across the reservoir. This experience or "feeling" is normally not tabulated and so is very difficult to support statistically or to plot, as compared to geophysical profiling. It can be useful, however, when a decision is necessary to prevent a well from overshooting the upper/lower boundaries of the reservoir in real-time drilling or to immediately detect if you're on a fault's footwall or hanging wall and determine in which direction to drill back to the reservoir. It is especially useful in sediments confined by similar monotonous lithofacies. This technique is possible when the formations have similar facies, and thus similar geophysical properties, but do not have assemblages with the exact same microfossil proportions.

Multivariate ecostratigraphy biosteering (MEB) provides a statistically robust technique, using subtle paleoecological variations across a reservoir's unit(s), that helps support a biostratigrapher's "feeling" in ultra-high-resolution analyses. Specifically, MEB's output can be plotted together with and directly compared to other geophysical profiling data.

MEB provides a case-specific solution for each reservoir, i.e., a certain assemblage function is valid only for a specific and confined sequence of formation(s) because it is sensitive to lateral variation of biofacies. The solution is interpreted and refined from previous characterizations of assemblages across the entire reservoir in question and adjacent formations.

MEB can be applied to any time interval, i.e., to any calcareous nannofossil assemblage. Because it normally uses the most abundant taxa, it allows rapid counts per sample and fast results, and thus is suitable for real-time drilling decisions.

MEB doesn't need the biostratigrapher to change any of his/her taxonomic concepts because it feeds on his/her own everyday experience, namely which species are more pertinent for characterizing reservoir boundaries, and thus its application is specifically designed for each biostratigrapher's needs. Fast assemblage counts can be performed in a quantitative, semi-quantitative, or qualitative scale, as long as there is enough pertinent information. This can be tested and a solution validated during the assemblage characterization of a reservoir's bottom-to-top polarization.

Data from a theoretical scenario will be presented to illustrate MEB capabilities. Everyone is welcome to bring actual encoded and unspecified data and put MEB to the test.

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Reference

Shirley, K. 2002. 'Bugs' showing the path for Drillbit. AAPG *Explorer* (12Dec2002). (http://www.aapg.org/explorer/2002/123dec/biosteering.cfm)

Coccolithophore assemblages in Philippine inland seas

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Few nannoplankton research studies deal with coccolithophore assemblages found in inland seas, such as the Mediterranean and Black Seas in southern Europe and the Seto Sea in Japan. The Philippine archipelago encompasses several inland seas and, therefore, presents an interesting site for studying and identifying morphological differences between species found at higher and lower latitudes. The study was made possible through the PhilEx 2007-2008 Oceanographic Cruise in the Bohol, Sibuyan, and Sulu Seas onboard R/V *Melville* and the Sonne 228 Cruise in the Philippine Sea in 2013 onboard R/V *Sonne*. The surface-water samples collected during these cruises were filtered onboard using a 0.45 μm Millipore filter. Although several of the samples have already been observed with a polarizing microscope, the present study will involve documentation of coccolithophores through scanning electron microscopy. In this project, photomicrographs of coccolithophores from Philippine surface waters will be provided, along with detailed morphological descriptions. This study represents one of the first attempts to document extant coccolithophores in Philippine inland seas, hence, contributing to baseline data on coccolithophore assemblages in a low-latitude tropical setting.

Nannofossil biostratigraphy of northwest Leyte (Visayan Basin)

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The calcareous nannofossil biostratigraphy of northwest Leyte Island (central Philippines) was investigated for the present study. Northwest Leyte is part of the Visayan Basin, which has been the focus of several sedimentological and biostratigraphic studies in the past few years. Similar to Negros Island, northwest Leyte is comprised of fossiliferous sedimentary units, most notable of which are the chemosynthetic, mollusk-bearing Pliocene mudstones. Based on the calcareous nannofossil assemblages, the sections were dated at Pliocene to Pleistocene in age. The Pliocene (Zones NN12-NN15) was recognized based on an assemblage consisting of *Amaurolithus tricorniculatus*, *Ceratolithus armatus*, *Discoaster blackstockae*, *D. brouweri*, *D. pentaradiatus*, *D. surculus*, *D. tamalis*, *D. variabilis*, *Reticulofenestra pseudoumbilicus*, and *Sphenolithus abies*. The Pleistocene (NN19) was recognized on the basis of *Calcidiscus macintyrei*, *Gephyrocapsa* spp. (> 4 μm), *Helicosphaera sellii*, and *Pseudoemiliania lacunosa*. Based on the established nannofossil biostratigraphy, an unconformity was recognized within the Pliocene-Pleistocene interval. A diverse assemblage of the genus Scyphosphaera was also present in the Pliocene mudstones of the investigated sections (Zones NN13-15). This probably corresponds to the abundance acme of the genus that has been reported from the late Miocene to late Pliocene elsewhere.

North Atlantic paleo-productivity changes during Marine Isotope Stages (MIS) 10 to 16 – coccolithophore Sr/Ca evidence

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The North Atlantic is the primary deep ventilator of the oceans, playing a key role in thermohaline circulation through the Atlantic meridional overturning circulation, whose strength can be affected by regional or global climatic changes. During abrupt climate change events (e.g., Heinrich Events), the southward migration of the Polar Front, induced by iceberg discharge and melt-water pulses, led to abrupt decreases in sea-surface temperatures and salinity, which then affected primary productivity. Paleoproductivity signals in the North Atlantic are controversial. Primary productivity is believed to contribute to a CO_2 decrease during glacial periods through the uptake of atmospheric CO_2. As primary producers and the most important calcifying organisms in the ocean, coccolithophores play a key role, not only in the ocean ecosystem but also in the global carbon cycle, through their combined effects on both the biological and carbonate pumps. The coccolith Sr/Ca ratio is linked to productivity with a higher ratio indicating faster growth rates and thus higher coccolith productivity.

This study aims to determine paleoproductivity variability based on coccolith Sr/Ca ratios at IODP Site U1313 (41°N, 33°W) between 676 and 355 ka ago, encompassing three glacial/interglacial cycles. MIS 12 is considered to be the most extreme glacial event of the last 500 ka, experiencing Heinrich-type ice-rafting events, while MIS 14 was a relatively mild glacial. For the MIS 12-10 interval, for which data corrections and interpretation have already been completed, the Sr/Ca data clearly show that coccolithophore productivity was substantially higher during glacial than interglacial or interstadial periods. Heinrich EVENTS, on the other hand, greatly diminished paleoproductivity. Analyses that are underway for the older stages will determine whether similar patterns exist in these intervals and how productivity varied in the relatively colder interglacials MIS 13 and MIS 15 in comparison to MIS 11.

5 Ma coccolith records and their paleoceanographic significance in the south of the South China Sea

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For this research, calcareous nannofossils were identified and percentages counted for 1411 samples from ODP Site 1143. In addition, 500 of these samples were analyzed with SYRACO (Système de Reconnaissance Automatique de Coccolithes). The results reveal changes in predominant coccolith species, the depth of the nutricline, and the primary productivity of surface waters, as well as their response to paleoceanographic events. The Mid-Brunhes Event (MBE) is used as an example to explain a possible mechanism for the eccentricity-triggered blooming of the coccoliths and the relationship between the coccolith community and the δ^{13}Cmax event, as well as changes in the long-term cycle of the ocean carbon reservoir.

The dominant Quaternary species in the South China Sea, *Florisphaera profunda*, *Gephyrocapsa oceanica*, *Emiliania huxleyi*, and *Gephyrocapsa caribbeanica*, all experienced significant changes during paleoceanographic events at 0~0.05, 0.26~0.48, 0.9, and 1.4~1.6 Ma. Coinciding with the four δ^{13}Cmax events, the primary productivity increased, which suggests that coccolith productivity has been an important influence on the ocean carbon reservoir.

There are four stages in changes in the nutricline depth at ODP site 1143. Comparing the monsoon record, SST, and other results, the change in the nutricline depth is primarily influenced by the monsoons and by expansion of the Arctic ice sheet. The structure of the upper water varied before and after 0.9 Ma reflecting changing monsoonal patterns. Before 0.9 Ma (Marine Isotope Stage 22), as the summer monsoon intensified during an interglacial, the depth of the nutricline shallowed. After 0.9 Ma, as the winter monsoon intensified during a glacial, the depth of the nutricline shallowed.

Spectral analysis of the primary coccolith species shows a 100ka eccentricity cycle, a 40-ka obliquity cycle, and a 20-ka precession cycle, which indicate that orbital cycles are the main motivator for the coccolith community's change.

In the mid-Brunhes interval (0.26~0.48 Ma), the percentage of *F. profunda* declined, while *Gephyrocapsa (Gephyrocapsa caribbeanica)* was blooming. Meanwhile, the structure of the sea water changed, the nutricline depth decreased, and primary productivity increased. Studies show that during the mid-Brunhes interval the eccentricity was at a low level, and we conclude three possible mechanisms to explain this situation: (1) eccentricity can influence the Si supply via weathering, which changes the diatom/coccolith ratio and the carbon reservoirs, (2) periods of low eccentricity are optimal for the growth of coccoliths, and (3) eccentricity can influence the productivity of the Southern Ocean and, via "Si leakage," control coccolith productivity.

Spectral analysis of *F. profunda* percentages shows a 500-ky cycle at 0~1.6 Ma and 400-ky cycles at 1.6~5 Ma, which means that at this time the coccolith community was primarily influenced by eccentricity forcing. The *F. profunda* percentage is primarily controlled by the change in the structure of the Southern Ocean and "Si leakage". Therefore, with intensified fluctuations, the coccolith community can change the ocean carbon reservoirs.

Quantitative analysis of calcareous nannofossil bioevents of the Late Cretaceous (late Cenomanian-Coniacian) Western Interior Seaway and their relative reliability

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Calcareous nannofossil assemblages from eight localities in the upper Cenomanian-Coniacian of the central (Colorado and Kansas) and southern (Texas) Western Interior Seaway were analyzed to produce a new high-resolution biostratigraphic framework for the Greenhorn Formation, Eagle Ford Formation, and basal Austin Chalk. Eighteen datasets from coeval successions, including the Global Stratotype Section and Point (GSSP) at Pueblo, CO, and proposed reference sections for the base of the Turonian and candidate GSSPs for the base of the Coniacian in Germany, Poland, and New Mexico, were incorporated from literature sources. Ranking and scaling (RASC) of 48 selected bio-events produced a quantitatively-derived optimum sequence of biostratigraphic events. Scaling of the events along a relative time scale revealed an 8-9% evolutionary turnover during OAE2 and net speciation at the basal Coniacian boundary. Comparison with the qualitatively developed CC (Perch-Nielsen, 1985) and UC (Burnett, 1998) nannofossil zonations revealed inconsistencies, largely due to the recognition of new/amended species concepts. Discrepancies near the Turonian/Coniacian boundary reflect changes to its placement in recent revisions to the geologic time scale. A sequence of bioevents documented by Lees (2008) provided an accurate proxy for the Turonian/Coniacian boundary in the absence of the inoceramid index fossil *Cremnoceramus deformis erectus* (Meek).

References

Burnett, J.A. 1998. Upper Cretaceous. *In:* P.R. Bown (Ed). *Calcareous Nannofossil Biostratigraphy*. British Micropalaeontolical Society Publication Series. Chapman and Hall/Kluwer Academic Publishers, London: 132-199.

Lees, J.A. 2008. The calcareous nannofossil record across the Late Cretaceous Turonian/Coniacian boundary, including new data from Germany, Poland, the Czech Republic and England. *Cretaceous Research*, **29**: 40-64.

Perch-Nielsen, K. 1985. Mesozoic calcareous nannofossils. *In:* H.M. Bolli, J.B. Saunders, & K. Perch-Nielsen (Eds). *Plankton Stratigraphy*. Cambridge University Press: 329-426.

Presence of specific calcareous nannoplankton assemblages along the NE Florida continental margin: a look at Loop Current shedding and the Desoto Canyon funnel effect

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There are a number of hypotheses that provide a multitude of mechanisms for investigating the shifting patterns in annual water-property characteristics of the Gulf of Mexico. Most of the available data rely heavily on numerical experimentation and long-term, acoustic-based ship-board analysis. However, calcareous nannoplankton, a large component of the base of the food chain along the continental margin off the Florida panhandle, can also be utilized as a biostratigraphic and geomorphologic tool. Specific species, such as *Gladiolithus flabellatus* and *Florisphaera profunda*, which are normally found deep in the photic zone, can be used to signal circulation abnormalities. These species can bloom in unusual places under the proper conditions, such as those initiated by warm-core eddies. For example, in the summer-fall months, warm-core eddy spin-off events are evident in the numerical data. However, these species can also be used to trace Loop Current shedding events back to their origin. We began monthly sampling between August and September from 2011 to the present along three transects across the Florida Panhandle shelf. We have collected over 500 samples through the photic zone via Niskin-bottle rosettes, and their quantitative nannoplankton census data are being taken via scanning electron microscopy. Our goal is to use these data to link specific nannoplankton species to annual eddy shedding events and to investigate the DeSoto Canyon funnel effect during the months of our study interval. We also plan to compare our data with all available twelve-month data for our four-year sampling interval.

A review of late Oligocene to mid Miocene sphenolithids from DSDP Leg 94, Site 608 and DSDP Leg 25, Site 242

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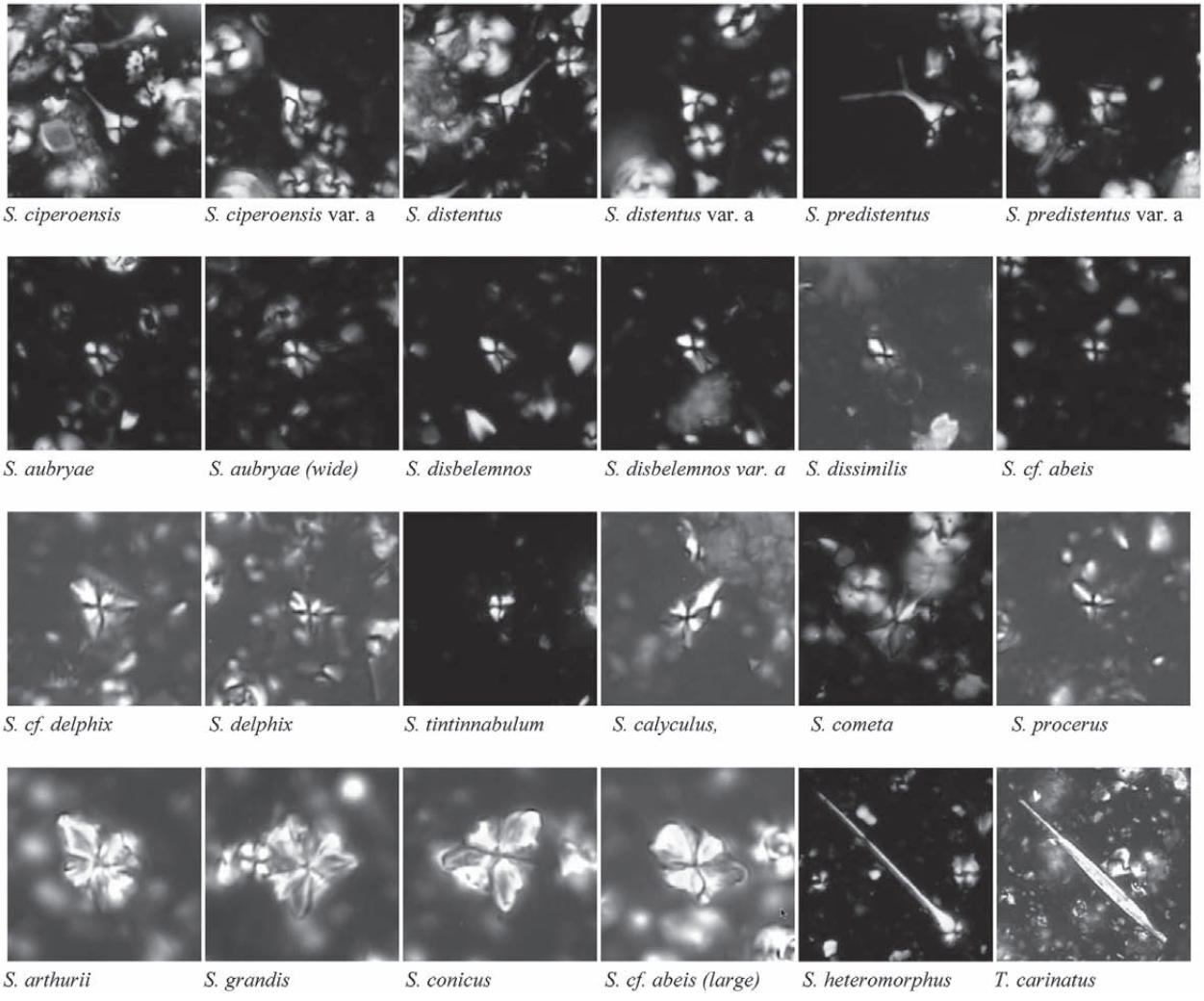
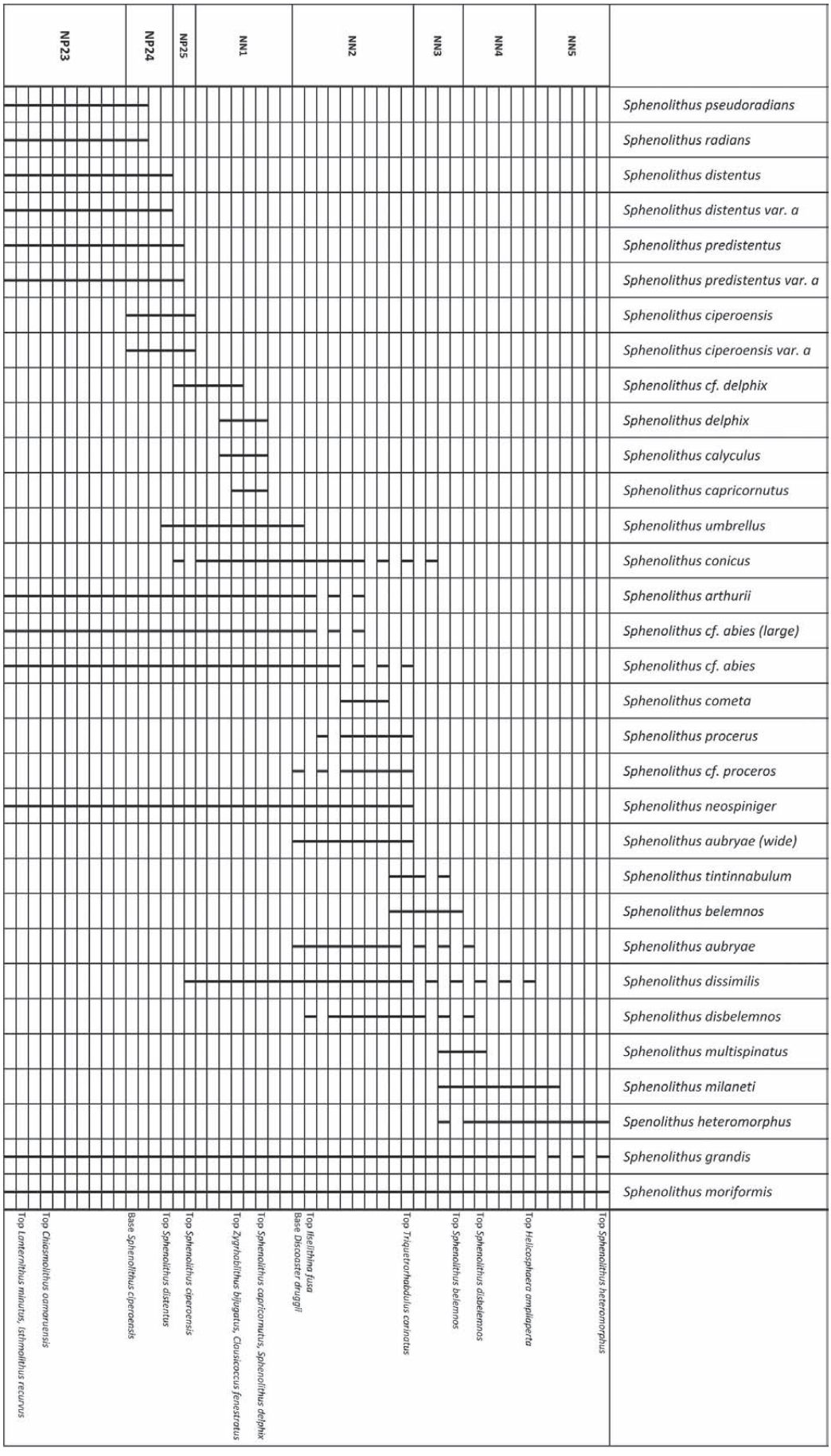
A high-resolution biostratigraphic study of late Oligocene to early-mid Miocene calcareous nannofossils from core samples at Deep Sea Drilling Project (DSDP) Leg 25, Site 242 and Leg 94, Site 608 allowed the verification and refinement of taxonomic concepts, and introduced new combinations and several new variations with potential speciation value. In addition, the stratigraphic distribution of sphenolithids from both legs was compared and suggests globally synchronous events. This study emphasizes the generic usefulness of providing high-resolution mid-Miocene to late Oligocene stratigraphic subdivisions. The age ranges are described in reference to Martini (1971) and provide alternative means of subdividing Zones NP24 to NN5.

In addition, the problems of species concepts and variations on the following groups are emphasized: (1) *S. predistentus*, *S. distentus*, and *S. ciperoensis*; (2) *S. aubryae*, *S. disbelemnos*, and *S. dissimilis*; (3) *S. cf. abies* and *S. aubryae* (wide); (4) *S. cf. spiniger*, *S. cf. delphix*, *S. delphix*, and *S. tintinabulum*; (5) *S. delphix*, *S. calyculus, S. cf. calyculus*, and *S. cometa*; (6) *S. cf. proceros* and *S. proceros*; (7) *S. grandis*, *S. cf. abies* (large), *S. conicus,* and *S. arthurii*. Finally, the similarity between broken *Sphenolithus* spines and *Triquetrorhabdulus carinatus* and the problems associated with *Helicosphaera ampliaperta/scissura* and ?*Helicosphaera granulata* for assigning Zones NN2 and NN4 respectively is discussed.

Reference

Martini, E. 1971. Standard Tertiary and Quaternary calcareous nannoplankton zonation. *Proceedings 2nd Planktonic* Conference, Rome 1969: 739-785.




NP23
NP24
NP25
NN1
NN2
NN3
NN4
NN5
Sphenolithus pseudoradians
Sphenolithus radians
Sphenolithus distentus
Sphenolithus distentus var. a
Sphenolithus predistentus
Sphenolithus predistentus var. a
Sphenolithus ciperoensis
Sphenolithus ciperoensis var. a
Sphenolithus cf. delphix
Sphenolithus delphix
Sphenolithus calyculus
Sphenolithus capricornutus
Sphenolithus umbrellus
Sphenolithus conicus
Sphenolithus arthurii
Sphenolithus cf. abies (large)
Sphenolithus cf. abies
Sphenolithus cometa
Sphenolithus procerus
Sphenolithus cf. proceros
Sphenolithus neospiniger
Sphenolithus aubryae (wide)
Sphenolithus tintinnabulum
Sphenolithus belemnos
Sphenolithus aubryae
Sphenolithus dissimilis
Sphenolithus disbelemnos
Sphenolithus multispinatus
Sphenolithus milaneti
Spenolithus heteromorphus
Sphenolithus grandis
Sphenolithus moriformis
Top Lanternithus minutus, Isthmolithus recurvus
Top Chiasmolithus oamaruensis
Base Sphenolithus ciperoensis
Top Sphenolithus distentus
Top Sphenolithus ciperoensis
Top Zygrhablithus bijugatus, Clausicoccus fenestratus
Top Sphenolithus capricornutus, Sphenolithus delphix
Base Discoaster druggii
Top Ilselithina fusa
Top Triquetrorhabdulus carinatus
Top Sphenolithus belemnos
Top Sphenolithus disbelemnos
Top Helicosphaera ampliaperta
Top Sphenolithus heteromorphus

A revision of reticulofenestrid taxonomy and biostratigraphy

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Based on exhaustive taxonomic research, a revision of the Eocene-Holocene reticulofenestrids, including the genera *Dictyococcites* and *Reticulofenestra*, is proposed. A special attempt has been undertaken to find all published species of this group in the worldwide literature from the middle of the 20th century to today. The first *Reticulofenestra* micrographs were published by Deflandre & Fert (1954) as *Discolithus dictyodus*, by Black (1962) as *Coccolithus celticus*, and by Hay & Towe (1962) as *Cyathosphaera martinii*. The first *Dictyococcites* species was published by Hay & Towe (1962) as *Heliolithus helianthus*. A total of 106 species and subspecies have now been described in the literature with 27 of them placed in the genus *Dictyococcites* and 48 in the genus *Reticulofenestra*. The other 31 species are either invalid, a junior synonym, or more properly belong in another genus.

The generic name *Reticulofenestra* was introduced by Hay, Mohler & Wade (1966) and *Dictyococcites* by Black (1967). Both have been emended several times since then. A large controversy exists in the use of the genus *Dictyococcites* since the emendation of Stradner & Edwards (1968). In general, the reticulofenestrids are classified by their rim structure (*Emiliania*, *Salisia* ex *Pseudoemiliania*), but also by the central area structure as in *Gephyrocapsa* (presence of a bridge) or in *Noelaerhabdus* (presence of an apical and/or antapical distal process).

Some authors consider the genus *Dictyococcites* to be synonymous with *Reticulofenestra* and do not consider the variations in the central-area structure to be of generic value. The central area structure of *Dictyococcites* species is complex and can show important variations, but in general, two layers (proximal and distal) of coarse elements close the central-area. In *Reticulofenestra*, the central area structure is composed of only one proximal layer and is made of very thin/delicate elements. Because of these differences, the birefringence in cross-polarized light of the central area differs in each genus: *Dictyococcites* has a bright central area, and *Reticulofenestra* has a non-birefringent central area. Important differences in their biostratigraphic ranges also would also indicate value in keeping these two genera.

With precise measurements of all holotypes and paratypes completed, it is proposed to reclassify the two genera based on key indicators: length and width of

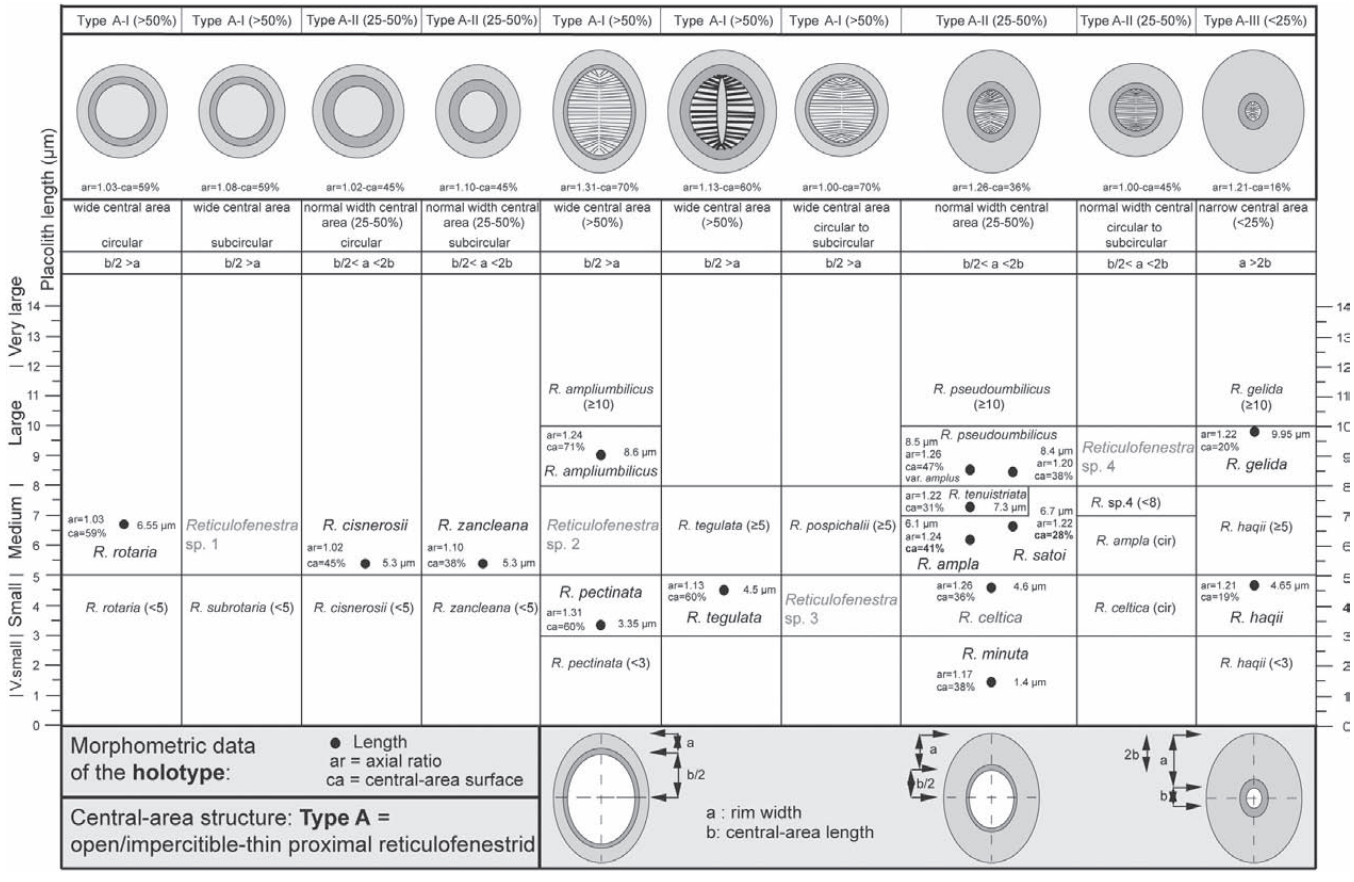

Table 1. Classification of the genus *Reticulofenestra* (Neogene)

coccoliths (axial ratio: ar), rim length, central area length, central area structure, and central area surface (ca). Four tables summarize this proposed classification and facilitate a method for rapid determination of a species (one table is shown as an example). These four working tables will allow all nannofossil paleontologists to be consistent in the use of this group for ecological or biostratigraphic studies. Because coccolith size and shape are two of the key characteristics for biostratigraphy, some species have been split based on those two criteria.

Coccolith shape is not retained as the primary characteristic to separate genera. Both *Reticulofenestra* and *Dictyococcites* include large variations in shape from circular to elliptical. *Reticulofenestra rotaria* (circular) and *Reticulofenestra pectinata* (normally elliptical) belong to the same genus. The same variation is observed in *Dictyococcites* with *Dictyococcites reticulatus* (circular) and *Dictyococcites productellus* (normally elliptical). Four new *Reticulofenestra* species are described. In addition, two new replacement names and eighteen new combinations are also proposed.

References

Black, M. 1962. Fossil coccospheres from a Tertiary outcrop on the continental slope. *Geological Magazine*, **99**(2): 123-127.

Black, M. 1967. New names for some coccolith taxa. *Proceedings of the Geological Society of London*, **1640**: 139-145.

Deflandre, G. & Fert, C. 1954. Observations sur les Coccolithophoridés actuels et fossiles en microscopie ordinaire et électronique. *Annale de Paléontologie*, **40**: 115-176.

Hay, W.W., Mohler, H.P. & Wade, ME. 1966. Calcareous nannofossils from Nal'chik (northwest Caucasus). *Eclogae Geologicae Helvetiae*, **59**(1): 379-400.

Hay, W.W. & Towe, K.M. 1962: Electron microscopic examination of some coccoliths from Donzacq (France). *Eclogae geologicae Helvetiae*, **55**(2): 497-517.

Stradner, H. & Edwards, A.R. 1968. Electron microscopic studies on upper Eocene coccoliths from the Oamaru Diatomite, New Zealand. *Jahrbuch der Geologischen Bundesanstalt (Wien)*, **13**: 1-66.

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

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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 calcite compensation depth (CCD) of over a kilometer (Coxall *et al*., 2005). The role of surface ocean productivity changed, especially at low latitudes, and carbon cycle perturbations remain open to question, as do 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 micropaleontologic 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 of the radiolaria and the loss of the multi-rayed discoasters, prior to the onset of the major phases of Antarctic glaciation. Three characteristic phytoplankton assemblages were identified in the shift from the late Eocene to the early Oligocene: a late Eocene coccolithophore-dominated assemblage (multi-rayed *Discoasters*, *Coccolithus formosus*, and *Reticulofenestra dictyoda*), a transitional coccolithophore assemblage (increased abundances of *R. bisecta*), and an earliest Oligocene mixed coccolithophore-diatom assemblage. The timing and nature of these changes support progressive cooling in the latest Eocene that is associated with enhanced upwelling in the equatorial Pacific, and which occurred 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 oldest calcareous nannofossils: Middle Triassic coccoliths from China

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Calcareous nannofossil investigations were carried out on a few samples from the late Ladinian Zhuganpo Member of the Falang Formation in an outcrop near the village of Nimaigu (Wusha District, Xingyi City, Guizhou Province, southern China). Since August 2011, a scientific excavation has made a bed-by-bed collection that has produced rich reptilian, fish, and ammonite faunas, including findings of the oldest “flying” fish to date.

A few samples contained relatively frequent and diversified coccoliths and nannoliths. Some of the observed taxa resemble previously established species, but others have not been previously documented. It must be emphasized that the oldest reliable nannofossils are Carnian in age, so the findings in the Wusha samples presumably document the oldest calcareous nannofossils to date. These results are relevant for dating and understanding coccolithophore calcification. The relatively diversified assemblages imply an even older origination for coccolith/nannolith-bearing phytoplankton. Further analyses are planned in order to expand the data and characterize the origin, distribution, and evolution of calcareous nannoplankton.

Life in extreme oceans: calcareous nannoplankton adaptations and strategies during Oceanic Anoxic Event 2

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At the present time, about one third of the carbon dioxide (CO_2) released in the atmosphere from fossil fuel burning is absorbed by the oceans. The invasion of anthropogenic CO_2 into the oceans increases seawater acidity and decreases carbonate ion concentration and carbonate saturation. This dramatic change in the carbonate system can have a huge impact on the marine ecosystem and, in particular, can seriously impair marine calcifiers (e.g., corals, foraminifera, and coccolithophores). Coccolithophorid algae are sensitive to ocean acidification, and most studies show a strong decline in growth and/or reduction in calcification rate and/or increase in coccolith malformation with increasing CO_2 concentration.

During the Cretaceous, the Earth had already experienced extreme environmental change through the construction of Large Igneous Provinces (LIPs) that formed gigantic oceanic plateaus, which affected ecosystems on a global scale. Volcanism on these provinces probably triggered global warming and enhanced primary productivity with consequent increased oxygen consumption and burial of massive amounts of organic matter at a global scale. These episodes are known as Oceanic Anoxic Events (OAEs). We investigated calcareous nannoplankton morphological variation through one of the most interesting anoxic events of the Cretaceous, the latest Cenomanian OAE2. This episode of global anoxia is associated with the formation of the Caribbean Plateau (CP) that triggered a massive release of excess CO_2, causing general global warming. Recent studies of the OAE2 episode have demonstrated the existence of climatic variability and fluctuations in the atmCO_2 concentration. In fact, a cooling episode and CO_2 drop in the early phase of OAE2 is connected with a weathering spike, followed by a new increase in CO_2 and warming.

We investigated OAE2 sections from Sicily, southern France, England, and Colorado. The major result that we observed was a change to tiny/dwarf coccoliths, although of differing amplitudes, through OAE2. Calcareous nannofossil size variations followed the pCO_2 fluctuations and recorded an increase in size when pCO_2 started to decrease, while dwarf coccoliths were coeval with a strong increase in CO_2. The record of paleofertility during OAE2 was not straightforward, and mid-latitude localities seem to have been affected by a decrease in nutrient availability, whereas, in the Atlantic tropical waters, the nutrient content increased. Comparing these data with our morphometric results, we noticed a lack of repetitive pattern. Therefore, it seems unlikely that nutrient content controlled coccolith dwarfism during OAE2.

Another selected case history is the Aptian OAE1a, which was associated with the submarine construction of the Ontong Java Plateau (OJP) that triggered a disruption of the oceanic carbonate system. At the onset of the carbon isotopic anomaly, during the most profound paleoenvironmental perturbation, excess CO_2 caused ocean acidification, which resulted in a temporary failure of the rock-forming nannoconids and the formation of dwarf and malformed coccoliths.

The inferred warmer conditions and excess CO_2 during intervals of LIPs' volcanism suggest a potential influence on nannoplankton calcification. Hydrothermal plumes during construction of both the OJP and the CP introduced biolimiting metals that fertilized the global ocean. However, some toxic metals may have disturbed the functioning or hampered calcification of some intolerant coccolithophorid species.

Different patterns and degrees of dwarfism and malformation during OAE1a and OAE2 suggest unequal volcanic CO_2 emissions (rates, pulses, and amount) and/or variable combinations of CO_2, climate, and fertility. LIPs' emplacement through geologic time, therefore, only resulted in limited similarities in their effect on coccolithophorid species.

Calcareous nannofossil biostratigraphic studies in the Visayan Basin (central Philippines)

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The Visayan Basin is a northeast-southwest trending sedimentary basin located in the central part of the Philippines. The basin consists of Cretaceous volcanic flows and intrusives, and folded and slightly metamorphosed Cretaceous sediments that are overlain by Eocene and younger sedimentary formations, including the marine sediments that were deposited from late Oligocene to Pleistocene (Porth *et al*., 1989). This study in the Visayan Basin began in 2003, as part of the research program on the "Cenozoic molluscan faunal study and refinement of Cenozoic formations in the Philippines". As part of this program, samples for calcareous nannofossil analysis were collected on Bohol Island, southeast Negros, and northwest Leyte where the fossil mollusks had been collected in order to establish the age of the mollusk-bearing units and, at the same time, refine the stratigraphy and age of the sedimentary formations.

On Bohol Island, nannofossil analysis of the samples resulted in the recognition of a late Miocene sedimentary unit in an area that was previously mapped as part of a middle Miocene formation. Zone NN11 (CN9) was established based on the occurrence of *Discoaster quinqueramus* and *Discoaster berggrenii*. Several sections were investigated on Negros Island, and the results include: (1) the recognition of a late Oligocene sedimentary unit in an area previously mapped as late Miocene to early Pliocene and (2) confirmation of the late Oligocene to earliest Miocene age of the Escalante Formation (assigned to Zones NP24 - NN1) based on the occurrence of marker taxa *Cyclicargolithus abisectus*, *C. floridanus*, *Reticulofenestra bisecta*, *R. daviesii*, *Discoaster deflandrei*, *Helicosphaera recta*, *Sphenolithus ciperoensis, S. distentus*, *S. predistentus,* and *S. delphix*. The southeastern part of Negros Island is one of the few localities in the Philippines where the fossil mollusk Vicarya can be found. The Oligocene age obtained from nannofossils, therefore, suggests that the study area includes the oldest fossil record of *Vicarya* in the Philippines and probably in Asia.

Northwest Leyte is located in the northeastern part of the Visayan Basin. The area is known as one of the very few localities in the world with well-preserved fossils of chemosynthetic mollusks that represent cold-seep assemblages (Majima *et al*., 2007, 2010). Investigation of several sections revealed a diverse assemblage of Pliocene to Pleistocene calcareous nannofossils. The nannofossil assemblage confirms that the chemosynthetic mollusk assemblages are Pliocene in age, corresponding to Zones NN12-NN15. The Pliocene was recognized based on the occurrence of *Amaurolithus tricorniculatus*, *Ceratolithus armatus*, *Discoaster tamalis*, *Discoaster blackstockae, Reticulofenestra pseudoumbilicus*, and *Sphenolithus abies*. The Pleistocene, on the other hand, was recognized based on the occurrence of large (>5um) *Gephyrocapsa*

spp., large circular forms of *Pseudoemiliania lacunosa*, and the LO of *Calcidiscus macintyrei*. Based on established nannofossil biostratigraphy, there was a considerable gap within the investigated sections, corresponding to Zones NN16-NN18, suggesting that there was an erosional and/or non-depositional event that spanned at least 1.8 million years during the late Pliocene. This may correspond to a basin-wide unconformity during the late Pliocene-Pleistocene interval in the Visayan Basin (Porth *et al*., 1989). A diverse assemblage of scyphosphaerids also was present in the Pliocene mudstones of the investigated sections within Zones NN13-NN15. This probably corresponds to the abundance acme of the genus reported by Siesser (1998) from the late Miocene to late Pliocene interval (Zones NN9-NN15), which is now recognized for the first time in the Visayan Basin.

References

Majima, R., Kase, T., Kawagata, S., Aguilar, Y.M., Hagino, K. & Maeda, M. 2007. Fossil cold-seep assemblages from Leyte Island, Philippines. *Journal of Geography*, **116**: 643-652.

Majima, R., Jenkins, R.G., Kase, T., Aguilar, Y.M., Nanjo, T., Wani, R., Wada, H., Fernando, A.G.S. & Hayashi, H. 2010. In situ Calyptogena colonies from Pliocene back-arc basin fills in Leyte Island, Philippines. *Journal of the Geological Society of Japan*, **116**(10); XV-XVI.

Porth, H., Müller, C. & von Daniels, C. H. 1989. The sedimentary formations of the Visayan Basin, Philippines. *In:* H. Porth and H. von Daniels (Eds). *On the Geology and Hydrocarbon Prospects of the Visayan Basin, Philippines*. *Geologisches Jahrbuch*, Reihe B, **70**: 28-88.

Siesser, W.G. 1998. Calcareous nannofossil Genus Scyphosphaera: structure, taxonomy, biostratigraphy, and phylogeny. *Micropaleontology*, **44**(4): 351-384.

Calcareous nannofossil biostratigraphy of selected sedimentary formations on Negros Island (Visayan Basin, Central Philippines)

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Negros Island (central Philippines) occupies the southwestern part of the Visayan Basin, which has been the object of petroleum exploration for the past 100 years. Despite this, very few sedimentological and calcareous nannofossil studies have been done in the area. In order to refine the ages of the sedimentary formations and the stratigraphy of the island, the calcareous nannofossil biostratigraphy of several sections on Negros Island was investigated.

The present study focused on the south-central part of the island where late Oligocene to early Pliocene sedimentary units are exposed. The oldest sedimentary unit is represented by the Escalante Formation, which was assigned to nannofossil Zones NP24 to NN1. The zones were established using the occurrence of *Cyclicargolithus abisectus*, *Cyclicargolithus floridanus*, *Reticulofenestra bisecta*, *Reticulofenestra daviesii*, *Discoaster deflandrei*, *Helicosphaera recta*, *Sphenolithus ciperoensis*, *Sphenolithus distentus*, *Sphenolithus predistentus*, and *Sphenolithus delphix*. The data suggest a late Oligocene age for the mollusk *Vicarya* spp., which was collected from the same formation. The present study also reports the presence of previously unrecognized early to middle Miocene sedimentary units in the study area, which will change the current understanding of the stratigraphy of Negros Island.

Advances in calcareous nannofossil biostratigraphy based on Toarcian-Aalenian sections from the Lusitanian Basin (Portugal)

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Two sections from the Jurassic Lusitanian Basin (LB) were studied for calcareous nannofossil content. This basin lay along the western margin of the Iberian Meseta and was bounded on the west by the Berlengas-Farilhões igneous and metamorphic basement horst. This narrow basin had an approximate N-S orientation and was located at a paleolatitude of 25-30ºN (Dercourt *et al*., 2000). Lower Jurassic carbonate sediments were deposited on a homoclinal low-angle ramp that dipped NW (Duarte & Soares, 2002; Duarte, 2004).

The lower to middle Toarcian section from Rabaçal represents the most proximal marine setting of the LB, and the upper Toarcian to middle Aalenian section from Cabo Mondego is the most distal location. Both sections are characterized by limestone-marl alternation with common ammonites, belemnites, gastropods, bivalves, and brachiopods. In the 42 m of the Rabaçal section that span the Polymorphum, Levisoni, and Bifrons ammonite Zones (AZ), 138 samples were examined. In the 85 m of the Cabo Mondego section that span the Maneghinii (?), Aalensis, and Opalinun AZ, 72 samples were examined. All samples were prepared using the random settling technique described by Geisen *et al*. (1999) and studied under an optical polarized microscope with x1000 magnification. Whenever possible, at least 300 coccoliths were counted, thus species making up more than 1.7% of the total assemblage were recorded with a confidence level of 99.5%, and species with more than 0.9% of the assemblage at a confidence level of 95% (Fatela & Taborda, 2002).

The calcareous nannofossil assemblage was fairly diverse throughout the Rabaçal section, although sometimes scarce and badly preserved. The transition from the Levisoni to the Bifrons AZ (lower to middle Toarcian) was marked by the last occurrence (LO) of *Mitrolithus jansae* and the first occurrence (FO) of *Watznaueria fossacincta* in the Levisoni AZ, followed almost immediately by the FO of *Watznaueria colacicchii* in the lowermost Bifrons AZ. Although Mattioli & Erba (1999) recorded *W. colacchii* FO in the uppermost lower Toarcian, poor preservation may explain its absence in the Levisoni AZ. The FO of *Discorhabdus striatus* in the Levisoni AZ is an indicator for the uppermost part of the Levisoni AZ, according to the Bown & Cooper (1998) and Mattioli & Erba (1999) biozonation scheme for this interval. Mattioli & Erba (1999) recorded the FO of Carinolithus superbus in the Polymorphum AZ, but this taxon's FO was only observed in the Levisoni AZ at Rabaçal. This species' delayed appearance may be due to environmental conditions.

The Cabo Mondego section contained more pristine, diverse, and abundant calcareous nannofossils. Although an ammonite biozone calibration has not yet been made for this location, and the Toarcian-Aalenian boundary cannot be identified due to the lack of robust FO/LO bioevents, the Cabo Mondego section did contain the LO of *Crepidolithus cavus* and the FO of *Retecapsa incompta* in the upper Toarcian stage, indicating the top of the Toarcian (Mattioli & Erba, 1999). Another bioevent, the FO of *Watznaueria contracta* in the uppermost Toarcian, is likely to be a close indicator for the Toarcian-Aalenian boundary. A calibration of calcareous nannofossils with the AZ and a detailed biometric study are in progress, and they may soon shed some light on the evolutionary transition from *Lotharingius* to *Watznaueria* where intermediate morphologies make species identification difficult. Nevertheless, at Cabo Mondego, the Toarcian-Aalenian boundary was identified by the LO of *C. cavus*, the FO of *R. incompta* and *W. contracta* in the upper Toarcian, and the FO of *Hexalithus magharensis* and the LO of *Bussonius prinsii* and *B. leufuensis* in the Opalinum AZ (lower Aalenian), the latter ones following the de Kaenel *et al*. (1996) zonation scheme for Portugal. In this work, the LO of *Carinolithus poulnabronei* occurred in the upper Toarcian, probably in the Aalensis AZ, earlier than reported by Mattioli & Erba (1999).

References

Bown, P.R. & Cooper, M.K.E. 1998. Jurassic. *In:* P.R. Bown (Ed). *Calcareous Nannofossil Biostratigraphy*. Cambridge, 34-85.

de Kaenel, E., Bergen, J.A. & Perch-Nielsen, K. von S. 1996. Jurassic calcareous nannofossil biostratigraphy of western Europe. Compilation of recent studies and calibration of bioevents. *Bulletin de la Société Géologique de France*, **167**: 15-28.

Dercourt, J., Gaetani, M. & Vrielynck, B. 2000. Atlas Peri-Téthys and explaining notes (S. Crasquin coord.) *CCGM*, Paris.

Duarte, L.V. 2004. The geological heritage of the Lower Jurassic of Central Portugal: selected sites, inventory and main scientific arguments. *Rivista Italiana di Paleontologia e Stratigrafia*, **110**: 381-387.

Duarte, L.V. & Soares, A.F. 2002. Litostratigrafia das séries margo-calcárias do Jurássico inferior da Bacia Lusitânica (Portugal). *Comunicações do Instituto Geológico e Mineiro*, **89**: 135-154.

Fatela, F. & Taborda, R. 2002. Confidence limits of species proportions in microfossil assemblages. *Marine Micropaleontology*, **45**: 169-174.

Geisen, M., Bollmann, J., Herrle, J.O., Mutterlose, J. & Young, J.R. 1999. Calibration of the random settling technique for calculation of absolute abundances of calcareous nannoplankton. *Micropaleontology*, **45**: 437-442.

Mattioli, E. 1997. Nannoplankton productivity and diagenesis in the rhythmically bedded Toarcian-Aalenian Fiuminata section (Umbria-Marche Apennine, central Italy). *Palaeoceanography, Palaeoclimatology, Palaeoecology*, **130**: 113-133.

Mattioli, E. & Erba, E. 1999. Synthesis of calcareous nannofossil events in the Tethyan Lower and Middle Jurassic successions. *Rivista Italiana di Paleontologia e Stratigrafia*, **105**: 343-376.

Middle Eocene – lower Oligocene nannofossil biostratigraphy and paleoceanography from ODP Site 711 (Equatorial Indian Ocean)

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Quantitative nannofossil assemblage analysis was conducted on middle Eocene- lower Oligocene sediments from Ocean Drilling Program (ODP) Site 711, located in the western equatorial Indian Ocean. The aim of this work was primarily to increase the biostratigraphic resolution for this time interval, comparing the reliability of the results with recently proposed additional bioevents (e.g., Bown & Dunkley Jones, 2012; Toffanin *et al*., in press). A high-resolution quantitative study across a ~12 myr time interval allowed the recognition of 29 nannofossil bioevents. Recent magnetostratigraphic data obtained for this site (Savian *et al*., 2013) made it possible to date the bioevents, compare them with other sites from low to high latitudes, and evaluate their reproducibility within and outside the equatorial region.

Precise dating through the use of biomagnetostratigraphy allows the identification of variations in the nannofossil assemblage in response to global climatic and paleoceanographic events, such as the Middle Eocene Climatic Optimum (MECO) and the earliest Oligocene Oi-1. In the equatorial Indian Ocean, this confirms influences due to the transition of the Earth's climate from the early Paleogene "Greenhouse" into the late Paleogene "Icehouse".

References

Bown, P.R. & Dunkley Jones, T. 2012. Calcareous nannofossils from the Paleogene equatorial Pacific (IODP Expedition 320 Sites U1331-1334). *Journal of Nannoplankton Research*, **32**(2): 3-51.

Savian, J.F., Jovane, L., Bohaty, S.M. & Wilson, P.A. 2013. Middle Eocene to early Oligocene magnetostratigraphy of ODP Hole 711A (Leg 115), western equatorial Indian Ocean. *Geological Society of London, Special Publication*, **373**, doi: 10.1144/SP373.16.

Toffanin F., Agnini, C., Rio, D., Acton, G. & Westerhold, T. In press. Middle Eocene to early Oligocene calcareous nannofossil biostratigraphy at IODP Site U1333 (equatorial Pacific). *Micropaleontology*.

Preliminary Pleistocene calcareous nannofossil biostrati-graphy for IODP Site 1385 (Shackleton Site)

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One of the objectives expressed for IODP Expedition 339 (Mediterranean Outflow) was "producing a marine reference section of Pleistocene millennial-scale climate variability and changes in surface and deep-water circulation. Climate signals from this reference section will constrain the temporal relationships of abrupt climate change recorded in the northeast Atlantic Ocean, the polar ice cores, and European terrestrial records" (Stow *et al*., 2011). To carry out this objective, IODP Site U1385 was selected and drilled on the Portuguese margin at a location close to the Shackleton Site MD95-2042 (in honor of the late Sir Nick Shackleton; 37°48'N 10°10'W, 3146 m). The Site U1385 core has preserved a high-fidelity record of millennial-scale climate variability for the last glacial cycle that can be correlated precisely to polar ice cores in both hemispheres. For this glacial, surface waters at the site have a Northern Hemisphere signal, while bottom waters have a Southern Hemisphere influence (Shackleton *et al*., 2000). The peculiar position of this site also offers the possibility for a comparison with terrestrial records from the Iberian Peninsula, which is an exceptional opportunity for combining and correlating paleoclimatic signals.

IODP Site U1385 was recovered using a triple APC technique, ensuring a continuous record that covers the last 1.2 Ma. We present preliminary results on the succession of standard and alternative calcareous nannofossil events. At this time, we offer a preliminary calibration with the paleomagnetic and astronomical signal that was estimated by comparing geophysical and logging parameters. In the future, the availability of a refined isotope curve will permit a more accurate calibration in a section that can be referenced for mid-latitudes in the Atlantic Ocean.

References

Shackleton, N.J., Hall, M.A. & Vincent, E. 2000. Phase relationships between millennial-scale events 64,000–24,000 years ago. *Paleoceanography*, **15**(6): 565–569.

Stow, D., Hernandez-Molina, F.J., Hodell, D. & Alvarez Zarikian, C.A. 2011. Mediterranean outflow: environmental significance of the Mediterranean Outflow Water and its global implications. *IODP Scientific Prospectus*, **339**. doi:10.2204/iodp.sp.339.2011

Biostratigraphy of Lower Jurassic calcareous nannofossils from the Schandelah core (NW Germany)

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A comprehensive calcareous nannofossil zonation scheme for the Lower Jurassic in low- to mid-latitude sequences from NW Europe was proposed by Bown & Cooper (1998), and it has been successfully applied in Italy and southern France (Mattioli & Erba, 1999) and northern Spain (Perilli *et al*., 2010). However, a detailed nannofossil zonation is currently not available for the Lower Jurassic of NW Germany.

The Schandelah core comprises a 338-meter thick succession of Toarcian to Rhaetian sediments. A total of 110 samples were taken every 1 to 3 m and prepared for semiquantitative analyses. Calcareous nannofossils were rare to common and moderately to well preserved. Calcareous nannofossil biostratigraphy was mainly based upon the first and last occurrences (FO and LO) of age diagnostic species. All calcareous nannofossil zones and subzones (CNZ and CNSz), as well as the main and secondary calcareous nannofossil events defined by Bown & Cooper (1998), were identified.

Schizosphaerella punctulata was found in the lower part of the Hettangian. The FO of *S. punctulata* defines the base of the NJ1 *S. punctulata* CNZ. This species is continuously present and rare to common throughout the Schandelah core. A sharp decrease of *S. punctulata* was observed slightly above the Toarcian-Pliensbachian boundary, which represents the *Schizosphaerella* crisis described in different European basins (Mattioli *et al*., 2008; Fraguas *et al*., 2012). The species *Parhabdolithus liasicus* first occurred below the Hettangian-Sinemurian boundary. This main event defines the base of the NJ2 *P. liasicus* CNZ. The first appearances of *Crepidolithus pliensbachensis* and *Mitrolithus elegans* were found slightly above this, further supporting the position of the Hettangian-Sinemurian boundary in the Schandelah core. The NJ2 *P. liasicus* CNZ is divided into two subzones, NJ2a *Parhabdolithus marthae* and NJ2b *M. elegans,* based on the LO of *P. marthae*. This event occurs within the upper Sinemurian *obtusum* Zone. The most important biostratigraphic marker for the Sinemurian stage is *Crepidolithus crassus*, which first occurred at the upper Sinemurian *oxynotum-raricostatum* Zone boundary. This event defines the base of the NJ3 *Crepidolithus crassus* CNZ.

The FO of *Similiscutum cruciulus* is located near the lower Pliensbachian *jamesoni-ibex* Zone boundary, marking the base of the NJ4 S. *cruciulus* CNZ. This zone is subdivided into two subzones, NJ4a C. *pliensbachensis* and NJ4b *Crepidolithus granulatus*, on the basis of the LO of *P. robustus*. In the Schandelah core, this event occurred at the lower Pliensbachian *ibex-davoei* Zone boundary. The FO of the index species *Lotharingius hauffii* occurred in the lowermost part of the upper Pliensbachian margaritatus Zone. This event defines the base of the NJ5 *Lotharingius hauffii* CNZ. The FO of *Biscutum finchii* was located in the same place. *Lotharingius sigillatus* first occurs within the margaritatus Zone. The FO of *L. sigillatus* in the Schandelah core was earlier compared to NW Europe (Bown & Cooper, 1998) and northern Spain (Perilli *et al*., 2010), where this event lies within the *spinatum* Zone. The NJ5 *Lotharingius hauffii* CNZ is divided into two subzones, NJ5a *B. finchii* and NJ5b *Crepidolithus impontus*, based on the FO of *C. impontus*. In the Schandelah core, *C. impontus* appeared within the margaritatus Zone.

The first biostratigraphic marker found in the Toarcian stage was *Carinolithus superbus*, which first occurred within the serpentinum Zone. This event defines the base of the NJ6 Carinolithus superbus CNZ. The FO of *Discorhabdus striatus* is located within the *bifrons* Zone, and it marks the beginning of the NJ7 *Discorhabdus striatus* CNZ.

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References

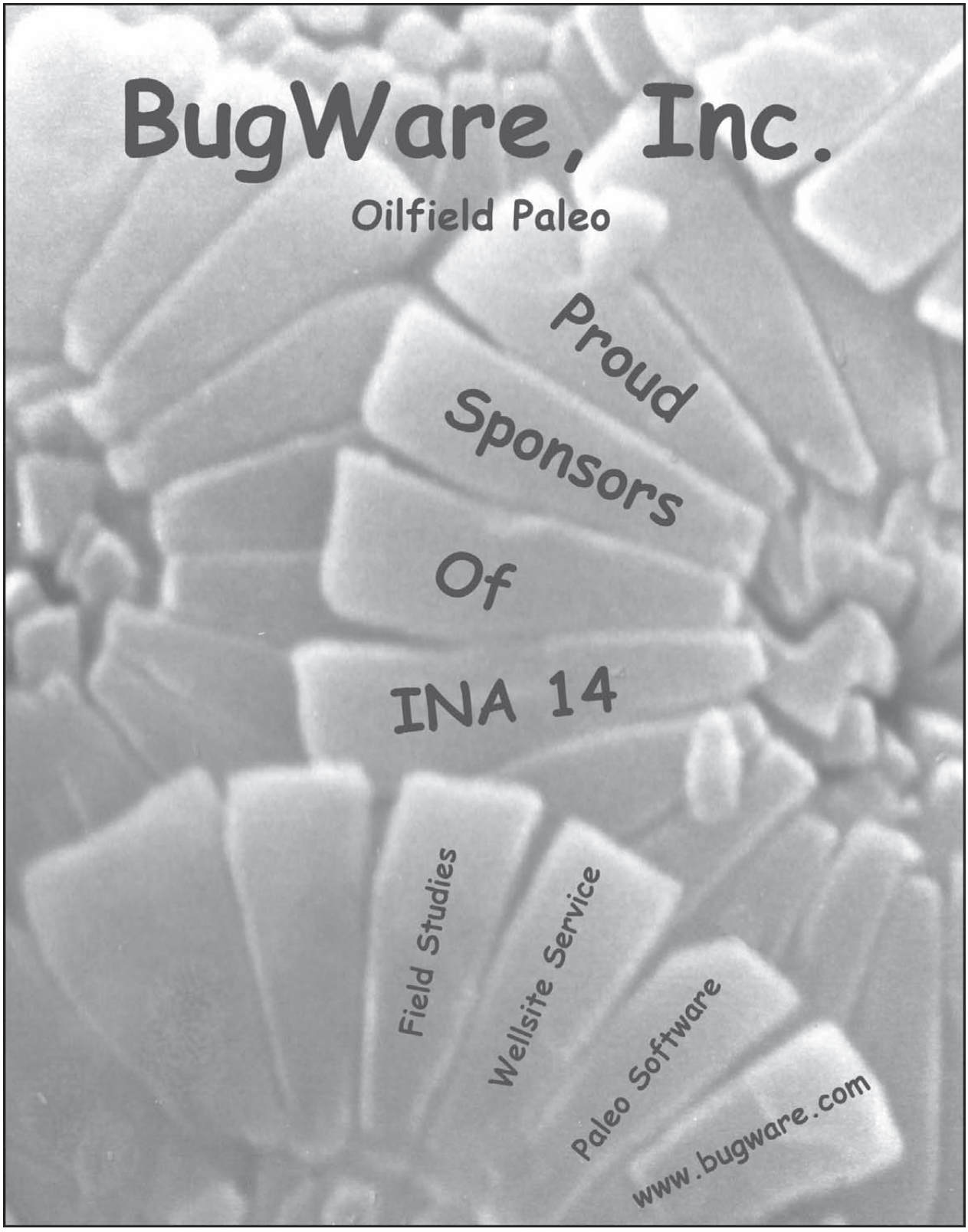
Bown, P.R. & Cooper, M.K.E. 1998. Jurassic. *In:* P.R. Bown (Ed.). *Calcareous Nannofossil Biostratigraphy*. Kluwer Academic, London: 34-86.

Fraguas, A., Comas-Rengifo, M.J., Gómez, J.J & Goy, A. 2012. The calcareous nannofossil crisis in Northern Spain (Asturias province) linked to the Early Toarcian warming-driven mass extinction. *Marine Micropaleontology*, **94-95**: 58-71.

Mattioli, E. & Erba, E. 1999. Synthesis of calcareous nannofossil events in Tethyan Lower and Middle Jurassic successions. *Rivista Italiana di Paleontologia e Stratigrafia*, **105**: 343-376.

Mattioli, E., Pittet, B., Suan, G. & Mailliot, S. 2008. Calcareous nannoplankton changes across the early Toarcian oceanic anoxic event in the western Tethys. *Paleoceanography*, **23**: PA3208.

Perilli, N., Fraguas, A. & Comas-Rengifo, M. J. 2010. Reproducibility and reliability of the Pliensbachian calcareous nannofossil biohorizons from the Basque-Cantabrian Basin (N Spain). *Geobios*, **43**: 77-85.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A new technique for observing calcareous nannofossils: methodology and applications.

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A new technique for observing calcareous nannofossils is presented. It will have a wide range of applications in nannofossil biometry and identification and for measuring the calcite quantity produced by coccolithophores. When observed with this technique, the shape of the coccolith is closer to its real shape than when linear polarized light is used. This results in more accurate measurements because the boundaries of the coccoliths are clearly defined.

Although descriptions of the taxa have previously been done observing coccoliths with linear polarization, the new technique is useful because there is no need to rotate the stage in order to identify all the parts, such as the bridge, or to detect all the coccoliths that are in the sample. The use of this technique can also overcome some of the problems that currently exist in automated systems for identifying and counting taxa in a sample because there is no need to compare several images from the same field of view from different angles. All the coccoliths can be seen at once, and the shape of the coccoliths is always the same.

The new technique was developed because calculation of the amount of calcite produced by coccolithophores is a very important application. Images taken with the new technique allow the user to determine the volume of tiny calcite platelets because a single coccolith can be selected and measured. The method can also be applied to a complete field of view so that the amount of calcite in a sample can be automatically measured, which makes it possible to calculate the effect of coccoliths on the carbonate flux.

Coccolithophore variability in response to coastal upwelling in the west coast of the Baja California Peninsula

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The coccolithophore community was analyzed from a highly productive zone adjacent to Magdalena Bay on the west coast of the Baja California Peninsula from October 2009 to June 2010. Fifty-four water samples from 0 to 60 m were collected monthly at an oceanographic station located at 24°31.85'N 112°06.431'W. Approximately two liters of seawater were filtered on polycarbonate membranes. Subsequently, 1500 images of each membrane were taken with a Zeiss Supra VP55 scanning electron microscope. The digitized samples were analyzed offline on a PC with the AnalySIS®-pro 5.0 imaging program. The oceanographic characterization was done using CTD data collected on a monthly basis, as well as using online data from NOAA, NASA, and Oregon State University. Of the 94 taxa identified, *Emiliania huxleyi*, *Gephyrocapsa oceanica*, *Syracosphaera orbiculus*, and *Florisphaera profunda* var. elongata (median) were the most abundant species in a sample (>30%). The species richness and diversity (Shannon-Weaver, H) showed high values (43 species and 2.7 H) prior to maximum upwelling (March to June). These values then decreased to 29 species (2.26 H), and assemblages were dominated by generalist species (e.g., *E. huxleyi*). However, total cell density did not change significantly prior to ($65x10^3$ cells/l at 10 m in January) or during the maximum period of upwelling ($67x10^3$ cells/l at 0 m in April). Temperature appeared to be the main factor driving coccolithophore cell density and succession in the studied area.

Calcareous nannofossils across the K-T boundary at Um Sohryngkew, Meghalaya, northeastern India

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The Um Sohryngkew section in Meghalaya, northeast India, exposes one of the most complete, shallow-marine, Cretaceous-Paleogene boundary (K-Pg) sequences in the world. It contains an Iridium (Ir) anomaly, a $\delta^{13}C$ shift, and a thin red K-Pg layer. The section provides an excellent record of the abrupt mass extinction of Cretaceous calcareous nannofossils below the Ir-spike-bearing red layer and the first appearance of typical Danian markers in the immediately overlying sediments. Investigations of the distribution of moderately to well-preserved nannofossils across the K-Pg transition reveal a succession of well-established global datum events within the late Maastrichtian-early Danian interval (*Micula murus, Micula prinsii*, *Biantholithus sparsus*, *Neobiscutum romeinii*, *Neobiscutum parvulum*, and *Cruciplacolithus primus*). Five zones, including CC26a, CC26b, and three subzones within Zone NP1/CP1 (*Neobiscutum romeinii*, *Neobiscutum parvulum*, and *Cruciplacolithus primus*) are identified. These zones correlated with nannofossil zonations known from the Tethyan and low-mid latitude sections from different parts of the world and the planktic foraminiferal zonation of this section.

Quantitative analysis of the nannofossils in the studied interval demonstrates a nannofossil succession pattern comprising "Cretaceous", "Paleogene", and "survivor" species similar to that observed at several stratigraphically complete sections across the globe. Latest Maastrichtian assemblages were abundant and diverse with Cretaceous species richness showing minor fluctuating trends. *Micula decussata* and *Watznaueria barnesae* were the most abundant species, and *Arkhangelskiella cymbiformis*, *Eiffellithus turriseifelli*, *Prediscosphaera cretacea*, and *Cribrosphaerella ehrenbergii* were the next most common species. Their percentages fluctuated before extinction occurred for all Cretaceous species at the K-Pg. The predominance of dissolution-resistant *M. decussata* reflects a sustained period of high environmental stress. However, the common occurrence of dissolution-prone species (*P. cretacea*, *C. ehrenbergii*, and *M. prinsii*) precludes a major effect from dissolution.

Only very minor reworking of Cretaceous species was noted in the basal Danian. No *Thoracosphaera* blooms at the K-Pg boundary were recorded in the present section. The first appearance of the incoming Paleogene species *Neobiscutum romeinii* was noted just above the Ir-rich red layer, followed by *Biantholithus sparsus*, *Neobiscutum parvulum*, and *Cruciplacolithus primus*, in ascending order. The Um Sohryngkew Section is considered to be a rare, low-latitude K-Pg section lying close to the paleoequator with a complete biostratigraphic record provided by nannofossils, planktonic foraminifera, and dinoflagellate cysts.

Phosphorus limitation does not change the ratio of calcite to organic carbon in Coccolithus spp.

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The ratio of calcite (PIC) to organic carbon (POC) in coccolithophores is an important variable in ocean-atmosphere-CO_2-exchange. Photosynthesis binds CO_2 into organic matter, whereas calcification releases it, so that the PIC/POC-ratio determines whether a coccolithophore bloom acts as a source or a sink of CO_2. Numerous studies have shown that this ratio can be modified by environmental parameters such as ocean pH, temperature, salinity, and nutrients, and yet most studies have focused on the cosmopolitan species, *Emiliania huxleyi*. Although abundant in the modern ocean, *E. huxleyi* may not be the best representative of coccolithophores' general response towards changing environmental parameters because species-specific responses towards ocean acidification that have been described for it. We therefore studied two species of the genus *Coccolithus*, *C. pelagicus* and *C. braarudii*, which produce heavily calcified *coccoliths* and contribute substantially to marine carbonate production, with PIC/POC-ratios generally above unity. We examined the effect of phosphorus limitation, a parameter predicted to change with a warming climate, on growth and calcification in these species by growing triplicate batch cultures under phosphate limiting and nutrient replete conditions. Organic carbon production in the cultures was examined by means of growth rate, cellular POC quota, and cell size. Inorganic carbon production was evaluated by cellular PIC quota and coccosphere and coccolith size, as well as coccolith malformations.

Phosphorus limitation did not influence exponential growth rates but led to lower cell densities in the stationary phase and a significantly lower cellular phosphorus quota. Phosphorus-limited cultures had increased cell and coccosphere sizes compared to nutrient replete cultures. However, mean coccolith size was the same under both nutrient regimes, and larger cells were covered by more, rather than larger, coccoliths. Although the percentage of malformed coccoliths increased slightly under phosphorus limitation, there was no overall change in PIC/POC-ratios between phosphorus-limited and nutrient-replete cultures. It appears that *C. pelagicus*, in contrast to *E. huxleyi*, has limited plasticity to increase its cellular calcite quota. A primary reason for this may be that this species produces a single coccolith layer, whereas *E. huxleyi* has a high capacity for increasing PIC quota by forming multiple coccolith layers. This fundamental difference between lineages needs to be taken into consideration when modeling climate feedback of coccolithophore blooms as changing nutrient availability will presumably not change PIC/POC ratios in single-coccolith-layer species, such as *C. pelagicus* and *C. braarudii*.

The mid-Cenomanian event in a Tethyan section (Blieux, SE France): integrated stratigraphy and paleoenvironmental conditions

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A detailed integrated stratigraphic analysis was carried out on lower-middle Cenomanian hemipelagic deposits from the Blieux section (SE France) in order to identify the Middle Cenomanian Event I (MCE I) in the Vocontian Basin (Reboulet *et al*., 2013). These deposits are represented by three calcareous bundles that are composed of limestone-marl alternations, which are separated by thick marly intervals. A sequence stratigraphic analysis recognized two orders of depositional sequences (medium-scale: 400 ky and large-scale: third order). The MCE Ia was identified just above the lower-middle Cenomanian boundary, based on the first appearance of the ammonite *Cunningtoniceras cunningtoni*, and lying within the nannofossil Subzone UC2C of Burnett *et al*. (1998). This interval also corresponds to a positive excursion of $\delta^{13}C$ (+ 0.6‰; lowermost part of the ammonite *Acanthoceras rhotomagense* Zone), while a second increase (+ 1.1‰), which corresponds to a plateau rather than a peak, is interpreted as the MCE Ib. Based on sequence stratigraphic analysis, the duration of the MCE I was estimated to be less than 400 ky. Quantitative analyses of calcareous nannofossil, ammonoid, and clay mineral assemblages were conducted on material from around the MCE I and compared to the carbon cycle perturbation and sea-level changes. The nannofossil primary productivity, as recorded by nannofossil fluxes and relative abundances of meso-eutrophic taxa, is low before and during the MCE Ia, then slightly increases in the interval including the MCE Ib. Very oligotrophic levels at the sea surface that were recorded during the MCE Ia are related to both arid climatic conditions (strong decrease in the percent of kaolinite within the clay assemblages) and major sea-level fall (both 3rd order and medium-scale, low-stand deposits). The ammonoid assemblages are characterized by a significant change during the MCE I: planispirals (mainly *Schloenbachia*) are dominant until the MCE Ia, whereas heteromorphs (mainly *Sciponoceras*) become dominant from the MCE Ib onward. A decrease in bathymetry could partly explain the decrease in the relative abundance of *Schloenbachia*. Nannofossil primary productivity and occurrences of *Sciponoceras* have been observed in the *Cenomanian* in different settings. Comparing these locations shows that (1) sea-surface fertility is reduced in both the MCE I and Ocean Anoxic Event 2 (OAE 2) and (2) iterative occurrences of *Sciponoceras* seem to be mainly restricted to the third order transgressive system tracts, and their first occurrences take place during positive shifts of $\delta^{13}C$.

References

Burnett, J.A., Gallagher, L.T. & Hampton, M.J. 1998. Upper Cretaceous. *In:* P.R. Bown (Ed). *Calcareous nannofossil biostratigraphy*. British Micropalaeontological Society Publications Series, Chapman and Hall/Kluwer Academic Publishers: 132-199.

Reboulet S., Giraud F., Colombié C. & Carpentier A., 2013. Integrated stratigraphy of the lower and middle Cenomanian in a Tethyan section (Blieux, southeast France) and correlations with boreal basins. *Cretaceous Research*, **40**: 170-189.

Relationships among *Braarudosphaera bigelowii*, *Chrysochlomulina parkeae*, and the prymnesiophyte host of the cyanobacterium UCYN-A

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Braarudosphaera bigelowii (Prymnesiophyceae) is a living coccolithophore with a long fossil record extending back to the Late Cretaceous. Living and fossil *B. bigelowii* have significant variation in the size of their pentaliths. A morphological and molecular phylogenetic study of living *B. bigelowii* revealed that morphotypes of living *B. bigelowii*, which are classified based on the size of pentaliths, can be related to the 18S rDNA genotypes. Therefore, it is thought that living *B. bigelowii* is a species complex that consists of at least four discrete species, which can be differentiated from each other based on size of pentaliths and 18S rDNA sequences (Hagino *et al*., 2009). A recent study revealed close phylogenetic relationships among *B. bigelowii* sensu stricto (morphotype Intermediate form B, 18S rDNA Genotype III), *Chrysochlomulina parkeae* (Prymnesiophyceae), and a prymnesiophyte cell that has a symbiotic association with the nitrogen-fixing cyanobacterium UCYN-A. The prymnesiophyte host cell receives nitrogen from the cyanobacterium in exchange for fixed carbon (Thompson *et al*., 2012). This was an unexpected relationship because *B. bigelowii* is dissimilar to *C. parkeae* in general morphology, and *B. bigelowii* differs from UCYN-A in geographic distribution. Living *B. bigelowii* is a notable coastal-neritic dweller, while the UCYN-A occur abundantly in the oligotrophic open ocean (Moisander *et al*., 2010).

In order to examine these relationships, we have conducted transmission electron microscopic and molecular phylogenetic studies of *B. bigelowii* sensu stricto (Intermediate form-B, 18S rDNA genotype III) and *C. parkeae*. In this talk, we will show the relationships among *B. bigelowii*, *C. parkeae*, and the prymnesiophyte host of the UCYN-A that is based on new evidence from our morphological and molecular phylogenetic studies.

References

Hagino, K., Takano, Y. & Horiguchi, T. 2009. Pseudocryptic speciation in *Braarudosphaera bigelowii* (Gran and Braarud) Deflandre. Marine Micropaleontology, **72**: 210-221.

Moisander, P.H., Beinart, R.A., Hewson, I., White, A.E., Johnson, K.S., Carlson, C.A., Montoya, J.P. & Zehr, J.P. 2010. Unicellular cyanobacterial distributions broaden the oceanic N_2 fixation domain. *Science* **327**:1512-1514.

Thompson, A.W., Foster, R.A., Krupke, A., Carter, B.J., Musat, N., Vaulot, D., Kuypers, M.M.M. & Zehr, J.P. 2012. Unicellular cyanobacterium symbiotic with a single-celled eukaryotic alga. *Science*, **337**: 1546-1550.

Paleoenvironmental conditions during the late Aptian-early Albian in the Essaouira-Agadir Basin (Morocco): evidence from sedimentology, calcareous nannofossils, and carbon and oxygen isotope records

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In the southern Tethyan margin, the late Aptian-early Albian interval, which is characterized by organic-rich matter and thus potential energy resources, is poorly understood because the sedimentary successions are frequently incomplete, and dating is difficult to perform. The Essaouira-Agadir Basin (Morocco) has many good late Aptian-early Albian outcrops that are easy to access. The aim of this work is to (1) establish an accurate time framework based on a high-resolution biostratigraphy (ammonite and calcareous nannofossil zonations) and sequence- and chemo-stratigraphy (carbon and oxygen stable isotopes) and (2) understand the role of paleo-ecological factors on carbonate production and development of black shales through qualitative and quantitative calcareous nannofossil analyses.

Two sections were selected along a proximal-distal transect in the southern part of the basin. In the eastern part (Tinfoul section), the thickness of Aptian-Albian deposits is reduced, and the sedimentary facies are indicative of very shallow-water environments. The section at Anzate is located in the middle part of the basin where the sediments are thicker. A sedimentary facies analysis recognized a deepening upwards in both sections. Twenty-three and twenty-six samples were collected from the distal Anzate section (early Albian) and from the more proximal Tinfoul section, respectively. The $\delta^{13}C$ records were used to place the Aptian/Albian boundary. The $\delta^{13}C$ increased in the latest Aptian and decreased during the early Albian, which is consistent with other Tethyan and Atlantic settings. The calcium carbonate content decreased upward through early Albian time in both sections, with values being lower in the western distal Anzate than the eastern proximal Tinfoul section. Calcareous nannofossil preservation varied from good to moderate and moderate to poor in the Anzate and Tinfoul sections, respectively. The nannofossil total abundance and species richness were higher in the distal section at Anzate than in the proximal section of Tinfoul, and total absolute abundance decreased in the upper part of the section at both locations. Calcareous nannofossil assemblages were characterized by 93 identified species, but only 15 taxa comprised approximately 90% of the total assemblage. The nannofossil cold-water taxa increased upward through time, while the warm taxa showed an opposite trend. Both nannofossil absolute abundance and carbonate content decreased upward with progressively colder sea-surface conditions, indicating a decrease in the carbonate production in the early Albian. Meso-eutrophic taxa fluctuated but had a general decrease upward through the early Albian, which could be the result of a reduced nutrient influx. A drop in carbonate production, associated with deepening of the paleoenvironment and cooler climatic conditions, and a sharp decrease in the $\delta^{13}C$ values characterize the Aptian-Albian transition in the Essaouira-Agadir Basin.

Phenotypic evolution of the "planktic superspecies" Coccolithus pelagicus

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Marine microfossils have the most detailed record of plankton evolution, and time series studies of their phenotypic (size, shape) variability are perhaps the most direct way of observing evolutionary change. We investigated a time series of coccolith size (mean size and its variation), using models based on linear stochastic differential equations (SDEs) with hierarchical structure (Reitan *et al*., 2012) to test what processes have driven phenotypic evolution in the fossil lineage of Coccolithus pelagicus (Wallich 1877) Schiller 1930 over the past 57 million years. Fossil time series data from six different DSDP/ODP sites revealed site-specific dynamics, as well as correlations among sites. We found no detectable influence of long-term (>100 ky) climatic change on the phenotypic evolution of *C. pelagicus* (sensu lato). Long-term phenotypic variations appear to have been driven primarily by the speciation and extinction of (cryptic) sibling species within this "planktic superspecies" (*cf*. de Vargas *et al*., 2004).

Speciation is defined by genetic isolation, which unfortunately cannot be directly tested in the fossil record. By constraining the phenotypic variability of single extant genotypes in the laboratory, however, we can obtain a better estimate of how many genotypes are represented by fossil phenotypes. Short-term experiments with two strains of the sibling species, *C. pelagicus* and *C. braarudii*, revealed no significant plasticity in coccolith size (mean and variation) despite extreme experimental growth conditions. This confirms that the coccolith size variability observed in the fossil record is unlikely to represent a plasticity response to environmental change in one cosmopolitan species. Rather, an increase (or decrease) in size variation in fossil populations points to a changing number of closely related (cryptic) sibling species with different local adaptations and shifts in their abundances due to changing biotic and/or abiotic selection pressures.

References

de Vargas, C., Sáez, A.G., Medlin, L.K. & Thierstein, H.R. 2004. Super-species in the calcareous plankton. *In:* H.R. Thierstein & J.R. Young, (Eds). *Coccolithophores: from molecular processes to global impact*. Berlin Heidelberg, Springer-Verlag: 271-298.

Reitan, T., Schweder, T. & Henderiks, J. 2012. Phenotypic evolution studied by layered stochastic differential equations. *Annals of Applied Statistics*, **6**: 1531-1551.

Response of calcareous nannoplankton assemblages to the Middle Miocene Climatic Transition in the epicontinental sea (Carpathian Foredeep, Central Paratethys)

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Using the astronomically calibrated dates from the Mediterranean area (di Stefano *et al*., 2008), the lower boundary of the study interval can be dated at 14.9 Ma (the last occurrence of *Helicosphaera ampliaperta*), the upper boundary at 13.92 Ma (the first occurrence of *Globorotalia praemenardii*), and can be divided into two parts by the last occurrence of *Helicosphaera waltrans* (14.357 Ma). The interval correlates well with the early stage of the Middle Miocene Climatic Transition (Flower & Kennett, 1994).

In addition to global climatic changes, the interval is locally influenced by a large transgression into the Paratethyan area and strong tectonic and volcanic activity. The local climate, which was interpreted from the terrigenous palynomorphs and generally was subtropical, can be characterized by (1) aridification connected with decrease of terrigenous input, (2) increase of seasonality, principally expressed in seasonality of precipitation, (3) catastrophic climatic events (*i.e*., intensive rainfall; Harzhauser *et al*., 2010), (4) cyclicity (oscillations of cold + dry and wet + warm periods), and (5) cooling.

Calcareous nannoplankton assemblages were dominated by small-sized *Reticulofenestra* spp. (*R. minuta* and *R. haqii*) and occasionally by *Coccolithus pelagicus*. Abundances, which varied from very rare to massive occurrences, were higher in the marginal part of basins where the massive occurrences are represented by blooms of *R. minuta*. This indicates a prevailing continental nutrient source. Cyclical changes in calcareous nannoplankton assemblages are not as pronounced as in the planktonic foraminifera. Using multivariate statistical techniques, the following assemblages can be distinguished:

(1) The *Reticulofestra minuta* assemblage is indicative of environmental stress and characterized by quick changes within that environment, including oscillation of salinity and nutrient content. The assemblage is accompanied by 5-chambered small globigerinids typical of cold, non-stratified water masses, which respond rapidly to changes in nutrient supply. Its marked dominance agrees with an expected increase in seasonality of precipitations.

(2) The *Reticulofestra haqii* assemblage has oscillations between abundances of *Reticulofenestra minuta* and *R. haqii* that are characteristic of the middle and upper part of study interval and reflect orbitally-forced climatic changes. Higher abundances of *R. haqii* are accompanied by occurrences of *Orbulina* and *Globigerinoides* spp., which indicate warmer oligotrophic conditions. Marked differences between oxygen and carbon isotopic compositions of benthic and planktonic foraminifera indicate stratification of the water column.

(3) The *Coccolithus pelagicus*-assemblage was recorded mainly in volcanic influenced deposits and in the lower part of the study interval. *Coccolithus pelagicus* is a traditional indicator of cold and nutrient-rich water, but the species was recorded in waters up to 18°C. Its disappearance in the upper part of interval indicates a decrease in nutrients due to aridification associated with a decrease in decisive terrigenous input of nutrients.

References

Flower, B.P. & Kennett, J.P. 1994. The middle Miocene climatic transition: East Antarctic ice sheet development, deep ocean circulation and global carbon cycling. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **108**: 537–555.

Harzhauser, M., Piller, W.E., Müllegger, S., Grunert, P. & Michee, A. 2010. Changing seasonality patterns in Central Europe from Miocene climate optimum to Miocene climate transition deduced from the Crassostrea isotope archive. *Global and Planetary Change*, **76**: 77-84.

di Stefano, A., Foresi, L.M., Lirer, F., Iaccarino, S.M., Turco, E., Amore, F.O., Morabito, S., Salvatorini, G., Mazzei, R. & Abdul Aziz, H. 2008. Calcareous plankton high resolution bio-magnetostratigraphy for the Langhian of the Mediterranean area. *Rivista Italiana di Paleontologia e Stratigrafia*, **114**: 51-76.

Distribution and malformation of extant Coccolithophores in the East China Sea in summer, 2011

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The distribution of extant coccolithophores, collected in June 2011, from surface waters (0-2 m) of the East China Sea (ECS) was determined using a scanning electron microscope. Of the 64 stations, only nine water samples yielded coccolithophores, most of which were located over the Changjiang River plume area. The abundance of coccolithophores in most of the nine samples ranged from 2,500 to 7,500 cells/l. *Gephyrocapsa oceanica* Kamptner (1943) dominated the coccolithophore community and developed a bloom that has not been reported before in the ECS. The cell density reached as many as 620,000 cells/l, which was at the station located near the center of the East China Sea Cold Eddy. The cyclonic eddy induced an upwelling system that brought nutrients to the surface waters, and this may have facilitated the *G. oceanica* bloom.

Coccolithophores with various degrees of deformity were identified in the surface waters of the ECS, which we attribute to malformation and stunted growth of the coccolith elements. The distribution of malformed living coccolithophores has been previously investigated in the East China Sea (Okada and Honjo, 1975; Yang *et al*., 2004), in Indonesian marginal seas (Kleijne, 1990), and off Namibia (Giraudeau *et al*., 1993). Most of the authors attributed the malformation to nutrient deficiency. In our investigation, a high rate and severity of malformation was found in shelf waters of the ECS, while only normal cells occurred around the Changjiang River estuary area. In the ECS, river inputs of total alkalinity (TA) can reach ~2200+3340 (from particle inorganic carbon) $\times 10^9$ mol $year^{-1}$, suggesting a great amount of TA (Chen &Wang, 1999). Hence, there is a higher amount of CO_3^{2-} and $\Omega(CaCO_3)$ adjacent to the Changjiang River estuary than on the shelf with its more constant pH value. It is suggested that the occurrence and distribution of malformation in the ECS may have been caused by the carbonate chemistry in its ambient water.

References

Chen, C.T.A., & Wang, S.L. 1999. Carbon, alkalinity and nutrient budgets on the East China Sea continental shelf. *Journal of Geophysical Research*, **104**(C9): 20675-20.

Giraudeau, J., Monteiro, P., & Nikodemus, K. 1993. Distribution and malformation of living coccolithophores in the northern Benguela upwelling system off Namibia. *Marine Micropaleontology*, **22**(1): 93-110.

Kleijne, A. 1990. Distribution and malformation of extant calcareous nannoplankton in the Indonesian Seas. *Marine Micropaleontology*, **16**(3): 293-316.

Okada, H. & Honjo, S. 1975. Distribution of coccolithophores in marginal seas along the western Pacific Ocean and in the Red Sea. *Marine Biology*, **31**(3): 271-285.

Yang, T.N., Wei, K.Y., Chen, M.P., Ji, S.J., Gong, G.C., Lin, F.J., & Lee, T.Q. 2004. Summer and winter distribution and malformation of coccolithophores in the East China Sea. *Micropaleontology*, **50**(Suppl. 1): 157-170.

The Melbourne Code: implications for nannofossil and silicoflagellate taxonomy

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The latest edition of the International Code of Nomenclature (ICN) for algae, fungi, and plants (formerly the International Code of Botanical Nomenclature; ICBN) was adopted in 2011 and published in 2012. The new code (known as the Melbourne Code) has implications for certain fossil groups, particularly nannofossils and silicoflagellates. In particular, Article 11.8 states that a non-fossil genus (based on an extant type species) has priority over a fossil genus (based on a fossil type species), regardless of the publication date. At present, only diatoms are exempt from this ruling.

To continue the use of a long-standing fossil generic name with extant representatives, it is strongly recommended that its name be conserved against any future generic names based on one or more of the extant taxa. This problem is limited to only a few genera, but includes *Cruciplacolithus* and *Reticulofenestra* among calcareous nannofossils and *Dictyocha* among silicoflagellates. Furthermore, if a chance for discussion arises, it would be advisable to propose that nannofossils and silicoflagellates be treated in the same manner as diatoms. This would allow the names of fossil genera to compete with those of non-fossil genera, thus protecting older names via publication date and negating the rulings of Articles 11.7 and 11.8.

An additional concern arises when extant taxa are assigned as subspecific taxa of a fossil species, because the elevation of an extant subspecific taxon to species level could result in the renaming of the fossil species. An example is *Dictyocha fibula*, the type species of the genus, which was originally described from the Miocene, and now has many subspecific taxa. While it is uncertain whether *D. fibula* occurs in the Recent, the generic name is widely used by both paleontologists and biologists. Thus, conservation of the specific epithet *fibula* may be necessary to avoid the undesirable scenario of it becoming a senior synonym.

Unfortunately, there is no guarantee that either conservation or exemption will be accepted by the committee members of the ICN, and even if the proposal were accepted, ratification would take place at the next Botanical Congress in 2017. In the meantime, nannofossil and silicoflagellate taxonomy will be in a state of limbo.

Middle to Upper Jurassic calcareous nannofossil biostratigraphy, onshore North Kuwait

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The Middle to Late Jurassic in Kuwait consists predominantly of carbonates, calcareous shales, and evaporites that comprise five formations, in ascending order: Dhruma, Sargelu, Najmah, Gotnia, and Hith (Yousif *et al*., 1997). The calcareous shale of the Dhruma Formation gradually grades upwards into limestones of the Sargelu Formation (Neog *et al*., 2010). The Sargelu is unconformably overlain by the Najmah Formation (Al-Husseini, 2008), which is comprised of the Najmah Kerogene and the Najmah Limestone. The Najmah Kerogene consists of three members: Najmah-Sargelu Transition, Lower Najmah Kerogene, and Upper Najmah Kerogene. The Najmah Limestone is unconformably overlain by the calcareous shale of the non-evaporitic Gotnia Formation (Neog *et al*., 2010) and is capped by a succession of evaporites of the Gotnia and Hith Formations.

Biostratigraphic analyses were performed on a total 373 core samples from 12 wells from onshore North Kuwait. Forty-six species were identified, and the results were summarized using nannofossil Jurassic Zones (Bown & Cooper, 1998; Mattioli & Erba, 1999) and Kuwait Nannofossil Events (Packer *et al*., 2012, 2013), as well as the Jurassic Time Scale (Ogg *et al*., 2008). Six intervals, the NJT10a Subzone, NJT10b Subzone, combined NJT12 - lower NJT13 Zones, NJT14 - NJT15 Zones, and sparse assemblage intervals, were established in the studied sections. Calcareous nannofossils were abundant in the Dhruma and Sargelu-Dhruma Transition with moderately diverse assemblages. Abundance decreased in the Sargelu, Najmah Kerogene, Najmah Limestone, and non-evaporitic Gotnia Formation.

The Dhruma Formation was placed in the NJT10a Subzone, based on the presence of *W. manivitiae*, *C. superbus*, *S. punctulata*, and *W. contracta*, which suggests an early-late Bajocian age. The top of the late Bajocian was picked at the top of the NJT10b Subzone, identified near to the top of the Dhruma-Sargelu Transition, based on the last occurrence of *C. magharensis*. The Sargelu Limestone was barren of nannofossils. The age of the overlying Najmah Kerogene is Callovian to early Oxfordian (Zones NJT12 - lower NJT13), based on nannofossil assemblages dominated by *Watznaueria barnesae*, *W. britannica*, *W. fossacinta*, and *W. manivitiae*. The Najmah Limestone was virtually barren of nannofossils. However, the occurrence of the index palynomorph species *Systematophora* spp. suggests an age no older than Oxfordian (Watson, 2005). The unconformity that separates the Najmah Limestone from the Gotnia Formation, therefore, appears to occur within the Oxfordian-Kimmeridgian interval. The assemblages in the overlying non-evaporitic Gotnia Formation were characterized by a dominance of *Watznaueria* spp. with *P. beckmanii* observed in one well, which indicates placement in the Kimmeridgian-Tithonian NJT14-NJT15 Zones.

References

Al-Husseini, M.I. 2008. Middle East geologic time scale 2008. *GeoArabia*, **13**(4).

Bown, P.R. & Cooper, M.K.E. 1998. Jurassic. *In:* P.R. Bown (Ed). *Calcareous Nannofossil Biostratigraphy*. Kluwer Academic Press, London: 35-85.

Mattioli, E. & Erba, E. 1999. Synthesis of calcareous nannofossil events in the Tethyan Lower and Middle Jurassic. *Rivista Italiana di Paleontologia e Stratigrafia*, **105**: 343-376.

Neog, N., Rao, N.S., Al-Mayyas, R., De Keyser, T., Perrin, C. & Kendall, C. 2010. Evaporite facies: a key to the mid Mesozoic sedimentary stratigraphy of North Kuwait. *ICE Convention Abstract*, Calgary, 2010.

Ogg, J.G., Ogg, G. & Gradstein, F.M. 2008. Jurassic Period. *The concise Geologic Time Scale*. Cambridge University Press, New York: 107-115.

Packer, S.R., Starkie, S.P. & Stead, D.T. 2012. *Biostratigraphic analysis of selected intervals from Cretaceous & Jurassic, Kuwait*. Millennia SC Unpublished Report, 737/12.

Packer, S.R., Starkie, S.P. & Stead, D.T. 2013. *Biostratigraphic analysis of the Late-Middle Jurassic, onshore Kuwait*. Millennia SC Unpublished Report, 751/12.

Watson, P. 2005. *Biostratigraphic analysis of selected Jurassic core samples from the Marrat to Najmah Formations, onshore Kuwait*. Robertson Research International Limited Unpublished Report No. 6619/ib.

Yousif, S. & Nouman, G. 1997. Jurassic geology of Kuwait. *GeoArabia*, **2**(1): 91-110.

Mid-Cretaceous calcareous nannoplankton biostratigraphy and paleoenvironment of Wasia Group, onshore Kuwait

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The mid-Cretaceous sediments of the Wasia Group, onshore Kuwait, comprise a range of lithologies from clastic at the base to carbonate at the top, and consist of six formations and one member: Burgan, Mauddud, Wara, Ahmadi, Rumaila, and Mishrif Formations and the Tuba Member (Al-Fares *et al*., 1998). The lower and upper boundaries of the group consist of unconformities of early Aptian and early Turonian age respectively (Al-Husseini, 2008). This interval can be subdivided into five zones and six sub-zones based on a combination of global markers and local Kuwait calcareous nannofossil events (Thierstein, 1976; Sissingh, 1977; Perch-Nielsen, 1985; Bown *et al*., 1998; Al-Fares *et al*., 1998; Packer *et al*., 2011, 2012; Kadar *et al*., 2012). In stratigraphic ascending order, these subdivisions are KN32, KN31, KN30, KN29c, b, a, KN28c, b, and a.

On the basis of lithology and nannofossil and micropaleontological data in Packer *et al*. (2011, 2012) and from the current study, the depositional environment of the interval can be determined. The upper Albian Burgan Formation has a sparse microfauna and is barren of nannofossils, indicating that the formation was deposited in nonmarine to transitional and partially inner neritic environments. The upper Albian Mauddud Formation contains a large amount of microfossils, especially foraminifera and ostracods, but only rare nannofossils, probably indicating inner- to middle-neritic conditions. The lithology and depositional environment of the upper Albian-lower Cenomanian Wara Formation are similar to the Burgan Formation, comprising nonmarine to inner neritic with a thin fossiliferous outer- to middle-neritic interval, which is interpreted as a maximum flooding surface within this unit. The depositional environment of the Ahmadi, Rumaila, and lower Mishrif Formations, as well as the Tuba Member, was determined to be middle to outer neritic. The micropaleontological data from the upper Mishrif Formation indicate a nonmarine to inner-neritic environment. The Burgan Sand, Mauddud Limestone, and Wara Sand form the main hydrocarbon reservoir in the Greater Burgan Field (Brennan, 1990). The Tuba Limestone is a reservoir in the Bahrah Field, and the Mishrif Limestone is in the Minagish Field.

References

Al-Fares, A.A., Bouman, M. & Jeans, P. 1998. A new look at the Middle-Lower Cretaceous stratigraphy, offshore Kuwait. *GeoArabia*, **3**(4): 543-560.

Al-Husseini, M.I. 2008. Middle East geologic time scale 2008. *GeoArabia*, **13**(4).

Bown, P.R., Rutledge, D.C., Crux, J.A. & Gallagher, L.T. 1998. Lower Cretaceous. *In:* P.R. Bown (Ed). *Calcareous Nannofossil Biostratigraphy*. Kluwer Academic Press: 86-131.

Brennan, P. 1990. Greater Burgan Field. *In:* E.A. Beamount & N.H Foster (Eds). *Structural Traps I*. AAPG Treatise of Petroleum Geology, Atlas of Oil and Gas Fields: 103-128.

Kadar, A.P., Youssef, A., Packer, S.R., Starkie, S.P., Al-Baghli, M. & Karam, K.A. 2012. *Albian-Cenomanian calcareous nannofossil biostratigraphy and depositional environment of the Wasia Group, onshore Kuwait*. 10th Middle East Geosciences Conference and Exhibition, Bahrain, March 2012.

Packer, S.R, Starkie, S.P. & Stead, D.T. 2011. *Biostratigraphic analysis of the Burgan, Mauddud, Wara, Ahmadi Formations and Tuba member (Wasia Group)*. Kuwait. 1-2. Millennia SC. Project No. 728/10.

Packer, S.R, Starkie, S.P. & Stead, D.T. 2012. *Biostratigraphic analysis of the Rumaila and Mishrif Formations (Wasia Group)*. Kuwait. 1-2. Millennia SC. Project No. 736/12.

Perch-Nielsen, K. 1985. Mesozoic calcareous nannofossils. *In:* H.M. Bolli, J.B. Saunders, & K. Perch-Nielsen (Eds). *Plankton Stratigraphy*. Cambridge University Press: 329-426.

Sissingh, W. 1977. Biostratigraphy of Cretaceous calcareous nannoplankton. *Geologie en Mijnbouw*, **56**: 37-65.

Thierstein, H.R. 1976. Mesozoic calcareous nannoplankton biostratigraphy of marine sediments. *Marine Micropaleontology*, **1**: 325-362.

Calcareous nannoplankton off NW Africa (Cape Blanc) – seasonal and inter-annual dynamics of coccolithophore fluxes

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Coccolith fluxes from sediment traps moored off Cape Blanc (21°08.7'N 20°41.2'W) over three years (March 1989 to November 1991) were examined to reveal inter-annual and seasonal changes in species composition, and factors influencing these fluxes and changes in the assemblage. Based on this long-term record, a detailed species composition and seasonal patterns for the region were identified. Within the winter season, most of the yearly exported coccolith flux settled, whereas during the summer and fall, the proportion of the yearly coccolith flux was reduced. The species composition revealed at least 74 coccolithophore species with *Emiliania huxleyi*, *Florisphaera profunda*, and *Gephyrocapsa* spp. dominating the assemblage. The changes in fluxes, as well as in species composition, document and sensitively reflect the highly variable water characteristics off the Cape Blanc region. In particular, significant changes in coccolith fluxes coincide with changes in sea-surface temperature, which may be related to shifts in near-coast upwelling pulses.

In general, three different intervals could be distinguished, each characterized by a distinct species composition and associated changing environmental parameters. The first interval covers the period from March 1988 to the winter of 1990-1991. The assemblage during this interval was dominated by *E. huxleyi, F. profunda*, *G. flabellatus*, *G. oceanica*, and *G. ericsonii* fluxes, while other species contributed consistently but in low fluxes to this assemblage. Distinct changes within this assemblage point to the occurrence of changing surface waters from influences such as offshore meandering filaments. A second interval (winter 1990-1991) reveals a significant change in fluxes and species composition. It appears to be the result of a significant high occurrence of *Ophiaster* spp., *Acanthoica* spp., *Calciosolenia* spp., *Calciopappus* spp., and *Syracosphaera* spp. in the surface water, accompanied with enhanced transport into deep water. The third interval, covering the time from spring to fall of 1991, is characterized by significantly reduced fluxes of all coccolithophore species. The species composition is similar to that of the first interval, thus the assemblage seemingly returns to the “original” state (the first interval).

Age and paleoenvironmental constraints based on calcareous nannofossil and foraminifera assemblages from the Eocene–Miocene of Lord Howe Rise, southwest Pacific Ocean

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Lord Howe Rise is located within a series of basins and ridges in the southwest Pacific Ocean that formed during the Cretaceous breakup of Gondwana and is today located east of Australia and northwest of New Zealand. Coring on Lord Howe Rise during Deep Sea Drilling Project (DSDP) Legs 21 and 90 recovered Upper Cretaceous rhyolitic volcanics overlain by pelagic sediments of Late Cretaceous to Cenozoic age. Neogene sequences in the region contain few hiatuses, whereas the Paleogene interval records an Eocene-Oligocene unconformity of varying duration that is interpreted to reflect major oceanographic circulation changes resulting from the development of the Antarctic Circumpolar Current. Recent work, based primarily on stratal geometries and seismic reflection facies, suggests that the unconformity may be related to uplift of the rise to or near sea level as a result of subduction processes in the New Zealand region. To test this hypothesis, we collected high-resolution samples across the unconformity at four sites that were cored on or around Lord Howe Rise (DSDP Sites 206, 207, 208, and 592) to refine the age of the hiatus and to examine changes in paleoenvironment. Biostratigraphic results, based on calcareous nannofossils and planktonic foraminifera, indicate that the unconformity is of different ages in different locations. At Sites 206, 207, and 208, the Eocene-Oligocene boundary is missing, with sediments below the unconformity of middle Eocene age and sediments above the unconformity of early Oligocene to Miocene age. In contrast, Site 592 records a complete Eocene-Oligocene boundary sequence, with the hiatus spanning the early Oligocene to early Miocene. Paleodepths based on benthic foraminiferal assemblages suggest some shallowing across the unconformity at all sites. These results have implications for the paleoceanographic and tectonic setting of Lord How Rise during the late Paleogene.

Calcareous nannofossils tie organic-rich sedimentation in the SW Pacific to an early late Paleocene climatic event

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A distinctive, organic-rich (total organic carbon = 1-12 wt%) marine mudstone occurs in many locations throughout the New Zealand region. First identified as the Waipawa Formation in the East Coast Basin, it is correlative to the Tartan Formation described from Canterbury and Great South Basins, and grades laterally into facies equivalents throughout New Zealand and other regions of the southwest Pacific. The high organic content makes this mudstone a potential source rock for oil and gas, and it is therefore of keen interest to the petroleum industry. The organic-rich facies typically consist of non-calcareous to weakly calcareous, bioturbated dark mudstone. The paucity of calcareous microfossils has made constraining the age of the unit difficult. Lateral facies equivalents include a siliceous mudstone (Mead Stream, New Zealand), siliceous chalk (Ocean Drilling Program [ODP] Site 1121 on the Campbell Plateau), and greensand (Tawanui, New Zealand). Calcareous nannofossil assemblages from calcareous intervals of the Waipawa Formation and its equivalents are reasonably diverse with variable preservation. The first appearance of *Heliolithus kleinpellii* occurs just below or near the base of the organic-rich sediment, with the first appearance of *Discoaster mohleri* at or near the top of the formation, indicating deposition during nannofossil Zone NP6. These results, combined with results from other microfossil groups and paleomagnetics from ODP Site 1172 on the Tasman Plateau, indicate that this organic-rich sediment was deposited in the late Paleocene between ~58.7 and 58.2 Ma, and may correlate with the Early Late Paleocene Event (ELPE) reported from the central Pacific. Geochemical analyses for sea-surface and bottom-water temperatures, based on Mg/Ca, TEX_{86}, and $\delta^{18}O$, indicate cooling of 2–4°C over a short period of time. There is also evidence from benthic foraminifera and palynofacies for a drop in sea level associated with this interval. Taken together, these results support the presence of short-lived ice sheets on Antarctica during the early late Paleocene.

Upper water structure and primary productivity variations of the central West Pacific Warm Pool in the last ~380 kyr

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Coccoliths from two cores, KX21-2 and KX12-1, in the central West Pacific Warm Pool (WPWP) from the last ~380 kyr were analyzed with SYRACO (Système de Reconnaissance Automatique de Coccolithes) (Beaufort & Dollfus, 2004). *Emiliania huxleyi*, *Gephyrocapsa oceanica*, and *Florisphaera profunda* were the most abundant species. Upper water structure and primary productivity (PP) variations were reconstructed with the relative abundance of *Florisphaera profunda* (Molfino & Mclntyre, 1990; Beaufort *et al*., 1997). Primary productivity from coccoliths correlated well with other paleoproductivity proxies (e.g., Ca concentration, ln(Ca/Ti), and ln(Ba/Ti)) (Zhou *et al*., 2011), which suggests that coccoliths are a reliable paleoproductivity proxy. PP records in the two cores present patterns similar to other published records in this area (Beaufort *et al*., 2001). A time series analysis indicates that the Earth's precession has been an important factor controlling the long-term variability of coccolithophore production in the equatorial Indo-Pacific Ocean. The most remarkable characteristic of these cores is the presence of a significant increase of PP spikes during the last four deglacials. We presume that ocean stratification, combined with nutricline oscillation, changed nutrient supply to the photic zone, which caused short-term PP variation in glacial terminations.

References

Beaufort, L. & Dollfus, D. 2004. Automatic recognition of coccoliths by dynamical neural networks. *Marine Micropaleontology*, **51**: 57-73.

Beaufort, L., Garidel-Thoron, T., Mix, A.C. & Pisias, N.G. 2001. Enso-like forcing on oceanic primary production during the late Pleistocene. *Science*, **293**: 2440-2444.

Beaufort, L., Lancelot, Y., Camberlin, P., Cayre, O., Vincent, E., Bassinot, F. & Labeyrie, L. 1997. Insolation cycles as a major control of equatorial Indian Ocean primary production. *Science*, **278**(5342): 1451-1454.

Molfino, B. & McIntyre, A. 1990. Precessional forcing of nutricline dynamics in the equatorial Atlantic. *Science*, **249**(4970): 766-769.

Zhou, C., Jin, H.Y. & Jian, Z.M. 2011. Variations of the late Quaternary paleo-productivity in the western Equatorial Pacific: evidence from the elemental ratios. *Quaternary Sciences*, **31**(2): 276-283. (In Chinese with English abstract)

Calcareous nannofossils and Late Cretaceous climate cooling: Campanian through Maastrichtian assemblages from the Evans-Shuqualak borehole (Mississippi)

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In comparison to the mid-Cretaceous (Albian-Turonian) super greenhouse world, the latest Cretaceous (late Campanian-Maastrichtian) is thought to be an interval of relatively cool climate (Huber *et al*., 2002; Miller *et al*., 2005). The late Campanian-early Maastrichtian cooling particularly affected calcareous nannofossil assemblages, as recorded by the expansion of putative cool-water taxa (*Ahmuellerella octoradiata*, *Gartnerago segmentatum*, *Kampnerius magnificus*, and *Nephrolithus frequens*) towards low latitudes (Lees, 2002; Thibault & Gardin, 2006) and the retreat of supposed warm-water taxa, such as *Watznaueria barnesiae*, from high latitudes (Watkins *et al*., 1996). The rate and structure of Late Cretaceous sea surface temperature (SST) changes are, however, generally poorly known because of the lack of stratigraphically complete sections that contain well-preserved microfossils. In order to fill this gap, we studied a Campanian through Maastrichtian section (~83.3 – 65.5Ma) from Shuqualak, Mississippi, USA (Evans-Shuqualak borehole, 32°58'49"N 88°34'8"W), which has excellent preservation of calcareous microfossils and organic biomarkers. The paleoclimatic trends have been studied using TEX_{86} estimates of SST (Kim *et al*., 2010), supported by integrated calcareous nannofossil and planktonic foraminifer biostratigraphy, abundance counts on calcareous nannofossil assemblages, nannofossil biometry on *Watznaueria*, *Arkhangelskiella*, and *Broinsonia*, and geochemical studies (Sr/Ca) on coccolith calcite of particular nannofossil species.

TEX_{86}-measurements show that the Campanian represented a transitional interval from the warm mid-Cretaceous towards a relatively cool Maastrichtian climate. Using the TEX_{86}^{H} calibration with SST (Kim *et al*., 2010), we suggest that early Campanian subtropical SSTs (~35°N) were a maximum of 35°C, similar to Santonian tropical SSTs (Forster *et al*., 2007). SSTs cooled towards ~28°C across the Campanian-Maastrichtian boundary, with slightly higher values (~30°C) in the Maastrichtian. Calcareous nannofossil abundance trends show no striking correspondence with SSTs, but *W. barnesiae* declines from 10% to 3% across the Campanian-Maastrichtian boundary and increases again in the latest Maastrichtian. No clear correspondence to the cooling is seen within taxa previously identified as having cooler water affinities (*A. octoradiata*, *G. segmentatum*, and *K. magnificus*) as their abundances were mostly below 3%. There seems to be a link between the coccolith-size history of the *Broinsonia/ Arkhangelskiella* group and Campanian-Maastrichtian boundary cooling. Prior to this cooling, the group is dominated by large specimens of *Broinsonia parca* and medium-sized *Arkangelskiella cymbiformis*, resulting in a mean size >10μm. As cooling occurred, the large Broinsonia parca disappeared, specimens of *A. cymbiformis* became smaller, and the mean size dropped below 8μm. The mean size of *Arkhangelskiella* gradually recovered in the Maastrichtian towards values of >10μm. Larger specimens of *Arkhangelskiella maastrichtiana* subsequently replaced small specimens of *A. cymbiformis*.

References

Forster, A., Schouten, S., Baas, M. & Sinninghe Damsté, J.S. 2007. Mid-Cretaceous (Albian-Santonian) sea surface temperature record of the tropical Atlantic Ocean. *Geology*, **35**: 919-922.

Huber, B.T., Norris, R.D. & MacLeod, K.G. 2002. Deep-sea paleotemperature record of extreme warmth during the Cretaceous. *Geology*, **30**: 123-126.

Kim, J.H., van der Meer, J., Schouten, S., Helmke, P., Willmott, V., Sangiorgi, F., Koç, N., Hopmans, E.C. & Sinninghe-Damsté, J.S. 2010. New indices and calibrations derived from the distribution of crenarchaeal isoprenid tetraether lipids: implications for past sea surface temperature reconstructions. *Geochimica et Cosmochimica Acta*, **74**: 4639-4654.

Lees, J.A., 2002. Calcareous nannofossil biogeography illustrates paleoclimate change in the Late Cretaceous Indian Ocean. *Cretaceous Research*, **23**: 537-634.

Miller, K.G., Wright, J.D. & Browning, J.V. 2005. Visions of ice sheets in a greenhouse world. *Marine Geology*, **217**: 215-231.

Thibault, N. & Gardin, S. 2006. Maastrichtian calcareous nannofossil biostratigraphy and paleoecology in the Equatorial Atlantic (Demerara Rise, ODP Leg 207 Hole 1258A). *Revue de Micropaléontologie*, **49**: 199-214.

Watkins, D.K., Wise, S.W., Pospichal, J.J. & Crux, J. 1996. Upper Cretaceous calcareous nannofossil biostratigraphy and paleoceanography of the Southern Ocean. *In:* A. Moguilevski & R.Whatley (Eds). *Microfossils and Oceanic Environments*. University of Wales, Aberystwyth Press: 355-381.

Patterns and mechanisms of calcareous nannoplankton productivity and upwelling in the western Tropical Atlantic: interplay between the Intertropical Convergence Zone and the Northern Hemisphere

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We analyzed new high-resolution records (~ 120 to ~700 yr.) for the calcareous nannoplankton assemblage from the Western Tropical Atlantic (WTA) over the last climatic cycle (the last 150,000 yr.). The aim was to reconstruct the patterns of coccolithophore production and its relationship with the surface ocean conditions in the Guyana Basin. For this purpose, we used Core MD03-2616 retrieved from the Demerara Rise (7º48.75'N, 53º00.80'W at 1233 m) during the PICASSO Cruise of IMAGES (Shipboard Scientific Party, 2003).

Calcareous nannoplankton slides were prepared following the decantation technique outlined by Flores & Sierro (1997), and quantitative measurements were obtained for 380 samples. More than 500 coccoliths were counted using a light microscope under cross-polarized light at ×1000 magnification. In order to examine productivity and surface-water conditions, we used the N index and Nannofossil Accumulation Rates (NAR). The N index shows the ratio between the relative proportion of taxa usually living in the upper photic zone (small Noelaerhabdaceae, *Emiliania huxleyi*, and *Gephyrocapsa oceanica*) and taxa usually inhabiting the lower photic zone (*Florisphaera profunda*) to track coccolithophore production and the nutri-thermocline depth (Flores *et al*., 2000; López-Otálvaro *et al*., 2009). Thus, a high N index (close to 1) denotes episodes of high productivity and a shallow nutri-thermocline due to the strengthening of upwelling conditions. In contrast, a low N ratio (close to 0) indicates episodes of low productivity and the deepening of the nutri-thermocline caused by the weakening of the upwelling cells.

Our data illustrate long-term variations in paleoproductivity during the past climatic cycle. The N index and the NAR values are higher during interglacial substages, pointing to episodes of high productivity, a shallow nutri-thermocline, and upwelling linked to the northward migration of the Intertropical Convergence Zone (ITCZ). In contrast, lower N index and NAR values during glacial substages illustrate scenarios of low productivity, a deep nutri-thermocline, and the collapse of the upwelling cell in the Guyana Basin. This latter scenario is associated with the southern migration of the ITCZ. In addition, high productivity and a shallow nutri-thermocline in the Guyana Basin coincide with times of maximum summer insolation in the Northern Hemisphere. Our results directly link paleoproductivity of calcareous nannoplankton to the latitudinal migration of the ITCZ and the Northern Hemisphere insolation cycles. Together, they confirm that the combination of these mechanisms determines the temporal structure of the surface ocean waters and the production of calcareous nannoplankton at the WTA.

References

Flores, J.-A., Bárcena, M.A. & Sierro, F.J. 2000. Ocean-surface and wind dynamics in the Atlantic Ocean off northwest Africa during the last 140,000 years. Palaeogeography, *Palaeoclimatology, Palaeoecology*, **161**: 459–478.

Flores, J.-A. & Sierro, F.J. 1997. Revised technique for calculation of calcareous nannofossil accumulation rates. *Micropaleontology*, **43**: 321-324.

López-Otálvaro, G.-E., Flores, J.-A., Sierro, F.J., Cacho, I., Grimalt, J.-O., Michel, E., Cortijo, E. & Labeyrie, L. 2009. Late Pleistocene palaeoproductivity patterns during the last climatic cycle in the Guyana Basin as revealed by calcareous nannoplankton. e-Earth, **4**: 1-13. http://www.electronic-earth.net/4/1/2009/ee-4-1-2009.pdf

Shipboard Scientific Party. 2003. MD132-PICASSO, IMAGES XI, Cruise Report, 76pp.

Composition and distribution of living coccolithophores in the Yellow Sea and East China Sea

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Species composition, cell abundance, and estimated fluxes of living coccolithophores were studied along the continental shelf of the Yellow Sea and the East China Sea. Samples were collected by filtration of one liter of seawater onto 0.45 μm polycarbonate filters from discrete depths at each site. The cells (coccospheres) and detached coccoliths were counted with a polarizing microscope (Motic BA300Pol), and species identification was performed with a Tabletop Microscope (TM3000) using morphological differences (Winter & Siesser, 1994; Cros & Fortuño, 2002; Young *et al*., 2003).

A total of 27 species of marine living coccolithophores were recorded. They were classified into ten families and four orders, and most of these species were heterococcolithophores. Six species were recorded for the first time from the coastal waters of the China seas: *Cyrtosphaera lecaliae*, *Syracosphaera histrica*, *S. marginaporata*, *Pappomonas* cf. sp. type 3, *Calyptrolithophora papillifera*, and *Corisphaera strigilis*. Three types of Emiliania huxleyi, type A, type B/C, and type C, were recorded. Species of the genus Syracosphaera, in addition to E. huxleyi and Gephyrocapsa oceanica, frequently occurred at the surveyed sites. The cell abundance of total coccolithophores in spring was significantly higher than that in the winter ($p<0.01$), with means of 15,387 and 2,470 cells l-1, respectively. On average, E. huxleyi accounted for 58.3% of the total coccolithophores, while the average proportion of G. oceanica abundance in the total assemblage was only 16.1%.

Of note, the coccolithophore assemblages in offshore waters of the East China Sea were characterized by high species richness—fourteen species in one sample. This finding indicates that the shelf waters adjacent to the Kuroshio path were ideal habitats for living coccolithophores. The variation in taxonomic composition of these calcifiers could be associated with differences in their preferred habitats. We also found habitat selection of coccolithophores in the southeastern Yellow Sea (32~35°N, 123~125°E). This habitat was characterized by sharp temperature gradients during spring and winter seasons as the result of water exchange between the shelf waters and the Yellow Sea Warm Current. Moreover, the cell abundance, standing crops, and estimated fluxes of coccolithophores were abnormally high in contrast with other areas. The habitat preference of coccolithophores in the Yellow Sea was directly related to hydrodynamic conditions. Unfavorable light conditions due to intense convective mixing were responsible for the low biomass of coccolithophores during winter. However, increasing temperatures from the warm current, in combination with the good water stability, triggered a spring bloom of coccolithophores in the southern Yellow Sea.

References

Cros, L. & Fortuño, J.M. 2002. Atlas of northwestern Mediterranean coccolithophores. *Scientia Marina,* **66**(Supplement 1): 1-186.

Winter, A. & Siesser, W.G. 1994. Atlas of living coccolithophores. *In:* A. Winter & W.G. Siesser (Eds). *Coccolithophores*. Cambridge University Press, Cambridge: 107-159.

Young, J.R., Geisen, M., Cros, L., Kleijne, A., Sprengel, C., Probert, I. & Østergaard, J. 2003. A guide to extant coccolithophore taxonomy. *Journal of Nannoplankton Research*, Special Issue, **1**: 1-125.

Can sample preparation techniques affect data on the relative abundance of Florisphaera profunda?

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This study aims to find the most accurate way of determining the relative abundance of *Florisphaera profunda*. This species is involved in the paleoproductivity indices "N ratio" (Flores *et al*., 2000) and "%Fp" (Beaufort *et al*., 2010) because it is one of the most important deep-water dwellers. Therefore, an accurate assessment of its relative abundance is key to monitoring variations in nutricline depth. This species consists of low birefringent nannoliths with a flat polygonal shape (mainly 1.5-4μm), each consisting of a single calcite crystal. As a consequence of its particular morphology, F. profunda may be inaccurately counted during analyses because it is poorly visible in the light microscope, and because its numbers vary with the different methods of sample preparation. To determine the most accurate abundance counting technique for *F. profunda*, we studied 59 samples from ODP Site 1209B (Shatsky Rise, NW Pacific) from the last 450 ka. Each sample was prepared using three different standard techniques (settling, filtration, and smear slide) and analyzed with a light microscope. Samples prepared with the smear slide method were also analyzed with the automated recognition system SYRACO (Système de Reconnaissance Automatique de Coccolithes).

Of the three techniques, settling resulted in the lowest abundance counts for *F. profunda*. The different *F. profunda* abundances may result from (1) elimination of very small and tabular shaped particles with the settling technique, (2) entrapment of the species on the filter as indistinct aggregates with the filtering technique, probably leading to an abundance underestimation, and (3) absence of size selection with the smear slide technique, thus providing the highest percentages.

When comparing abundances of *F. profunda* obtained with a light microscope to those using SYRACO, SYRACO counts are consistently higher. This finding would imply that SYRACO somehow overestimates the abundance of *F. profunda*. The program reads and discriminates images based on morphology and birefringence, and the shape of *F. profunda* is very similar to that of kaolinite or mica. To verify the presence of these minerals in our samples, and thus to confirm the accuracy of the SYRACO method, we performed a diffraction analysis (XRD) on three samples. The first had comparable relative abundances, the second had SYRACO and smear slide abundances higher than filtration and settling ones, and in the third, SYRACO abundances were strongly higher than abundances performed with the other techniques. In each sample, we found the same moderate percentage of clay minerals (up to 20%), excluding the possibility of an overestimation made by the SYRACO method. However, clear differences between the counts are apparent and deserve further study.

Finally, for each set of data, we correlated an independent paleoproductivity index, the $\Delta\delta^{13}C_{p\text{-}b}$, with the nannofossil indices 'N' and Fp%. All the data show good correlation between nannofossil and geochemical indices, although the settling technique provided the best correlated N index (r= 0.68). This probably is because the technique produces more homogeneous preparations where not only specimens of *F. profunda*, but also other small coccoliths that are involved in the N formula, are dispersed evenly in the fields of view, and thus are more visible for counting.

References

Beaufort, L., van der Kaars, S., Bassinot, F.C. & Moron, V. 2010. Past dynamics of the Australian monsoon: precession, phase and links to the global monsoon concept. *Climate of the Past*, **6**: 695-706.

Flores, J.A., Gersonde, R, Sierro, F.J. *et al*. 2000. Southern Pleistocene calcareous nannofossil events: calibrations with isotope and geomagnetic stratigraphies. *Marine Micropaleontology*, **40**: 377-402.

Calcareous nannofossil biostratigraphy across the Cenomanian–Turonian boundary of the Great Valley Group, California

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Calcareous nannofossil biostratigraphy across the Cenomanian-Turonian (C-T) boundary in the Budden Canyon Formation was reinvestigated using samples collected at closely spaced intervals. The C-T boundary was previously recognized within the Gas Point Member using the first occurrence (FO) of *Eprolithus octopetalus*, a supplementary event in the UC zonation scheme (Burnett *et al*., 1998) that occurs prior to the FO of *Quadrum gartneri* and the last occurrence (LO) of *Helenea chiastia*, which have been used as C-T boundary markers in several studies. Preliminary investigation of the samples revealed the occurrence of additional marker taxa and nannofossil events that can further refine the biostratigraphy across the C-T boundary in the Budden Canyon Formation. Although black shales have not been reported within the formation, the occurrence of a distinct TOC (total organic carbon) excursion between the UC3e to UC6a Zones probably does correspond to an organic carbon excursion during the oceanic anoxic event 2 (OAE2). This makes the Budden Canyon Formation one of the few sections in the northeast Pacific Region where the global C-T boundary OAE2 event can be observed.

References

Burnett, J.A., Gallagher, L.T. & Hampton, M.J. 1998. Upper Cretaceous. *In:* P.R Bown (Ed). *Calcareous Nannofossil Biostratigraphy*. British Micropalaeontological Society Publication Series, Chapman & Hall/ Kluwer Academic Publishers, London: 132-199.

Late Maastrichtian-early Paleocene calcareous nannofossil biostratigraphy in southwest Iran

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High-resolution calcareous nannofossil biostratigraphy was carried out across the K/Pg boundary interval in the Tange-Pabdeh section in southwest Iran (Zagros Basin, part of the Neo-Tethys). There is a stratigraphically continuous Cretaceous-Paleogene boundary sequence here, and this section has been investigated with several micropaleontology groups (foraminifera, dinoflagellates, and calcareous nannofossils). The calcareous nannofossil assemblages are abundant, and their preservation is moderate to good, making is possible to obtain a precise bio-event sequence across the K/Pg boundary. The studied interval extends from the *Nephrolithus frequens* Zone (CC26) to the *Fasciculithus tympaniformis* Zone (NP5). In this section, calcareous nannofossil events across the K/Pg boundary are similar to those recorded elsewhere in the Tethyan Realm (Aguado, 1993; Pospichal, 1995; Gardin, 2002; Tantawy, 2003, *et al*.).

Latest Maastrichtian assemblages are abundant and diverse, and no significant decrease was observed approaching the boundary. At the K/Pg boundary, there is a decrease in the Cretaceous calcareous nannofossil abundances and diversity, along with an increase in dinoflagellate cysts and *Thoracosphaera operculata*, and the appearance of new Paleocene taxa (e.g., *Futyania petalosa*, *Cruciplacolithus primus*, etc.). Blooms of *Thoracosphaera operculata* at the K/Pg boundary have been reported from several middle- to lower latitude sites (Jiang & Gartner, 1986; Gardin & Monechi, 1998; Tantawy, 2003; Bernaola & Monechi, 2007). In other parts of the Tethyan Realm, a bloom of Braarudosphaera bigelowii (e.g., Egypt: Tantawy, 2003; SE Spain: Lamolda *et al*., 2005) has been observed after the Thoracosphaera operculata acme, but this was not observed in the studied section. Above the K/Pg boundary, Cretaceous calcareous nannofossils were observed together with new Paleocene species.

The major problem at the K/Pg boundary interval is whether the Cretaceous species found in the Danian should be considered to be totally or partially reworked. Some authors state that most Cretaceous species found in the Danian sediments are reworked (Gartner, 1996). Nevertheless, a few authors consider that several Cretaceous species did survive the catastrophe and then disappeared a short time after this (Gardin, 2002; Bernaola & Monechi, 2007). In the studied section, some of the Cretaceous calcareous nannofossils passed the K/Pg boundary with good preservation and continued above the boundary and are considered to be survivors. Some Cretaceous species, however, had moderate to poor preservation above the boundary and were only sporadically present, and these are regarded as reworked.

References

Aguado, R. 1993. *Nanofósiles del Cretácico de la Cordillera Bética: biostratigrafía*. Unpublished PhD thesis, Universidad de Granada, Granada, Spain.

Bernaola, G. & Monechi, S. 2007. Calcareous nannofossil extinction and survivorship across the Cretaceous–Paleogene boundary at Walvis Ridge (ODP Hole 1262C, South Atlantic Ocean). *Palaeogeography, Palaeoclimatology, Palaeoecology*, **255**: 132–156.

Gardin, S. 2002. Late Maastrichtian to early Danian calcareous nannofossils at Elles (Northwest Tunisia): a tale of one million years across the K-T boundary. *Palaeogeography, Palaeoclimatology, Palaeoecology,* **178**: 211-231.

Gardin, S. & Monechi, S. 1998. Paleoecological change in middle to low-latitude calcareous nannoplankton at the Cretaceous/Tertiary boundary. *Bulletin de la Société Géologique de France*, **169**: 709-723.

Gartner, S. 1996. Calcareous nannofossils at the Cretaceous/Tertiary Boundary. *In:* N. Maclead & G. Keller, (Eds). *Cretaceous-Tertiary mass extinctions. Biotic and Environmental changes*. W.W. Norton & Company, Inc., New York: 27-47.

Jiang, M.J. & Gartner, S. 1986. Calcareous nannofossil succession across the Cretaceous-Tertiary boundary in east-central Texas. *Micropaleontology*, **32**: 232-255.

Lamolda, M.A., Melinte, M.C. & Kaiho, K. 2005. Nannofloral extinction and survivorship across the K/T boundary at Caravaca, southeastern Spain. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **224**: 27-52.

Pospichal, J.J. 1995. Cretaceous-Tertiary boundary calcareous nannofossils from Agost, Spain. *In:* J.A. Flores & F.J. Sierro, (Eds). *Proceedings of the 5th INA Conference in Salamanca*: 185-217.

Tantawy, A.A. 2003. Calcareous nannofossil biostratigraphy and paleoecology of the Cretaceous–Tertiary transition in the central eastern desert of Egypt. *Marine Micropaleontology*, **47**: 323–356.

Seasonal patterns of coccolithophores, silicoflagellates, and ebridians from a coastal time series in the Gulf of Trieste (North Adriatic Sea)

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Since March 1986, there has been a monthly time series collected through water sampling in the Gulf of Trieste. The sampling station (C1-LTER, 45º42'30"N 13º42'36"E) is located 200 m from the coastline with a water depth of 18 m. Water-column samples (0.5, 5, 10, and 15 m) were analyzed from the 1986-2010 time series (Cabrini et al., 2012) in order to identify phytoplankton seasonal evolution and community structure. The analysis of total phytoplankton composition showed a clear seasonal cycle with peak concentration values in late winter to early spring due to monospecific diatom blooms, and low values in late spring to summer when the phytoplankton is dominated by small flagellates. There is a second smaller peak in the fall that is dominated by diatoms, and low values occur in early winter, when nanoflagellates dominate. In addition, Cabrini et al. (2012) detected an important regime shift within the analyzed time series: a period from 1986 to 1994 that is characterized by high phytoplankton abundance values and dominated by phytoflagellates, and a second period from 1995 to 2007 with low cell concentrations that is dominated by diatoms.

In this work, we analyzed the time series from August 2011 to July 2012, specifically addressing the vertical and seasonal distribution of selected phytoplankton groups – those possessing a mineralized skeleton and thus potentially preserved in the sediments and able to leave a fossil record. Coccolithophores are a major group in the oligotrophic eastern Mediterranean, and Cabrini et al. (2012) showed that they also can be seasonally important in the shallow areas of the Gulf of Trieste. In the present dataset, coccolithophores showed a primary abundance peak (up to 3.2x105 coccospheres/liter) from November to February and a second smaller peak (up to 1x105 coccospheres/liter) in May to June. *Emiliania huxleyi* was the most abundant species throughout the analyzed time series, but *Acanthoica quattrospina* also made an important contribution in January, while holococcolithophores (*A. quattrospina* HOL, *Corisphaera gracilis*, *C. strigilis*, and *C. mediterranea* HOL) and small *Syracosphaera* species were the most important group within the May to June peak. In addition, there was a widespread occurrence, especially in the subsurface layer, of species inhabiting the intermediate photic zone during the late summer to fall period (*Algirosphaera robusta*, *Calciopappus rigidus*, *Ophiaster hydroideus*, and *Calciosolenia* spp.), while *Rhabdosphaera clavigera* and *Syracosphaera pulchra* were most important during the summer months.

Among the flagellate groups, Cabrini et al. (2012) reported silicoflagellates and ebridians from the Gulf of Trieste. Worldwide, these silicifying groups make a minor contribution to phytoplankton, and little is known about their specific vertical and seasonal distribution because only a few studies have dealt with their occurrence in water samples. An improved knowledge of their ecological characteristics would be of great value, considering their potential use in paleoecological reconstructions. In the present dataset, the occurrence of silicoflagellates was restricted to the fall-winter-spring period. *Octactis pulchra* was the dominant species, occurring throughout the water column from September to March, with peak values ($8x10^4$ cells/liter) in January. *Dictyocha* species were present from September to January, primarily in the subsurface layers, while *Distephanus speculum* occurred only sporadically at different times and depths. Ebridians also showed a very clear seasonality, with *Ebria tripartita* occurring from January to March in the sub-surface layers and *Hermesinum adriaticum* occurring throughout the water column from June to August.

Reference

Cabrini, M., Fornasaro, D., Cossarini, G., Lipizer, M. & Virgilio, D. 2012. Phytoplankton temporal changes in a coastal northern Adriatic site during the last 25 years. *Estuarine, Coastal and Shelf Science*, **115**: 113-124.

Lateral versus downward coccolith flux in a canyon setting at the southwestern Cretan margin (eastern Mediterranean Sea)

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A total of eight sediment traps (June 2005-May 2006) were deployed along six moorings at the southwestern Cretan margin to obtain time series results. The continental slope here (between Crete and Gavdos islands) is cut by major submarine canyon systems that drain into the deep Gortys-Gavdos Troughs. From west to east, four moorings were deployed at different depths along the axis of the Samaria Canyon and on the Gavdos rise, one mooring along the axis of the Paximades Channel, and one mooring on the northern side of the eastern South Cretan Trough.

The major canyon systems coincide with subaerial canyons onshore, pointing to a strong tectonic control. Geophysical analyses of the area (Alvez et al., 2007) revealed a Pliocene-Holocene sedimentation pattern that coincides with the modern canyons' locations, showing a greater thickness in regions coinciding with modern depocenters. The Pliocene-Holocene sedimentary unit is represented by alternations of fine-grained turbidites and coarse-grained mass-wasting deposits, which are typical of confined deep-water basins.

The majority of the sediment traps were located in close proximity to the bottom (15 m above the sea floor) in order to detect activity in the canyon systems.

At these mooring sites, coccolithophore fluxes were analyzed as part of the sediment-forming material. Coccolithophores are a major phytoplankton group in the eastern Mediterranean and contribute significantly to carbonate sedimentation in pelagic and hemipelagic settings.

In this study, we analyzed the combined flux of intact coccospheres and single coccoliths. The coccosphere/coccolith ratio is an important ecological indicator in water samples (Cachão et al., 2000), and in sediment traps, fluxes of coccospheres represent the primary signal of export production, while fluxes of single coccoliths may indicate that there also was lateral transport.

A detailed analysis of coccolithophore export production (Malinverno et al., 2009) from the eight sediment traps by means of intact coccosphere flux revealed a consistent pattern of seasonal variation in species' distribution and total coccolithophore export. A major export peak in late spring to early summer, decreasing flux during summer-fall, and an overall low flux in winter correspond to the seasonal variations in sea-surface temperature, surface-mixed layer depth, and precipitation that are associated with varying total surface primary production, as detected through remote sensing in the surface waters.

In our dataset, the coccosphere/coccolith ratio decreases with the collection depth as a function of coccosphere disruption. Malinverno et al. (2009) also showed that robust coccospheres *(Emiliania huxleyi)*, which are more easily preserved, increase in relative abundance in the coccosphere assemblage at increasing collection depths. In addition, minimum values of the coccosphere/coccolith ratio occur at distinct intervals at some mooring sites. These intervals coincide with peak mass fluxes and likely represent events of redeposition of material mobilized from the bottom at the margins of the canyon system.

References

Alvez, T.M., Lykousis, V., Sakellariou, D., Alexandri, S. & Nomikou, P. 2007. Constraining the origin and evolution of confined turbidite systems: southern Cretan margin, Eastern Mediterranean Sea (34°30–36°N). *Geo-Marine Letters*, **27**: 41-61.

Cachão, M., Oliveira, A., Silva, A., Geisen, M., Ziveri P., Broerse, A. & Probert, I. 2000. The ecological potential of (cocco)liths versus (cocco)spheres. *Journal of Nannoplankton Research*, **22**(2): 87-88.

Malinverno, E., Triantaphyllou, M.V., Stavrakakis, S., Ziveri, P. & Lykousis, P. 2009. Seasonal and spatial variability of coccolithophore export production at the south-western margin of Crete (eastern Mediterranean). *Marine Micropaleontology*, **71**: 131-147.

Coccolithophore fluxes and variability from central and eastern Sulu Sea sediment traps in 2008-2009

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Sediment traps facilitate measurement of the settling of calcium carbonate particles, such as coccolithophores, through the water column. These calcareous organisms play an essential role in the sequestration of carbon from the atmosphere into the oceans. This study investigates coccolithophore flux from sediment traps collected in the eastern and central parts of the Sulu Sea from January 2008 to February 2009. The eastern Sulu site (8°23.009'N 121°08.220'E) had traps at 1089 and 3317 m, and the central Sulu site (8°55.014'N 121°57.443'E) had traps at 1127 and 3459 m. In all the traps, *Gephyrocapsa oceanica* dominated the assemblage, followed by *Florisphaera profunda*. Other species include *Reticulofenestra parvula*, *Umbilicosphaera foliosa*, *U. sibogae*, *Calcidiscus leptoporus*, *Emiliania huxleyi*, and *Gladiolithus* sp. An inverse correlation between *G. oceanica* and *F. profunda* abundances is evident in the results from all the traps. Coccolith flux is higher in the central Sulu traps than in the eastern Sulu traps. However, coccosphere flux is higher in the deep-water eastern Sulu trap. Coccolith flux is highest during the winter monsoon (NE monsoon), which affects the Philippines from November to early April. In the shallower water central trap, coccosphere flux maxima occur in January, March-April, and June, traversing the latter part of the NE (winter) monsoon and the beginning of the SW (summer) monsoon. Most of the variability in the coccolithophore abundances may be attributed to upwelling off the coast of Zamboanga and probably farther east along Negros Island. The stronger NE monsoon winds may be the main driving force for the upwelling events during the winter months. However, for the deeper traps, the coccosphere flux is highest in July to August, well into the summer monsoon. This may indicate that the upwelling extended into the summer monsoon months, during which time the winds are usually weaker than in the winter. *Gephyrocapsa oceanica* comprises most of the total coccolith and coccosphere flux except for a few months in the winter monsoon (especially in December 2008) when *F. profunda* dominated the assemblage. This may mean that during these months, monsoon-driven upwelling may not have been strong enough to raise the nutricline to shallower depths, making it more advantageous for *F. profunda* production.

Reconstruction of surface-water dynamics at IODP Site U1314 during the mid-Pleistocene transition (Marine Isotope Stages 30-19) based on coccolithophore analyses

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Changes in surface-water dynamics were reconstructed in the North Atlantic Ocean using coccolithophore assemblages from IODP Site U1314 (56°21'N 27°53'W, 2800 m) in the interval of Marine Isotope Stages (MIS) 30-19 (1050-780 ka) at orbital resolution. This study includes the mid-Pleistocene transition (MPT) when the dominant periodicity of climate cycles changed from obliquity to eccentricity in the absence of substantial change in orbital forcing. In the North Atlantic, the general trend of paleoproductivity showed an increase during interglacials and a decrease during glacials. Paleoproductivity is consistently low during glacials but shows more rapid fluctuations during interglacials. North Atlantic productivity is controlled by the oscillations of cold and productive Arctic waters or by the warm and oligotrophic North Atlantic Current (NAC) (Naafs et al., 2010). This balance generates oscillations in the position of the Irminger Current (IC) (Ólafsdóttir et al., 2010). This pattern has been primarily observed for the intervals MISs 30-25 and MISs 21-19. An influence of subtropical water occurred during MIS 23 and persisted through the glacial MISs 24 and 22. These stages are considered to be the coldest of the entire studied time interval (Heslop et al., 2002; Hernández-Almeida et al., 2012) Comparison of insolation in June at 60°N with the nannofossil accumulation rate of eutrophic species allows one to observe good correlation of paleoproductivity fluctuations with insolation cycles. Variations in insolation controlled the continuous displacement of the sub-polar gyre with the arrival at the site of sub-polar surface waters or IC and caused fluctuations in paleoproductivity. The insolation curve in October at 60°N shows an interesting pattern during MIS 23, when it does not show the decrease in amplitude that was observed for the insolation curve in June at 60°N. During MIS 23, therefore, the possible influence of subtropical waters at the site can be related to more insolation during the fall season, causing a weakening of summer insolation influence on the sub-polar gyre system. The result of this study concludes that the North Atlantic system is highly sensitive to even extremely weak perturbations in insolation at millennial time scales.

References

Hernández-Almeida, I., Sierro, F.J, Cacho, I. & Flores, J.-A. 2012. Impact of suborbital climate changes in the North Atlantic on ice-sheets dynamics at the mid-Pleistocene Transition. *Paleoceanography*, **27**, PA3214: 14.

Heslop, D., Dekkers, M.J. & Langereis, C.G. 2002. Timing and structure of the mid-Pleistocene transition: records from the loess deposits of northern China. *Palaeogeography, Palaeoclimatology, Palaeoecology* **185**: 133-143.

Naafs, B.D., Stein, R., Hefter, J., Khélifi, N. & De Schepper, S. 2010. Late Pliocene changes in the North Atlantic Current. *Earth and Planetary Science Letters,* **298**: 434-442.

Ólafsdóttir, S., Jennings, A.E., Geirsdóttir, A. & Giffird, H.M. 2010. Holocene variability of the North Atlantic Irminger current on the south and northwest shelf of Iceland. *Marine Micropaleontology*, **77**(3-4): 101-118.

Recent advances in calcareous nannofossil biostratigraphy across the Pliensbachian-Toarcian boundary in the Peniche section, the GSSP candidate, and comparisons with other Tethyan settings

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The main candidate for the Global Boundary Stratotype Section and Point (GSSP) for the base of the Toarcian Stage is the Peniche section (Lusitanian Basin, Portugal), which satisfies most of the requirements recommended by the International Commission on Stratigraphy (ICS). The Pliensbachian-Toarcian boundary at Peniche is part of a continuous section that encompasses over 450 m of carbonate-rich sediments. At the Pliensbachian-Toarcian boundary, observed in an alternating marl-limestone unit, no significant vertical facies changes, stratigraphic gaps, or hiatuses have been recorded. The paleontological record shows abundant, diverse, and well-preserved macro- and microfossil assemblages.

The excellent record of Toarcian sediments allows the identification of calcareous nannofossil events (primarily first occurrences) that were previously attributed to younger strata because of a combined effect of (1) condensation or hiatuses in many classical areas of the western Tethys previously studied for nannofossil biostratigraphy, and (2) a Lazarus effect that controlled the distribution of species routinely used in biostratigraphy. In fact, a temporary disappearance of some coccolith species is recorded during the early Toarcian anoxic event. These re-occur consistently in strata younger than the event. Recently acquired nannofossil data, and a re-evaluation of nannofossil biostratigraphy in previously studied sections, indicate that a similar pattern is recorded in expanded sections from Morocco, central Italy, and Spain.

A very tight correlation of the Peniche section to the magnetostratigraphy of Almonacid de la Cuba (Iberian Range, Spain) allows us to discuss the magnetic record and to correlate it to the Karoo volcanic reversed/normal polarity succession. This provides the ability to project Karoo ages onto the Toarcian boundary interval.

Fossil and Recent silicoflagellate double skeletons: clues to evolutionary history, taxonomy, and the formation of skeletons

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An intriguing and largely overlooked aspect of silicoflagellate biology and paleontology is the occurrence of double skeletons (also termed doublets or paired skeletons). As few as 50 double skeletons have been illustrated to date in the reviewed scientific literature. The two skeletons making up a doublet are generally understood to be connected along the surfaces of the elements and spines that compose the basal structure, with the pikes reaching into the cellular domain of the sibling skeleton to help hold the pair together. Basal rings of a double skeleton were understood to have in all cases the basal corners aligned with sibling basal spines against one another along the abbasal surfaces.

Fossils from several Upper Cretaceous localities in the Arctic regions of Canada and Russia show a dramatically different double skeleton configuration in which the basal corners are aligned with the mid-basal sides of the sibling skeleton in a "star-of David" design. This general configuration was observed for three Cretaceous genera and on very rare double skeletons of three- and four-sided specimens from the Paleogene. This presents interesting possible alternative interpretations for early silicoflagellate evolution and taxonomy.

The double skeleton design has also been interpreted for some of the oldest known silicoflagellates (Early Cretaceous of Antarctica), which do not have basal rings. The sibling skeletons were connected along limbs composed of several skeletal components. Both the general and double skeleton morphologies were interpreted through the construction of physical models, which show that, despite obvious differences, radial spines and pikes are largely similar to modern skeletons. The limb terminations are connected and aligned with what appear to be apical, but can be interpreted as basal, spines of the sibling skeleton.

A study of modern double skeletons of *Distephanus speculum* and *Dictyocha messanensis* suggests that the skeletal morphology is transposed from the mother to the daughter skeleton through the center of the cell. This produces a copy of the mother skeleton that preserves the sinistral rotation of the strut attachments and apical rings on both skeletons. This transposition of skeletal morphology across the cell is generally consistent with observations of the interpreted double skeletons from the Early Cretaceous. This suggests that the two silicoflagellate lineages that produce double skeletons in contrasting patterns share a common ancestor. Furthermore, some of the well-established fossil taxa (e.g., *Corbisema*) may require taxonomic reevaluation in the light of their mode of double skeleton formation.

Coccolith calcification changes during glacial terminations in the North Atlantic Ocean

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Glacial to interglacial environmental changes have a strong impact on coccolithophore assemblage composition, as do glacial terminations, which are characterized by a relatively strong increase in atmospheric CO_2 concentration. In order to determine how these two processes influence calcite production of coccolithophores, we compared coccolith weight estimates obtained with the automated coccolith recognition system SYRACO (Système de Reconnaissance Automatique de Coccolithes) with scanning electron microscope (SEM) assemblage counts for the last two glacial terminations (T1 and T2). Samples were obtained from sediment cores in the North Atlantic (MD3180, Azores; ODP Site 980, Rockall Plateau; SO164-17-2, Florida Strait). The most common observation was an increase in the average weight of Noelaerhabdaceae coccoliths at times of increasing atmospheric CO_2, which contradicts previous findings. This effect is strongest during termination T2 in the Florida Strait. An assemblage shift towards heavier calcifying morphotypes can only partially explain the observed coccolith weight increase, which appears to be partly due to an increase in coccolithophore calcification. Therefore, carbonate system variability is only a minor component for driving coccolithophore calcification at the observed sites.

Living on the edge of CaCO3 undersaturation: a recurring autumn coccolithophore bloom in Kiel Bay (SW Baltic Sea)

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Although one of the first detailed investigations of living coccolithophores was conducted in the Kiel Bay at the beginning of the 20th Century (Lohmann, 1908), little is known about their distribution in the Baltic Sea. Lohmann's centrifuge sampling technique revealed that *Emiliania huxleyi* (at that time called *Pontosphaera huxleyi*) occurred in the bay between November and August of 1905/1906. In contrast, a century later, Tyrrell et al. (2008) assumed that the absence of coccolithophores from the Baltic proper could be due to undersaturation with respect to $CaCO_3$ during the winter.

We present plankton sampling counts from the innermost Kiel Fjord near the Tirpitz Harbor in Kiel and from several short cruises aboard the RV *Polarfuchs*, the RV *Littorina*, and the RV *Alkor* from the years 2009 to 2012, which show that coccolithophores are a common member of the autumn phytoplankton bloom in Kiel Bay. Usually only a few isolated liths or single cells were detected on the filters throughout the year. However, depending on the year, cell numbers of *E. huxleyi* started increasing between the end of August and the end of September. This time of the year is characterized by decreasing temperature (from maximum values of about 20°C in August to about 8°C in December), the highest salinity values of around 18 to 22 psu, and a nutrient increase following the nutrient depletion during the summer. Cells became undetectable between mid-October and late December. Timing and average cell numbers were similar to 100 years ago (about 10^5 cells/l; Lohmann, 1908), but during exceptional years, coccolithophore cell numbers reached bloom strength (>10^6 cells/l in September 2009). Morphometric analyses showed that only *E. huxleyi* Type A is present in the Kiel Bay. The liths were rather small (mostly below 3μm on average) but calcified normally. In addition to *E. huxleyi*, several other coccolithophore species were observed. The species *Algirosphaera robusta* and *Acanthoica quattrospina* (both heterococcoliths and holococcoliths) were the most abundant, while *Syracosphaera borealis* and *Alisphaera extenta* were only minor components. Furthermore, a previously undescribed calcifying nannoplankton species was found. These species are also commonly found in North Sea and Skagerrak coccolithophore communities. Taking into account the sporadic occurrence of *E. huxleyi* throughout the year, it seems likely that coccolithophores are a permanent constituent of the Baltic Sea plankton community, but only reach detectable levels during the autumn phytoplankton bloom.

Blooms of *Emiliania huxleyi* in the surface layer co-occurred with $CaCO_3$ undersaturation in bottom waters (~18 m water depth). In order to test if carbonate system parameters are limiting the growth of *E. huxleyi*, a batch of sea water was collected at the end of the growth season in late November 2012, and was incubated at constant temperature (9°C) and light conditions (light-dark cycle 9/15 hours, 50 μmol m^{-2} s^{-1}). Whereas cell numbers in the field continued to decrease, *E. huxleyi* started growing exponentially (0.24 divisions per day) in the incubated water until it was outgrown by co-occurring diatoms after 15 days of incubation. This demonstrates that the carbonate system is most likely not limiting growth, but rather decreasing temperature, low light levels, and increasing turbidity are responsible for the decline of coccolithophores in winter. To investigate whether the Baltic Sea *E. huxleyi* population is morphologically and genetically different from the North Sea and Skagerrak populations, and possibly shows an adaptation to low $CaCO_3$ saturation levels, remains an interesting task for the future.

References

Lohmann, H. 1908. Untersuchungen zur Feststellung des vollständigen Gehaltes des Meeres an Plankton. *Wissenschaftliche Meeresuntersuchungen, Abteilung Kiel*, Neue Folge, **10**: 132-270.

Tyrrell, T., Schneider, B., Charalampopoulou, A. & Riebesell, U. 2008. Coccolithophores and calcite saturation state in the Baltic and Black Seas. *Biogeosciences*, **5**(2): 485-494.

The Middle Eocene Climatic Optimum (MECO) event in the Keresta borehole in the southern Russian Platform and changes in nannofossil and dinoflagellate cyst assemblages

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A section from the Keresta borehole in the Ergeny area (Georgia) (42°21'51"N 43°24'52"E) penetrated the uppermost part of the Kuberla Formation, the Keresta Formation, and the lower part of the Solonka Formation. The uppermost part of the Kuberla Formation is composed of glauconitic quartz sands, grading into sandy carbonate clays (6 m) upwards in the section. The nannoplankton complex contains *Nannotetrina fulgens*, *N. cristata*, *N. pappii*, *N. nitida*, *D. prebifax*, *Chiasmolithus gigas*, and *Discoaster martini*, placing it in Subzone CP13b.

The white and greenish coccolith limestones of the Keresta Formation (8.5 m) are separated from the underlying Kuberla Formation by a distinct sedimentation break. *Discoaster bifax* appears at the base of the formation. *Zygrhablithus bijugatus* increases and becomes dominant. *Pontosphaera* spp., *Transversopontis* spp., *Pemma basquensis*, and *Braarudosphaera bigelowii* become numerous, and rare *Scyphosphaera expansa* appear. Substantial numbers of *Nannotetrina fulgens*, *N. cristata*, *N. pappii*, and solitary *Discoaster martini* still occur. All coccoliths increase in size and are often encrusted with secondary calcite, and warm-water species increase. *Discoaster bifax* places this interval in the lowermost part of Subzone CP14a. The warm-water nannoplankton complex, high $CaCO_3$ content, and substantial reduction of C_{org} suggest that the Keresta Formation was formed in normal oxic conditions with high water temperatures, and may correspond to the Middle Eocene Climatic Optimum (MECO).

The overlying Solonka Formation bears signs of a break at its base, and its lower part consists of brown marls (1.5 m) that are rich in dispersed organic matter and contain numerous fish scales and bones. Up section, the marls grade into greenish, slightly calcareous clays (4 m) with abundant radiolarians. The lower marl member corresponds to the upper part of Subzone CP14a based on the occurrence of numerous large (>14μm) specimens of *Reticulofenestra umbilicus*, *Cribrocentrum reticulatum*, *Clathrolithus spinosus*, and *Corannulus germanicus*, while *Nannotetrina* spp. almost disappear, and only solitary specimens of *N. cristata* occur.

The greenish clays of the upper part of the Solonka Formation have a depleted nannofossil assemblage, and *Chiasmolithus solitus* and *Rhabdosphaera gladius* disappear almost completely with only solitary specimens and fragments observed. Only *R. umbilicus*, *Coccolithus pelagicus*, *C. eopelagicus*, and small *Reticulofenestra* spp. are still numerous. These clays are tentatively placed in Subzone CP14b. Similar successive appearances of the above species were observed in the middle Eocene section along the Kheu River (northern Caucasus), and *D. bifax* first occurrence (FO) was recorded in the base of the first basal interlayer of the brown marls of the Kuma Formation that were formed in anoxic near-bottom water conditions. Large specimens of *Reticulofenestra umbilicus* (>14μm) appear higher, near the middle of the lower half of the formation.

The Keresta-1 section is represented by rich and diverse complexes of dinocysts and green algae. The Kuberla and the Keresta Formations are in the *Enneadocysta arcuata* Zone of the middle Eocene Lutetian Stage. The Solonka Formation is described from layers with *Wilsonidium intermedium*. A series of successive biotic dinocyst events, such as FO of *Wisonidium echinosuturatum*, FO, acme, and last occurrence (LO) of *Phthanoperidinium cornutum*, FO of *W. tabulatum*, FO of *P. distinctum*, FO of *Enneadocysta multicornuta*, and FO and acme of *Wisonidium intermedium* may be used for intraregional correlations through that stratigraphic interval. The Keresta Formation dinocyst association is represented by thermophilic taxa inclusive of *Wisonidium echinosuturatum* and most probably corresponds to the MECO event.

The following conclusions can be made for the Keresta borehole: (1) the upper part of the Kuberly Formation corresponds to Subzone CP13b, (2) the white coccolith-rich limestones of the Keresta Formation of Subzone CP14a were deposited in normal oxic conditions and correspond to the lower part of the Kuma Formation, which formed in a deeper water part of the basin with anoxic conditions near its base, (3) the Keresta Formation corresponds to the MECO episode, and (4) the Solonka Formation (Subzone CP14a and probably Subzone CP14b) probably corresponds to the upper half of the northern Caucasus Kuma Formation.

Calcareous nannoplankton response across the Eocene-Oligocene transition in the North Atlantic Ocean

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The Paleogene greenhouse-icehouse transition was an interval of profound long-term climatic change that was accompanied by significant biotic change and, in particular, turnover and diversity loss in the calcareous nannoplankton. The middle Eocene through early Oligocene experienced climatic deterioration from a greenhouse into an icehouse world, culminating in a sharp cooling at the Eocene-Oligocene transition (EOT). The interval includes key climatic events such as the Middle Eocene Climatic Optimum (MECO) and the Eocene-Oligocene boundary (EOB). The EOB, which lies within the EOT, is defined by a biotic marker, the extinction of the Hantkenindae family of planktonic foraminifera. A range of global environmental disruptions 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 a marine biotic disturbance with elevated levels of plankton extinction and turnover. Calcareous nannoplankton appear to have been the dominant oceanic phytoplankton group in the early Paleogene until the EOT, at which time they declined in diversity, although we still know little of the structure and timing of this diversity decline through the late Eocene.

Here we will present calcareous nannofossil data from a stratigraphically expanded EOT succession at IODP Site 1411 that yields exceptionally well-preserved calcareous microfossils. The section was recovered in the NW Atlantic Ocean during IODP Expedition 342 (June-July 2012). Semi-quantitative data and simple abundance counts highlight high-resolution species extinction events, originations, and acmes, as well as major shifts in abundance patterns across the EOT transition. The demise of *Discoaster barbadiensis*, *Discoaster saipanensis*, *Reticulofenestra reticulata*, and *Coccolithus formosus*, and an increase in *Reticulofenestra daviesii* clearly indicate that the paleoclimatic/paleoceanographic conditions changed to a cooler 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 elsewhere at this time.

Living coccolithophores in the Western Pacific Warm Pool

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The Western Pacific Warm Pool (WPWP) is characterized by some of the warmest sea waters of the global ocean, with sea surface temperatures (SST) exceeding 28°C. The WPWP is a major source of heat to the atmosphere, as well as a site of deep atmospheric convection and heavy rainfall. It has been the subject of many studies in recent years because of its significant role in the Earth's climate system. This study investigates the distribution of living coccolithophores from surface and subsurface (deep chlorophyll maximum – DCM) water samples that were taken during the MR13-01 cruise of R/V *Mirai* in March 2-17, 2013, in the West Caroline Basin and the West Philippine Basin-Southern Sub Basin (WPB-SSB), located in the WPWP. The abundance and species diversity of surface-water coccolithophores were very low to zero. Coccolithophores in the subsurface water (40–100 m) were more abundant. A total of 27 living species were recorded. Coccolithophore abundance in the WPWP increased with a decline in the amounts of dissolved oxygen. *Umbellosphaera irregularis* was the dominant species in oligotrophic surface waters, while *Florisphaera profunda* characterized the oligotrophic subsurface assemblage. The eutrophic surface and subsurface waters were marked by an abundance of *Gephyrocapsa oceanica*, while at deeper depths *Oolithotus antillarum* was much more abundant. Floral composition shows that the productivity levels in the waters of the West Caroline Basin increase northward, while waters in the WPB-SSB are generally eutrophic.

A cellular perspective on coccolithophore growth and biomineralization at the Paleocene-Eocene Thermal Maximum

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The geological record provides a valuable archive of coccolithophore responses to past climate change and ocean acidification (OA) that are of relevance for predictions of coccolithophore responses to modern environmental perturbation. Here, we apply morphometric methods to quantify the skeletal thickness of fossil coccoliths and combine this with new data from fossil coccospheres across an interval of past climate warming and OA at the Paleocene Eocene Thermal Maximum (PETM, ~56 Ma). Applying the results of experiments with modern coccolithophore species (Gibbs et al., 2013) to our PETM fossil data, we provide unprecedented insights into species-specific calcification responses during the PETM at a cellular level. Specifically, we use the recently identified relation between coccosphere geometry and cellular growth rate (Gibbs et al., 2013) to estimate rates of calcification in fossil coccolithophore populations for the first time.

Our data reveal transient thinning of *Coccolithus pelagicus* coccoliths immediately prior to the PETM, which represents a hypothesized biomineralization response to surface OA. In addition, we observe a decrease in growth and calcification rates of *C. pelagicus* populations during the interval of maximum warmth, which contrasts with the consistent growth and calcite production of populations of *Toweius pertusus*, an ancestral species of modern *Emiliania huxleyi*. Our analyses indicate that the net effect of changing coccolith thickness on whole-cell calcite production is modest during the PETM. We determine, however, that due to the typically larger size of modern *C. pelagicus* coccoliths and the increased difference in morphotypic calcite mass of *E. huxleyi* (Young & Ziveri, 2000), ongoing environmental change will likely have greater implications for modern and near-future global coccolithophore calcite production than that observed during the PETM.

References

Gibbs, S.J., Poulton, A.J., Bown, P.R., Daniels, C.J., Hopkins, J., Young, J.R., Jones, H.L., Thiemann, G.J., O'Dea, S.A. & Newsam, C.* 2013. Species-specific growth response of coccolithophores to Palaeocene-Eocene environmental change. *Nature Geoscience*, **6**: 218-222, doi: 10.1038/NGEO1719.

Young, J.R. & Ziveri, P. 2000. Calculation of coccolith volume and its use in calibration of carbonate flux estimates. *Deep-Sea Research Part II-Topical Studies in Oceanography* **47**: 1679-1700.

Biostratigraphic correlation of Paleogene sediments based on calcareous nannofossils in four wells from the Tampico-Misantla Basin, Gulf of Mexico

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Based on a calcareous nannofossils study of cuttings and core samples from wells here named A, B, C, and D, a biostratigraphic correlation of the upper Oligocene to lower Paleocene sediments was carried out in the Tampico-Misantla Basin. The age of the sediments in Well A extends from the middle Eocene (Lutetian) to the lower Paleocene (Selandian). The biozones include NP16-NP12, NP10-NP9, NP6, and NP4. In Well B, the upper Oligocene (Chattian) to upper Paleocene (Thanetian) was identified, and the following biozones were recognized: NP24-NP19, NP17-NP14, NP12-NP11, and NP9. Sediments from the middle Eocene (Lutetian) to the upper Paleocene (Thanetian) were documented in Well C, and the biozones include NP14-NP9. In well D, the middle Eocene (Lutetian) to lower Eocene (Ypresian) was recognized, and the following biozones were identified in this well: NP15, NP13-NP11.

A biostratigraphic analysis of the wells allowed chronostratigraphic correlation of biozones from the upper Paleocene (Thanetian) to the middle Eocene (Lutetian). Biozone NP9, which occurs in A, B, and C wells, is overlain by biozone NP10 only in wells A and C. The NP11 biozone can be recognized in wells B, C, and D. Biozone NP12 is the only biozone found in all four wells. NP13 occurs in wells A, C, and D, always overlying biozone 12. Biozone NP14 was documented in wells A, B, and C. In wells A, B, and D, biozone NP15 is present. This biozone underlies biozone NP16 in wells A and B. A continuous sequence from biozone NP19 to biozone NP24 was recognized only in borehole B. From this biostratigraphic analysis, it can be concluded that several discontinuities are present. In well A, discontinuities for nannofossil biozones NP11, NP8, NP7, and NP5 occur. In Well B, the discontinuities detected are for NP18, NP13, and NP10. In well D, a discontinuity for NP14 was observed. These discontinuities are interpreted either to be hiatuses related to erosion or may represent nondepositional events associated with sea-level fluctuations. In the later scenario, the sea-level changes might have stimulated nannoflora migration.

References

Bown, P. 2005. Palaeogene calcareous nannofossils from the Kilwa and Lindi areas of coastal Tanzania (Tanzania Drilling Project 2003-4). *Journal of Nannoplankton Research*, **27**(1): 21-95.

Perch-Nielsen, K. 1985. Cenozoic Calcareous Nannofossils In: H.M. Bolli, J.B. Saunders & K. Perch-Nielsen (Eds). *Plankton Stratigraphy*. Cambridge University Press, New York: 427-545.

Coccolithophore flux in sediment traps from northern South China Sea

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Annually, the South China Sea is greatly affected by strong monsoons, which make it sensitive to climate change and results in a strong seasonal signal in primary production. Thus, it is particularly ideal for seasonal variability studies. It is located between two major weather regimes of the world: the Indian Ocean monsoon area and the vast Pacific and Australian and Asian monsoon systems. It is essential to gain an understanding of the effect of these atmospheric events on the productivity of the waters and on the sediments falling to the sea floor. Sediment traps provide the opportunity for collection of settling particulate matter in the water column over a fixed period of time. This study investigates the flux of coccolithophores in sediment trap samples collected in the northern South China Sea from May 2011 to April 2012. Three sediment traps were recovered at different depths (1003, 2158, and 3196 m). The influence of the monsoons on variations in coccolithophore abundance and species assemblage will be analyzed in each of the trap depths.

Micropaleontology in archaeology: reconstruction of provenance of ancient ceramics through calcareous nannofossils

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Archaeological discoveries of prehistoric pottery occur frequently in northern Italy (Bernabò Brea et al., 1997). It is uncommon, however, to discover calcareous nannofossils in prehistoric pottery. Two different cases of provenance reconstruction of prehistoric artifacts are presented here that resolved with the use of calcareous nannofossils. This confirms the importance of an integrated archaeological/paleontological method of investigation (Quinn et al., 2007).

Case 1 - Some specimens of macroforaminifers (*Nummulites* spp.) were observed in an isolated fragment of prehistoric vase bottom recovered from the Po River (Cremona Province, Italy). This finding led us to look for calcareous nannofossils in the vase in order to date the calcareous sediment that was used as a degreaser in the vase's construction. Calcareous nannofossils were recovered from inside some carbonate clasts, and together with the Paleogene macroforaminifers, as well as a heterogeneous lithological assemblage recognized in other clasts, it is probable that the sediments came from geological formations east of Garda Lake (Luciani, 1987; Zampieri et al., 1994). This location is likely to be the origin for the vase's material and where it was manufactured. Since the vase was found in a region far from this location, this information can be used to reconstruct migration paths and/or commercial trade routes in protohistory (de Marinis, 1997).

Case 2 - Ten smear slides were prepared for calcareous nannofossil study from carbonate clasts in four different fragments of pottery from a prehistoric site in Vicofertile, near the Baganza River (northern Italy). The micropaleontological investigation showed a calcareous nannofossil assemblage characteristic of the early Eocene. This biostratigraphic result allowed correlation of the calcareous sediments with the "Monte Sporno Formation" that crops out in the Northern Apennines (Italy) and in particular with the Armorano Member (APAT-Regione Emilia Romagna, 1990, 2002). These results suggest that prehistoric men from the Vicofertile site collected calcareous pebbles from the nearby Baganza River that had been eroded out of and transported away from the Monte Sporno Formation and then used them for making ceramics.

References

APAT- Regione Emilia Romagna. 1990. Foglio 217 Neviano degli Arduini della carta geologica d'Italia alla scala 1:50.000, A. Cerrina Feroni, P. Elter, G.Plesi, A. Rau, D. Rio, P. Vescovi & G. Zanzucchi (Eds). S.EL. CA., Firenze.

APAT- Regione Emilia Romagna. 2002. Note illustrative al Foglio 217 Neviano degli Arduini della Carta geologica d'Italia alla scala 1:50.000, A. Cerrina Feroni & P. Vescovi (Eds). S.EL.CA., Firenze.

Bernabò Brea, M., Cardarelli, A. & Cremaschi, M. (Eds). 1997. *Le Terramare - La più antica civiltà padana*. Catalogo della Mostra (Modena 1997). Milano.

de Marinis, R. 1997. L'età del bronzo nella regione benacense e nella pianura padana a nord del Po; In: M. Bernabo' Brea, A. Cardarelli & M. Cremaschi (Eds). *Le Terramare. La più antica civiltà padana*. Catalogo della Mostra (Modena 1997). Milano: 405-422.

Luciani V. 1987. La dorsale paleogenica del M. Baldo-M. Bondone: suo significato paleogeografico e paleotettonico. *Rivista Italiana di Paleontologie e Stratrigrafia,* **93**: 507-520.

Quinn, P.S. & Day, P.M. 2007. Ceramic micropalaeontology: the analysis of microfossils in ancient ceramics. *Journal of Micropaleontology*, **26**: 159-168.

Zampieri, D. & Zorzin, R. 1994. Carta geologica dei Lessini centro-occidentali, tra la Valpantena e la Val d'Illasi (Prealpi Venete). In: Geologia, idrogeologia e qualità dei principali acquiferi veronesi (a cura di L. SORBINI). *Memorie del Museo Civico di Storia Naturale di Verona, serie II, Sezione B, Scienza della Terra*, (**4**): 150pp.

The effects of climate change on coccolithophore productivity over the Eocene–Oligocene transition

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The Eocene-Oligocene transition (E-OT)(~34 to 33.5 Ma) is the most extreme period of climate change in the Cenozoic: from a "greenhouse" to an "ice house" world with permanent ice forming at the Antarctic within ~400 ky. The environmental changes are accompanied by extinctions among tropical oligotrophic microplankton and a shift from coccolithophore domination to mixed coccolithophore-diatom primary productivity. This shift may be associated with changes in nutrient cycling and/or ocean thermal structure due to changes in ocean circulation, such as the onset of the Antarctic Circumpolar Current.

This project aims to produce direct records of coccolithophore growth rates in the equatorial Pacific (IODP U1334) across the E-OT using coccolith Sr/Ca ratios. Sr/Ca has been analyzed in individual coccoliths using SIMS (secondary ion mass spectrometry) and on mixed coccolith fractions using ICP-AES (inductively coupled plasma-atomic emission spectrometry). The mixed fractions were also analyzed for oxygen and carbon isotopes using a DI-IRMS (dual-inlet isotope ratio mass spectrometer). The data reveal a significant shift in coccolithophore growth rates over the E-OT that is linked with changes in both $\partial^{12}C$ and $\partial^{18}O$.

The potential for using coccolithophores for geochemical analysis

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Due to their small size, coccoliths are often perceived to preserve poorly compared with the much larger foraminifera, and coupled with this until recently, it has been difficult to obtain species-specific geochemical data for individual specimens of coccolith species. Historically, this has proved a limiting factor in the use and interpretation of coccolithophore geochemical proxies.

Here, we demonstrate the preservation of primary coccolithophore calcite, which is suitable for geochemical analysis, in deep ocean sediments that lack planktic foraminifera. This supports the further use and interpretation of both coccolith trace elements and stable isotope data as proxies for past environmental change. Using TOF-SIMS and SIMS (time of flight-secondary ion mass spectrometry), it is possible to demonstrate that the Sr/Ca values from fossil coccoliths are comparable to those collected from their modern counterparts. It has also been possible to examine the distribution of different ions within individual coccoliths, demonstrating the presence of primary biogenic calcite and identifying that the effects of diagenesis can often be overcome.

When did the Jurassic Sea date the western Indian craton: revelations by nannofossils

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Jurassic rocks are present in the Kachchh Basin of India in two belts: a NW-SE series of domes on the mainland and the E-W trending series of uplifts "islands") in the Raan of Kachchh known as the Island Belt. The Island Belt is separated into five hillocks: Patcham, Khadir, Bela, Chorar, and Wagad. The domes and uplifts are bounded by faults, and some domes are faulted anticlines. The Mesozoic rocks of Kuar Bet, an isolated uplift, are situated NW of Patcham Island and expose the oldest strata in the Kachchh Basin. The timing of the earliest epeiric transgressive event in the Kachchh Basin was recorded using calcareous nannofossils as other datable parameters are absent.

The extension of the Ethiopian Gulf as an arm of the Tethys Sea after the breakup of Gondwanaland left imprints in western India during the Jurassic. The oldest ages in the Kachchh Basin are provided by the ammonite *Leptosphinctes* sp., indicating a latest Bajocian age (~167.7 Ma) and by the coral *Amphiastraea-Isastraea* sp., indicating early? Bajocian (~171.6Ma). The diverse and moderately preserved calcareous nannofossil marker species, represented by *Biscutum finchii*, *Bussonius prinsii*, *Crepidolithus pliensbachiansis*, *Crucirhabdus primulus*, *Discorhabdus criotus*, and *D. striatus*, from the Dingi Hill Member of the Kaladongar Formation exposed at Kuar Bet assign an age of from Zones NJ4a to NJ7 of Bown et al. (1988) of lower Pliensbachian (Tethyan ammonite *Jamesoni* Zone) to middle Toarcian age (*Variabilis* Zone). The presence of *Lotharinguis* sp. and *Triscutum sullivanii* within the assemblage suggests extension up to the middle Aalenian (~177Ma). The coarse-grained sandy facies with monospecific abundance of small bivalves at limited levels was deposited as a storm event. This was followed by the deposit feeding ichnofossils *Rhizocorallium*, *Paleophycus*, and *Skolithos*, and this post storm activity suggests that there was rapid facies variation in a coastal marine environment that lacked ammonites. The Early Jurassic sediments of Pliensbachian age were probably laid down in the Kachchh Basin in response to a short episode of epeiric transgression due to the cumulative effect of the breakup of Gondwanaland, eustatic sea-level rise, and local tectonics.

Several domes on the Kachchh mainland and the Wagad highland have Early Jurassic calcareous nannofossils reworked into Middle-Late Jurassic sequences. The Mesozoic lithostratigraphy of Kachchh provided by Biswas (1977) is followed herein. The formations in ascending order are the Jhurio (Bajocian-lower Callovian?), Jumara (Callovian-Oxfordian), Jhuran (Kimmeridgian-Valanginian), and Bhuj (Aptian-Albian). The oldest part of the Jhurio Formation is exposed on Pachchham Island (Kuar Bet) and here is called the Kaladongar Formation. In the Mainland domes, the Jumara Formation is capped by condensed Dhosa Oolite beds containing mixed Oxfordian ammonites from several zones, whereas in Wagad, the Oxfordian-Kimmeridgian is exposed and contains ammonites (in hard beds), calcareous nannofossils, and organic walled dinoflagellate cysts (in associated shales). The Callovian nanno assemblage from the Jumara Formation of the Jara Dome, situated on the westernmost extremity of Kachchh Mainland, contains reworked Early Jurassic *Crepidolithus pliensbachiansis* and *Triscutum sullivanii*. The nanno assemblage from the lower part of the type Jumara Formation (Callovian age) of the Jumara Dome in the vicinity of Jara contains Early Jurassic reworked specimens: *Biscutum finchii*, *Diductius constans*, *Mazaganella protensa*, *Mitrolithus elegans*, and *Parhabdolithus liasicus*. In contrast, the lower Jhuran Formation of the Habo Dome, situated on the easternmost extremity of Kachchh Mainland, contains reworked Early Jurassic *Triscutum sullivanii*. In the Wagad Highland, the Oxfordian age Patasar Shale member contains the Early Jurassic reworked nannofossils: *Crucirhabdus primulus*, *Diductius constans*, *Mazaganella protensa*, and *Parhabdolithus liasicus*.

These findings clearly demonstrate that an Early Jurassic (Pliensbachian-Toarcian) shallow transgressive event occurred as a consequence of eustatic sea-level rise coupled with local tectonics that encroached on the western Indian craton and was possibly eroded during a successive transgression in Bajocian time? Small bivalves, dominated by one or two species and restricted to a few horizons, later were accumulated and cemented in a clay matrix, and finally were deposited in the Kuar Bet area of Pachchham Island.

References

Biswas, S.K. 1977. The Mesozoic rock-stratigraphy of Kutch. *Quarterly Journal of Geological Mining and Metallurgical Society of India*, **49**:1-51.

Bown, P.R., Cooper, M.K.E. & Lord, A.R. 1988. A calcareous nannofossil biozonation scheme for the early to mid Mesozoic. *Newsletters on Stratigraphy*, **20**(2): 91-114.

Coccolithophore CaCO3 fluxes in the Alfonso Basin

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As part of a multidisciplinary research project, we analyzed the coccolithophore assemblages (unicellular autotrophic marine organisms) and associated carbonate flux at CATS (Cuenca Alfonso Time-series Station, Bay of La Paz, B.C.S., 24º39'N 110º36'W) from summer 2006 to winter 2008. The overall goal of the research project was to determine the composition and vertical fluxes of various components of particulate matter, including coccolithophores. Coccolithophores are an important part of the biogeochemical carbon cycle, and coccoliths are a major component of marine sediment.

Sinking material was collected with a Technicap sediment trap (model PPS-3 with an opening of 0.125 m^2, 6-15 day opening interval) that was installed at a water depth of 350 m. Individual samples were split into 1/4500, filtered on a nucleopore membrane of 0.8 micron, and 1500 images were taken using a scanning electron microscope (Zeiss Supra VP55). All analyses were done offline on a computer.

In total, 46 species of coccolithophores were identified in 41 samples. *Emiliania huxleyi*, *Gephyrocapsa oceanica*, *Florisphaera profunda* var. *elongata*, and *Umbellosphaera irregularis* were the most abundant taxa and constituted about 90% of all assemblages. The total flux of coccoliths varied considerably with time. However, there was a clear seasonal pattern, and minimum fluxes ($256.6x10^6$ coccoliths m^{-2} d^{-1}) occurred in spring to summer, and maximum fluxes ($12,800x10^6$ coccoliths m^{-2} d^{-1}) were in autumn to winter. The highest fluxes of coccoliths were associated with wind gusts greater than $4ms^{-1}$, low surface temperatures, a maximum flux of large fecal pellets, low nutrient concentration, and a maximum flux of lithogenic material. In 2006, the highest flux ($5,672x10^6$ coccoliths m^{-2} d^{-1}) was dominated by *G. oceanica*, while in 2007, the highest flux ($12,800x10^6$ coccoliths m^{-2} d^{-1}) was dominated by *E. huxleyi*. *Florisphaera profunda* had its highest flux ($508x10^6$ coccoliths m^{-2} d^{-1}) during autumn to winter. In contrast, *U. irregularis* had its highest flux ($758x10^6$ coccoliths m^{-2} d^{-1}) during the spring to summer period. The main contributor to the coccolithophore carbonate flux is *G. oceanica* at 40%, followed by *E. huxleyi* at 14%. This represents about 30% of the total $CaCO_3$ flux. The coccolith fluxes documented in this work are the highest reported to date from the Gulf of California.

Morphometric study of gephyrocapsids in surface sediments from offshore western Luzon and semi-enclosed bays of the Philippines

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The presence of the genus *Gephyrocapsa* and its dominance in some areas of Philippine waters makes it ideal for morphological studies. Species in this genus are differentiated using the measurements of their placolith length and bridge angle. The morphology of *Gephyrocapsa* in Holocene sediments has been extensively studied over the years, and there now exists a useful informal nomenclature. Bollmann (1997) categorized the morphologies of gephyrocapsids in Holocene sediments into six categories: equatorial, oligotrophic, transitional, cold, larger, and minute. These categories are based primarily on variations in size (i.e., coccolith length) and bridge angle. Each morphotype is interpreted to have distinct ecological preferences. Preliminary results from measurements of *Gephyrocapsa* in surface sediments from offshore western Luzon (eastern South China Sea) and semi-enclosed bays in the Philippines (Lingayen Gulf, Subic Bay, Boac Bay, and Calancan Bay) show the presence of equatorial and larger *Gephyrocapsa* morphotypes. The equatorial morphotype prevails in the majority of the water bodies studied. The larger *Gephyrocapsa* morphotype manifests itself primarily in warmer waters.

Reference

Bollmann, J. 1997. Morphology and biogeography of Gephyrocapsa coccoliths in Holocene sediments. *Marine Micropaleontology*. **29**: 319-350.

The calcareous nannofossil record in the Cenomanian-Turonian boundary interval: implications for regional and global correlations

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The Cenomanian-Turonian boundary (CTB) interval was studied in several sections in different settings for detailed nannofossil biostratigraphy: France, Western Interior, Morocco, Italy, and the Indian and Pacific Oceans. Section selection was based on availability of stratigraphic data (e.g., isotopic stratigraphy and planktonic foraminifera biostratigraphy) or where these data are currently in progress.

Nannofossil biostratigraphic investigations were performed on smear slides prepared from the same samples used for planktonic foraminifera or isotopic investigations. Smear slides were analyzed using standard light microscope techniques under cross polarizers and transmitted light, at 1250X magnification, and semi-quantitative analyses were conducted. Results highlight the reproducibility of eight biostratigraphic events: last occurrences of *Corollithion kennedyi*, *Lithraphidites acutus*, *Axopodorhabdus albianus*, and *Helenea chiastia*; first occurrences of *Eprolithus octopetalus*, *Quadrum intermedium*, *Eprolithus eptapetalus*, and *Quadrum gartneri*. Some discrepancies were noticed in the sequence of events in the various sections. Some additional events of regional or global value are suggested to refine the accuracy of nannofossil events in the CTB interval. Particular attention was paid to taxonomic aspects of the Polycyclolithaceae.

Biogeographic distribution of living coccolithophores in the Pacific sector of the Southern Ocean

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The distribution of living coccolithophores in the upper water column of the Pacific sector of the Southern Ocean (SO) is poorly known. We investigated plankton samples collected during the RV *Polarstern* cruise ANT-XXVI/2 along a broad E-W transect in the SO during the austral summer. One hundred and fifty samples from twenty-nine stations were collected from the upper 150 m of the water column. Coccoliths and coccospheres per sample were counted separately using a scanning electron microscope (SEM).

Maximum numbers of $640 \cdot 10^3$ coccospheres/l were reached close to the Subtropical Front (STF), and increases in the numbers of coccospheres and coccoliths were recorded both at the Subantarctic Front (SAF) and the Polar Front (PF). However, numbers decreased southward until there was almost a monospecific and sporadic record of *Emiliania huxleyi* (types B/C and C) south of the PF. Thirty-three coccolithophore species, including sixteen species found as isolated coccoliths, were identified, and *Emiliania huxleyi* was clearly the most dominant coccolithophore taxa in the studied samples. Two primary coccolithophore assemblages were established that coincided with areas bounded by the Polar Front Zone (PFZ) and the Subantarctic Zone (SAZ). In the upper photic zone of the SAZ, *Acanthoica quattrospina*, *Calcidiscus leptoporus*, *Coccolithus braarudii* HOL, *Emiliania huxleyi* type A, *Ophiaster* spp., and *Syracosphaera* spp., among others, were found. The PFZ was characterized by a reduced number of species, i.e., *Calciopappus caudatus* and *E. huxleyi* types B, B/C, and C, as well as *Pappomonas* spp. and *Papposphaera* spp. The sea-surface temperature measured in situ was the most prominent factor influencing coccolithophore diversity, distribution, and assemblage compositions in the Pacific sector of the SO. Coccolithophore biogeography in the study area showed marked differences from that in the northern high latitudes, such as the absence of the cold water species *Coccolithus pelagicus*, which is abundant in the (sub) Arctic region, and the dominance of *E. huxleyi* type B/C and C in the SO, which contrasts with the dominance of *E. huxleyi* types A and B in the North Atlantic. Findings such as these fill in existing gaps in an unexplored area of the SO, as well as supporting previous research performed in neighboring areas. Living coccolithophore numbers and assemblage distribution in relation to the frontal dynamics of the SO provide valuable information for potential future paleoceanographic reconstructions.

Climate, carbonate compensation depth, and calcareous nannofossils: actions and feedback during the middle Eocene

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Pelagic carbonates constitute the majority of ocean sediments, particularly since the Jurassic, and they record climatic and oceanic changes. Cenozoic sediments record glacial and interglacial periods, as well as thermal maximums, such as the PETM (Paleocene-Eocene Thermal Maximum) and the MECO (Middle Eocene Climatic Optimum). The MECO, dated at about 40 Ma, occurred during a period of climate transition in the middle Eocene. This geological period shows variations in temperature and atmospheric CO2, as well as in the carbonate compensation depth (CCD).

This study aims to highlight the actions and feedbacks among climate (regulated by temperature, atmospheric CO_2, etc.), CCD fluctuations, and calcareous nannofossils through the study of fluxes and assemblages between 48 and 39 Ma. Calcareous nannofossils were studied in 57 samples taken approximately every 50 cm from ODP (Ocean Drilling Project) Leg 198 Site 1209A on the Shatsky Rise in the North Pacific. This site was previously studied by Bralower et al. (2002) and Bralower (2005). The samples have been prepared with the Geisen et al. (1999) technique for absolute quantification of nannofossils.

The age model proposed by Bralower et al. (2002) has been slightly modified based on new data for nannofossil biostratigraphy and recalibrated according to the Geologic Time Scale 2012 (Gradstein et al., 2012). Nannofossil assemblages and sizes show long-term changes during the middle Eocene. For example, *Discoaster* spp. show a decrease in size and relative abundance from 48 to 39 Ma. At 40 Ma, during the MECO, proportions of *Dictyococcites* spp. and *Reticulofenestra pseudoumbilicus* (>14 μm) increase.

Nannofossil fluxes show a significant increase during the CAEs 1 to 4 (Carbonate Accumulation Event; Lyle et al., 2005), but they are low during the MECO. Fluxes appear not to be related to atmospheric CO_2 (pCO_2) changes (see compilation in Pälike et al., 2012). Conversely, the nannofossil flux seems to have had an important impact on the oceanic carbon cycle by creating a carbonate flux into the deep ocean that was able to deepen the CCD.

References

Bralower, T.J. 2005. Paleocene-early Oligocene calcareous nannofossil biostratigraphy, ODP Leg 198 Sites 1209, 1210, and 1211 (Shatsky Rise, Pacific Ocean). In: T.J. Bralower, I. Premoli Silva, M.J. Malone et al. (Eds). *Proceedings of the Ocean Drilling Program, Scientific Results*, **198**: 1-15.

Bralower, T.J., Premoli Silva, I., Malone, M.J. et al. 2002. *Proceedings of the Ocean Drilling Program, Scientific Results*, **198**: doi:10.2973/odp.proc.ir.198.105.2002.

Geisen, M., Bollmann, J., Herrle, J.O., Mutterlose, J. & Young, J.R. 1999. Calibration of the random settling technique for calculation of absolute abundances of calcareous nannoplankton. *Micropaleontology*, **45**: 437-442.

Gradstein, F.M., Ogg, J.G., Schmitz, M. & Ogg, G. 2012. *The Geologic Time Scale 2012*, 2-Volume Set, Volume 2. Elsevier.

Lyle, M., Olivarez Lyle, A., Backman, J. & Tripati, A. 2005. Biogenic sedimentation in the Eocene equatorial Pacific - the stuttering greenhouse and Eocene carbonate compensation depth. In: P.A. Wilson, M. Lyle & J.V. Firth (Eds). *Proceedings of the Ocean Drilling Program, Scientific Results*, **199**: 1-35.

Pälike, H. et al. 2012. A Cenozoic record of the equatorial Pacific carbonate compensation depth. *Nature*, **488**: 609-615. doi:10.1038/nature11360.

Coccolith biostratigraphy across the Cretaceous-Paleogene boundary of the Dababiya Quarry core, Egypt

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High-resolution coccolith studies on the Dababiya Quarry core (DBQc), which was drilled in the Dababiya Quarry (Egypt) near the GSSP for the Paleocene-Eocene boundary, revealed an almost complete sedimentary record across the Cretaceous-Paleogene (C-P) boundary. Thirty samples (over ~70 m of section) were taken across the boundary interval. These samples were analyzed in order to identify the calcareous nannoplankton biozones using the zonal schemes of Martini (1971) for the Paleogene and Sissingh (1977) and Perch-Nielsen (1979) for the upper Maastrichtian. They yielded abundant and diverse assemblages, although, due to variable preservation, we only could identify four lower Paleocene zones (NP1 to NP4) and three Maastrichtian subzones: *Micula murus*, *Nephrolithus frequens*, and *Micula prinsii*. The C-P boundary is located within the Dakhla Formation and was delineated between the highest occurrence of M. prinsii and the lowest occurrence of *Biantholithus sparsus*. The thinness of the *M. prinsii* Subzone (~0.6 m) and the absence of the acmes of *Thoracosphaera operculata* and *Braarudosphaera bigelowii* suggest a possible minor gap at the C-P boundary in the core. This is in agreement with planktonic foraminiferal stratigraphy.

References

Martini, E. 1971. Standard Tertiary and Quaternary calcareous nannoplankton zonation. *Planktonic Conference, 2d, Rome 1969, Proceedings:* 739-785.

Perch-Nielsen, K. 1979. Calcareous nannofossil zonation at the Cretaceous/Tertiary boundary in Denmark. *Proceedings Cretaceous-T ertiary Boundary Event Symposium, Copenhagen*, **1**: 115-135.

Sissingh, W. 1977. Biostratigraphy of Cretaceous calcareous nannoplankton. *Geologie en Mijnbouw*, **56**(l): 37-65.

The Probable Datum Method (PDM): a statistical technique for determining the true age of nannoplankton origination or extinction

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The accurate interpretation of origination and extinction in the fossil record is crucial in paleontology. Fossil datums, the observed age of first or last occurrences, are subject to bias and error as a result of preservation and low abundances. Several techniques have been developed to assess the effects of these biases on macrofossil datums. However, due to the discrete sampling most commonly used in microfossil data, these methods cannot be applied to nannofossils. Here we develop a new technique, the Probable Datum Method (PDM) that can be used with nannoplankton and other microfossils. The PDM determines the original abundance of a taxon and the probable true age of its first or last occurrence. It uses a model in which original abundance is related to count abundance through preservation and the counting process. This model is parameterized, simulated, and then inverted to determine likely original abundance and true datum age from count abundance data. The true age of a first or last occurrence can be correlated globally to determine if originations or extinctions were truly synchronous or diachronous. The results of the PDM can be used to make inferences about the true nature of origination and extinction. For example, if after using the PDM, an extinction event is clearly diachronous, there is gained confidence that this global extinction trend was true and did not relate simply to differences in preservation. The method was applied to the origination of nannoplankton after the Cretaceous-Paleogene boundary to determine whether observed diachrony was real or merely a result of variable fossil preservation. The statistical nature of the PDM, its experimentally derived parameters, and its lack of many assumptions make it easily applicable to other fossil groups. In particular, the new technique can be used in a wide array of paleontological problems to increase the confidence in interpretations made from global correlations of fossil datums.

How to slow dissolution of calcareous nannofossils: a comparison of three preservation techniques

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It has been documented that rapid post-sampling dissolution of calcareous nannofossils has occurred in organic- and/or pyrite-rich Atlantic Coastal Plain sediments (Self-Trail & Seefelt, 2005), while only minor amounts of dissolution have been recorded from carbonate-rich deep-sea sediments (Dunkley Jones & Bown, 2007). In an attempt to halt or slow down dissolution of calcareous nannofossils in organic- and/or pyrite-rich sediments, three different methods of short-term storage were tested. Three cores were chosen because of their diverse sediment types: siliciclastic marine clays and silts from the Cambridge-Dorchester core, glauconitic, pyritic, and siliciclastic sediments from the Dixon core, and carbonate-rich packstones and wackestones from the Pineora core.

All three cores were systematically sampled on the day that coring occurred, and an on-site control smear slide was immediately prepared (a). Each sample was then split in two, and one split was used to prepare control slides at one-month (b1) and six-month (c1) intervals. The second split was used to test storage preservation methods. Each control sample was stored in a separate sample bag. Each test split was placed in either a vacuum-packed bag, a vial filled with argon gas, or a vial filled with buffered water in order to neutralize pH. They were sampled at one-month (b2) and six-month (c2) intervals for comparison with the control slides (b1 and c1). All slides were examined using a Zeiss Axioplan 2 light microscope at 1250x magnification. Abundance counts of total calcareous nannofossils per 150 fields of view (FOV) were tallied for each slide. The decrease in calcareous nannofossil percent abundance was calculated over six months, and the control slides were directly compared to the storage preservation test slides. Counts showed that none of the three test methods was consistently effective in reducing loss due to dissolution. In most cases, the control onsite slides (a) had better retention of calcareous nannofossils. Although there were a few positive results from the vacuum packed, argon gas, and buffered water samples, the overall decrease of nannofossil abundances suggests that the new preservation techniques did not work. Even the carbonate-rich sediments of the Pineora core experienced significant loss of calcareous nannofossils, possibly due to the presence of disseminated, micron-sized pyrite in bryozoan pore spaces.

References

Dunkley Jones, T. & Bown, P.R. 2007. Post-sampling dissolution and the consistency of nannofossil diversity measures: a case study from freshly cored sediments of coastal Tanzania. *Marine Micropaleontology*, **62**: 254-268.

Self-Trail, J.M. & Seefelt, E.L. 2005. Rapid dissolution of calcareous nannofossils: a case study from freshly cored sediments of the south-eastern Atlantic Coastal Plain. *Journal of Nannoplankton Research*, **27**(2): 149-157.

An improved sample preparation technique for calcareous nannofossils in organic-rich mudstones

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For many decades, calcareous nannofossils have been routinely applied as a biostratigraphic tool in the oil industry. The traditional double-slurry method for nannofossil slide preparation has been favored because it is relatively fast, simple, and uses few chemicals. A relatively recent increase in unconventional resource plays within the oil industry has resulted in a significant number of nannofossil biostratigraphy projects derived from assets such as shale gas. While the double-slurry method has been satisfactory for nannofossil samples in most lithologies, this preparation has proved insufficient for some organic-rich mudstones. Shale-gas source rocks are often rich in clays, silts, opaque minerals, and significant organic components. In addition, amorphous organic material within the sediment can bond the grains together, trapping the nannofossil specimens and impeding identification. We propose a modified method of sample preparation for calcareous nannofossils that minimizes these issues, while increasing the number of identifiable specimens.

This relatively simple method is modeled after foraminiferal cleaning techniques for paleothermometry, which focus on minimizing the adulteration of fossil specimens. The proposed technique for calcareous nannofossils uses sodium hypochlorite (NaClO) to lighten the organic matter and to aid in the dissociation of organic matter and clays from nannofossil specimens. Several iterations of the method have been tested, with variations in pH, duration and number of washing cycles, and use of an ultrasonic bath for further disaggregation of clays. A preliminary semi-quantitative analysis shows significant reduction in organic matter and increases in relative abundance and diversity of nannofossil assemblages. In addition, there is no visible damage to specimens in the light microscope at 1000x magnification. The technique has been applied to samples from the Upper Cretaceous Eagleford and La Luna Formations and the Upper Jurassic-Lower Cretaceous Haynesville Formation. All intervals show significant improvement with the proposed cleaning technique. Overall, the method is relatively quick, and the minor increase in cost associated with sample preparation is well-balanced by the improvement in data quality and the potential for higher resolution biostratigraphy in unconventional resource plays.

Nannofossil biostratigraphy and paleoecology of the Danish Lower Cretaceous reservoir chalks (Tuxen and Sola Formations)

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Chalk accumulation in northern Europe began in the Hauterivian in the center of the North Sea Basin and formed (1) the chalks of the Tuxen Formation (Hauterivian-Barremian), including the organic-rich Munk Marl Bed, and (2) the marls and subordinate chalks of the Sola Formation (Barremian-early Albian), including the organic-rich marlstones of the lower Aptian Fischscheifer Member (OAE 1a of Ineson, 1993). In the Danish sector of the North Sea, recent exploration and production developments have resulted in renewed interest in these early chalks, and future exploration and appraisal of existing hydrocarbon fields will rely on the ability to refine existing local and regional Early Cretaceous depositional and paleoceanographic models.

Calcareous nannofossils are a valuable proxy for recording paleoecological changes during chalk and marl deposition, and they can shed light on temperature and salinity variations and nutrient flux during the Hauterivian-Aptian in the restricted North Sea Basin. A nannofossil study of the Lower Cretaceous (BC6 – BC17 of Bown et al., 1998) carbonate package of the North Jens-1, Adda-2, and SE Adda-1 wells (distal to proximal), reveals fluctuations in important paleoecological indicator species, which contribute to the understanding of the depositional environment of the boreal chalks and marls.

Micrantholithus spp. are inferred to tolerate low-salinity levels and thereby proximity to the coast. High abundances of *M. obtusus*, *M.brevis*, and *M. hoschulzii* in the Hauterivian are therefore suggestive of increased freshwater input. Coincident with increases in *Micrantholithus*, high levels of Biscutum constans, *Biscutum constans cavum*, *Discorhabdus ignotus*, and *Zeugrhabdotus* spp. (inferring elevated nutrient influx) further support increased continental runoff. High relative abundance of Rhagodiscus asper and the presence of the Tethyan taxon *Micrantholithus stellatus* indicate that there was an incursion of warm water in the late Barremian, (Jeremiah, 2001). *Nannoconus* spp., which are thought to have favored clear-water oligotrophic conditions, became a significant part of assemblages in the upper Hauterivian and constituted up to 83% of the assemblage during part of the Barremian. The endemic species *N. borealis*, *N. abundans*, and *N. inornatus* are of stratigraphic significance and also support the idea that the North Sea Basin was restricted during the Barremian. A decline in the proportion of nannoconids corresponded to increasing clay content in the lowermost Sola Formation (Barremian-Aptian boundary level), and the 'nannoconid crisis' was recorded immediately prior to the onset of deposition of the Fischschiefer Member, coincident with increasing evidence of direct Tethyan links.

References

Bown, P.R., Rutledge, D.C., Crux, J.A. & Gallagher, L.T. 1998. Lower Cretaceous. *In:* P.R. Bown (Ed). *Calcareous Nannofossil Biostratigraphy*. British Micropalaeontological Society Series. Chapman and Hall/Kluwer Academic Press, London: 86-131.

Ineson, J. R. 1993. The Lower Cretaceous chalk play in the Danish Central Trough. In: J.R. Parker, (Ed). *Petroleum Geology of Northwest Europe*. Proceedings of the 4th Conference, London. The Geological Society of London: 175-183.

Jeremiah, J. 2001. A Lower Cretaceous nannofossil zonation for the North Sea Basin. *Journal of Micropalaeontology*, **20**: 45-80.

Stratigraphy of the late Campanian–Maastrichtian boreal chalk based on foraminifera, calcareous nannofossils, and carbon stable isotopes: new results from the Femern Bælt, Denmark and Germany

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A biostratigraphic and isotopic study was carried out on late Campanian-Maastrichtian chalks that were penetrated during geological investigations in preparation for the construction of a tunnel between Denmark and Germany under the Femern Bælt. Chalk from the 09.A.006 and 09.A.008 wells was analyzed for nannofossil and foraminifera content and for oxygen and carbon stable isotopes.

The two wells contain sediments from the late Campanian nannofossil subzone UC15d^{BP} to the latest Maastrichtian subzone UC20d^{BP} (using the zonation of Burnett, 1998). The study enabled further testing of the rigidity of the UC zonation scheme and its marker species for the Boreal Province, following recent biostratigraphic investigations on Danish chalk boreholes. The first occurrence of *Arkhangelskiella maastrichtiana* as a marker for the base of UC20c is considered unreliable, as is the subdivision of UC16 using the last occurrences of *Heteromarginatus bugensis*, *Tortolithus caistorensis*, and *Monomarginatus quaternarius*. In addition, the use of recently proposed 'new' markers, such as *Zeugrhabdotus praesigmoides* (syn. *Zeugrhabdotus meudinii* and *Tranolithus stemmerikii* of some authors), *Prediscosphaera mgayae*, and *Helicolithus trabeculatus*, is also tested.

For foraminifera, the FCS zonation, relevant for the chalk facies of the North Sea (King et al., 1989) was applied with some success to the 09.A.008 well, which spanned subzones FCS21b–FCS23a. Useful markers included the occurrence of *Gavelinella monterelensis* in the late Campanian, the last occurrence of *Angulogavelinella bettenstaedti* in the early Maastrichtian, and the occurrence of *Bolivinoides draco* and *Reussella szajnochae* in the late Maastrichtian. However, in some intervals the foraminiferal assemblages were more comparable with those recently described from southeast Poland (Dubicka & Peryt, 2012), in particular regarding *Rugoglobigerina* spp. and *Globigerinelloides* spp. fluctuations. The present study outlines the need for local adaptations of existing zonations.

As for other sites in Denmark and northern Germany, the large negative δC^{13} isotope excursion at the Campanian-Maastrichtian boundary was seen in both cores. Despite the isotopic study being of lower resolution than for previous Danish cores, some of the short-lived excursions defined by Thibault et al. (2012) were identified, allowing for correlation of the Femern Bælt sites to the astronomically calibrated Indian Ocean site 762C. Subsequently, an age model is proposed for the Femern Bælt cores.

This study allows, for the first time, correlation of boreal late Campanian-Maastrichtian foraminifer zones with the calcareous nannofossil zonation and C isotope stratigraphy. Integration of these data with recent results from several Danish Basin boreholes allows for the proposal of a multidisciplinary stratigraphic scheme for the Late Cretaceous of the boreal realm.

References

Burnett, J. 1998. Upper Cretaceous. *In:* P.R. Bown (Ed). *Calcareous Nannofossil Biostratigraphy*. Chapman and Hall/Kluwer Academic Publishers, London: 132-199.

Dubicka, Z. & Peryt, D. 2012. Latest Campanian and Maastrichtian palaeoenvironmental changes: implications from an epicontinental sea (SE Poland and western Ukraine). *Cretaceous Research*, **37**: 272-284.

King, C., Bailey, H.W., Burton, C.A. & King, A.D. 1989. Cretaceous of the North Sea. In: D.G. Jenkins & J.W. Murray (Eds). *Stratigraphic Atlas of Fossil Foraminifera*. Ellis Horwood, Chichester: 372-417.

Thibault, N., Harlou, R., Schovsbo, N., Schiøler, P., Minoletti, F., Galbrun, B., Lauridsen, B.W., Sheldon, E., Stemmerik, L. & Surlyk, F. 2012. Upper Campanian-Maastrichtian nannofossil biostratigraphy and high-resolution carbon-isotope stratigraphy of the Danish Basin: towards a standard δ13C curve for the Boreal Realm. *Cretaceous Research*, **33**: 72-90.

Coccolithophore assemblage composition and cell densities at Alfonso Basin, Gulf of California

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Since 2002, a multidisciplinary research project has been carried out in the Alfonso Basin, Bahia de La Paz, in order to understand better the coastal ecosystem of the Gulf of California. The Alfonso Basin is of particular interest because long-term environmental changes are preserved in the underlying laminated sediments. In this study, we present the vertical distribution of coccolithophores in the water column from February 2007 to January 2008. Data on the coccolith fluxes for the same period are presented elsewhere.

Monthly seawater samples were collected at depths from 0 to 60 m, and *in situ* conductivity, temperature, and depth (CTD) data were collected. Coccolithophore cell densities and species composition where determined from the filtered samples at Universidad Autónoma de Baja California Sur (UABCS) using a Hitachi S-2300 scanning electron microscope.

A total of 61 coccolithophore species were identified: 49 heterococcoliths, 21 holococcoliths, and 4 *incertae sedis* species. The most abundant species (> 50%) were *Emiliania huxleyi*, *Calciopappus rigidus*, *Gephyrocapsa oceanica*, *G. ericsonii*, *E. huxleyi* type B/C, *Florisphaera profunda*, *Pappomonas* sp. type 3, and *Solisphaera blagnacensis*. Fourteen species of the *Syracosphaera* genus were identified, and although always present they were never abundant. The species richness (SR) varies seasonally with high values in late winter to early spring (SR= 17, April, 10 m) and late summer to early fall (SR=19, September, 45 m). The Shannon diversity index showed high values (H'>2) in late winter to early spring (H'_{max}= 2.6, April, 10 m) and in late summer and early fall (H'_{max}=3.5, September, 75 m). Coccolithophores were commonly observed down to a depth of 75 m, with different assemblage composition above and below 30 m.

Cell densities also varied seasonally with a maximum in early spring (128 $x10^3$ cel l^{-1}, March, 0 m) and in early winter (41.7 $x10^3$ cel l^{-1}, December, 0 m). *Emiliania huxleyi* was the species with the highest cell density in March (51.46 $x10^3$ cel l^{-1}, 0 m). *Calciopappus rigidus* was observed mainly in the upper photic zone (0-30 m) with a maximum in March (41.3 $x10^3$ cel l^{-1}, 0 m). *Gephyrocapsa oceanica* was present throughout the year with the highest values in November (19.3 $x10^3$ cel l^{-1}, 15 m). *Emiliania huxleyi* type B/C was present only in May with cell density values of up to 15.3 $x10^3$ cel l^{-1} (0 m). *Gephyrocapsa ericsonii* was present all year in low cell densities and showed a maximum cell density in March (12.6 $x10^3$ cel l^{-1}, 0 m). *Florisphaera profunda* was common between 30-75 m with a maximum cell density in October (5 $x10^3$ cel^{-1}, 60 m).

The dominance of *E. huxleyi* and *G. oceanica* is related to mixing conditions during winter. *Emiliania huxleyi*, holococcoliths, *F. profunda*, and *Rhabdosphaera* spp. were present during a period of water stratification in late winter to early spring. *Emiliania huxleyi*, holococcoliths, *Syracosphaera* spp., and *Papposphaera* spp. were present during an upwelling event in summer. *Gephyrocapsa oceanica*, *Syracosphaera* spp., holococcoliths, *A. Quattrospina*, *F. profunda*, and *Solisphaera blagnacensis* were characteristic of the late summer to early fall stratification period.

A Cretaceous (late Albian-early Maastrichtian) cocktail of cold and warm water nannoflora from Jaisalmer, western India and its paleobiogeographic implications

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The Cretaceous is known for its extensive global marine transgressions, including the western part of the Indian subcontinent. We report here on highly diversified (over 200 species) and well-preserved calcareous nannofossil assemblages from outcrops and the subsurface (Tanot bore well #1) of late Albian-early Maastrichtian sequences in the Jaisalmer Basin, western India. The presence of *Nannoconus* species and *Rhagodiscus asper* suggests warm conditions and moderate productivity. However, *Watznaueria barnesae* dominates the assemblage throughout the late Albian-early Maastrichtian. The abundance of nannoconids and braarudosphaerids throughout the succession indicates shallow, neritic conditions that were prone to dissolution. *Nannoconus truitii* with its several subspecies is typical of a Tethyan environment, and its distribution is said to be controlled by the paleogeographic setting and warm tropical climate of the Indian subcontinent during the Cretaceous.

Provincialism was prevalent in Early Cretaceous calcareous nannoplankton assemblages, and this forms the basis for delineating the Boreal and Tethyan realms. Mutterlose & Kessels (2000) recognized a bipolar, high-latitude assemblage, a mid- to low-latitude, cool-water assemblage, and a low-latitude warm-water assemblage. Distinguishing among these realms became more difficult during Aptian-Albian time, as evidenced in the present material. The Late Cretaceous witnessed a time of nannofloral change. *Seribiscutum primitivium*, a bipolar high-latitude form restricted to 40º to 50º N and 35º to 60º S (Mutterlose, 1992), has been documented from Albian-Campanian sediments in Tanot #1. This species is recorded from a 15° to 35°S paleogeographic position in India during the late Albian (Kale & Phansalkar, 1992) to early Maastrichtian with other cold-water forms (*Angulofenestrellithus snyderi*, *Broinsonia matalosa*, *Bukrylithus ambiguous*, *Eiffellithus monechiae*, *Eiffellithus pospichalii*, *Nephrolithus corystus*, *Nephrolithus frequens*, *Octolithus multiplus*, *Radiolithus hollandicus*, *Retecapsa ficula*, *Stoverius achylosus*, and *Tortolithus hallii*.). Along with these cold-water forms, there were significant numbers of some typical warm-water forms (*Ceratolithoides pricei*, *Ceratolithoides ultimus*, *Micula murus*, *Micula praemurus*, *Nannoconus truitii frequens*, and *Prolatipatella multicarinata*), which indicates that there was mixing of warm and cold water currents from the western part of India during the Late Albian (Rai et al., 2013) onwards, which is more pronounced during the Campanian to early Maastrichtian. Therefore, the possibility of an African-Australian/Australian-Antarctic sea route cannot be ruled out.

References

Kale, A.S. & Phansalkar, V.G. 1992. Nannofossil biostratigraphy of the Utatur Group, Trichinopoly District, South India. *Memorie di Scienze Geologiches*, XLIII: 89-107.

Mutterlose, J. 1992. Biostratigraphy and palaeobiogeography of Early Cretaceous calcareous nannofossils. *Cretaceous Research*, **13**: 167-189.

Mutterlose, J. & Kessels, K. 2000. Early Cretaceous calcareous nannofossils from high latitudes: implications for palaeobiogeography and palaeoclimate. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **160**: 347-372.

Rai, J., Singh, A. & Garg, R. 2013. Calcareous nannofossils of Albian age from Tanot Well 1, Jaisalmer Basin, Rajasthan and its palaeobeogeographic significance. *Journal of the Palaeontological Society of India*, **58**(1): 67-73.

Integrated high-resolution nannofossil biostratigraphy and cyclo-magnetostratigraphy of the upper Maastrichtian: correlation between the Bjala (Bulgaria) and Sopelana (Spain) sections

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An integrated high-resolution nannofossil biostratigraphy and cyclo-magnetostratigraphy was developed for the upper Maastrichtian interval of two distant sections: Bjala (Bulgaria, Black Sea coast) and Sopelana (Basque Country, Atlantic coast). Both sections display similar rhythmic sedimentary successions due to astronomical climate forcing (Milankovitch cyclicity). The calcareous nannofossil biozonation for the upper Maastrichtian interval is primarily based on the low-latitude UC "TP" scheme of Burnett (1998).

The calcareous nannofossils are abundant throughout the studied sections. They are represented by highly diverse associations (> 144 species were identified), showing good to very good preservation. In order to distinguish the main bio-events, a semi-quantitative analysis was performed. The cyclo-magnetostratigraphic framework has been extended from the K-Pg boundary, uppermost Maastrichtian C29r, down to the lower/upper Maastrichtian boundary, C31n-C31r. It encompasses a total of ~60 m in the Sopelana and ~45 m in the Bjala sections and provides accurate ages for the bio-events.

The succession of nannofossil datums is similar to, or comparable with, other records from low-latitude sites, e.g., Zumaia, Contessa highway and Bottaccione sections (Gardin et al., 2012; Pérez-Rodrígez et al., 2012; Dinarès-Turell et al., 2013). The main documented nannofossil bio-horizons include: (1) FO of *Lithraphidites quadratus*, (2) FO of *Micula murus*, and (3) FO of *Micula prinsii*.

The FO of *Lithraphidites quadratus*, an important low-latitude bio-horizon, is recorded well down in the section, close to the C31r/C31n magnetic reversal. Its position in Sopelana can be correlated to the previously reported bio-event in the Umbria-Marche sections (Gardin et al., 2012) and in Zumaia (Pérez-Rodrígez et al., 2012). The species is reported to have wide geographic distribution in low-latitude sections and thus can be used as a reliable correlation bio-horizon there.

The FO of *Micula murus* is documented at Bjala and Sopelana just a few meters below the FO of *M. prinsii*. It is found within the upper part of chron C30n. The acme of *M. murus* is observed stratigraphically up section, within the prinsii Zone. Our observations are in line with those of Gardin et al. (2012) that the base of M. murus acme can be used as a proxy for UC20d^{TP} subzone.

The occurrence of *Ceratolithoides kamptneri* is not recorded in either of the studied sections, making it impossible to distinguish the UC 20c^{TP} subzone. The FO of *Micula prinsii* is a sound bio-horizon in the studied sections. It is recorded relatively low in the succession, within C30n. It is a primary biostratigraphic marker for the uppermost part of the Maastrichtian, identifying subzone UC 20d^{TP} in low-latitude sites. Here, it is usually reported near the base of C29r. However, some studies have recorded it at the upper part of chron C30n (Self-Trail, 2001), which is in agreement with the data from Bjala and Sopelana.

References

Burnett, J.A. 1998. Upper Cretaceous. In: P.R. Bown (Ed). *Calcareous Nannofossil Biostratigraphy*. British Micropaleontological Society Publication Series. Chapman and Hall/Kluwer Academic Publishers, London: 132–199.

Dinarès-Turell, J., Pujalte, V., Stoykova, K. & Elorza, J. 2013. Detailed correlation and astronomical forcing within the upper Maastrichtian succession in the Basque Basin. *Boletin Geológico y Minero*, **124**(2): 253-282.

Gardin, S., Galbrun, B., Thibault, N., Coccioni, R. & Premoli-Silva, I. 2012. Biomagnetochronology for the upper Campanian-Maastrichtian from the Gubbio area, Italy: new results from the Contessa Highway and Botaccione sections. *Newsletters on Stratigraphy,* **45**(1): 75-103.

Pérez-Rodrígez, I., Lees, J., Larrasoana, J., Arz, J. & Arenillas, I. 2012. Planktonic foraminiferal and calcareous nannofossil biostratigraphy and magnetostratigraphy of the uppermost Campanian and Maastrichtian in Zumaia, northern Spain. *Cretaceous Research*, **37**: 100-126.

Self-Trail, J.M. 2001. Biostratigraphic subdivision and correlation of upper Maastrichtian sediments from Atlantic Coastal Plain and Black Nose, western Atlantic. *Geological Society of London Special Publication*, **183**: 93-110.

Calibration of calcareous nannofossils and ammonites bio-events across the Jurassic-Cretaceous boundary: a case study from Bulgaria

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In the last few years, there has been renewed interest in the definition of the Jurassic-Cretaceous (J-K) boundary. Progress is mainly related to the activity of the international stratigraphy community, collaborating within the framework of the Berriasian Working Group of the International Subcommission on Cretaceous Stratigraphy (ISCS) (Casellato, 2010; Channell et al., 2010; Wimbledon et al., 2011). Because the original definition of the Berriasian is based exclusively on ammonites, integration of calcareous nannofossil and ammonite data (at least in the Tethyan area) is of crucial importance when considering a new workable definition for the J-K boundary.

We present a comprehensive integrated biostratigraphic study of calcareous nannofossils and ammonites across the J-K boundary interval in three sections from West Bulgaria (Kopanitsa, Berende, and Burlya). Ivanov et al. (2010) were the first to recognize the *Durangites* spp. Zone in Bulgaria and correlate nannofossil and ammonite markers in the Tithonian-Berriasian interval. The sedimentary successions in this region consist of siliciclastic turbidites (Kopanitsa and Berende) and hemipelagic limestones (Burlya). A total of 293 nannofossil samples from the upper Tithonian-Berriasian interval were processed and fixed on smear-slides. The sampling resolution varied between 1 to 2 m. Preservation of the calcareous nannofossils throughout the boundary interval was generally good to moderate. There were several ammonite-bearing levels, and more than 300 ammonite specimens are found, >120 of them could be identified and used for the present work.

In the J-K boundary interval, all previously known calcareous nannofossil zones and subzones were clearly recognized (Bralower et al., 1989; Casellato, 2010). The Tethyan ammonite zonation for the upper Tithonian and lower Berriasian was applied, consisting of the *microcanthum*, *Durangites* spp., *jacobi*, and *occitanica ammonite* Zones and their subzones. Correlation of nannofossil events to the ammonite zones was consistent among the sections studied, and four distinct biohorizons were recognized:

1) The first successive occurrences of *Nannoconus infans*, *N. compressus*, *N. puer*, and *N. globulus minor*, in the lower part of *Durangites* Zone, co-occur with *Durangites singularis*, *D. vulgaris*, *D. astillerensis*, and *Protacanthodiscus andreaei*.

2) The first occurrence (FO) of *Nannoconus wintereri* and the beginning of the local acme of *Polycostella senaria* are remarkably synchronous events with the FO of *Berriasella jacobi*, which marks the J-K boundary in an ammonite sense.

3) The FO of *Nannoconus steinmanni minor* and *N. kamptneri minor* are clearly Berriasian events (in terms of ammonites) and occur in the middle of the *jacobi* ammonite Zone.

4) The FO of the large nannoconids species *N. steinmanni steinmanni* and *N. kamptneri kamptneri* was recorded in the former "*grandis*" ammonite Zone, i.e., close to the boundary between the *jacobi* and *occitanica* ammonite Zones.

References

Bralower, T.J., Monechi, S. & Thierstein, H.R. 1989. Calcareous nannofossil zonation of the Jurassic-Cretaceous boundary interval and correlations with the Geomagnetic Polarity Timescale. *Marine Micropaleontology*, **14**: 153-235.

Casellato, C.E. 2010. Calcareous nannofossil biostratigraphy of Upper Callovian-Lower Berriasian successions from Southern Alps, North Italy. *Rivista Italiana di Paleontologia e Stratigrafia*, **116**: 357-404.

Channell, J.E.T., Casellato, C.E., Muttoni, G. & Erba, E. 2010. Magnetostratigraphy, nannofossil stratigraphy and apparent polar wander for Adria-Africa in the Jurassic-Cretaceous boundary interval. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **293**: 51-75.

Ivanov, M., Stoykova, K. & Idakieva, V. 2010. New biostratigraphic data on the Upper Tithonian and Lower Berriasian in the Krayshte area (SW Bulgaria). *Annals University of Sofia, Faculty of Geology and Geography*, **102**(1): 21-41.

Wimbledon, W.A.P., Casellato, C.E., Reháková, D., Bulot, L.G., Erba, E., Gardin, S., Verreussel, R.M.C.H., Munsterman, D.K. & Hunt, C. 2011. Fixing a basal Berriasian and Jurassic-Cretaceous (J-K) boundary – perhaps there is some light at the end of the tunnel? *Rivista Italiana di Paleontologia e Stratigrafia*, **117**: 295-307.

Nanometric X-ray fluorescence elemental mapping of Middle Jurassic coccoliths (~170Ma)

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Coccolithophore algae produce micrometric calcite platelets called coccoliths. The geological record for coccoliths is continuous from their appearance 220 Ma ago until today, and they have been abundant in the marine environment during this time interval. Hence, coccoliths have a huge potential for geochemical reconstruction of the Earth's paleoclimate and paleoceanography. We performed a nanometric X-ray fluorescence analysis of three species of early Bajocian (Middle Jurassic) coccoliths using the beamline ID22NI at the European Synchrotron Radiation Facility (ESRF) in Grenoble, France. Based on this analysis, we have a better understanding of the chemical composition of coccoliths and thus of the marine waters where they were precipitated. Samples were collected at Cabo Mondego, Portugal, the international reference section (GSSP) for the early Bajocian interval, and they were selected based on their preservation. Coccoliths were separated from the matrix using a picking technique and deposited on 500 nm-thick silicon nitride membranes. With an excitation beam at 17 KeV and a resolution of 100 μm, we mapped 14 elements in the coccoliths: S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Cu, Zn, Br, Rb, and Sr. The mapping allowed the recognition of elements that were biologically incorporated in the coccoliths and those that are due to a diagenetic overprint. Calcium, strontium, and manganese are biologically organized in coccoliths. Sulfur, chlorine, chromium, and bromine were also homogenously incorporated with no relation to the crystallographic organization of the coccolith. Conversely, potassium, iron, copper, zinc, titanium, and rubidium are related to diagenetic processes and clay contamination.

These results (1) improve the understanding of the chemical incorporation of elements, (2) recognize diagenetic effects on coccolith chemistry, and (3) make it possible to develop new paleoceanographic proxies, e.g., the chlorine and bromine incorporation in coccoliths for salinity reconstructions. Further analysis, especially on living species, will greatly help in the calibration of these proxies.

History of the oceanic carbonate cycle based on calcareous nannofossil absolute abundance and flux in the past 190 Myr

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Calcareous nannoplankton produce half of the calcium carbonate found in the deep ocean, so they are a main actor in the modern carbonate cycle. In today's ocean, the carbonate cycle relies extensively on pelagic production (Cretan ocean of Zeebe & Westbroek, 2003). Calcareous nannofossils first appeared at the end of the Triassic, and prior to this major oceanic event, carbonate production was restricted to epicontinental platforms (Neritan ocean of Zeebe & Westbroek, 2003). The transition from neritic-supported to pelagic-supported carbonate production was influenced by the evolution of calcareous nannofossils. Unfortunately, this transition has poor time constraints, which limits the ability to understand the processes and their forcing (climatic, evolutionary, and chemical) that occurred. Here, we present a compilation of calcareous nannofossil absolute abundances and fluxes from the Early Jurassic (~190 Ma) to the end of the Pleistocene (~0.12 Ma). Absolute abundance quantification was made using random settling methods, and the sedimentation rates are based on cyclostratigraphy or biostratigraphy from Gradstein et al. (2012).

The calcareous nannofossil absolute abundance and flux records show an increase from the Early Jurassic to the Early Cretaceous followed by stable values until the Pleistocene, which is interrupted by some short-term decreases. Apparently, the transition from Neritan to Cretan oceans was a slow transitional event throughout the Jurassic, whereas effective pelagic production only began in the Early Cretaceous. The evolution of calcareous nannofossil production in the Mesozoic-Cenozoic interval is a complex interplay between nannofossil evolution and environmental conditions, such as sea level, temperature, nutrients concentration, and ocean chemistry. Nevertheless, on a long-term perspective, there is an intriguing inverse relationship between atmospheric CO_2 concentrations and calcareous nannofossil fluxes that merits further study.

References

Gradstein, F.M., Ogg, J.G., Schmitz, M.D. & Ogg, G.M. 2012. *The Geologic Time Scale 2012*. Elsevier, Amsterdam.

Zeebe, R.E. & Westbroek, P. 2003. A simple model for the CaCO3 saturation state of the ocean: the "Strangelove," the "Neritan," and the "Cretan" Ocean. *Geochemistry, Geophysics, Geosystems*, **4**(12): 1104.

Is phosphate availability significant to the morphological diversity within Helicosphaera carteri?

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Helicosphaera carteri (Wallich) Kamptner is the most common modern representative of the genus *Helicosphaera* Kamptner. Since its first occurrence in the late Oligocene, the species has exhibited remarkable phenotypic variation, which has resulted in a number of described variants both in the fossil record (Theodoridis, 1984) and in modern assemblages (Geisen et al., 2004). While the general morphology of the coccoliths (size, shape, blanket elements, and flange structure) is maintained throughout the fossil record and within modern variants, the key morphological characters used for distinguishing among the variants are the ultrastructural features of the central area. A detailed morphological analysis of two cultured strains of *H. carteri* var. *carteri* revealed that almost all of the coccolith types described in the fossil and modern *H. carteri* variants can be produced by a single genotype. These findings suggest that *H. carteri* var. *carteri*, as the oldest and phenotypically most plastic variant, may have acted as a source of phenotypic and genotypic diversity from which other less plastic variants (e.g., *H. carteri* var. *wallichii*) and species (e.g., *H. hyalina*) diverged. This is supported by the molecular data of Sáez et al. (2003). The contribution of various coccolith types and varieties to total *H. carteri* coccolith counts varies significantly in the fossil record. This plasticity and subsequent evolution of the group may be driven by changing environmental conditions, such as nutrient availability. This hypothesis was tested with batch culture experiments that investigated the effects of phosphate limitation on the physiology and morphology of two *H. carteri* var. *carteri* strains.

Both strains, obtained from the Roscoff culture collection, were isolated at sites with different nutrient regimes: strain RCC1323 in the South Atlantic (high availability of phosphate) and strain RCC1334 in the western Mediterranean (area limited in phosphate). Batch cultures were grown in triplicate in K/2 medium with phosphate concentrations modified to induce P-limitation. Stable temperature (17ºC), light (150 μE m^{-2} s^{-1}), and light/dark (14h:10h) conditions were ensured by keeping cultures in a culture chamber. Cells were harvested as soon as the P-limited batch cultures reached stationary growth phase due to phosphate limitation. Control cultures were sampled at the same cell concentration to be comparable with phosphate limited batch cultures. Besides various measurements of cell physiology, and cellular organic and inorganic quotas, detailed morphological analysis was performed using scanning electron microscopy.

Under replete phosphate conditions, the most common coccolith type (with the bridge dividing the central area into two small pores) accounted for on average 75% of coccoliths in strain RCC1323, and 63% in strain RCC1334. A morphotype without the bridge, and with one large pore in the middle of the central area, was second most abundant with 19% contribution in strain RCC1323 and 31% in strain RCC1334. Three less abundant coccolith types accounted for 6% of the coccoliths in RCC1323 and 5% in strain RCC1334, with the coccoliths with only one small pore being dominant in RCC1323, and a more diverse composition of rare coccoliths being observed in RCC1334. Under phosphate limitation, no significant change in coccolith composition was observed in strain RCC1323, while in strain RCC1334 a shift was observed in the ratio between the two most common coccolith types. This observation may indicate a strain specific response to phosphate limitation. Overall, however, our results suggest that phosphate limitation does not have a strong effect on coccolith plasticity in *H. carteri* var. *carteri*, and we therefore conclude that selection pressure of phosphate availability may be of minor importance to the phenotypic evolution of this species.

References

Geisen, M., Young, J.R., Probert, I., Garcia Sáez, A., Baumann, K.-H., Bollmann, J., Cros, L., De Vargas, C., Medlin, L.K. & Sprengel, C. 2004. Species level variation in coccolithophores. *In:* H.R. Thierstein & J.R. Young (Eds). *Coccolithophores- from Molecular Processes to Global Impact*. Springer-Verlag, Heidelberg: 327-366.

Sáez, A.G., Probert, I., Geisen, M., Quinn, P., Young, J.R. & Medlin, L.K. 2003. Pseudo-cryptic speciation in coccolithophores. *Proceedings of the National Academy of Sciences*, **100**: 7163-7168.

Theodoridis, S. 1984. Calcareous nannofossil biozonation of the Miocene and revision of the helicoliths and discoasters. *Utrecht Micropaleontological Bulletins*, **32**.

Nannofossils across the late Cenomanian to middle Coniacian interval, Běchary section, Bohemian Cretaceous Basin: state of the art

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Research core Běchary Bch-1 was chosen as a key reference section to reconstruct mid-Cretaceous sea-level changes, paleoceanography, and paleoclimate. The core is located in the offshore sediments of the Bohemian Cretaceous Basin, east-central Czech Republic and reached 404.6 m in depth. The depocentre was part of a seaway developed along the reactivated Elbe Fault System (Uličný et al., 2009) during the latest Cenomanian-Coniacian and connected the epicontinental basins of the NW European Platform to the deep-sea basins of the NW Tethys (now the Western Carpathians).

The nannofossil study is a part of multidisciplinary research that has focused on nannofossil distribution, abundance and preservation, first (FO) and last (LO) occurrences of marker species, and semiquantitative counting. Attention was paid to fluctuating numbers of species (*Biscutum* spp., *Braarudosphaera* ssp., *Lucianorhabdus* sp., *Marthasterites furcatus*, etc.) that may reflect sea-level changes and other paleoenvironmental conditions, and contribute significantly to the understanding of the depocenter's architecture. Altogether, 96 samples were analyzed. Nannofossil events were first correlated with inoceramids.

The upper Cenomanian strata contained poorly preserved nannofossils in the UC4b Zone (Burnett, 1998) with higher numbers of *Biscutum ellipticum*, *Broinsonia signata*, and *Watznaueria barnesiae*. The co-occurrence of *Lithraphidites acutus* and *Axopodorhabdus albianus* was suddenly interrupted by a short interval with poor nannofossil content. A Turonian age is indicated by the FO of *Eprolithus octopetalus*, Zone UC5c–UC6a, followed quickly by the FO of *E. moratus* (Zone UC6b). The uppermost Cenomanian, the Cenomanian-Turonian boundary, and the lowermost Turonian were marked by an omission surface, associated with a distinct hiatus that probably spanned the UC5a–b Zone interval.

The next succession of FOs of nannofossil markers came during the lower-middle Turonian: *Lucianorhabdus* sp., *Eiffellithus perch-nielseniae*, *Octolithus multiplus*, *Quadrum gartneri*, *Eiffellithus eximius*, *Kamptnerius magnificus*, *Lithastrinus septenarius*, *Liliasterites angularis*, and *Marthasterites furcatus*. Above the first discovery of inoceramid species Inoceramus perplexus, the base of the upper Turonian has the FOs of *Ottavianus giannus*, *Zeugrhabdotus biperforatus*, and *Broinsonia parca expansa*. The base of the acme of *M. furcatus* approximately coincides with a decrease in $CaCO_3$ content and an increase in SiO_2 content in the sediments, and with the *Didymotis* Event I. Some of the above mentioned nannofossil events are of local stratigraphic importance (Švábenická, 2012).

The Coniacian stage was recognized by the FO of *Cremnoceramus deformis erectus*. Above this, the FOs of *Micula adumbrata* and the top of the acme of *M. furcatus* were recorded. The species *H. turonicus* and *O. giannus* were already absent. The short interval of the inoceramid *Cremnoceramus deformis crassus* Zone marked the uppermost early Coniacian. The FOs of *M. staurophora* and *Uniplanarius gothicus* in the overlying strata suggest a middle Coniacian age.

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References

Burnett, J.A. 1998: Upper Cretaceous. *In:* P.R. Bown (Ed). *Calcareous Nannoplankton Biostratigraphy.* British Micropalaeontological Society Publication Series. Chapman and Hall/Kluwer Academic Publishers, London: 132-199.

Švábenická, L. 2012. Nannofossil record across the Cenomanian-Coniacian interval in the Bohemian Cretaceous Basin and Tethyan foreland basins (Outer Western Carpathians), Czech Republic. *Geologica Carpathica*, **63**: 201-217.

Uličný, D., Špičáková, L., Grygar, R., Svobodová, M., Čech, S. & Laurin, J. 2009. Palaeodrainage systems at the basal unconformity of the Bohemian Cretaceous Basin: roles of inherited fault systems and basement lithology during the onset of basin filling. *Bulletin of Geosciences,* **84**: 577-610.

Size variations in the coccolith species Calcidiscus leptoporus in the Sulu Sea during the late Pleistocene to Holocene

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A morphological analysis of the coccolithophore species *Calcidiscus leptoporus* in the Sulu Sea from the late Pleistocene to the Holocene shows a significant correlation between coccolith diameter size and the number of radial elements. Results of this study also show that *C. leptoporus* responded to changes in temperature and nutrient contents in the study area. Variations in the abundances of the small (<5μm), intermediate (5-8.5μm), and large (>8.5μm) *C. leptoporus* specimens are associated with global climatic shifts, such as the timing of the Older Dryas, the Bølling-Allerød, and the Younger Dryas during the late Pleistocene-Holocene transition in the Sulu Sea. During the Older and Younger Dryas in the Sulu Sea, greater numbers of the large forms ("winter-type") of *C. leptoporus* are recorded. Surface-water enrichment from coastal upwelling off the Zamboanga Peninsula during the interstadials led to an increase in and/or dominance of the small forms of *C. leptoporus*. The intermediate forms dominated in most of the warm episodes where they comprised almost 90% of the *C. leptoporus* assemblage.

The last 150 years of coccoliths in the Carmen Basin, Gulf of California

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In order to reconstruct the paleoceanography in the Gulf of California, a Reineck core was obtained in 670 m of water from the Carmen Basin (25°53.311'N 110°52.267'W). Core C53B is 26 cm long, and 25 samples were collected and observed under a cross-polarizing light microscope (1000x) by counting 300 coccoliths per slide (Fatela & Taborda, 2002). Samples were prepared using the decantation technique described by Flores & Sierro (1977).

The coccolithophore assemblage was dominated by *Gephyrocapsa* (> 3μm) with an average of 43.1%, followed by *Emiliania huxleyi* with 26.9%, while a significantly lower abundance was seen for *Helicosphaera* spp. (9.2%), *Calcidiscus* spp. (5.5%), *Gephyrocapsa* <3μm (3.4%), and *Acanthoica* spp. (3%). The following minority abundance taxa were also considered: *Umbilicosphaera* spp. (1.4%), *Oolithotus fragilis* (0.7%), *Pontosphaera* spp. (0.5%), and *Syracosphaera* spp. (0.4%).

Relative abundances and environmental affinities suggest the following paleoceanographic scenarios for the Carmen Basin. In the basal core section (26-14 cm), the presence of *Gephyrocapsa* > 3μm and *E. huxleyi* indicated waters with high productivity and the influence of upwelling. The presence of *Helicosphaera* spp., *Calcidiscus* spp., *Acanthoica* spp., *Oolithotus* fragilis, and *Syracosphaera* spp. indicated waters of low productivity and little upwelling. According to the conditions and abundance peaks of the minority taxa, we suggest a eutrophic environment with varying intensities of upwelling. In the middle of the core (14-8 cm), the dominant taxa showed constant values exceeding abundance averages, and *Gephyrocapsa* (> 3μm) exhibited a linear abundance trend, while the abundance of *E. huxleyi* increased slightly. We thus infer that during times of upwelling, conditions were fairly stable. In the upper core section (8-0 cm), the abundance of taxa showed fluctuating trends, and *Gephyrocapsa* <3μm increased in a manner very similar to what is at the top of the core. We deduce a mesotrophic environment with alternating intensities of upwelling.

References

Fatela, F. & Taborda, R. 2002. Confidence limits of species proportions in microfossil assemblages. *Marine Micropaleontology*, **45**: 169-174.

Flores, J.A. & Sierro, F.J. 1997. Revised technique for calculation of calcareous nannofossil accumulation rates. *Micropaleontology*, **43**: 321-324.

Weakly calcified polar coccolithophorids: the genus Pappomonas revisited.

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An assemblage of weakly calcified coccolithophorid genera and species were described from Polar Regions almost 40 years ago. In the interim period, a few additional findings have been reported that expand the known habitat of some of the species. The genus *Pappomonas* is revisited here with the purpose of providing, based on additional sampling from both the Arctic and Antarctic regions, an update on species morphology, life history events, and biogeography that can serve as a reference for the future. The examination of a substantial number of cells unequivocally supports the identification of a new species of *Pappomonas* (previously referred to as *P. flabellifera* var. *borealis*) as a separate taxon because it differs from *P. flabellifera* in a number of critical morphological features. Additional evidence in favor of linking *P. virgulosa* and *Balaniger balticus* in a shared life history, in combination with profound differences in coccolith morphology between the *Pappomonas* type species (*P. flabellifera*) and *P. virgulosa*, has prompted us to recommend that *P. virgulosa* be removed from *Pappomonas* and in the future be referred to as *Balaniger balticus* HET. A new *Pappomonas* species is described to accommodate Antarctic material from the Weddell Sea. While fitting convincingly into the *Pappomonas* generic concept, this species adds new dimensions to the overall appearance of the coccolith armor of the cell and emphasizes the close relationship between species of *Pappomonas* and *Papposphaera*.

Coccolithophore assemblages during sapropel S1 deposition in the NE Mediterranean Sea: paleoceanographic and paleoclimatic implications

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The Mediterranean Sea, a semi-closed basin, is a small-scale ocean with high environmental variability and steep physicochemical gradients, and it is influenced by both tropical and mid-latitude climatic processes. The climatic changes imprinted on the sedimentary archive of the Mediterranean Sea are closely dependent upon (1) orbital, suborbital, and solar cyclicities, (2) global atmospheric teleconnection patterns, and (3) shifts in the Intertropical Convergence Zone (ITCZ) over Africa. The Aegean Sea is a crucial area in the Mediterranean due to its rapid response to atmospheric forcing, thus making it an ideal case study for the analysis of deep-water formation and its relationship to climate change. The Aegean Sea, located at the NE edge of the eastern Mediterranean, is not directly affected by Atlantic oceanic circulation and is unique in terms of (1) sea-bottom geomorphology (i.e., several sub-basins with diverse bathymetries) and (2) productivity levels in the individual sub-basins. As opposed to present-day oceanographic conditions, the quasi-periodic occurrence of organic-rich layers, so-called sapropels, throughout the last 13.5 million years indicates intervals of dramatically different oceanographic and trophic conditions. Recent paleoceanographic findings suggest that during the Holocene, the northeastern Mediterranean climate was less stable than previously thought. Indeed, several recently generated Aegean paleoceanographic records of sapropel S1 suggest that during the Holocene, there were short-term potentially global cooling episodes, which resulted from North Atlantic climatic fluctuations and possibly were related to solar variability. These episodes were superimposed on the underlying regional subtropical/tropical influences on the hydrography and ecosystems.

The present study compares several paleoceanographic records from the northeastern Mediterranean in order to (1) identify sensitivities and response-modes to temperature and hydrological change during the sapropel S1 times through the use of coccolithophores and (2) determine paleoceanographic exchanges between the northeastern Mediterranean and the Black Sea, given the influence of the latter on deep-water formation, lower salinity influx, and the supply of nutrients to the Aegean Sea/NE Mediterranean.

Detailed quantitative analyses of coccolithophores were performed on the deep-sea deposits of the northeastern Mediterranean Sea from five gravity cores from the North Aegean Sea (SL 152), the SE Aegean (NS-14, NS-18), the SW Aegean (SK-3), and the south Cretan continental margin (HCMR 2/22). The focus of the study was on the regional expression of sapropel S1 deposition. At all sites, higher values of *Florisphaera profunda*, *Helicosphaera* spp., and *Braarudosphaera bigelowii*, and the concomitant increase of stratification S index in the sapropel intervals, can be interpreted to result from elevated marine production and enhanced inflow of fresh water during the S1 period. A series of cooling events were discovered in the S1 depositional interval that may be linked to outbursts of cold northerly air masses and related pulses in the deep-intermediate water ventilation, which caused a temporary cessation of S1 at ~8 ka. During this interval, the peak of *Emiliania huxleyi*, the decrease in abundance of *F. profunda*, *Helicosphaera* spp., and *Rhabdosphaera* spp., and a general increase in net primary production (NPP), are related to shoaling of the nutricline and higher production in the surface layer. The stratification S index is significantly higher in the north Aegean with respect to the south Cretan margin, reflecting higher productivity in the deep photic zone during S1 deposition. The concomitant increased presence of *B. bigelowii* is linked to prominent riverine input in the north Aegean basins and the influx of Black Sea waters after 8 ka.

The effect of coccolith shape on coccolithophore fluid dynamics

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Coccolithophore species exhibit a variety of coccolith morphologies. Although the exact function of these structures is as yet unclear, it is possible to posit and test specific consequences for an individual cell. In this study, we carried out sinking experiments using scaled-up coccolithophore models in order to test the effect that coccolith shape has on whole-organism sinking dynamics. We constructed models of three of Young's (1994) proposed coccosphere types – placolith-bearing, umbelliform, and floriform – which correlate to different environments. When we compared placolith-bearing forms with different coccolith sizes, we found that the model with the largest coccoliths had a slower terminal velocity than the other size classes. The floriform model preferentially oriented itself when sinking so that the concave side faced upwards; it fell with a speed similar to that of the large placolith model. The umbelliform model sank at a slower speed than all the other models, despite being significantly heavier. (All other models had identical masses.) This is likely a result of the stalked coccoliths increasing the effective radius of the model, thus increasing its drag without increasing its mass (which would be the case if it were a solid sphere). A sphere of equal mass with a radius equal to that of the inner radius of the umbelliform model sank with a greater terminal velocity; the Stokes radii of the umbelliform model and the equal-mass sphere differed by an order of magnitude. To test the effect of coccolith arrangement in a coccosphere, we systematically removed coccoliths from the umbelliform model, thus changing the packing density of the structures. We found that terminal velocity decreased in a linear fashion, though the magnitude of decrease cannot be explained by the decrease in mass alone. Our experiments demonstrated that coccolith shape influences the overall fluid dynamics of coccolithophores.

Reference

Young, J.R. 1994. Function of coccoliths. In: A. Winter & S.G. Siesser (Eds). *Coccolithophores*. Cambridge University Press, Cambridge: 63-82.

Nannofossil biostratigraphy in the Campanian – a Tethyan perspective

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The Santonian-Campanian boundary and the upper Campanian were investigated from Tethyan sections in Austria, Hungary, Spain, and Turkey. Sections in the Austrian part (Northern Calcareous Alps and Ultrahelvetic units) of the northwestern Tethys recorded Late Cretaceous nannofossil biostratigraphic events within neritic to bathyal environments. It was possible to correlate calcareous nannoplankton and planktonic foraminiferal bioevents with macrofossils and isotope chemostratigraphy.

The Santonian-Campanian boundary interval was investigated in several sections. The crinoid *Marsupites laevigatus* (uppermost Santonian with last occurrence proposed as a marker event for the base of the Campanian by Gale et al., 1995) was found, along with ammonites and inoceramids (Wagreich et al., 2009). *Globotruncanita elevata* with its first (local) appearance indicated the *asymetrica–elevata* planktonic foraminiferal Concurrent Range Zone, which straddles the boundary interval. Nannofossils in our sections placed the boundary within standard Zone CC17 (Sissingh, 1977; Perch-Nielsen, 1985) and Zones UC12-13 (Burnett, 1998), with *Arkhangelskiella* cf. *cymbiformis* already present in the upper Santonian sediments. The first occurrence of the nannofossil *Broinsonia parca parca*, which defines the base of standard Zones CC18/UC14, was found in early Campanian sediments. The nannofossil event closest to the inferred boundary in the Tethyan sections was the first common occurrence of curved *Lucianorhabdus cayeuxii*. The base of Chron 33r, the first reversal after the Long Cretaceous Normal and another candidate marker event for the base of the Campanian (Ogg & Hinnov in Gradstein et al., 2012: 83.6 Ma), was within Subzone CC17b.

In the late Campanian, the base of Zone CC22 - UC15d^{TP}, defined by the first occurrence of *Uniplanarius trifidus*, correlated to the first occurrence of *Radotruncana calcarata* (base of the *calcarata* planktonic foraminifera Zone; Wagreich et al., 2012). This combined nannofossil and planktonic foraminiferal event is situated above a mid-Campanian carbon isotope event and below the late Campanian event, a significant negative carbon isotope excursion in the upper part of nannofossil Zone CC22-23a.

References

Burnett, J.A. 1998. Upper Cretaceous. In: P.R. Bown (Ed). *Calcareous Nannofossil Biostratigraphy*. British Micropalaeontological Society Publications Series, Chapman and Hall/Kluwer Academic Publishers, London: 132-199.

Gale, A.S., Montgomery, P., Kennedy, W.J., Hancock, J.M., Burnett, J.A. & McArthur, J.M. 1995. Definition and global correlation of the Santonian-Campanian boundary. *Terra Nova*, **7**: 611-622.

Gradstein, F.M., Ogg, J.G., Schmitz, M.D. & Ogg, G.M. (Eds). 2012. *The Geologic Time Scale 2012*. Elsevier, Amsterdam: 1144pp.

Perch-Nielsen, K. 1985. Cenozoic calcareous nannofossils. In: H.M. Bolli, K. Perch-Nielsen & J.B. Saunders (Eds). *Plankton stratigraphy*. Cambridge University Press, Cambridge: 427-554.

Sissingh, W. 1977. Biostratigraphy of Cretaceous calcareous nannoplankton. *Geologie en Mijnbouw*, **56**: 37-65.

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**: 80-96.

Wagreich, M., Summesberger, H. & Kroh, A. 2009. Late Santonian bioevents in the Schattau section, Gosau Group of Austria – implications for the Santonian-Campanian boundary stratigraphy. *Cretaceous Research*, **31**: 181-191.

Integrated geochronology: how microscopic fossils influence the design of deepwater production facilities

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Geological hazard assessments are vital to the success of deepwater production facility design. We investigated the geochronology of 14 geophysical horizons to understand better the timing of fault displacement and subsequent submarine mass wasting as part of a geohazard assessment for a field located in the deep waters of the Gulf of Mexico. To calculate the ages for these geophysical horizons in the supra- and extra-salt sections near the field area, radiocarbon, stable oxygen isotopes, and biostratigraphy were evaluated in 420 samples from a series of geotechnical bore holes and cores collected from sediments shallower than 500' below mudline. The stable oxygen isotope record was utilized to help reduce uncertainty in the age of sediments between biostratigraphically constrained events. These events are crucial to interpreting the stable isotope record, due to geological and sampling gaps.

Late Pleistocene published nannofossil datums were utilized to constrain the geochronology of cored sediments (Martini, 1971; Gartner, 1977; Okada & Bukry, 1980; de Kaenel et al., 1999). The first stratigraphic event beyond the limits of radiocarbon utility is the highest common occurrence of *Gephyrocapsa* spp. at 70 ka, when it becomes significantly more abundant than *Emiliania huxleyi*. Likewise, a nannofossil assemblage dominated by *Gephyrocapsa oceanica* (base of CN14) was recognized at ~161 ka. The lowest occurrence of *E. huxleyi* (base of NN21/CN15) is a well-established event occurring between 248 ka and 270 ka (de Kaenel et al., 1999; de Kaenel, 2000). We adopted the age for this horizon at 270 ka as it is constrained by oxygen isotope stratigraphy in the Mediterranean (datum 3 of de Kaenel et al., 1999). The Highest Occurrence (HO) of circular *Pseudoemiliania lacunosa lacunosa* (=*Salisia kamptneri*; base of NN20/CN14b) is a significant, widely used nannofossil event that occurs at 439 ka (datum 4 of de Kaenel et al., 1999).

Assigned depositional ages of mapped horizons were derived from the integrated assessment of all the geochronological data from samples above and below mapped horizons in all sampled boreholes. Several sources of error will be discussed when considering the depths and assigned ages of mapped horizons. For example, geophysical mapping uncertainty, velocity-depth conversion, borehole sampling relative to seismic acquisition lines, and under sampled horizons introduce larger uncertainties. Estimates in age uncertainty are discussed and assigned for each horizon.

Comparing these horizons with global sea-level curves and marine isotope stages, the hypothesis is that recent activity of principle geohazards are tied to drops in sea level and increases in sediment mass accumulation rate. Therefore, a predicted larger magnitude and higher rate of fault displacement and mass wasting in the area are then linked to sea-level lowstands or glacial maxima.

References

de Kaenel, E., Siesser, W.G. & Murat, A. 1999. Pleistocene calcareous nannofossil biostratigraphy and the western Mediterranean sapropels, Sites 974, 977, and 979. In: R. Zahn, M.C. Comas, & A. Klaus (Eds), *Proceedings of the Ocean Drilling Program, Scientific Results*, **161**: 159-183.

de Kaenel, E. 2000. Mediterranean Pleistocene calcareous nannofossil biochronology. *8th International Nannoplankton Conference, Bremen, September 11-15, 2000*.

Gartner, S. 1977. Calcareous nannofossil biostratigraphy and revised zonation of the Pleistocene. *Marine Micropaleontology*, **2**: 1-25.

Martini, E. 1971. Standard Tertiary and Quaternary calcareous nannoplankton zonation. *Proceedings 2nd Planktonic Conference, Rome, 1970*, **2**: 739-785.

Okada, H. & Bukry, D. 1980. Supplementary modification and introduction of code numbers to the low-latitude coccolith biostratigraphic zonation (Bukry, 1973; 1975). *Marine Micropaleontology*, **5**: 321-325.

Nannotax – creating a web directory of nannofossil taxonomy

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The World Wide Web (WWW) has revolutionized access to information, enabling anyone to search for and hopefully find information on virtually anything. Conversely, it means that 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 specialization, increasingly expect to find answers via the Web rather than from traditional monographs and may even trust answers found via the Internet more than from printed publications. So, there is a general need to deliver authoritative taxonomic data via the Web, and this certainly applies to micropaleontology.

Nannotax is an online database of nannofossil taxonomy and images that we have been developing over the past five years, and while progress has not been as speedy as we had hoped, it still has been considerable. The system now contains high-quality images of nearly all nannofossil species with concise diagnostic notes on most species and longer descriptions of some. The Mesozoic module in particular has been vastly improved over the past couple of years.

There has also been a major software upgrade to the underlying "scratchpads" Content Management System (see http://scratchpads.eu/). The Nannotax site has migrated into this new system, and by the time of the INA14 meeting, the new version should be fully online, incorporating various suggestions made by end users. We will demonstrate the changed system and outline future plans.

Cruise-based multi-factorial investigation of the impact of ocean acidification on the pelagic biosphere

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The pelagic ecosystem is a critical component of the earth's biosphere and biogeochemistry. It is also, however, a complex and in many respects poorly understood system. As a consequence, predicting the likely impact of ocean acidification on the pelagic realm is problematic, and predicting the possible secondary biogeochemical effects of these impacts is "challenging". Nonetheless there is a major societal need to predict these impacts and outcomes.

Within the UK Ocean Acidification Programme, our consortium is tasked with "improving the understanding of the impact of ocean acidification on surface ocean biology, community structure, biogeochemistry, and on feedbacks to the climate" (http://www.surfaceoa.org.uk). To ensure that we are complementary with other programmes, we have adopted a cruise-based approach. Three cruises have been undertaken: Cruise D366 in the summer of 2011, around the northwest European shelf, Cruise JR271 in the summer of 2012, to the Arctic Ocean, and a final cruise to the Antarctic in January/February 2013. On each cruise, we combined extensive environmental observations with deck-board incubation experiments. The environmental observations were made with both continuous sampling techniques and CTD (conductivity, temperature, and depth) sampling. The cruise tracks were designed to cross environmental gradients in ocean chemistry and especially in carbonate chemistry. The objective is to produce a high quality matrix of multiple environmental parameters, including fully characterized carbonate chemistry (pH, CO_2, DIC, and alkalinity were measured), nutrient chemistry, trace elements, climatically active gases, TEP (triethyl-phosphate), phytoplankton and zooplankton composition, and biocalcification. The biocalcification studies include a microfabric study of pteropods, *in situ* calcification rates, and integrated morphometric and assemblage composition analyses of coccolithophores.

The incubation experiments were conducted with the use of a dedicated culture facility that was constructed in a shipping-container laboratory. This allows large-scale well-controlled experiments to be carried out that produce samples for analysis using the same range of techniques as the environmental sampling. On each cruise, six 4-day incubation experiments were carried out in diverse oceanographic settings with four CO_2 levels.

Overall, the project was specifically designed to create a dataset that allows testing of a wide range of hypotheses on the possible direct impacts and secondary effects of ocean acidification. This talk will include an overview of results to date on coccolithophores, a key group of biocalcifying organisms, and the degree to which they support these diverse hypotheses.

POSTERS

Student Posters

SP-1: Garcia Romero, F.*, Cortés, M.M.Y., *et al*., Coccolithophore variability in response to coastal upwelling in the west coast of the Baja California Peninsula

SP-2: Sidon Caseña, K.*, Cortés, M.M.Y., *et al*., Coccolithophore assemblage composition and cell densities at Alfonso Basin, Gulf of California

SP-3: Rochín Bañaga, H., Cortés, M.M.Y., *et al*., Coccolithophore CaCO3 fluxes in the Alfonso Basin

SP-4: Carag, J.W.M., and Fernando, A.G.S., Coccolithophore assemblages in Philippine inland seas

SP-5: Nogot, J.R.C.P., Peleo-Alampay, A.M., *et al*., Living coccolithphores in the Western Pacific Warm Pool

SP-6: Marquez-Ardiente, D.J.D., Peleo-Alampay, A.M., *et al*., Coccolithophore fluxes and variability from central and eastern Sulu Sea sediment traps in 2008-2009

SP-7: Rosario, D.J.G.*, Peleo-Alampay, A.M., and Fernando, A.G.S., Morphometric study of gephyrocapsids in surface sediments from offshore western Luzon and semi-enclosed bays of the Philippines

SP-8: Tangunan, D.N.*, and Peleo-Alampay, A.M., Size variations in the coccolith species Calcidiscus leptoporus in the Sulu Sea during the late Pleistocene to Holocene

SP-9: Cabarcos, E.*, Flores, J.-A., *et al*., Are Indian Ocean dynamics controlled by the Pacific Ocean or vice versa: ENSO versus monsoonal dynamic at a suborbital scale?

SP-10: Cruz, J., Agbali, A., *et al*., Presence of specific calcareous nannoplankton assemblages along the NE Florida continental margin: a look at loop current shedding and the DeSoto Canyon funnel effect

SP-11: Ausín, B., Flores, J.-A., *et al*., High resolution reconstruction of productivity using coccolithophores in two sites in the Alboran Sea (Western Mediterranean Sea) during the last 25 kyr

SP-12: Castro, A.*, Fernando, A.G.S., *et al*., Nannofossil biostratigraphy of northwest Leyte (Visayan Basin)

SP-13: Newsam, C.*, and Bown, P., Calcareous nannoplankton response across the Eocene-Oligocene transition in the North Atlantic Ocean

SP-14: Salaviale, C.*, and Mattioli, E., Climate, CCD , and calcareous nannofossils: actions and feedback during the middle Eocene

SP-15: Salem, R.*, and Aubry, M.-P. Coccolith biostratigraphy across the Cretaceous-Paleogene Boundary of the Dababiya Quarry Core, Egypt

SP-16: Brace, B.*, and Watkins, D.K., North American Middle and Late Cretaceous paleoceanographic trends evidenced by Biscutum

SP-17: Magtoto, C.Y.*, Fernando, A.G.S., *et al*., Calcareous nannofossil biostratigraphy across the Cenomanian-Turonian boundary of the Great Valley Group, California

Posters

P-1: Malinverno, E., Triantaphyllou, M.V., *et al*., Lateral versus downward coccolith flux in a canyon setting at the southwestern Cretan margin (eastern Mediterranean Sea)

P-2: Meier, K.J.S., and Kinkel, H., Living on the edge of CaCO3 undersaturation: a recurring autumn coccolithophore bloom in Kiel Bay (SW Baltic Sea)

P-3: Köbrich, M.I., Baumann, K.-H., *et al*., Calcareous nannoplankton off NW Africa (Cape Blanc) – seasonal and inter-annual dynamics of coccolithophore fluxes

P-4: Balestra, B., Flores, J.-A., *et al*., Living and fossil coccolithophore communitites in the West Iberia Margin and Gulf of Cadiz (IODP Exp. 339): oceanographic and environmental controls

P-5: Baumann, K-H., Böckel, B., *et al*., Biogeography and ecology of Calcidiscus and Umbilicosphaera in the South Atlantic

P-6: Baumann, K.-H., and Meggers, H., Coccolithophores in the Eastern Boundary Current System off NW Africa: response to abrupt climate events during the last 45,000 years

P-7: Temazatzi, A., Carmen Álvarez, M., *et al*., The last 150 years of coccoliths in the Carmen Basin, Gulf of California

P-8: Athanasiou, M., Dimiza, M.D., *et al*., Climate variability at the North Aegean Sea (eastern Mediterranean Sea) during the last two millennia: coccolithophore evidence

P-9: Bordiga, M., Cobianchi, M., and Lupi, C., Paleoceanographic changes in the NW Pacific Ocean over the last 450 ka: evidence from statistical analysis of calcareous nannofossil assemblages

P-10: Cavaleiro, C., Voelker, A., *et al*., North Atlantic paleo-productivity changes during Marien Isotope Stages (MIS) 10 to 16 – coccolithophore Sr/Ca evidence

P-11: Buitrago Reina, Y.M., Flores, J.-A., and Sierro, F. J., Calcareous nannofossils and water dynamics in the eastern Pacific and Caribbean (western Atlantic) during the final phase of the emersion of Central America

P-12: Chuanlian, L., 5 Ma coccolith records and their paleoceanographic significance in the south of the South China Sea

P-13: Holcová, K., and Doláková, N., Response of calcareous nannoplankton assemblages to the Middle Miocene Climatic Transition in the epicontinental sea (Carpathian Foredeep, Central Paratethys)

P-14: Musatov, V., and Vasilyeva, O., The Middle Eocene Climatic Optimum (MECO) event in the Keresta borehole in southern Russian Platform and changes in the nannofossil and dinoflagellate cysts assemblages

P-15: Bartol, M., Tulbure, M., *et al*., The Badenian-Sarmatian boundary in the Getic Depression: preliminary results of integrating biostratigraphy and magnetostratigraphy

P-16: Fernando, A.G.S., Magtoto, C.Y.*, *et al*., Calcareous nannofossil biostratigraphy of selected sedimentary formations on Negros Island (Visayan Basin, Central Philippines)

P-17: Fioroni, C., Persico, D., *et al*., Middle Eocene – lower Oligocene nannofossil biostratigraphy and paleoceanography from ODP Site 711 (Equatorial Indian Ocean)

P-18: Kulhanek, D.K., Morgans, H.E.G., *et al*., Age and paleoenvironmental constraints based on calcareous nannofossil and foraminifera assemblages from the Eocene-Miocene of Lord Howe Rise, southwest Pacific Ocean

P-19: Padilla, P.E., Reyes, A., *et al*., Biostratigraphic correlation of Paleogene sediments, based on calcareous nannofossils in four wells from the Tampico-Misantla Basin, Gulf of Mexico

P-20: Mahanipour, A., Parandavar, M., and Aghanabati, A., Late Maastrichtian-early Paleocene calcareous nannofossil biostratigraphy in southwest Iran

P-21: Stoykova, K., Dinares-Turell, J., *et al*., Integrated high-resolution nannofossil biostratigraphy and cyclomagnetostratigraphy of the upper Maastrichtian: correlation between the Bjala (Bulgaria) and Sopelana (Spain) sections

P-22: Sheldon, E., Morigi, C., *et al*., Stratigraphy of the late Campanian-Maastrichtian boreal chalk based on foraminifera, calcareous nannofossils, and carbon stable isotopes: new results from the Femern Baelt, Denmark and Germany

P-23: Sheldon, E., Ineson, J., *et al*., Nannofossil biostratigraphy and paleoecology of the Danish Lower Cretaceous reservoir chalks (Tuxen and Sola Formations)

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Demonstrations

Covington, M., Demo of BugWin and BugCAD

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