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Welcome to INA17!

The 17th International Nannoplankton Association Conference (INA17) is being held in the Southern Hemisphere for the first time, here in Santos, Brazil, at the invitation of the Oceanographic Institute of the University of São Paulo. INA17 provides our international scientific community – being represented at this meeting by contributors from 34 countries, from Argentina to the USA, Kenya to Morocco, from across Europe and Scandinavia, Israel to Ukraine, India to Iran, and New Zealand/Australia to China and Japan – with the opportunity to present their latest research on calcareous nanofossils and living coccolithophores. The meeting has been divided into five sessions that cover different, but interconnected, themes. These range from the systematics of living organisms to palaeoclimatic reconstructions based on fossil organisms.

INA17 also offers a time for fellowship and the exchange of experiences, which are important for strengthening and growing our community of specialists. In addition, the exchange of knowledge between renowned researchers in the field with those just embarking on their studies provides an incentive for the next generation of experts. We hope you enjoy both the scientific and social programmes!

**INA17 Programme**

**Friday 13th – Sunday 15th September**

Pre-event fieldtrip (Cananéia)

**Sunday 15th September**

16:00 – 18:00 – Registration
16:00 – 18:00 – INA Council meeting
19:30 – 21:00 – Ice-breaker reception/Cocktails in the Sheraton Hotel lobby

**Monday 16th September**

09:00 – 09:20 – Opening ceremony, welcome and announcements
Convenors: Felipe Toledo & Giuliana Villa

**Session 1 – Coccoliths: What are their uses?**
Chairs: Ric Jordan & Aurea Narciso
09:20 – 09:40
* Bottini et al. – Are coccoliths waste bins for toxic elements?
09:40 – 10:00
* Holcová & Scheiner – Corrosion of coccoliths as a proxy for pH in sediments
10:00 – 10:30
* Faucher et al. – Environmental control on coccolithophore morphology: Do modern species yield information that is transferable to the geological past?

Coffee break

**Session 2 – Ecology and biology of living coccolithophores**
Chairs: Jeremy Young & Cinzia Bottini
10:50 – 11:10
* Guerreiro et al. – Transatlantic gradients in coccolithophore species fluxes: Influence of thermocline depth, Amazon water and Saharan dust
11:10 – 11:30
* Rigual-Hernández et al. – Monitoring the seasonal cycle of *Emiliania huxleyi* populations in the subantarctic Southern Ocean
11:30 – 11:50
* Hernández-Becerril et al. – Composition, abundance and distribution of coccolithophores in the Gulf of California (Mexican Pacific) during the summer, and their relation to oceanographic conditions
11:50 – Keynote talk 1
* Mariem Saavedra-Pellitero – Living on the edge: Polar coccolithophores

Lunch

**Session 2 (cont’d) – Ecology and biology of living coccolithophores**
Chairs: Karl-Heinz Baumann & Catarina Guerreiro
14:00 – 14:20
Bendif et al. – Integrating molecular genomic and palaeobiological data on the evolution of the Gephyrocapsa-Emiliania clade
14:20 – 14:40
Winter et al. – Importance of coccolithophores in the deep-ocean biomass
14:40 – 15:00
Archontikis & Young – Exploring the life-cycle of Ceratolithus cristatus Kumptner

Coffee break

15:30 – 15:50
Jin et al. – Two production stages of coccolithophores in the winter, as revealed by sediment traps in the northern South China Sea
15:50 – 16:10
Perrin et al. – Strain-specific calcification response of Gephyrocapsa huxleyi to pH change: COCCACE, a high-throughput live imaging method
16:10 – 16:30
Jordan et al. – Are Macrora and Clathropyxidella fossil siliceous haptophytes?

16.30 – 18.00 – Poster session

Tuesday 17th September

Session 3 – Palaeoecology, palaeoceanography and palaeoclimate
Chairs: Luc Beaufort & Giulia Faucher
09:00 – 09:20
Guerra et al. – Calcareous microfossils and palaeoenvironmental changes across the Cretaceous–Paleogene (K–Pg) boundary in the Cerro Azul section, Neuquén Basin, Argentina
09:20 – 09:40
Hoshina et al. – Palaeoenvironmental reconstruction of the Passerano and Marmorito (NW Italy) diatomites based on microfossil assemblages
09:40 – 10:00
Miniati et al. – The ‘Micula acme’ during Oceanic Anoxic Event 3 (Coniacian–Santonian)
10:00 – 10:20
Routledge et al. – Plankton community dynamics through the Paleogene–Neogene transition from the northwest Atlantic (IODP Expedition 342, Sites U1406 and U1411)

Coffee break

10:50 – 11:10
Shmeit et al. – The role of continental runoff versus upwelling in triggering the Weissert Oceanic Anoxic Event (mid-Valanginian): Micropalaeontological and isotopic data
11:10 – 11:30
Quadros et al. – Calcareous nannoplankton response to an AMOC shift during the last 200 kyr in the western South Atlantic
11:50 – Keynote talk 2
José Abel Flores – Scientific drilling in the South American oceans in the origin of the paradigms

Lunch

Session 3 (cont’d) – Palaeoecology, palaeoceanography and palaeoclimate
Chairs: Emanuela Mattioli & Diego-Felipe Vallejo
14:00 – 14:20
Cachao & Ramalho – Calcareous nannofossils in tsunamigenic deposits: A Cape Verde case-study
14:20 – 14:40
Cappelli et al. – Calcareous nannofossils and stable isotope records from the Early–Middle Eocene North Atlantic Ocean (IODP Site U1410): Biostratigraphy, evolutionary trends and palaeoenvironmental interpretations
14:40 – 15:00
Ma et al. – Eocene–Oligocene calcareous nannofossil assemblages and palaeoenvironmental changes in the northern South China Sea
15:00 – 15:20
Mazza et al. – Characterisation of the Helminthoid Flysch facies through calcareous nannofossil assemblage variations (Upper Cretaceous, northern Apennines, Italy)

Coffee break

15:50 – 16:10
Fonseca et al. – The Late Cretaceous
palaeobiogeography of *Braarudosphaera bigelowii*

16:10 – 16:30

**Vignano & Agnini** – Calcareous nannofossils across the Eocene–Oligocene transition at ODP Site 756 (Ninetyeast Ridge, Indian Ocean): Implications for biostratigraphy and palaeoceanographic clues

16:30 – 16:50

**Karatsolis et al.** – What drives coccolithophore productivity changes and species turnovers? A Pliocene case-study from the NW Australian shelf

16.50 – 18.00 – **Poster session**

**Wednesday 18th September**

**Session 3 (cont’d) – Palaeoecology, palaeoceanography and palaeoclimate**

Chairs: Claudia Agnini & Boris Karatsolis
09:00 – 09:20

**González-Lanchas et al.** – The role of the *Gephyrocapsa* complex in the reconstruction of atmospherically-driven water-column variability in the western Mediterranean (ODP Site 977) during Marine Isotope Stage 11

09:20 – 09:40

**Menini et al.** – Calcareous nannofossil fluxes and mass across the Paleocene–Eocene Thermal Maximum

09:40 – 10:00

**Zhou et al.** – Primary productivity dynamics in the northeastern Indian Ocean since the Last Glacial Maximum: Towards a better understanding of tropical climate change

09:00 – 11:30

**Coric & Torres-Silva** – Eocene to early Oligocene calcareous nannofossils from western and central Cuba

11:30 – **Keynote talk 3**

**Henrique Lima** – Calcareous nannofossils and Aptian marine post-salt rocks in Brazilian coastal basins: New biochronostratigraphical insights into South Atlantic evolution

Lunch

**Session 4 (cont’d) – Evolution, systematics and biostratigraphy**

Chairs: Giuliana Villa & Odysseas Archontikis
14:00 – 14:20

**Chaumeil Rodriguez et al.** – Lower Jurassic calcareous nannofossils from the Neuquén Basin, Argentina: New insights on the opening of the Hispanic Corridor

14:20 – 14:40

**de Kaenel & Bord** – Gelasian–Pleistocene calcareous nannofossil cyclostratigraphy for ODP Leg 154 (western equatorial Atlantic, north of Brazil)

14:40 – 15:00

**Nyerges et al.** – Changes in calcareous nannoplankton assemblages and the evolution of biomarkers in the Hungarian Paleogene Basin (Central Paratethys)

15:00 – 15:20

**Howe** – Ultrastructure in the Order Braarudosphaerales

Coffee break

15:50 – 16:10

**Mattioli & Abdi** – A new calcareous nannofossil record in the Lower Jurassic from Kermanshah, western Iran: A clue for evolutionary reconstructions

16:10 – 16:30

**Utsunomiya et al.** – Morphologic variation in the genus *Umbilicosphaera* from the Pliocene through Pleistocene of ODP 709C (western Indian Ocean) and 994C (northwestern Atlantic) cores

16.30 – 18.00 – **Poster session**

19:30 – Conference dinner
Session 4 (cont’d) – Evolution, systematics and biostratigraphy
Chairs: Cleber Alves & Anita Nyerges
09:00 – 09:20
Vallejo et al. – Upper Cretaceous–Cenozoic calcareous nannofossil biostratigraphy of northwestern Colombian basins
09:20 – 09:40
Chira et al. – Eocene–Oligocene calcareous nannofossils from the Transylvanian Basin (Romania): Biostratigraphy, sedimentology and palaeoecology
09:40 – 10:00
Galovic – Sarmatian (Late Serravallian–Early Tortonian) biostratigraphy: A case-study in a marginal sea

Coffee break
10:30 – 10:50
Visentin et al. – Taxonomic revision of the genus Carinolithus (Early–Middle Jurassic) based on morphometric analyses and diagenesis observations: Implications for biostratigraphy and evolutionary trends
10:50 – Keynote talk 4
Elisabetta Erba – Origin and evolution of calcareous nannoplankton during the Mesozoic: Causes and consequences

Lunch

Session 5 – Advances in nannofossil science
Chairs: Eric de Kaenel & Alessandro Menini
14:00 – 14:20
Beaufort et al. – A method for measuring coccolith thickness in polarising microscopy that is independent of light intensity
14:20 – 14:40
Young et al. – Nannotax and mikrotax, an evolving system for palaeoinformatics

Coffee break
15:10 – INA Business meeting and Closing ceremony

Friday 20th – Monday 23rd September

Post-event fieldtrip (Ubatuba)

Invited speaker keynote talk summaries

Mariem Saavedra-Pellitero
Living on the edge: Polar coccolithophores
This talk will tackle the increasing interest in coccolithophore and calcareous nannofossil ecology at high latitudes. Polar plankton communities are already experiencing the impacts of global warming and the acidification of ocean surface waters. As coccolithophores calcify and photosynthesise, they exert a major influence on the global carbon cycle. The audience will gain a better understanding of the changes taking place in these iconic regions, where coccolithophores dwell amongst some of the earth’s most extreme conditions. The latest findings from International Ocean Discovery Program Expedition 383 (May–July 2019) will be presented. This expedition investigated Pliocene–Pleistocene atmosphere-ocean-cryosphere dynamics of the Pacific Antarctic Circumpolar Current, and their roles in regional and global climate and atmospheric CO₂.

José-Abel Flores
Scientific drilling in the South America oceans in the origin of paradigms
Scientific drilling began in the 1960s, with projects like MOHOLE and the Deep-Sea Drilling Project, in the environs of the South American oceans. The material extracted and the data generated allowed us to test seafloor spreading. Later, in the equatorial Pacific, the orbital theory of Milankovich was determined from the sedimentary record via new initiatives, such as the Ocean Drilling Program. These are two of the outstanding paradigms tracked today in geology. To carry out these discoveries, the development of new biostratigraphical scales were determinant, particularly those developed using calcareous nannofossils. This is a small tribute to those pioneers of the study of our beloved coccoliths and their seas.
Henrique Lima
Calcareous nannofossils and Aptian marine post-salt rocks in Brazilian coastal basins: New biochronostratigraphical insights on South Atlantic evolution

Current chronostratigraphic charts from the Santos, Campos and Espírito Santo Basins point to an Albian age for the post-salt rocks that comprise the first strata of the early South Atlantic Ocean. Consequently, the pre-salt oil-fields have been considered to be Aptian or older, once they are above the evaporites. On the other hand, new biostratigraphical data, provided by samples from deep- and ultra-deep-water drilling campaigns, have revealed a microfossil association older than previously recovered. Between these, the calcareous nannofossil associations in these intervals contain occurrences of *Nannoconus troelsenii* and *Braarudosphaera pseudobatilliformis*. Nannofossil, palynological and microfacies analyses have allowed the calibration of nannoconids, miospores, organic- and calcareous-walled dinoflagellates, and calpionellids. These bioevents, sometimes recognised up to 800 m above the evaporites, suggest relatively deep marine conditions that are 5 to 10 Myr older than previous assumptions.

Elisabetta Erba
Origination and evolution of calcareous nannoplankton during the Mesozoic: Causes and consequences

The geological history of calcareous nannoplankton indicates that the Mesozoic evolution of this group has been characterised by a general increase in diversity, punctuated by speciations, mass extinctions and turnovers. Times of accelerated rates and/or drops in nannofossil diversification partly correlate with global changes in the geosphere, hydrosphere and atmosphere, suggesting that these evolutionary patterns are intimately linked to environmental modifications. In particular, the most significant events in Mesozoic nannoplankton origination and evolution are correlatable with changes in pCO₂, nutrient availability, the chemistry of the oceans, climate and sea-level fluctuations. However, it is difficult, if not impossible, to separate single causes that have triggered and/or inhibited coccolithophore production and evolution. Rather, a combination of various environmental modifications seems to have been responsible for evolutionary innovations and stability. Global environmental changes are intimately interconnected with, and determined by, processes operating inside the earth and, therefore, we should link biosphere evolution to Earth’s interior. Calcareous nannofossil diversity, diversification and extinction rates represent an incomplete record of nannoplankton history and potential environmental impacts/pressures. Species richness alone cannot measure the productivity-production of coccolithophores through time. Moreover, improved dating (high-resolution stratigraphy and more precise radiometric ages) of various geological events is crucial for timings and correlations, and will greatly contribute to the understanding of the Mesozoic evolutionary history of calcareous nannoplankton.

**Posters**

*Abe et al.* – A new species of *Hyalolithus* from Upper Miocene sediments in Sicily

*Austin et al.* – Palaeoproductivity changes and upwelling dynamics in the Iberian margin driven by abrupt deglacial climate variability

*Baumann et al.* – Calcareous plankton fluxes in the upwelling area off NW Africa (Cape Blanc): Dynamics and trends from selected sediment trap series over the past 25 years

*Belia et al.* – Record of Late Eocene to Early Oligocene calcareous nannofossils from the lower part of the Pisco Basin, west central Peru

*Bruno et al.* – Albion–Cenomanian calcareous nannofossils from DSDP Site 364 (Kwanza Basin, Angola): Biostratigraphic implications for the South Atlantic

*Bruno et al.* – Late Cretaceous (Coniacian–Maastrichtian) calcareous nannofossils and ostracods from the São Paulo Plateau (DSDP Site 356): Biostratigraphic implications

*Concheyro et al.* – Late Cretaceous (Campanian–Maastrichtian) calcareous nannofossils from ODP Site
762: Evolution of the genus *Eiffellithus*

**El Mehaghag et al.** – Nannofossil biostratigraphy of the Neogene in the offshore A1-89 well, NE Libya

**Ferrarese et al.** – Coccolithophore assemblage variation and its relation to palaeoproductivity changes in the western South Atlantic during the last 14 kyr

**Fioroni et al.** – Biostratigraphic distribution of Miocene carbonates associated with gas hydrates in the northern Apennines (Italy) and their relationship with sea-level lowering

**Fioroni et al.** – Middle Eocene to Late Oligocene climate variability: A new integrated calcareous nannofossil and magnetostratigraphic record from the equatorial Indian Ocean

**Fonseca & Cachão** – How old is *Braarudosphaera bigelowii*? The evolution and acceptance of scientific claims and what the sociology of science can say

**Gonçalves et al.** – Contribution of coccolithophores to carbon burial during the Late Quaternary at the southern Brazilian continental margin

**González-Lanchas et al.** – Updates on the calcareous nannoplankton biostratigraphy of the Lutetian to Lower Priabonian strata in the Jaca Basin (southern Pyrenees, Spain).

**Granchovski** – Calcareous nannofossil and stable isotope stratigraphy of the Upper Campanian–Maastrichtian in NW Bulgaria (SE Europe): Preliminary results

**Gutierrez-Puente et al.** – Microfacies analysis and integrated biostratigraphy from an Aptian–Albian section in the Tamaulipas Formation, western Hidalgo State, Mexico

**Hernandez-Almeida et al.** – Quantitative reconstruction of primary productivity in low latitudes during the Last Glacial Maximum and the mid- to Late Holocene from a global *Florisphaera profunda* calibration dataset

**Hirama et al.** – Surface productivity variation based on coccolithophore assemblages in the Santos Basin during the last 35,000 years

**Holcová et al.** – Use of artificial intelligence to identify nannoplankton species

**Hoshina et al.** – Palaeoceanographic implications for the closure of the eastern Tethys Ocean based on calcareous nannofossils from southern Tibet

**Jaques et al.** – Nannofossils used to determine the provenance of artworks

**Kulhanek et al.** – Calcareous nannofossils from IODP Expedition 374 to the Ross Sea, Antarctica

**Leonhardt et al.** – Coccolithophore carbonate contribution to the ocean floor on the southern Brazilian continental margin

**Mahanipour & Hassani Sadi** – Calcareous nannofossils at the Aptian–Albian boundary in the Zagros Basin (SW Iran)

**Mahanipour & Rajaiian** – Eocene–Oligocene calcareous nannofossils in the Zagros Basin (SW Iran)

**Matias** – Characterisation of Upper Cretaceous geological formations in the south-central Pyrenees based on calcareous nannofossils

**McKnight et al.** – Biostratigraphy in the Foz do Amazonas Basin: A multidisciplinary approach

**Mendes et al.** – Reconstructing palaeoproductivity in the western South Atlantic since the Last Glacial Maximum: An integrated study using coccoliths and benthic foraminifera

**Millan & Winter** – Direct and indirect evidence of coccolithophore activity in the deep euphotic zone: A review

**Molina et al.** – *Calcidiscus* size variation and correlations with palaeoproductivity and
palaeotemperature proxies in the Santos Basin during the last 14,000 years

Motta et al. – Preliminary results on Miocene–Pliocene calcareous nannofossils from the Rio Grande Rise and Vema Channel (DSDP Leg 72, Sites 516A and 518, SW Atlantic Ocean): Biostratigraphy and palaeoecological inferences

Monechi et al. – The Paleocene–Eocene Thermal Maximum in the Río Gor section (southern Spain): Microcodium-rich turbidites give new insights on Mediterranean climate

Narciso et al. – Biodiversity of extant coccolithophores in Macaronesia (northeast Atlantic Ocean)

Pedrão et al. – Coccolithophore biogeography and its relationship to environmental variables in western South Atlantic surface sediments

Pedrão et al. – Coccolithophore palaeoproductivity variations related to hydrographic changes from the Last Glacial Maximum to the Holocene in the western South Atlantic Ocean

Pedrosa et al. – Biostratigraphic study of Palaeogene calcareous nannofossils from DSDP Leg 39, Site 354, Ceara Rise, equatorial Atlantic

Persico et al. – Calcareous nannofossil biostratigraphy of the External Dinarides Flysch (Vrčić-Staravasa Pag Island, Croatia): Key to an Eocene tectonostratigraphic and palaeoenvironmental interpretation

Rigual-Hernández et al. – A revision of silicoflagellate species composition in the western Mediterranean inferred from sediment traps

Rigual-Hernández et al. – Modern silicoflagellate assemblages as indicators of the primary hydrological zonal systems of the Southern Ocean

Rivas et al. – Calcareous nannoplankton thanatocoenosis distribution in the southwestern Atlantic Ocean: New evidence in the western Malvinas Current gyre

Saavedra-Pellitero et al. – Calcification and latitudinal distribution of extant coccolithophores across the Drake Passage during late austral summer 2016

Saino et al. – Studies on fossil silicoflagellate assemblages from North America

Sander et al. – Pliocene–Holocene calcareous nannofossils from the Sergipe-Alagoas Basin (Piston Core SA5-0033): A preliminary study

Stoykova et al. – Variations in calcareous nannofossil assemblages during the Paleocene–Eocene transition on the Moesian Platform, Bulgaria: Constraints and significance for a low- to mid-latitude record of the PETM

Strack & Baumann – Development and occurrence of Emiliania huxleyi morphotypes in the North Atlantic Ocean during the last 270,000 years

Tangunan & Menapace – Constraining the Fantangisña serpentinite mud volcano (Mariana Forearc) episodicity using calcareous nannofossils

Tomazella et al. – Biogenic carbonate composition throughout the last 140 kyr in pelagic sediments of the western South Atlantic

Trejos-Tamayo et al. – MicroRange, a tool for determining the stratigraphic distribution and geologic age of microfossils

Tsutsui et al. – Coccolithophore and silicoflagellate assemblages in the East China Sea and Japan Sea

Tungo et al. – Albian–Cenomanian (Cretaceous) calcareous nannofossils from DSDP Site 364, Bacia de Kwanza, Angola

Uezato & Jordan – Quaternary silicoflagellate assemblages from the subarctic Pacific

Utsunomiya et al. – Morphological variation in the genus Umbilicosphaera from the Pliocene through Pleistocene of ODP 709C (western Indian Ocean) and
994C (northwestern Atlantic) cores

Waga et al. – Preliminary nannofossil biostratigraphic results from the Mariakani Formation, onshore Lamu Basin (SE Kenya)

Zhang et al. – The trigger for the mid-Brunhes coccolithophore bloom: New evidence from coccolith assemblages and geochemical and morphological data
A new species of Hyalolithus from Upper Miocene sediments in Sicily

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In modern oceans, diatoms are the most important primary producers involved in the biogeochemical cycling of silica. However, the role of other siliceous phytoplankton may have been severely underestimated due to the tiny and delicate mineralised structures that make up their cell coverings. These structures were once considered to be too dissolution prone to be preserved in the underlying sediments, but it is now known that they may be preserved under exceptional conditions. So, a thorough investigation of these smaller siliceous components in a wide range of marine sediments is warranted in order to improve our knowledge of their palaeodiversity.

Following the identification and subsequent study of Hyalolithus, a living siliceous haptophyte (Yoshida et al., 2006; Jordan et al., 2015), fossil specimens were encountered in Middle Eocene tropical/subtropical sediments (Abe et al., 2016). This latter discovery suggested the possibility of finding additional specimens in other time intervals. As part of our ongoing studies of fossil silicoflagellates, we conducted a detailed LM/SEM investigation of the type materials of Ehrenberg (notably Late Miocene samples from Caltanissetta, Sicily). These samples contained the siliceous scales of a new species of Hyalolithus, which possesses two peaks of differing size and, as yet, no ‘tumor’-like structure.

References
Exploring the life-cycle of *Ceratolithus cristatus* Kamptner

**Odysseas A. Archontikis, Jeremy R. Young**

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Coccolithophores are characterised by a heteromorphic life-cycle that is composed of two morphologically distinct phases, one haploid and commonly holococcolith-producing, the other diploid and bearing heterococcoliths. The life-cycle association of *Ceratolithus cristatus* Kamptner, however, traditionally involves a heterococcolith-producing phase that occurs simultaneously with a nannolith-bearing phase, and it has been described as producing three different types of calcareous structures (Alcober & Jordan, 1997; Young et al., 1998). The nannolith-constructed phase of *C. cristatus* is represented by horseshoe-shaped ceratoliths, whereas the heterococcolith-bearing phase is associated with either hoop-shaped interlocking heterococcoliths or overlapping planolith-type heterococcoliths that bear a central opening surrounded by a collar.

During IODP Expedition 359, several plankton samples were acquired from the Maldives surface waters, most of which were subsequently studied via SEM. Two samples, Plkt-38 and Plkt-45, which were retrieved on the 20th and 24th of November, 2015, respectively, revealed the existence of several *C. cristatus* combination coccospheres, two of which bore all three morphologically distinct coccolith types – horseshoe-shaped *C. cristatus* var. *telesmus* ceratoliths, delicate hoop-shaped coccoliths and circular *Neosphaera coccolithomorpha* var. *coccolithomorpha* Lecal-Schlauder planoliths. These findings, combined with similar observations of different *Ceratolithus* morphotypes from the Canary Islands (Sprengel & Young, 2000) and the NW Mediterranean Sea (Cros & Fortuño, 2002), provide further evidence to associate the *C. cristatus* HET *nishidae* and the *C. cristatus* HET *coccolithomorpha* forms with, respectively, *rostratus*-type and *telesmus/cristatus*-type ceratoliths. This allows a simplification of the taxonomic terminology for these forms. We also discuss the potential role of hoop-shaped coccoliths in the *Ceratolithus* life-cycle and the role of the hoops in its biomineralisation process.

**References**


Palaeoproductivity changes and upwelling dynamics in the Iberian margin driven by abrupt deglacial climate variability

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Variations in primary productivity (PP) and the upwelling system dynamics on the SW Iberian margin for the last 28 kyr were assessed by combining nannofossil, X-ray fluorescence, ice-rafted debris, and stable carbon and oxygen isotope record data from a very well-dated sediment core. Centennial variations in upwelling and the related productivity were proven to be controlled primarily by hydrographic and environmental conditions that were the result of abrupt deglacial climatic events.

Overall, a good correlation among higher PP, shallower nutricline and upwelling reinforcement was observed for the Last Glacial Maximum, Bolling-Allerød and Late Holocene. Conversely, lower PP, deeper nutricline and upwelling weakening/absence were observed during the cold Heinrich Stadials 2 and 1 and the Younger Dryas, and the warmer Early and mid-Holocene.

The highly-detailed records presented here allowed documentation of palaeoproductivity changes and upper water-column dynamics never observed before. For instance, this is the first time, to our knowledge, that the impact of the internal complexity of Heinrich events has been found in palaeoproductivity proxies. Further work at higher resolution (i.e. a multi-decadal timescale) will help unambiguously unravel the sequential order of events that impacted surface hydrography and productivity during these periods.
Calcareous plankton fluxes in the upwelling area off NW Africa (Cape Blanc): Dynamics and trends from selected sediment trap series over the past 25 years

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Coccolithophore-derived carbonate fluxes were determined from four time intervals (1989/90, 1998/99, 2002/03 and 2008/09) off Cape Blanc (21°15’N, 20°45’W) in the filamentous mixing area of one of the prominent eastern boundary upwelling systems. The sediment-trap data, collected at 3600 m water depth, revealed seasonal and interannual changes in species fluxes and assemblage composition, as well as long-term trends in total carbonate fluxes (also including planktonic foraminifera and pteropods).

The study and comparison of the selected time intervals, which were not influenced by any major climatic oscillations, such as the North Atlantic Oscillation, the El Niño-Southern Oscillation or the Atlantic Meridional Overturning, revealed variable flux patterns that reflect the prevailing hydrographic conditions of this dynamic, offshore, upwelling region. Seasonal variations, both in species fluxes and assemblage compositions, occurred in the most prominent calcareous groups, whereas interannual fluctuations were less obvious and, in this case, all groups showed a surprisingly constant flux pattern, with only small variations. The coccolithophore assemblages were dominated by *Emiliania huxleyi*, lower-photic-zone species (mainly *Florisphaera profunda*) and gephyrocapsids. The coccolith flux was generally the highest during the winter/spring and early fall (up to $500 \times 10^7$ m$^{-2}$ d$^{-1}$), whereas it was reduced during the summer and late fall. The highest fluxes of planktonic foraminifera (up to 50 mg m$^{-2}$ d$^{-1}$) were observed during the summer (predominantly species preferring cooler water conditions) and winter (warm-water species). The pteropod flux showed the most constant pattern over the years, with distinct maxima (up to 180 mg m$^{-2}$ d$^{-1}$, <1 mm fraction) in the late summer and minima in the winter. No long-term trend of any carbonate producer was observed. The organism fluxes, as well as the general compositions of the assemblages, have not changed, and the calculated carbonate fluxes of the major plankton groups (even aragonitic pteropods were observed in quite constant numbers) gave no evidence of an increasing influence of ocean acidification or any ecosystem change.
A method for measuring coccolith thickness in polarising microscopy that is independent of light intensity

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The birefringence characteristics of coccoliths in polarised microscopy have been used to estimate their mass with linear polarisers (Beaufort, 2005), rotating polarisers (Beaufort et al., 2014) and circular polarisers (Bollmann, 2014; Fuertes et al., 2014). This method is rapid and precise. Camera sensors produce reliable measurements of light that can be converted into thickness. This general methodology has been validated by recent independent measurements made by X-ray tomography at the European Synchrotron Radiation Facility (Beuvier et al., 2019). One of its limitations is that it requires a precise calibration of the microscope brightness. The light intensity, the diaphragm opening, the position of the condenser and the exposure time of the camera have to be strictly identical during the calibration and analysis of the calcite crystal. A slight change in one of these parameters significantly alters the results. Another limitation is that the measured light intensity is not linearly proportional to thickness, but follows a sigmoidal pattern (Beaufort et al., 2014; Bollmann, 2014), making it difficult to estimate thickness precisely at the two ends of the calibration. The use of standard polychromatic light introduces small imprecisions related to the temperature of the light used. There is a theoretical limit to the thickness estimation of around 1.56 µm when using a black and white camera. Here, we propose a new method that solves these problems. The estimations are independent from any calibration or precise tuning of the microscope and light. The calcite thickness results from a simple equation that can be applied to crystals as thick as 2.0 µm. It is based on the alternative use of one left circular polariser and one right circular polariser with a monochromatic light source.

References
Record of Late Eocene to Early Oligocene calcareous nannofossils from the lower part of the Pisco Basin, west-central Peru

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The East Pisco Basin contains a Cenozoic sedimentary record of the Andean Foreland and is one of the few known onshore outcrops that records nannoplankton in the eastern equatorial Pacific region. Previously published studies on Eocene–Oligocene calcareous nannofossils in the basin (Marty et al., 1988; Dunbar et al., 1990; DeVries et al., 2006) contain no detailed biostratigraphic analyses. Models for the basin would be enhanced by increasing the resolution and extent of the biostratigraphic work.

This study presents a calcareous nannofossil biostratigraphic interpretation from one unit with no previously established age or formation assignment in the Pisco Basin. We collected samples of fine-grained calcareous sediments that onlap the east end of an extension of the Cerros Media Luna. The section is laterally within 180 m of the contact of sedimentary rocks with the basement. Semiquantitative data and relative abundance counts of the 30 nannofossil taxa identified indicated rare to common occurrences with poor to moderate preservation. The assemblages comprised primarily Coccolithus pelagicus, Cyclicargolithus floridanus, Ericsonia formosa, Helicosphaera compacta, Isthmolithus recurvus, Micrantholithus sp., Reticulofenestra bisecta (<10 µm), R. dictyoda (4–10 µm), R. lockeri, R. minuta (<3 µm), R. stavensis (5–10 µm), and R. umbilicus. Because most of the discoasters showed strong recrystallisation, a confirmed identification of Discoaster saipanensis was not possible. The occurrence of E. formosa and I. recurvus in the assemblage suggests an age of Late Eocene to Early Oligocene, Zones NP19–NP20 to Zone NP21 (Martini, 1971). This study documents the first biostratigraphic work on Eocene–Oligocene calcareous nannofossils in the Pisco Basin, thus contributing to the baseline data on nannoplankton assemblages for low latitudes in the eastern equatorial Pacific region.

References
Integrating molecular genomic and palaeobiological data on the evolution of the *Gephyrocapsa-Emiliania* clade

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Most Quaternary and modern coccolithophore assemblages are dominated by the Noelaerhabdaceae, especially the genera *Gephyrocapsa*, *Emiliania* and *Pseudoemiliania*. They include key bloom-forming species, underpin Quaternary biostratigraphy, and have been extensively studied in cultures. The combination of their rapid recent evolution, enormous abundance in both the fossil record and the modern ocean, and ready accessibility for laboratory study make them a very attractive study group for microevolutionary studies. Indeed, they are one of the most accessible groups for integrating molecular and palaeontological approaches to plankton evolution. However, molecular genetic studies have long proven to be problematic. Studies of slow-evolving genes, such as 18S rRNA, have failed to produce any useful data because well-established species, such as *Gephyrocapsa oceanica* and *Emiliania huxleyi*, have proved to have identical gene sequences. Conversely, studies of fast-evolving genes have produced contradictory results and suggestions of complex interactions of hybridisation and inherited polymorphism (e.g. Bendif et al., 2014).

However, new data from whole-genome sequencing has largely resolved these problems. Whole-genome sequencing allows evolutionary inferences from hundreds of genes to be compared and, from this work, a clear synthesis has emerged. On one hand, the classic extant morphospecies are well supported. On the other hand, the entire set of extant species is closely related, and a molecular clock interpretation, based on the well-established first occurrence of *E. huxleyi*, suggests that the clade diversified from a common ancestral population ca. 500 ka ago. This suggests that the generic distinctions are inflated and arguably untenable. More significantly, the evolutionary pattern inferred from molecular genetic data can be directly compared to that from the fossil record (e.g. Samtleben, 1980; Matsuoka & Okada, 1990). It appears that the size-reduction event (extinction of *Gephyrocapsa omega/Gephyrocapsa* sp. C), which has been observed in multiple geological studies, corresponds to the base of the radiation of the modern *Gephyrocapsa-Emiliania* clade. By extension, it appears highly likely that previous size-reduction events in the reticulofenestrid record were similarly significant macroevolutionary events. Moreover, the pattern suggests that evolutionary turnovers were both abrupt and occurred via sympatric, rather than allopatric, evolution.

References


Are coccoliths waste bins for toxic elements?

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Over the last few decades, several works have been dedicated to the study of coccolithophore mineralisation, including the factors that can alter it. Deciphering the regulating mechanisms of calcification under normal and stress conditions is fundamental to forecasting the evolution of the present-day ocean/atmosphere system. Although important advances in the understanding of biocalcification have been made, and we have information regarding how coccolith Sr/Ca and Mg/Ca values change with environmental conditions, very little is known about trace-element concentrations in coccoliths. The primary aim of this work was, therefore, to detect which elements, if any, enter into the calcite structure during coccolithogenesis. Because coccoliths are produced intracellularly, it is possible that some elements are incorporated into the calcite, and that their presence is related to the water composition in which the coccolithophore lived. If so, these elements could be important environmental tracers. We investigated the elemental composition of specimens of Coccolithus pelagicus and Gephyrocapsa oceanica that were cultured in a controlled environment under ‘normal’ conditions and excess trace-metal (V, Ni, Pb, Zn) concentrations. Isolated specimens were studied at a resolution of 50 nm using X-ray fluorescence (XRF), performed at the European Synchrotron Radiation Facility in France.

The XRF analyses showed that, in addition to Ca and Sr, there were other trace elements that displayed distribution patterns different from Ca. Some elements (e.g. S and Se) had a homogenous distribution and were involved in cell and/or calcite growth. Others were localised, including Cl and ‘toxic’ metals (V, Ni, Pb, Zn). Their concentrations were proportional to those used in the cultivation solution, and may reflect their incorporation into the coccolith calcite or deposition on the coccolith surface. Thus, the preliminary data from this study suggest that some of the elements present in the cultivation solution interact with coccolithogenesis. However, further analyses are required to understand if their presence is systematic and if they can be used as environmental proxies.
Taxonomic revision of Late Paleocene Heliolithaceae

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The taxonomic relationships and characteristics of some Late Paleocene nannofossil species are not sufficiently understood, so that any associated biostratigraphic zonations may be difficult to apply in practice. We analysed Upper Paleocene samples that were collected from several globally-distributed core and outcrop sections to resolve the taxonomic issues existing in the family Heliolithaceae. This study primarily used DSDP/ODP/IODP samples, but included some samples from onshore Turkey (Kokaksu). We utilised a mobile-mounting technique to facilitate identification and an understanding of the main taxonomic groups that exist in the Heliolithaceae. This technique makes it possible to map all (side-)views of various species. Through mapping of the different profiles of Heliolithaceae, we identified four unique groups that can be separated on the basis of characteristics of, and relationships between, the column and the general cycle(s) (e.g. distal and proximal).

The identified groups were either placed into the appropriate genera based on correspondence with existing taxonomic descriptions or, as necessary, into a new genus. Three of the identified groups were placed into *Heliolithus*, *Heliotrochus* and *Bomolithus*, which are generally defined as possessing a structure consisting of one or more cycles and a central column, each of which displays a diagnostic birefringence pattern. In this group, *Heliolithus* has one cycle, *Heliotrochus* exhibits two cycles of different diameter and *Bomolithus* has two cycles of equal diameter. A new genus has been identified as the fourth group, which possesses a structure consisting of one non-birefringent cycle and a birefringent column.

In addition to the above revisions, *Bomolithus bramlettei* will be assigned to the new genus because this species is a placolith with a vestigial proximal shield. Also, *Bomolithus supremus* should be assigned to *Coccolithus* because this species is a placolith with a narrow proximal cycle/shield. Finally, *Discoasteroides megastypus* has been retained because this species is a rosette-shaped discoaster with a birefringent process.
Late Cretaceous (Coniacian–Maastrichtian) calcareous nannofossils and ostracods from the São Paulo Plateau (DSDP Site 356): Biostratigraphic implications

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Micropalaeontological studies conducted on DSDP drill cores in the 1970s and 1980s in the South Atlantic are considered to be important references, especially sites such as those from the São Paulo Plateau. Carminatti et al. (2008) predicted that petroliferous activity in Brazil would be focused on deep-water Cretaceous deposits, making it necessary to reinterpret previously-established biostratigraphic zonations for these areas. This work presents a biostratigraphic study of calcareous nannofossils that were identified from 66 smear-slides of sediments found in the basal section of the core drilled in the offshore Site 356, DSDP Leg 39, in the southeastern portion of the São Paulo Plateau. These samples were also prepared for ostracods, with the objective of calibrating ostracod ages with calcareous nannofossil ages. A total of 140 nannofossil taxa and 34 ostracod species were identified. The nannofossil assemblages were diverse and abundant, with preservation varying from moderate to good, and were dominated by *Watznaueria barnesiae*, *Micula staurophora*, *Prediscosphaera cretacea* and *Cribrosphaerella ehrenbergii*. In contrast, ostracods were rare and poorly preserved, frequently fragmented and weathered, and the most diverse genera were *Cytherella*, *Krithe* and *Bythocypris*. Following the zonation proposed by Burnett et al. (1998), five calcareous nannofossil biozones were identified from the Late Turonian to the Late Maastrichtian, and the top of the section was Danian in age – Zones UC10, UC11, UC15c, d, e), UC19 and UC20a, b, c, d. Two of the identified ostracod species have biostratigraphic value (*Dutoitella mimica* and *Phacorhabdotus subtridentus*), which reinforced the nannofossil ages. The project was sponsored by the IODP/CAPES grant 8888.091703/2014-01.

References
Albian–Cenomanian calcareous nannofossils from DSDP Site 364 (Kwanza Basin, Angola): Biostratigraphic implications for the South Atlantic

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The Early Cretaceous is described in the literature as the last expression of the Gondwana fragmentation, thus representing a fundamental time interval for understanding the geological evolution of the South Atlantic (e.g. Kennedy & Cooper, 1975; Koutsoukos & Dias-Brito, 1987). In the South Atlantic, biostratigraphic studies using calcareous nannofossils are scarce, and the zones utilised for them are outdated in light of current knowledge regarding Albian guide species. Important taxonomic revision studies of the guide species Prediscosphaera cretacea and Eiffellithus turriseiffelii have been published (e.g. Kennedy et al., 2000; Watkins & Bergen, 2003), which significantly aid in the identification of these species, and thus refine their use in biostratigraphic interpretations. This study analysed 72 samples from Site 364 of DSDP Leg 40, which was drilled in the Kwanza Basin, Angola. According to Bolli et al. (1978), the studied interval is composed predominantly of limestone and black shales from cores 42 to 26. Smear-slides were prepared following the double slurry method (Watkins & Bergen, 2003). The biostratigraphic analysis was based on Sissingh (1977), Perch-Nielsen (1979, 1985), Bown et al. (1998) and Burnett et al. (1998). A total of 103 taxa were identified. The basal interval contains Prediscosphaera columnata and the bases of Hayesites albiensis, Tranolithus orionatus, Axopodorhabdus biramiculatus and Eiffellithus monechia, which indicate an Albian age. The stratigraphic interval between the base of Eiffellithus turriseiffelii and the top of Watznaueria britannica was interpreted as Late Albian–Early Cenomanian. A Middle–Late Cenomanian age was inferred by the occurrences of Cretarhabdus striatus, Eiffellithus perch-nielseniae, Rhagodiscus asper and A. biramiculatus. The observed assemblages have a subtropical-tropical affinity, which can be considered indicative of the Albian–Late Cenomanian interval and of a surface-water connection between the central and South Atlantic segments. This project was sponsored by IODP/CAPES grant 8888.091703/2014-01.

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Calcareous nannofossils in tsunamigenic deposits: A Cape Verde case-study

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Calcareous nannofossils have been used with a variable degree of success in the study of tsunamigenic deposits (e.g. 1755 historical Lisbon; 2004 Lhok Nga, Sumatra, Indonesia; 2011 Sendai Plain, Japan; Andrade et al., 2003; Paris et al., 2010; Szczucinski et al., 2012). Under the project UNTieD (unlock the megatsunami deadlock), which focuses on the study of tsunamigenic deposits in the context of the Macaronesia region of the Cape Verde Archipelago, field samples were collected from several potential tsunamigenic sedimentary units on Santiago Island (northern and southwestern sectors) and processed according to a new sample preparation method (under development) in order to study and interpret the nannofossil content in coastal settings. Preliminary results, including a new, biogenic micron-sized nannolith description, will be presented.

References


Calcareous nanofossils and stable isotope records from the Early–Middle Eocene North Atlantic Ocean (IODP Site U1410): Biostratigraphy, evolutionary trends and palaeoenvironmental interpretations

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The Early Eocene climatic optimum (EECO, 53–49 Ma; Westerhold et al., 2018) witnessed a fundamental change in calcareous nanofossil assemblages as the Paleocene Princeinae family declined to extinction and was replaced by the extant Noelaurhabdaceae family (i.e. reticulofenestrids) that likely expanded in response to global cooling and water-column destratification (Schneider et al., 2011). We present integrated calcareous nanoplankton and bulk stable isotope records (δ^{18}O and δ^{13}C) across the Early–Middle Eocene interval (~52–43 Ma) from IODP Site U1410 (northwest Atlantic; Norris et al., 2012), where Middle Eocene deposits occur as clay-rich drift sediments that reflect the formation of persistent deep currents in the North Atlantic (Boyle et al., 2017). Using both light and scanning electron microscopy, this study has: 1) strengthened the calcareous nanofossil biostratigraphy for this interval; and 2) benefited from the exquisite preservation of nannofossils in the clay-rich drift sediments in their ability to provide evolutionary models for the biostratigraphically-significant Coccolithus gigas and Sphenolithus furcatolithoides groups. In addition, our assemblage data clearly show a major switch from Early Eocene warm, oligotrophic communities with high abundances of the genera Zygrhablithus and Discoaster to a Middle Eocene temperate, eutrophic community that was dominated by Reticulofenestra species. This transition is associated with slightly higher δ^{18}O values that likely indicate a transient cooling interval between the end of the EECO and the Early–Middle Eocene boundary. A restoration of warmer conditions characterised the lower part of the Middle Eocene, which is marked by negative stable isotope excursions, an increase in Discoaster sublodoensis, and major changes in the sphenolith assemblages. A comparison of our results with different datasets highlights an enigmatic scenario, in terms of the bio-chemo-magnetostratigraphy and assemblage shifts across the Early–Middle Eocene transition, and future work will serve to trace a clearer global picture of this interval.

References
Lower Jurassic calcareous nannofossils from the Neuquén Basin, Argentina: New insights on the opening of the Hispanic Corridor

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The existence of a marine connection between the Tethys and Panthalassa Oceans has been a topic of debate for a long time. Ziegler (1971) first proposed the existence of a seaway (the Hispanic Corridor) in the Early Jurassic, but the precise timing of its opening is still undefined. Consensus set the Early Pliensbachian as the age of this event, but most studies were conducted on macrofossils or nectonic organisms, without using any microfossil data (Bown, 1992; Boomer & Ballent, 1996; Arias, 2007; Angelozzi & Pérez Panera, 2016; Martínez & Olivera, 2016) or isotopes (van de Schootbrugge et al., 2005; Dera et al., 2014). With regard to nannofossils, the western Tethys (Europe and North Africa) is the classic region that has been studied in detail to interpret palaeogeographic changes in the Lower Jurassic. A sporadic coccolith record has been documented from the Southern Hemisphere (Pacific Realm), and we present a detailed report on calcareous nannofossils from this area. The Matuasto I section (Los Molles Formation, Neuquén Basin), which can be dated as Early Pliensbachian (~190 Ma), between the base of Similiscutum and the base of Biscutum grande, yielded an assemblage with abundant typically-Tethyan taxa, such as Mitrolithus lenticularis and Schizosphaerella punctulata. The occurrence of these species was sporadic in the northern Tethys, but they were common in its southern part (Bown, 1987) and in the proto-Atlantic region (Portugal and Morocco). There may have been a connection between the Tethys and Panthalassa Oceans at that time because nannoplankton need a well-established active current system to migrate. Thus, calcareous nannofossils can be a powerful tool for improving previous reconstructions of the connection between the Tethys and Panthalassa Oceans during the Jurassic.

References
Eocene–Oligocene calcareous nannofossils from the Transylvanian Basin (Romania): Biostratigraphy, sedimentology and palaeoecology

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Eocene–Oligocene calcareous nannofossils were examined from three sections in NW Transylvania (Brebi, Mera, Baciu) and one section in southern Transylvania (Turnu Rosu). At Brebi, the exposure consists predominantly of marls, including several carbonate levels. The calcareous nannoplankton assemblage contains Ericsonia subdisticha, which places it in Zone NP21. In the upper part of the exposure, the Middle Eocene to Late Oligocene bivalve Gigantostrea gigantica was found. The basal outcrop at Mera has clays that are rich in calcareous nannoplankton, indicating a transgressive phase and a reversal in depositional environments. One level also contains Gigantostrea gigantica. The entire succession confirms an overall transgressive trend. The calcareous nannoplankton assemblage identified the Zone NP21/NP22 boundary. The exposure from Baciu is predominantly terrigenous, with clays and sands rich in tempestite intercalations, and Gigantostrea gigantica occurs in the upper part. The calcareous nannoplankton assemblage is the same age as at Brebi (Zones NP21/NP22) and contains frequent ascidian spicules.

These successions show differences in sedimentary facies, indicating different depositional environments with significant variations in energy. The facies from Mera and Baciu have similar depositional environments and environmental energy, and probably indicate an open area of the basin. The facies at Brebi indicate a more terrigenous environment, with lower energy typical of a gulf isolated from the main currents. The calcareous nannoplankton assemblage with the presence of Ericsonia subdisticha indicates Zone NP21.

In the southern part of the Transylvanian Basin, the outcrop at Turnu Rosu contains conglomerates at its base, followed by structureless massive sandstones, very rich in calcareous nannofossils from Zones NP17–NP18 (Middle to Late Eocene/Bartonian–Priabonian). The sandstones are overlain by clays belonging to Zone NP19 (Late Eocene/Priabonian). Overlying the clays, the top of the section contains limestones that are extremely rich in various mollusc species and very rare small reticulofenestrids and Coccolithus pelagicus. For this study, diversity indices and non-hierarchical and hierarchical clustering were conducted.
Late Cretaceous (Campanian–Maastrichtian) calcareous nannofossils from ODP Site 762: Evolution of the genus *Eiffellithus*  

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Well-preserved Campanian to Maastrichtian nannofossil assemblages from ODP Hole 762C (19°53.24’S, 112°15.24’E) confirm the evolution and final history of the genus *Eiffellithus* before its ultimate extinction at the Cretaceous–Palaeogene boundary. Following the radiation of the genus in the Late Albian–Cenomanian and then its decline, only a few species dominated the Late Cretaceous, with only three species first appearing in the Late Campanian. Quantitative analyses of a total of 69 samples suggests a continuous, expanded record in the core, which is ideal for biostratigraphic resolution and the investigation of *Eiffellithus* evolution.  

In this paper, we used the species *E. paralleus*, *E. eximius* and *E. gorkae*, using the application of their biostratigraphic utility as described in Shamrock and Watkins (2009), and found that deposition occurred during the Late Campanian to Late Maastrichtian (zones CC22–CC26 and UC16–UC20). The quantitative nannofossil study recovered 71 species, and *E. turriseiffelii*, *Prediscosphaera cretacea*, *Micula staurophora*, *Watznaueria barnesiae* and *Broinsonia* spp. dominated the assemblages. In addition, the pattern of diversification of the assemblages and the abundance patterns of the taxa may be related to the Late Cretaceous climate cooling that began in the Campanian, and to the palaeoceanographic regime in austral provinces, when Site 762 was located at an estimated palaeolatitude of 43°S (Thibault et al., 2012).  

References  
Eocene to Early Oligocene calcareous nannofossils from western and central Cuba

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Eocene and Oligocene calcareous nannofossils, planktonic foraminifera and larger benthic foraminifera were studied from a few sections in western and central Cuba. The Eocene–Oligocene boundary in the Noroña section had previously been documented using planktonic foraminifera (Molina et al., 2015).

Calcareous nannofossil assemblages were very common and very well preserved in the Noroña section, with a dominance of the species *Cyclicargolithus floridanus* and the regular occurrence of the species *Bramletteius serraculoides*, *Blackites spinosus*, *Coccolithus formosus*, *C. pelagicus*, *Lanternithus minutus* and *Zygabhithus bijugatus*. Discoasters were represented by *Discoaster barbadiensis*, *D. deflandrei*, *D. gemmeus*, *D. gemmifer*, *D. saipanensis*, *D. tanii* and *D. tanii ornatus*. Among the reticulofenestrids, the most common and regularly-occurring species were *Reticulofenestra bisecta*, *R. hillae*, *R. stavensis* and *R. umbilicus*, while the sporadically occurring species were *R. dictyoda*, *R. lockeri*, *R. minuta* and *R. scrippsae*. Helicoliths were represented by *Helicosphaera bramlettei*, *H. compacta*, *H. euphratis*, *H. reticulata* and *H. seminulum*. *Sphenolithus pseudoradians*, *Isthmolithus recurvus*, *Discoaster barbadiensis* and *D. saipanensis*. *Clausiococcus subdistichus* was absent or occurred only very sporadically and thus could not be used for biostratigraphic purposes. *Coccolithus formosus*, the last occurrence of which defines the top of Zones NP21/CP16a, was present throughout the entire section. The occurrence of the typical Early Oligocene taxon *Sphenolithus tribulosus* in the middle part of the section indicated an Early Oligocene age.

References
Biostratigraphy and palaeobiogeographic inferences from calcareous nannofossils in the UFRJ-2-LRJ-01-SE core, Sergipe-Alagoas Basin, Brazil

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The cored well UFRJ-2-LRJ-01-SE, drilled in the Sergipe-Alagoas Basin, Brazil, contains one of the best and most complete Middle Cretaceous recovered sections in all of South America (Silva, Jr. et al., 2019; Valle et al., 2019a, b). This work presents a biostratigraphic framework and some palaeobiogeographic considerations based on the calcareous nannofossils from that well. A total of 78 samples were analysed through the core, allowing the recognition of 11 biostratigraphic intervals (Zones BC26–UC7, Late Albian–Early Turonian). The Albian–Cenomanian boundary was placed at a depth of 328 m, based on the tops of *Braarudosphaera africana*, using a local zonation. The reworked Aptian species *Nannoconus quadriangulus* and *N. troelsenii* were recorded in the lower part of the section. The absence of index fossils between Zones UC0/BC27b and UC1 was due to tectonic activity (Valle et al., 2019), suggesting a stratigraphic break or unconformity. The nannofossil assemblages showed great affinity with other coeval sections in the Tethyan province. The occurrence of a species with a boreal affinity (*Sollasites horticus*) in the Late Albian–Late Cenomanian interval may be related to an increased effectiveness of oceanic currents from the central Atlantic to the South Atlantic. Beginning in the Late Cenomanian, there was an upward decrease in nannofossil taxa with Tethyan affinities (e.g. *Nannoconus*), suggesting the development of less restrictive oceanic conditions. The absence of species with austral affinities may be related to less effective ocean currents coming from the southern part of the South Atlantic. In fact, the influence of palaeogeomorphic obstacles, such as the Rio Grande Rise-Walvis Ridge, may have reduced the ocean circulation pattern, at least until the earliest Turonian.

References
A new Gelasian–Pleistocene analysis is presented that is based on samples from ODP Leg 154 and calibrated with cyclostratigraphy. The preliminary results are based on 220 samples from 0 to 2.6 Ma, or one sample every 11 kyr. Time-series and cyclostratigraphic analyses were performed on the calcareous nannofossil data. These results provided strong evidence for an orbital control over the calcareous nannofossil populations. Spectral analyses on selected nannofossil groups revealed the obliquity cycle (41 kyr) as being the dominant contributor to the abundance and diversity patterns.

These new analyses also provided new ages for the bioevents used in the standard zonations (Martini, 1971; Gartner, 1977; Okada & Bukry, 1980) and in other biostratigraphic schemes, and finalise the Pleistocene zonation presented by de Kaenel (2017). More than 230 species from the genera *Algirosphaera*, *Alisphaera*, *Alveosphaera*, *Flosculosphaera* and *Syracosphaera* were observed and illustrated, some of which have never been recorded before in fossil sediments.

References


Nannofossil biostratigraphy of the Neogene in the offshore A1-89 well, NE Libya

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In a biostratigraphic study of the A1-89 well (offshore NE Libya), 60 species of Miocene to Pliocene (Zones NN10–NN15) calcareous nannofossil species were identified in samples with common to abundant occurrences and good to moderate preservation. During the Late Miocene, there was a gradual decrease in the diversity of nannofossils in the Tortonian to Messenian. The position of the Miocene–Pliocene boundary could not be accurately determined due to a caving problem, but could be placed within the interval of 1440 to 1560 ft. Three definite calcareous nannofossil biozones were recognized – NN10 (*Discoaster calcarts*), NN11 (*D. quinqueramus*) and NN12 (*Amaurolithus tricorniculatus*).
Environmental control on coccolithophore morphology: Do modern species yield information that is transferable to the geological past?

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It is generally assumed that calcareous nannofossils conserve palaeoenvironmental information from the time of their formation. Changes in coccolith morphology can result from physiological responses to environmental drivers. Temperature, salinity, nutrient concentration, light and carbonate chemistry are among the environmental drivers that impact extant coccolithophores and may alter coccolith size, as well as coccosphere size and morphology. Many palaeo-reconstruction studies have assessed the biological responses of living coccolithophore species to environmental drivers with the expectation that it is possible to use this information for calibrating the biomineralisation responses of ancient coccolithophores. However, there is a large uncertainty concerning whether the morphological responses of living coccolithophores to environmental changes are similar to the morphological responses of fossil species, when you consider the fact that millions of years of evolutionary adaptation lie between the extant species and their fossilised ancestors. In order to test this caveat, we examined four extant species (Emiliania huxleyi, Gephyrocapsa oceanica, Coccolithus pelagicus subsp. braarudii and Pleurochrysis carterae), which have been evolutionarily distinct for millions of years. We cultured them under changing environmental conditions in order to evaluate any changes in coccolith morphology. Our underlying hypothesis was that if the species showed a uniform reaction to any of the tested environmental drivers, then this would suggest that the same response may well occur over geological timescales, and that coccolith morphological changes could serve as a palaeo-proxy for that particular driver. Our experiments demonstrated that the four species had no common response to changing light intensity, Mg/Ca, nutrient content or temperature with respect to coccolith size. These results revealed the difficulties in using coccolith size as a proxy for environmental drivers. One exception was an increase in malformations when coccolithophores were grown under excess CO₂, and these data provided evidence that this response variable can be used as a palaeo-proxy for episodes of acute carbonate chemistry perturbations.
Coccolithophore assemblage variation and its relation to palaeoproductivity changes in the western South Atlantic during the last 14 kyr

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This study aims to use coccolithophores to estimate the palaeoproductivity in the western South Atlantic during the last 14 kyr, and to combine this information with previous geochemical and foraminiferal data (Pivel et al., 2011) in order to explore the factors controlling local productivity changes. The study was conducted on core KF-02 (continental slope on the southeast Brazilian margin). We estimated the nutricline index using coccolithophores (N-ratio; Flores et al., 2000), and the data suggest that there was stable surface-water productivity from 14.4 kyr to 5.8 kyr, at which point the N-ratio began to decrease, indicating reduced primary productivity. However, high productivity indicators exhibited individually-distinct patterns, suggesting that different mechanisms may have favoured fertilisation of the surface waters. Gephyrocapsa oceanica productivity was influenced by shelf water during the end of the deglacial and Early Holocene. In addition, the positive correlations between G. oceanica and the productivity proxies of Pivel et al. (2011) suggest that this species indicates a higher surface-water productivity interval. When relative sea level was lower, the narrowing of the shelf and the displacement offshore of the main flow of the Brazil Current promoted nutrient increase and enhanced productivity (e.g. Mahiques et al., 2007). With the last marine transgression, the increased distance from the coast and displacement of the Brazil Current towards the continent reduced the shelfal influence, and the thermocline/nutricline depth variations seem to be the most important factor influencing productivity. During the mid-Holocene, a shallower nutricline (compared to the Late Holocene) must have sustained a photic zone relatively enriched in nutrients, and this interval contains abundant Emiliania huxleyi and small Gephyrocapsa. The Late Holocene was characterised by a marked reduction of N-ratio, and a Florisphaera profunda increase suggests deepening of the thermocline/nutricline during this interval.

References
Biostratigraphic distribution of Miocene carbonates associated with gas hydrates in the northern Apennines (Italy) and their relationship with sea-level lowering

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Gas hydrates are widespread in modern continental margin sediments, and their stability is related to temperature, pressure, and the availability of gas and water. Their sensitivity to tectonic activity and climate is still poorly constrained, and more efforts are needed to understand how they respond to these forcing processes. Gas hydrates are frequently associated with carbonates called clathrites that may form bodies of large dimension and are marked by geochemical indicators, such as $^{13}$C-depleted and enriched $\delta^{18}$O values.

A number of Miocene seep-carbonates crop out in different geological settings in the northern Apennines of Italy (Argentino et al., 2019), with characteristics that suggest palaeo-gas hydrate occurrences, and thus can be considered to be clathrites. Our biostratigraphic investigation of the sediments containing the gas-hydrate-associated carbonates showed that they are generally concentrated in three main intervals – the Langhian (Subzone MNN5a), the Upper Serravallian–Lower Tortonian (Subzone MNN6b to Zone MNN7) and the Upper Tortonian–lowermost Messinian (Zones MNN10 and MNN11). By comparing seep distributions with the third-order eustatic curves of Haq et al. (1987), they appear to match phases of sea-level lowering.

Determining the relationship among gas hydrate destabilisation, climate change, sea-level variations, tectonic activity and fluid circulation is particularly challenging in the fossil record. In the examined carbonates, a drop in the hydraulic pressure of the plumbing system during sea-level lowering would have shifted the base of the gas hydrate stability zone into shallower depths, inducing gas-hydrate destabilisation. The uplift of the different sectors of the wedge-top foredeep system during tectonic migration could have increased the effect of the concomitant eustatic sea-level drop, reducing the hydrostatic load on the seafloor and inducing gas-hydrate decomposition. Thus, a precise biostratigraphic framework of palaeo-clathrites in the sedimentary record may help to shed light on gas-hydrate long-term evolution and the relation with sea-level changes and tectonics.

References
Middle Eocene to Late Oligocene climate variability: A new integrated calcareous nannofossil and magnetostratigraphic record from the equatorial Indian Ocean

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A new record of calcareous nannofossil biostratigraphy and magnetostratigraphy from the Middle Eocene to the Late Oligocene allows the establishment of a precise biochronology and information about climatic variability in the equatorial Indian Ocean. The dataset compares Site 709 with results obtained from Site 711 (Fioroni et al., 2015).

This palaeoecological investigation, based on grouping taxa with similar responses to environmental conditions using statistical analysis, first shows a response of the nannofossil assemblages to the Middle Eocene climatic optimum with a short-lived increase in the abundance of warm-water taxa. This is followed by a long cooling trend that leads to the greenhouse-icehouse change across the Eocene–Oligocene transition (EOT). Most notably, we documented a complete reorganisation in the nannofossil assemblages, shown by abundance variations in ecologically-significant species that preceded the onset of the EOT. This prominent change in the phytoplankton community is interpreted as a response to increasing nutrients in the surface waters. The strengthened nutrient supply could be the result of a lowering sea level, which in turn could be linked to ice-sheet expansion in East Antarctica and equatorial upwelling of the Subantarctic Mode Water.

The response of the phytoplankton community to the Late Oligocene warming event was also recognised. A comparison with recent data (Dunkley Jones et al., 2008; Fioroni et al., 2015; Jones et al., 2019) makes possible the reconstruction of a basin-scale palaeoceanography of the low-latitude Indian Ocean.

References


How old is *Braarudosphaera bigelowii*? The evolution and acceptance of scientific claims and what the sociology of science can say

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Scientific claims are described as synthetic affirmations that directly emanate from empirical evidence. To produce them, scientists are believed to assess both previous claims and the data collected and published in the scientific literature to justify the claims. Science progresses, it is assumed, as newer claims prove more capable of withstanding the test of newly-collected evidence. The sociology of science has been defying these simplistic assumptions for over 40 years, but in-depth case-studies remain scarce.

An international and multidisciplinary database of scientific and technical documents on the species *Braarudosphaera bigelowii* was constructed that spans 83 years, in order to identify as many scientific references concerning the species as possible, and to pinpoint claims about the age of its first occurrence in the fossil record. We identified 37 claims made between 1956 and 2016 that are grouped around the four main statements that it is of: 1) Tithonian age; 2) Berriasian age; 3) Aptian age; and 4) Cenomanian age. The claims were then related to each other in a citation map. Concomitantly, data contradicting a claim published before it was made, was quantified. We found that claims are apparently oblivious to dozens of studies offering contradictory empirical evidence because they do not acknowledge or refute them. These four statements have endured over time, and persist in parallel in the literature even now.

Four hypotheses tested whether ignored contradictory data comes from: 1) marginal authors; 2) marginal regions; 3) marginal documents; and/or 4) marginal publications. All hypotheses were refuted. The results indicated that consensus is not shifted primarily by data. In fact, every major shift in consensus was associated with the publication of a reference book by a renowned scientist. The authority of textbooks and the notoriety of their authors, rather than the systematic consideration of data and the collective discussion of claims, appears to be, in this case, the best explanation for how the claims have evolved.
The Late Cretaceous palaeobiogeography of *Braarudosphaera bigelowii*

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Since its first description 83 years ago, a significant amount of data has been collected about the coccolithophore *Braarudosphaera bigelowii*. Despite the accumulation of local and regional data, only limited attempts (both in quantity and in scope) have been made to compile a global database and systematically analyse the geographic distribution of *B. bigelowii* occurrences. Here, we present the results of a recently-published study on the Late Cretaceous that comprehensively reviews the palaeobiogeography of *B. bigelowii* during that period of time, by compiling more than 700 onshore and offshore records.

The results show that, during the Cenomanian, *B. bigelowii* was found throughout the European seaways, at the base of the North America Interior Seaway, in the palaeo-Atlantic margin of South America, in the Neuquén Basin, on the southern tip of the Indian Plate and on the Kerguelen Plateau. During the Late Cretaceous, it gradually expanded northwards along the North Sea, into the North American Interior Seaway, eastwards through the interior European seaways, across central Russia, southeastwards into China and along the Asian coast up to Japan. The Falkland Plateau appears to have played a pivotal role in the colonisation of the eastern coast of South America and the Atlantic and Indian Ocean margins of Africa, Madagascar, India, western Antarctica and Australia.

Because biogeographic information is scarce for the northern coast of South America, for several areas along the African margin, and for the overall Pacific coasts, it was difficult to resolve the biogeographic history in these areas. The presence of *B. bigelowii* could not be confirmed on the northern coast of South America or on the North Atlantic African margin. It is also not possible to ascertain whether the African margin facing the Indian Ocean was completely colonised by the end of the Cretaceous.
Sarmatian (Late Serravallian–Early Tortonian) biostratigraphy: A case-study in a marginal sea

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Late Serravallian–Early Tortonian calcareous nannofossil events in northern Croatia were studied. The LCO of *Heliocosphaera walsberdorfensis*, the prevalence of larger *Reticulofenestra pseudoumbilicus* specimens in the assemblage, and the LRO of *Cyclicargolithus floridanus* indicated Paratethyan Subzone NN6d. This marks the Badenian–Sarmatian boundary and gives an age of 12.8 Ma (Sant et al., 2015), which suggests correlation to Chron C5Ar, as found at low latitudes. The beginning of the Sarmatian was characterised by the acme of *Calcidiscus pataecus*, along with abundant *Coccolithus pelagicus* and *R. pseudoumbilicus*. The base of the Early Sarmatian Subzone NN7a was characterised by the FO of *Discoaster cf. D. kugleri*, which coincides closely with the LCO of *C. pataecus*, while the upper part is marked by the LO of *H. walsberdorfensis*, *D. deflandrei* and *Rhabdosphaera poculi*, the disappearance of *Pontosphaera* spp. and *Rhabdosphaera* spp., and the FO of *D. braarudii*. The mid-Sarmatian comprises Subzones NN7b–NN8a. The LO of *D. kugleri* defines the NN7/NN8 boundary. The LAD of *D. cf. D. kugleri* and the FAD of *Catinaster coalitus* mark Subzones NN8a–NN8b (Middle-Late Sarmatian boundary), which occurs at low latitudes at 11.531 Ma (de Kaenel et al., 2017), as in the Paratethys. The Sarmatian–Pannonian boundary is characterised by the FO of endemic *Isolithus semenenko* in the coastal zone and by the FO of short-lived, small, warm-water species of the Ceratolithaceae (*Nicklithus amplificus*, *Amaurolithus tricorniculatus* and *A. primus*) in the deeper basinal region.

References
Contribution of coccolithophores to carbon burial during the Late Quaternary on the southern Brazilian continental margin

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The carbon biological pump is key to understanding climate variability because of the importance of the carbon cycle in climate regulation. The Late Quaternary record shows a clear relation between glaciation cycles and greenhouse gas concentrations (Petit et al., 1999). Understanding this period can provide important information about where climate change may be leading us in the future. Coccolithophores, which are very important in the operation of the biological pump, have been providing very accurate information about the palaeoclimate record. For this reason, they have been studied extensively. The aim of this work is to understand the variations in biological productivity and their relation to organic carbon and carbonate burial and to the oceanographic processes that resulted from Late Quaternary climate change on the southern Brazilian continental margin. We studied a sediment core recovered from the slope of the Pelotas Basin (south of Brazil, 29.221286°S, 47.283805°W), which covers from 47 to 7 kyr BP. The N-ratio and the abundance of coccolithophores in the assemblages were the main palaeoproductivity proxies used in the study. Measures of total organic carbon (TOC) and carbonate content in the sediments were also obtained. Our results show that coccolith-rich biogenic carbonate sediments dominated the sediment core, particularly during MIS 3 and MIS 1, which demonstrates a higher contribution of these organisms to carbonate burial during the warmest periods. With regard to productivity, both the N-ratio and TOC curves had a negative correlation with the end of summer/beginning of autumn insolation curve and a positive correlation with the spring insolation curve at 29°S. We infer that this must be due to a strengthening of the Brazil Current meandering flow that promoted shelf-break upwelling of nutrient-rich South Atlantic Central Water during periods of northeasterly wind intensification (Campos et al., 2013), which is analogous to the modern spring/summer condition. This project was sponsored by the IODP/CAPES grant 88887.091729/2014-01.

References
Role of the *Gephyrocapsa* complex in the reconstruction of atmospherically-driven water-column variability in the western Mediterranean (ODP Site 977) during Marine Isotope Stage 11

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A high-resolution coccolithophore analysis, along with oxygen and carbonate isotopes and UK’37 alkenone-derived sea-surface temperatures (SSTs), was carried out on western Mediterranean ODP Site 977 (Alborán Sea) sediments, with the aim of reconstructing changes in palaeoproductivity and surface dynamics at the millennial scale during Marine Isotope Stage 11.

Coccoliths of the genus *Gephyrocapsa* were the most abundant taxa in the interval. The dominance of small *Gephyrocapsa* spp. (<3 µm) and *Gephyrocapsa caribbeana* revealed high primary productivity variability, related to the weakening and strengthening of upwelling conditions, as well as changes in Mediterranean/Atlantic-water exchange. The atmosphere to ocean-surface connection in the Alborán Sea during MIS 11 was reconstructed using the *Gephyrocapsa* complex. Short-term oscillations in wind and precipitation tracks, which were controlled by the North Atlantic Oscillation during MIS 11, are proposed as being responsible for this variability.

The identification of several morphotypes/species within the *Gephyrocapsa* complex (‘*G. caribbeana*’, *G. oceanica* and *G. muellerae*) allowed us to present a hypothesis about the relationship between their changes in connection to oceanic processes operating at the regional and global scales during MIS 11 and the Mid-Brunhes interval. In addition, we provide new information about the behaviour of Mediterranean taxa, such as *Syracosphaera* spp. and *Helicosphaera carteri*, and others of Atlantic origin, such as *Calciscus leptoporus* and *Coccolithus pelagicus* subspecies (*pelagicus, braarudii* and *azorinus*), and introduce a discussion about their palaeoecological responses in the Alborán Sea.
Updates on the calcareous nannoplankton biostratigraphy of the Lutetian to Lower Priabonian strata in the Jaca Basin (southern Pyrenees, Spain)

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The Lutetian to Priabonian strata of the Jaca Basin record the transition from deep-marine to terrestrial environments, while passing through intermediate deltaic systems. In this work, we summarise the calcareous nannoplankton content from the Jaca town transect. The sedimentary succession starts with the Roncal-Fiscal megaturbidite (Mt-5), continues with the upper Hecho Group turbidites, and ends with the deltaic systems of the Sabiñánigo Sandstone and lower Belsué-Atarés Formation (Sobás Delta). The main biohorizons of the Middle Eocene were recognised on the basis of the global standards and calibrated events of Agnini et al. (2014).

The calcareous nannofossil assemblages in the Lutetian–Bartonian upper Hecho Group were placed in the CNE11–CNE15 or NP15–NP16 biozones, within a time span of ~3.45 Myr, between 43.96 and 40.51 Ma (González-Lanchas et al., 2019/in press). These results were compared with available palaeomagnetic studies. Preliminary results from the Sabiñánigo Sandstone and the distal Sobás Delta placed these sediments in the Bartonian to Priabonian, based on the morphological evolution of Cribrocentrum erbae.

The resulting age model improves the existing model for the south-central Pyrenean Basin and also permits a detailed temporal and spatial correlation framework for genetically-related depositional systems at the basin scale.

References
Calcareous nannofossil and stable isotope stratigraphy of the Upper Campanian–Maastrichtian in NW Bulgaria (SE Europe): Preliminary results

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Shallow-marine sediments of Late Cretaceous–Paleogene age are exposed at Kladorub (NW Bulgaria). These Upper Campanian–Ypresian strata consist of silty to fine-sandy marlstones, occasionally interbedded with marly limestones and sandstones, and they encompass the well-known K–Pg boundary and the PETM in a previously understudied region. In order to establish an improved, integrated stratigraphic context for this section, a detailed investigation of the calcareous nannoplankton assemblages, and the carbon and oxygen isotope ratios based on benthic foraminifera, was carried out. The studied 123-m-thick succession spans the Upper Campanian to lowermost Danian and correspond to parts of nannofossil Zones UC15dTP to NP1. A total of 164 samples were analysed for both nannofossils and stable C and O isotope ratios at a 50-cm resolution. Owing to poor exposure, the sampling resolution was decreased to 1 m for the lowermost portion of the section, and there were some limited intervals of non-exposure in UC15eTP, UC16aTP, UC16bTP and around the K–Pg boundary interval.

The nannofossil assemblages were abundant, moderately well preserved and taxonomically rich, allowing 31 datums to be recognised. Based on scanning electron microscope analyses, the foraminifera showed no evidence of significant test dissolution, recrystallisation or overgrowth. In addition, the carbon and oxygen isotope co-variation was weak, raising confidence that primary environmental information was retained in their tests, at least for the carbon isotope ratios. Indeed, several previously-established carbon isotope excursions were identified. Due to the incompleteness of the isotope record at Kladorub, particularly around the base and top of the Maastrichtian, further investigations are planned to discriminate between the distinct isotopic events.

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Calcareous microfossils and palaeoenvironmental changes across the Cretaceous–Paleogene (K–Pg) boundary in the Cerro Azul Section, Neuquén Basin, Argentina

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We investigated changes in calcareous nannofossil and ostracod communities across the Cretaceous–Paleogene (K–Pg) transition in the Cerro Azul Section, Jagüel Formation, Neuquén Basin, Argentina. Changes in the nannofossil assemblage compositions were compared with geochemical and magnetic property characterisations of the sediments in order to identify probable environmental drivers. The K–Pg transition in the Cerro Azul section is characterised by a change in calcareous nannofossil and ostracod compositions, in assemblages dominated by Cretaceous forms, to assemblages dominated by incoming Danian taxa, along with several survivor species. These changes in the assemblages are associated with a collapse in carbonate production at the K–Pg boundary, probably related to a drop in surface-water productivity, followed by a subsequent recovery in the Early Danian, as suggested by trends in the carbonate content and log(Ba/Fe) and log(Ba/Ti) ratios in the sediments. During the Late Maastrichtian, peaks in the relative abundances of *Eiffellithus* spp. just before the K–Pg transition were probably related to enhanced surface-water productivity. Stressed environmental conditions during the earliest Danian, probably related to decreased surface productivity, are evidenced by *Cervisiella operculata* blooms, coupled with increased abundances of the Cytheruridae and low abundances of members of the Trachyleberididae, both ostracod families. This interval is followed by increased relative abundances of *Braarudosphaera bigelowii* in the Danian, which probably can be correlated with intensified weathering conditions and, consequently, increased fresh-water input and/or continental runoff. This project was sponsored by IODP/CAPES grant 8888.091703/2014-01.
Transatlantic gradients in coccolithophore species fluxes: Influence of thermocline depth, Amazon water and Saharan dust

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Tropical oceans provide interesting perspectives as modern analogues for future ocean productivity, in the context of an increasingly warm, stratified and nutrient-depleted upper ocean. In order to obtain knowledge of the spatiotemporal variability of the phytoplankton communities thriving in these regions, we investigated one year of coccolithophore export fluxes and seasonal dynamics from a transatlantic transect of four sediment traps, moored between NW Africa and the Caribbean (at ~12ºN). The results show large ecological contrasts across the transatlantic array. Wind-forced, basin-scale variations in the thermocline/nutricline were clearly reflected in the distribution of distinct coccolith species fluxes. The surface-dwelling, opportunistic species *Emiliania huxleyi* and *Gephyrocapsa oceanica* decreased in abundance from east to west, while the deep-dwelling species *Florisphaera profunda* and *Gladiolithus flabellatus* increased in the same direction. Decreasing abundances of the surface-dwelling, opportunistic species *Emiliania huxleyi* and *Gephyrocapsa oceanica* from east to west, and the concurrent increase of the deep-dwelling species *Florisphaera profunda* and *Gladiolithus flabellatus* in the same direction, followed the geostrophic shoaling (deepening) of the thermocline/nutricline towards the eastern (western) tropical North Atlantic. We found that coccolith fluxes at the westernmost site (M4), closest to the Caribbean, at 49ºW, were up to three to five times higher than at the other sites, including the highly-productive Cape Blanc upwelling region, and were primarily due to coccolith production in the poorly-illuminated lower photic zone. Finally, the pulsed flux maxima of opportunistic species, which were also observed in the western tropical North Atlantic, point to the occurrence of intermittent nutrient input. This is the result of sea-surface cooling and wind-forced vertical mixing that combines with dry dust deposition in the spring, and nutrient enrichment derived from Amazon River discharge that combines with wet dust deposition in the fall. Our findings: 1) provide relevant evidence to support the hypothesis that Saharan dust acts as a fertiliser for marine phytoplankton in the Atlantic Ocean; and 2) highlight the importance of coccolithophore production in the lower photic zone, with potential implications for the oceanic carbonate budget.
Microfacies analysis and integrated biostratigraphy from an Aptian–Albian section in the Tamaulipas Formation, western Hidalgo State, Mexico

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A microfacies analysis of 114 samples from a section cropping out in the western portion of Hidalgo State, Mexico, provided palaeoenvironmental and biostratigraphic information on the Aptian–Albian transition in the lower and upper Tamaulipas Formations (Tampico-Misantla Basin). The 92-m-thick section consists of a succession of mudstones and wackestones that were deposited in open-marine conditions below the storm wave base and contains abundant planktonic microfossils.

Using a biostratigraphic analysis of planktonic foraminifera and colomiellids, it was possible to infer that this section was deposited in the time interval between the *Globigerinelloides blowi* and *Ticinella primula* Zones, and the Aptian–Albian boundary was established at the top occurrence of *Paraticinella eubejaouensis* and the base occurrence of colomiellids such as *Colomiella mexicana* and *C. recta*.

As an initial approach to the calcareous nannoplankton analysis, variations in the abundance of this group were observed. Wide-canal nannoconids, which were absent in the basal portion of the section, became abundant and exhibited a gradual increase in size throughout the transition of the *Leupoldina cabri-Globigerinelloides ferreolensis* Zones. This nannoconid assemblage was dominated by *Nannoconus kamptneri*, *N. wassallii* and *N. circularis*. At the Aptian–Albian boundary, the sedimentary succession was characterised by thin shale levels that are interbedded with wackestones and mudstones, and coccoliths were recovered from here. The nannofossil assemblage was composed primarily of species of the Watznaueriales group, such as *Cyclagelosphaera margerelii*, *Watznaueria barnesiae* and *W. biporta*.

The U/Th index from the gamma ray curve for the studied section indicated levels of high organic matter content. This suggests a correlation with episodes of global anoxia, as previously recorded in the lower Tamaulipas Formation (Li et al., 2008). Therefore, a detailed characterisation of the nannofossil associations and bioevents can support our understanding of Aptian and Albian anoxic events and their expression in Mexican basins, as well as their palaeogeographic implications in the Tethyan realm. This is a contribution of the DGAPA-UNAM grant PAPIIT IN 108919.

References
Quantitative reconstruction of primary productivity in low latitudes during the Last Glacial Maximum and the mid- to Late Holocene from a global *Florisphaera profunda* calibration dataset

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In this study, we investigated the modern biogeography and environmental factors controlling the global distribution of the coccolithophore species *Florisphaera profunda*. This species typically has been used as a primary productivity proxy by the palaeoceanographic community. However, its robustness as a productivity proxy has only been evaluated regionally and in surface sediment samples. Here, we have developed a full calibration study that included 26 sediment traps, 1258 surface sediment samples (mainly from the published literature, and which are distributed globally), and satellite estimates of net primary productivity (NPP), in order to evaluate the potential of this species as a global indicator of ocean primary productivity. We also assessed the limitations and potential bias of this approach. Sensitivity analyses of surface sediment and sediment-trap %*F. profunda* to different environmental variables indicated that this shows its best response to NPP at low latitudes (between 30°N and 30°S). In contrast, at higher latitudes, the *F. profunda* relative abundance is mainly controlled by other factors, such as temperature or assemblage composition. Therefore, the interpretation of %*F. profunda* as a productivity indicator in the fossil record in high-latitude regions should be made with caution. Using the surface-sediment data, we developed a new global, low-latitude NPP-%*F. profunda* calibration model to reconstruct this key component of the marine carbon cycle. We applied the calibration model to published downcore *F. profunda* relative abundance data from 105 globally-distributed sediment cores that cover the Last Glacial Maximum and mid- to Late Holocene. A 15% higher NPP during glacial times compared to the Holocene was observed at low latitudes, reflecting the relevance of these latitudes in the global carbon cycle. Our study provides a substantial advance in quantifying past changes in NPP. It also adds information to the general understanding of how the earth’s climate affected past ocean productivity, and how future climate changes will potentially affect it.
Composition, abundance and distribution of coccolithophores in the Gulf of California (Mexican Pacific) during the summer and their relation to oceanographic conditions

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Recent studies on the Gulf of California, an inlet sea within the Mexican Pacific, have revealed conditions such as the presence of oceanographic eddies. The influence of these processes has only recently been revealed and is as yet poorly defined. The basic structure (composition, abundance and distribution) of the coccolithophore community was studied from samples collected along a transect parallel to the main axis of the Gulf of California during the summer of 2011 (July–August), where two oceanographic eddies were detected. Physicochemical variables (temperature, salinity and dissolved oxygen) were measured in situ with a conductivity, temperature, depth (CTD) device, and fluorescence was also determined using a fluorimeter at 23 fixed stations. Additionally, bottle samples were taken from four to five different depths at seven stations in order to analyse nutrients and phytoplankton. For this study, only those samples that were filtered to analyse the coccolithophores were included. Thirty-one coccolithophore species were identified, using both the LM and SEM, and counts of each species and the total communities were made. Emiliania huxleyi and Gephyrocapsa oceanica were the most frequent and abundant species, with total maximum densities reaching $6.7 \times 10^6$ cells L$^{-1}$. This coccolithophore flora is fairly common in subtropical areas. The spatial distribution of the coccolithophores was heterogeneous, but, amazingly, the latitudinal distribution followed the patterns of properties such as temperature and fluorescence, which in turn were affected by the two eddies. The vertical distribution usually showed maximum species densities in the subsurface between 18 and 35 m, which usually coincided with chlorophyll maximum layers. This demonstrates the enormous influence of oceanographic processes on environmental variables and phytoplankton, as represented by the coccolithophores.
Surface productivity variations based on coccolithophore assemblages in the Santos Basin during the last 35,000 years

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In order to estimate marine primary productivity (PP) in the near-surface environment and relate it to variations in the major elements (Ti, Fe, Ca, Al, K) over the last 35,000 years, this work involved a quantitative analysis of coccolithophore species from the marine sediment core GL-1109, from the continental slope of the Santos Basin at a depth of 848 m. The Ti/Ca, Fe/Ca, Fe/K and Al/Si results showed that PP had a correlation with these ratios during periods of low sea level, but did not seem to be related after the last marine transgression. During a glacial period, PP was strongly influenced by species such as Emiliania huxleyi and Gephyrocapsa spp. During MIS 2, Gephyrocapsa spp. reached greater abundances. During MIS 3 and the first half of MIS 1, the decrease in major-element ratios influenced the decrease in PP. In addition, we identified some coccolithophore assemblages. The assemblage differences were based on greater or lower relative abundances of species in glacial and interglacial periods. The typical glacial assemblage contained a greater abundance of Gephyrocapsa spp., Syracosphaera spp., Rhabdosphaera spp., Pontosphaera spp. and Tetrolithoides quadrilaminata, among others. Tetrolithoides quadrilaminata occurred only during a glacial period. A typical interglacial assemblage primarily contained E. huxleyi, Umbilicosphaera spp., Umbellosphaera spp. and Florisphaera profunda. Finally, we attempted to correlate the variation in coccolithophore species to the Younger Dryas and Heinrich 1/2/3 climatic events. However, the taxa did not present a clear pattern of abundance variation during these events.
Use of artificial intelligence to identify nannoplankton species

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The Institute of Geology and Paleontology, Faculty of Science, Charles University, in cooperation with Cogniware, has tested a system for the automatic recognition of coccoliths using artificial intelligence technology. During the testing experiment, the goal was the unequivocal identification of the species *Cyclicargolithus floriganus* with no confusion with morphologically-similar species. With the software programme designed by Cogniware, a professional palaeontologist marks an object, and the software prepares it for so-called deep neural network training. Thanks to this software, the palaeontologist can use their knowledge without knowledge of the neural network training.

By training a deep neural network, a system is created that is able to process thousands of images over an hour, recognise specimens of certain species and record the number of this species. The training consists of selecting appropriate specimens of *C. floriganus*, marking them, preparing them for training the model (automatic adjustments, such as turning the annotated samples) and training the neural network. At least 1000 specimens of each species are necessary for creating the model. The model is then corrected and overtrained so that the results can be used for professional processing. The project is based on the assumption that the recognition rate must be over 90%. The long-run result could be a qualitative and quantitative analysis of calcareous nannoplankton assemblages on slides in only seconds.
Corrosion of coccoliths as a proxy for pH in sediments

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Cyclical variations in the degree of coccolith corrosion were recorded from the Middle Miocene of the central Paratethys epicontinental sea. The application of multiproxy palaeontological and geochemical data enabled a complex interpretation of the palaeoenvironment. Anti-estuarine circulation has been suggested for this period, with the surface waters having a Mediterranean affinity and the bottom-waters being Paratethyan. The cyclical oscillations of quantitative palaeontological parameters were probably triggered by obliquity cycles. Eutrophic to mesotrophic conditions were based on primary intrabasinal production. Although the biostratigraphically-determined age agrees with the Mi-3b pronounced global cooling, a significant influence of local mesoclimate was deduced from the persistence of a warm subtropical climate that influenced both the continental and marine biotopes. Palaeodepth – a factor important for the dissolution of coccoliths – could not be precisely interpreted for the epicontinental sea. Using several proxies (ostracoda, foraminifera, difference in Mg/Ca palaeothermometry between the surface and bottom waters, and otoliths), a palaeodepth of about 200–500 m was predicted.

pH and CO$_3^{2-}$ oscillations in the sediment were estimated using two independent proxies. For the first proxy, the Mg/Ca offset between infaunal and epifaunal foraminifera was based on differences in the incorporation of Mg and Ca into the foraminiferal shells during calcification, which was influenced by gradients in pH and CO$_3^{2-}$ concentrations in the sediment. For the second proxy, the foraminiferal δ$^{13}$C was based on benthic species with different palaeoecological requirements. A comparison of the δ$^{13}$C values points to the life strategy of a particular species within the sediment. Possible pH and CO$_3^{2-}$ oscillations were reflected in the foraminiferal δ$^{13}$C data, as opposed to the species that have comparable habitat preferences.

The ratio of corroded coccoliths, as well as the intensity of the corrosion, agrees with the interval with decreased pH, as interpreted from the above-mentioned proxies.
Palaeoceanographic implications for the closure of the eastern Tethys Ocean based on calcareous nanofossils from southern Tibet

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The India-Asia collision led to the demise of the Tethys Ocean, and the subsequent uplift of the Qinghai-Tibet Plateau had a profound impact on Cenozoic topography, oceanography and climate. A wide range of collision times has been proposed due to the different collision definitions and methodologies used by various researchers. The cessation of marine deposition can be used to constrain the minimum age of collision. The Enba and Zhaguo Formations of the Qumiba section, located in the Tethys-Himalaya of Tibet, represent the youngest marine sequences of the eastern Tethys Ocean. From these sequences, 36 samples were systemically collected from the same location as Hu et al. (2012). Although we observed high numbers of Early Cretaceous–Paleocene reworked nanofossil assemblages (>70%), nanofossils indicative of Zone NP11 (Toweius gammation, Discoaster barbadiensis, D. kuepperi, Sphenolithus arthuri, S. orphanknol-lensis, S. radians, S. conspicua and Tribrachiatus orthostylus) were detected at the cessation of marine sequences in the eastern Tethys Ocean. Based on the reworked nanofossil assemblages, a tectonic evolution model was constructed for the duration of the deposition in the Qumiba section, where increasing numbers of reworked fossils upsection suggest the increased weathering and uplift of older sequences.

References
Palaeoenvironmental reconstruction of the Passerano and Marmorito (NW Italy) diatomites based on microfossil assemblages

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The outcrop at Marmorito in northwestern Italy consists of the Marmorito limestone, sandstone and diatomite, in ascending order. The limestone has extremely low values, derived from the reaction between bacteria and methane. Bonci et al. (1990) reconstructed the palaeoenvironment of the Marmorito diatomite using diatoms and foraminifera, and placed the deposit into foraminiferal Zone N6 (Late Aquitanian–Burdigalian, Early Miocene). However, they did not examine the calcareous nannofossils. In this study, we collected samples from all 28 diatomite layers from the same location as Bonci et al. (1990), and made observations using light and scanning electron microscopy, on standard smear-slides and stubs, respectively. Based on the presence of Helicosphaera ampliaperta, the diatomite sedimentation was placed in Zones MNN2b–MNN3a (Mediterranean nannofossil zonation of Fornaciari & Rio, 1996). Surprisingly, Tergestiella adriatica, recently observed in the Japan Sea and off Croatia (Hagino et al., 2015), was occasionally observed in the Marmorito diatomites as coccospheres. Individual coccoliths of T. adriatica can be difficult to distinguish from the reworked Cretaceous species Cyclagelosphaera margerelii. To keep the coccospheres intact for ease of identification, the samples were filtered and mounted using immersion oil and Norland Optical Adhesive No. 61 for further light microscope analysis.

References
Ultrastructure in the Order Braarudosphaerales

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The Order Braarudosphaerales is a group of coccolithophorids with coccoliths that share a structure of circular to polygonal discs made up of a number of radially-arranged, thin polygonal calcite plates that abut or partially overlap each other. In each individual coccolith, multiple discs are vertically stacked upon each other. The number of discs in each coccolith varies greatly between species, resulting in a great range in coccolith height. A central pore in each disc may be present, resulting in a central canal along the long axis of the coccolith. In each disc, the calcite $c$-axis of each of the calcite plates making up the disc is always tangential relative to the centre of the disc.

From genetic studies, it has been shown that the modern species *Braarudosphaera bigelowii* is a coccolithophorid, even though it does not form either hetero- or holococcoliths. The coccoliths of *B. bigelowii* are formed extracellularly, and constitute a third major type of coccolith in the coccolithophorids. It is assumed here that all members of the Order Braarudosphaerales (based on their clearly-shared ultrastructure) are coccolithophorids that form coccospheres of externally-calcified coccoliths.

The Braarudosphaerales originated in the Early Tithonian, with the appearance of *Nannoconus beckmannii* from an unknown ancestor. *Nannoconus beckmannii* is the first member of the Family Nannoconaceae, and possesses coccoliths that are low in height, with 6–10 elements in each disc, with some overlap between adjacent elements. Nannoconid coccolith height and complexity rapidly increased through a long-ranging lineage that went extinct in the Campanian. The number of discs in each coccolith varies greatly between species, from very low (giving an overall form of a thin, flat disc) in *N. magnadiscus*, to very high (giving the form of a tall tapering cylinder) in *N. steinmannii*.

The Family Braarudosphaeraceae originated from *N. beckmannii* with the evolution of *Polycostella senaria* in the mid-Tithonian. Species in the Braarudosphaeraceae have a fixed number of elements in the discs of each coccolith and have no overlap between adjacent elements in each disc, unlike in the Nannoconaceae. With a reduction in the number of elements in each disc from six to five, *Polycostella* gave rise to *Micrantholithus* in the earliest Berriasian, and hence to the long-ranging lineage of pentaliths that continue to the present day. Five elements per disc allow a dodecahedral coccosphere, which further allows the coccosphere to completely enclose the living cell. Completely enclosing the cell isolates it from its environment, which seems to be key for surviving the highly variable chemical and physical conditions in the coastal environments favoured by modern *B. bigelowii*. 
Nannofossils used to determine the provenance of artworks

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Although nannofossils have been used previously for provenance analyses, mainly of gothic artworks, no systematic method has been developed for this application. The aim of the current provenance analysis was to establish the best method for determining the age and palaeobiogeographical position of rock materials that are used as base layers in paintings and in statues and to establish a reference materials database.

There are two main problems with artwork samples. The first is the difficulty in identifying nannofossils from extremely small samples that are man-made (natural rock material mixed with organic binders). Non-destructive methods might be preferred for this type of study (i.e. nano-CT scans and SEM), but not a lot of information can be obtained using these methods. Smear-slides still remain the best way for nannolith determination, but the standard methods for slide preparation have been shown to be ineffective for the isolation of nannofossils from aggregates of rock material containing binders. An extraction process was developed by empirical testing on a chalk and binder mixture made to resemble material from medieval base layers. The mixture was de-agglomerated at different temperatures, various ultrasonic times, and using eight chemicals, mainly micro-emulsions. The second problem is the availability of reference rock materials. We used two sources of materials – purchases from art shops (e.g. Rügen, Belgium and Champagne chalk) and samples taken from historical mining areas (e.g. the Sassuolo ceramic district). We plan to establish a database of nannofossils present in these materials, along with chemical and mineralogical data. These datasets will be published on a website that will be available to the scientific community.
Two production stages of coccolithophores in the winter as revealed from sediment traps in the northern South China Sea

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Coccolithophores are one of the most successful marine calcifying algae in the modern ocean, and coccoliths are the calcareous fossil remnants left in marine sediments after coccolithophores die. These calcite scales record the environmental conditions of the near-surface ocean (e.g. primary productivity, sea-water temperature and carbonate chemistry) and are promising subjects in palaeoceanographic and palaeoclimatic studies. Hence, a comprehensive understanding of the ecology and phenology of living coccolithophores, as well as their interactions with other plankton, is needed to develop better constraints for their use in palaeoenvironmental studies. Here, we have documented modern coccolithophore production using coccolith fluxes in samples that were collected from sediment traps at ~500 m water depth from 2013 to 2015, in the northern South China Sea. In addition to the expected seasonality of coccolithophore production, which increases during the winter due to the strong water-mixing induced by monsoon winds, a two-stage mode of coccolithophore production was also recognised in relatively coastal waters. The first stage includes the production of *Gephyrocapsa oceanica* in December, when the macronutrient inventory is built, and the second stage describes the growth of *Emiliania huxleyi* in late February, with the depletion of silicate nutrients. This two-stage mode originates from subtle differences in the ability of the two species to assimilate nutrients. In addition, coccolithophore production is significantly influenced by decadal oceanic events (i.e. El Niño) in the northern South China Sea.
Are *Macrora* and *Clathropyxidella* fossil siliceous haptophytes?

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The siliceous haptophyte genus *Hyalolithus* Yoshida et al. inhabits modern subtropical/tropical waters (Yoshida et al., 2006; Jordan et al., 2015) and has a fossil record dating back at least to the Middle Eocene (Abe et al., 2016). Thus, there is a strong possibility that enigmatic living siliceous phytoplankton (e.g. *Petasaria* Moestrup) and siliceous microfossils (e.g. *Macrora* Hanna and *Clathropyxidella* Deflandre) may be closely related (Jordan et al., 2015). Interestingly, *Hyalolithus*, *Macrora* and *Clathropyxidella* have similar geographic distributions, and all three can be found in Middle Eocene sediments, although the former two are also present in Neogene sediments. *Macrora stella* (Azpeitia) Hanna was originally described as the diatom *Pyxidicula stella* Azpeitia, while a similar form was assigned to a new diatom genus, *Pseudorocella* Deflandre. However, they do not possess any diatom-like features, particularly a rimoportula, which is present in *Rocella* Hanna. Like *Hyalolithus*, *Macrora* has a similar-sized, perforated siliceous plate and a thickened, hollow marginal rim. *Clathropyxidella*, on the other hand, has been associated with silicoflagellates and ebridians, but has a hollow skeleton (unlike ebridians), lacks pikes or basal spines (which are present in many silicoflagellate genera), and strongly resembles a highly-domed form of *Macrora*. Illustrations of silicoflagellates like *Cannopilus jouseae* Bachmann from the Middle Miocene and *Dictyocha rotundata* var. *secta* Glezer from the Late Eocene–Early Oligocene bear some similarities to *Clathropyxidella*, but require detailed observations with the use of the scanning electron microscope to determine whether or not they bear pikes and/or basal spines.

**References**


What drives coccolithophore productivity changes and species turnovers? A Pliocene case-study from the NW Australian shelf

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The Late Miocene to Pliocene coccolithophore assemblages from two IODP drill sites (Expedition 356, Sites U1463 and U1464), located on the NW Australian shelf, were dominated by small-sized species of the Noelaerhabdaceae family. Despite their overall dominance, we observed a significant abundance crash and a major species turnover at around 4.6 Ma. This event marks a transition from assemblages dominated by small Reticulofenestra species to those dominated by small Gephyrocapsa species, but is not related to any extinctions. Although similar coccolithophore turnover events have been observed through time, it is still difficult to attribute them to specific global or regional driving mechanisms. Here, we tested how changes in the eccentricity of the Earth, and temperature and nutrient availability are related to this Pliocene coccolithophore turnover event. To achieve this, we used the record of absolute and relative coccolithophore abundances, Mg/Ca-based temperature estimates from nearby ODP Hole 763A, and a series of proxy elements (K, Ti, Fe) that are indicative of terrigenous input (and thus nutrient supply) in the area. An approach based on spectral analysis was used to attribute the observed evolutionary changes to specific Earth eccentricity cycles.
Calcareous nannofossils from IODP Expedition 374 to the Ross Sea, Antarctica

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IODP Expedition 374 cored Neogene sequences at five sites on the Ross Sea continental shelf, slope and rise in order to examine ice-sheet advance and retreat. This expedition specifically targeted intervals of past warmer-than-present climate, including the Miocene Climatic Optimum, mid-Pliocene Warm Period and Pleistocene super interglacials, in order to get a better understanding of how ice sheets respond to warmer temperatures. In particular, the marine-based, West Antarctic ice sheet is particularly vulnerable to increasing ocean temperatures, but a lack of proximal records limits the ability of ice-sheet modellers to use palaeoclimate records to constrain potential future retreat. Expedition 374 cored two sites on the continental shelf, one on the outer continental shelf and two on the banks of Hillary Canyon on the continental slope and rise. Although calcareous nannofossils are sparse in the Antarctic Neogene and Quaternary assemblages, their presence can be used as a palaeoenvironmental indicator of past warm periods. Shipboard examination of select samples from several sites cored during Expedition 374 revealed calcareous nannofossils were present in some discrete intervals. In particular, a sample from continental slope Site U1525 yielded a sparse assemblage of moderately-preserved calcareous nannofossils that include the genera Reticulofenestra, Calcidiscus and Coccolithus, indicative of the Neogene. Targeted analyses of select intervals from Sites U1523 (outer continental shelf) and U1524/U1525 (continental rise/slope) will provide a snapshot of warmer-than-present intervals when conditions were conducive for the presence of coccolithophores in the Ross Sea region of the Antarctic.
Coccolithophore-carbonate contribution to the ocean floor on the southern Brazilian continental margin

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Exchanges of CO₂ between the ocean and atmosphere have an important role in global climate change. Coccolithophores participate in both the carbonate and organic carbon pumps. In this context, coccolithophore participation in carbonate accumulation at the ocean floor was evaluated in a sedimentary core collected on the slope of the southern Brazilian continental margin (29°S, 47°W), an area that is influenced by the Brazil Current. Slides were prepared by dilution and pipetting (Koch & Young, 2007), and 500 coccoliths were counted for each sample. The age model was based on 14C-calibrated ages, and the δ¹⁸O curve was obtained from benthic foraminifera (compared to the standard curve of Lisiecky & Stern, 2016). The carbonate content present in the coccoliths was estimated using C-Calcita software (Fuertes et al., 2014). The record contains Marine Isotopic Stages (MISs) 3 and 2. Coccolith abundances in the sediments were higher during MIS 3 than during MIS 2. The values varied from 68.9 to 6.1x10⁸ coccolith/g. The coccolithophore assemblages were dominated by *Emiliania huxleyi*, *Florisphaera profunda*, small *Gephyrocapsa* and *G. oceanica*. The coccolith carbonate content curve varied from 0.7 to 0.3 pg/µm². The correlation between these curves is 0.43, which is considered significant to *P*=0.05. However, both curves exhibit remarkable differences. For example, the decrease in carbonate content occurs later in the record, at 22.6 kyr. In addition, there are peaks in the coccolith numbers curve that do not have a correspondence in the carbonate content curve, and vice versa. These incongruities may be explained by differences in the fossil assemblages because some species (i.e. *Coccolithus pelagicus* and *Helicosphaera* spp.) produce larger and more robust coccoliths than others. Therefore, in order to understand the potential contribution of this phytoplanktonic group to climate change, a detailed identification and quantification of the species is needed. Financial support was provided by IODP-CAPES grant 88887.091727/2014-01.

References
Coccolithophore-carbonate contribution to the ocean floor on the southern Brazilian continental margin

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Exchanges of CO₂ between the ocean and atmosphere have an important role in global climate changes. Coccolithophores participate in both the carbonate and organic carbon pumps. In this context, coccolithophore participation in carbonate accumulation on the ocean floor was evaluated in a sedimentary core collected on the slope of the southern Brazilian continental margin (29°S, 47°W), an area that is influenced by the Brazil Current. Slides were prepared by dilution and pipetting (Koch & Young, 2007), and 500 coccoliths were counted for each sample. The age model was based on ¹⁴C-calibrated ages and the δ¹⁸O curve obtained from benthic foraminifera (compared to the standard curve of Lisiecki & Stern, 2016). The carbonate content present in the coccoliths was estimated using C-Calcita software (Fuertes et al., 2014). The record contains Marine Isotopic Stages (MIS) 3 and 2. Coccolith abundances in the sediments were higher during MIS 3 than during MIS 2. The values varied from 68.9 to 6.1 x 10⁸ coccolith/g. The coccolithophore assemblages were dominated by *Emiliania huxleyi*, *Florisphaera profunda*, small *Gephyrocapsa* and *G. oceanica*. The coccolith carbonate content curve varied from 0.7 to 0.3 pg/µm². The correlation between these curves is 0.43, which is considered significant to *P*=0.05. However, both curves exhibit remarkable differences. For example, the decrease in carbonate content occurs later in the record, at 22.6 kyr. In addition, there are peaks in the coccolith numbers curve that do not have a correspondence in the carbonate content curve, and vice versa. These incongruities may be explained by differences in the fossil assemblages resulting from some species (i.e. *Coccolithus pelagicus* and *Helicosphaera* spp.) producing larger and more robust coccoliths than others. Therefore, in order to understand the potential contribution of this phytoplanktonic group to climate change, a detailed identification and quantification of the species is needed. Financial support was provided by IODP-CAPES grant 88887.091727/2014-01.

References
Eocene–Oligocene calcareous nannofossil assemblages and palaeoenvironmental changes in the northern South China Sea

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Numerous models have been proposed to explain how the South China Sea was formed, yet Palaeogene palaeoenvironmental research has been hindered by the paucity of long, continuous, well-dated geological records. In this work, Eocene to Oligocene nannofossil biostratigraphy and assemblage changes were studied from a sediment section from the northern South China Sea in order to shed light on these issues. We established an age model that confined the studied section to between ~40 and 22 Ma based on 17 calcareous nannofossil datums. The age model enabled us to date the most prominent seismic reflector T_{60} (~26.8 Ma), a regional tectonic event interpreted as corresponding to the ‘ridge jump event’ in the early phase of South China Sea spreading. Changes in nannofossil abundance and assemblage compositions infer a continuous transgression and deepening of the water depth from the Late Eocene to the Early Miocene. During the Late Eocene, the studied area was a neritic sea with relatively eutrophic conditions that supported abundant specimens of the *Reticulofenestra* *lockeri* group and *Coccolithus* *pelagicus*. From ~34 Ma to ~27 Ma, during the Oligocene, the earlier neritic environment was replaced by the relatively warm and oligotrophic conditions of a shallow sea, as indicated by higher concentrations of *Cyclicargolithus floridanus*, *Sphenolithus* spp. and *Helicosphaera* spp. Since ~26 Ma, pelagic conditions again prevailed, small *Reticulofenestra* (<5 µm) became dominant, and *Discoaster* spp. also increased in response to the deepened water depth.
Calcareous nannofossils at the Aptian–Albian boundary in the Zagros Basin (SW Iran)

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The Kazhdumi Formation in the Zagros Basin (SW Iran) primarily consists of alternations of marls, silty marls and thinly-bedded limestones. This formation was deposited under pelagic conditions in the southeastern parts of the Tethyan realm. Calcareous nannofossil biostratigraphy and palaeoecology were investigated across the Aptian–Albian interval. The studied interval spans calcareous nannofossil Zones NC7 to NC10B (Roth, 1978). The most important bioevents are the bases of *Eprolithus floralis*, *Prediscosphaera columnata*, *Axopodorhabdus albianus* and *Eiffellithus turriseiffeli*. *Eprolithus floralis* was recorded from the oldest sample in the studied interval. The youngest bioevent was the base of *Corollithion kennedyi*. Based on calcareous nannofossil taxa, the base of *P. columnata* was the most reliable bioevent for identifying the Aptian–Albian boundary. An increase in the relative abundance of *Lithraphidites carniolensis*, *Discorhabdus ignotus* and small *Zeugrhabdotus* spp. was recorded at the Aptian–Albian boundary. Simultaneously, a decrease in the relative abundance of *Nannoconus* spp. and *Watznaueria barnesiae* – markers of an oligotrophic environment – was also recorded. *Lithraphidites carniolensis*, *D. ignotus* and small *Zeugrhabdotus* spp. are considered to be eutrophic taxa, so a high relative abundance of these taxa indicates eutrophic environmental conditions at the Aptian–Albian boundary, which agrees with findings from other parts of the world.
Eocene–Oligocene calcareous nannofossils in the Zagros Basin (SW Iran)

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The upper part of the Pabdeh Formation in the Zagros Basin is a pelagic interval that consists primarily of marls and marly limestones. Eight calcareous nannofossil bioevents were identified in the studied interval. Based on calcareous nannofossil index species, the studied interval extends from Zones CNE17 to CNO3 of Agnini et al. (2014) and Zones NP18 to NP23 of Martini (1971). *Cribrocentrum erbae* occurred in the oldest sample. The next bioevent is the last common occurrence of *C. erbae*, identifying the top of Zone CNE17. According to Agnini et al. (2014), Zone CNE17 corresponds to the lower part of Zone NP18. The base of *Cribrocentrum isabellae* is the next bioevent, marking the top of Zone CNE18, which is equivalent to Zone NP18 and the lower part of Zone NP19/NP20. This is followed by the top of *Cribrocentrum reticulatum*, indicating the top of Zone CNE19. The tops of *Discoaster barbadiensis* and *D. saipanensis* were also identified, and the latter species also marks the top of Zone CNE20. Zones CNE19 and CNE20 correspond to the middle and upper parts of Zone NP19/NP20, respectively. The next bioevent is based on the common occurrence of *Clausiococcus subdistichus*, which marks the top of Zone CNE21 and the Eocene–Oligocene boundary. The top of *Ericsonia formosa* was used to define the top of Zone CNO1. Zones CNE21 and CNO1 are equivalent to Zone NP21. The top of *Reticulofenestra umbilicus* marks the top of Zone CNO2, which correlates to Zone NP22. The last bioevent identified was the base of *Sphenolithus distentus*, which marks the top of Zone CNO3 and is equivalent to the lower part of Zone NP23. Based on these data, the upper part of the Pabdeh Formation in the studied interval can be considered to be Late Eocene–Early Oligocene in age.

References
Characterisation of Upper Cretaceous geological formations in the south-central Pyrenees based on calcareous nannofossils

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The evolution of the Upper Cretaceous basin in the south-central Pyrenees is especially interesting because of how the various facies reveal their relation to the alpine tectonics that created the Pyrenees Mountains (Rosell et al., 2009; Mencos et al., 2015). The Flamicell-Pallaresa section is located in the western part of the south-central Pyrenees and presents a fairly complete sequence of Upper Cretaceous sediments, which range from the Cenomanian to the latest Campanian–Maastrichtian. Seven geological formations occur in this section, six of them marine deposits (Caus et al., 1981). Samples were collected from all of the marine formations, and a standard method was used for their preparation and examination in the light microscope. This analysis of the calcareous nannofossils has improved our knowledge of the chronology and palaeoecology of these formations, and thus has aided in an understanding of the evolution of the Upper Cretaceous basin in this region.

References
A new calcareous nannofossil record in the Lower Jurassic from Kermanshah, western Iran: A clue for evolutionary reconstructions

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An accurate calcareous nannofossil analysis was performed for the first time on Jurassic radiolarian-bearing deposits in the Kermanshah area (High Zagros Belt, western Iran). The Zagros orogenic system is a NW–SE-trending fold belt that stretches from southwestern Iran to northern Iraq. The belt was produced during the collision between the Arabian Plate and the Central Iran Cimmerian Block (Ziegler et al., 2001; Abdi et al., 2014). The High Zagros Belt corresponds to the tectonostratigraphic domain that marks the northeastern rim of the former Arabian passive margin. According to palaeogeographic reconstructions, this region was located along the northern margin of the Tethys Ocean. Calcareous nannofossils not only allowed a precise age assignment of these sediments to a latest Sinemurian to Early Pliensbachian age (~190 Ma, Subzone NJT2b of Mattioli and Erba, 1999), but also revealed an assemblage dominated by *Mitrolithus elegans* and *M. lenticularis*, species considered to be typical of the Tethyan domain (i.e. southwestern part of the epi-continental Tethys; Bown, 1987). More surprisingly, some samples contained an undescribed species of *Mitrolithus* that is characterised by a very thick spine. The spine possesses a conical globular shape and is composed of plates spirally arranged around an axial canal. The calcite plates are arranged tangentially to the longitudinal axis. The spines, which are similar to loxolith coccoliths with their delicate, tubular structure, are easily detached, and individual spines can be identified and recorded. This study opens new avenues for the interpretation of evolutionary patterns of Mesozoic calcareous nannofossils, and might bring new insights on the origin of the enigmatic nannoconid group.

References


Characterisation of the Helminthoid Flysch facies through calcareous nannofossil assemblage variations (Upper Cretaceous, northern Apennines, Italy)

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The Helminthoid Flysches (HFs) of the northern Apennines (Italy) are among the most famous and spectacular turbidite deposits in the world. Understanding the processes of their formation in confined basins, and how this relates to individual facies, is of fundamental importance for the reconstruction of the Apennine chain’s evolutionary history. Generally, the HFs are characterised by impressive tabular (sheet-like) turbidite beds, consisting of an alternation of sandstone, carbonate and shale divisions that were deposited in a tectonically-confined deep basin below the CCD (Scholle, 1971), where ponding and flow-reflection processes played an important role (Tinterri & Mazza, 2019).

This study is based on a detailed bed-by-bed, high-resolution stratigraphy, biostratigraphy and sedimentology of the Monte Cassio Flysch. Eight stratigraphic sections were measured for a total thickness of 5 km. The analysis of 100 samples, which were collected along the extent of the Monte Cassio Flysch, has revealed nannofossil assemblages with preservations ranging from poor to good and total abundances from barren to common. The presence of *Uniplanarius trifidus* and *Broinsonia parca* subsp. *constricta* indicate an age from Subzone UC15d to the top of Zone UC16 (Burnett, 1998; equivalent to CC22 and CC23 of Sissingh, 1977).

Clear differences were apparent with regard to the abundance variations of ecologically-significant taxa. For example, *Micula* spp. and *Watznaueria barnesiae* varied considerably through the section, and a relationship between their abundance and facies types has been highlighted. In light of the varying palaeoecological significance of the predominant species and the total abundances, our goal was to identify a model for the relationship between the nannofossil assemblage variations and the turbidite facies, and to unravel possible links between nannofossil assemblage variations and depositional processes. Therefore, this work aimed to create a palaeogeographic reconstruction of the Palaeotethys in the Apennine and Alpine Basins during the Late Cretaceous that applies to the HF model.

References


Biostratigraphy in the Foz do Amazonas Basin: A multidisciplinary approach

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The Foz do Amazonas Basin – the northernmost offshore sedimentary basin in Brazil – is an area of renewed interest for the petroleum industry due to recent hydrocarbon discoveries in neighboring French Guiana. Because the basin was positioned in the tropics throughout the Cenozoic, it is a poorly-represented region for palaeoenvironmental studies. However, it also has the potential to contain valuable environmental records that span the major intervals of global climate change. While there has been work on shelf sediments, such as the Amapá Formation carbonates and the Amazon Cone, little work has been published on the deeper-water sediments, the fine-grained nature of which may yield well-preserved microfossils, and therefore biostratigraphic and geochemical signals. ‘Well 2’ was drilled on the shelf slope at an approximate 750 m water depth and provides an almost continuous section of Middle Eocene to Pleistocene mudstones and siltstones. Here, we present the results of a calcareous nannofossil biostratigraphic analysis of ‘Well 2’ that was integrated at key Cenozoic intervals with planktonic foraminiferal biostratigraphy, as well as a compilation of other published biostratigraphic data from the basin, with a view to providing a framework for the development of age models in the region.
Reconstructing palaeoproductivity in the western South Atlantic since the Last Glacial Maximum: An integrated study with coccoliths and benthic foraminifera

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The main objective of this study was to assess upper slope palaeoproductivity in the western South Atlantic (core GeoB2107-3, 27°18’S, 46°45’W) during the last deglacial period (23–10 kyr BP) by combining coccolithophore assemblages, benthic foraminiferal faunas and geochemistry (Molfino & McIntyre 1990; Wefer et al. 1999; Su et al. 2015). To our knowledge, this is the first study on the southwestern Atlantic to combine all these proxies for the last deglacial period. Benthic foraminiferal-based tracers indicate clear changes between the Last Glacial Maximum (LGM) and the deglacial, including: 1) an increase in δ13C in the benthic foraminifer Uvigerina peregrina (Pereira et al., 2018); 2) a decrease in the percentage of infaunal taxa; and 3) changes in faunal assemblages, such as the shift of dominance between U. peregrina and Bulimina aculeata. These changes indicate that conditions of higher productivity during the LGM gave way to lower productivity at the beginning of the Holocene. The coccolith analysis, which is not yet complete, is being performed at CEREGE (Centre Européen de Recherche et d’Enseignement des Géosciences de l’Environnement) using an automated method that allows the identification of Noelaerhabdaceae coccoliths through an artificial neural network (Système de Reconnaissance Automatique de Coccolithes – SYRACO; Dollfus & Beaufort, 1999; Beaufort & Dollfus, 2004; Beaufort et al., 2014). This method enables rapid data acquisition, which will be compared to foraminiferal faunal and stable isotope data. The data acquisition will target indicators such as %Florisphaera profunda, the weight of small coccoliths, and the Emiliania/Gephyrocapsa ratio. These data will complement the foraminiferal proxies, and will contribute to the comprehension of western South Atlantic palaeoproductivity conditions and the relationship between the proxies during the last deglacial.

References
Calcareous nannofossil fluxes and mass across the Paleocene–Eocene Thermal Maximum

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The Paleocene–Eocene Thermal Maximum (PETM, ~56 Ma) is one of the most severe greenhouse warming events in Earth’s history. Thousands of petagrams of carbon were released into the atmosphere-ocean system in only a few thousand years, ultimately causing ocean acidification (Zachos et al., 2005). The gradual sequestration of this light carbon took place during the recovery phase of the event. Silicate weathering is thought to have been the fundamental negative feedback that triggered the input of carbonate ions (CO$_3^{2-}$) into the oceans. While this could be expected to lead to an increase in pelagic carbonate production, the fact is that a major calcification crisis has been reported in the literature. This is a paradox because the production of pelagic carbonate is directly related to the carbonate saturation state and alkalinity of the oceans. Here, we present new data for calcareous nannofossil fluxes (nannofossils/m$^2$/year) and mass (picograms) that can be used to evaluate pelagic carbonate production across the PETM at ODP Site 1209 (Shatsky Rise). To calculate the nannofossil mass, we used the automated system of Beaufort et al. (2014). Calcareous nannofossils were particularly sensitive to the palaeoenvironmental changes induced by this hyperthermal event, and a significant turnover has been reported from all the basins, as well as a reorganisation of the planktonic communities (Gibbs et al., 2006; Raffi et al., 2009). While the overall response of calcareous nannofossils to the PETM is known, systematic analyses to quantify the fluxes of different genera of pelagic carbonate have not been performed to date. Through a comparison of calcareous nannofossil fluxes, mass and independent proxies, we show how their mutual interactions affected the pelagic carbonate production across the PETM.

References
Direct and indirect evidence of coccolithophore activity in the deep euphotic zone: A review

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A large part of our knowledge of oceanic primary productivity comes from satellite information. Satellites are a valuable tool that offers convenient remote access for monitoring marine surface conditions and providing periodic observations, and this accessibility to spatial and temporal information has provided important contributions to marine sciences. However, our understanding of primary productivity dynamics is restricted to the surface layer because of the satellites’ limited capacity to reach environmental processes and population dynamics that occur deeper in the water column. Little is known about the deep euphotic zone (DEZ) because most studies of phytoplankton distributions in relation to environmental conditions and carbonate chemistry are limited because studies must rely on using ships of opportunity. Moreover, the literature studying phytoplankton populations has omitted, incorrectly classified or misinterpreted data from coccolithophore communities, resulting in the mischaracterisation of the population dynamics occurring in the DEZ. Only a handful of studies have observed monthly/seasonal phytoplankton changes in the DEZ in which the coccolithophore communities have been fully characterised. Coccolithophores contribute to the base of the marine food web and play an essential role in the cycling of carbon. Therefore, it is critical to our understanding of the biogeochemistry of the Earth system to identify the partitioning of carbon between the surface and deep layers in the marine environment. This integration allows us to expand our knowledge of the role and contribution of coccolithophores to the carbon pump, as well as their sensitivity to changes in carbonate chemistry and ocean acidification.
The ‘Micula acme’ during Oceanic Anoxic Event 3 (Coniacian–Santonian)

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Oceanic Anoxic Event (OAE) 3 has been identified in the Coniacian–Santonian interval. However, it differs from previous OAEs in that it is only of regional extent, as documented by the deposition of black shales in the equatorial to mid-latitudinal Atlantic Ocean and, in part, adjacent basins. OAE 3 is not associated with a distinctive δ¹³C anomaly, and the temporal distribution of the organic-carbon-rich sediments appears to be diachronous.

With the aim of assessing the impact of OAE 3 on calcareous nannoplankton, a biostratigraphic and quantitative analysis of ODP/DSDP sites situated in the Demarara (ODP Site 1261), Angola (DSDP Site 364), and Guinea (ODP Site 959) Basins (Atlantic Ocean) was conducted. The results showed that there were distinctive phases of enrichment in *Micula* spp., primarily in Zones CC14 and CC17 of Late Coniacian and Late Santonian age. The genus shows correlatable abundance maxima, although with different values in different locations. The highest percentages were detected at ODP Site 959. The study was extended into the Indian Ocean, and ODP Site 763 (Exmouth Plateau) and the Tanzania Drilling Program Site 39 (TDP39) were sampled. Here, *Micula* spp. showed minor increases in abundance compared to the Atlantic sites.

In addition to increases in abundance of the *Micula* group, we also detected peaks of *Marthasterites* (up to 50%) in the Early Coniacian at the supposed onset of OAE 3 and just prior to the oldest *Micula* pulse. The shifts in nannofossil composition suggest unusual oceanographic conditions, although the palaeoecological affinity of *Micula* and *Marthasterites* remains to be assessed.
Calcidiscus size variation and correlations with palaeoproductivity and palaeotemperature proxies in the Santos Basin during the last 14,000 years

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This study compared morphometric studies of the coccolithophore genus *Calcidiscus* with sea-surface temperature (SST) and palaeoproductivity proxies, based on coccolithophores and planktonic foraminifera, for the last 14 kyr. Distal shield diameter measurements of 100 *Calcidiscus* specimens were carried out on 42 samples from sediment core KF-02, drilled on the continental slope off the southeastern Brazilian margin. Specimens were selected under a polarised-light microscope and analysed using the software Axio VS40 v.4.8. *Calcidiscus* size groups were designated as small (<5 µm), intermediate (5–8 µm) and large (>8 µm), following Young et al. (2005). The *Calcidiscus* size variation showed a moderate relationship with productivity proxies and a weak, but significant, correlation with SST. No relationship between the size category of *Calcidiscus* and the preservation indices was found. Large *Calcidiscus* specimens showed a positive correlation with productivity, and the highest abundances were during the late deglacial and Early Holocene. Intermediate *Calcidiscus* dominated the studied time interval, increasing in abundance mainly from 9.7 kyr to the Recent, with an increase in SST that was associated with the displacement of the warm and oligotrophic Brazil Current towards the continent. However, during intervals of minimum SST (14–12 kyr and 9–8 kyr), intermediate *Calcidiscus* increased in abundance, while large *Calcidiscus* decreased. Small *Calcidiscus* exhibited the lowest abundances, and had a similar trend as intermediate *Calcidiscus*, increasing in abundance throughout the Holocene. We observed a strong correlation between relative sea-level estimates from benthic oxygen isotopes and *Calcidiscus* size variation. Large *Calcidiscus* showed higher abundances during low relative sea level, possibly related to the influence of nutrient input from coastal waters. Polarising-light microscope analyses were useful for identifying *Calcidiscus* size variations with minimum costs and rapid results. In addition, the size variations allow us to obtain more information than just the abundances of the genera, which, by itself, did not provide any significant correlations with the other proxies.
The Paleocene–Eocene Thermal Maximum in the Río Gor section (southern Spain): Microcodium-rich turbidites give new insights on Mediterranean climate

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The Río Gor section in the Subbetic Zone (Betic Cordillera) comprises a very expanded and quite complete Lower Palaeogene succession that contains a record of several Paleocene and Eocene hyperthermal events (Pujalte et al., 2017). The succession is characterised by hemipelagic deposits and contains numerous turbidite beds that are rich in Microcodium remains. This study reports on a multidisciplinary (lithostratigraphy, biostratigraphy, stable carbon isotope and mineralogy) study of the PETM interval in the Río Gor section. The studied interval is 21 m thick, and calcareous nannofossil and planktonic and benthic foraminifera analyses constrained the P–E boundary to an approximately 14-m-thick interval in a grey unit. Calcareous nannofossils were rich and well diversified. The studied section spans the NP9–NP10 zonal boundary of Martini (1971). Species of the genus Rhomboaster, together with asymmetrical and deformed discoasters, occurred within the PETM. The Fasciculithus/Zygrhablithus reversal defined the top of the PETM. A major turnover in the benthic foraminifera identified the benthic extinction event, and the planktonic foraminiferal distribution confirmed the base of the PETM, which coincided with a massive influx of Microcodium.

Two distinctive features characterised the PETM – a significant increase in the proportion of palygorskite and a large number of redeposited Microcodium remains, which imply arid/semiarid conditions and extreme precipitation events. Increased aridity and frequent episodes of extreme precipitation demonstrate that the PETM greatly enhanced the typical seasonal contrast of the Mediterranean climate in the Subbetic Zone.

References

Preliminary results on Miocene–Pliocene calcareous nannofossils from the Rio Grande Rise and Vema Channel (DSDP Leg 72, Sites 516A and 518, SW Atlantic Ocean): Biostratigraphy and palaeoecological inferences

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Fluctuations in the global carbon cycle and deep ocean circulation were typical during the Neogene, which resulted in a gradual worldwide cooling and the subsequent establishment of large ice sheets in Antarctica (Zachos et al., 2001). Some disruptive events stand out during this interval, such as the Miocene climate optimum (Herold et al., 2012), the Messinian salinity crisis (Hodell et al., 1994) and the Isthmus of Panama closure (Wright & Miller, 1996). The Rio Grande Rise, an aseismic feature in the southwestern Atlantic, is a critical area for understanding the displacement history of thermohaline systems because four of these systems are present in modern local hydrography, with the input of Antarctic bottom water enabled by the Vema Channel (Barker et al., 1983). Forty-six samples of calcareous oozes were recovered from DSDP Leg 72 (Hole 516A and Site 518). Slides were prepared through gravity settling, and qualitative analyses were conducted using petrographic microscopy and scanning electron microscopy, with the aim of refining the biostratigraphic framework and detecting possible palaeoecological fluctuations. Three hundred specimens were counted per sample, and 75 taxa were identified. Four biozones (NN16, NN15, NN14 and NN11) and one subzone (NN11b) were detected at both sites. Three biozones (NN13, NN12 and NN10) and one subzone (NN11a) were only found in Hole 516A, while biozones NN6 and NN5 were found only at Site 518. High relative abundance values were observed for discoasterids and reticulofenestrids, which, when associated with Pontosphaera spp., Syphosphaera spp. and the Calcidiscus leptoporus group, might indicate tropical assemblages and thus stable and oligotrophic conditions. Many preservational morphotypes of discoasterids were found throughout the section. Additional samples from Site 516 are currently being analysed.

References
Nannoconid assemblages from the Forcall Formation (Maestrat Basin, Spain): A preliminary study of Late Barremian–Early Aptian bioevents

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A preliminary characterisation of the nannoconid content from the Forcall Formation (Maestrat Basin, Spain) is presented here. The lower portion of the Forcall Formation is characterised by a poor nannoconid assemblage with a few reworked Barremian narrow-canal Nannoconus specimens (e.g. N. colomii, N. bermudezi). The assemblage is also represented by N. quadriangulus subsp. quadriangulus associated with N. truittii in Sample MIB19. The base of Rhagodiscus gallagheri was recorded 4 m above Sample M11. The suggested position for the Barremian–Aptian boundary in the Miravete section is based on the top of the dinoflagellate cyst Pseudoceratium pelliferum in Sample MIB21, 2 m above Sample M11 (Danubio, 2018). An increase in the population of Nannoconus was recorded from the middle portion of the Forcall Formation. The base of Rhagodiscus angustus was recorded in Sample MIB23, which may represent the base of OAE 1a in the Miravete section (Aguado et al., 2014). In this section, OAE 1a is considered to be coeval with a coral-rubble level with Lithocodium-Bacinella incrustations (Bover-Arnal et al., 2016) and lies 9 m above the base of R. angustus. An increase in the relative abundance of wide-canal nannoconids (34% in MIB25) was recorded in the upper portion of the Forcall Formation, associated with the appearance of wide-canal species, such as N. vocontiensis, N. wassallii and N. bucheri. Nannoconus bucheri increased from 15% to 24% in Samples M113 to MIB26. These abundances are interpreted to be a possible N. bucheri pulse above OAE 1a (Erba, 1994). Despite the limited number of samples, these preliminary results are very promising, and could help constrain the position of the Barremian–Aptian boundary and OAE 1a, a debated topic in the Miravete section (Cors et al., 2015; Bover-Arnal et al., 2016). Further analyses will be necessary to answer the question of whether Nannoconus species are reliable enough to characterise the Barremian–Aptian boundary.

References


Biodiversity of extant coccolithophores in Macaronesia (northeast Atlantic Ocean)

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Our study aimed to characterise the extant coccolithophore communities around the islands and seamounts of Macaronesia. The results reflect the analysis of 393 sea-water samples, using polarising-light microscopy, that were collected during four oceanographic campaigns – POS466 around the Madeira Archipelago (March 2014), MSM49 around Cape Verde (November–December 2015) and BIOMETORE 7 and 8 around several seamounts between the Madeira Archipelago and the Portugal mainland (Madeira-Tore complex; August–September 2016).

Around the Madeira Archipelago, two biogeographic domains, with distinct physicochemical and calcareous nannoplankton characteristics, were identified that are separated by a transient frontal zone. The more productive northeastern sector, with maximum coccolithophore densities of 112x10³ cells L⁻¹, was linked to the injection of a westerly flow with its origin in the Azores frontal system. *Emiliania huxleyi*, along with small *Gephyrocapsa* spp., dominated the assemblages. *Gephyrocapsa oceanica*, *Michaelsarsia* spp., *Syracosphaera* spp., *Umbilicosphaera* spp. and *Algirosphaera robusta* were relevant subordinate taxa. No vertical succession of coccolithophore species was found due to the occurrence of a homogeneous and well-mixed surface layer (Narciso et al., 2019). Around the Cape Verde Archipelago, including the Senghor Seamount, densities reached up to 30x10³ cells L⁻¹, whereas in the Madeira-Tore complex (Gorringe, Josephine and Seine seamounts), they reached up to 43x10³ cells L⁻¹. In these two regions, a strong stratification of the water column during the sampling period was inferred from coccolithophore depth distributions. At Cape Verde, *E. huxleyi* was the dominant species, followed by *G. oceanica*. *Florisphaera profunda*, small *Gephyrocapsa*, *A. robusta*, *Helicosphaera* spp., *Syracosphaera* spp. and *Umbellosphaera* sp. were the subordinate taxa. In the Madeira-Tore complex, small *Gephyrocapsa* exceeded *E. huxleyi*, and *Umbellosphaera* sp., *G. muellerae*, *F. profunda*, *Syracosphaera* spp. and *Rhabdosphaera* spp. were the subordinate taxa.

References
Changes in calcareous nannoplankton assemblages and the evolution of biomarkers in the Hungarian Palaeogene Basin (Central Paratethys)

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The Eocene–Oligocene climate transition (EOT) was a major greenhouse to icehouse shift that ended the warm, ice-free early Palaeogene world and ushered in Antarctic glaciation. The Paratethys was a unique epicontinental sea in a palaeogeographically complex area that was influenced by the ongoing Alpine Orogeny. This study focused on the Hungarian Palaeogene Basin in the Central Paratethys, aiming to characterise the effect of the global cooling event on microfossil assemblages and to reconstruct the palaeoenvironmental evolution of the region across the EOT. The Cserépváralja-1 (CSV-1) drill core was sampled at a ~20-cm spacing and studied using palaeontological and statistical analyses.

The calcareous nannoplankton biostratigraphy was focused on Zones CNE21 and CNO1 (NP 21), which include the Eocene–Oligocene boundary. The base of Zone CNE21 is drawn at the last common occurrences of Discoaster saipanensis and D. barbadiensis. The first common occurrence of Clausiococcus subdistichus may mark the base of Zone CNO1, and the top of Ericsonia formosa marks its upper boundary. Using hierarchical cluster analysis, we distinguished five successive assemblages in the studied core section. Our results show that taxa with a preference for oligotrophic and warm surface-waters dominated the oldest assemblage. Above this, at the onset of the EOT, were taxa indicative of oligotrophic conditions, but temperate surface-water. Nannoplankton abundances dropped to their minimum in the third phase, when taxa that were adapted to cool surface-waters gradually became dominant. We interpreted this as a combination of the effects of the cooling climate and local magmatic activity related to uplift of the Alps. A gradual rebound in nannoplankton abundance was observed in the fourth phase. After the end of the EOT, the youngest assemblage included mainly eurytopic taxa, which could tolerate increased fresh-water and terrestrial influxes.

As part of an ongoing project, the studied core was resampled at a lower resolution of an ~34–12 Ma interval, and the biostratigraphy of the organic-walled dinoflagellate assemblages are being studied. Furthermore, using calcareous nannoplankton and dinoflagellate data combined, with co-occurring biomarker distributions, we will be able to reconstruct the sea-surface temperature of the Central Paratethys and provide more information about the primary biomarkers in the marine sediment to support the expanding field of combined micropalaeontology and geochemistry.
Early–Middle Eocene calcareous nannofossil biostratigraphy of the central Negev (southern Israel)

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The Negev, located on the northeastern extension of the African-Arabian Plate, is the most stratigraphically complicated area in Israel. During the Eocene, most of this area was exposed to the open-ocean conditions of the southern Tethys. Some of the outcrops indicate deposition in an off-shelf environment, and other outcrops indicate inter-basin deposition, especially in relation to active tectonic elements, such as faults and folds. The Eocene outcrops consist mainly of pelagic chalks, sometimes with chert and limestone intercalations.

The biostratigraphic analysis was based on the Lower–Middle Eocene deposits of the Ein Zik 1 and Ein Zik 2 sections (central Negev), situated between the northern Negev anticline and the Ramon anticline. The standard calcareous nannoplankton zonation of Martini (1971) was applied. The Ein Zik 1 section (95 m) exposes the Takiye Formation (grey marls, 6 m), the overlying Mor Formation (chalky deposits with silica layers and chert nodules, 38 m) and the Nizzana Formation (chalk and limestone intercalations, 51 m). The Ein Zik 2 section (69 m) continues the Ein Zik 1 section, and exposes the Horsha Formation (chalks, 35 m) and the overlying Matred Formation (chalks with limestone intercalations, 34 m).

At Ein Zik 1, the Takiye Formation and the lowermost part of the Mor Formation belong to the Early Eocene Zone NP11. The lower part of the Mor Formation belongs to the Early Eocene Zone NP12, whereas its upper part and the lower part of the Nizzana Formation belong to the Early Eocene Zone NP13. The rest of the Nizzana Formation can be referred to the Middle Eocene Zone NP14 (NP14a and NP14b subzones). At Ein Zik 2, the lower part of the Horsha Formation belongs to the Middle Eocene Subzone NP14b, and its middle and upper parts are referred to the Middle Eocene Zone NP15 (NP15a and NP15b). The Matred Formation belongs to the Middle Eocene Subzone NP15c and Zone NP16.

References
Coccolithophore biogeography and its relationship to environmental variables in western South Atlantic surface sediments

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In this study, the coccolithophore assemblages from 44 marine surface-sediment samples from the western South Atlantic were analysed and compared with local oceanographic variables in order to determine their biogeographical and ecological affinities. In addition, the analyses of 36 samples from the study of Boeckel et al. (2006) were included. *Emiliania huxleyi*, *Florisphaera profunda* and *Gephyrocapsa* spp. were the most abundant species. *Emiliania huxleyi* dominated the assemblages of cold and nutrient-rich waters, while *Gephyrocapsa* spp. were more abundant in regions with lower mixed-layer depths. These species demonstrate a preference for environments with a shallower nutricline. On the other hand, *F. profunda* was more abundant in the warm and oligotrophic environments of subtropical regions, revealing its preference for a deeper nutricline. The correlation results between the water parameters and the relative abundances of the species revealed an affinity of *Calcidiscus leptoporus*, *E. huxleyi*, *Coccolithus pelagicus* and *Gephyrocapsa ericsonii* with waters more enriched in nutrients. In contrast, *Gephyrocapsa* spp., *Gephyrocapsa oceanica* and *Helicosphaera* spp. were associated with coastal and mesotrophic regions. Because *Gladiolithus flabellatus* and *Discosphaera tubifera* appear to be associated with waters from deeper mixed layers in the tropical region, they may be used, together with *F. profunda*, as indicators of a deeper thermocline/nutricline. Using principal component analysis, we identified four different biogeographic provinces that reflect the oceanographic characteristics of the photic zone: 1) *G. flabellatus* and *D. tubifera* were characteristic of the North Brazil Current region; 2) *F. profunda* and the subtropical species were more abundant in the Brazil Current region of the subtropical gyre; 3) higher abundances of *Gephyrocapsa* spp. occurred in the shallower environments of the Brazil Current; and 4) *E. huxleyi* dominated the cold, eutrophic southern regions.

References
Coccolithophore palaeoproductivity variations related to hydrographic changes from the Last Glacial Maximum to the Holocene in the western South Atlantic Ocean

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The aim of this study was to acquire information about palaeoproductivity records based on coccolithophore assemblages and relate them to the contribution of terrigenous sediments. Sediment core GL-824 was collected from the upper slope of the western South Atlantic Ocean at 532 m water depth. Terrigenous-supply proxies (Fe/Ca and Ti/Ca) were measured by XRF and showed a very similar pattern when compared with the fine-fraction sediments – higher values throughout the Last Glacial Maximum (LGM) and lower values during the Holocene. The dominant species in the coccolithophore assemblages were *Emiliania huxleyi*, *Gephyrocapsa* spp. and *Florisphaera profunda*, with these species together representing between 82 and 99% of the total assemblages. They, along with a few subordinate species, were used for the palaeoproductivity analysis. The N ratio and the estimate of primary production (EPP) exhibited a very similar trend, with higher values of productivity during the LGM. Towards the Late Holocene, the values lowered at ~15 kyr, when the N ratio and the EPP reached their minimum values. Palaeoproductivity was controlled mainly by the position of the main flow of the Brazil Current (BC), which can be linked directly to relative sea level. In periods of high sea level (low Fe/Ca and Ti/Ca), the BC transported the warm and oligotrophic waters to the upper slope, preventing any nutrient arrival from deeper layers or coastal waters. In contrast, during low sea-level periods (high Fe/Ca and Ti/Ca), the offshore displacement of the BC allowed the presence of coastal waters (more nutrient rich than tropical waters) and the erosion of the exposed shelf, which provided more nutrients to the photic zone, thus enhancing primary productivity.
Biostratigraphic study of Paleogene calcareous nannofossils from DSDP Leg 39, Site 354, Ceara Rise, equatorial Atlantic

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The Ceara Rise is located in the equatorial Atlantic Ocean at a depth of approximately 3000 m, and is bordered on the north, east and south by the Ceara Abyssal Plain, and on the west/southwest by the Amazonas Basin. This rise is characterised as a submarine topographic elevation that is embedded in the oceanic crust (Kumar & Embley, 1977). This work conducted a biostratigraphic study of Eocene–Oligocene calcareous nannofossils from DSDP Site 354. Fifteen slides were prepared, described and quantified. Richness and abundance indices were recorded for each sample. Some of the primary species present are *Isthmolithus recurvus*, *Sphenolithus pseudoradians*, *S. ciperoensis*, *Discoaster barbadiensis*, *D. saipanensis*, *Clausiococcus subdistichus*, *Sphenolithus distentus*, *S. predistentus*, *Cyclicargolithus abisectus*, *Helicosphaera recta*, *H. euphratis* and *Triquetrorhabdulus milowii*. The main species were photographed and measured in order to construct a detailed biozonation, and a total of six biozones were identified from the Eocene–Oligocene interval. There was a gradual decrease in specimen size upsection, which, in association with the occurrence and preservation of the specimens, suggests a possible transition from a favourable palaeoenvironment for nannoplankton to a less favourable one. This study has shown that it is possible to stratigraphically identify this interval, and this method can be used at similar elevations in equatorial seas.

References
Distribution of *Micula murus* in the Late Maastrichtian southwestern Atlantic Ocean and its contribution to palaeoceanographic reconstructions

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During the Late Maastrichtian, evidence of a global warming episode was recorded on the Atlantic coast of northern Argentina (Salado, Colorado and Neuquén Basins). The recovered assemblages of marine invertebrates, dinoflagellates, foraminifera and nannofossils show affinities to coeval assemblages from northern Brazil and Africa, and Caribe (e.g. Guler et al., 2019). These nannofossil assemblages differ in taxonomic composition and relative abundance from the ones of southern Patagonia. In the Salado, Colorado and Neuquén Basins, the Late Maastrichtian nannofossil assemblages were dominated by *Micula* spp., with *M. staurophora* being the most abundant. The palaeoenvironmental significance of these *Micula*-dominated assemblages is not fully understood, but has been long discussed (e.g. Keller et al., 2007), and they seem to respond to high environmental stress. This acme of *Micula* spp. has proved to be useful in local biostratigraphic schemes (Pérez Panera et al., 2016). *Micula murus* is present in some localities in the Neuquén Basin (Scasso et al., 2005; Keller et al., 2007; Musso et al., 2012) and in four of the nine Salado and Colorado Basins wells. The relative abundance of *M. murus* is less than 1%, and was found in assemblages with high diversity indices. An exception was the Pejerrey Well (northeastern Colorado Basin), where *M. murus* constituted as much as 20% of the assemblage and was one of the most abundant species. Previous works have pointed out that this warm-water taxon migrated northwards and southwards during a mid-Cretaceous warming episode, and became abundant in the latest Maastrichtian (Thibault et al., 2010; do Monte Guerra et al., 2016; Thibault, 2016). The northeastern Colorado Basin area reflect the confluence of northern warm waters and southern cold waters, and the southern Colorado Basin may represent the boundary between mid-latitude and high-latitude realms in the southwestern Atlantic Ocean during the Late Cretaceous.

References


Strain-specific calcification response of *Gephyrocapsa huxleyi* to pH change: COCCACE, a high-throughput live imaging method

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In *Gephyrocapsa huxleyi*, the calcification response to changing carbonate chemistry is believed to be strain-specific. In order to test this hypothesis, we developed a high-throughput live imaging method of microscopy, coupled with an experimental setup, that would be able to: 1) continuously estimate the calcification of the coccolithophores; 2) control and stabilise the pH and pCO₂; and 3) have numerous cultures in the same batch. We used an automated inverted microscope, a light wavelength of 562 nm (that does not excite chlorophyll), a pair of circular polarisers, a 48-multiwell plate placed in an atmosphere-controlled chamber via a CO₂ mixer, and a numerical camera. A computer controlled this setup. Twenty-three strains of *G. huxleyi* were selected in order to represent a large panel of oceanographic conditions. Five pH experiments were made, ranging from 8.20 to 7.44. After being acclimated to the medium, two replicates of each of these strains were transferred into the wells for about 80 hours, with an alternating day/night of 12/12 hours. Twenty-four fields of view for each well were imaged every two hours. The pH was maintained by flushing with a %CO₂ atmosphere that corresponded to the desired pH. The images were treated with software that measured the number of coccospheres in each well, their size, their area and the calcite mass. It was therefore possible to estimate instantaneous calcification rates. The reproducibility among the replicates was high. A circadian evolution of the calcification was observed in most cases. The optimum pH of calcification for each strain was evaluated. Four cases were observed – strains that calcify best at high, mid or low pH, and those that were not influenced by pH. This work illustrates the complexity of predicting the potential adaptation to future ocean acidification by *G. huxleyi*. 
Calcareous nannofossil biostratigraphy of the External Dinarides Flysch (Vrčić-Staravasa Pag Island, Croatia): Key to an Eocene tectonostratigraphic and palaeoenvironmental interpretation

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The calcareous nannofossil biostratigraphy and palaeoecology were studied from two turbiditic successions that are exposed on Pag Island (Croatia), the age of which is still a matter of debate. The age assignment for the deposition of the turbiditic succession has important implications for understanding the geodynamic and palaeoenvironmental evolution of the External Dinarides (Vlhanovic et al., 2012; Babić & Zupanič, 2016). We collected samples from well-exposed sedimentary sections in the southwestern limb of the Pag anticline, and performed quantitative calcareous nannofossil analyses that revealed abundant and highly-diverse species. Age-diagnostic species indicated the presence of the CNE14–CNE15 biozones, so the flysch deposition occurred in the Lutetian–Bartonian, and the age could possibly be further restricted to the lower part of CNE15 (43–39.7 Ma). This result contrasts with the Miocene age proposed by Mikes et al. (2008) for the same section. The vertical facies variation and palaeoecological indications suggest an increasing palaeobathymetric depth during deposition. Implications for our new data on the evolution of the External Dinarides will be discussed. The calcareous nannofossils provided an age assignment of the flysch that is comparable with the Middle Eocene Climatic Optimum (MECO). This is consistent with the MECO in the presence of common warm-water taxa, which were also recorded in the Tethyan basin in central Italy (Jovane et al., 2007).

References


Calcareous nannoplankton response to an AMOC shift during the last 200 kyr in the western South Atlantic

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Palaeoceanographic changes during the last 200,000 years in the western South Atlantic were studied by means of calcareous nannoplankton from three sediment cores drilled in the Santos Basin (Brazilian margin) between 1900 and 2200 m water depth. Modern surface-water circulation is controlled by the oligotrophic Brazil Current (BC) that flows southwards, transporting tropical water and meandering to form mesoscale eddies and upwelling near the cities of Cabo Frio and Arraial do Cabo (Silveira et al., 2000). These processes are responsible for bringing colder, nutrient-rich South Atlantic Central Water to the surface. Deep circulation is controlled by the deep western boundary current (DWBC) that is bathed by North Atlantic deep water (NAWD) along the continental slope (Stramma & England, 1999). The NADW provides good preservation conditions for calcite, while the deeper Upper Circumpolar Deep Water (UCDW) is undersaturated in carbonate, resulting in the poor preservation of carbonate sediments. Estimates of primary palaeoproductivity were obtained from calcareous nannoplankton abundance and accumulation rates, and palaeoproductivity proxies, calcium carbonate content and complementary geochemical data analyses were performed. The results demonstrate that the palaeoproductivity record and calcareous nannoplankton accumulation were related to changes in ocean dynamics at the surface and in the deep ocean. Well-preserved coccoliths were recorded during episodes of strengthened Atlantic meridional overturning circulation (AMOC), which is similar to modern conditions. During these episodes, nannoplankton assemblages recorded higher productivity and diversity (Quadros, 2017), which was associated with prolonged sea-surface warming in the western South Atlantic (Santos et al., 2017). However, we also recorded poor preservation conditions and lower coccolith accumulation rates, diversity and productivity, which were interpreted as a northward advance of southern-sourced deep waters (UCDW) due to the AMOC weakening and the BC strengthening. Changes in calcareous nannoplankton primary palaeoproductivity during the last 200,000 years were separated into seven intervals.

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Modern silicoflagellate assemblages as indicators of the primary hydrological zonal systems of the Southern Ocean

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Silicoflagellates are a small group of unicellular phytoflagellates that resemble some Haptophyta. During one phase of their life-cycle, silicoflagellates form a siliceous skeleton that is composed of a network of tubular and hollow elements made of biogenic silica that are connected by triple junctions. Silicoflagellates are widespread in present-day oceans, and are particularly abundant in coastal regions and areas under the influence of river discharge, where siliceous phytoplankton often dominate the phytoplankton communities. In the Southern Ocean, silicoflagellates are a common component of living phytoplankton communities, and have a widespread presence in silica-rich sediments. Due to their sensitivity to changes in sea-surface temperature, silicoflagellate skeletons have been used as biotic proxies for palaeotemperature. Recent research, using sediment traps deployed along a transect in the Australian sector of the Southern Ocean, has suggested that the position of the Subantarctic Front could be traced using an index that is based on the proportions of two different species of the genus Dictyocha. Here, we provide new silicoflagellate flux data from a sediment trap that was deployed in the subantarctic waters southeast of New Zealand to assess the applicability of this index to the New Zealand sector of the Southern Ocean.
A revision of silicoflagellate species composition in the western Mediterranean inferred from sediment traps

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In this study, variations in the composition and abundance of silicoflagellate sinking assemblages were reanalysed from materials collected from a set of sediment traps deployed in three distinct regions of the western Mediterranean – the Gulf of Lions, the Catalan margin and the Alboran Sea. These samples were previously studied by Rigual-Hernández et al. (2010), who identified three silicoflagellates species across the study transect – Dictyocha fibula, D. speculum and Octatis octonaria. Here, we examined the species taxonomy of the genus Dictyocha in order to determine whether those specimens classified as D. fibula were one, or possibly more, species. A detailed taxonomic analysis allowed us to subdivide D. fibula into two species – D. stapedia and D. aculeata. Dictyocha stapedia provided the largest contribution to the silicoflagellate assemblage in the northern sites (up to 80%), suggesting an affinity with areas of high nutrient availability. Species such as Stephanocha speculum and O. octonaria were also observed. Stephanocha speculum was most abundant in the northern locations, highlighting the affinity of this taxon for cold water-masses. Octatis octonaria was restricted to the Alboran Sea sediment traps, where temperatures reached their highest values and nutrients were scarcer. Other species, such as Dictyocha crux, D. pentagona and Corbisema sp., were observed to have double skeletons and aberrant skeletons.

References
Monitoring the seasonal cycle of *Emiliania huxleyi* populations in the subantarctic Southern Ocean

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Anthropogenic CO$_2$, which has been accumulating in the oceans since the industrial revolution, decreases carbonate-ion concentrations and the pH of the surface ocean. Polar and subpolar regions can be expected to experience the most severe impacts of ocean acidification. Increased CO$_2$ concentrations in laboratory cultures often have a negative effect on the physiological processes of the most abundant calcifying phytoplankton species, *Emiliania huxleyi*. However, a few studies have found no trend, or even elevated calcification, in *E. huxleyi*. A possible explanation for this may lie in the genetic diversity in *E. huxleyi*. Laboratory experiments are often focused on single strains, and are unable to reproduce the complexity of natural ecosystem features. Therefore, it is of critical importance to assess the response of *E. huxleyi* populations to changing environmental conditions in their natural habitat.

Here, we report on seasonal variations in the abundance and composition of *E. huxleyi* assemblages that were collected using an autonomous water sampler and four moored sediment traps deployed in the Australian and New Zealand sectors of the subantarctic zone. The combination of morphometric and taxonomic analyses, together with in-situ measurements of environmental parameters, allowed us to monitor, with unprecedented detail, the seasonal cycle of *E. huxleyi* morphotypes in the pelagic waters of the subantarctic zone. Additionally, seasonal changes in coccolith weights were estimated using circularly polarised micrographs. A similar seasonality was found in all the time-series analysed, which suggests that the observed seasonal succession of *E. huxleyi* morphotypes must be a circumpolar feature of the subantarctic zone. Finally, the contribution of other coccolithophore species to carbonate export fluxes is discussed.
Calcareous nannoplankton thanatocoenosis distribution in the southwestern Atlantic Ocean: New evidence in the western Malvinas Current gyre

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The coccolith thanatocoenoses were qualitatively and quantitatively analysed from 34 surface samples collected during a north-south transect along the Argentine continental margin. The aim of this study was to identify biogeographical distribution patterns in relation to actual surface-water environmental parameters, such as temperature, nutrient availability and salinity. A preservation index based on the differential dissolution between robust *Calcidiscus leptoporus* versus delicate *Emiliania huxleyi* and *Gephyrocapsa* small spp. was applied, and we estimated that there was no carbonate dissolution in the study region. In general, *E. huxleyi* is the most abundant species in the study area. The cluster analysis results, based on the relative abundance of *E. huxleyi*, *G. muellerae*, *C. leptoporus* and *Gephyrocapsa* small spp., revealed two main groups (A and B), separated at 14 units of linkage distance. Group A, which is restricted to off the southwestern Malvinas Islands (53°S), is dominated by *G. muellerae* (>57%). Group B, which is dominated by *E. huxleyi* (>85%), is distributed in two geographical areas: 1) in the south (55°S, near Sloggett Canyon); and 2) in the north (between 40°S and 47°S). These two groups reflect the characteristics of the overlying surface waters, and their distributions appear to be controlled by temperature and nutrient availability. Moreover, Group A, which is dominated by *G. muellerae*, is geographically constrained to the previously-proposed Malvinas Current gyre area. *Gephyrocapsa muellerae* has a strong negative correlation with temperature and salinity, and a positive correlation with nutrients. Our results are consistent with the existence of a western Malvinas Current gyre that transports cold, nutrient-rich Antarctic waters and upwells near the western Burdwood Bank area.
Plankton community dynamics through the Palaeogene–Neogene transition from the northwest Atlantic (IODP Expedition 342, Sites U1406 and U1411)

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The later Palaeogene saw a significant climate change as the Earth system shifted from greenhouse to icehouse mode. This dramatic switch saw major extinctions and compositional changes in plankton across the Eocene–Oligocene boundary, but we lack the long-term quantitative records that document the structure and timing of coccolithophore diversity through this interval, and which would allow us to test whether climatic shifts played a significant role in plankton evolution, population variability and population composition.

Here, we present long-term community records of nannoplankton from deep-sea sites U1406 and U1411 (IODP 342) that provided stratigraphically-expanded Eocene through Early Miocene sections, including exceptionally well-preserved Eocene to Early Oligocene and Late Oligocene to Early Miocene calcareous nannoplankton (Site U1406), and moderately well-preserved Oligocene nannoplankton (Site U1411). This ~23-Myr record (45 to ~22 Ma) enables us to track nannoplankton diversity and community compositions through this interval, and to compare these data with proxies of climate and ocean changes.
Calcification and latitudinal distribution of extant coccolithophores across the Drake Passage during late austral summer 2016

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There has been recent interest in polar coccolithophore communities, but field observations regarding their biogeographic distributions are scarce for the Southern Ocean. This study documents the latitudinal variability in coccolithophore assemblage compositions and coccolith mass variations of the ecologically-dominant species Emiliania huxleyi across the Drake Passage. Ninety-six water samples were collected, from 10 to 150 m water depth at 18 stations, during the POLARSTERN Expedition PS97 (February–April 2016). A minimum of 200 cocoliths per sample were identified using the scanning electron microscope, and the coccolith mass was estimated using light microscopy. We found that coccolithophore abundance and diversity decreased southwards, marking different oceanographic fronts as ecological boundaries. We were able to characterise three zones: 1) the Chilean margin, where E. huxleyi type A (normal and overcalcified) and type R are present; 2) the Subantarctic Zone, where E. huxleyi reaches maximum values of 212.5x10^3 cells/L, and types B/C, C and O are dominant; and 3) the Polar Front Zone, where E. huxleyi types B/C and C dominate. We link the decreasing trend in E. huxleyi coccolith mass to the poleward latitudinal succession of type A to type B. Remarkably, we found that coccolith mass is strongly anticorrelated to total alkalinity, total CO₂, bicarbonate ion and pH. We speculate that low temperatures are a greater limiting factor than carbonate chemistry in the Southern Ocean. However, further in-situ oceanographic data are needed to verify the proposed relationships. We hypothesise that assemblage composition and calcification modes of E. huxleyi in the Drake Passage will be strongly influenced by the ongoing climate change.
Studies on fossil silicoflagellate assemblages from North America

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The western and eastern coasts of North America have very different oceanographic characteristics, with the former associated with cooler, upwelled waters and the latter with warm Gulf Stream waters. Because it is known that living silicoflagellates are somewhat sensitive to changes in water temperature, these differences should be apparent in the fossil silicoflagellate assemblages found in coastal diatomaceous outcrops. Many of these outcrops were deposited during the Miocene, when significant tectonic and oceanographic changes were occurring, as well as silicoflagellate extinctions (Naviculopsis and Corbisema) and shifts in skeletal morphology (e.g. the change in bridge orientation in Dictyocha). Our results show that on the Pacific side, the assemblages were often dominated by the cold-water genus Stephanocha, while on the Atlantic side, Distephanopsis was more numerous, suggesting the latter may be related to warm water.

Some fossil silicoflagellate species exhibit a wide range in skeletal size and morphology, as well as having long stratigraphic ranges. This is certainly the case with the species complex Distephanopsis crux, and in order to understand this variation, the type materials, or samples from the type localities, should be examined. In this study, which focused on D. crux from Miocene–Pliocene samples, the specimens could be separated into three types on the basis of the major-axis basal spine length, the apical ring diameter and the major-axis basal ring diameter. Type 1, D. longispinus (D. soljanii and D. contraria are probably synonyms), has very long major-axis basal spines, shorter minor-axis basal spines, and a large apical ring. Type 2, D. crux sensu stricto (D. schauinslandii subsp. stradneri is probably a synonym), has variable-sized basal spines and a small apical ring, while Type 3, D. cf. D. crux f. asper, has variable-sized basal spines and a large apical ring.
Pliocene–Holocene calcareous nannofossils from the Sergipe-Alagoas Basin (Piston Core SA5-0033): A preliminary study

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The objective of the present study was to identify calcareous nannofossils in seven samples collected between 40 and 100 cm in piston core SA5-0033 that the National Petroleum Agency of Brazil drilled in the Sergipe-Alagoas Basin. A 1-m section in this well can be subdivided into three sedimentary facies – carbonaceous mud with 20% bioclasts (100–90 cm), marl with bioclasts (90–10 cm) and carbonaceous mud (10–0 cm). The samples were prepared using the random decantation method of Antunes (1997), using two adaptations – the use of Norland optical adhesive and allowing the sample to settle for four minutes. The interval studied contains a very rich and diversified calcareous nannofossil assemblage from the Pliocene to Holocene, with a total of 37 species – 23 species of coccolithophores and 14 species related to ascidians, braarudospheres, discoasters and calcareous dinoflagellates. The dissolution was more evident in the thoracospheres that are related to the calcareous dinoflagellates. Three poorly-preserved specimens were observed at 90 cm, and another individual at 70 cm, and it was possible to recognize Discoaster cf. D. brouweri, D. cf. D. asymmetricus and Discoaster cf. D. pansulus, which may indicate that deposition occurred in the Pliocene. As this study continues, we intend to confirm oscillation in the fossil composition and review the influence of geological and paleoceanographic events. [IODP/CAPES 8888.091703/2014-01].

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The role of continental runoff versus upwelling in triggering the Weissert Oceanic Anoxic Event (mid-Valanginian): Micropalaeontological and isotopic data

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The Weissert Oceanic Anoxic Event corresponds to the first significant carbon-isotope excursion of the Cretaceous, and has been associated with a global increase in marine surface-water productivity and a biocalcification crisis (Erba et al., 2004). This study aimed to examine the fertility increase and trace the source of nutrients during this event into the Essaouira-Agadir Basin (EAB, Morocco). During the Valanginian, the EAB was a temperate platform, with mixed carbonate/siliciclastic deposits on a topographic ramp. Calcareous nannofossil abundances and assemblages, along with brachiopod-derived δ18O data, were used to examine changes in marine primary productivity and temperature. Neodymium and lead isotope analyses, which can be used to trace the source of nutrients, are still in progress. We used ammonite data to obtain a high-resolution biostratigraphic framework. We present here the results obtained from the Zalidou distal section. The Weissert Event has now been identified for the first time in southern Tethyan margin carbonate deposits. It is characterised by three phases (rising, plateau and smooth decrease) in the δ13C record, as described by Martinez et al. (2015). Prior to the Weissert Event, there was a decline in nannoconid abundance. The increasing δ13C values are associated with a decrease in both carbonate production and nannofossil total absolute abundance (NTAA). The latter, excluding poor preservation or dilution by terrigenous influx, suggests unfavourable conditions for nannofossils. Simultaneously, the relative abundance of the high-fertility taxon *Diazomatolithus lehmani* increases. This phase is concomitant with both a transgression and cooler marine temperatures. As the δ13C further increased, nannofossil primary productivity increased, as attested to by both rising NTAA and the relative abundance of high-fertility, small *Zeugrhabdotus* spp. This is also concomitant with higher terrigenous input, as recorded by the presence of sandstone deposits. During the δ13C plateau and decrease, favourable conditions for the nannofossil community were established, as attested to by the recovery of large calcifiers, such as nannoconids.

References
Variations in calcareous nannofossil assemblages during the Paleocene–Eocene transition on the Moesian Platform, Bulgaria: Constraints and significance for a low- to mid-latitude record of the PETM

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Previous studies have identified a drastic shift in calcareous nannofossil composition in two Bulgarian sections – Bozhuritsa and Riben – that are situated in the central part of the Moesian Platform of northern Bulgaria (Stoykova & Ivanov, 2005). Biostratigraphic analyses indicate that the sampled sections (Zones NP9 to NP10) provide insights into the biotic response of nannoplankton communities to the remarkable global warming event – the Paleocene-Eocene Thermal Maximum (PETM). Variations in calcareous nannofossil assemblages before, during and after the PETM were examined through high-resolution sampling of the targeted interval. Two dissolution zones, the first at the onset of the PETM (NP9b) and the second in the lowermost Eocene (NP10), were almost barren of calcareous nannofossils. Moreover, the negative δ¹³C excursion interval contained a warm-water assemblage, including Rhomboaster spp., Toweius serotinus and rare Discoaster araneus. The variations in calcareous nannofossil assemblages in Bulgarian sections are fully comparable to those reported worldwide (e.g. Angori et al., 2007; Self-Trail et al., 2012) for low- to mid-latitude records of the PETM. The sedimentology of the studied successions suggests that deposition likely took place in a middle shelf setting.

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References


Development and occurrence of *Emiliania huxleyi* morphotypes in the North Atlantic Ocean during the last 270,000 years

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The currently-accepted morphotype classification for *Emiliania huxleyi* is based entirely on modern samples, and the stratigraphic range of distinct morphotypes is unknown. Therefore, the main objective of this study was to investigate the occurrence of known *E. huxleyi* morphotypes in the fossil record and to study chronological and geographic changes in the composition of *E. huxleyi* assemblages in the North Atlantic Ocean during the last 270,000 years.

In total, four sediment cores, aligned along a N–S transect covering the equatorial to subpolar North Atlantic Ocean, were investigated. Counts of morphometric coccolith parameters were conducted using an SEM, and measurements of these parameters on SEM images were analysed using statistical methods. Three normally-calcified morphotypes (Types A, B/C and O) and one heavily-calcified morphotype (here named Type T) could be distinguished in the fossil record. In addition, a morphotype (Type R*) characterised by extensive distal shield calcification, was observed. All records show a similar, but diachronous, size evolution of *E. huxleyi* coccoliths, with the largest coccolith sizes occurring during MIS 4 and MIS 3. A size increase at higher latitudes, with up to 30% larger coccoliths, was also observed. In addition, a dominance of *E. huxleyi* Type O was observed at low latitudes, although this morphotype has previously been considered to be a cold-water type.
Constraining the Fantangisña serpentinite mud volcano (Mariana Forearc) episodicity using calcareous nannofossils

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In 2016, sediments were collected during IODP Expedition 366 from the Mariana Convergent Margin and analysed to address key questions regarding the age and episodicity of the eruption of the Fantangisña serpentinite mud volcano (SMV), one of three mud volcanoes (MVs) in the Mariana Forearc. Here, we used the calcareous nannofossils in the pelagic sediments collected from the MV summit and flank to estimate the age of the MV edifice, supplementing this with planktonic foraminifera in some coarse-grained intervals. Because of their deep origin, most of the MV sediments were barren of nannofossils, although some contained rare to very rare, poorly-preserved specimens, hence making them unreliable biostratigraphic markers. On the other hand, the pelagic sediments draping the MV or beneath the edifice contained abundant, well-preserved nannofossils, and thus provided a rather precise age estimate. Results from this study show that the biostratigraphic age of the Fantangisña SMV can be well constrained. The pelagic cover on top of the serpentinite mudflows yielded an age of ~0.44 Ma (Late Pleistocene), marked by the top of Pseudoemiliania lacunosa. The forearc sediments were dated at ~11.21 Ma (Late Miocene), based on the last occurrence of Calcidiscus premacintyrei. This indicates that the timespan for the build-up of the entire Fantangisña edifice at the Mariana Forearc is ~10.77 Myr, and was consequently actively erupting mud up until ~0.44 Myr ago. The occurrence of reworked Late Oligocene to Early Miocene nannofossil taxa (Triquetrorhabdulus carinatus and Reticulofenestra bisecta) in the investigated samples from the flanks of the SMV also suggests the presence of older pelagic sediments in the Mariana Forearc region.
Biogenic carbonate composition throughout the last 140 kyr in pelagic sediments of the western South Atlantic

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This study evaluated the variation in total calcium carbonate (CaCO$_3$) content over time, as well as whether calcareous nannofossils or foraminifera contributed more to the composition of the total CaCO$_3$ content. For this study, 57 samples from a marine piston core (GL-1090), located in the western South Atlantic, were analysed for the last 140 kyr (last glacial/interglacial cycle). For this purpose, the CaCO$_3$ content was calculated in different size fractions – bulk, sand (>63 µm), coarse and medium silt (63–20 µm) and fine silt to clay (<20 µm). The observed variations were typical for the Atlantic Ocean, with higher CaCO$_3$ values during interglacial periods and lower values during glacial periods. Observing the different sediment fractions, it was noted that calcareous nannofossils were the most important contributors to carbonate deposits in the region throughout the entire studied period, but the percentages of their contribution were higher in glacial periods than interglacial intervals. This is probably due to the effects of regional preservation, which are related mainly to differences in the carbonate chemistry of the water-masses and dilution by terrigenous sediments. In addition, the calcareous nannofossil contribution showed a synchronicity with other dissolution proxies, allowing the conclusion that dissolution is the main factor controlling the contribution of each organismal group to CaCO$_3$ content. These variations revealed alternating modes of high and low carbonate preservation that were influenced by circulation-induced changes in water-masses. The lower-volume preservation events are probably related to a more corrosive, southern-sourced water-mass during a glacial at the depth where the core was collected (2225 m).
MicroRange, a tool for determining the stratigraphic distribution and geologic age of microfossils

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MicroRange is a software program that processes biostratigraphic information to provide a faster and more efficient method for making age calculations of microfossil samples. This software was created using the multi-paradigm programming language Python 3.6.5. Its algorithm was fashioned to calculate ages by taking into account the existing micropalaeontological associations in a sample, as well as the base and top occurrences of some microfossil species. To construct this software, we took into account the databases available on the Internet (i.e. Mikrotax.org of Young et al., 2017a, b) and papers with biostratigraphic and biochronological data (i.e. Lourens et al., 2004; Raffi et al., 2006; Jaramillo et al., 2011; Wade et al., 2011; Backman et al., 2012; Agnini et al., 2014). The database created from this software currently summarises the biostratigraphic distribution and bioevents of more than 1500 Cenozoic microfossil events of calcareous nannofossils, planktonic foraminifera and palynomorphs in northwestern South America.

The MicroRange operation calculates the numerical age range of a sample by means of its micropalaeontological content. In order to input information, the software only needs a micropalaeontological count table in Excel. The software can display results as a graphic of taxon distribution based on the Geologic Time Scale 2102 (Gradstein et al., 2012) and as a table with the biostratigraphic information presented by species (age range and author of the biostratigraphic datum) for each sample. This tool may be of benefit to the entire micropalaeontology community, and can be used both for academic and industrial purposes.

References


Satellite imagery can provide regional and seasonal distribution patterns of living phytoplankton by the remote sensing of chlorophyll-a concentrations, while surface-water physicochemical parameters (e.g. temperature, salinity, nutrients and light) often determine their horizontal and vertical distributions. However, species-specific details of these assemblages still require in-situ collection and shipboard/land-based analyses. Nowadays, the average sea-surface temperature (SST) is increasing, and phytoplankton distributions are migrating. Therefore, this study focuses on: 1) absolute phytoplankton abundances (notably of coccolithophores and silicoflagellates) along a transect from Nagasaki to Tsuruga or Toyama Bays, central Japan via the East China Sea and the Tsushima Strait (southwestern Kyushu) during the May, August and October 2018 cruises of the T/S Nagasaki-Maru of Nagasaki University; and 2) their relationship to records of SST, salinity and chlorophyll-a obtained by the ship’s recorder.

The species assemblages identified in the summer of 2018 in the East China Sea and the central/coastal area of the Japan Sea are nearly identical. There are three common coccolithophores (Emiliania huxleyi, Gephyrocapsa oceanica and Umbilicosphaera sibogae) and three common silicoflagellates (Dictyocha stapedia, which is often misidentified as the fossil species D. fibula, D. cf. D. subelinata and Octactis pulchra). The main diatom contributors include the genera Chaetoceros, Guinardia, Rhizosolenia, Bacteriastrum and Cocconeis. Our results show that: 1) geographic boundaries of phytoplankton assemblages could be recognised in the Kanmon Strait (northern Kyushu), the northeastern area of Oki Islands and the Noto Peninsula; 2) the SST in the Japan Sea is steadily increasing, with similar assemblages seen in the East China Sea and Japan Sea in summer 2018; and 3) the symbiotic relationship between Reticulofenestra sessilis and Thalassiosira sp., normally found in offshore deep-photic waters, was observed in the coastal area of Tsuruga or Toyama Bays of northern central Japan.
Albian–Cenomanian (Cretaceous) calcareous nannofossils from DSDP Site 364, Bacia de Kwanza, Angola

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The fragmentation of Gondwana resulted in the creation of the Atlantic Ocean through the separation of the South American and African tectonic plates. This palaeogeographic occurrence favoured the diversification and geographic distribution of marine organisms throughout the sedimentary basins of the South Atlantic. Many studies using DSDP/ODP sites have revealed a biostratigraphic unconformity in the Upper Albian–Turonian interval (Bolli et al., 1978). DSDP Site 364 was drilled in the offshore portion of the Kwanza Basin (Angolan coast), where this biostratigraphic unconformity was observed. However, the zonation scheme that was applied to it is out of date when compared to current biozonations. The biostratigraphic zones for calcareous nannofossils in the Albian–Turonian interval that were proposed by Burnett et al. (1998) were likely to be present in the sedimentary section of Site 364. With the aim of identifying these biozones, and analysing the distribution and composition of their nannofossil assemblages, 11 samples from between the depths of 672 and 715 mbsf were prepared using the smear-slide method. The first results show that all studied samples contained diverse and abundant Cretaceous nannofossil assemblages, with distinct degrees of dissolution and recrystallisation in all samples. Species such as *Eiffellithus turriseiffelii*, *Axopodorhabdus biramiculatus*, *Helenea chiastia* and *Rhagodiscus asper* are typical of the Upper Albian–Cenomanian interval. Future studies with more precise nannofossil identifications and designation of biostratigraphic events at Site 364 will confirm this. This study was supported by IODP/CAPES grant 8888.091703/2014-01.

References
Quaternary silicoflagellate assemblages from the subarctic Pacific

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Quaternary sediments from the subarctic Pacific Ocean and Bering Sea have been studied using diatoms, radiolarians and other siliceous microfossils (silicoflagellates and ebridians). However, there is little information on the skeletal morphometrics and morphological variation in silicoflagellates, which has led to identification difficulties.

Two recent studies of water samples from the Southern Ocean have demonstrated a wide morphological variation within *Stephanocha speculum* using morphometrics (Tsutsui et al., 2009; Malinverno, 2010). These studies have suggested that there may be a number of pseudocryptic species within the *S. speculum* complex.

Piston cores and/or multiple Ashura cores (three-tubed multiple cores) were collected from six sites in the subarctic Pacific Ocean and Bering Sea in 1999. The silicoflagellates in these cores were observed, photographed and measured using the light microscope and scanning electron microscope. The data show that there is a relatively high species diversity, including three *Dictyocha* species (*D. aculeata*, *D. stapedia* and *D. subarctios*) and six *Stephanocha* species (*S. cf. S. boliviensis*, *S. medianoctisol*, *S. octangulatus*, *S. octonarius*, *S. quinquangulatus* and *S. cf. S. speculum*). Observations on the *S. speculum* complex revealed a wide variation in pike morphology and portal shape, which could be useful as separation criteria. All specimens of *Dictyocha* and *Stephanocha* in this study bore pikes. The coastal species *Octactis pulchra* was not present in our core samples, although another study recorded it in a subarctic Pacific sediment trap.

References
Estimating the origins of submarine landslide deposits by means of calcareous nannofossil assemblages: An example from the Pleistocene forearc basin, central Japan

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Submarine landslides and the resulting downslope deposits (mass-transport deposits or MTDs) have received a great deal of attention because they are associated with large amounts of sediment flux into the deep sea and geohazards, such as tsunamis, and because they have the potential to destroy nearshore infrastructure. I introduce an example named MTD1 from the Pleistocene forearc basin, central Japan, which has already been reported on by Utsunomiya (2018). MTD1 can be traced laterally for more than several tens of kilometres, and its overall thickness ranges from ~20–100 m. MTD1 consists of folded blocks that range from tens of centimetres to more than tens of metres in width and thickness, in a sandy mud matrix that commonly contains volcanioclastics. Some of the tephra beds in the blocks contain glass shards and unique mineral compositions, and so can be distinguished from the underlying (i.e. older) tephra beds. In addition, *Gephyrocapsa* spp. in the underlying strata show an upward increase in maximum size from <3.5 μm to >5.5 μm. Although the MTDs are intercalated in the horizon characterised by the large (>5.5 μm) *Gephyrocapsa* spp. zone, the blocks containing *Gephyrocapsa* spp. show a wide variety of maximum sizes (<4 to >5.5 μm). These assemblages are typically found in the older strata, down to 250 m below MTD1, which suggests that the blocks may have originated from a deeply excavated slope failure. A combination of studies on MTD textures, tephrostratigraphy and biostratigraphy has the great advantage of being able to determine the spatial distribution, the original stratigraphic position that the MTDs originated from, and the mechanism that generates the variable occurrences of MTDs.

References
Morphological variation in the genus Umbilicosphaera from the Pliocene through Pleistocene of ODP 709C (western Indian Ocean) and 994C (northwestern Atlantic) cores

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The present study examined the calcareous nannofossil biostratigraphy of, and the morphological variation in, the genus *Umbilicosphaera* from the Pliocene through Pleistocene in ODP cores 709C (western Indian Ocean) and 994C (northwestern Atlantic). An unreported morphotype was identified from Okada and Bukry's (1980) Zone CN12 through Subzone CN10b. The first occurrence (>5 Ma) of this morphotype is much older than those of *U. sibogae* and *U. foliosa*. This morphotype is similar to *U. sibogae* in having a wide (>1 µm) central opening and monocyclic, imbricated elements in both shields, but differs in having the proximal shield smaller than the distal shield. The difference between the central-area diameter and the central-opening diameter is less than 0.7 µm in the new morphotype, which is due to the steeper surface of the tube elements around the central opening, while *U. sibogae* has a larger central-area ratio to the central opening. This new morphotype is referred to as *Umbilicosphaera* sp. A. *Umbilicosphaera sibogae* became dominant over *Umbilicosphaera* sp. A in subzones CN11b–CN12a. The presence of intermediate forms of *U. sibogae* and *Umbilicosphaera* sp. A suggests that *U. sibogae* evolved from *Umbilicosphaera* sp. A, rather than from either *U. rotula* or *U. jafari*. These results suggest that evolution in the *Umbilicosphaera* spp. occurred simultaneously with the evolution in eutrophic taxa (*Gephyrocapsa* spp.) as part of the floral turnover during the Pliocene–Pleistocene transition.

References
Upper Cretaceous–Cenozoic calcareous nannofossil biostratigraphy of northwestern Colombian basins

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After several decades of reliance on palynology and foraminifera as the primary biostratigraphic tools in Colombia, this is the first report on the calcareous nannofossil biostratigraphy through the Upper Cretaceous–Cenozoic sedimentary record from six basins in northwestern Colombia. More than 3000 samples were prepared and analysed from these basins. A discontinuous Upper Mesozoic–Cenozoic sedimentary record was interpreted from the nannofossil biostratigraphy, allowing us to solve some stratigraphic problems in the northwestern Andes. Our micropalaeontological dataset can be grouped into eight biostratigraphic intervals – Campanian–Maastrichtian, Selandian–Thanetian, Ypresian, Bartonian–Priabonian, Rupelian–Chattian, Aquitanian–Burdigalian, Tortonian–Pliocene and Pleistocene. Our results are comparable to the major oceanic pulses previously documented by sedimentological, palynological and foraminiferal studies. This work, which is based on nannofossil biostratigraphy, also reveals episodes of high influxes of reworked microfossils into Upper Miocene and Pliocene formations. This is associated with the erosion of Oligocene and Lower Miocene marine rocks that were uplifted by tectonic readjustment during the most recent northern Andean Orogeny.
Early Turonian nannofossils and microfossils were examined from various shallow core samples collected from the Cauvery Basin, eastern India. The nannofossil assemblages were extremely diverse and well preserved. The unique character of these nannofossil assemblages are exemplified by the atypically high abundance of holococcoliths found in the samples, with the holococcolith group comprised about 15-42% of the total assemblages.

We utilised a mobile-mounting technique to identify, and gain an understanding of, several new holococcolith species from this section. This technique makes it possible to map all views (sides) of the various species, and it proved to be an especially useful tool during our taxonomic study of the holococcoliths. We mapped the different profiles of the holococcoliths and were able to place the species into two main groups based on the presence or absence of a distal structure. The group that contains species with a distal process include Isocrystallithus compactus, I. maghredaswampensis, Isocrystallithus sp., Owenia hillii, Pharus sp., Paulpearsonia ecclesiata and several unpublished species. This group of holococcolith species (i.e. possessing distal processes) were often observed in both plan and side view. The group that contains species without a distal process, or that possess a vestigial distal process, include Zebrashapka alta, several unpublished species and various species of Russelia and Ottavianus. This group of holococcoliths (i.e. not possessing distal processes) were often observed only in plan view.

In addition, we used the mobile-mounting technique to capture definitive evidence that Isocrystallithus and Owenia are two distinct genera, and to provide refined biostratigraphic ranges for Varolia cistula and Varolia gracilimura. Finally, an analysis of the foraminiferal assemblages was able to identify well-oxygenated distal ramp settings (e.g. 150–300 m deep) and restricted open-marine conditions, in spite of the low abundances of planktonic foraminifera. This evidence proves that abundant and diverse holococcolith assemblages can thrive in deep-water settings.
Calcareous nannofossils across the Eocene–Oligocene transition at ODP Site 756 (Ninetyeast Ridge, Indian Ocean): Implications for biostratigraphy and palaeoceanographic clues

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The Eocene–Oligocene transition (EOT; ca. 34–33.5 Ma) represents a key point in Cenozoic climatic evolution, marking the onset of a semipermanent ice sheet on Antarctica and a major step from a greenhouse to icehouse climate state (e.g., Coxall & Pearson, 2007). The timing and modalities of the nannoplankton response to this climatic phase are still poorly understood, and only a few nannofossil biohorizons are considered to be globally synchronous and reliable.

In this study, the calcareous nannofossil response to the EOT was investigated in ODP Hole 756C (27°21.25’S, 87°35.89’E) that was drilled on the Ninetyeast Ridge (eastern Indian Ocean) during Leg 121 (Peirce et al., 1989). Quantitative and semiquantitative analyses were carried out on 102 samples and showed no evidence for dramatic extinctions in the calcareous nannofossil assemblages at the Eocene–Oligocene boundary (EOB, 33.89 Ma). However, significant bioevents occurred short distances below this boundary, such as the successive disappearance of the rosette-shaped Discoaster barbadiensis and D. saipanensis and, a short distance above, there is an acme of Clausiocalculus subdistichus. Based on the abundance patterns of the standard and additional marker species, the study section extends from nannofossil Zones NP19–NP20 to NP23 (Martini, 1971), which is equivalent to the CNE20–CNO4 interval of Agnini et al. (2014), and has an estimated duration of ca. 5.6 Myr.

High-resolution analyses allowed us to monitor new, potentially useful and reliable calcareous nannofossil biohorizons, and changes affecting the calcareous nannofossil communities across the EOT. In particular, our data suggest that during the EOT, trophic conditions were likely more important than temperature in controlling the variations observed in the relative abundances of the taxa. Of notable interest were the acme intervals of C. subdistichus and the holococcolith Lanternithus minutus, both of which are possibly related to episodic increased food supply during the earliest Oligocene.

References


A total of 100 specimens of the genus *Carinolithus* were selected from published papers and new sampling of sections in the Tethys Ocean (Sogno Core and Breggia sections, Lombardy Basin). The species *C. poulnabronei* and *C. cantaluppii* have diagnostic characters that cannot be confused with other those of species and, consequently, were not considered for morphometric analysis. Size measurements were performed for the following parameters: total height, height without proximal and distal shields, stem width (SW), proximal shield width, distal shield width (DS) and thickness of the distal shield (TDS). Only three (DS, TDS and SW) were diagnostic for taxon discrimination. Based on the DS, two groups were distinguished – >7.8 µm and <6.8 µm. Two groups were distinguished based on the TDS – >1.8 µm and <1.5 µm. Analogously, based on the SW, two groups of specimens were identified – >1.3 µm and <1.0 µm.

Our results provide a revised subdivision of *C. superbus* and *C. magharensis* based on a simple, but effective, morphometry that can be seen with a polarising-light microscope. An additional 50 specimens of *C. cantaluppii* were qualitatively investigated to assess the potential role of diagenesis on its morphology. Four pictures were taken for each specimen – with and without a quartz-plate, and at 0° and 45° to the polarisers. All investigated specimens revealed that *C. cantaluppii* is a diagenetic artifact that is produced through different degrees of overgrowth on specimens of *C. poulnabronei*, *C. superbus* and *C. magharensis*. Using a quartz-plate at 45° to the polarisers allows: 1) recognition of the species that have undergone the diagenetic modification; and 2) the degree of diagenetic change. This impacts the taxonomy and correct identification of this species, and suggests a method for the evaluation of nannofossil/sediment preservation. The morphometry-based revised taxonomy of the genus *Carinolithus* has the potential for improving the biostratigraphic resolution of the Toarcian–Aalenian interval, and has implications for the reconstruction of evolutionary trends.
Preliminary nannofossil biostratigraphic results from the Mariakani Formation, onshore Lamu Basin (SE Kenya)

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During the mid-Jurassic, eastern Gondwana experienced a drastic tectonic and palaeogeomorphological reorganisation that was characterised by a shift from the continental depositional environments of the Karoo Superformation to the marine incursions of the transgressive Kambe Formation. There is a faulted contact between the lacustrine Mariakani and Mazeras Formations (both Triassic) and the marine Kambe Formation (Jurassic) in the Mombasa Basin (Caswell, 1953, 1956; Karanja et al., 1993).

Two samples (60 and 61) were collected from an exposure located about 15 km from the Kinango-Kwale junction, mapped as the Mariakani Formation (Caswell, 1953, 1956). The samples consist of a light grey, weathered, soft shale (Sample 60) and a heavily-jointed and fractured, light greyish, fine-grained sandstone with minor cross-bedding (Sample 61). Only Sample 61 contained moderately-preserved, rare nannofossil remains, including *Watznaueria barnesiae*, *W. britannica*, *Thoracosphaera* sp., *Lotharingius cf. L. contractus*, *Discorhabdus striatus* and *Triscutum sullivani*.

The age of this assemblage was identified as uppermost Bajocian–lowermost Bathonian or Zone NJ9 (*Watznaueria britannica*) to lower Zone NJ11 (*Pseudoconus enigma*), based on the bases of *W. britannica* and *W. barnesiae* (Bown & Cooper, 1998). This interval corresponds to the *laeviuscula-garantiana/parkinsoni* Ammonite Zones. Thus, the obtained results biostratigraphically correlate Sample 61 with the upper shaly member of the lower Kambe Formation (Chiocchini et al., 2005) and the Upper Bajocian ammonite zones (*Strenoceras niortense* and *Garantiana garantiana*) of Galasz (2017) from the Mwache River area (25 km to the NE), and also re-evaluates the age of the Mariakani Formation at this location. These data also continue the discussion of how far west the Jurassic marine sequences overlap the Karoo/Duruma sandstone series, first discussed by E. Fraas (see Caswell, 1953).

References
Importance of coccolithophores in the ocean deep biomass

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The deep biomass (DB), which is located in the lowest part of the euphotic zone (approximately 80–300 m deep) and occurs primarily in the subtropical gyres, is an unexplored part of primary production (PP). It is one of the largest biomes on our planet, considering that subtropical regions occupy 60% of the total ocean. Observations indicate that the major oceanic gyres have expanded recently by 15%, a phenomenon attributed to global warming. As the gyres expand and warm, they become more stratified, which could be expected to favour coccolithophores. The biological community in the DB, however, is not well known, and their contribution to export production has never been quantified. Productivity estimates for oceanic net primary production show that regions with oligotrophic surface-waters contribute significantly to global productivity due to their deep phytoplankton communities. Some model estimates indicate that there has been a recent increase in net oceanic primary production in oligotrophic ocean gyres. If we consider: 1) the total area covered by the DB; 2) the expansion of the ocean gyres; 3) the PP that occurs throughout the year; and 4) the global depth-integrated NPP of the mixed layer in the tropics and subtropical gyres that displays very small seasonal variability, it is reasonable to assume that the DB ecosystem is likely to be as important for productivity and chemical recycling as seasonally-active upwelling areas. The role in PP of this enigmatic biome cannot be easily determined using chlorophyll because organisms in the deep photic zone, particularly coccolithophores, do not possess much chlorophyll per biomass. It is thus probable that carbon export from the DB is underestimated in models. With the upper euphotic zone of the oceans already impacted by acidification, the DB can arguably be considered to be the last refuge for marine organisms. We need to determine how anthropogenic activity is affecting the phytoplankton that comprise the DBM and the ensuing biogeochemical cycling of carbon.
Nannotax and mikrotax, an evolving system for paleoinformatics

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The Nannotax project has been running since 2007, with the objective of providing high-quality online data on nannoplankton taxonomy and biodiversity. The current version was launched in 2013 at the INA13 conference in Reston VA, USA. Since then, the system has been continuously maintained, expanded and updated, and is now a prime resource for anyone interested in extant or fossil nannoplankton. It currently holds original descriptions and illustrations of >4000 taxa, descriptions and range data on >3000 currently-recognised taxa, 25,000 images and, via the Neptune database (MFN Berlin), access to >250,000 occurrence records of nannofossils.

Recent improvements, which have included developing new tools to access the Neptune database, make it possible to investigate the palaeobiogeographical distributions of species and to reconstruct occurrence tables for DSDP and ODP sites held in the database. Mesozoic and Cenozoic nannofossil information has been continuously updated. Notably, the new synthesis of Neogene taxonomy from the BP group, as published in the JNR (e.g. Bergen et al., 2017; Browning et al., 2017) has been reviewed and incorporated. However, this type of taxonomic revision does present some problems for the system, as will be discussed.

Equally important, the system underlying Nannotax is now a demonstrably robust solution to providing a database of online microfossil taxonomy and for integrating taxon-related data. We have used the system to provide a similar level of coverage of planktonic foraminifera (Huber et al., 2017), and we are now actively developing applications for acritarchs and radiolarians. This expansion of coverage has necessitated the development of new capabilities, such as plotting evolutionary trees and improving the underlying software and web-editing tools. It has also led to the system being recognised as a prime example of effective modern palaeoinformatics.

References
The trigger for the mid-Brunhes coccolithophore bloom: New evidence from coccolith assemblages and geochemical and morphological data

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Several coccolithophore bloom events have been discovered in the Pleistocene. Among these events, the mid-Brunhes Gephyrocapsa caribbeanica bloom can be recognised globally. During this event, the coccolith calcium carbonate accumulation rate increased to approximately 5–10 times greater than in the period above and below this event, and this may have altered the ocean carbon cycle dramatically (e.g. Barker et al., 2006). However, the trigger for this event is still undetermined. Moreover, most previous studies have focused on the mid- or high latitudes.

In this study, we measured coccolith geochemical and morphological data from four cores from both the high and low latitudes during the last 800 kyr, and reviewed published data from another 14 cores, to try to determine the mechanism driving coccolithophore blooms, especially any processes other than glacial-interglacial effects. Significant coccolithophore bloom events were identified in 15 cores during the period 600–350 ka, but the timing of these blooms was different in different regions. Generally, the blooms first occurred at high latitudes and in the East Pacific upwelling and then spread to low latitudes, such as the East Pacific warm pool. It appears that the bloom events were not globally synchronous, which may challenge the previous insolation-driven hypothesis. Instead, we suggest that coccolithophore blooms were triggered by nutrient patterns in the ocean. For regions where the nutrient level is controlled by ocean circulation, there may be a rapid response time for changes in the dynamics of Earth’s boundary conditions, while for regions in which nutrient content is controlled by weathering and river input, the response time may be longer than one glacial-interglacial cycle.

References
Primary productivity dynamics in the northeastern Indian Ocean since the Last Glacial Maximum: Toward a better understanding of tropical climate changes

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Ocean primary productivity (PP) is regulated by atmospheric and oceanic circulation, which may control upper seawater stratification and mixing, and thus impact nutrient distribution in the euphotic zone. While several reconstructions of PP variations have been obtained for the tropical Indian Ocean (TIO) to document oceanic and climatic changes in the past, PP records in the northeastern Indian Ocean (NEIO), including the Bay of Bengal and the Andaman Sea, are relatively scarce. The aim of this study was to reconstruct PP changes in the NEIO since the Last Glacial Maximum (LGM) in order to understand their dynamics, identify the forcing factors behind them, and get a clearer picture of climate evolution during this time interval.

We reconstructed two palaeoproductivity records over the last 26,000 years, using two sediment cores from the northeastern Bay of Bengal (NE-BoB) and northwest of Sumatra (NWoS). The palaeoproductivity was derived from the coccolith assemblages and, more particularly, the relative abundance of *Florisphaera profunda*. These two variations showed diverse patterns at both the millennial and orbital scales. In the NE-BoB, there was no significant difference in PP between the LGM and the Late Holocene, but peaks occurred around 17–15 ka BP and 12–9 ka BP. In contrast, the NWoS record shows that PP was about 15% higher during the LGM than during the Late Holocene, and a significant decrease was observed during deglaciation. Comparisons with other published PP records and a new climate model output (IPSL-CM5A-LR) suggest that the NE-BoB PP record is most probably associated with changes in Indian Monsoon dynamics, while TIO Walker circulation might play a more important role in PP variations in the NWoS.
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