

Reproducibility of species recognition in modern planktonic foraminifera

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Planktonic foraminifera have been extensively used in palaeoceanographic and biostratigraphic studies. Many of these applications require a high degree of taxonomic certainty and recognition. Any disparity between researchers has the potential to influence temperature or diversity reconstructions. Despite this potential source of uncertainty, the reproducibility of species recognition has not yet been tested. In order to ascertain the degree of species recognition reproducibility, a modern subtropical sample was selected for its high species richness and sieved through the $>125\mu\text{m}$ and $>150\mu\text{m}$ size fractions respectively. These fractions were then split using a microsplitter into aliquots of approximately 300 individuals, and a representative 300 individuals were then selected and fixed. Participants of varying expertise from different institutions were asked to identify each individual and note down their classification. This procedure allowed for a direct comparison of each participant's identification for each of the individuals. It was then possible to determine the absolute levels of consistency between participants and the overall effects of inconsistency on diversity and temperature estimates. The absolute levels of consistency between all participants were surprisingly low: 50% in the $>150\mu\text{m}$ size fraction and 35% in the $>125\mu\text{m}$ size fraction. When all of the participants identifications were compared individually with one another, the maximum pairwise conformity was found to be 80% in the $>150\mu\text{m}$ size fraction and 65% in the $>125\mu\text{m}$ size fraction. The minimum pairwise concurrence was found to be 65% in the $>150\mu\text{m}$ and 55% in the $>125\mu\text{m}$ size fraction. This implies that there are a substantial number of specimens among modern planktonic foraminifera, which are difficult to identify unambiguously. Surprisingly however, it was revealed that the overall effect of this inconsistency was negligible in the $>150\mu\text{m}$ size fraction on SST

Palaeoclimatic changes across the Palaeocene/ Eocene boundary

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The late Palaeocene/early Eocene boundary has been identified as one the most critical times in Cenozoic history, with significant changes in global climates and oceanic circulation during this interval. The present work deals with the study of palaeoclimatic changes through the P/ E boundary of four sections from north east Sinai (Gabal Muwaylih & Gabal Amr), west central Sinai (Gabal Bir El Markha) and south western Sinai (Gabal Mukattab). The Palaeocene/ Eocene (P/E) boundary is located in the lower part of the Esna Formation and can be traced at the first appearance datum of *Acarinina sibaiaensis* (base of P5b Subzone, planktic foraminifera) and at the base of NP9b Subzone as defined by the first appearance of *Rhombosters* spp. and *Discoaster araneus* (calcareous nannofossils).

The late Palaeocene/ early Eocene boundary interval is dcharacterize by rapid global deep sea Benthic Foraminiferal Extinction Event (BFEE); sharp turnover among calcareous nannofossils; rapid diversification in planktic foraminifera and a carbon Isotope Excursion (CIE). All these events occurred in connection with sudden warming events. The intermediate water during the late Palaeocene/ early Eocene interval was warmed by ~8 °C at high latitude and from 4-6 °C in tropic regions. These conditions were recognized by studying variations in species richness and relative abundance of cool and warm water species of both planktic foraminifera and calcareous nannofossil species in the current study. *Morozovella velascoensis* Group/*Morozovella subbotinae* Group and *Discoaster/Chiasmolithus* ratios are considered as a good guide to delineate the surface water palaeotemperature. These ratios increase rapidly during the P/E boundary interval and reflect increasing in water temperature through that interval.

A seasonal study of benthic foraminifera and diatoms from the Eden Estuary, NE Scotland

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The results of seasonal sampling of surface sediments along a transect of extensive intertidal mudflats from the Eden Estuary, Northeast Scotland are presented. We demonstrate that the total standing stock/abundance of benthic foraminifera increases in a lagged fashion, following increases in chlorophyll *a* and *c*. We observe two dominant species: *Elphidium williamsoni* Haynes and *Haynesina germanica* (Ehrenberg), which appear to vary in anti-phase with each other throughout the seasonal cycle. Patterns of total foraminiferal biomass also exhibit a marked seasonality, with a pronounced peak in May-June, from 15 $\mu\text{g C cm}^{-2}$ (high intertidal) to 25 $\mu\text{g C cm}^{-2}$ (low intertidal). While we confirm that foraminifera exploit benthic diatoms as a food resource (e.g. Austin et al., 2005) in the Eden Estuary, it is unlikely that this is the only food resource being used. While benthic foraminifera show a marked change in seasonal standing stock/abundance, little seasonality is evident in the chlorophyll *c* measured, suggesting that benthic diatoms (food) are not limiting in this particular environment.

Keywords: benthic foraminifera, benthic diatoms, seasonality, population dynamics.

Reference:

Austin, H. A., Austin, W. E. N. and Paterson, D. M., (2005) Extracellular cracking and content removal of the benthic diatom *Pleurosigma angulatum* (Quekett) by the benthic foraminifera *Haynesina germanica* (Ehrenberg). *Marine Micropaleontology* 57, 68–73.

An improved ¹⁴C chronology for Marine Isotope Stage 3 based on planktonic foraminifera

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Abrupt climate transitions, punctuating Marine Isotope Stage (MIS) 3, are identified in Northeast Atlantic sediment core MD95-2006 (57°01.82' N, 10°03.48' W, water depth 2,120 m). These so-called Dansgaard-Oeschger events are very clearly expressed in planktonic foraminiferal assemblage changes, which at this latitude can be directly correlated with the changes in $\delta^{18}\text{O}$ observed in Greenland ice cores. We demonstrate the synchronous nature of the abrupt changes in relative abundance of *Neogloboquadrina pachyderma* (sinistral) and ice core $\delta^{18}\text{O}$ using a tephra isochrone (North Atlantic Ash Zone II) common to both records. Using the abrupt climate transitions of both records as common tie-points, we have developed an age-depth model for MD95-2006 derived from the chronology of the GISP2 ice core of central Greenland. Detailed sampling and AMS ^{14}C dating of planktonic foraminifera (*Globigerina bulloides*) through the warm interstadial events that punctuate MIS 3 enable us to estimate the differences in ^{14}C and ice core (calendar) ages throughout this period. We provide a new and improved synthesis of Northeast Atlantic MIS 3 interstadial ^{14}C chronologies and highlight the palaeoceanographic significance of spatial gradients in ^{14}C ages derived from planktonic foraminifera in very high-resolution marine sediment records.

Keywords: planktonic foraminifera, Northeast Atlantic Ocean, Dansgaard-Oeschger events, radiocarbon, Greenland ice cores

Pliocene Intensification of Northern Hemisphere Glaciation

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Seasonal cooling and changes in moisture supply at boreal high latitudes have both been proposed as major triggers of northern hemisphere glaciation (NHG) during the mid-Pliocene. Much of our uncertainty regarding their relative roles can be directed at a lack of high-resolution unambiguous records of temperature and ice volume for this phase of climate deterioration. With the aim of developing a more complete picture of NHG we are developing new high-resolution (sub-orbital) records of the abundance of ice-rafted debris and stable isotopes ($\delta^{18}\text{O}$, $\delta^{13}\text{C}$) and Mg/Ca in benthic and planktic foraminiferal calcite from IODP Site 1308 between 2.59 and 2.50 Ma (MIS 103-99), during the late phase of the onset of NHG.

This will enable us to evaluate palaeoclimate variability in surface and deep waters within the North Atlantic IRD belt during the pronounced obliquity-paced Pliocene intensification of NHG and to estimate the contribution of global and regional ice growth versus North Atlantic seasonal cooling and assess the stability of IRD and stable isotope records in these sediments at millennial time-scales.

Spatial variability of living (stained) benthic foraminiferal faunas at 550m depth in the Bay of Biscay

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Deep-sea benthic foraminifera are used as proxies for palaeo-environmental reconstructions. To improve their calibration, it is important to improve our knowledge of their ecology. Temporal surveys at a particular sampling site are useful to determine the influence of episodic phytoplankton bloom events on living benthic foraminiferal faunas. However, one question is left unanswered: what is the part of the observed differences due to spatial variability (patchiness) and what is the part really related to temporal changes? A seasonal survey of live (stained) deep-sea benthic foraminiferal faunas (>150 µm) from cores sampled at 550 m water depth in the Bay of Biscay was carried out between October 1997 and April 2001. Using the data gathered during this study and also data obtained from 4 more replicate cores sampled at the same station in May 2004, we performed a statistical study (Detrended Correspondence Analysis) to determine if spatial faunal variability overshadows the seasonal changes of foraminiferal faunas. To depict patchiness, we used 4 cores sampled in May 2004 as well as 5 pairs of replicate cores collected during Oxybent cruises. The statistical analyses of whole cores foraminiferal densities (based on the 17 most abundant species) allowed us to conclude that spatial variability exists, but is not important enough to obscure temporal variability. To study thoroughly the impact of patchiness, we also carried out statistical analyses considering, separately, different sediment intervals. We observed that spatial variability becomes proportionally more important deeper in sediment than at the surface. In fact, labile organic matter inputs have a limited influence on intermediate and deep infaunal taxa. Because 85% of the total fauna is found in the first 2 centimetres of the sediment, we conclude that patchiness does not distort benthic foraminiferal faunal changes observed during a seasonal variability study.

Keywords: living foraminifera, patchiness, Bay of Biscay, Detrended Correspondence Analyses, temporal variability

Reproduction and growth of deep-sea benthic foraminifera: A laboratory study

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Since about 20 years, the isotopic composition and trace element ratios of foraminiferal shells have served to retrace past climatic changes. Unfortunately, the relations between the composition of the foraminiferal shell and the specific physico-chemical parameters of the environment in which the organism calcifies are still poorly understood. Studies in natural environments, comparing the ecology of recent benthic foraminifera with the stable isotopic composition and trace element ratios of their shells, have been performed, but the results are often ambiguous, because the calcification processes of these organisms are influenced by numerous interfering factors. The study of foraminifera under controlled laboratory conditions is a potential solution to this problem. It will allow us to better understand the effect of single environmental parameters on the isotopic composition and trace element ratios of the foraminiferal shell.

We investigate the temperature effect on the oxygen isotopic ratio ($\delta^{18}\text{O}$) under controlled laboratory conditions. Monospecific experiments (*Bulimina marginata*) and plurispecific experiments with faunal assemblages (*Bolivina subaenariensis*, *Valvulineria bradyana*, *Hyalinea balthica*, *Uvigerina peregrina*) are carried out at various temperatures (6, 8, 10, 12°C). Living adult specimens marked using the calcein probe are isolated and incubated at these 4 different temperatures. Food (dried green algae) is added in order to stimulate reproduction. After 3 months, the stable isotopic composition of specimens formed under controlled conditions will be analysed.

Keywords: benthic foraminifera, cultures, reproduction, oxygen isotopes, temperature

Lateral and vertical coccolithophore distribution along productivity gradients: examples from the South Atlantic Ocean

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Coccolithophore plankton communities from different photic zone depth profiles (0-220 m) collected throughout the South Atlantic Ocean were examined qualitatively and quantitatively. The cell concentrations were related to environmental gradients in order to characterize the ecological niche occupied by coccolithophores as a phytoplankton group. Maximum cell numbers were found in areas of divergence, i. e. along the subtropical front and the offshore fringe of upwelling areas. Low coccolithophore concentrations predominate in the central subtropical gyre. To narrow down the ecological preferences of single species and/or morphotypes further multivariate statistical analyses on the abundance and hydrographic data from the water-column was carried out. For example, *Calcidiscus leptoporus* ssp. show distinct differences with respect to their environmental preferences. Among the three subspecies *C. leptoporus* small is associated with highest nutrient levels. *C. leptoporus* ssp. *leptoporus* exhibits rather broad ecological tolerances.

Palaeogene calcareous nannofossils from the Kilwa and Lindi areas of coastal Tanzania (Tanzania Drilling Project)

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Calcareous microfossils from Palaeogene hemipelagic clays of coastal Tanzania were first described in the foraminiferal work of Blow and Banner (1962), who described new species of planktonic foraminifers and several biozones from the Lindi area. The Tanzanian Drilling Project (TDP) has returned to this area, with the primary aim of recovering pristinely-preserved foraminifera and organic biomarkers for geochemical analysis in order to improve records of late Mesozoic-Palaeogene tropical sea-surface temperatures and pCO₂ (Pearson et al., 2004). In addition to glassy foraminifera, the material has also yields spectacularly diverse and well-preserved calcareous nannofossil assemblages that essentially constitute a long-time-series conservation-lagerstätte. Results so far include the description of 86 new species (Bown, 2005; Bown and Dunkley Jones, 2006), effectively doubling the existing diversity estimates for many important Palaeogene-Extant families, and revised data concerning the origination of several coccolith families. The data also demonstrate the dramatic diversity gradient that existed between Eocene shelf and ocean assemblages, the most striking in the groups' history, and representing, for the middle Eocene, a factor of three to four difference. This contrast appears to be partly taphonomic and partly palaeoecologic, but in any case provides fascinating additional information for critical intervals such as the Palaeocene-Eocene and Eocene-Oligocene boundary.

Keywords: Palaeogene calcareous nannofossils lagerstätte diversity

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Living benthic foraminifera of the Okhotsk Sea: faunal composition, standing stock and microhabitats

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The living (Rose Bengal stained) benthic foraminifera were investigated in the size fraction $>125 \mu\text{m}$, in the upper 8 cm of duplicate sediment cores. Cores were recovered with a multicorer at five stations along the Sakhalin margin and at three stations on the south-western Kamchatka slope (the Okhotsk Sea). Stations are characterized by different productivity regimes and located between 609 and 1740 m water depth, which is within the present Okhotsk Sea oxygen minimum zone. Foraminiferal standing stock, composition, maximal habitat depth and microhabitats of calcareous species were determined and related to environmental parameters. At the Kamchatka stations in the high productivity and ice-free areas, the living benthic foraminifera show maximal total standing stock, strong dominance of calcareous species (up to 87-91%), the relatively deep habitat depths (up to 5.2-6.7 cm) and a total faunal vertical distribution with two maxima. The intermediate and deep infaunal species dominate the calcareous assemblages at these stations. At the Sakhalin margin stations, which are less productive and seasonally sea ice covered, the living faunas have the relatively low total standing stock (calcareous up to 10-64%), shallow habitat depths (up to 2.5-5.4 cm) and a total faunal vertical distribution with maximum in the uppermost cm. The calcareous assemblages consist mainly of shallow infaunal species. The pronounced seasonal sea ice cover, the relatively low upwelling productivity and low bottom water oxygenation within oxygen minimum zone along Sakhalin margin are suggested to be the key factors responsible for differences in the living foraminiferal assemblages between Sakhalin and Kamchatka stations.

Keywords: benthic foraminifera, microhabitat, organic flux, oxygen minimum zone, Okhotsk Sea

The distribution of modern benthic foraminifera in Loch Sunart surface sediments

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There is a dearth of benthic foraminiferal distribution studies from NW European fjords. The majority of studies focus on Scandinavian fjords, which typically exhibit different hydrography to the sea lochs (or fjords) of NW Scotland. We present the first distribution study of modern benthic foraminifera from Loch Sunart: a Scottish sea loch with a relatively good connection (and exchange) with 'open' coastal waters. An understanding of the modern benthic foraminiferal distribution in Loch Sunart is important for the interpretation of high-resolution palaeoenvironmental records recently obtained from this sea loch. Multivariate statistical analyses identified 4 benthic foraminiferal assemblage groups in the surface sediments of the loch: A) restricted basin (*Eggerelloides scaber*); B) high current activity (*Cibicides lobatulus*-*Asterigerinata mammilla* –*Ammonia beccarii*); C) calm depositional environment under a stratified water column (*Bulimina marginata*-*Nonionella turgida*-*Stainforthia fusiformis*) and D) coastal water influence and mild/episodic current activity (*A. beccarii*-*C. lobatulus*-*Spiroplectammina wrightii*-*Elphidium excavatum*).

Loch Sunart presents two potential areas for future palaeoclimatic research. The calm depositional environment of the deep main basin presents well preserved, high diversity benthic foraminiferal assemblages which are likely to respond to inter-annual changes in seasonal stratification, organic matter input and temperature: changes which may be reflected in test geochemistry and possibly reconstructed using qualitative and quantitative approaches. The agglutinated-dominated assemblages from the inner basin are likely influenced by salinity changes and terrestrial organic matter input, thus sedimentary archives from this basin may provide useful records of palaeoenvironmental change in the catchment. Future work will explore the benthic foraminiferal assemblages from a highly expanded Holocene record (MD04-2832) and implement quantitative methods of palaeoenvironmental reconstruction, such as a transfer function approach, to reconstruct bottom water temperature.

Keywords: NW Scotland, fjord, sea loch, benthic foraminiferal assemblages, palaeoclimate

Absolute abundances across the Jurassic/Cretaceous boundary: preliminary data from M.te Pernice section, Southern Alps (Italy)

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The Jurassic/Cretaceous boundary is characterized by a significant increase of carbonate-rich sediments (Maiolica Fm.) and a concomitant appearance of highly-calcified nannofossil groups (*Conusphaera*, *Polycostella*, *Nannoconus* and *Faviconus*). Absolute abundances of calcareous nannofossils have been obtained using thin sections, 7-8 mm thick. All specimens in 1 mm² (= 50 microscope fields of view) have been counted to reconstruct nannofossil calcite paleofluxes.

In the uppermost Tithonian abundances of *C. mexicana minor*, *C. mexicana mexicana*, and *P. beckmannii* increase significantly, and subsequently decrease across the Tithonian/Berriasian boundary. Nannoconids appear and rapidly develop reaching high abundances in the lowermost Berriasian. Variations in nannofloral abundance and composition are consistent with previous works on relative and absolute abundances in the central Atlantic (Bornemann et al., 2003; Tremolada et al., 2006). In the M.Pernice section, changes in micrite composition and carbonate productions are quantified as paleofluxes and directly correlated to calpionellid biostratigraphy. The rise in nannoconid abundance corresponds to the appearance of calcitic calpionellids, indicating the onset of palaeoenvironmental conditions favourable to calcification. The appearance of highly-calcified genera may be triggered by many factors: low pCO₂ levels (Weissert & Erba, 2004; Erba, 2006); a cooling phase during the Tithonian (Price, 1999); increasing transfer rate of alkali from continents to oceans, possibly inducing variation of surficial marine water pH (Weissert & Erba, 2004).

The diversification and proliferation of nannoconids and nannolith *Conusphaera* interpreted as inhabitants of the lower photic zone, like (Erba, 1994, 2004; Herrle, 2003) might indicate the establishment of a thermocline/nutricline in the deep photic zone. The diversification of high-calcified taxa affected the carbonate production and the global carbon cycle at short and long time scales.

Key words: Jurassic/Cretaceous Boundary; calcareous nannofossils; absolute abundances

Pelagic evolution and environmental recovery after the Cretaceous-Palaeogene mass extinction

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The record of the Cretaceous/Palaeogene (K/Pg) mass extinction in the marine realm shows a pattern of pronounced extinction among pelagic vertebrates, invertebrates, phytoplankton and zooplankton and a catastrophic decline in the flux of organic matter to the deep ocean that took more than three million years to recover. Marine fossil records from the Palaeocene also suggest multi-million year delays in the evolutionary recovery. Most K/Pg recovery studies, however, focus on the period immediately after the extinction and little is known about the timing of evolutionary diversification in relation to carbon cycling and the state of the recovering pelagic ecosystem. Here we explore links between the two by comparing Palaeocene planktic foraminiferal evolutionary histories with geochemical records of K/Pg environmental change from the Atlantic and Pacific Oceans. The results demonstrate that evolutionary recovery of planktic foraminifera from the K/Pg extinction was closely linked to recovery of the marine carbon system. Both the evolutionary recovery and the biogeochemical recovery occurred in two stages. The second stage of planktic foraminifera evolutionary radiation peaked nearly four million years after the extinction, immediately after the abrupt final recovery of the organic flux to deep waters. The timing of these events suggests that the final post-extinction recovery of planktic foraminiferal diversity was directly contingent on the final recovery of the marine carbon cycle. This second radiation was defined by the diversification of tropical photosymbiotic forms that dominated low- and mid-latitude assemblages long into the Eocene. We hypothesize that this diversification exploited the re-appearance of oligotrophic oceans as the organic flux from the surface ocean to deep water fully recovered from the mass extinction.

Cenomanian/early Turonian benthic foraminiferal faunas of the Demerara Rise depth transect (ODP Leg 207)

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Studied sediments from Demerara Rise (Leg 207, tropical Atlantic, off Suriname) consist of laminated black shales with TOC values between 5 and 29% and include OAE 2 and the Mid-Cenomanian Event (MCE). Benthic assemblages in this eutrophic environment are characterized by low diversities and strong fluctuations of abundances, indicating oxygen depleted and high organic matter fluxes. During the MCE, however, there is a significant change in the assemblages from more diverse and specimen-rich to lower diverse and specimen-poor assemblages. These faunal patterns characterize the entire Upper Cenomanian, up to the OAE 2. Just below the OAE 2, benthic faunas of the shallower sites indicate anoxic to sometimes slightly dysoxic bottom-waters. The deepest site, in contrast, reflects more oxygenated bottom waters with an almost continuous occurrence of benthic foraminifera. It is therefore suggested that the shallower sites were located amidst the oxygen minimum zone (OMZ), whereas the deeper sediments were deposited below the OMZ. During OAE 2 anoxic conditions prevail at the shallower sites. At the deeper site benthic foraminifera indicate severe dysoxic but not anoxic conditions. This pattern is proposed to reflect a strengthening of the OMZ possibly related to increasing primary production. A short-termed repopulation event of benthic foraminifera located in the lower third of the OAE 2 was observed at all sites, reflecting a brief bottom-water oxygenation event within the OAE 2. This event parallels a surface-water cooling and is probably equivalent to the "Plenus Cool Event" in Europe and the "benthic zone" in the Western Interior. The benthic foraminifera of a ~0.5 Ma interval following the OAE 2 still indicate oxygen depletion of bottom waters. Subsequently, however, a strong increase in benthic foraminiferal abundance and diversity reflects a better oxygenation of the bottom-water masses, probably related to a weakening of the OMZ.

Keywords: Cenomanian, Turonian, OAE 2, benthic foraminifera, black shales

Ocean acidification and calcareous nannoplankton at the Palaeocene-Eocene thermal maximum

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The Palaeocene-Eocene Thermal Maximum (PETM, ~55 Ma) was a transient interval of global warming and ocean acidification that resulted from the rapid release and oxidation of methane from ocean sediments. The PETM has received considerable attention in recent years as it may provide us with invaluable clues as to how the earth system will respond to current and predicted levels of carbon emissions. The addition of massive amounts of carbon to the ocean-atmosphere system at the PETM, analogous to modern fossil fuel burning, caused prominent lysocline shoaling (Zachos et al., 2005). However, the estimated emission rates are an order of magnitude lower than present day and may not have been great enough to result in a significant, concurrent drop in surface water saturation state. The record of calcareous nannoplankton allows us to test this prediction. The onset of the PETM carbon cycle perturbation coincides with a peak in nannofossil origination and extinction rates compared to background levels (Gibbs et al., 2005), coeval with dramatic localized and global shifts in assemblage character driven primarily by changes in nutrient availability and temperature (Bralower, 2002; Gibbs et al., 2006). Assemblage shifts are clearly related to localised environmental conditions and suggest no overriding global saturation control. Furthermore, the pattern of extinctions and originations lack a calcification bias and the presence of large, robust nannofossil taxon (e.g. *Rhomboaster* and *Discoaster*) suggest that surface water saturation levels across the event did not inhibit calcification. Our records suggest that rates of CO₂ emission across the PETM were not great enough to significantly perturb surface water saturation state, or at least not to the point where it would be detrimental to calcareous nannoplankton survivorship, with no evidence for a crisis in calcification among the calcareous nannoplankton.

Morphological variation of Emiliana huxleyi: A new tool for reconstructing sea water salinities?

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Morphometric analysis of coccoliths of various coccolithophore species from core top and culture samples has revealed that the morphology of single placoliths can be affected by environmental parameters such as temperature, salinity, and productivity. In this study, we have tested the morphological variations of placoliths of *Emiliana huxleyi*, the most common coccolithophore species in the modern ocean, with respect to environmental gradients. We have investigated especially the potential effect of salinity on the morphology, as it is known from culture studies that the growth of *E. huxleyi* placoliths is strongly influenced by varying salinities.

Morphometric analysis of about 1900 placoliths from 32 globally distributed core top samples reveals that the morphology of *E. huxleyi* varies significantly along a sea-surface salinity gradient from 33 to 38 psu. Morphological parameters such as the mean size of placoliths are used as explaining variables in multiple regression analysis to reconstruct sea surface salinities (SSS). The best model for mean SSS yields an R^2 of 0.88 with a standard error of 0.49 psu whereas statistical models describing surface water temperature or productivity are less reliable and accurate. This suggests that salinity strongly affects the size and shape of *E. huxleyi* placolith morphology. The frequency and tiny size of different *E. huxleyi* placoliths in the sedimentary record may thus allow the reconstruction of SSS on millennial to annual scales in laminated intervals from low- to mid-latitudes for at least for the last ~20 ka.

The “*Challenger Foraminifera*” online

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The “Challenger Collection” is one of the most important and widely consulted collections of foraminifera at the Natural History Museum, London. It consists of many 1000s of slides pertaining to the cruises of the *Challenger* herself (1872-1876), the *Lightning* (1868), the *Porcupine* (1869), the *Knight Errant* (1879) and to the Austro-Hungarian and British Polar expeditions (1872-74 and 1875-76 respectively). The “*Challenger Report*”, the final instalment of which was published by H. B. Brady in 1884 was a landmark publication, the comprehensiveness and attention to detail exhibited in this work is such that it remains the most famous of the classic monographs of foraminiferal studies and is the most often cited. This volume, because of its outdated taxonomy, arising from the intellectual atmosphere of the “English School” where a broader species concept was employed, has had a number of revisions. The main revisions to this work include those of Thalmann (1932 - 1942) and Barker (1960). Since Barker’s time many more revisions were published which ultimately were incorporated in the publication of Jones (1994), “The Challenger Foraminifera”. Inevitably sections of this publication became taxonomically out of date soon after it was published.

To reflect the continual revision of the taxonomy of the “*Challenger*” foraminifera and the importance of this collection the next publication will be electronic rather than a print-based monograph. To take advantage of present initiatives in taxonomic database publication and the accessibility of the WWW the “*Challenger Collection*” will soon be available online. Using a straightforward SQL database, JSP and JSTL technologies the collection will also be augmented by full-colour, fully-focused, digital images of many of the specimens. New techniques using Infinite Focus Microscopy will also be used to produce accurate full-colour 3-dimensional images to further augment the illustrations. The data will hopefully be integrated with the main online palaeontological databases (e.g. GBIF, CHRONOS, Paleobiology Database) and the authors are keen to collaborate with colleagues working with similar projects. The database has the added benefit that taxon searches on Google will retrieve this data.

Micropalaeontological characterisation of Cenozoic deep-sea fan deposits, Congo Fan, offshore Angola

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The Congo Fan is a terrigenous wedge largely built of Oligocene and Miocene sands and shales organised into thick sedimentary packages containing palaeocanyons, palaeochannels, and overbank deposits. The well in this study spans the Oligocene to Middle Miocene. It has a water depth of ~2000m, and is located ~170km offshore Angola (Block 31). The Upper Oligocene section consists of predominantly black muds and silts with interbedded sandy horizons, which continues into the Lower Miocene with little sedimentological change until reaching a large sand/silt body interpreted as a submarine palaeochannel. The foraminifera are almost entirely agglutinated, and are present in most samples at medium to low abundances. Typical cosmopolitan Palaeogene forms can be identified (*Nothia robusta*, *Ammodiscus latus*, *Reticulophragmium amplexans*), along with several dominating high productivity forms (e.g. *Portatrochammina alta* n.sp. and *Scherochorella congoensis* n.sp.). The diversity ranges from medium to low with significant faunal variation possibly related to medium to high productivity fluctuations.

The overlying sand horizon becomes barren after foraminiferal diversity and abundance drops away leaving only rare specimens of *Nothia* and *Ammodiscus*. Above this, the sand changes to Lower and Middle Miocene silts and muds containing gradually more calcareous and planktonic foraminifera as well as persistent agglutinated forms. The diversity and abundance is high, showing significant variation which could be related to fluctuations in the CCD during the Middle Miocene, or due to secondary geochemical effects such as remobilised hydrocarbons. Faunas become more diverse with typical Middle Miocene calcareous benthics (*Eponides crebbsi*) and Miocene agglutinated foraminifera (*Cyclammina acutidorsata*, *Haplophragmoides carinatus*) with some typical Palaeogene forms persisting (*Glomospira irregularis*, *Haplophragmoides excavatus*). Planktonic foraminifera have been used to assign the upper section of the well to Langhian.

Keywords: Benthic Foraminifera, West African Margin, Congo deep-sea fan, palaeoceanography, biostratigraphy

The complex history of Gephyrocapsa – Pliocene to modern evolution

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We have investigated morphological patterns among coccoliths of the genus *Gephyrocapsa*, which provide a complex and rapid evolutionary pattern from their first occurrence in the Early Pliocene till today. The early history of the genus provides valuable insights into the principals of speciation of coccolithophores, which seems to resemble a “try and error” kind of pattern, whereas selection of successful species appears to be controlled by environmental forcing. It is apparent, that the relatively simple structural design and strong genetic control on biomineralisation of *Gephyrocapsa* and *Reticulofenestra* coccoliths provided a limited number of morphological variations and thus repetitive evolutionary patterns are common and distinction of morphological defined species require detailed observations of multiple characters under the scanning electron microscopy.

Evolutionary rates within the genus *Gephyrocapsa* are extremely fast, providing valuable short-term biostratigraphic markers, but raise questions on the dispersal, extinction and adaptation mechanisms in *Gephyrocapsa* and other coccolithophores. Therefore we compare evolutionary events from different ODP sites with high temporal resolution to resolve synchronous and diachronous patterns and influence of environmental forcing. Finally we compare the results of the morphological evolution of *Gephyrocapsa* since the Pliocene to modern day distribution patterns and molecular phylogenies.

Keywords: Evolution, *Gephyrocapsa*, Morphometry, Pliocene, Pleistocene

Sea surface temperature during Heinrich Events in the NE Atlantic, evidence from coccolithophore-based proxies

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Recent research into the Heinrich (H) events of the last glacial provide conflicting records of sea surface temperature (SST), questioning the true climatic conditions under which periodic collapse of the Laurentide ice sheet occurred. High resolution planktonic foraminiferal Mg/Ca SST records appear to oppose those based on faunal assemblage composition, suggesting elevated summer SSTs immediately preceded and persisted through each of the last five H events. It is possible that these discrepancies may be related to anomalous salinity conditions or to variable seasonal conditions having differential effects on the various proxies. To constrain our understanding of these records we present coccolithophore based SST records in parallel with Mg/Ca and faunal assemblage investigations of planktonic foraminifera selected cores from the NE Atlantic.

We have used two independent coccolithophore-based approaches: the well-established organic geochemical alkenone palaeothermometry technique, based on lipids produced by Noelaerhabdacean coccolithophorids (primarily *Gephyrocapsa* and *Emiliania*) and a novel coccolithophore assemblage-based method using relative abundance of different *Coccolithus* morphotypes. All available evidence from molecular genetics, culture experiments and biogeography suggests that size-defined morphotypes of *Coccolithus* are pseudo-cryptic species with discrete temperature preferences and so can be used for palaeotemperature reconstruction. We found strong patterns of size variation in *Coccolithus* and will present these results in a framework of independent data from alkenone and planktonic-foraminifera derived data.

Does the quality of organic carbon matter to benthic foraminifera?

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A phytoplankton bloom was simulated under controlled laboratory conditions using the diatom species *Thalassiosira pseudonana*. A 'labile' component consisted of fresh freeze dried algae, while a 'refractory' part was prepared by salinity shock treatment of diatoms with UHQ water. This process causes rupture of the diatom cells and releases labile carbon as CO₂. 39mg of either labile or refractory diatoms were added in the fed cores. In addition, blank cores were observed as a reference. Sampling was carried out at four time intervals: at experiment set up, before feeding, at four weeks and at eight weeks after feeding.

In addition to foraminiferal counts, a core was sampled for geochemical analyses, including porewater and overlying water NO₃⁻, NH₄⁺ and DOC concentrations and fluxes, and bulk sediment C_{total}, C_{org} and N_{total} concentrations. The porewater oxygen profiles were measured periodically. Bacterial potential activity is investigated in the different treatments and at each sampling time to ensure that the activity was consistent between the cores. Plate counts are used to quantify aerobic bacteria whereas most probable number (MPN) technique is applied to determine the activity of sulphate reducers and denitrifiers.

Preliminary results indicate that the number of foraminifera increase after the feeding, in both high and low food quality settings. In addition, the microhabitat of benthic foraminifera deepens after addition of food, as the oxygen content is not limiting and more C_{org} is available. This agrees with the predictions of the TROX model. The initial assemblage is heavily dominated by *Melonis barleeanum*, however at four weeks after the feeding some species such as *Bolivina alata* and *Chilostomella oolina* start to show higher relative abundances. In addition, in the high quality setting some living foraminifera show severe signs of dissolution, which may be related to CO₂ release from the degrading labile C_{org}.

Keywords: living benthic foraminifera, organic carbon, laboratory study, bacteria

Reassessing cold-end Mg/Ca temperature calibrations of *N. pachyderma* (sin.) using paired $d^{44/40}\text{Ca}$ and Mg/Ca measurements

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Previous Mg/Ca temperature calibrations of the polar to subpolar planktic foraminifera *N. pachyderma* (sin.) were refined using a multi-proxy approach comprising $d^{44/40}\text{Ca}$, $d^{18}\text{O}$ and Mg/Ca ratios of core top samples from the Norwegian Sea. Despite thermodynamic considerations requiring an exponential temperature dependence of the Mg-uptake into foraminiferal calcite, our data fit onto a linear Mg/Ca temperature equation for water temperatures below 7°C ($\text{Mg/Ca} = 0.13T + 0.31$; $r = 0.77$, $n = 19$). This new temperature equation for high latitude *N. pachyderma* (sin.) is further verified by $d^{18}\text{O}$ derived calcification temperatures, assuming a $d^{18}\text{O}$ vital effect of 0.6‰ for core top *N. pachyderma* (sin.) as published in previous studies. However, we were not able to reproduce the very low Mg/Ca ratios in the range of 0.6 to 0.8 mmol/mol of Nürnberg (1995) at the 'cold end'. Instead, we found Mg/Ca ratios from 0.9 to 1.4 mmol/mol in foraminiferal tests precipitated in water temperatures below 3.5°C. Moreover, the general Mg/Ca-trend in foraminiferal samples originating from these cold water masses points towards increasing Mg content with decreasing temperature, forming an almost parabolic temperature calibration with lowest Mg/Ca ratios between 3 to 4°C water temperature.

Keywords: *N. pachyderma* (sin.), Ca-isotopes, Mg/Ca, Nordic Seas, multi-proxy approach

The significance of coiling direction in planktonic foraminifera

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Planktonic foraminiferal shells with trochospirally arranged chambers can exhibit either dextral or sinistral coiling. Some species show a strong preference for one coiling direction, while other species exhibit mixed coiling proportions. Recent genetic studies demonstrated that coiling direction in planktonic foraminifera with preferential coiling is a genetic trait. This concept can be exemplified by the high-latitude planktonic foraminifer *Neogloboquadrina pachyderma*, where genetic evidence shows that the two opposite coiling morphotypes diverged many millions of years ago and have distinctly different ecologies. The discovery of genetic control on coiling direction raises two important questions: (1) what is the fidelity of the genetic determinism in proportionate coiling (i.e., what is the incidence of errors) and (2) what controls coiling direction in species with proportionate coiling.

Using *N. pachyderma* as a model for biased coiling, we show evidence for a consistent, low level (< 3%) aberrant coiling associated with each morphotype, indicating that like in other organisms, non-lethal departures from the preferred symmetry occur among planktonic foraminifera. With respect to the second question, we reanalyse the largest existing dataset on coiling direction in a single species of planktonic foraminifera (the Miocene *Globorotalia scitula*), showing that the coiling direction in this species remained statistically random. This would suggest that proportionate coiling occurs in species where there is no genetic control on coiling direction. However, an analysis of recent *Globigerina bulloides* shows a more complicated pattern with a significant bias towards sinistral coiling that does not appear to be genetically controlled, nor respond systematically to environmental variation. Such pattern would imply either a genetic control biasing the coiling towards a non-extreme value or an as yet unresolved level of genetic differentiation within the population.

Keyword: planktonic foraminifera, molecular genetics, coiling direction

Impact of Panama uplift on nannofossil evolution

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The late Miocene to Pliocene closing history of the Panamanian Gateway is a turning point in earth climate, ocean circulation patterns and plankton evolution. In order to reconstruct these fundamental changes we investigate the coccolithophorid assemblages on both sides of the Isthmus, from ODP Site 1000 (central Caribbean) and ODP Site 1241 (tropical eastern Pacific) with respect to their biostratigraphy, morphometry, ecology, and geochemistry.

Here we present results of a combined quantitative biostratigraphic study of calcareous nannoplankton with Scanning Electron Microscopy and Light Microscopy. Detailed focus is taken on nannofossil evolutionary events like the paracme of *Reticulofenestra pseudoumbilicus*, the short range of *Reticulofenestra rotaria* and the extinctions of *Sphenolithus abies* and *Reticulofenestra pseudoumbilicus*. We investigate synchrony or diachrony of these events based on orbital tuned high-resolution records to identify temporal and spatial schemes, as well as the varieties between several taxa. Biometry is used to qualify intragenetic species variations, such as patterns of evolution and differences between taxa. Possible relations of floral changes to biodiversity, biogeography, ecology, and carbonate fluxes were analysed. We determine the influence of these ecological and/or evolutionary induced changes within the coccolithophorid assemblages on palaeoproductivity and palaeoceanography.

Keywords: Coccolith carbonate, Isthmus of Panama, Miocene, Pliocene, Evolution

Mid-Holocene change of benthic foraminiferal assemblages off Guadiana River (Northern Gulf of Cadiz)

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The aim of this work is to reconstruct the evolution of the middle shelf mud body in the Northern Gulf of Cadiz, using grain size analyses, benthic foraminifer's and AMS radiocarbon dating, from a 3.53m long sediment core extracted from a mid depth position in the mud body at 72 m water depth. The core shows a fining upward sedimentary trend, with muddy sands at the bottom and fine-grained mud at the top. From the base with 10400 ± 70 yr. BP to a depth of 200 cm (207 cm -9320 ± 50 yr. BP) the abundance of *Asterigerinata mamila*, *Cribronion gerthi*, *Nonionella stella* and *Bolivina ordinaria* generally decreases (Group 1) and *Epistominella vitrea*, *Brizalina spathulata* and *Cassidulina laevigata* (Group 2) presented lower abundances. From 200 until 150 cm -4170 ± 40 yr. BP, the species from group 1 continued to decrease and abundance from group 2 increases. From this depth to top the two groups presented variations with general tendency to stabilization. A dating made at 103 cm indicates 1650 ± 40 yr BP.

According to the studies in the area, the abundance of species from group 1, decreases from inner to outer shelf, and species from group 2 increases. This tendency is interpreted as a transgressive general upward trend from base until 150 cm and a relative stabilization of environment at the top. The low sedimentation rates observed between 200 and 150 cm, could be related with reduction of sediment supply, caused by rapidly increasing distance from the sediment source and by high sediment rates observed inside the Guadiana estuary between 9800 to 7000 yr. BP.

Keyword: Holocene, Gulf of Cadiz, continental shelf, benthic foraminifera

Observations on Massilina secans (d'Orbigny), 1826 in culture

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Specimens of *Massilina secans* (d'Orbigny) from the littoral of Ile d'Yeu, Biscay Bay were cultured in Petri dishes during April and May in 35 per mille salinity. Dead *Dunaliella* was given as a food. The colour of living animals was orangey-pink, with thin uncoloured pseudopodia of variable length (exceeding the length of the shell 2.5 times or less), going usually in 1-2 bunch, or all around the shell, only rarely branching at the ends, sometimes merging into a flat band or forming a straight trunk. Food particles stream along the pseudopodia to the aperture, where they form a whitish plug later becoming bright green and disappearing through 1 – 3 days. Sometimes some amount of pink cytoplasm could little protrude through the aperture. In the cases of very high salinity (up to 45 or 65 per mille) nearly all the cytoplasm of the animal is extruded from the test. When salinity changes back to normal conditions, the cytoplasm is intruded back and the animal continued to live. The animals with the protruded pseudopodia were either lying on their lateral sides or standing vertically-obliquely with their aperture turned to the bottom, in the later position they could move in the direction opposite to the pseudopodia with the velocity 2 cm in half an hour. In search of food they could climb up the dish wall and lie on the water film during several days with their pseudopodia gathering food from the surface of the water. Sometimes the shell is attached to the water film only by its aperture, the whole shell being sunk in the water but its pseudopodia on the water surface. Some of the specimens with broken chambers repaired the disturbed wall or build a new chamber, the process usually going inside the cyst.

The relationship between the 2004 spring bloom in the Baltic Sea and the feeding, growth and biogeochemistry of *Elphidium excavatum clavatum*

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A population of *Elphidium excavatum clavatum* was monitored between January and July 2004 in the Kiel Bight, western Baltic Sea. This species shows a profound reaction to the deposition of organic detritus from diatoms during the spring bloom. The detritus deposition took place in three main pulses. The foraminiferal response to the pulsed flux of organic matter to the seafloor was enhanced growth and thereafter reproduction leading to high population densities. Stable carbon isotopes and benthic foraminiferal biomass estimates indicate a considerable short-term fixation of organic carbon from the detritus deposition.

Keyword: benthic foraminifera, carbon fixation, carbon isotopes, reproduction, Baltic Sea

A millions years of shape variation of G. truncatulinoides: interplay of evolution and response to environment

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Based on molecular data, *Globorotalia truncatulinoides* includes four cryptic “species” characterised by different environmental preferences and subtle morphological differences (de Vargas et al., 2001). The complex in its modern form was established between c. 300 kyrs (differentiation of warm vs. cold water ancestors) and 130 kyrs (divergence of the cold-temperate and sub-antarctic species). Shape variations of *G. truncatulinoides* are linked to environmental changes in the last 130 kyrs. Changes in the relative contribution of the cryptic “species” within an assemblage reflect habitat tracking (Renaud and Schmidt, 2003). On longer time scales, evolutionary changes become more important in driving shape changes of *G. truncatulinoides*.

We analysed the morphometric variations of *G. truncatulinoides* using outline analyses (Fourier transform) over the last million year in two cores from the South Atlantic: a stable setting in the northern subtropical gyre (GeoB1413) and a core at Walvis Ridge with a more pronounced environmental changes due to the variable influence of the Namibian upwelling and the Benguela current.

The range of shape variation in the 1 Myr record does not encompass the extreme shape of the recent subantarctic assemblages. Some samples of the coldest core, however, are close to the oldest subantarctic sample, suggesting an evolutionary relationship. In both cores, shape variations are not related to palaeoenvironmental proxies. However, the Mid Bruhnes Event seem to have caused a morphological excursion. The lack of a relationship between shape and environment between 130-1000 kyrs may be attributed to two causes: (1) the ancestor taxon displayed little reaction to environmental changes in contrast to the shape variation after the differentiation into separate genetic entities. (2) The minor environmental fluctuations had a limited impact on *G. truncatulinoides*. These two causes are not exclusive. The increasing environmental variation likely triggered the differentiation of the ancestor *G. truncatulinoides* into more specialised descendent “species”, thus increasing the overall range of adaptation of the taxon.

Sediment transportation on the Gulf of Cadiz contourite; insights from benthic foraminiferal assemblage data

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The northern slope of the Gulf of Cadiz (southwest Iberia) is characterised by a sediment contourite drift deposited by the Mediterranean Outflow. Geochemical and coarse sediment distribution data from the Gulf of Cadiz shelf indicate that sediment deposited by the plume is supplied primarily by the rivers of Iberia. This inference is supported by the presence of the tests of benthic foraminifera typical of the continental shelf (e.g. *Elphidium crispum*, *Elphidium macellum*, *Planorbulina mediterraneensis*) within sediment samples taken from the deep water (>800m) part of the drift. In addition to confirming the major pathway taken by sediment finally deposited on the drift, the presence of abundant shelf-dwelling taxa within the coarse fraction of drift deposits suggest that sand deposited on the Gulf of Cadiz contourite must have a significant residence time on the shelf, and be supplied to the Mediterranean Outflow by mass-wasting processes. The allochthonous tests also show a distinct succession from those that are largest and heaviest (proximal) to those that are most easily transported along the declining current velocity gradient (distal), reflecting hydraulic sorting of the transported test population by the Mediterranean Outflow.

In current-influenced areas test transportation is an important factor in modifying dead foraminiferal assemblage composition, and size-distribution evidence indicates that hydraulic sorting of tests also plays a role in determining where specific elements of the allochthonous assemblage are deposited. This offers potential for un-mixing of the allochthonous and autochthonous elements in assemblages from sediment cores recovered from the Gulf of Cadiz, and in comparable sediment drift deposits elsewhere.

Microplankton and nanoplankton succession during spring bloom in the North Atlantic

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Ecologic demand and temporal position of planktic foraminifers, coccolithophores, diatoms and dinoflagellates phytoplankton succession have been assessed for the spring bloom in the eastern North Atlantic, on a north-to-south transect at 20 W. The coccolithophores *Emiliana huxleyi* and diatoms were the first groups that flourished when euphotic condition allowed new production, at complete mixing, low temperature, and high nutrient concentration at 45 N. Only one day later, diatoms had by far outnumbered coccolithophores. Another two days later dinoflagellates were most frequent at maximum chlorophyll a concentration in the vicinity of the Azores Front. Temperature, salinity, fluorescence, and distribution of macronutrients indicate that the 2004 spring bloom was fully developed between 35 -39 N, March 14-15. An open marine early spring bloom of *E. huxleyi* occurred at complete mixing of the upper 200 m of the water column. Although cell number integrated per meter square were high, dispersion caused rather low cell numbers per litre of sea water, and the bloom has not been detected by satellite imagery. Due to low abundance of zooplankton, coccolithophores are not quantitatively incorporated within faecal pellets and sedimentation of coccoliths is low. Early spring blooms of *E. huxleyi* at mid latitudes during spring they would therefore be largely underestimated from the sedimentary archive.

Key words: coccolithophores, *Emiliana huxleyi*, planktic foraminifers, spring bloom, North Atlantic

The evolutionary history of calcification in planktic foraminifers and its influence on the global carbon cycle

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The ocean absorbs a large proportion of the world's anthropogenic CO₂ emissions. As a consequence, the pH and carbonate supersaturation state of the oceans are changing to values which are rare in the geological record of the last 300 Myrs. The relative long-term stability of the pH of the oceans is a result of a feedback between biogenic production and calcite dissolution. Fluxes of carbonate to the deep ocean depend on calcification of marine plankton. Thus, an understanding of calcification processes is crucial to the accuracy of predictions of the impact of anthropogenic change. Understanding the relative contribution of the carbonate producers and how and why these change over time may provide us with tools to predict future impacts on the global carbon cycle and, hence, the pelagic feedback on atmospheric CO₂. Modern carbonate production is a snapshot of the evolutionary history of these carbonate producers. Today, foraminifers produce up to 25% of marine carbonate and 50% of the pelagic carbonate, but their contribution was negligible in the Cretaceous.

We have determined the changes in foraminiferal carbonate production during the last 100 Myrs in the Atlantic and Indian Ocean from the tropics and the mid latitudes. We have analysed Mg/Ca and Cd/Ca in these foraminifers to constrain the abiotic environmental factors which are prerequisites for high calcification. Throughout most of Cretaceous and Palaeogene, planktic foraminiferal carbonate production is negligible in comparison with coccolith carbonate production with the exception of the Maastrichtian when foraminifers briefly account for up to 40% of pelagic carbonate. The evolution towards modern carbonate production happened in two events: the first at the Eocene/Oligocene boundary, the second around the Miocene/Pliocene boundary with a reversal back to insignificant values in the Mid-Late Miocene. The first step is not paralleled by increases in foraminiferal size, whereas the second one roughly coincides with the time when sizes in foraminiferal assemblages reached ranges larger than they had been at any time before in the last 110 Ma.

Long-term changes of benthic foraminiferal assemblages in the western Baltic Sea associated with Anthropocene environmental changes

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Living benthic foraminiferal assemblages were monitored between January 2004 and March 2006 in the Kiel Bight, Baltic Sea. Depositional pulses of organic matter associated with the spring bloom 2004 were recorded by elevated pigment concentrations in the surface sediment. The foraminiferal assemblage composition remained constant but the population density of *Elphidium excavatum clavatum* increased by 500 % within a few days after organic detritus deposition. The assemblage composition was compared to earlier studies in this area. *Elphidium excavatum*, *Ammotium cassis*, and *E. incertum* dominated the living fauna in the 1960ies and 1970ies. The recent survey revealed a predominance of *E. excavatum* subspecies. Arenaceous species were not observed in samples from Kiel Fjord taken in 2005 though they were common in the 1930ies to 1990ies here. *Ammonia beccarii* was absent or rare in the Kiel Fjord during the 1940ies to 1990ies, but it was frequent in 2005. Malformations of *Ammonia beccarii* tests were common in samples close to a marina, possibly due to a high level of contaminants and environmental stress. The average population densities in the Kiel Bight and inner Kiel Fjord were 6 to 15 times higher in 2004 and 2005 than in the 1960ies to 1990ies. Persistent, high nutrient levels and recent salt-water inbursts from the Kattegat were considered as reasons for the profound change of living benthic foraminiferal assemblages in the Kiel Bight during the last 30 years.

Keyword: benthic foraminifera, environmental change, Baltic Sea

Molecular phylogeny of the Rotaliida (calcareous foraminifera) based on the complete SSU (small subunit) of rDNA (ribosomal DNA)

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In morphology-based classifications, the hyaline calcareous foraminifers are traditionally placed in the order Rotaliida or divided into two orders: the Buliminida (presence of a tooth-plate, loop-shaped aperture, high trochospiral coil) and the Rotaliida (absence of a tooth-plate, slit-like aperture, low trochospiral coil). To study the relationships between the different taxa of hyaline calcareous foraminifers, we obtained partial and complete SSU (small subunit) rDNA sequences from 59 and 23 species, respectively.

The first molecular analyses were based on 1/3 or 2/3 of the total length of the SSU rDNA. The partition Buliminida/Rotaliida was not confirmed by the molecular analysis of the SSU. Instead, four groups were observed but the analyses failed to obtain a good statistical support for the deep nodes of the phylogenetic tree. The main reason was probably a lack of genetic signal. Analysis of the complete SSU confirmed the four groups found with analyses of the partial SSU and allowed drastical improvement of the statistical support of these groups.

The monophyly of some taxa was confirmed by molecular analyses, whereas others appeared polyphyletic. Other interesting points are the high genetic homogeneity of some populations or species (e.g. *Uvigerina peregrina*), whereas other species include genetically distinct populations living in the same location, which can possibly be interpreted as cryptic species.

Keywords: molecular phylogeny, SSU rDNA, Rotaliida, benthic foraminifera, evolution

Palaeoecology of late middle Eocene planktic foraminifera and evolutionary implications

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The late middle Eocene is marked by accelerated global cooling, representing part of the long transitional interval separating the early Eocene 'greenhouse' and later Oligocene 'icehouse' climatic regimes. This time interval is also regarded as having witnessed a decline in planktic foraminiferal diversity following the extinction of most of the muricate clade (genera *Acarinina* and *Morozovelloides*) at approximately 39 Ma. Here we examine planktic foraminiferal assemblages recovered at ODP Site 1052 (Blake Nose, NW Atlantic) and, by recording a high level of taxonomic diversity including several previously undocumented morphotypes, we suggest that the diversity of late middle Eocene planktic foraminifera may have been underestimated. Depth habitats of every species within these late middle Eocene assemblages are reconstructed using oxygen and carbon stable isotope ratios. Furthermore, because stable isotope analyses suggest that species of *Globoturborotalita* appear to have generally calcified during winter months, these taxa offer, in combination with predominantly summer surface dwellers such as *Morozovelloides*, the potential to reconstruct patterns of seasonality during the late Palaeogene. Using extremely well preserved 'glassy' planktic foraminiferal calcite from a contemporaneous hemipelagic drill site, detailed SEM imaging of test microstructures and wall textures confirm that many modern features of foraminiferal ecology and test architecture had already evolved by the late middle Eocene. The common occurrence of the cancellate wall texture, combined with the wide variety of reconstructed foraminiferal depth habitats, indicates that there is no necessary relationship between foraminiferal wall textures and habitat and that wall textures are evolutionary conservative features of the foraminiferal test.

Keywords: Eocene; planktic foraminifera; taxonomy; palaeoecology; stable isotopes

Globigerinoides ruber (white) morphotype-specific stable isotope records for reconstructing upper surface water column structure in the southern South China Sea over the past 22 kyr

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Based on stable isotope data of Wang (2000) and plankton tow sampling of Kuroyanagi and Kawahata (2004), it has been shown that the two *Globigerinoides ruber* (white) morphotypes (*G. ruber* sensu stricto and *G. ruber* sensu lato) inhabit different depths within the water column. *G. ruber* s.s. is predominantly found in surface waters above 30 m whereas *G. ruber* s.l. occurs in the water column below 30 m. Mg/Ca ratios further indicate a colder precipitation temperature for *G. ruber* s.l. than for *G. ruber* s.s. suggesting that *G. ruber* s.l. calcifies at a greater depth in the surface waters than *G. ruber* s.s. (Steinke et al., 2005). Here we use *G. ruber* (white) morphotype-specific stable isotopes records in order to reconstruct changes in the upper surface water column structure in the southern South China Sea (SCS) over the past 22 kyr at IMAGES station MD01-2390 (06°28,12N; 113°24,56E; 1591 m water depth). Comparison of the stable oxygen isotope signatures of both morphotypes reveals complete separation of both morphotypes over the past 22 kyr. This suggests that a well-stratified upper water column structure prevailed in the southern SCS over the past 22 kyr. Our results contradict with the notion of previous results for stronger mixing of the upper surface water layer in the southern SCS due to intensified winter monsoon winds during the last glacial.

Keywords: *Globigerinoides ruber*, morphotypes, isotope geochemistry, last glacial cycle, South China Sea

***Pleistocene pelagic carbonate budget on Walvis Ridge (ODP LEG 208):
Distribution and preservation of Coccoliths and planktonic Foraminifers.***

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We intend to reconstruct the development of the different water masses in the SE Atlantic Ocean in a Pleistocene timescale. The current project investigates the preservation stage of planktonic foraminifers as one of the major calcareous plankton groups in order to assess the pelagic carbonate budget. An additional aim of this study is to estimate the palaeoclimatic influence on pelagic carbonate in this region. Due to the process of carbonate dissolution in the water column as well as close to or at the sediment/water interface, there is a progressive breakdown of calcareous particles. This process leads to changes in bulk sediment parameters such as the carbonate content and the distribution of the sand fraction. Analyses of a depth transect have already started on

Pleistocene material from ODP Leg 208 where foraminiferal nannofossil oozes with very high carbonate content cover the Walvis Ridge. First results show increasing carbonate dissolution with increasing water depth reflected in the decreased CaCO₃- and sand content. Preliminary results from examinations of the fine fraction with a SediGraph show a similar trend within the investigated sections; a rapid increase of the clay fraction in the older part of the cores can be noticed. First SEM analyses of the bulk sediment show a relation with a change in the assemblage of the coccoliths. *Gephyrocapsa caribbeanica* dominate the composition of the fine fraction in the older part of the cores. To compare the assemblages of the coccoliths and the foraminifers further examinations are necessary. Furthermore, a fragmentation index of broken planktonic foraminifers over whole tests will be used to describe the carbonate preservation in dependence on palaeoclimatic changes. Additionally, the use of a microbalance (accuracy of measurement $\pm 0,002\text{mg}$) for quantification of the dissolution of foraminifers is planned.

Keywords: SE Atlantic Ocean, Pleistocene, pelagic carbonate budget, preservation of planktonic foraminifers, *Gephyrocapsa caribbeanica*,

Coccolithophore assemblages as indicators for short-term climatic changes during the Late Pleistocene in the North Atlantic

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Main focus of the project is the establishment and evaluation of coccolithophores as a tool for the reconstruction of environmental conditions and their forcing factors in the North Atlantic region in the last 150.000 years. Therefore biological and chemical proxy indicators, mainly derived from coccolithophores, are used. It is well known and documented from Greenland ice core records that short term intervals of climate variability occurred within this interesting time interval of the last 150.000 years. This work wants to investigate those events using mainly the primary producers coccolithophores as a palaeoclimatic tool.

The investigations of mainly coccolithophorid assemblages are carried out on a late Pleistocene sediment sequence from the Rockall Plateau (ODP Leg 162 Site 980). The sedimentary record provides a good succession from the late Marine Isotope Stage (MIS) 6 up to MIS 1. The studies of coccolithophorid assemblages show that contents of coccolithophores rapidly increase with the beginning of MIS 5e (Eemian) and remain at relatively high contents during MIS 5, being dominated by the species *Emiliana huxleyi* and *Gephyrocapsa muellerae*. In comparison to this, coccolith contents decrease with the beginning of MIS 4, whereas *G. muellerae* disappears almost completely. During MIS 3 reworked Cretaceous nannofossils are found, which correspond with the occurrence of Heinrich events. Those changes in coccolithophore assemblages point out that coccolithophores strongly react to climatic changes. The described changes of floral assemblages indicate adaptations of species to different kinds of water masses.

The present study needs to be extended more detailed; additionally, special emphasis will be given to species specific isotope analyses in the near future. As a first step the separation of the size fraction <20µm and of the clay fraction (coccoliths <5µm) has already started. Later on, species specific separations will be performed and complement the investigations on the sediment core.

Keywords: Coccolithophores, Late Quaternary, North Atlantic, palaeoclimate

Modes of planktonic foraminiferal flux in the vicinity of the Azores Front: three sediment trap records from 33N/22W for the years of 2002-2004

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Sediment trap time series from the long-term Northeast Atlantic mooring station L1Kiel276 (including two traps at 2000m and 3000m), each consisting of 18 consecutive sampling intervals between 16 and 62 days, were investigated by means of their planktonic foraminiferal (PF), pteropod, radiolarian, and fecal pellet flux. Here, we report results from the two sampling years 2002/2003 and 2003/2004 including data on species counts of PF.

During 2002/2003 the flux of PF >125 microns at 3000m depth varied between 40 und 2532 Ind./(m^2/d) with a strong peak during spring time (end of February 2002 to the end of May), whereas during summer, PF flux is below 200 Ind./(m^2d). The second spring bloom recorded near the end of this time series for the spring season of 2003, however is much lower than that of 2002, with a maximum of <400 Ind./(m^2d) only. Furthermore, the record of 2003/2004 from the same depth of 3000m in general shows bulk and PF fluxes 1-2 orders of magnitude lower than during spring 2002 with a weak spring maximum in 2004. Faunal composition also shows significant changes for the two sampling periods: the high-flux year 2002/2003 is dominated by the species *Globigerinita glutinata*, the low-flux year 2003/2004 is dominated by *Globigerinoides ruber* (white).

Comparison of these distinct flux patterns with the long-term record of bulk flux from L1Kiel276 (Waniek et al., 2005, Deep Sea Research I) spanning eight complete annual cycles since 1993, suggest two distinct modes that also can be traced by the PF species flux and species composition. Statistical tests using neural network and modern analogue transfer function techniques from surface sediment data will help to decipher the stationarity of these modes in the faunal composition over a larger area and its importance for the reconstruction of the Azores Front from fossil PF assemblages.

Keywords: Planktonic foraminifera, northeast Atlantic, sediment traps, Azores Front, flux pattern.

Palaeoecological features of calcareous nannofossils in the Atlantic ocean during the Maastrichtian (results from ODP site 1258A and DSDP site 525A)

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Biostratigraphic and palaeoecological analyses of calcareous nannofossils have been conducted on the Maastrichtian interval of ODP site 1258A (Demerara rise, West equatorial Atlantic) and DSDP site 525A (Walvis ridge, South Atlantic). At site 1258A, the FAD of *C. kamptneri* could help the magnetostratigraphic interpretation of chrons C31n to C30n which were not subdivided. Indeed, this datum is supposed to be a reliable event, occurring almost concurrently with the C31n/C30r boundary (Self-Trail, 2001). At both sites, the following sequence of palaeoecological events was found in the upper Maastrichtian, suggesting an extreme climatic variability:

- A "cooling event" is identified inside chron C30n by the higher abundances of "cool water taxa" (*A. octoradiata*, *G. segmentatum* and *K. magnificus*)

- The decrease of these "cool water taxa" in the uppermost part of C30n, immediately followed by the disappearance of high-fertility taxon *B. constans* and by the acme of tropical taxon *Micula murus* in C29r are interpreted as a strong warming event accompanied by lowered productivity towards the end of the Maastrichtian.

This climatic evolution, evidenced by means of calcareous nannofossils, is in agreement with the evolution of stable isotopes and patterns of planktic foraminifera at site 525A (Li and Keller, 1998). The warming event prior to the K-P boundary is likely related to major Deccan trap volcanic degassing (Ravizza and Peucker-Ehrenbrink, 2003).

Keywords: calcareous nannofossils, Maastrichtian, Atlantic, Biostratigraphy, Palaeoecology

***New results from ODP and IODP on the greenhouse-icehouse transition:
Evidence for Eocene bipolar glaciation associated with global carbon
cycle changes***

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The transition from the extreme global warmth of the Eocene "greenhouse" to glacial conditions is one of the most prominent in Earth's climatic evolution, yet one of the most poorly understood. It is widely accepted that large ice sheets first appeared ~34 Ma, coincident with decreasing $p\text{CO}_2$ and a deepening of the calcite compensation depth (CCD), and that glaciation in the Northern Hemisphere began much later, between 10 and 6 Ma. In a recently published study, we presented records of sediment and foraminiferal geochemistry covering the greenhouse-icehouse climate transition from sequences recovered during recent Ocean Drilling Program Legs 199 (Paleogene Equatorial Transect) and 208 (Walvis Ridge). The carbonate content of Leg 199 and 208 sequences contain evidence for synchronous deepening and subsequent oscillations in the calcite compensation depth in the tropical Pacific and South Atlantic oceans from ~42 Ma, with a permanent deepening 34 Ma. The most prominent variations in the calcite compensation depth coincide with changes in seawater oxygen isotope ratios of up to ~1.5, suggesting a lowering of global sea level by at least 100 to 125 metres during the middle Eocene through significant storage of ice in both hemispheres. Sediment cores retrieved from the Lomonosov Ridge in the Arctic Ocean during Integrated Ocean Drilling Program Leg 302 (Arctic Coring Expedition) contain ice-rafted sand into the middle Miocene and ice-rafted pebbles into the middle Eocene, consistent with an early glacial onset in the Northern Hemisphere. We suggest that the greenhouse-icehouse transition was closely coupled to the evolution of atmospheric carbon dioxide.

Keywords: glaciation, Eocene, palaeoclimate, CCD, cryosphere

Asymmetry and the protective function of coccoliths

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The functional morphology of protists and especially planktonic protists is notoriously difficult to elucidate. Coccolithophores are a fine example of this. They produce beautifully elaborate coccospheres, but which if any aspects of the morphology are genuinely functional as opposed to being accidental outcomes of the biomineralisation process? We have previously argued with some ingenuity that the basic function of coccoliths was probably defensive. This has, however, failed to convince our colleagues and does not address the question of which aspects of morphology are functional. We recently returned to this subject and have used a combination of modelling and experimental techniques to demonstrate that coccolith structure is optimised for mechanical strength and so can provide significant protection. Asymmetry provides a further line of evidence. The primitive state for coccoliths is to show radial symmetry and departure from this has to be a product of active cellular regulation of the biomineralisation process for a functional purpose. Re-examination of all extant coccolithophores showing asymmetric coccoliths shows that asymmetry is consistently used to improve interlocking of coccoliths and increase the strength of the coccosphere. This also suggests that coccolith shape is much more intimately controlled and functionally adaptive than we have assumed.