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The Micropalaeontological Society

Cushman Foundation for Foraminiferal Research
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THE MICROPALAEONTOLOGICAL SOCIETY

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FORAMINIFERA SPRING MEETING 2024

COLOGNE, MAY 21-24, 2024

ABSTRACTS

FORAMINIFERA & THE EVOLVING EARTH SYSTEM

The Micropalaeontological Society

The Cushman Foundation for Foraminiferal Research

Foraminifera Spring Meeting 2024

"*Foraminifera & the Evolving Earth System*"

hosted by the

Institute of Geology and Mineralogy, University of Cologne

Cologne, Germany

May 21-24, 2024

ABSTRACTS

Edited by

Patrick Grunert & Olga Koukousioura
University of Cologne
Institute of Geology and Mineralogy
Otto-Fischer-Straße 14
50674 Cologne
Germany

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KEYNOTE LECTURE

Nitrogen Isotopes unveiling Earth's mysteries – From changing sea level and ocean oxygenation to foraminifera ecology

Alexandra AUDERSET[1]

[1] School of Ocean and Earth Science, University of Southampton, Southampton, United Kingdom; a.auderset@soton.ac.uk

Foraminifera-bound nitrogen isotopes (FB-$\delta^{15}N$) is an emerging geochemical proxy capable of unveiling Earth's mysteries through its diverse applications in reconstructing both environmental and ecological changes in the geological past. In this keynote presentation, I will showcase three studies using FB-$\delta^{15}N$ to explore different aspects of the evolving Earth system.

In the first case study, a link is identified between the FB-$\delta^{15}N$ and variations in sea level over time. FB-$\delta^{15}N$ is used to reconstruct changes in Nitrogen fixation across glacial/interglacial cycles. The data shows that Nitrogen fixation, a process that supplies the ocean with essential bioavailable nitrogen, is coupled to sedimentary denitrification. In turn, sedimentary denitrification depends on sea level with reduced denitrification rates during glacials when sea level is low and the shelf areas are exposed to air.

Moving further back in time, the second case study uses FB-$\delta^{15}N$ to reconstruct the bacterial process of water column denitrification, which is sensitive to ocean oxygen concentration. We explore ocean oxygenation during the Cenozoic era and reveal the surprising behaviour of oxygen-deficient zones getting smaller during climate optima and hyperthermals in the Miocene and Eocene. This stands in contrast to the deoxygenation trend predicted for global warming of the 21st century.[1,2]

Finally, I show how FB-$\delta^{15}N$ can serve as a window into ecological niches and feeding strategies of planktic foraminifera in the modern and past ocean. Evidence from South Atlantic sediments indicates a pronounced $\delta^{15}N$ difference between shallow and deep dwelling planktic foraminifera, as well as between dinoflagellate-bearing and asymbiotic species.

In conclusion, these case studies underscore the transformative potential of FB-$\delta^{15}N$ as a versatile tool for probing Earth's evolutionary history. As this proxy is still in its early days, the applications will continue to expand, e.g. for more deep-time questions like the emergence and evolution of symbiosis. But this is for another time.

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The evaluation of the Ecological Quality Status of the Sepetiba Bay (SE Brazil): benthic foraminiferal and abiotic indices

Maria Virgínia ALVES MARTINS[1,2*], Johann HOHENEGGER[3], Vincent BOUCHET[4], Fabrício Leandro DAMASCENO[1], Luiz Guilherme Costa SANTOS[5], João Graciano MENDONÇA FILHO[5], Rubens FIGUEIRA[6], Egberto PEREIRA[1], Thaise M. SENEZ-MELLO[1,7], Luzia ANTONIOLI[1], Silvia Helena de MELLO e SOUSA[6], Mauro Cesar GERALDES[1], Fabrizio FRONTALINI[8]

[1] Universidade do Estado do Rio de Janeiro, UERJ, Av. São Francisco Xavier, 524, Maracanã. CEP: 20550-013 Rio de Janeiro, RJ, Brazil; virginia.martins@ua.pt, fabricioldamasceno16@gmail.com, egberto@uerj.br, thaise_senez@id.uff.br, luantonioli7@gmail.com, geraldes@uerj.br

[2] Universidade de Aveiro, GeoBioTec, Departamento de Geociências, Campus de Santiago, 3810-193 Aveiro, Portugal

[3] Universität Wien, Institut für Paläontologie, Althanstrasse 17, A 1090 Wien, Austria; johann.hohenegger@univie.ac.at

[4] University of Lille, Laboratoire d'Océanologie et de Géosciences Avenue Foch, 62930 Wimereux. France; vincent.bouchet@univ-lille.fr

[5] Universidade Federal do Rio de Janeiro – UFRJ, Dpto Geologia - Instituto de Geociências, Rio de Janeiro, RJ, Brazil; guilherme@lafo.geologia.ufrj.br, graciano@geologia.ufrj.br

[6] Instituto Oceanográfico, Universidade de São Paulo (IOUSP). Pça. do Oceanográfico, 191, Butantã, São Paulo, Brazil; rfigueira@usp.br, silviahelenamello@gmail.com

[7] Marine Geology Lab – LAGEMAR, Federal Fluminense University (UFF), Rio de Janeiro, Brazil

[8] Department of Pure and Applied Sciences, Università degli Studi di Urbino "Carlo Bo", 61029, Urbino, Italy; fabrizio.frontalini@uniurb.it

*Corresponding author: virginia.martins@ua.pt

The Sepetiba Bay (SB), located in the western region of Rio de Janeiro State (SE Brazil), is a unique and sensitive ecosystem. The surrounding area is densely populated and highly industrialized, with mega tourist developments and intense port activities. This study applies an integrated, multifaceted approach to analyze the response of foraminifera to environmental stress and to infer the Ecological Quality Status (EcoQS) in this complex ecosystem. To this end, living foraminifera assemblages were analyzed in 50 sediment samples along with physicochemical parameters (e.g., depth, temperature, salinity, pH and Eh at the sediment-water interface) and combined with textural and geochemical data (total organic carbon and potentially toxic elements). The species diversity ($exp(H'_{bc})$) and the relative abundance of the main species (>3% in at least six samples) were compared with abiotic indices, such as elemental enrichment factors (EF), pollution load index (PLI), potential ecological risk (PERI) and total organic carbon (TOC) and mud contents. The results show a clear negative response of the foraminiferal assemblages to the increase of mud, TOC, and trace element contents. The $exp(H'_{bc})$ identify 31 stations with poor and bad EcoQS, 4 with moderate EcoQS, and 15 with good to high EcoQS. The inner zone of SB and the areas close to the continent have poor to bad EcoQS that can be ascribed to eutrophication processes and potentially toxic elements pollution. On the other hand, higher EcoQS are associated with outer areas of the SB.

Inferring the Paleo-Ecological Quality Status of the Sepetiba Bay: A Foraminiferal Perspective

Maria Virgínia ALVES MARTINS[1,2*], Murilo Barros SAIBRO[1], Wellen CASTELO[1], Anita PINTO SIMON[1], Layla SILVA[1], Vincent BOUCHET[3], Egberto PEREIRA[1], Rubens FIGUEIRA[4], Heitor EVANGELISTA[5], Marcus Vinícius LICÍNIO[6], Josefa Varela GUERRA[7], Antonio Tadeu DOS REIS[7], Fabricio Leandro DASMACENO[1], Thaise SENEZ-MELLO[1], Mauro Cesar GERALDES[1], João Wagner de Alencar CASTRO[8], Fabrizio FRONTALINI[9], Rodolfo DINO[1], Silvia Helena MELLO SOUSA[4]

[1] Universidade do Estado do Rio de Janeiro, UERJ, Faculdade de Geologia, Av. São Francisco Xavier, 524, sala 4037F, Maracanã, 20550-013, Rio de Janeiro, RJ, Brazil; virginia.martins@ua.pt, murilosaibro@id.uff.br, wellenflc@yahoo.com.br, anitafspinto@gmail.com, laylageologiauerj@gmail.com, egberto@uerj.br, fabricioldamasceno16@gmail.com, thaise_senez@id.uff.br, geraldes@uerj.br

[2] Universidade de Aveiro, GeoBioTec, Departamento de Geociências, Campus de Santiago, 3810-193, Aveiro, Portugal

[3] University of Lille, Laboratoire d'Océanologie et de Géosciences Avenue Foch, 62930 Wimereux. France; vincent.bouchet@univ-lille.fr

[4] Universidade de São Paulo, USP, Instituto Oceanográfico, Pça. do Oceanográfico, 191, Butantã, 05508-120, São Paulo, Brazil; rfigueira@usp.br, smsousa@usp.br

[5] Universidade do Estado do Rio de Janeiro, UERJ, Instituto de Biologia Roberto Alcantara Gomes, IBRAG, Laboratório de Radioecologia e Mudanças Globais, LARAMG, Rua São Francisco Xavier, 524, Maracanã, 20550-013 Rio de Janeiro, RJ, Brazil; evangelista.uerj@gmail.com

[6] Universidade Federal do Espírito Santo, UFES, Departamento de Ciências Fisiológicas, Centro de Ciências da Saúde, CCS, Avenida Marechal Campos, 1468, Maruipe, Vitória, ES; mv.ufes@gmail.com

[7] Universidade do Estado do Rio de Janeiro, UERJ, Faculdade de Oceanografia, Av. São Francisco Xavier, 524, 4 andar, Bloco E, sala 4018, 20550-013, Rio de Janeiro, RJ, Brazil; josie.guerra@gmail.com, tadeu.reis@gmail.com

[8] Universidade Federal do Rio de Janeiro, Museu Nacional, Quinta da Boa Vista s/n, São Cristovão, 20940-040 - Rio de Janeiro, RJ – Brazil; castro@mn.ufrj.br

[9] Department of Pure and Applied Sciences, Università degli Studi di Urbino "Carlo Bo", 61029, Urbino, Italy; fabrizio.frontalini@uniurb.it

*Corresponding author: virginia.martins@ua.pt

The Sepetiba Bay (BS), located in the Rio de Janeiro State (SE Brazil), is considered a region of great economic importance due to two major ports and intense industrial activity linked to the mining, petrochemical, and steel sectors. The SB, bordered to the south by Barreira da Marambaia Island, has a limited connection to the Atlantic Ocean. This bay has undergone significant changes over time due to natural causes and, more recently, under the influence of anthropogenic activities. Therefore, this study aims to disentangle the impact of natural and anthropogenic changes in the BS during the region's late Holocene, pre- and post-industrialization. To achieve it, sediment cores (e.g., SP2, SP5, SP8 and SP11) were analyzed by using a multiproxy approach (e.g., ^{210}Pb and ^{137}Cs and radiocarbon dating, as well as textural, mineralogical, geochemical and foraminiferal data). The diversity-based index, exp(H'$_{bc}$), was used to infer the SB's Paleo-Ecological Quality Status (PaleoEQS). The study reveals that variations in sea level, intense storm events, changes in the configuration of the coastal plain and mainly in the Marambaia Barrier Island, and, more recently, anthropogenic activities in the region have strongly influenced the foraminiferal assemblages in the SB. If, on the one hand, the best PaleoEQS is recorded in the outer area of the SB during the middle Holocene, at a higher sea level than today, the worst PaleoEQS are associated with events of significant sedimentary disturbance due to intense storms and ruptures on Marambaia Barrier Island and more recently, from the 1970s onwards, by the impact of the excessive load of total organic carbon (TOC) and potentially toxic elements (PTEs) related to anthropogenic activities taking place in the region. The results provide evidence of the PaleoEQS's evolution and define the SB's background conditions. It also strongly advocates for taking mitigation actions to recover this ecosystem.

Paleoceanographic changes provided by foraminiferal and XRF data at Southern High Latitudes across the OAE 2 (IODP Sites U1513 and U1516, Mentelle Basin, SW Australia).

Giulia AMAGLIO[1*], Maria Rose PETRIZZO[1], Erik WOLFGRING[1,2], Ann HOLBOURN[3], Wolfgang KUHNT[3]

[1] Dipartimento di Scienze della Terra "Ardito Desio", Università degli Studi di Milano, via Mangiagalli 34, I-20133 Milano, Italy; giulia.amaglio@unimi.it, mrose.petrizzo@unimi.it

[2] University of Vienna, Department of Palaeontology, Josef Holaubek Platz 2, 1090 Vienna, Austria

[3] Institut für Geowissenschaften, Christian-Albrechts-Universität, Olshausenstr 40, 24118 Kiel, Germany; wolfgang.kuhnt@ifg.uni-kiel.de, ann.holbourn@ifg.uni-kiel.de

*corresponding author: giulia.amaglio@unimi.it

The Cenomanian-Turonian Oceanic Anoxic Event (OAE 2) is the greatest global environmental perturbation in the Late Mesozoic that also affected marine biota. International Ocean Discovery Program (IODP) Sites U1513 and U1516 in the Mentelle Basin (SW Australia) document a continuous foraminiferal record suitable to reconstruct the paleoenvironmental conditions in the water column and at the seafloor.
Below and in the lower part of the OAE 2, the foraminiferal assemblage shows low species diversity and is dominated by the opportunistic taxa *Gavelinella*, *Gyroidinoides*, *Stensioeina*, *Microhedbergella* and *Muricohedbergella*. Agglutinated foraminifera are rare, but more abundant at Site U1516. XRF data show an increase in terrigenous input and more humid conditions, with the exception of a short interval characterized by a positive peak in Zr/Rb ratios in the uppermost part of this interval, indicating a drier environment. This short interval is characterized by the unique occurrence of *Stensioeina truncata* and by a slightly increase in epi-infaunal taxa, indicating an improvement of seafloor conditions that might allow identification of the Plenus Cold Event (PCE) at high latitudes. An interval of low $CaCO_3$ content within the OAE 2 interval with the dominance of radiolarians indicates an extremely eutrophic environment marked by a sharply increase in terrigenous input and rainfalls. However, Site U1516 shows few samples with the occurrence of benthic and planktonic foraminifera.
Above this interval, a different benthic foraminiferal assemblage characterizes both sites with the occurrence of *Conorboides claytonensis*, an increase in agglutinated taxa and in *Praebulimina elata* and a major diversification of planktonic foraminifera indicating an improvement of environmental conditions, especially at the seafloor. A humid environment but with a decrease in rainfalls is still suggested by XRF data. In the uppermost part of OAE 2, planktonic foraminifera show the greatest diversification of thermocline, intermediate and surface dwellers, indicating the emplacement of a well-stratified water column in a mesotrophic regime, but with a slower recovery at Site U1516. However, the dominance of *Microhedbergella* and the decrease in agglutinated foraminifera above the OAE 2 suggest a turnover towards more eutrophic conditions.

Enhancing Coastal Management: Leveraging Benthic Foraminifera for Sediment Quality Monitoring in Boulogne-sur-Mer Harbor, France - An 11 years Longitudinal Study

Eric ARMYNOT DU CHÂTELET[1], Alain TRENTESAUX[1], Vincent BOUCHET[2], Fabio FRANCESCANGELI[3], Nicolas TRIBOVILLARD[1], Eric MASSON[4]

[1] Laboratoire d'Océanologie et de Géosciences. UMR 8187 LOG. CNRS, Univ. Lille, Univ. Littoral Côte d'Opale, IRD, F-59000 Lille, France; eric.armynot@univ-lille.fr, alain.trentesaux@univ-lille.fr, nicolas.tribovillard@univ-lille.fr

[2] Laboratoire d'Océanologie et de Géosciences. UMR 8187 LOG. Univ. Lille, CNRS, IRD, Univ. Littoral - Côte d'Opale, Station Marine de Wimereux, F-59000 Lille, France; vincent.bouchet@univ-lille.fr

[3] Department of Geosciences – Geology University of Fribourg, CH-1700 Fribourg, Switzerland; fabio.francescangeli@unifr.ch

[4] Laboratoire Territoires, Villes, Environnement & Société. ULR 4477 TVES, Université de Lille. F-59000 Lille, France; eric.masson@univ-lille.fr

Benthic foraminifera from the transitional zone naturally exhibit high tolerance to highly varying conditions. In the harbor of Boulogne-sur-Mer (Northern France), historical data have demonstrated a correlation between the decline of benthic foraminiferal communities and pollution levels. A total of 241 samples were collected during three campaigns, all organized early spring: in 2008, immediately after the dismantling of industrial facilities, followed by sampling in 2014 and 2019. The aim was to observe the evolution of benthic foraminifera communities alongside environmental changes, as reflected by the sediment nature and texture, as well as organic and inorganic geochemistry.
The density of foraminifera showed a noteworthy increase in parallel with a decrease in trace metal elements concentrations in the sediment. Species richness also increased over time: 31 alive species were identified in 2008, whereas 41 were observed in 2019. These included commonly described species in such environments: *Cribroelphidium magellanicum*, *C. excavatum*, *Haynesina germanica*, and *Ammonia* group. Calculated diversity, however, exhibited minimal variation over time.
Consequently, assessing foraminiferal density provides a dependable indicator of sediment quality, without the need for detailed species and diversity analysis. Nonetheless, interpretations of potential pollution effects must be nuanced, considering sediment texture, e.g. coarse sediments may not support foraminiferal development.

Accelerated Subtropical Gyre in times of Atlantic Meridional Overturning Circulation oxygenated the eastern tropical North Atlantic Oxygen Minimum Zone during the last deglaciation: evidence from benthic foraminifera

Sofía BARRAGÁN-MONTILLA[1,2]

[1] University of Bremen, MARUM, FB5, Bremen, Germany (sobarraganmo@gmail.com)

[2] GeoLatinas, Latinas in Earth and Planetary Sciences

Atlantic Meridional Overturning Circulation (AMOC) is projected to slow down over the 21st century, making it necessary to understand its relationship with ocean circulation processes that influence global climate. During the last deglaciation, AMOC slowdown resulted in decreased ventilation of the deep Atlantic. However, the response of the intermediate and subsurface circulation processes remains poorly understood. This gap in our knowledge introduces important challenges in climatic models, which in turn are unable to reproduce the mean shape and known trends of Atlantic Oxygen Minimum Zones. This is the case of the suboxic eastern Tropical North Atlantic Oxygen Minimum one (ETNA-OMZ) off the NW African margin. In this study, we used benthic foraminifera detailed taxonomy and quantitative analyses to reconstruct the oxygen concentrations changes of site GeoB9512-5 (793 m water depth) from the low oxic margin of the ETNA-OMZ. This new record registered oxygen changes in the last 27.000 years with an average age resolution of 270 years. We find that in times of reduced AMOC, in the Heinrich Stadial 1 (first between 17.5 and 16.4 ka BP; and then between 15.5 – 14.8 ka BP) and in the Younger Dryas-early Holocene (12.2 – 10.9 ka BP), the low oxic end of ETNA-OMZ became high oxic. Our findings suggest that during this time, the subtropical gyre circulation in the north Atlantic accelerated with steeper temperature gradients related to AMOC slowdown. This accelerated circulation provided more ventilated waters, bringing more oxygen at intermediate depths and oxygenating ETNA-OMZ. Our results provide new valuable information about subsurface circulation relationship to AMOC changes, and puts forward evidence on the impact in Atlantic OMZs.

Distribution of benthic foraminifera in the Gulf of Lions, Mediterranean Sea: Response to trawling activity or natural variability?

Christine BARRAS[1], Damien LE MOIGNE[1], Meryem MOJTAHID[1], Céline LABRUNE[2], Aurélia MOURET[1], Edouard METZGER[1], Grégoire MAILLET[1], Célestine MORISSEAU[1], Audrey PRUSKI[2], Gilles VETION[2], Lyvia LESCURE[2], Sandrine VAZ[3]

[1] University of Angers, Nantes Université, Le Mans Université, CNRS, Laboratoire de Planétologie et Géosciences, LPG UMR 6112, 49000 Angers, France; christine.barras@univ-angers.fr

[2] CNRS, Laboratoire d'Ecogéochimie des Environnements Benthiques, Sorbonne Université, LECOB UMR 8222, 66650 Banyuls-sur-Mer, France

[3] MARBEC, Univ Montpellier, CNRS, Ifremer, IRD, Sète, France

The Marine Strategy Framework Directive (MSFD) is a major step forward for the management of marine environments by extending the monitoring to the entire Exclusive Economic Zone. On the continental shelf, the major human disturbance of soft-bottom sea floor is due to demersal fisheries. Recently, abrasion maps, expressed as swept area ratio (SAR), have been produced to quantify the pressure from bottom-contacting gears. These analyses show that little areas are left untouched from this anthropogenic activity, and it is therefore complex to define reference conditions in order to evaluate the ecological quality status.
In this context, the IMPEC project aims at investigating different environmental and biological parameters to evaluate the impact of trawling activity on benthic ecosystems. Ten stations were sampled along a gradient of SAR (from ~0.5 to 3 SAR/year) in the Gulf of Lions, Mediterranean Sea (100 m water depth). Geochemical and sedimentary analyses, including organic matter characterisation, were performed to provide proxies for the impact of *in situ* sediment reworking. Several benthic organisms (epibenthic megafauna, macrofauna, nematodes and foraminifera) were used as biological indicators integrating the various environmental consequences of this trawling activity. These were studied using different approaches including *in situ* imagery and sediment sampling.
The preliminary results of the living foraminiferal analyses reveal high density and diversity in all stations. However, there is a shift in major species representation between western stations (e.g. *Gyroidina umbonata, Cancris auriculus*), located west of the Lacaze-Duthiers Canyon, and eastern stations (e.g. *Uvigerina peregrina, Bulimina aculeata*), characterised by finer sandy sediments. It is difficult to disentangle if these changes in faunal assemblages are the result of natural variability or a response to different trawling intensity. The ongoing analyses of dead foraminiferal assemblages in long sedimentary cores will inform us about the benthic ecosystem before the onset of trawling activities on the continental shelf. In the absence of actual reference conditions, this approach could help to evaluate the impact of bottom fisheries on benthic ecosystems.

Assessing the impact of different carbonate system parameters on benthic foraminifera from controlled growth experiments

Christine BARRAS[1], Claire ROLLION-BARD[2], Carole LA[1], Aurélia MOURET[1], Pauline DEPUYDT[1], William GRAY[2], Guillaume PARIS[3], Hélène REBAUBIER[2], Patricia RICHARD[2], Meryem MOJTAHID[1]

[1] Univ Angers, Nantes Université, Le Mans Université, CNRS, Laboratoire de Planétologie et Géosciences, LPG UMR 6112, 49000 Angers, France; christine.barras@univ-angers.fr

[2] Laboratoire des Sciences du Climat et de l'Environnement, LSCE/IPSL, CEA-CNRS-UVSQ, Université Paris-Saclay, 91191 Gif-sur-Yvette, France

[3] CRPG-CNRS, université de Lorraine, 15, rue Notre-Dame-des-Pauvres, 54501 Vandœuvre-les-Nancy cedex, France

Insights into past marine carbon cycling and water mass properties can be obtained by means of geochemical proxies calibrated through controlled laboratory experiments with accurate seawater carbonate system (C-system) manipulations. Here, we studied the potential effect of seawater carbonate parameters on the geochemical elemental composition of low-Mg and high-Mg species through controlled growth experiments. To this aim, we used two experimental set-ups to decouple as much as possible the individual components of the carbonate system, i.e., changing pH at constant dissolved inorganic carbon (DIC) and changing DIC at constant pH. Four climatic chambers were used with different controlled concentrations of atmospheric pCO_2 (180, 410, 1000, and 1500 ppm). Under these different carbonate conditions, we analysed the growth ability of two deep-sea species (*Bulimina marginata* and *Cassidulina laevigata*), one intertidal species (*Ammonia* T6) and 3 large tropical symbiont-bearing benthic species (*Amphistegina lessonii*, *A. lobifera* and *Heterostegina depressa*). For all species, we explored the composition in Sr/Ca and Mg/Ca of the chambers calcified under the controlled conditions, and additionally explored Li/Ca, B/Ca and Zn/Ca composition of the large benthic foraminifera. Our data highlight different effect of the carbonate chemistry on the incorporation of trace elements depending on the species considered.

Connecting the nitrogen isotopic composition of planktic foraminifer tissue to surface ocean nitrogen cycling in the northern South China Sea

Aaron L. BIELER[1], Lena HEINS[1], Sandi M. SMART[2], Jassin PETERSEN[3], Birgit GAYE[4], Joanna J. WANIEK[5], Gerald H. HAUG[1,6], Alfredo MARTÍNEZ-GARCÍA[1], Ralf SCHIEBEL[1]

[1] Climate Geochemistry Department, Max Planck Institute for Chemistry, Hahn-Meitner-Weg 1, Mainz, Germany; aaron.bieler@mpic.de; lena.heins@mpic.de; gerald.haug@mpic.de; a.martinez-garcia@mpic.de; ralf.schiebel@mpic.de

[2] Department of Geological Sciences, The University of Alabama, 7th Avenue 201, Tuscaloosa, USA; sandi.smart@alumni.uct.ac.za

[3] Institute of Geology and Mineralogy, University of Cologne, Otto-Fischer-Straße 14, Cologne, Germany; jassin.petersen@uni-koeln.de

[4] Institute of Geology, Universität Hamburg, Bundesstraße 55, Hamburg, Germany; birgit.gaye@uni-hamburg.de

[5] Leibniz Institute for Baltic Sea Research, Seestraße 15, Rostock, Germany; joanna.waniek@io-warnemuende.de

[6] Department of Earth Sciences, ETH Zürich, Sonneggstrasse 5, Zurich, Switzerland; gerald.haug@erdw.ethz

The cycling of marine nitrogen (N), a major nutrient, produces distinct N isotopic signals ($\delta^{15}N$) in the tissue of planktic foraminifers (PF) providing information on the surface ocean ecosystem. Organic matter preserved within the tests of PFs presents a sedimentary archive of past N dynamics. Therefore, a comprehensive understanding of the formation of $\delta^{15}N$ signals in PF tissue across modern environments is needed to accurately interpret PF-bound $\delta^{15}N$ in the sedimentary record.
We present water-depth resolved species-specific bulk tissue $\delta^{15}N$ of PFs from net tows from the open ocean to the inner continental shelf of the northern South China Sea in late summer of 2019. At open ocean stations PF $\delta^{15}N$ is lower by >2 ‰ in the shallow mixed layer and across the nitrate depleted thermocline compared to local subsurface nitrate, suggesting that surface ocean ammonium recycling causes the PF N isotopic signal to deviate from the subsurface nitrate supply. Inside a plume with increased productivity arising from a recent local upwelling PF tissue $\delta^{15}N$ is elevated relative to subsurface nitrate by up to 4 ‰, consistent with a nitrate drawdown signal. Vertical differences in the PF $\delta^{15}N$ within the surface water column underscore the sensitivity of PFs to the complex interplay of small-scale biogeochemical processes. Species-specific N isotope signals of *T. sacculifer*, *G. ruber albus*, and *G. glutinata* are consistent with different trophic niches. Our results highlight the necessity to refine the interconnections between ecosystem parameters and PF tissue $\delta^{15}N$ in the modern ocean to access the rich information on N dynamics preserved in the sedimentary PF record for a better understanding of past ocean and climate change.

Evolution of the Humboldt Current System across the Miocene/Pliocene boundary based on foraminifera assemblages

Fatima Zohra BOUHDAYAD[1], Laura SCHNEIDER[1], Laura MAKOWKA[2], Tiago MENEZES FREIRE[1], Jassin PETERSEN[1], Sven N. NIELSEN[3], Marcelo M. RIVADENEIRA[4,5], Patrick GRUNERT[1]

[1] Institute of Geology and Mineralogy, University of Cologne, Zülpicher Str. 49b, 50674 Cologne, Germany; bouhdayad.fatima@uni-koeln.de, lschne67@uni-koeln.de, tiagomefreire@gmail.com, jassin.petersen@uni-koeln.de, pgrunert@uni-koeln.de

[2] Universidad de Salamanca, Salamanca, Spain; laura_makowka@yahoo.de

3 Instituto de Ciencias de la Tierra, Universidad Austral de Chile, Valdivia, Chile ; sven.nielsen@uach.cl

[4] Centro de Estudios Avanzados en Zonas Áridas (CEAZA), Coquimbo, Chile ; marcelo.rivadeneira@ceaza.cl

[5] Departamento de Biología Marina, Facultad de Ciencias del Mar, Universidad Católica del Norte, Coquimbo, Chile; marcelo.rivadeneira@ceaza.cl

Diatom-rich deposits of north-central Chile represent unique Neogene archives of the Humboldt Current System, triggering intense coastal upwelling of cold, nutrient-rich subsurface waters and an extensive oxygen minimum zone. This study presents foraminiferal data from a c. 9 m-thick, Upper Miocene to Lower Pliocene diatomaceous mudstone deposit cropping out at the Quebrada Tiburón (27°42' S, 70°59' W, Bahía Inglesa Formation). Our aim is to evaluate the paleoenvironmental implications of fossil assemblage shifts. The expected results from benthic foraminifera will shed light on export productivity and bottom water oxygenation. Ultimately, through integration with planktonic foraminifera and diatom abundances, this study will contribute to the increasing understanding of the Humboldt Current System evolution across the Miocene/Pliocene boundary and its potential coupling to paleoclimate fluctuations in the Atacama Desert.
Benthic foraminiferal assemblages from the mudstones generally indicate high export productivity and limited oxygen supply at the seafloor, related to a setting with coastal upwelling supported by planktonic assemblages dominated by *Globigerina bulloides*, *Neogloboquadrina acostaensis* (sinistral) and *Globigerinita glutinata*. The low-diversity fauna is mostly dominated by < 250 µm *Bolivina granti/pacifica*, *Epistominella obesa*, and *Eubuliminella bassendorfensis* individuals. Across the Miocene/Pliocene boundary, the relative abundances of *Bolivina granti/pacifica* and *Epistominella obesa*, respectively, increase and decrease, and *Bolivina aenariensis* disappears. This shift may be explained by changes in the amount and/or frequency of organic matter input. In intercalated sandstones, *Bolivina granti/pacifica*, *Eubuliminella bassendorfensis*, and *Epistominella obesa* still predominate, with minor contributions of uvigerininds, *Bolivina advena* and shallow-water taxa (e.g., *Buccella peruviana*). The faunal composition of these sandstones differs from neritic upper Tortonian-lower Messinian and upper Pliocene sandstones below and above the studied section, in which *Bolivina advena*, cibicids and *Buccella* spp. dominate.
This study contributes to CRC 1211 "Earth-Evolution at the dry limit", funded by the Deutsche Forschungsgemeinschaft (DFG).

Stable isotope palaeoecology of middle Eocene to early Oligocene planktonic foraminifera from IODP Expedition 342, north-western Atlantic Ocean

Paige BREEN[1] and Kirsty M. EDGAR[2*], Max HOLMSTRÖM[3], Simon D'HAENENS[1], Helen K. COXALL[3], Anieke BROMBACHER[1], Pincelli HULL[1]

1 Department of Earth and Planetary Sciences, Yale University, New Haven, Connecticut 06511, USA

2 School of Geography, Earth and Environmental Sciences, University of Birmingham, B15 2TT, UK

3 Department of Geological Sciences, Stockholm University, SE-106 91, Stockholm Sweden

4 Peabody Museum of Natural History, Yale University, New Haven, Connecticut 06520, USA

*corresponding author: k.m.edgar@bham.ac.uk

During the early Eocene through early Oligocene (~50-34 Ma), the Earth transitioned from the relative warmth of the early Eocene "hothouse" to a "coolhouse" climate state, associated with decreasing global temperatures, increasing latitudinal temperature gradients and ocean restructuring, culminating with a major increase in Antarctic continental ice volume across the Eocene-Oligocene transition ~34 Ma. Alongside these ocean climate transitions, marine plankton communities underwent pronounced restructuring, involving a general loss of warm water favouring and oligotrophic species, ecological adjustments in some groups and diversification of cooler water species. Existing perspectives tend to focus on low latitudes, and little is known about the planktonic foraminifera ecological responses at mid-high latitudes, where the strongest climatic and oceanic signals occurred. During Integrated Ocean Discovery Program (IODP) Expedition 342, offshore Newfoundland in the North Atlantic Ocean, multiple sites containing clay-rich sediments host well preserved ("glassy") foraminifera spanning the middle Eocene to Oligocene. Sampling pelagic environments in the northern branch of the palaeo North Atlantic subtropical gyre, the high quality, diverse assemblages of planktonic foraminifera are ideally suited for geochemical analyses allowing, arguably, accurate ecological reconstructions. Here we present ~550 new size-constrained, species-specific, planktonic foraminiferal stable oxygen and carbon isotope measurements for investigating palaeoecologies and ecological evolution in this environmentally sensitive region. The data comprise suites of ~5-20 species from 13-time windows spanning the middle Eocene to earliest Oligocene (~46-33 Ma) from IODP sites U1408 and U1411. These data provide insight into the palaeoecology of >50 extinct taxa, including the first size-specific isotopic data for multiple species during this critical transition interval.

The past 1,000 years of oceanographic variability based on benthic foraminifera and sediment proxies from Southeast Greenland fjord records

Inda BRINKMANN[1], Jens HESSELBJERG CHRISTENSEN[2], Christine S. HVIDBERG[2], Jochen KNIES[3], Camilla S. ANDRESEN[1]

[1] Department of Glaciology and Climate, Geological Survey of Denmark and Greenland, Copenhagen, Denmark; inbri@geus.dk, csa@geus.dk

[2] Physics of Ice, Climate and Earth, Niels Bohr Institute, University of Copenhagen, Copenhagen, Denmark; hesselbjerg@nbi.ku.dk, ch@nbi.ku.dk

[3] Geological Survey of Norway, Trondheim, Norway & CAGE – Centre for Arctic Gas Hydrate, Environment and Climate, UiT The Arctic University of Norway, Tromsø, Norway; jochen.knies@ngu.no

The Greenland Ice Sheet is an important factor for future scenarios under current global climate change, due to its sensitivity to changes in ocean heat transport and climate. In turn, variation in melt water fluxes to the surrounding water masses, i.e. North Atlantic, shapes their temperature and salinity. Modelling studies suggest that such changes may modulate large-scale atmospheric circulation, by blocking of high pressure systems, and, thus, weather conditions over Europe. Important context for the interaction between climate, ice sheet melt and ocean circulation can be derived from past glacio-marine records near Greenland. Here we focus on marine sediment cores from cores from Ikersuaq (Brede-) and Sermilik Fjord, South/Southeast Greenland, to reconstruct variations in the influence of Atlantic water masses and ice sheet melt over the past c. 1,000 years. This period comprises a broader range of decadal climate variability than shorter-term instrumental records, spanning key climate episodes including the Medieval Climate Anomaly and the cold Little Ice Age. The proxy records are based on benthic foraminiferal assemblages, combined with alkenone paleothermometry and sedimentary parameters (grain size, total organic carbon), to infer bottom-, surface water and outlet glacier variability, in decadal to multi-decadal resolution. The outcomes contribute to the interdisciplinary project

'GreenPlanning', which addresses the question of Greenland Ice Sheet melt and sea surface conditions around Greenland affecting climate modes and weather fluctuations in Europe, by combining climate and glacier modeling with palaeoceanographic records.

Using foraminifera to understand coral bleaching events: a combined approach using modern benthic and fossil planktic foraminifera

Torin CANNINGS[1], Stephanie STAINBANK[2], Dick KROON[†], Erica DE LEAU[3], Chiara PISAPIA[4], Daniela BASSO[5], Michael MARTÍNEZ-COLÓN[6], Elias SAMANKASSOU[1], Silvia SPEZZAFERRI[7]

[1] Department of Earth Sciences, University of Geneva, Rue des Maraîchers 13, 1205 Geneva, Switzerland; torin.cannings@unige.ch, elias.samankassou@unige.ch

[2] Kudala Environmental Ecology Lab (KEEL), Priscilla Vale Estates 17426, E603, Eston 3740, South Africa; stephaniehayman.23@gmail.com

[3] School of GeoSciences, Grant Institute, University of Edinburgh, The King's Buildings, James Hutton Road, Edinburgh EH9 3FE, United Kingdom; E.S.deLeau@ed.ac.uk

[4] King Abdullah University of Science and Technology, Saudi Arabia; chiara.pisapia.1@gmail.com

[5] Department of Earth and Environmental Sciences, University of Milano-Bicocca; CoNISMa, ULR of Milano-Bicocca, Piazza della Scienza 4, 20126, Milano, Italy; daniela.basso@unimib.it

[6] Florida A&M University FSH Science Research Center, RM306B 1515 South MLK Blvd, Tallahassee, FL, 32307, USA; michael.martinez@famu.edu

[7] Department of Geosciences, University of Fribourg, Chemin Du Musée 6, 1700, Fribourg, Switzerland; silvia.spezzaferri@unifr.ch

Tropical and subtropical coral reefs are biodiversity hotspots and are currently under unprecedented stress. Bleaching is a predominant stressor on reefs. One of the main drivers of bleaching is drastic temperature change. However, in the fossil record, bleaching cannot be observed. To reveal potential past bleaching events, we combine observations of modern shallow-water habitats with palaeoclimate records from nearby deep-water sites.

In these modern shallow-water environments, we use the *Amphistegina* Bleaching Index (ABI) to assess coral reef photo-inhibitory stress using the symbiont-bearing benthic genus *Amphistegina*. The Foraminifera in Reef Assessment and Monitoring Index (FoRAM-Index or FI) is used to assess water quality in reefs based on relative abundances of symbiont-bearing, opportunist, and stress-tolerant taxa.

We conduct this research on foraminifera in modern shallow-water habitats in tandem with research on benthic communities (corals, calcareous coralline algae, bacterial mats) providing a holistic assessment of ecosystem health status in coral reef environments.

New data from modern shallow-water environments allow us to establish thresholds (e.g., thermal and photic stress) for bleaching. An improved understanding of bleaching thresholds in the modern environment can then be used together with new improved palaeotemperature records from the deep-sea counterparts of our shallow-water sites. We aim to assess palaeotemperature from planktic foraminifera from core samples, to assess if bleaching thresholds were reached during past interglacials.

The study and imaging of both planktic and benthic foraminifera made during this project also contribute to ongoing taxonomic efforts, such as the Neogene Quaternary planktonic Foraminifera Working Group and prospective new atlases for benthic foraminifera in the shallow water study sites (e.g., Lizard Island, NE Australia).

We thank Swiss National Science Foundation Grant 200020_201106 for funding this research.

Response of benthic foraminifera to triple stressors: acidification, warming, and deoxygenation

Constance CHOQUEL[1,2], Elsa MULLER[1], Sam DUPONT[3], Emmanuelle GESLIN[4], Helena L. FILIPSSON[1]

[1] Department of Geology, Lund University, Lund, Sweden; helena.filipsson@geol.lu.se, elsa.muller36@orange.fr

[2*] Mediterranean Institute of Oceanology (MIO), Aix-Marseille University, Marseille, France; constance.choquel@univ-amu.fr

[3] Department of Biological and Environmental Sciences, Kristineberg Center for Marine Research and Innovation, University of Gothenburg, Kristineberg, Sweden; sam.dupont@bioenv.gu.se

[4] Laboratoire de Planétologie et Géosciences, CNRS, Univ. Angers, Nantes Université, Le Mans Université, Angers, France; emmanuelle.geslin@univ-angers.fr

Global changes include ocean acidification and warming, and hypoxia in coastal regions. The combined effects of these three stressors on an essential calcium carbonate-secreting marine microorganism, foraminifera, are not well understood mainly due to the inherent complexity of conducting a multiple stressors experiment and accurately assessing the variability in species survival rates. Our experiment was designed to culture benthic foraminifera under two temperatures (*in situ* 9°C and +4°C), two different oxygen concentrations (oxic *versus* hypoxic), and three different pH (average present pH 8.0, extreme of the present range of natural variability, pH 7.6; and a near future ocean acidification scenario, pH 7.4). We cultured two mudflat foraminifera *Ammonia confertitesta* and *Quinqueloculina seminula*, and two fjord species, the indigenous *Nonionellina labradorica,* and the non-indigenous *Nonionella* sp. T1. The experiment was performed in two thermoregulated rooms, duplicate aquaria were used for the three pH conditions but not for hypoxia.
The survival rates for fjord species were lower than for mudflat species. *Nonionella* sp. T1 and *Nonionellina labradorica* showed higher survival rates under hypoxic cold conditions (~30%). *N.* sp. T1 has a feeder cyst surrounding the entire test, we noticed that this species had a higher loss rate (i.e. unobserved tests), perhaps due to increased dissolution of the test when grown without its feeder cyst, which could weaken the test. Conversely, *Ammonia confertitesta* known for its partial cyst, showed higher survival rates (~60%) and a lower loss rate (0%) in hypoxia under cold and warm conditions. Given the variability in survival rates and loss rates among duplicates for pH conditions, firm conclusions are challenging to draw for the moment; however, the trend appears to indicate an increase in survival rates with decreasing pH under cold conditions and a reverse trend under warm conditions. The Mg-Mn-Ba/Ca performed on *A. confertitesta* indicated ontogenetic effects except for Sr/Ca. A negative correlation between Sr/Ca and pH decrease was found, and no significant influence of temperature was observed, suggesting that Sr/Ca may be independent of temperature fluctuations. Sr/Ca could potentially serve as a reliable proxy for carbonate chemistry during oxic conditions.

Ostracoda and foraminifera from the Střeleč profile - auxiliary section for the Turonian/Coniacian boundary

Markéta CHROUSTOVÁ[1*], Zofia DUBICKA[2]

[1] Institute of Geology and Paleontology, Faculty of Science, Charles University, Albertov 6, 128 43, Prague, Czech Republic

[2] Faculty of Geology, University of Warsaw, Al. Żwirki i Wigury 93, 02-089, Warszawa, Poland

* Corresponding author: marketa.chroust@gmail.com

The Global Boundary Stratotype Section and Point (GSSP) for the Turonian/Coniacian boundary has been ratified in Salzgitter-Salder (Germany). Additionally, three auxiliary sections have been designated: Střeleč (Czechia), Słupia Nadbrzeżna (Poland), and El Rosario (Mexico). The establishment of the auxiliary sections is important mainly for the correlation of different lithological facies. While the stratotype section in Salzgitter-Salder and auxiliary section in Słupia Nadbrzeżna are developed in the carbonate facies, the Střeleč section

represents more clastic facies of the depositional system influenced by relatively high terrigenous clastic input. In the lower part of the section silt-poor mudstones with silt-rich mudstones to siltstones alternate. The upper part of the profile is characterized by fine-grained sand-rich siltstones. The Střeleč section is 11 meters thick and crops out in the scarp of the railway cutting. Supplementary information for the Střeleč profile has been obtained from the near borehole V-800. Both profiles are correlated based on the organic carbon isotope data ($\delta^{13}C_{org}$) and on the gamma-ray logs (GR log). The most important macrofossil event for biostratigraphy, marking the base of the Coniacian, described from the profile is the first appereance of inoceramid *Cremnoceramus deformis erectus* at 4.5 m. It is in correspondence with the occurrence of this species in the V-800 core depth of 58 m. Studied foraminiferal assemblage from the V-800 core shows some benthic foraminiferal species (*Stensioena granulata*, *Gavelinella pertusa* and *Praebulimina intermedia*) which are typical for the lower Coniacian in the Bohemian Cretaceous Basin. Unfortunately, these species have not been found in the Střeleč section. What is more there are no foraminiferal species in Střeleč that are diagnostic for the Lower Coniacian. The ostracod assemblage of Střeleč is composed of Střeleč the species of which 'stratigraphic ranges' are from the Upper Turonian to the Coniacian (*Parvacythereis subparva, Planileberis cuneata, Golcocythere calkeri*); none of species typical only for the Lower Coniacian have been documented. Micropaleontological studies (nannofossils and palynomorphs) of the Střeleč section are in progress. This holistic approach of the chronostratigraphy might bring more complex understanding of the Turonian-Coniacian transition.

Nordic *Nummulites*: An unusual occurrence of *Nummulites planulatus* from Jyske Rev, Danish North Sea

Laura J. COTTON[1]

[1] Natural History Museum of Denmark, Copenhagen, Denmark; laura.cotton@snm.ku.dk

Small reticulate *Nummulites* are found across the Eocene shallow marine deposits of the Paris Basin, Belgium, as far north as northern Germany and southern UK. Only two isolated instances of *Nummulites* at higher latitudes than this are known, from the Rockall bank and Wyville-Thomson Ridge in the North Atlantic, and no *Nummulites* have been reported from the Nordic North Sea Basin. Until now. Here we describe *Nummulites planulatus* within a glacial erratic dredged from Jyske Rev in the Danish North Sea of likely Ypresian age. Whilst the specimen is not in situ, it indicates that populations of *Nummulites* were living further north in the North Sea region than previously know. This range expansion may have been facilitated by the hyperthermal events of the early Eocene.

Surviving the ice-house: Morphological trends in reticulate *Nummulites* across the Eocene–Oligocene transition

Laura J. COTTON[1], Ravi K. KOORAPATI[2], Benjamin C. MOON[3]

[1] Natural History Museum of Denmark, Copenhagen, Denmark; laura.cotton@snm.ku.dk

[2] Department of Earth Sciences, Binghamton University, Binghamton, NY 13902, United States; rkoorap1@binghamton.edu

[3] Palaeobiology Research Group, School of Earth Sciences, University of Bristol, Bristol, UK; ben@themoons.uk

The Eocene-Oligocene transition (EOT; approximately 34.44–33.65 Ma) remains one of the most important episodes of climatic change within the Cenozoic marking a long-term shift from 'greenhouse' to 'icehouse' conditions. Oxygen isotopes show a rapid stepwise increase linked to both temperature decrease and ice growth in Antarctica alongside evidence for large oceanographic changes and surface productivity. Within the shallow marine realm, larger foraminifera suffer extinction of widespread groups such as the orthophragmines, Pellatispiridae, and a number of species of *Nummulites*. While the timing, magnitude, and cause of the extinction event has been the focus of several studies, relatively little work has focused on the larger foraminiferal survivors.

The Tanzania Drilling Project (TDP) recovered three drill core records crossing the EOT. These records are exceptionally well constrained by microfossil, nannofossil, and chemostratigraphy. They also contain a continuous record of the distinctive and biostratigraphically important reticulate *Nummulites*, which survives the EOT. Using both, traditional oriented thin sections and micro-CT scanning we examined the morphology of a total of 159 individual specimens, from before, during and after the EOT. Our results show a clear expansion in morphospace across the EOT, which we interpret as a speciation event-in-progress, linked to the climatic event. Rapid shifts in temperature and nutrient levels may be driving the morphological change seen and the relative importance of these drivers appears to have changed across the transition.

Early Pliocene variability in calcareous productivity driven by Antarctic Circumpolar Current dynamics in the Central South Pacific

Sunil K. DAS[1], B. SAHOO[1], S. SARKAR[1], Raj K. SINGH[1], IODP Expedition 383 Scientists[2]

[1] School of Earth, Ocean and Climate Sciences, Indian Institute of Technology Bhubaneswar, Odisha, 752050; skd16@iitbbs.ac.in

[2] Texas A&M University, College Station, United States; expedition_383_participants@iodp.tamu.edu

The Antarctic Circumpolar Current (ACC) is the key to understand the impacts of the Southern Ocean (SO) on the global climate and the stability of the Antarctic ice-sheet. The Pliocene epoch is significant to assess the ACC variability and its influence during the warmer than present-day atmosphere with similar global land-sea settings and the lone polar ice cap over the Antarctica. Further, a recent study has documented that ACC strength was at its maximum during the Pliocene. Hence, this study examined the early Pliocene (5.6 - 3.6 Ma) samples of Central South Pacific (CSP), from the IODP Site U1541 to assess productivity at CSP with varying ACC strength during the Pliocene. Calcareous productivity were measured in terms of benthic foraminiferal accumulation rate (BFAR) and coarse fraction accumulation rate (CFAR), and *C. wuellerstorfi* $\delta^{18}O$ and published biogenic opal content was considered to measure siliceous productivity. R-mode principal component analysis shows strong positive correlations between increasing ACC strength and calcareous productivity proxies. The gradual rise in BFAR and CFAR, during the Pliocene, exhibit negative correlations with siliceous productivity in the CSP, which declined during that period. The significantly stronger ACC flow in warmer intervals within the Pliocene is supported by the decreasing *C. wuellerstorfi* $\delta^{18}O$ during 5.2- 4.9 Ma, and 4.0 - 3.6 Ma. The productivity proxies reveal their possible linkages with ACC dynamics by attaining their maxima during the same intervals.

From electrical cable bacteria acidification to eelgrass colonisation: seasonal monitoring of foraminiferal ecology and shell preservation on estuarine mudflats

Maxime DAVIRAY[1], Emmanuelle GESLIN[1], Eric BENETEAU[1], Sophie QUINCHARD[1], Matéo TOUGNE[1], Edouard METZGER[1]

[1] University of Angers, Nantes Université, Le Mans Univ, CNRS, LPG, F-49000 Angers, France; maxime.daviray@univ-angers.fr

This study presents the seasonal monitoring of sediment acidification in two intertidal mudflats in the Auray river estuary (Atlantic coast, France). Sediment geochemistry and living benthic foraminifera as well as the preservation of their shells were seasonally investigated from April 2022 to July 2023. The development of eelgrass meadows was observed in both mudflats during Summer, something that had not happened for over ten years. Before Summer 2022, the mudflats were bare, colonised by cable bacteria (Daviray et al., 2024) with seasonal algal deposits. Cable bacteria activity (CBA) redesigns sediment diagenetic processes generating strong pH gradients within the first few centimetres of sediment leading to acidic conditions.
The upstream mudflat station showed seasonal dynamics of CBA. Cable bacteria appeared to be inactive in Winter (ΔpH = 0.4) and led to intense pore water acidification during Autumn (ΔpH = 1.9) under meadow senescence. At the downstream mudflat station, CBA were detectable through the year with ΔpH from 0.9 in Winter to 2.3 in Autumn. Lower pH recorded were 5.94 and 5.40 respectively.
All year long, calcareous specimens, mostly dominated by *Ammonia* morphocomplex *tepida* and *Haynesina germanica*, showed test dissolution below the sedimentary oxic layer. During autumn, at both stations, calcareous specimens dwindled, and tests were extremely corroded. In the meantime, the agglutinated species *Ammobaculites balkwilli* dominated the assemblage. During spring, the upstream station was the setting for a *H. germanica* bloom after the cable bacteria seemed no longer active in winter. During summer, the upstream station showed a well-developed eelgrass meadow together with CBA (ΔpH = 1.3). Agglutinated species dominated the foraminiferal assemblage with *A. balkwilli* in the upper 5-mm and *Eggerelloides scaber* deeper down. The eelgrass colonisation had seemed to be beneficial to the foraminiferal community and stimulated its dynamism by encouraging a new species equilibrium in the assemblage. The most impacted species seemed to be *A.* morphocomplex *tepida* as between summer 2022 and 2023 their density and relative abundance felt sharply in favour of *Elphidium* spp., *Quinqueloculina* spp. and *A. balkwilli*. These observations were quite different from those at the downstream station where cable bacteria were active all year long. Surprisingly, agglutinated species remained in minor proportions and *A.* morphocomplex *tepida* more or less constant. Moreover, dead assemblages showed important losses of calcareous tests when cable bacteria were very active in autumn conducting to an organic lining and agglutinated enrichment with depth.
To summarize, our study shows that foraminiferal ecology responds quickly to environmental changes in coastal sediments making them suitable for biomonitoring while the loss of their tests in acidic environments weakens their applicability for reconstructing temporal environmental chronicles.

Large Benthic Foraminifera as proxies for environmental and diversity reconstruction: the middle-late Eocene western Thrace Basin (Neotethys Ocean, Greece)

Vasiliki-Grigoria DIMOU[1], Olga KOUKOUSIOURA[1,2], György LESS[3], Martin R. LANGER[4]

[1] School of Geology, Aristotle University of Thessaloniki, 54124, Thessaloniki, Greece; dimouvaso@geo.auth.gr, okoukous@geo.auth.gr

[2] Institute of Geology and Mineralogy, University of Cologne, Zülpicher Str. 49a, 50674, Cologne, Germany; okoukous@uni-koeln.de

[2] Department of Geology and Mineral Resources, University of Miskolc, H-3515, Miskolc-Egyetemváros, Hungary; gyorgy.less@uni-miskolc.hu

[4] Institute of Geosciences, Rheinische Friedrich-Wilhelms-Universität Bonn, Nussallee 8, 53115, Bonn, Germany; martin.langer@uni-bonn.de

The Thrace region is a large Paleogene-Neogene molassic basin in the northern Aegean (Greece, NW Turkey, Bulgaria). The architecture of the basin is the result of middle-late Eocene NE-SW extension processes, which led to the formation of a supra-detachment basin divided into three sub-basins that are characterized by a

complex stratigraphy. The evolution and paleoenvironmental reconstruction of the basin were carried out with the help of sediment, thin section and microfacies analyses and, above all, the analysis of larger benthic foraminifera (LBF) as proxies for carbonate deposits of the middle to upper Eocene. Several new outcrops were analyzed comprising shallow-water carbonate deposits in the wider region of the Greek part of the Thrace Basin, including localities on the mainland and the north-eastern Aegean islands of Samothrace and Lemnos. Analysis of the sedimentological and paleontological data allowed the identification of 16 microfacies types, assigned to a sequence of inner, middle and outer shelf environments. A model of a rimmed carbonate shelf with isolated platforms was reconstructed, where both open and restricted water circulation patterns prevailed on and between the platforms. Triggered and driven by dynamic syn-rifting, topographic highs have developed in this area. Here we document hyperdiverse, late Eocene assemblages of larger symbiont-bearing foraminifera, characterizing the Thrace Basin not only as a particularly species-rich and diverse area, but also as a hotspot of LBF diversity.

A new organic attached living foraminifera of the Brazilian continental margin (Santos Basin, Southwest Atlantic)

Sibelle Trevisan DISARÓ[1], Joicce DISSENHA[1,2]

[1] Laboratório de Foraminíferos e Micropaleontologia Ambiental, Museu de Ciências Naturais, Universidade Federal do Paraná, Av. Cel. Francisco H. dos Santos, s/n Curitiba (PR), Brazil; stdisaro@ufpr.br

[2] Pós Graduação em Zoologia, Departmento de Zoologia, Universidade Federal do Paraná, Av. Cel. Francisco H. dos Santos, s/n Curitiba (PR), Brazil; joi.ddg@gmail.com

The suprageneric categorization of organic foraminifera is being revised, incorporating new results from molecular and morphological analyses; therefore, we will not assign a suprageneric classification now. We have a new species and, perhaps, a new genus of an attached foraminifera on the Brazilian continental margin. The description presented here was based on integrated observations of the morphology and composition of the test, in addition to internal characteristics observed in the studied specimens. The species was recorded on the outer shelf of the Santos Basin (150 m) and the São Paulo Plateau (2,200 m) during the studies of the "*Santos Project—Regional Environmental Characterization of the Santos Basin (PCR-BS)*", coordinated by PETROBRAS/CENPES.

Scanning electron microscopy (SEM), energy dispersive spectroscopy (EDS), and optical microscopy analyses helped identify this new species' chemical and morphological characteristics. It has semi-globular to semi-elliptical chambers with a circular to oval outline, and a small terminal opening is generally visible in the last chamber. Most examples have five chambers that increase as they are added; in adults, the last one is about seven times the size of the proloculum. The main characteristic of this species is the presence of a darker peripheral border that is generally grayish and visible by transparency. Many stercomata are visible internally and deposited close to the edge of the test. SEM analyses let us record coccoliths inside these stercomata, possibly making up part of the species' diet. The species is attached to shell fragments on the edge of the continental shelf; however, at the Sao Paulo Plateau, it is attached to the inner surface of pteropod shells.

Careful examination of sedimentary grains was necessary for its registration. Future molecular analyses can help understand its phylogenetic affinities.

How long does a species live? The occurrence of a new Lazarus genus provides fresh insight into this discussion

Sibelle Trevisan DISARÓ[1], Joicce DISSENHA[1,2]

[1] Laboratório de Foraminíferos e Micropaleontologia Ambiental, Museu de Ciências Naturais, Universidade Federal do Paraná, Av. Cel. Francisco H. dos Santos, s/n Curitiba (PR), Brazil; stdisaro@ufpr.br

[2] Pós Graduação em Zoologia, Departmento de Zoologia, Universidade Federal do Paraná, Av. Cel. Francisco H. dos Santos, s/n Curitiba (PR), Brazil; joi.ddg@gmail.com

In 1848, Geinitz described *Serpula pusilla*, originating from Poland's Permian, and in 1959, Wolanska produced a detailed amendment to *Agathammina pusilla* (Geinitz, 1848). According to the available bibliography, this genus appears in different places, from the Paleozoic (Carboniferous) to the Mesozoic (Cretaceous).
In Brazil, it was recorded in the Araripe Basin for the Cretaceous (Aptian - lower Albian) in outcrops in the state of Pernambuco by Araripe et al. (2021). Carrying out environmental characterization studies of Brazilian oceanic sedimentary basins with living foraminifers, we recorded live specimens of *Agathammina* on the slope of the Potiguar Basin, on the NE Brazilian continental margin (Rio Grande do Norte), and on the São Paulo Plateau, in the Santos Basin (SE, Brazil). The Brazilian Cretaceous record is located between the two places where *Agathammina* sp. was living on the Brazilian coast.
From the morphological point of view, we obtained tomography images that show longitudinal and transversal sections that coincide with Wolanska's detailed illustrations. Our specimens' wall thickness, growth striations, and aperture coincide with the images published in the species amendment. Although we could carry out molecular analyses (DNA) with living specimens, it is currently impossible to do so with fossils.
If there aren't morphological changes between the Permian specimens of *Agathammina pusilla* illustrated in detail by Wolanska and our current material, what should we call our living specimens? Can a species live from the Upper Permian to the present day?

Estimating past bottom water oxygenation based on *Eubuliminella exilis* in the Eastern Tropical North Pacific

Yaima DOMÍNGUEZ-SAMALEA[1], Alberto SÁNCHEZ-GONZÁLEZ[2]

[1] Department of Oceanology, Centro Interdisciplinario de Ciencias Marinas, Instituto Politécnico Nacional, Avenue Instituto Politécnico Nacional SN, Playa Palo de Sta Rita, La Paz, Mexico; ydominguezs2200@alumno.ipn.mx

[2] Department of Oceanology, Centro Interdisciplinario de Ciencias Marinas, Instituto Politécnico Nacional, Avenue Instituto Politécnico Nacional SN, Playa Palo de Sta Rita, La Paz, Mexico; alsanchezg@ipn.mx

Subsurface water masses with permanent oxygen deficiency (oxygen minimum zones, OMZ) are typically associated with upwelling regions and are considered in expansion in the face of global warming. Past decades´ research has shown that its expansion has negative economic and ecological consequences on food chains, biogeochemical cycles, marine ecosystems, and fisheries. To investigate the relationship between OMZ expansion and global climate changes in the Mexican Pacific during the last millennium, quantitative oxygen reconstructions are needed. Climatic events such as the Medieval Warming have occurred, a key piece to understand how the biogeochemical cycles of the ocean would respond to the recent and future warming of the planet.
Therefore, the aim of this study is to estimate the variability of the concentration of dissolved oxygen in the OMZ in the Magdalena margin during the last 1200 years, based on the relative abundance of the taxon *Eubuliminella exilis* (Brady, 1984). Multicore MC-2 used in this research was recovered at a depth of 680 m

on the southwestern margin of Baja California Sur, Mexico. *E. exilis* is commonly found in OMZ, is a shallow infaunal species and tolerates dysoxic conditions (0.1-0.5 ml L^{-1}). The methodology used in this study was developed by Tetard et al. (2021). The estimated dissolved oxygen concentrations, inferred from *E. exilis*, suggests that the OMZ has maintained dysoxic conditions over the past 1200 years. The use of this species to estimate the oxygen concentration of bottom waters in OMZ is supported.

Benthic foraminiferal to climate related sediment depositional events: insight from the S1 and E1 Northern Adriatic LTER Sites

Roberta D'ONOFRIO[1], Luciana FERRARO[2], Fabio FRANCESCANGELI[3], Francesco RIMINUCCI[4], Lucilla CAPOTONDI[4]

[1] CNR, Marine Science Institute (ISMAR), Arsenale Castello 2737/f, 30122, Venezia, Italy; roberta.donofrio@cnr.it

[2] CNR, Marine Science Institute (ISMAR), Calata Porta di Massa, 80133, Napoli, Italy; luciana.ferraro@cnr.it

[3] Department of Geosciences, University of Fribourg, 1700, Fribourg, Switzerland; fabio.francescangeli@unifr.ch

[4] CNR, Marine Science Institute (ISMAR), Via Piero Gobetti, 101, 40129 Bologna, Italy; francesco.riminucci@bo.ismar.cnr.it; lucilla.capotondi@cnr.it

In the contest of the ongoing climate change, the increase in frequency of severe storms and flooding significantly affect the sedimentary supply to coastal areas with deleterious effects on marine biota. Despite several studies focused on macrobenthos, to date little is known about the microfauna, which represents lower steps of the trophic chain. Main goal of this study is to document the relationship between benthic assemblages (BF) of the North Adriatic Sea and sediment depositional events. The investigation is based on samples collected from 2016 to 2023 in two Long Term Research (LTER) Sites, S1 and E1, located south of the Po Delta river and in the Rimini offshore respectively. Our results document that while a major driver influencing BF assemblages at Site S1 is the Po riverine discharge, BF composition at Site E1 is mainly controlled by sediment reworking due to storm waves. Indeed, after major increases in river flow rate, at S1, closer to the delta, BF density and diversity strongly decrease, environmental quality get worse and BF population became dominated by strongly opportunistic taxa tolerant to organic rich sediments and oxygen deficiency such as buliminids and *Nonionoides turgidus*, with subordinate *Stainforthia fusiformis* and *Hopkinsina pacifica*. Differently, at Site E1, BF assemblages are commonly dominated by taxa tolerant to moderate organic matter concentrations. Although environmental indices do not change, after major storm wave episodes lowest BF density and diversity values are recorded along with strong increase in abundance of *Ammonia* species belonging to the *parkinsoniana* and *tepida* morphogroup, *Aubignyna perlucida* and a parallel abrupt reduction in fragile agglutinant taxa. All the taxa used for this study and related data will allow us to contribute to the development of the Research Infrastructure DiSSCo (Distributed System of Scientific Collections), making information accessible and thus enhancing the role of foraminiferal records.

Biotic impact of the Paleocene-Eocene Thermal Maximum on the US Coastal Plain

Monika DOUBRAWA[1], Peter STASSEN[1,2], Ellen THOMAS[3], Robert P. SPEIJER[1]

[1] Department of Earth and Environmental Sciences, KU Leuven, Celestijnenlaan 200E, 3001 Leuven, Belgium; Monika.Doubrawa@kuleuven.be

[2]Royal Belgian Institute of Natural Sciences, OD Earth and History of Life, Brussels, Belgium

[3]Yale University, 210 Whitney Ave, New Haven CT 06511, USA

The Paleocene-Eocene Thermal Maximum (PETM) is the most pronounced hyperthermal of the early Paleogene. In the subsurface of the US Atlantic Coastal Plain the PETM is recorded in a thick, fine grained sediment package (Marlboro Clay), and characterized by a negative stable isotope excursion ($\delta^{13}C$, $\delta^{18}O$), as well as a turnover off the benthic foraminiferal assemblage, to a low-oxygen / high-temperature tolerant community.
Species-specific stable isotope data of foraminifera (site Wilson Lake, New Jersey) show enigmatic patterns across the PETM onset and the core-phase. The $\delta^{18}O$ data of benthic and planktic foraminifera, as well as the benthic $\delta^{13}C$ values, of both epi- and infaunal living species, converge in the ~2 m following the onset of the PETM, then diverge gradually throughout the consecutive interval. Additionally, the $\delta^{18}O_{benthic}$ data show a cyclic pattern, potentially indicating ~20-kyr precession cycles in seasonal seafloor temperatures and/or salinity. A pattern which is not mirrored by Mg/Ca derived temperatures. The first potential cycle coincides with the "converged" stable isotope data, where the benthic and planktic $\delta^{18}O$ indicates a possible collapse of the thermocline, resulting in a more homogeneous water column. The converged $\delta^{13}C$ data could be caused by a temporary change of habitat of benthic foraminifera to e.g., only infaunal. Benthic assemblages indicate a low oxygen environment, possibly causing this shift. Preliminary Mn/Ca data are increased, supporting the hypothesis of lowered oxygen content and/or a deeper infaunal lifestyle. While overall low oxygen conditions, as per the benthic assemblage, remain for the core-phase, parallel to the second cycle *Paralabamina lunata*, a species less tolerant to dysoxic conditions, appears in the assemblage indicating a slight increase in bottom water oxygenation. The $\delta^{13}C$ signatures also start to diverge into a clear in- and epifaunal signal, indicating a renewed diversification of lifestyle.

Intraspecific and interspecific features drive surface sediment reworking of benthic foraminifera

Manon DOUTRELANT[1,2], Vincent M.P. BOUCHET[1], Alicia ROMERO-RAMIREZ[2], Aurélie CIUTAT[2], Olivier MAIRE[2]

[1] Univ. Lille, CNRS, Univ. Littoral Côte d'Opale, UMR 8187, LOG, Laboratoire d'Océanologie et de Géosciences, Wimereux, France; manon.doutrelant@univ-lille.fr, vincent.bouchet@univ-lille.fr

[2] Université de Bordeaux, CNRS, EPOC, UMR 5805, 33400 Talence, France; alicia.romero-ramirez@u-bordeaux.fr, aurelie.ciutat@u-bordeaux.fr, olivier.maire@u-bordeaux.fr

Sediment reworking has a crucial role in the functioning of marine ecosystems. Numerous studies on this topic demonstrate the impact of macrofauna on the sediment, but it was shown recently that benthic foraminifera can also participate in sediment reworking processes. Noticeably, intertidal foraminifera can have different surface sediment reworking rate according to their functional trait. In this context, the aim of the study was to understand the role of intra- and inter-specific features in the surface sediment reworking rate (SSRR) performed by intertidal foraminifera. The intra-specific difference was studied within *Quinqueloculina spp* of different sizes. Whereas, the inter-specific difference was explored by comparing *Ammonia spp*, *Eggerelloides scaber*, *Haynesina germanica*, *Quinqueloculina spp*, four intertidal foraminifera, known to live in different microhabitats and/or having different burrowing behavior. Our result showed an intraspecific difference for *Quinqueloculina spp*, the SSRR is correlated with the size of the individuals, ranging for 0.32 ± 0.03 $mm^3.ind^{-1}.day^{-1}$ for individuals with a size between 200 and 300 µm to 11.01 ± 3.18 $mm^3.ind^{-1}.day^{-1}$ for individuals with a size between 600 and 700 µm. By contrast, the interspecific difference of SSRR is not size dependent. In fact, for the same size between 300 and 400 µm *H. germanica* have a lower SSRR than *Ammonia spp* and *Quinqueloculina spp*. While, the individuals of *E. scaber* with a size between 700 and 800 µm have the same SSRR that this smaller species.

Sediment substrate and benthic foraminiferal distribution along Chandipur Coast, Odisha, India

Jumee DOWARI[1*], Urbashi SARKAR[1]

[1]Department of Earth Science, Assam University, Silchar - 788011

[*] Corresponding author jdowari92@gmail.com

A comprehensive study was conducted to investigate the substrate control variability of benthic foraminifera in the coastal region of Chandipur, India (Lat: 21º27'45" N, Long: 87º00'12" E), characterized by diverse sub-environment (tidal flat, back bar, and estuary mouth). Utilizing standard procedures, 29 sediment samples were collected from all the sub-environments, each at a depth of <10cm. Further, the samples were processed in the Department of Earth Science, Assam University, Assam and foraminiferal assemblages were determined. This study aimed to analyze the composition and distribution of recent benthic foraminiferal communities according to the substrate which, in turn, is the result of different environmental condition. A total of 1,866 foraminiferal specimens, comprising 34 species and 18 genera, were picked and identified. Within the tidal flat area, distinct correlations emerge between sedimentary substrate, species diversity, and abundance. The tidal flat samples are divided into two parts, viz., closer to the sea and near shoreline. The samples collected from the tidal flat closer to the sea where the tidal currents exert their greatest influence, reveals high sand content (>80%) and low mud content (<20%), indicative of high-energy conditions conducive to the transportation and deposition of coarser size sediments. Notable species in tidal flat include *Ammonia inflata*, *Asterorotalia multispinosa, Nonion* sp., and *Nonionella decora*. Here the species diversity and abundance is less. Conversely, the samples collected from the tidal flat near shoreline regions where the influence of tidal currents diminishes, leading to a decrease sand content (<60%) and increased mud content (>40%), marking a transition to lower-energy conditions and facilitating the settling of finer sediments. Mud-rich tidal flat support thriving populations of species like *Haynesina germanica, Rosalina bradyi, Melonis bradyi*, and *Haynesina depressula*. Here the foraminifera abundance and species diversity are high compared to the other sub-environments. Back bar, indicative of a further decrease in energy levels, characterized by mud content >30% and sand <70% with higher abundance and diversity of foraminiferal species as well, harbor unique species like *Labrospira evoluta*. Common foraminiferal species across tidal flat and back bar include *Bolivina* sp., *Bathysiphon* sp., and *Cibicides* sp. Estuary mouth exhibit distinct sediment compositions, with low mud (<15%) and high sand (>85%) content. Foraminiferal species prevalent in this area is represented by species such as *Ammonia beccarii*, *Asterorotalia trispinosa* and *Triloculina* sp. Although benthic foraminiferal density was high at estuary mouth but the species diversity were relatively lower. The distribution of foraminiferal taxa (*Ammonia beccarii*, *Asterorotalia trispinosa, Elphidium limpidum*, *Hemirotalia* sp.,) is consistent across sub-environments, with higher densities observed in estuary area compared to the other sub-environments.

The distribution and diversity of foraminifera are closely linked to the varying levels of sand and mud content within different environmental conditions. Specifically, there is a discernible correlation between the distribution of foraminiferal species and the prevalence of sand and mud within the studied area. Notably, areas characterized by higher mud content, such as the tidal flats near the shoreline and the back-bar, demonstrate an increasing trend in species richness, with maximum counts reaching up to 18 species in certain samples . Similarly, in the back-bar, in one sample the species richness is upto 17. Conversely, regions with lower mud content, particularly the tidal flat near the sea, showcase the lowest species richness and diversity. This variation highlights the role of environmental conditions, particularly sand and mud content, in shaping the distribution and diversity of foraminifera within these ecosystems.

New insights into the early Pleistocene *Neogloboquadrina atlantica* dextral record and extinction in the mid-latitudes of the North Atlantic Ocean

Mónica DUQUE-CASTAÑO[1,2,3], Antje H.L VOELKER[2,3], Emilia SALGUEIRO[2,3], Katharina BILLUPS[4], Stephen BARKER[5], David HODELL[6]

[1] Universidade do Algarve, Campus de Gambelas, Faro, Portugal; monica.duque.castano@gmail.com

[2] Divisão de Geologia e Georecursos Marinhos, Instituto Português do Mar e da Atmosfera, Algés, Portugal; antje.voelker@ipma.pt, emilia.salgueiro@ipma.pt

[3] Centre of Marine Sciences (CCMAR), Universidade do Algarve, Faro, Portugal

[4] School of Marine Science and Policy, University of Delaware, Newark, United States; kbillups@udel.edu

[5] School of Earth and Environmental Sciences, Cardiff University, Cardiff, Wales; Barkers3@cardiff.ac.uk

[6] Department of Earth Sciences, University of Cambridge, Cambridge, England; dah73@cam.ac.uk

The species *Neogloboquadrina atlantica* is a key biostratigraphic marker in the North Atlantic, primarily distinguished by its coiling direction. Although focus has been on the extinction of the sinistral variant (ca. 2.4 Ma), dextral occurrences in the Pleistocene have been noted in biostratigraphic observations from IODP Exp. 306 and 339, but not systematically analyzed. Here, we present the record of *N.atlantica* dextral during the early Pleistocene and its extinction event in the North Atlantic. We are analyzing samples from IODP Sites U1387 (36°48.3´N 7°43.1´W) and U1385 (37°34.3′N, 10°7.6′W) on the Portuguese margin, ODP Site 1058 (31° 41'N, 75° 35'W), and ODP Site 983 (60° 24.2'N, 23° 38.4'W), with some additionally data from IODP Site U1313 (41°N, 32.9°W). The main goal is to assess the extinction event of this species as a stratigraphic marker and explore how paleoenvironmental changes might have influenced its distribution and extinction.
At IODP Site U1387, the extinction event occurred at the onset of Marine Isotope Stage (MIS) 40 at 1,301.06 kyr. Higher abundances were observed during interglacial MIS 49 and MIS 43 (22.7% and 18.7% respectively), when sea-surface temperature (SST) averaged ~21.1°C in summer. At ODP Site 1058, *N. atlantica* dextral was recorded between MIS 43 (1350.40 kyr) and MIS 40 (1299.11 kyr), although abundances were lower (0.6-2%) with SSTs around 25.7°C in summer. This suggests a synchronous early Pleistocene extinction at the eastern and western margin of the subtropical gyre. No *N. atlantica* dextral specimens were found at subpolar gyre Site 983 during that time interval, but are present in IODP Site U1313 core catcher samples. So, to define the northern boundary of the event and/or its affinity with subtropical to transitional water masses originating from the Gulfstream/North Atlantic Current, we will study IODP Site U1308 (49°52.7'N, 24°14.3'W) next.

Late Neogene–Quaternary Planktic Foraminiferal Biostratigraphy of IODP Hole U-1474A: Agulhas Current region, SW Indian Ocean

Rahul DWIVEDI[1], Vikram Pratap SINGH[1]

[1] Department of Geology, Indira Gandhi National Tribal University, Amarkantak (M.P.); drahul718@gmail.com, vikram.singh@igntu.ac.in

Planktic foraminifera are tiny marine organisms that live in the oceans and are exposed to various stresses caused by changes in the atmosphere and environment. They have a faster rate of evolution and are used as index fossils, particularly for the Cenozoic era. These microorganisms are preferred over other groups for conducting biostratigraphic studies because of their facies-independent distribution, size, abundance, diversity, relatively continuous stratigraphic records, and strong latitudinal provincialism.
The IODP Hole U-1474A is located in the northernmost Natal Valley (31^0 13.00' S; 31^0 32.71'E) in the Agulhas Current region. This site is located very close to the latitude where the Agulhas Current initiates and

is under the direct influence of the current. Thus, it has the potential to record the changes in the Agulhas Current, which can be studied by analysing the variations in the faunal records.
We studied 700 deep-sea samples from the core acquired from the IODP Hole U-1474A, spanning the Late Neogene-Quaternary. The detailed qualitative and quantitative analysis showed that tropical-subtropical forms dominate this site, but there are intervals which show a very high abundance of temperate and subpolar forms as well. This region is affected by the two water masses due to variations in the Agulhas Current. The biozonation for this region, therefore, could not be completely based on either the tropical or the temperate schemes.
On the basis of a detailed qualitative analysis of planktic foraminifera from IODP Hole U-1474A, we have subdivided the Late Neogene–Quaternary section into eight zones, comprising of the biozones from the tropical-subtropical scheme for the Quaternary, while biozones from the temperate scheme for the Late Neogene.
The sequential order of planktic foraminiferal events (FO and LO) has been determined, and 22 events spanning the Late Neogene-Quaternary have been identified. There are 13 events marked for the Late Neogene and 9 events for the Quaternary. The *Globorotalia margaritae* Interval Zone marks the Miocene-Pliocene boundary, the *Globorotalia tosaensis* Interval Zone marks the Pliocene-Pleistocene boundary, and the Pleistocene-Holocene boundary is marked by *Globorotalia truncatulinoides* Interval Zone, at IODP Hole U-1474A. The numerical age estimates of the events were made by integration with the polarity zone boundaries estimated during the shipboard studies.

A multi-proxy approach to decipher global sea-level and ice-volume dynamics during late Cenozoic "snapshot" intervals based on benthic foraminifera from tropical Pacific ODP Site 849

Isabel EHMCKE ESPINOSA[1], Oliver FRIEDRICH[1]

[1] Institute of Earth Sciences, Heidelberg University, Heidelberg, Germany; isabel.ehmcke@geow.uni-heidelberg.de, oliver.friedrich@geow.uni-heidelberg.de

The response of ice sheets and sea-level to a warming climate is a matter of widespread concern, as it is both anthropogenically influenced, as well as most likely impactful on current, and future human lives. The study and understanding of such dynamics is therefore a highly relevant task. In order to do so, the planned project aims to reconstruct past ice sheet and sea-level dynamics in a warming climate from late Cenozoic (Plio-Pleistocene) glacial-interglacial `snapshot´ intervals. Specifically, the objective is to provide a new, quantitative and highly resolved sea-level record for six glacial/interglacial (G-IG) cycles of the past ~5 Myrs. The chosen intervals reflect a wide range of different boundary conditions in terms of glacial strength, amplitude and duration of G–IG cycles, as they comprise the critical transition from the Pliocene greenhouse to stronger G–IG cycles towards the Pleistocene `icehouse´. The intervals are therefore characterized by climatic conditions which are relevant to the understanding of future climate warming and the accompanying sea-level/ice-volume changes, as they represent warmer-than-present temperatures, comparable atmospheric greenhouse-gas concentrations, and an orbital-analogy to the present-day.
The project will be based on material from ODP Site 849 in the Eastern Equatorial Pacific – a site which meets all necessary paleoceanographic and stratigraphic criteria for the proposed research. This is due to its quasi-global signal without strong local or terrestrial imprints owed to its open-oceanic position in the largest ocean basin, and the occurrence of abundant and well-preserved foraminifera. Analytical methods include the paired analysis of benthic $\delta^{18}O$ and Mg/Ca, as well as carbonate clumped isotope thermometry (Δ_{47}) as proxies for bottom-water temperature to reconstruct the isotopic composition of seawater and therefore sea-level. Available $\delta^{18}O$- and Mg/Ca-based sea-level reconstructions show that this approach delivers reliable data for interglacials, whereas Mg/Ca- based sea-level and bottom-water-temperature (BWT) reconstructions might be

less reliable for glacials, as absolute glacial lowstand values seem to exceed the level derived from other, albeit less-well resolved, datasets. In order to produce more reliable data for glacials this project will explore a refined approach for sea-level reconstruction that combines more traditional benthic $\delta^{18}O$ and Mg/Ca data with Δ_{47}. This will be done by generating Mg/Ca and $\delta^{18}O$ datasets (~700-yr resolution) using the benthic foraminifer *Oridorsalis umbonatus* which then will be integrated into the results from Δ_{47} thermometry based on mixed foraminiferal species (~2.85-kyr resolution). The main research questions encompass the exploration of the offset between Mg/Ca- and Δ_{47}-derived BWTs used for sea-level reconstruction, as well as the determination of the exact rate of sea-level variability during the six intervals and their comparison to previous estimates.

Tectonically induced vertical motions on the Island of Rhodes (Greece) during the Plio-Pleistocene

Daniela EICHNER[1], Gerhard SCHMIEDL[1,2], Jürgen TITSCHACK[3,4], Yvonne MILKER[1,2]

[1] Institut für Geologie, Universität Hamburg, Bundesstraße 55, Hamburg, Germany; daniela.eichner@uni-hamburg.de, gerhard.schmiedl@uni-hamburg.de, yvonne.milker@uni-hamburg.de

[2] Center for Earth System Research and Sustainability (CEN), Universität Hamburg, Bundesstraße 55, Hamburg, Germany

[3] MARUM — Center for Marine Environmental Sciences, Leobener Straße, Bremen, Germany; jtitschack@marum.de

[4] Senckenberg am Meer, Marine Research Department, Südstrand 40, Wilhelmshaven, Germany

The Island of Rhodes, located at the eastern end of the Hellenic fore-arc, experienced intensive tectonic motions during the Plio-Pleistocene, with phases of uplift and subsidence. Along the eastern coast of the island, microfossil-rich marine sediments of Plio-Pleistocene age have been uplifted and are outcropping at scattered locations.

Here we present new insights into the neotectonic evolution of the island by reconstructing past tectonically induced vertical motions and by identifying the large- and small-scale differences between different sedimentary depocenters along the island. To do so, an existing transfer function was applied to the fossil benthic foraminiferal assemblages from different depocenters for reconstructing the paleo-water depths. To extract the tectonic component, the estimates were corrected for the effect of glacio-eustatic sea-level changes and precession-driven changes.

The application of the transfer function to three Pleistocene sediment sections along the middle- and northeastern coast of the island, revealed that all were influenced by tectonically induced long- and small-term vertical motions, reflecting the tectonic uplift and subsidence of the island, as well as individual motions of graben structures. Long-term subsidence and uplift rates vary between 0.9 and 2.2 mm a^{-1} and between 0.6 and 1.0 mm a^{-1}, respectively, while each sediment section revealed multiple small-scale cycles of transgression and regression with rates up to 10.4 mm a^{-1}. While comparing with already existing data, remarkable differences in the timing and rates of vertical motions and maximal drowning are noticeable.

Globigerina bollii Cita and Premoli Silva 1960: a lost biostratigraphic marker?

Alessio FABBRINI[1,2], Maria Rose PETRIZZO[3], Isabella PREMOLI SILVA[3], Luca Maria FORESI[4], Bridget Susan WADE[1]

[1] Department of Earth Sciences, University College London, Gower Street, London, WC1E 6BT, UK; a.fabbrini@ucl.ac.uk, b.wade@ucl.ac.uk

[2] Department of Geography, University of Galway, Distillery Road, Galway, H91 CF50, Ireland; alessio.fabbrini@universityofgalway.ie

[3] Department of Earth Sciences "A. Desio", University of Milan, Via Mangiagalli 34, 20133 Milano, Italy; mrose.petrizzo@unimi.it, isabella.premoli@unimi.it

[4] Department of Physical Sciences, Earth and Environment, University of Siena, Strada Laterina 8, 53100 Siena, SI, Italy; luca.foresi@unisi.it

Globigerina bollii Cita and Premoli Silva was described from the historical Langhian type section in Langhe, Piedmont (Italy). Due to its peculiar compact morphology, it was set apart from all the other globigerinids typical of the coeval Mediterranean fauna, and only reported for a short stratigraphic range. The taxon became a first order marker for the local biostratigraphy with its own *Globigerina bollii* Zone within the Langhian stage. However, the species was later synonymised with *Globigerina falconensis* Blow ending its use in biostratigraphic schemes, and no longer utilised by authors working in the Mediterranean area and Paratethys. We present here a reassessment of *Globigerina bollii*, of the type series of specimens, and a comparative study with Mediterranean individuals from Cretaccio Section (Italy) and extra-Mediterranean individuals from ODP Site 747 in the Kerguelen Plateau (Indian Ocean).
We compare *G. bollii* to other four-chambered morphospecies inhabiting the oceans during the Miocene, providing a detailed discussion of their morphological differences, which allow us to retain *G. bollii* as a valid taxon and to disclaim its synonymy with *Globigerina falconensis*. Our taxonomical observations also allow us to reassign *Globigerina bollii* to the genus *Globoturborotalita*, due to its strong affinities with other members of that genus such as *G. eolabiacrassata* Spezzaferri and Coxall, and *G. ouachitaensis* (Howe and Wallace). An additional comparison is also discussed with *Globigerina bollii lentiana* Rögl, a species endemic of the Paratethys. We infer that the presence of *G. bollii* in the Mediterranean Basin during such a confined stratigraphic range (Zone MMi4c-MMi4d), might be a palaeogeographical indicator of the intermittent opening of the eastern gateway with the Paratethys Sea, affecting the Mediterranean faunas during the Langhian, and their migration from oceanic realms into the Paratethys and Mediterranean.

Significance of millennial-scale coastal upwelling and Rio Loa variability for Atacama paleoclimate during MIS 2

Jessica FABRITIUS[1], Andrea JAESCHKE[1], Jassin PETERSEN[1], Volker WENNRICH[1], Patrick GRUNERT[1]

[1] Institute of Geology and Mineralogy, University of Cologne, Zülpicher Str. 49a, 50674 Cologne, Germany, jfabrit3@smail.uni-koeln.de

The Atacama Desert located in northern Chile is one of the driest places on Earth. The factors determining recent hyperarid climate conditions and their interplay and variability on interannual and decadal time scales are generally understood. Evidence for wetter (yet arid) conditions in the Atacama's past is mostly provided by ephemeral lacustrine and fluvial deposits. The main watercourse of the Atacama Desert is the Rio Loa sourced by rainfall in the Andean mountains. Information on changes in the terrestrial supply to the ocean is recorded in marine sediments off the Rio Loa mouth.
Sediment core SO-104-52KL has been collected on the upper continental slope (~340 m water depth, 21°S) off the Rio Loa during cruise 104, Leg 3 by RV Sonne in 1995. The preliminary chronology of the core based on ^{14}C dating constrains the top and base of the core to 16 and 42 ka, respectively, with a mean sedimentation rate of 30-40 cm kyr^{-1}. These very high average sedimentation rates allow reconstructions of the palaeoceanographic and paleoclimatic conditions during marine isotope stages (MIS) 3 and 2 on millennial to centennial time scales. The location of the core on the continental slope off the Rio Loa mouth allows for the parallel evaluation of the Humboldt Current System and Andean rainfall as moisture sources for the Atacama Desert.

Proxy data for upwelling properties are established from microfossil assemblages and lipid biomarkers. Preliminary results show that foraminifera are abundant and well-preserved in the upper 4 m of the core. While planktonic foraminifera are rare, benthic assemblages are rich. In total, 24 genera and 49 species of benthic foraminifera were distinguished. The three taxa *Bolivina, Bulimina*, and *Suggrunda*, which indicate hypoxic to dysoxic conditions at the seafloor, make up most of the individuals. The dominance of hypoxia tolerating taxa indicates strong upwelling conditions via the presence of a pronounced Oxygen Minimum Zone impinging on the upper continental slope. These data are put into context with relatively warm sea surface temperatures of average 21 °C as derived from alkenone data. Together with XRF data and grain-size analyses, both applied to characterize the terrestrial input by the Rio Loa, the expected proxy data will provide new insights into the dynamics of land-ocean coupling between the Atacama Desert and the eastern Pacific Ocean.
This study is part of the CRC 1211 "Earth-Evolution at the dry limit" project, funded by the German Research Foundation (DFG).

Integrated bio- and carbon-isotope stratigraphy as a tool to unravel the timing and causes of the end-Triassic extinction in Tethyan carbonate platforms

Francesca FALZONI[1,2], Andrea MONTANARO[2,3], Alessandro IANNACE[2], Mariano PARENTE[2]

[1] Present address: Istituto di Geologia Ambientale e Geoingegneria, Consiglio Nazionale delle Ricerche, via Mario Bianco 9, 20131 Milan, Italy; francesca.falzoni@cnr.it

[2] Dipartimento di Scienze della Terra, dell'Ambiente e delle Risorse, Università degli Studi di Napoli Federico II, via vicinale cupa Cintia 21, 80126 Naples, Italy; maparent@unina.it, aleianna@unina.it

[3] Present address: SOCOTEC Italia, Via Annibale Zucchini 69, 44122 Ferrara, Italy; montanaro.andr@gmail.com

We present a detailed bio- and carbon-isotope stratigraphy of three southern Tethyan carbonate platform sections, Mt. Messapion (Greece), Valle Agricola and Mt. Sparagio (southern Italy) across the Triassic/Jurassic boundary (TJB). In these sections, carbonate platform sedimentation persists across the TJB with no compelling evidence of a significant hiatus, thus potentially preserving the most detailed record of the end-Triassic extinction (ETE) in shallow tropical ecosystems. As such, these records differ from the classical sections of the northern Tethyan Realm (i.e., Northern Calcareous Alps, NCA, Austria and Lombardy Basin, northern Italy), where the extinction of carbonate platform assemblages coincides with a facies change and to the demise of the carbonate platform.
In the studied sections, the ETE is documented by the disappearance of megalodontid bivalves and involutinid benthic foraminifera, i.e. the typical aragonitic Dachstein-type biota, within a positive $\delta^{13}C_{carb}$ excursion, and few meters below a positive peak that, according to our study, correlates with the P1 peak documented in the Malanotte Fm of the Lombardy Basin. By contrast, the extinction of the Dachstein-type biota in the NCA and Lombardy Basin coincides with a negative carbon-isotope excursion (CIE) that is generally correlated to the initial CIE of the reference sections.
The bio- and carbon-isotope correlation performed in this study implies that extinctions in southern Tethys postdated the initial CIE, and thus are delayed compared to the NCA and Lombardy Basin. We contend that this level represents the true extinction of the Dachstein-type biota, while the disappearance in sections at the northern Tethyan margin represents a pseudoextinction coinciding with the demise of the carbonate platform. As a consequence, sea-level changes and the perturbation of the carbon cycle recorded by the Initial CIE are excluded as possible killing mechanisms of the Dachstein-type biota at a global scale.

A new Midian (late Middle Permian) foraminiferal assembalge from the Khao Khwang Platform of the western Indochina Block (Phetchabun Province, central Thailand)

Shirin FASSIHI[1], Daniel VACHARD[2,3], Anisong CHITNARIN[4], Masatoshi SONE[5], Petra HEINZ[1]

[1] University of Vienna, Department of Palaeontology, Althanstrasse 14, UZA II Geozentrum, 1090 Vienna, Austria; fassihis22@univie.ac.at; petra.heinz@univie.ac.at

[2] University of Lille-Sciences and Technologies, UMR CNRS 8198 Evo-Eco-Paléo, 59655 Villeneuve d'Ascq cedex, France, Daniel.Vachard@free.fr

[3] CIRCAS, 1 rue des Tilleuls, 59152 Gruson, France, Daniel.Vachard@free.fr

[4] School of Geotechnology, Institute of Engineering, Suranaree University of Technology, 111 University Avenue, Mueang District, Nakhon Ratchasima Province, 30000, Thailand, anisong@sut.ac.th

[5] Department of Geology, Faculty of Science, Universiti of Malaya, 50603 Kuala Lumpur, Malaysia, masatoshi.sone@gmail.com

A moderately diverse, Middle Permian foraminiferal assemblage was recovered from limestone beds of the Phu Phra That area in the Phetchabun Province, central Thailand. This stratigraphic unit (upper Saraburi Group) represents the uppermost strata of the Carboniferous–Permian Khao Kwang Platform over the western margin of the Indochina Block. It appears to be a low-diversity fusulinid assemblage dominated by the species, "*Pseudofusulina*" *cambodgiensis* (Gübler), "*Pseudofusulina*" *padangensis* (Lange), *Rauserella staffi* (Skinner & Wilde), *Codonofusiella elongata* (Kobayashi), ?*Dunbarula* sp., and ?*Boultonia* sp. The fusulinids are accompanied by the smaller foraminifers including *Robuloides lens* Reichel and *Partisania* sp., suggestive of a Midian age. *Robuloides* and *Partisania* are reported for the first time from central Thailand. The grey limestones are described as the bioclastic wackestone, packstone, and grainstone. The microfacies of the fossil-bearing limestone beds suggests a warm-water, shallow-marine environment, likely an inner ramp. This assemblage reveals correlation to the upper Sisophon Limestone (Midian) of Cambodia (through an epicontinental sea of the Indochina Block). Nevertheless, the present collection lacks the typical Midian fusulinid elements of the eastern Tethys, such as *Lepidolina* and *Verbeekina* that are common in other parts of the Indochina Block. This low diversity was probably due to a lithofacies condition. It should be noted that Permian limestones in central Thailand are often referred to broadly and collectively as the Tak Fa Formation, the unit originally designated for the Early Permian (Sakmarian–Artinskian) strata. It is therefore most appropriate to consider a separate Midian lithostratigraphic unit for including the present strata: a desired future revision in regional geology.

Dramatic fluctuations in Eastern tropical Atlantic oxygenation across the Plio-Pleistocene transition revealed by *Globorotaloides hexagonus*

Florent FAYOLLE[1], Anya J. CROCKER[2], Catherine V. DAVIS[3], Paul A. WILSON[4]

[1] School of Ocean & Earth Science, University of Southampton, National Oceanography Centre Southampton, SO14 3ZH, United Kingdom; ff1n21@soton.ac.uk

[2] School of Ocean & Earth Science, University of Southampton, National Oceanography Centre Southampton, SO14 3ZH, Inited Kindgom; ajc1g08@soton.ac.uk

[3] Department of Marine, Earth, and Environmental Sciences, North Carolina State University, 2800 Faucette Dr,Raleigh, NC 27607, United States of America; cdavis24@ncsu.edu

[4] School of Ocean & Earth Science, University of Southampton, National Oceanography Centre Southampton, SO14 3ZH, United Kingdom; paw2@soton.ac.uk

Oxygen (O_2) is essential for life, but O_2 concentrations are rapidly declining in much of the ocean in response to global warming and anthropogenically forced eutrophication, putting stress on marine ecosystems,

biogeochemical cycles, and human societies. Oxygen loss and shifts in its distribution in the ocean drive the development of oxygen minimum zones (OMZs) in coastal areas and parts of the open ocean with aged subsurface waters and/or high marine productivity. Results of biogeochemically-enabled numerical model simulations suggest that, compared to today, the North Atlantic Ocean supported greatly expanded OMZs under warm Pliocene conditions. However, limited data has hindered both a robust validation of this prediction for the Eastern Tropical Atlantic as well as our understanding of how OMZ intensity responds to global climate forcing. Here we use fossil tests of *Globorotaloides hexagonus*, a rare species of planktonic foraminifera thriving in OMZ waters today, to reconstruct past ocean deoxygenation and the position of the mid-depth OMZ relative to the thermocline. We present new astronomically-resolved records of *G. hexagonus* flux, size, chamber number and stable isotopic signatures spanning the late Pliocene and intensification of North Hemisphere Glaciation (iNHG), from the eastern tropical North Atlantic Ocean. Our records reveal both strong precessionally-paced fluctuations in OMZ intensity during the Pliocene and a major shift in subsurface oxygenation associated with iNHG.

Benthic foraminiferal faunas associated with cold-water coral environments in the North Atlantic and Mediterranean realms

Robin FENTIMEN[1], Gerhard SCHMIEDL[2], Andres RUEGGEBERG[3], Anneleen FOUBERT[3]

[1] Univ Angers, Nantes Université, Le Mans Université, CNRS, Laboratoire de Planétologie et Géosciences, LPG UMR 6112, 49000 Angers, France; robin.fentimen@univ-angers.fr

[2] Institute of Geology, University of Hamburg, Bundesstrasse 55, 20146, Hamburg, Germany; gerhard.schmiedl@univ-angers.fr

[3] Department of Geosciences, University of Fribourg, Chemin du Musée 6, 1700, Fribourg, Switzerland; anneleen.foubert@unifr.ch

The comparitive study of surface benthic foraminiferal assemblages from cold-water coral mounds and reefs in the North East Atlantic indicates that they share common traits. These assemblages are dominated by elevated epibenthic and distinct infaunal species, which are typical of current-swept environments together with high food availability. Similar to macrofaunal and megafaunal communities, benthic foraminiferal communities are well diversified on the mounds and reefs where corals thrive. Benthic foraminiferal communities associated to cold-water coral mounds in the Alboran Sea (western Mediterranean Sea) show a similar pattern, with a greater contribution of small epibenthic species on-mound and a concentration of infaunal phytodetritus-feeding species. However, fossil evidence from cold-water coral mounds situated in the Alboran Sea shows contrasting conclusions, with numerous large epibenthic foraminifera rather associated with bryozoan bioconstructions dated back to the last deglaciation, than with fossil Holocene cold-water coral build-ups. Overall, our results demonstrate that benthic foraminiferal assemblages provide key paleo-environmental information in the complex cold-water coral mound sedimentary archives.

Morozovella and *Acarinina* contrasting response to the EECO (Early Eocene Climatic Optimum; 53-49 Ma) in Tropical Pacific Site Shatsky Rise 1209-1210

Giulia FILIPPI[1]*, Ruby BARRETT[2], Silvia SIGISMONDI[1], Daniela SCHMIDT[2], Valeria LUCIANI[1].

[1] Department of Physics and Earth Sciences, University of Ferrara, Via Saragt 1, Ferrara, Italy; giulia.filippi@unife.it; silvia.sigismondi@unife.it; valeria.luciani@unife.it

[2]School of Earth Sciences, Cabot Institute, University of Bristol, Queens Road, Bristol, UK; D.Schmidt@bristol.ac.uk; ruby.barrett@bristol.ac.uk

The EECO represents the long-term highest global average temperature and CO_2 levels of the Cenozoic. This past warming event provides the opportunity to explore the interplay between extreme warmth and marine ecosystems, of which planktic foraminifera are a crucial component.
We present here relative abundance, test-size analysis, foraminiferal mass accumulation rate (FMAR) and $\delta^{13}C$ data from this group at the tropical Pacific sites 1209-1210. Our study records a marked decline in *Morozovella* abundance and a parallel increase in *Acarinina* abundance at the EECO onset, as previously documented from the Atlantic Ocean. Given the dominance and large size of *Morozovella* in the Late Paleocene-earliest Eocene tropical assemblages, we postulated that this change would have reduced foraminiferal production and the assemblage test-size. In contrast, we record a relatively stable FMAR and a slight increase in test-size within assemblages. In addition, our analysis shows that the acarininids increase in abundance is coupled with a test size decrease and lower $\delta^{13}C$ values with respect to *Morozovella,* which unexpectedly records a test-size increase. This suggests a deepening in the mixed layer of *Acarinina* with a reduction in symbiosis activity as a possible strategy to survive the warming conditions. By reducing body size, *acarininids* may have increased their chances of survival and reproductive success in the face of environmental challenges, contrary to *Morozovella.*
Despite individual taxa responses, the overall stability of the foraminiferal assemblage's carbonate production implies complex ecological interactions and compensatory mechanisms at play.

Tracing the Impact of Deglaciation: Insights from the Baltic Sea-Skagerrak on North Atlantic Climate Dynamics

Helena L. FILIPSSON[1,*], Nadine B.QUINTANA KRUPINSKI[1], Andreas MACKENSEN[2], Y.B. FRIBERG[1], Anne-Sophie FANGET[3], Jonas DONNENFIELD[4], Karen L. KNUDSEN[3], Jeroen GROENEVELD[4], Marit-Solveig SEIDENKRANTZ[3]

[1] Department of Geology, Lund University, Lund, Sweden

[2] Alfred Wegener Institute, Bremerhaven, Germany,

[3] Paleoceanography and Paleoclimate Group, Arctic Research Centre, and iClimate Centre, Department of Geoscience, Aarhus University, Aarhus, Denmark

[4] College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, Corvallis, OR, USA

[5] Institute of Oceanography, National Taiwan University, Taipei City, Taiwan (R.O.C.)

*Corresponding author: helena.filipsson@geol.lu.se

The connection between the climate of the Baltic Sea-Skagerrak region and the North Atlantic has been strongly evident during the recent glacial-interglacial cycles. However, the detailed examination of this relationship has been limited due to the absence of continuous, high-resolution paleoclimatic data from the Baltic area. The collection of sediment cores during the IODP Expedition 347 has started to address this gap. Positioned near the Fennoscandian Ice Sheet (FIS) during the most recent deglaciation, these cores offer an ultra-high resolution look at the environmental shifts occurring during this period.
We analyzed stable oxygen and carbon isotopes, trace elements, and assemblages of benthic foraminifera from IODP Site M0060. This site, situated near Anholt Island in the Kattegat, spans from roughly 17.6 to 13.3 thousand years ago (ka BP). Here, we delineated three separate phases within the deglaciation period. Initially, a pronounced rapid freshening event was observed around 17.5 ka, near the ice margin. This was followed by two smaller freshening episodes around 17 ka and 16.3 ka.
From 17.6 to 15.5 ka, the conditions were fjord-like, with marked vertical stratification, restricted bottom-water circulation, and formation of sea ice, leading to a salinity reduction by about 10 units. The period from 15.5 to 13.3 ka saw conditions becoming saltier, warmer, and better ventilated. The meltwater pulses recorded

are thought to result from the retraction of the FIS. Importantly, the freshening events near 17 and 16.3 ka mirrored significant $\delta^{18}O$ shifts seen in the North Atlantic and Nordic Seas, indicating their widespread impact.

Orbitally driven bottom-water dynamics during the Maastrichtian

Alexa FISCHER[1], Oliver FIREDRICH[1], André BAHR[1], Silke VOIGT[2], Sietske BATENBURG[3]

[1] Institute of Earth Sciences, Heidelberg University, Heidelberg, Germany; alexa.fischer@geow.uni-heidelberg.de

[2] Institute of Geosciences, Goethe University, Frankfurt, Germany

[3] Departament de Dinàmica de la Terra i del'Oceà, Universitat de Barcelona, Barcelona, Spain

The long-term global cooling trend during the latest Cretaceous was interrupted by an intense global warming episode at ~69 Ma known as the mid-Maastrichtian event (MME). The MME is characterised by two positive $\delta^{13}C$ excursions with an overall magnitude of 0.6‰ to 1.5‰, separated by a negative inflection. The $\delta^{13}C$ excursions are accompanied by the extinction of inoceramid bivalves, an abrupt increase in deep-sea and sea-surface temperatures as well as high terrestrial mean annual temperatures between 21 and 23 °C at a paleolatitude of ~35° N. Changes in oceanic circulation, particularly a change in thermohaline circulation patterns, have been suggested to be one of the main drivers of the MME. In this study, we aim to test this hypothesis by the generation of new high-resolution $\delta^{13}C$ and $\delta^{18}O$ analyses, Mg/Ca-derived bottom-water temperatures and $CaCO_3$ wt% records from IODP Site U1403 (J-Anomaly Ridge, North Atlantic). Rhythmic variations in these geochemical records reflect an imprint of Earth´s astronomical parameters. Our results point towards a combination of Large Igneous Province (LIP) volcanism and simultaneous changes in deep-ocean circulation as triggers for the MME. For the North Atlantic, we observe an interplay between warmer and colder bottom-waters in combination with $CaCO_3$ dissolution events. This hints toward a switch in bottom-water source regions between a high- and a low-latitude source region, likely controlled by orbital forcing. With the termination of the MME, bottom-water temperatures started to decrease, and the $\delta^{13}C$ record indicates an abrupt reorganization of the ocean circulation system towards a solely high-latitude North Atlantic source region for bottom-water.

Unravelling the intertidal sedimentary record of the inner Ría of Vigo (NW Spain): A harsh environment for foraminiferal preservation

Jon GARDOKI[1], Alejandro CEARRETA[1], Ane GARCÍA-ARTOLA[1], José GÓMEZ-AROZAMENA[2], Víctor VILLASANTE-MARCOS[3]

[1] Departamento de Geología, Universidad del País Vasco UPV/EHU, Barrio Sarriena s/n, Leioa, Spain; jon.gardoqui@ehu.eus, alejandro.cearreta@ehu.eus, ane.garcia@ehu.eus

[2] Departamento de Ciencias Médicas y Quirúrgicas, Universidad de Cantabria, Avenida Herrera Oria s/n, Santander, Spain; jose.gomez@unican.es

[3] Laboratorio de Magnetismo de Materiales y Magnetismo Ambiental, Instituto Geográfico Nacional, C/Alfonso XII 3, Madrid, Spain; vvillasante@mitma.es

The Ría of Vigo is an elongated, funnel-shaped and highly productive coastal embayment situated at the NW Atlantic Iberian margin. In this area, prior studies have successfully empoyed benthic foraminifera for the reconstruction of both current and past environmental changes in subtidal sediments. Nevertheless, the modern and fossil benthic foraminifera in the extensive intertidal inner zone, known as the San Simón inlet, remain

unstudied. The primary goals of this research were to determine the ecological and taphonomic controls affecting the modern benthic foraminiferal assemblages and to unravel the recent environmental evolution of the innermost ría. Seven surface samples (80 cm^3) were collected from different intertidal areas of the San Simón inlet and stained with Rose Bengal to distinguish living individuals from dead tests. Additionally, a 50-cm-long sediment core was drilled in the innermost sector and dated with natural (^{210}Pb) and artificial (^{137}Cs, $^{239+240}Pu$) radionuclides. Various geochemical proxies were also analysed (TOC, TN, C_{org}/TN, TS, $\delta^{13}C$, $\delta^{15}N$) for the characterization of the organic matter and to trace potential changes in its source.
The results evidenced increasing abundances of brackish species (e.g., *Haynesina germanica*) toward the continental end-member. However, the modern assemblages were primarily influenced by strong taphonomic processes. Among these phenomena, potentially correlated with TOC concentrations, the most relevant were the chemical dissolution of hyaline taxa and disaggregation-breakage of agglutinated tests. The environmental evolution of the San Simón inlet in its innermost sector revealed a fundamental change, transitioning from an assemblage typical of inner ría sandy intertidal flats (*H. germanica, Eggerelloides scabrum*, *Ammonia* morphogroup *tepida*) to an environment where only the exclusive and scarce presence of agglutinated taxa (e.g., *E. scabrum*, *Trochammina inflata*) could be detected, accompanied by a primary increase in TOC, TN and TS. This change was potentially driven by the increase in the organic matter content, likely coming from a combination of natural and anthropogenic sources, ultimately affecting the preservation of foraminiferal tests.
These findings underscore the necessity of applying a multidisciplinary approach when dealing with (palaeo)environmental reconstructions in coastal settings.

Recent environmental evolution of the historically eutrophic Mondego estuary (N Portugal): Preliminary insights into its sedimentary infill

Jon GARDOKI[1], Alejandro CEARRETA[1], Ane GARCÍA-ARTOLA[1], María Jesús IRABIEN[1], José GÓMEZ-AROZAMENA[2], Víctor VILLASANTE-MARCOS[3], Filipa BESSA[4]

[1] Departamento de Geología, Universidad del País Vasco UPV/EHU, Barrio Sarriena s/n, Leioa, Spain; jon.gardoqui@ehu.eus, alejandro.cearreta@ehu.eus, ane.garcia@ehu.eus, mariajesus.irabien@ehu.eus

[2] Departamento de Ciencias Médicas y Quirúrgicas, Universidad de Cantabria, Avenida Herrera Oria s/n, Santander, Spain; jose.gomez@unican.es

[3] Laboratorio de Magnetismo de Materiales y Magnetismo Ambiental, Instituto Geográfico Nacional, C/Alfonso XII 3, Madrid, Spain; vvillasante@mitma.es

[4] Centre for Functional Ecology - Science for People & the Planet (CFE), Associate Laboratory TERRA, Department of Life Sciences, University of Coimbra, Portugal; afbessa@uc.pt

In the early 1990s, coastal modifications and abundant agricultural effluents led to rapid eutrophication and low-oxygen conditions in the southern arm of the Mondego estuary (N Portugal). Consequently, the Mondego became an excellent example of the detrimental effects of high nitrogen and phosphorus loadings in coastal systems in southern Europe. However, in 1998 mitigation and recovery measures were introduced, significantly improving its environmental quality status. Our previous results revealed that modern benthic foraminifera did not show any significant environmental disturbances, currently presenting abundant and diverse assemblages. Therefore, the primary goal of this study was to evaluate the environmental quality evolution and to reconstruct the natural and anthropogenic environmental changes recorded in the Mondego estuary during the last decades. For these purposes, an intertidal sediment core (50 cm long) was drilled in the upper sector of the Mondego southern arm and analysed from a multidisciplinary approach (benthic foraminifera, grain-size, TOC, TN, C_{org}/TN, TS, $\delta^{13}C$, $\delta^{15}N$, trace metals, magnetic susceptibility, ^{210}Pb, ^{137}Cs, $^{239+240}Pu$).

The basal section of this sedimentary record presents an assemblage typical of brackish intertidal flats dominated by *Haynesina germanica, Ammonia* morphogroup *tepida* and *Elphidium oceanense*, with low TOC, TN and $\delta^{15}N$. However, the upper section reveals a drastic reduction of *E. oceanense* and lower foraminiferal densities, whereas agglutinated low-salinity taxa increase (i.e., *Trochammina inflata* and *Entzia macrescens*). This shift, occurring in the late 1980s-early 1990s, is also accompanied by higher values in TOC, TN, $\delta^{15}N$ and trace metals. These changes indicate an overall decrease in tidal influence together with a higher continental influence and nutrient supply in the upper sector. These phenomena may be attributed to upstream physical modifications and the impact from agricultural effluents during the late 20th century.
Ongoing multidisciplinary analyses in additional cores will improve the understanding of the palaeoenvironmental evolution of the Mondego estuary. This will establish a knowledge framework for shaping future responsible coastal management policies and strategies.

A species-specific approach to benthic foraminifera pore patterns as paleoxygenation proxy in the Southeast Pacific

Sebastián GARRIDO[1,2], Frans JORISSEN[3], Julien RICHIRT[4], Dharma REYES-MACAYA[1,2,5], Iván HERNÁNDEZ-ALMEIDA[6], Marie P.A. FOUET[7], Dierk HEBBELN[5], Jorge CARDICH[8,9], Alexis CASTILLO BRUNA[2,9,10], Eugenia M. GAYO[2,11], Babette HOOGAKKER[1]

[1] Lyell Centre, Heriot-Watt University, Research Avenue, Currie, EH14 4BA, Edinburgh, UK; sag15@hw.ac.uk, b.hoogakker@hw.ac.uk, d.reyes_macaya@hw.ac.uk

[2] ANID - Millennium Science Initiative Program Nucleo Milenio UPWELL, Raúl Bitrán 1305, La Serena, Chile; sag15@hw.ac.uk, d.reyes_macaya@hw.ac.uk, kenagayoh@gmail.com, acastillo@ucm.cl

[3] Université d'Angers, Nantes Université, Le Mans Université, CNRS, Laboratoire de Planétologie et Géosciences, LPG UMR 6112, Angers, 49000, France; frans.jorissen@univ-angers.fr

[4] Institute for Extra-cutting-edge Science and Technology Avant-garde Research (X-star), Japan Agency for Marine-Earth Science and Technology (JAMSTEC), JAMSTEC, 2-15, Natsushima-cho, Yokosuka-city, Kanagawa, 237-0061, Yokosuka, Japan; richirt.julien@gmail.com

[5] MARUM - Center for Marine Environmental Sciences, University of Bremen, Leobener Str. 8, 28359, Bremen, Germany; d.reyes_macaya@hw.ac.uk, dhebbeln@marum.de

[6] PAGES - University of Bern, Hochschulstrasse 4, 3012, Bern, Switzerland; ivan.hernandez@unibe.ch

[7] UMR EPOC, Universit´e de Bordeaux, CNRS, UMR 5805, Station Marine d'Arcachon, 2 rue du Professeur Jolyet 33120, Arcachon, France. marie.fouet@u-bordeaux.fr

[8] Universidad Peruana Cayetano Heredia (UPCH), Av. Honorio Delgado 430 SMP, 15102, Lima, Perú; jorge.cardich.s@upch.pe

[9] J'EAI-CHARISMA (UMNG-Colombia; UCM-Chile; UCH-Chile; UPCH-Peru; IGM-Peru; IRD-France); jorge.cardich.s@upch.pe, acastillo@ucm.cl

[10] CIEAM - Centro de Investigación y Estudios Avanzados del Maule, Universidad Católica del Maule, Campus San Miguel, Avenida San Miguel 3605, Talca, Chile; acastillo@ucm.cl

[11] Departamento de Geografía, Universidad de Chile, Portugal 84, Santiago, Chile; kenagayoh@gmail.com

Benthic foraminifera (BF) can adjust their pore patterns (porosity, pore density, pore size) for gas exchange (e.g, O_2, CO_2) with the surrounding water, reflecting environmental factors such as bottom water dissolved oxygen (BWDO). Specifically, some BF increase their test porosity under lower BWDO concentration, becoming a potential paleoxygenation proxy. To validate this proxy in the Southeast Pacific (SEP), the pore patterns of six BF species (*Cibicidoides wuellerstorfi*, *C. lobatulus*, *C. ungerianus*, *Planulina limbata*, *P. ariminensis*, and *P. ornata*) were correlated with BWDO content. The BWDO levels were estimated through spatial analysis (DIVA) from empirical measurements over the last 20 years. The specimens were collected from surface sediment samples along the SEP (24–3,252 m water depth; 12°–44°S). Their pore patterns were

measured on the umbilical and spiral sides, and on the penultimate and antepenultimate chambers (PAP) on both sides. Our study revealed species-specific responses to BWDO, with most species increasing their porosity under lower BWDO content. However, while *Cibicidoides* species primarily increased umbilical porosity, *Planulina* species increased it on the spiral side. Hence, combining species for BWDO reconstruction is not advised in the SEP. Instead, focusing on individual species showed stronger correlations between BWDO and pore patterns. Particularly, umbilical PAP porosity of *C. wuellerstorfi* inversely correlated with BWDO ($R^2 = 0.64$). This correlation improved considering only *C. wuellerstorfi* forma *plana*, whose umbilical porosity ($R^2 = 0.77$) and pore density ($R^2 = 0.67$), as well as umbilical PAP porosity ($R^2 = 0.73$), inversely correlated with BWDO. Umbilical PAP porosity of *C. ungerianus* ($R^2 = 0.78$), and spiral porosity of *P. ornata* ($R^2 = 0.72$) also showed a strong inverse correlation with BWDO. These findings support BF pore patterns as reliable indicators for reconstructing past BWDO in the SEP, with an error range of ±5–20 µmol/kg.

Who is who in the foraminiferal world: taxonomic revision of selected *Cibicidoides* and *Planulina* species in recent Southeast Pacific marine sediments

Sebastián GARRIDO[1,2], Magali SCHWEIZER[3], Dharma REYES-MACAYA[1,2,4], María Yolanda NÚÑEZ[5], Alexis CASTILLO BRUNA[2,6,7], Babette HOOGAKKER[1]

[1] Lyell Centre, Heriot-Watt University, Research Avenue, Currie, Edinburgh, EH14 4BA, UK; sag15@hw.ac.uk, D.Reyes_Macaya@hw.ac.uk, B.Hoogakker@hw.ac.uk

[2] ANID, Millennium Science Initiative Program Nucleo Milenio UPWELL, La Serena, Chile; sag15@hw.ac.uk, D.Reyes_Macaya@hw.ac.uk

[3] Université d'Angers, Nantes Université, Le Mans Université, CNRS, Laboratoire de Planétologie et Géosciences, LPG UMR 6112, Angers, 49000, France; magali.schweizer@univ-angers.fr

[4] MARUM, Center for Marine Environmental Sciences, University of Bremen, Bremen, 28359, Germany; D.Reyes_Macaya@hw.ac.uk

[5] Escuela de Diseño, Pontificia Universidad Católica de Chile, Santiago, 7520246, Chile; mynunez.me@gmail.com

[6] J'EAI-CHARISMA (UMNG-Colombia; UCM-Chile; UCH-Chile; UPCH-Peru; IGM-Peru; IRD-France); acastillo@ucm.cl

[7] CIEAM, Centro de Investigación y Estudios Avanzados del Maule, Universidad Católica del Maule, Talca, 3480137, Chile; acastillo@ucm.cl

Cibicidoides and *Planulina* genera are vital in paleoceanography for reconstructing paleoceanographic conditions via stable isotope (i.e., $\delta^{18}O$ and $\delta^{13}C$) and morphological (i.e., pore patterns) studies. Their species often have an epifaunal microhabitat and are good indicators of bottom water conditions, making accurate taxonomic identification crucial. To develop a consistent classification framework for recent species of *Cibicidoides* and *Planulina* in the Southeast Pacific (SEP), we used stereomicroscopy, SEM imaging, and manual drawing. These were performed on specimens from surface sediment samples off Peru and Chile (12°S–44°S). Variations were observed in *Cibicidoides wuellerstorfi*, specifically in the suture curvature, chamber shape, and umbilical side convexity, leading to the identification of two distinct morphotypes: *C. wuellerstorfi* forma *convexa* and *C. wuellerstorfi* forma *plana*. *Cibicidoides lobatulus* exhibited test shape variability, mainly due to substrate attachment adaptations. *Cibicidoides ungerianus,* reported for the first time in the SEP, is characterized by its keeled, mostly biconvex test, inflated chambers, coarse pores, transparent test, and glassy sutures. Although *Planulina ariminensis* and *P. ornata* share resemblances with *C. wuellerstorfi*, they are differentiated by their test structure; *P. ariminensis* has a large planispiral test with almost parallel umbilical and spiral sides, while *P. ornata* is noted for its elevated umbilical sutures. *Planulina limbata* is distinct among the species discussed, with its prominent sutures, involute umbilical side, and elongated, narrow umbilical chambers. Therefore, despite similarities among *Cibicidoides* and *Planulina* species, they exhibit notable morphological differences. The classification criteria established through this

research will help and ease future studies in the SEP, especially for taxonomy-based calibration of proxies for paleoceanographic reconstructions.

Metabolic rates during chamber formation and dormancy in cultured planktonic foraminifera

Daniel GASKELL[1]

[1] Earth & Planetary Sciences Department, University of California Santa Cruz, Santa Cruz, CA, United States of America; dgaskell@ucsc.edu

Prior work on foraminiferal metabolism has focused on measuring healthy but starved individuals in an attempt to capture the "resting" or "basal" metabolic rate. However, it remains unknown whether these rates are an accurate reflection of the foraminifera's entire life-cycle or whether discrete events such as chamber formation or gametogenesis require additional energy, potentially biasing ecological and vital-effects assessments. To address this, living planktonic foraminifera (*Globigerina bulloides, Orbulina universa, Globigerinella siphonifera, Globigerinoides ruber*, and *Neogloboquadrina dutertrei*) from the Southern California Bight were cultured and measured for oxygen consumption in individual 1.5 mL photorespirometry chambers. Observed basal respiration rates were consistent with prior probe-based work. Respiration was highest closest to feeding, suggesting a transition between "active" and "resting" metabolic states. Respiration also increased significantly during gametogenesis. Interestingly, no significant increase in respiration rate was observed during chamber formation, suggesting modifications to the conventional view of the energetics of calcification and confirming that external acidification during chamber formation is driven primarily by proton pumping rather than by elevated production of metabolic CO_2. Evidence of multi-week dormancy and revival in *G. bulloides* is presented via culture observations and metabolic timeseries.

XXth century anthropogenic impact as recorded by benthic foraminifera off the Po Delta in the Northern Adriatic Sea

Rocco GENNARI[1], Leonardo CORINO[1], Pierluigi MARTINELLI[1], Francesco RIMINUCCI[2], Patrizia MAIORANO[3], Lucilla CAPOTONDI[2]

[1] Dipartimento di Scienze della Terra, Università di Torino, Via Valperga Caluso 35, 10125, Italy; rocco.gennari@unito.it, leonardo.corino@edu.unito.it, pierluigi.martinelli@unito.it

[2] CNR, Marine Science Institute (ISMAR), Via Piero Gobetti, 101, 40129 Bologna, Italy; francesco.riminucci@bo.ismar.cnr.it, lucilla.capotondi@cnr.it

[3] Dipartimento di Scienze della Terra e Geoambientali, Università degli Studi di Bari, Via E. Orabona 4, 70125. Italy; patrizia.maiorano@uniba.it

The Italian economic boom occurred after 1945 and was sustained by increasing population, industrialization and agricultural exploitation especially in the Po plain. As a consequence, the Po River was increasingly loaded with fertilizer and pesticide byproducts, industrial and urban wastewaters, which were transferred to the Adriatic Sea via runoff. At the same time, dam construction, soil protection and massive riverbed excavation during the XXth century determined a decrease of sediment supply to the prodelta area. These anthropogenic impacts were superimposed to increasing flood intensity compared to the XIXth century. To monitor the anthropogenic and environmental impact on the prodelta area, we analysed the benthic foraminiferal content of the EL-C01 marine sediment core and their relationship with trace metal concentrations. The 264 cm-thick

core was collected 7 km south of the Po di Goro outlet, in the station S1 (part of the LTER-Italy research site "Delta del Po and Costa Romagnola") at a 21.5 m water depth. We found that benthic foraminifer assemblages typical of river influenced seafloor prevail during most of the pre-1945 period. However, during the first half of the XXth century they are progressively replaced by infaunal taxa. Starting from ca. 1945 the assemblage became characterized by the dominance of taxa related to low oxygen and eutrophic environments. This pattern is strongly tied to the anthropogenic impact represented by trend of Pb and Zn. The decrease of Zn and Pb contents from the second half of the 1980s is probably the effect of the Italian Law 319/76 and anti-pollution environmental policies concerning industrial and urban emitters and is reflected by increasing biodiversity and decreasing dominance among benthic foraminifera.

Living benthic foraminifera from the seasonally hypoxic to anoxic Bedford Basin

Nicolaas GLOCK[1], Jonas Kamo ANSELM[1], Jana Marisa FISCHER[1], Subhadeep RAKSHIT[2], Christopher ALGAR[2], Maria ARMSTRONG[2], Markus KIENAST[2], Gerhard SCHMIEDL[1]

[1] Institute for Geology, Universität Hamburg, Bundesstrasse 55, 20146 Hamburg, Germany; nicolaas.glock@uni-hamburg.de, jonas.anselm@studium.uni-hamburg.de, jana.fischer-1@studium.uni-hamburg.de, gerhard.schmiedl@uni-hamburg.de

[2] Dept. of Oceanography, Dalhousie University, 1355 Oxford St, Halifax, Nova Scotia, B3H 4R2, Canada; Subhadeep.Rakshit@dal.ca, chris.algar@dal.ca, Maria.Armstrong@dal.ca, Markus.Kienast@dal.ca

The Bedford Basin is a seasonally hypoxic North-West-Atlantic fjord basin, which is usually ventilated in early spring due to winter convective mixing. Owing to the unprecedented warm winter in 2020/2021, a complete ventilation did not occur in spring 2021 resulting in anoxic conditions during winter 2021/2022. Here we summarize a timeline study on living benthic foraminifera assemblages from the deepest part of the basin including samples from November 2020 till July 2022. The low diversity assemblages are dominated by *Stainforthia fusiformis* and *Elphidium bartletti*, with minor abundance of *Eggerelloides advena* and *Spiroplectammina biformis*. Living abundances of *E. bartletti* showed only minor fluctuations but abundance of *S. fusiformis* severely decreased in early spring 2022 directly after the extended anoxia beginning late 2021. Also, before the anoxia, samples were dominated by small *S. fusiformis*, especially in the top cm of the sediments, but larger *S. fusiformis* dominated the assemblages after the anoxia, indicating that either only the adult specimens were able to survive or that they were not able to reproduce during the anoxia.
Analysis of intracellular nutrient storage reveals that all analyzed species are able to accumulate phosphate but only *S. fusiformis* can store nitrate for denitrification. Although they can denitrify our data suggests that *S. fusiformis* specimens adapt their pore density to oxygen instead of nitrate availability, most likely making them only facultative denitrifiers. This is different to some denitrifying bolivinids that are known to adapt their pore density to nitrate availability. Preliminary results of this study also indicate that *S. fusiformis* possibly adapts the pore density to the bottom water conditions during the time of chamber formation. Subsequently, this species might still be able to adapt the size of its pores "dynamically" after chamber formation, depending on the microenvironment it experiences within the pore water.

A quantitative reconstruction of deglacial bottom-water nitrate in marginal Pacific seas using the pore density of denitrifying benthic foraminifera

Anjaly GOVINDANKUTTY MENON[1*], Aaron BIELER[2], Hanna FIRRINCIELI[1], Niko LAHAJNAR[1, 5], Rachel ALCORN[3], Catherine V. DAVIS[3], Alfredo MARTINEZ-GARCIA[2], RALF SCHIEBEL[2], Dirk NÜRNBERG[4], Gerhard SCHMIEDL[1,5], Nicolaas GLOCK[1]

[1] Department of Earth System Sciences, Institute for Geology, Universität Hamburg, Bundesstrasse 55, D-20146 Hamburg, Germany

[2] Max Planck Institute for Chemistry, Climate Geochemistry Department, Mainz, Germany

[3] Department of Marine, Earth, and Atmospheric Sciences, North Carolina State University, 2800 Faucette Dr, Raleigh, NC, 27695, United States

[4] GEOMAR Helmholtz Centre for Ocean Research Kiel, Wischhofstr. 1-3, Geb. 8c, Raum 106, D-24148 Kiel, Germany

[5] Center for Earth System Research and Sustainability, Institute for Geology, Universität Hamburg, Bundesstrasse 55, D-20146 Hamburg, Germany

*Corresponding author: anjaly.govindankutty.menon@uni-hamburg.de

Nitrate (NO_3^-) is an important macronutrient that is limiting in some marine environments. Modelling studies have shown that NO_3^- concentrations are elevated during glacial periods due to reduced water column denitrification as compared to interglacials. The aim of our study is to provide a widespread, quantitative reconstruction of bottom-water NO_3^- concentrations ($[NO_3^-]_{BW}$) in the marginal Pacific seas covering the last deglaciation. Downcore samples taken from the Eastern Tropical South Pacific in the Gulf of Guayaquil (Peru, M77/2-059-1), and the Eastern Tropical North Pacific from the Mexican Margin (MAZ-1E-04), the Sea of Okhotsk (MDO1-2415), and the Gulf of California (DSDP-480) were used. The pore density of the denitrifying benthic foraminifera *Bolivina spissa* and *Bolivina subadvena* has been used as a proxy for deglacial $[NO_3^-]_{BW}$ concentrations. These shallow infaunal foraminifera species are abundant in oxygen-depleted environments throughout the Pacific. They can denitrify and take up NO_3^- as an electron acceptor through the pores, making their pore density a proxy for NO_3^- concentrations. We found that the $[NO_3^-]_{BW}$ in the Gulf of Guayaquil and the Gulf of California were higher during the glacial period than the Holocene. In all four cores, we also compared past and present $[NO_3^-]_{BW}$. Our data show that both the Gulf of Guayaquil and the Gulf of California had higher $[NO_3^-]_{BW}$ in the past than today indicating that today there is a stronger oxygen-deficient zone with higher denitrification. In contrast, the Mexican Margin and the Sea of Okhotsk had lower $[NO_3^-]_{BW}$ in the past than today suggesting increased oxygenation today with less denitrification.

A preliminary study on the nummulitic accumulation from middle Eocene Prang Limestone, Meghalaya, India

T. Ngamlengin HAOKIP[1], Urbashi SARKAR[1]

[1] Assam University, Silchar, India; tngamlengin.haokip@gmail.com, sarkarurbashi@gmail.com

The Meghalayan shelf marks the eastern margin of the Neo-Tethys, and the carbonate rock succession deposited during the middle Eocene Prang Limestone Member has been studied for the nummulitic accumulations. The carbonate has been investigated from the Lumshnong village area of East Jaintia Hills district, Meghalaya, India. The previous works on Prang Limestone Member have emphasized the studies of biostratigraphy and palaeoenvironmental evolution. However, the present study focuses primarily on the rich nummulites present here and their possible origin. It is done on the basis of microfacies study and biofabric analysis of larger benthic foraminifera. The distribution of the A: B ratio has been investigated from the representative samples using thin slides under a petrographic microscope. The microfacies types were studied to determine the depositional environment and nine microfacies types (MFTs) have been identified viz., nummulitid alveolinid grainstone-rudstone (P-MFT1), orthophragminid nummulitid grainstone (P-MFT2), nummulitid grainstone (P-MFT3), nummulithoclastic packstone (P-MFT4), assilinid grainstone (P-MFT5), nummulitid algal grainstone-rudstone (P-MFT6), algal nummulitid grainstone (P-MFT7), orthophragminids algal grainstone (P-MFT8), and orthophragminids nummulitid grainstone (P-MFT9). Again, from the assemblages, the nummulites test classification after Jorry et. al (2003) shows the predominance of robust types over the flat types in both small A- and large B- forms. Subsequently, the A: B ratio has been studied for

the aspects of comparisons with other nummulitic accumulations, for instance, the A: B ratio for a normal nummulitic bank is 10:1, however, most of the Prang Limestone samples have shown the A: B ratio as <7:1. This ratio determines the abundance of B-form in the accumulation and selective removal of A-form. Again, the biofabrics defining the nummulites tests assemblage commonly illustrate no imbrication, chaotic imbrication, and edgewise contact imbrication. Thus, inferring a random stacking, and connected nummulites tests lacking directional orientation which corresponds to be the result of para-autochthonous, and autochthonous residual assemblages. Consequently, sensu Papazzoni and Seddighi (2018), the nummulitic accumulation in Prang Limestone can be categorized as a non-nummulitic bank deposited in the shoal setting (P-MFT3), and the foraminiferal and algal accumulations in other samples can be attributed to deposition mostly in the reef (P-MFT1, P-MFT2, P-MFT5, P-MFT6, P-MFT7, P-MFT8, P-MFT9) and the slope (P-MFT4) depositional environment.

Benthic foraminifera from early Glacial to late Holocene coastal upwelling sediments: a case study from the eastern subtropical Pacific, off Peru

Sikandar HAYAT*[1], Meryem MOJTAHID[1], Mary ELLIOT[1], Jorge CARDICH[2], Matthieu CARRÉ[3]

[1] University of Angers, Nantes Université, Le Mans Université, CNRS, Laboratoirede Planétologie et Géosciences, LPG UMR 6112, 49000 Angers, France Angers, France

[2] CIDIS-Facultad de Ciencias e Ingeniería, UniversidadPeruana Cayetano Heredia, Lima, Peru

[3] IPSL/Laboratoired'Océanographie et du Climat: Expérimentations et Approches Numériques (CNRS-IRD-MNHN-SorbonneUniversités), Paris, France

*corresponding author: sikandar.hayat@univ-angers.fr

The Peruvian upwelling system (PUS) is one of the strongest upwelling systems in the world ocean and is embedded into the permanent, intense, and shallow oxygen minimum zone (OMZ) of the eastern subtropical South Pacific. The features of the PUS are impacted at interannual time scales by the El Niño-Southern Oscillation (ENSO). Paleoceanographic reconstructions of bottom-water oxygenation and surface productivity are instrumental to i) place recent climate-related changes of the PUS in a longer-term context, beyond the ~200 years of direct measurements, and ii) understand its dynamics linked or not to ENSO variability during changing climatic conditions. The first step toward achieving these goals is to understand the changes in benthic foraminiferal communities during the last 25 kyrs.

The benthic foraminifera assemblage composition (>125 µm) was documented for two sediment cores, G-10 (312 m depth) and G-14 (400 m depth), collectively covering the last 25 kyrs, extracted from the Peruvian margin, offshore Pisco (14°S). A total of 30 species were identified, exhibiting varying presence across the cores (0-16 species). Few or no foraminifera were observed during the intervals of less intense upwelling, low organic carbon in bottom sediments, and weak OMZ, i.e., Early Glacial, Last Glacial Maximum, Bølling-Allerød, and some intervals in the Holocene. *Bolivina seminuda* var. *humilis* was the most abundant species throughout the cores, with relative abundance reaching up to 80%, while species of *Fursenkoina* (*F. complanata*, *F. fusiformis*, and *F. texturata*) dominated the Heinrich Stadial 1 (HS1). Additionally, *Suggrunda porosa*, *Bolivina costata*, *B. plicata, Epistominella obesa*, and *Cassidulina pulchella* were among the major species. Most of the samples exhibit a low species diversity but high population densities, a characteristic trait of OMZ foraminiferal communities. No significant variations were observed in the Shannon diversity index. Nevertheless, discernible patterns emerged for some species; notably, the highest population density and relative abundance of *Fursenkoina* species were observed during HS1, coinciding with pronounced reducing conditions at the sediment-water interface and a slight increase in organic matter flux. Moreover, HS1 marks the peak of denitrification in the water column, possibly suggesting a potential role of Fursenkoina species in this process, given their known denitrifying ability. *Bolivina plicata* was present only during the Holocene in intervals characterized by elevated organic matter flux, while *B. seminuda var. humilis* does not exhibit a clear

trend. The high biogenic silica content (diatoms) in foraminifera-rich intervals probably indicates its role in foraminifera preservation.

Planktic foraminifers as proxies for upper ocean biogeochemical cycling: Observations from the *S/Y Eugen Seibold* expeditions in the eastern North Atlantic

Lena HEINS[1], Aaron L. BIELER[1,2], Hedy M. AARDEMA[1,2], Hans SLAGTER[1], Isabella HRABE DE ANGELIS[4], Maria Ll. CALLEJA[1,3], Antonis DRAGONEAS[1], David WALTER[1], Hubert VONHOF[1], Alfredo MARTINEZ-GARCÍA[1], Gerald H. HAUG[1,2], Ralf SCHIEBEL[1]

[1] Department of Climate Geochemistry, Max Planck Institute for Chemistry, Hahn-Meitner-Weg 1, Mainz, Germany; lena.heins@mpic.de, aaron.bieler@mpic.de, hedy.aardema@mpic.de, hans.slagter@mpic.de, i.hrabe@mpic.de, a.dragoneas@mpic.de, david.walter@mpic.de, hubert.vonhof@mpic.de, a.martinez-garcia@mpic.de, gerald.haug@mpic.de, ralf.schiebel@mpic.de

[2] Department of Earth Sciences, ETH Zürich, Sonneggstrasse 5, Switzerland

[3] Marine Ecology and Systematics (MarES) group, Biology Department, University of the Balearic Islands, Cra. de Valldemossa km 7.5, Palma de Mallorca, Spain; m.calleja@uib.eu

[4] Department of Multiphase Chemistry, Max Plank Institute for Chemistry, Hahn-Meitner-Weg 1, Mainz, Germany

Planktic foraminifers (PF) inhabit mostly the upper 200 m of the water column and are widely used in palaeoceanographic studies to reconstruct the hydrological structure and properties of the surface ocean. The stable isotopes of oxygen and carbon of the PF tests have been measured since more than half a century but a profound understanding of the underlying principles, in particular of carbon isotope fractionation, is still missing.
We characterize modern PF assemblages across a latitudinal transect in the eastern North Atlantic Ocean and combine population dynamics and geochemical ($\delta^{13}C$ and $\delta^{18}O$) results with in situ obtained environmental samples and data, such as the $\delta^{13}C$ signature of the dissolved inorganic carbon (DIC) of ambient seawater. We find that the isotopic composition of the PF test calcite reflects species-specific ecology and habitat demands rather than generalized water column properties. Further evaluation of the samples and ecological data concomitantly collected onboard S/Y *Eugen Seibold* in 2019-2022 is required to disentangle environmental and vital effects, facilitate new applications in the use of single-specimen analysis of stable isotopes, and provide new insights into the response of modern PF to climate change.

North Pacific Deep Water formation during the mid-Pliocene?

Babette HOOGAKKER[1], Dharma Reyes MACAYA[2], Katrina NILSSON-KERR[3], Helge WINKELBAUER[4], Melanie LENG[5]

[1] The Lyell Centre, Heriot-Watt University, Research Avenue South, Edinburgh, United Kingdom; b.hoogakker@hw.ac.uk

[2] The Lyell Centre, Heriot-Watt University, Research Avenue South, Edinburgh, United Kingdom; d.reyes_macaya@hw.ac.uk

[3] Department of Earth Sciences, University of Bergen, and Bjerknes Centre for Climate Research, Bergen, Norway; katrina.nilsson-kerr@uib.no

[4] The Lyell Centre, Heriot-Watt University, Research Avenue South, Edinburgh, United Kingdom; helge.winkelbauer@gmail.com

[5] The British Geological Survey, Nicker Hill, Keyworth, United Kingdom; mjl@bgs.ac.uk

There is no perfect past analogue for the warming our planet is currently undergoing, as our future warming is unprecedented in the context of the geological past. The Mid-Pliocene Warm Period (mPWP) represents a close analogue, with similar global temperatures as predicted for the year 2100 (+3-4ºC), while Earth's continental configurations, land elevations and ocean bathymetry were all very similar to today. Several lines of work indicate similarities between ocean circulation of the future and the mPWP, with a weaker thermohaline circulation, related to reduced ice sheets and sea ice, reduction or loss of the equatorial warm tongue and weaker atmospheric circulation. Others have suggested that prolonged active deep-water formation took place in the North Pacific, making it better ventilated than today. Some of this evidence comes from carbon isotope gradients across the Pacific Basin, which was proposed to be reversed during the mPWP compared to today/Holocene. These inferences were made based on a low resolution benthic foraminifera carbon isotope record from North East Pacific ODP site 1014. Here we present new higher resolution benthic foraminifera carbon isotope data for ODP Site 1014 across the Holocene and mPWP. Our new data show more depleted values during the mPWP compared with Holocene, and would argue against a mid-depth carbon isotope gradient reversal during the mPWP compared with the Holocene, nor would it support claims of North Pacific Deep Water influence at this location.

Application of micro-computed tomography on Oligocene/Miocene samples of Glacial Erratics to identify and assess included snails (Gastropoda) and Foraminifera

Ulrich KOTTHOFF*[1], Karolin ENGELKES[1], Yvonne MILKER[2], Gerhard SCHMIEDL[2], Michael HESEMAN[3], Muofhe TSHIBALANGANDA[4], Andre BEERLINK[4]

[1] Leibniz Institute for the Analysis of Biodiversity Change, Martin-Luther-King Platz 3, 20146 Hamburg, Germany

[2] Center for Earth System Research and Sustainability (CEN), Universität Hamburg

[3] Foraminifera.eu Lab, Hamburg

[4] Comet Yxlon GmbH, Essener Bogen 15, 22419 Hamburg

*corresponding author: u.kotthoff@leibniz-lib.de

Destruction-free three-dimensional assessment of fossils from sediments samples and sedimentary rocks is of great interest to the bio- and geoscience community. It allows assessing morphological features and improving morphometrical analyses.
Glacial erratics containing fossils such as the "Holsteiner Gestein" or the "Sternberger Gestein" are often found in northern Germany. The original deposition of these sediment types took place during the Oligocene/Miocene. Glaciation-related transport of this material occurred during the Pleistocene. The fossil content inside of these erratics and their paleoecology have rarely been investigated in detail. If analyzed at all, material like the "Holsteiner Gestein" is generally subjected to destructive methods to isolate fossils such as marine snails or foraminifers.
In 2023, we scanned a piece of "Holsteiner Gestein" with a Comet Yxlon FF35 CT system employing the directional beam tube: First, an overview scan (210 kV, 160 µA, 1.0 mm Cu filter, 50.00 µm iso-voxel size) was done. An area containing fossils of interest was scanned (210 kV, 160 µA, 1.0 mm Cu filter 7.23 µm iso-voxel size) with higher resolution using a scan trajectory with a flexible rotation center. Furthermore, a laminography scan (180 kV, 70 µA, 0. 5 mm Cu filter, 5.02x5.02x9.58 µm voxel size) was performed to achieve the maximum possible resolution. As a further pilot study, we aim at scanning "Sternberger Gestein" with a similar approach and applying conservative methods to assess the fossil content for comparison.
In case of the "Holsteiner Gestein", we were able to generate detailed 3D models of snail shells and foraminifera of less than 1 mm in size. The scanning approach allowed quantifying the number of microfossils inside a certain section. The foraminiferal taxa comprise agglutinating foraminifers which closely resemble

the genus *Entzia*. Additional scans with even higher resolution may allow to improve the taxonomical attribution.

Paleoenvironmental changes during MIS 1-5 based on benthic foraminifera and geochemical proxies from IODP Expedition 381, Corinth Rift (Eastern Mediterranean)

Olga KOUKOUSIOURA[1,2], Konstantinos PANAGIOTOPOULOS[1], Paula DIZ[3], Patrick GRUNERT[1]

[1] Institute of Geology and Mineralogy, University of Cologne, Zülpicher Str. 49a, 50674, Cologne, Germany; okoukous@uni-koeln.de, panagiotopoulos.k@uni-koeln.de, pgrunert@uni-koeln.de

[2] School of Geology, Aristotle University of Thessaloniki, 54124, Thessaloniki, Greece; okoukous@geo.auth.gr

[3] Centro de Investigaciones Marinas, Universidade de Vigo, Campus Lagoas-Marcosende s/n, 36310, Vigo, Spain; pauladiz@uvigo.gal

Benthic foraminiferal abundance and composition were studied in combination with a multi-proxy dataset (grain size, organic and inorganic carbon content, XRF) to investigate paleoenvironmental changes recorded in IODP Expedition 381 core M0080A during MIS 1-5 (0-36.5 mbsf). The expedition took place in the Gulf of Corinth, a relatively young (<5 Ma) and active continental rift zone in the eastern Mediterranean Sea, currently connected to the Ionian Sea through a shallow sill (60 m of depth) and to the Aegean Sea via the Corinth Canal. The M0080 core is located in the Alkyonides Gulf, a shallow semi-enclosed sub-basin within the northeastern part of the Gulf of Corinth. The closed drainage system and the high sedimentation rates make the study area ideal for investigating the complex interactions between sedimentary input, tectonics and climate through the basin's evolution.
The benthic foraminiferal record is highly variable during the Holocene and the Last Interglacial Complex with mesotrophic to eutrophic marine conditions, as indicated by the high abundance of infaunal species, likely to have occurred during high sea-levels. During glacial and interstadial intervals, benthic foraminifers are very low in numbers or even absent, suggesting a sea-level drop below sill level and the subsequent (semi-)isolation of the basin. Inorganic carbon content and elemental concentrations varied following the interpreted sea-level fluctuations. The beginning of the Holocene is marked by the re-establishment of marine conditions as the sea-level rose above the sill level and the basin re-connected with the Mediterranean Sea.
This study is funded through project GR 5285/3-1 "*Late Quaternary dynamics of marine paleoenvironments and ecosystems in the Gulf of Corinth (eastern Mediterranean)*" of the Deutsche Forschungsgemeinschaft (DFG).

Different associations of benthic foraminiferal assemblages of three depositional systems within the Gulf of Cadiz

Matthias KRANNER[1,2*], Johanna SCHMIDT[3], Daniel HERWARTZ[3], Sandra DE CASTRO[4], Francisco Javier HERNÁNDEZ-MOLINA[5], Anna SAUPE[3], André BAHR[6], Patrick GRUNERT[3]

[1] Geological – Paleontological department, Natural History Museum of Vienna, Burgring 7, 1010 Vienna, Austria

[2] Institute of Geosciences, Kiel University, Ludewig-Meyn-Straße 10, 24118 Kiel, Germany

[3] Institute of Geology and Mineralogy, University of Cologne, Otto-Fischer-Straße 14, 50674 Cologne, Germany

[4] Arquimea Research Center, Camino Las Mantecas, 38320 San Cristobal De La Laguna, Santa Cruz de Tenerife, Spain

[5] Department of Earth Sciences, Royal Holloway University London, Egham, Surey TW20 0EX, United Kingdom

[6] Institute of Geosciences, Heidelberg University, Im Neuenheimer Feld 234, 69120 Heidelberg, Germany

* Corresponding author: matthias.kranner@ifg.uni-kiel.de

The Gulf of Cadiz (GoC) is located in the north-eastern Atlantic Ocean, southwest of the active continental margin of the Iberian Peninsula and west of the Strait of Gibraltar (SoG), which connects the Atlantic Ocean with the Mediterranean Sea. Since the opening of the SoG, the Mediterranean Outflow Water (MOW) influenced and shaped the sedimentary system of the GoC and a unique complex sedimentary archive was developed represented by the Contourite Depositional System. Additionally, steep slopes of the Iberian Margin led to strong down slope transport of sediment, creating turbidites, which in turn were frequently reworked by the strong bottom water currents. The straightforward, sedimentology-based distinction of the (in many cases intercalated) contouritic, turbiditic and reworked deposits remains challenging.
For this study, a total of 43 samples from IODP Site U1389 in GoC, representing the three aforementioned types of deposits (24 samples of a bi-gradational contourite, 10 of a normal-graded turbidite and 9 of a reworked turbidite) were analyzed for its content of benthic foraminifera. The microfossil record will be integrated with the sedimentary facies with the aim to use the foraminiferal assemblages as a tool to easily distinguish between contourites, turbidites and reworked turbidites.
Our preliminary results, based on the identification of 253 foraminiferal taxa and 18,500 specimens, show that quantitative benthic foraminiferal analyses provide a potentially powerful tool complement sedimentological approaches to differentiate contourites, turbidites and especially reworked turbidites more reliably.

Historical Reconstruction In A Mud Depocenter Of The Santos Basin Based on Benthic Foraminifera

Isabela S. KROPIWIEC[1], Julia SAMBUGARO[1], Cristian T. TIMOSZCZUK[1], Paulo A. L. FERREIRA[1], Rubens C. L. FIGUEIRA[1], Marcia C. BÍCEGO[1], Silvia H. M. SOUSA[1].

[1]Department of Physical, Chemical and Geological Oceanography, Oceanographic Institute, Universidade de São Paulo, Brazil. Praça do Oceanográfico, 191, CEP: 05508-120, São Paulo, SP, Brazil; isabela.kropiwiec@usp.br, sambugaro@usp.br, cristiann@usp.br, paulo.alves.ferreira@usp.br, rfigueira@usp.br, marciabicego@usp.br, smsousa@usp.br

This study aims to assess environmental changes in a mud depocenter in the Santos Basin between 1940 and 2016. A high-resolution sediment core was analyzed for benthic foraminifera (BF) fauna, sedimentological and geochemical analyses. BF data were utilized to apply the Enhanced Benthic Foraminifera Oxygen Index (EBFOI), to estimate bottom oxygenation. Three organic indicators were used: dinosterol, a biomarker of autochthonous organic matter (OM), total n-alkanes, and Average Chain Length (ACL), which offer insights into terrestrial inputs and environmental stressors.
BF density ranged from 5,888 (1988) to 798 individuals/10 cm³ (2017). In recent years, there is a trend of decreasing BF density and an increase of diversity. The EBFOI indicates a low oxic environment between 1988 and 2007, with an average value of 15. Negative values indicate a shift to a suboxic environment after 2015. The Principal Component Analysis identifies two distinct groups of samples: i) higher ACL and dinosterol values, correlated with a drier climate on the continent and with phytoplankton contribution to OM, and ii) higher Total Organic Carbon and n-alkanes values, finer sediments, with higher richness and diversity of BF. Species found in the first group are associated with well-oxygenated environments and productivity (*Trifarina angulosa* and *Globocassidulina rossensis*). In contrast, the second group was dominated by opportunistic species tolerant of decreases in oxygen levels, such as *Bulimina marginata* and *Buliminella elegantissima*. Despite sharing similar morphological characteristics, *G. crassa* and *G. rossensis* were found in contrasting environmental conditions. This may suggest that these species could exhibit distinct responses regarding the source of OM in their habitats. The data suggests that environmental factors, such as climate on the continent and OM input, influence the density and diversity of BF over time.

Fragmented Test Abundance of *Ammonia beccarii* in Quaternary Deposits as an Indicator of a Marine Extreme Wave Event in the South Sicily Coastal Area

FX Anjar Tri LAKSONO[1,2], Ákos MIKLÓSY[1], Péter SZABÓ[1], Laura BORZI[3], János KOVÁCS[1,4]

[1] Department of Geology and Meteorology, University of Pécs, Ifjúság útja 6, Pécs, Hungary; anjar93@gamma.ttk.pte.hu, miklosy.akos@gamma.ttk.pte.hu, szabopet@gamma.ttk.pte.hu, jones@gamma.ttk.pte.hu

[2] Department of Geological Engineering, University of Jenderal Soedirman, Mayjen Sungkono Road, Blater, Purbalingga, Indonesia

[3] Department of Biological Geological and Environmental Sciences, University of Catania, Corso Italia 57, Catania, Italy; borzilaura@unict.it

[4] Environmental Analytical and Geoanalytical Research Group, Szentágothai Research Centre, University of Pécs, Ifjúság útja 20, Pécs, Hungary

The Mediterranean Sea is prone to marine extreme wave events such as storms and tsunamis due to its geographical location between three large continents connected to the Atlantic Ocean and the collision of three tectonic plates, namely Eurasia, Africa and Arabia. A region of the Mediterranean that has recorded several storm and tsunami events is Sicily, Italy. Extreme sea wave rise by storms occurred in Sicily with an intensity of almost four times a year, for instance, Medicane Zorbas in 2018 and Medicane Qendresa in 2014. Meanwhile, the devastating tsunami events in Sicily recorded in the EMTC are the tsunamis of 365 AD, 1693, and 1908. The detection of storm and tsunami deposits in eastern, northern and southeastern Sicily provided evidence of these events in the past. However, investigation of marine extreme wave events deposits in southern Sicily is still limited. Therefore, this study explores the deposit of marine extreme wave events in southern Sicily. The method used was benthic foraminiferal fossil analysis by binocular microscope and SEM on 0-60 cm depth drilling sediments at Pantano Longarini. Analytical results indicate that the sediments of medium silt-coarse silt at a depth of 40 cm - 60 cm contain fragmented tests of *Ammonia beccarii* with a percentage reaching 28 percent of the 300 benthic foraminifera identified. Besides *Ammonia beccarii*, other benthic foraminifera were also found with fragmented shells but smaller abundance such as *Ammonia parkinsoniana*, *Elphidium* sp., *Quinqueloculina seminulum*, *Cibicidoides* sp., and *Asterigerinata mamilla*. The presence of several fragmented benthic foraminifera specimens from the littoral to bathyal zones implies that these micro-organisms are allochtonous and have been transported onshore by high flow regimes, possibly storms or tsunamis.

Jullienella foetida Schlumberger, 1890, the largest shallow-water agglutinated foraminifer in modern oceans

Martin R. LANGER[1], Anna E. WEINMANN[2], Walid A. MAKLED[3], Andrew J. GOODAY[4,5]

[1] Institute of Geoscience, Paleontology, Rheinische Friedrich-Wilhelms Universität Bonn, Bonn, Germany; martin.langer@uni-bonn.de

[2] Geological-Paleontological Department, Natural History Museum Vienna, Vienna, Austria; anna.weinmann@NHM-Wien.ac.at

[3] Exploration Department, Egyptian Petroleum Research Institute (EPRI), Cairo, Egypt; walidmakled@yahoo.com

[4,5] National Oceanography Centre, Southampton, United Kingdom and Life Sciences Department, Natural History Museum, London, United Kingdom; ang@noc.ac.uk

Jullienella foetida Schlumberger, 1890 is probably the largest agglutinated foraminiferal species occurring in relatively shallow water (<100 m depth). The species was initially considered to be a bryozoan, but Schlumberger recognized its true character and correctly described it as a single-chambered (monothalamous) agglutinated foraminifer with a large, flat or slightly undulating plate-like test, leaf-like, or fan-like in overall

shape and with the chamber interior subdivided by longitudinal partitions. Since it was first described by Schlumberger (1890), *J. foetida* has been widely reported from depths of 14 to 89 m across the West African continental shelf from Western Sahara to Ghana. It occurs on fine sandy and muddy substrates at densities of up to 200 individuals per m^2 and covering up to 10% of the sandy seafloor. These large agglutinated structures often constitute the only available hard substrate on which sessile organisms can settle. It seems likely that this species fulfils an important, perhaps keystone, ecosystem role by providing the only extensive firm substrate on which sessile organisms can settle, thereby increasing local biodiversity, as well as by processing organic matter at the base of the benthic food chain.
X-ray images of the test reveal an elaborate system of radial partitions that subdivides the test interior into channels. These may serve to direct the flow of the cytoplasm, and perhaps increase its surface to volume ratio. The test wall of *J. foetida* comprises a smooth, outer veneer of small (<10 μm) mineral grains that overlies the much thicker inner layer. Micro-CT scans suggest that much of the test interior is filled with cytoplasm, which would mean that this species is possibly one of the largest of all foraminifera in terms of biomass. *J. foetida* resembles some xenophyophores in terms of test size and morphology, but lacks their distinctive internal organization; the similarities are therefore likely to be convergent.

Deep-sea benthic foraminiferal faunas and elemental composition to monitor ecosystem recovery after decades of bauxite residues disposal at sea

Laetitia L.LICARI[1], Christian GRENZ[2], Sophie SEPULCRE[3], Pauline GELY[2], Deny MALENGROS[2]

[1] Aix Marseille Université, CNRS, IRD, CdF, INRAE, CEREGE, Aix en Provence, France; licari@cerege.fr

[2] Aix Marseille Université, Université de Toulon, CNRS, IRD, MIO, Marseille, France; christian.grenz@mio.osupytheas.fr

[3] Université Paris-Saclay, CNRS, GEOPS, Orsay, France; sophie.sepulcre@universite-paris-saclay.fr

In December 2015, almost 50 yrs of continuous dumping of bauxite residues into Cassidaigne canyon (NW Mediterranean Sea, France) came to an end, replaced by liquid effluent of residual waters. While impacted sediments exhibit contamination by metals such as titanium, vanadium or chromium, toxicity of red muds on deep-sea benthic communities was assumed to be negligible. The main environmental impact of dumping was believed to be mechanical disturbance due to downslope spreading of fine-grained residues, preventing settlement by macro- and microfauna in the canyon axis (Dauvin, 2010). A few years after dumping stopped, assessing the recovery of benthic communities remains critical, given the accumulation and persistence of bauxite residues in the canyon. Furthermore, it represents a unique and reachable natural laboratory to finely study recolonization of disturbed seafloor by benthic foraminifera at various spatial- and temporal scales. Between 2017 and 2020, we proceeded to a seasonal survey of living benthic foraminifera and sediment oxygen fluxes at several stations located in contrasted environments in Cassidaigne canyon (i.e., outside, and in the severely red mud-impacted axis). Our results show that standing stocks and diversity remain extremely low in the canyon axis. Fauna still is dominated by opportunistic species such as Bulimids. Comparison to faunal data published at a nearby location several years before cessation of red-mud disposal indicates so far no significant change in recolonization of impacted sediment (Fontanier et al., 2012), although our data suggest slight diversity increase, as well as seasonal dynamics. Analysis of the elemental composition of several calcareous species suggests an enrichment in Fe, already observed by Fontanier et al (2012) but which cannot here simply be explained by a methodological bias. We also observed an overall increase in Pb/Ca, Al/Ca, Ti/Ca, Zn/Ca and Mn/Ca values, approaching the thresholds for polluted sites. These results highlight the need to continue monitoring benthic ecosystem recovery in the future.

From cars to the oceans: do water-soluble fuel compounds impact widespread marine microorganisms?

Michael LINTNER[1,*], Irina POLOVODOVA ASTEMAN[2], Wolfgang WANEK[3], Jan GOLEŃ[1], Jaroslaw TYSZKA[1]

[1] Institute of Geological Sciences of the Polish Academy of Sciences, Research Center in Krakow, Poland.

[2] Department of Marine Sciences, University of Gothenburg, Gothenburg, Sweden.

[3] Department of Microbiology and Ecosystem Science, University of Vienna, Vienna, Austria.

* Corresponding author: michael.lintner@univie.ac.at

Foraminifera are single-celled eukaryotic organisms, which occur in every marine habitat from shallow water areas to the deep sea. Due to their high population densities in all marine habitats and their high uptake rates of organic matter, it has been suggested that foraminifera importantly contribute to the global marine carbon and nitrogen cycles. In this study, we investigated the contaminant response of *Nonionella* sp. T1 which is a non-indigenous species in the Gullmar Fjord (Sweden) and has been reported for the first time in the Skagerrak in 2013. During laboratory experiments we investigated the effect of water-soluble diesel fuel components on the nutrition of *Nonionella*. Three different concentrations of diesel extracts (25, 50 and 100%) were applied and compared to a control (0% fuel extract) sample. The foraminifera were incubated for 3 days with a ^{13}C and ^{15}N enriched food source (*Chaetoceros calcitrans*) and later examined with different analytical methods. The results showed that the metabolism is influenced by the presence of fuel extracts. Food nitrogen uptake of the foraminifera was reduced ($p>0.001$) by the presence of any fuel extract while food carbon uptake was not significantly reduced during incubation with gasoline extract ($p=0.093$) but decreased during incubation with diesel extract ($p>0.001$). This pattern was also reflected by increases in cytoplasmic C:N ratios which indicates a change in protein production due to the presence of diesel extractives. Based on this study, it can be summarized that contamination of the marine environment with diesel fuel causes significant damage to foraminifera, even if they live in benthic habitats where they do not come into direct contact with the fuel itself.

Monitoring assemblage and behavioral changes on intertidal foraminifera during the alkalinity enhancement field experiment “RECAP” in the Ria Formosa Coastal Lagoon, Portugal

Julia LÜBBERS*[1], Isabel MENDES[1], Joachim SCHÖNFELD[2], Alexandra CRAVO[1]

[1] Centre for Marine and Environmental Research (CIMA) - Infrastructure Network in Aquatic Research (ARNET), Universidade do Algarve, Faro, Portugal

[2] GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany

* Corresponding author: jaluebbers@ualg.pt

Global warming poses a significant threat to humanity today. Despite extensive efforts to reduce CO_2 emissions, current measures are insufficient to halt the temperature rise. Recently, a promising approach has been a proposed to actively remove CO_2 from the atmosphere by marine alkalinity enhancement. The natural CO_2 uptake capacity of seawater is enhanced by the weathering of fine-grained alkaline minerals in marine environments. For the first time, this technique was tested with a monitored in-situ experiment at Ria Formosa Coastal Lagoon, Algarve, Portugal.
The experiment was conducted in the saltmarsh pioneer vegetation zone, with three replicate plots that were submerged twice a day. Each plot contained deployments of fine and coarse-grained olivine and basalt, with

an unchanged area serving as a control. The experimental plots and control were sampled every three months from September 2022 to March 2023 to analyze the effect of alkaline minerals on the assemblage composition and behavior of benthic foraminifera.
The living (rose-Bengal stained) foraminifera from the size fraction of 63-2000 µm were analysed. The most dominant species in the control areas were the agglutinated species *Trochammina inflata* and *Entzia macrescens*. Calcareous species are smaller and corroded compared with the fauna from the treated areas. In the areas treated with olivine and basalt, the most abundant species were the calcareous *Ammonia aberdoveyensis* and the agglutinated *Trochammina inflata* while *Entzia macrescens* being comparatively rare. This suggests that the Mg and Ca ions released from the weathered substrates, together with a higher pH, facilitated the good preservation and formation of large calcitic tests. In the control boxes, the average pH during the sampling period was 6.9, while the treatments exhibited higher pH values ranging from 7.1 to 7.3 on average.
Acknowledgement. Research supported by the Portuguese Science Foundation (https://doi.org/mppc).

Responses of calcareous plankton in the Ligurian Sea (north Tyrrhenian Sea) over the last 28 ka to the paleoclimatic and paleoceanographic changes

Pierluigi MARTINELLI[1], Rocco GENNARI[1], Laura BRONZO[2,3], Sergio BONOMO[4], Antonio CASCELLA[2], Letizia DI BELLA[5], Jaime FRIGOLA[6], Fabrizio MICHELANGELI[7], Mar SELVAGGI[5], Isabel CACHO[6], José-Abel FLORES[8], Fabrizio LIRER[5]

[1] Dipartimento di Scienze della Terra, Università di Torino, Via Valperga Caluso 35, 10125, Italy; pierluigi.martinelli@unito.it, rocco.gennari@unito.it

[2] Istituto Nazionale di Geofisica e Vulcanologia, Via della Faggiola 32, 52126 Pisa, Italy; antonio.cascella@ingv.it

[3] Dipartimento di Scienze della Terra, Università degli Studi di Firenze, Via La Pira 4, 50121 Firenze, Italy; laura.bronzo@unifi.it

[4] Istituto per l'Ambiente Marino Costiero (IAMC), Consiglio Nazionale delle Ricerche, Calata Porta di Massa, Interno Porto di Napoli, 80133 Naples, Italy; sergio.bonomo@iamc.cnr.it

[5] Dipartimento di Scienze della Terra, Sapienza Università di Roma, P. Aldo Moro 5, 00185 Roma, Italy; letizia.dibella@uniroma1.it; mar.selvaggimallorqui@uniroma1.it; fabrizio.lirer@uniroma1.it

[6] GRC Marine Geosciences, Universidad de Barcelona, Barcelona, Spain; jfrigola@ub.edu; icacho@ub.edu

[7] Dipartimento di Biologia Ambientale, Sapienza University of Rome, Piazzale Aldo Moro 5, 00185 Rome, Italy; fabrizio.michelangeli@uniroma1.it

[8] Department of Geology, University of Salamanca, Salamanca, Spain; flores@usal.es

Throughout the late Quaternary period, glacial-interglacial cycles, driven by periodic variations in Earth's orbital parameters, have repeatedly influenced the structure and dynamics of terrestrial and marine ecosystems. These climate changes, such as the Younger Dryas, Bølling-Allerød, and Heinrich events, that have had global implications, are fully attested also in the Mediterranean Sea.
Positioned at mid-latitudes, the Mediterranean is highly sensitive to climate changes, experiencing influences from polar and low-latitude dynamics. This study presents the first reconstruction of paleoceanographic conditions on a centennial time scale across the last deglaciation in the Eastern Ligurian Sea, off the Italian coast in the Western Mediterranean. This area offers a unique location for high-resolution paleoclimatic and paleoceanographic reconstructions hosting surface (Modified Atlantic Water; MAW) and subsurface (Levantine Intermediate Water; LIW and Tyrrhenian Intermediate Water; TIW) water masses, carrying signals from the Atlantic and the Eastern Mediterranean. To reconstruct the last 28ka main events in the Ligurian Sea, a 320cm long sediment core NDT_22_2016, recovered at 436m depth, onboard R/V Minerva Uno of CNR, was analyzed, using geochemical proxies and calcareous plankton assemblages (planktic foraminifera and coccolithophores).

Analysis of planktic foraminifera assemblages, reworked coccoliths, and XRF data revealed climate oscillations during the last glacial phase, chronologically correlated to western and eastern Mediterranean sectors. Planktic foraminifera suggests colder conditions in the Ligurian Sea compared to the southwestern Mediterranean, with pronounced seasonality, particularly during Heinrich and Heinrich-like events.
This research has been financially supported by the ERC-Consolidator 539 TIMED project (REP-683237), Project of Strategic Interest NextData PNR 2011–2013, and a PhD Scholarship funded by INGV.

Upper Valanginian to Lower Aptian benthic foraminiferal and paleobathymetry interpretations of Boulahouajeb's section, Northern Tunisia

Sarra MELLITI[1], M.Sabri ARFAOUI[1], Fetheddine MELKI[1], Fouad ZARGOUNI[1]

[1] Laboratory of Geodynamics, Geonumeric and Geomatrials (LR18ES37), Department of Geology, Faculty of Sciences of Tunis, University of Tunis El Manar, 1060 Tunis, Tunisia; sarramelliti@gmail.com, msarfaoui@gmail.com, fetheddine.melki@fst.utm.tn, fouadzargouni@yahoo.fr

The Lower Cretaceous is considered a period of flourishing benthic foraminifera and this is confirmed by the fauna observed in the area of Jebel Boulahouajeb in the Lansarine region. The analysis of benthic foraminifera assemblages reveal a diversity of species, which are dominated by calcareous taxa. The overall lithology and microscopic observations of the Jebel Boulahouajeb's section and benthic foraminiferal ecology were incorporated into the facies determination of the studied section. The massive and continous sediment of the Boulahouajeb's section input is deposited along four facies zones (FZ).
The outer shelf is attributed to the first facies zone FZ1. It represents the depositional environment for the Valanginian to upper Hauterivian. The foraminiferal assemblages are dominated by calcareous species.The sediments are deposited along a very low-gradient ramp, accompanied by the presence of some slumps. The foraminiferal assemblages of the upper Hauterivian to lower Barremian sediment differ significantly, with the presence of ostracods and agglutinated taxa. The presence of Epistominids suggests an environment relatively deep, and in communication with the open sea. Thus, the inner slope is attributed to the second facies zone FZ2. The distal slope and bathyal are attributed to the third facies zone FZ3. It represents the upper Barremian sediments. This part of the Boulahouajeb's section is characterized by a gravelly sequence at its base and followed by 1,670 meters of marls, marking the onset of a transgression. The fauna is composed of calcareous foraminifera, but with a dominance of agglutinated foraminifera (*Conorotalites*, *Hyperammina*, *Bathysiphon*, and Trochamines). The massive and thick marls, Lower Aptian sediments, indicate an increase in the sea level amplitude experienced during the Aptian transgression. This upper part of Boulahouajeb's section is attributed to the fourth facies zone FZ4, the abyssal zone.

Monitoring of alkalinity enhancement field experiment to assess biogeochemical changes and ecological impacts in intertidal environments

Isabel MENDES[1], Julia LÜBBERS[1], Joachim SCHÖNFELD[2], Alexandra CRAVO[1], Cátia CORREIA[1], Patricia GRASSE[3], A. Rita CARRASCO[1], Ana GOMES[4]

[1] Centro de Investigação Marinha e Ambiental (CIMA) – Universidade do Algarve, Portugal; imendes@ualg.pt

[2] GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany

[3] German Centre for Integrative Biodiversity Research Halle-Jena-Leipzig (iDiv), Germany

[4] Centro Interdisciplinar de Arqueologia e Evolução do Comportamento Humano (ICArEHB) – Universidade do Algarve, Portugal

In the scope of the *RECAP* project - *REduce atmospheric Carbon by Alkalinity enhancement in intertidal environments: Potential and impacts*, a novel in-situ experiment, monitored for 24 months, was installed in the Ria Formosa Coastal Lagoon, Algarve (Portugal), to assess the biogeochemical changes and ecological impacts of alkalinity enhancement (AE). Modelling and laboratory studies show that this marine carbon removal measure has a high potential to increase oceanic carbon uptake and storage and reduce ocean acidification, but data from field experiments under natural conditions are still lacking.
An undisturbed pioneer vegetation zone of the saltmarsh, colonized by *Spartina maritima* was select to install the experimental set-up, composed of three replicates, each with four deployments of fine and coarse-grained olivine and basalt, and an untreated control site. Monthly, supernatant and porewater samples are analyzed for temperature, salinity, oxygen concentration, pH, total alkalinity, nutrients, and trace metals. Sediment samples are collected every three months and analyzed for bacteria, diatoms, benthic foraminifera and meiofaunal composition. Preliminary data show a more pronounced increase in total alkalinity and pH in the porewaters in all the treatments shortly after substrate deployment, compared to the control, which decreases over time. Bacterial and benthic foraminiferal assemblages also show variations in abundance compared to the control, more pronounced for some bacterial phyla in the olivine treatments (e.g., Bacteriodota). The benthic foraminiferal assemblage, composed mainly of agglutinated species, shows a better preservation of calcareous tests in basalt and olivine treatments than in the control.
Research supported by the Portuguese Science Foundation (https://doi.org/10.54499/PTDC/CTA-CLI/1065/2021).

Biostratigraphy On The Boundary Of The Turonian And Coniacian In Western Georgia

Khatuna MIKADZE[1,2], Giorgi TLASHADZE[3], Nino LAPACHISHVILI[4], Zviadi CHKHAIDZE[1], Nana IKOSHVILI[3]

[1] Ivane Javakhishvili Tbilisi State University, Aleksandre Janelidze Institute of Geology, 31 Politkovskaia street, Tbilisi, Georgia; xatmikadze@yahoo.com

[2] Georgian National Museum, Institute of Anthropology and Paleobiology, 4 Niagvari street, Tbilisi, Georgia; xatmikadze@yahoo.com

[3] Georgia Technical University; 77 Kostava street, Tbilisi, Georgia; g_tlashadze@gmail.com; nanaikoshvili5@yahoo.com

[4] Ivane Javakhishvili Tbilisi State University, Chavchavadze av.1, Tbilisi, Georgia; nucalapachi@gmail.com

The territory of Georgia covers the north-western part of the Caucasian segment of the Alpine fold system. In terms of tectonic structure, the lithosphere of Georgia in the geological past was similar to the modern Pacific coast of the Asian type and represented the western part of the Tethys outskirts. Currently, interest has increased in reconstructions of climatic conditions and establishing the stratotype of the boundary between the Turonian and Coniacian stages.
The Turonian–Coniacian interval, covering a significant area of Western Georgia, is characterized by a carbonate type of sedimentation. These deposits were formed under conditions of a relatively calm tectonic regime and belong to the "greenhouse phases" in the history of the Earth's development. The study area is part of the Western molasses immersion zone – the Abash block. Within the territory, the Gumurishi formation has been identified, which is dated to the Middle Turonian–Coniacian.
Upper Turonian deposits are represented by light gray limestones with rare interlayers of tuff sandstones. They identified: *Inoceramus* cf. *cuvieri, In. lamarcki* (molluscs); *Marginotruncana pseudolinneiana, M. schneegansi, M. sigali, Whiteinella archaeocretacea, Dicarinella imbricate, D. hagni,* (PF); *Tethralitus pyramidu* (NNP).
The Lower Coniacian deposits are characterized by white and pinkish pelitomorphic limestones, slightly silicified. Found in them: *Inoceramus schloenbachi, In. involutus* (mollusks); *Marginotruncana coronata, M.*

angusticarinata, Concavatotruncana primitiva, C. concavata, Planoheterohelix reussi, Pl. globulosa (PF); *Arkhangelskiella cymbiformis, Tetralithus obscures* (NNP).
The results obtained made it possible to identify the following zones in the sections (The Gumurishi formation): *Marginotruncana shneegansi/M. pseudolinneina* (Middle–Upper Turonian), *Marginotruncana coronata, M. renzi/M. sigali (Lower Coniacian), Marginotruncana coronata*. The zonal stratigraphy of the Turonian-Coniacian deposits of Western Europe is based on the distribution of inoceramids, as well as ammonites. The lower boundary of the Turonian stage is associated with the global event OAE 2 (Bonarelli event), which could have had different durations in different water areas.

Foraminiferal assemblages in terrestrial salt ponds and meadows in Central Germany

Yvonne MILKER[1], Joachim SCHÖNFELD[2], Gerhard SCHMIEDL[1]

[1] Institute for Geology, Center for Earth System Research and Sustainability, Universität Hamburg, Bundesstrasse 55, Germany; yvonne.milker@uni-hamburg.de, gerhard.schmiedl@uni-hamburg.de

[2] GEOMAR Helmholtz Centre for Ocean Research Kiel, Wischhofstraße 1-3, 24148 Kiel; jschoenfeld@geomar.de

Benthic foraminifera are commonly reported from marine and coastal ecosystems, but they have also been observed in terrestrial brackish lakes and salt ponds. In Germany, first observations of inland benthic foraminifera date back to 1928, and since then single species of intertidal foraminifera have been reported from saline ponds and meadows, fed from late Paleozoic and early Mesozoic evaporites, in Sachsen-Anhalt, Thüringen, Niedersachsen and Schleswig-Holstein.
In 2022 and 2023, we took surface sediment samples along transects of vegetation zones from known and yet unexplored saline ponds and meadows in Sachsen-Anhalt and Thüringen to examine whether foraminifera are still living in these habitats. We found living (Rose Bengal stained) and dead foraminifera at all locations, partly with a higher species richness than in salt-marsh ecosystems at the German North Sea coast. The assemblages consist of *Entzia macrescens, Trochammina inflata, Trochamminita irregularis, Miliammina fusca, Haplophragmoides manilaensis,* and *Haplophragmoides wilberti* and we observed low numbers of calcareous species of the genera *Ammonia* and *Quinqueloculina*. We also observed species that have not yet been reported from temperate salt marshes in northern Germany such as *Trochamminita salsa* and *Gordiospira arctica*, and one *Entzia* species, which may be endemic to the saline ponds and meadows in Central Germany. We assume that foraminifera were transported to Central Germany via migrating birds. However, it is still unknown when and how often the terrestrial saline habitats have been colonized and whether the foraminifera originate from southern or northern Europe or from both regions. Future genetic analyses will clarify whether some of the inland foraminifera developed endemically. Further field campaigns will provide better insights into the population dynamics at various terrestrial saline ecosystems in Germany.

Foraminifera-bound nitrogen isotopes and metabolic-modelling of foraminifera size for the reconstruction of tropical and deep ocean oxygen: a study case from the Paleocene-Eocene Thermal Maximum (PETM)

Simone MORETTI[1,2] , Alexandra AUDERSET[3], Curtis DEUTSCH[4], Ronja SCHMITZ[1], Lukas GERBER[1], Ellen THOMAS[5], Valeria LUCIANI[6], Maria Rose PETRIZZO[7], Ralf SCHIEBEL[1], Aradhna TRIPATI[8], Philip SEXTON[9], Richard NORRIS[10], Roberta D'ONOFRIO[6], James ZACHOS[11], Daniel M. SIGMAN[4], Gerald H. HAUG[1], Alfredo MARTÍNEZ-GARCÍA[1]

[1] Max Planck Institute for Chemistry, Climate Geochemistry Department, Mainz, Germany; simone.moretti@mpic.de

[2] Istituto di Scienze Polari, Consiglio Nazionale delle Ricerche, Bologna, Italy

[3] University of Southampton, Southampton, United Kingdom

[4] University of Princeton, Princeton, United States

[5] Yale University, New Haven, United States

[6] Università di Ferrara, Ferrara, Italy

[7] Università Degli Studi di Milano, Milan, Italy

[8] University of California, Los Angeles, United States

[9] The Open University, Milton Keynes, United Kingdom

[10] Scripps Institute of Oceanography, University of California, San Diego, United States

[11] University of California, Santa Cruz, United States

Nitrogen isotopes in organic matter bound to the carbonate shell of foraminifera provide information on the past state of marine denitrification, a process linked to ocean oxygen. Metabolic modelling of foraminifera shell size provides a quantitative constrain on seawater oxygen partial pressure. Here, we discuss the application of these methods in the Paleocene-Eocene Thermal Maximum (PETM), a global warming event that occurred around 56 Ma ago, with patterns of change akin to ongoing and projected changes for the future. Results from foraminifera-bound nitrogen isotopes indicate a sudden decrease in water column denitrification rates within the North Pacific oxygen deficient zone (ODZ) at the onset of the PETM. This suggests an increase in oxygen levels surrounding the ODZs during warming. These findings align with oxygen partial pressure (pO_2) reconstructions based on the relationship between the size of planktic microfossils' shells and seawater pO_2, determined through metabolic modeling of aquatic ectotherms. The increase in body size observed at a location distant from the ODZs implies that oxygen levels rose from the upper pycnocline to the basal mixed layer depths across the tropical North Pacific, indicating that the contraction of ODZs was part of a broader increase in pO_2 in the tropical upper ocean. Applying the same metabolic modeling to benthonic foraminifera suggests a decline in deep ocean pO_2 while oxygen levels in the overlying subtropical ocean increase.
Changes in water column pO_2 were compared to projections from an Ocean General Circulation Model under the SSP5-8.5 scenario for 2300. Consistency was observed between the vertical structure of ocean oxygenation sensitivity to warming. In this model, despite a global decline in oxygen, tropical regions experience a rise due to reduced upwelling-driven biological productivity. Tropical oxygenation might have contributed to the modest degree of extinction in planktonic foraminifera in spite of the largest benthic foraminifera extinction of the Cenozoic.

Consequences of warming-induced environmental stress on benthic ecosystems: foraminifera as sentinels of ongoing changes in Arctic fjords

Maria Pia NARDELLI[1*], Corentin GUILHERMIC[1], Eleonora FOSSILE[1], Naïs FERRIE[1], Aurélia MOURET[1], Meryem MOJTAHID[1], Antonio PUSCEDDU[2], Agnès BALTZER[3], Hélène HOWA[1]

[1] Université d'Angers, Nantes Université, Le Mans Université, CNRS, Laboratoire de Planétologie et Géosciences, LPG UMR 6112, 49000 Angers, France; mariapia.nardelli@univ-angers.fr

[2] Department of Life and Environmental Sciences, University of Cagliari, 09126 Cagliari, Italy; apusceddu@unica.it

[3] LETG, UMR CNRS 6554, University of Nantes, Campus du Tertre, 44312 Nantes Cedex 3, France; agnes.baltzer@univ-nantes.fr

* Corresponding author

Arctic fjords are transitional areas between glacier-covered land and the ocean, characterized by strong environmental gradients and rapidly evolving under current global warming conditions. It is urgent to

understand the functioning of these complex environments, to better monitor their ongoing modifications. Kongsfjorden (Svalbard) has entered in an intense phase of warming and ice melting, which have prevented the winter formation of extensive sea-ice since 2009. The present-day situation of this fjord represents a first, and rapidly evolving, phase of transition from subpolar to future temperate conditions. In summer, the environment is intensely influenced by high glacier melting water production resulting in freshwater spreading at the surface, associated with high turbidity close to tidewater glacier fronts, and bottom waters influenced by Atlantic water intrusions. The presumed increase of the intensity and duration of melting-derived discharges in the near future could highly influence the biodiversity, the biozonations and therefore the ecosystem functioning of the fjord. We challenged benthic foraminifera as indicators of short-term evolution of this very contrasted environment.
The observation of benthic foraminifera's distribution in Kongsfjorden during summers 2018, 2021 and 2022 show a clear intensification and spatial expansion of the stressful conditions in the inner fjord, driven by Atlantic water inflow and sediment supply from the tidal glaciers. The intense sediment supply from the glaciers resulted in a widespread turbidity plume, negatively affecting phytoplanktonic production and sediment stability. The consequences of these processes on benthic biota are easily detected through the study of benthic foraminiferal assemblages.
Our findings support that foraminifera are powerful and significant indicators to monitor the effects of ongoing climate change on the benthic ecosystems of Arctic fjords.

Foraminifera diversity and their response to water masses circulation in the Nordic Sea

Ngoc-Loi NGUYEN[*1], Joanna PAWŁOWSKA[1], Jan PAWŁOWSKI[1]

[1] Institute of Oceanology, Polish Academy of Science, Sopot, Poland; loinguyen@iopan.pl, pawlowska@iopan.pl, Jan.Pawlowski@unige.ch

Arctic marine biodiversity is experiencing rapid shifts due to global warming and alterations in oceanic water circulation patterns. While the impacts of these changes on larger fauna are well-documented, the effects on smaller organisms, like foraminifera, which are crucial components of Arctic meiofauna, remain less understood. Previous studies on Arctic foraminifera have relied solely on morphological identification from sediment samples. Recently, metabarcoding is a powerful tool for studying biodiversity and ecosystem function, as it can provide rapid and accurate information on the composition of complex communities. However, there is a lack of understanding regarding the transportation and deposition of DNA that originates from foraminifera, from the ocean surface to the seafloor, and its eventual inclusion in the sedimentary records of marine environments. Here, we present the assessment of Arctic foraminifera diversity using metabarcoding of water and sediment DNA samples from the Nordic Seas. Our study highlights the influence of different water masses on the structure of foraminiferal communities, notably the impact of Atlantic water in the Svalbard region. We identified potential molecular foraminiferal indicators of the Atlantic and Arctic water masses, whose efficacy, however, needs to be confirmed by further analyses. Furthermore, our study also provides the diversity of Artic foraminifera, extending from the ocean surface to the surface layer of sediments. Our study emphasises the significance of metabarcoding studies in assessing the distribution and diversity of foraminifera in the Nordic Sea and their potential use as indicators of environmental changes in the region, particularly for monothalamous foraminifera not included in conventional morphology-based approaches. The findings have implications for understanding past and present marine ecosystems and their responses to climate change.

Development of the oxygen minimum zone in the Arabian Sea during the Holocene and the last glacial periods

Sha NI[1,*], Nicolaas GLOCK[1], Jan FIETZKE[2], Gerhard SCHMIEDL[1]

[1] Institute for Geology, University of Hamburg, Germany

[2] GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany

* corresponding author: sha.ni@uni-hamburg.de

Advancing our comprehension of how oxygen minimum zones (OMZs) evolve in the interglacial and glacial oceans enhances our insight into the response of OMZs to climate change. The Arabian Sea hosts the world's thickest OMZ, with suboxic intermediate ocean waters, consisting of different water masses, which are essential parts of the global oceanic circulation. Despite numerous attempts to infer improved oxygenation within the glacial Arabian Sea OMZ using qualitative indicators, the severity of oxygenation and the extent of OMZs during interglacial and glacial periods remain inadequately quantified. By combining the foraminiferal morphology and geochemistry data, we discover the link between shell morphology and multiple stresses, to be able to evaluate the impact of changes in the Arabian Sea OMZ on marine ecosystems and significantly improve the application of foraminiferal morphology as a proxy to reconstruct the seawater conditions. We investigate the porosity, trace elements and stable isotopes of benthic foraminifera species *Uvigerina peregrine*. We reconstructed bottom water temperature and salinity based on foraminiferal Mg/Ca and oxygen isotopes. Our study shows that the surface porosity inversely correlated to the bottom water salinity and dissolved oxygen concentration. The porosity indicates OMZ developed in the Arabian Sea during the Holocene Thermal Maximum (HTM, 8-4 ka BP) and the Last Glacial Maximum (LGM), the bottom water oxygen concentration was low during the LGM (25-22 ka BP) and increased during 21-15 ka BP. The fluctuation of the porosity also reveals a more unstable bottom water condition during the HTM than that during the LGM. Ba/Ca and Mn/Ca show the salinity and oxygen conditions in the Arabian Sea during the Holocene are more variable compare with those during the last glacial maximum.

Environmental quality status assessment of three Swedish west coast fjords by foraminifera-based genetic and morphological approaches

Phoebe O'BRIEN[1], Magali SCHWEIZER[2], Filip MORIN[1], Astrid HYLÉN[1, 3], Elizabeth K. ROBERTSON[1], Per O. J. HALL[1], Irina POLOVODOVA ASTEMAN[1]

[1] Department of Marine Sciences, University of Gothenburg, NATRIUM, Medicinaregatan 7B, 41390, Gothenburg, Sweden; phoebe.obrien@gu.se, elizabeth.robertson@gu.se, per.hall@marine.gu.se, irina.polovodova@marine.gu.se

[2] University of Angers, Nantes Université, Le Mans Université, CNRS, Laboratoire de Planétologie et Géosciences, LPG UMR 6112, 49000 Angers, France, magali.schweizer@univ-angers.fr

[3] Currently at: Department of Biology, University of Antwerp, Universiteitsplein 1, 2610 Wilrijk, Belgium; astrid.hylen@uantwerpen.be

Coastal ecosystems with high environmental variability pose a challenge to environmental assessment techniques. Benthic foraminiferal ecology and population dynamics recovered via observations and genetic metabarcoding (eDNA sequencing) are useful tools for ecosystem quality status (EcoQS) assessment. Conventional microscope-based methodology is constrained only to species with fossilization potential, whilst molecular tools have the capacity to detect both dormant stages (propagules) and soft-bodied individuals (monothalamids) but cannot give quantitative estimates. Foraminifera-based diversity and sensitivity indices

like Exp(H'bc) and TSI-med respectively have been shown to reliably estimate EcoQS, however given the novelty of molecular techniques applied to biomonitoring, thorough cross-validation with morphological data is still required. To test the ability of eDNA-based EcoQS techniques to detect foraminiferal response to environmental trends we conducted a spatially comparative study of three fjords on the Swedish west coast (permanently oxic Hake Fjord, seasonally hypoxic Gullmar Fjord and long-term anoxic By Fjord). Surface sediment samples (0-3 cm) taken at stations located at the mouth, centre and head of each fjord in September and October of 2021 provided three sediment sample replicates for eDNA and three sediment sample replicates for the foraminiferal assemblage and sediment geochemistry data. We hypothesize that the substantial variation in abiotic factors (DIC, TOC, TN, pigments, pore water nutrients and bottom water oxygen concentration) observed in the three fjords will impact the alpha and beta diversities reported by traditional (morphology-based) and molecular (DNA-based) techniques. The results will show if trends in foraminiferal diversity and EcoQS revealed by morphological and molecular methods will reflect steep environmental gradients observed in the studied fjord systems.

Integrated palaeoenvironmental analysis of the Lower Pliocene marine succession of Vale Farpado (Pombal, West Portugal) derived from Foraminifera and sedimentological data.

Mahima PAI[1,*], Pedro Miguel CALLAPEZ [2], Pedro A. DINIS[3], Paulo Alexandre LEGOINHA[4]

[1] Institute of Oceanology, Polish Academy of Sciences, 81-712 Sopot, Poland; mahima@iopan.pl

[2] Universidade de Coimbra, CITEUC - Centro de Investigação da Terra e do Espaço da Universidade de Coimbra, Faculdade de Ciências e Tecnologia, Departamento de Ciências da Terra, Polo II Rua Sílvio Lima, 3030-790 Coimbra, Portugal; callapez@dct.uc.pt

[3] Department of Earth Sciences, University of Coimbra, Portugal; pdinis@dct.uc.pt

[4] GEOBIOTEC, Department of Earth Sciences, NOVA School of Science and Technology Campus de Caparica P-2829 516 Caparica, Portugal; pal@fct.unl.pt

* Corresponding author: mahima@iopan.pl

The Pliocene marine deposits of the Vale Farpado region of western Portugal despite being rich in well-preserved marine fossils were lost to the scientific community for over 30 years. Thus, leaving the fossil data from the region incomplete and outdated. This study is from an outcrop that was recently rediscovered from the region and focuses on updating the list of foraminifera as well as using them to predict the palaeoenvironment and precise age of the deposits. Sedimentological studies were also done to back up the data found from foraminifera.

Nine layers of the outcrop were sampled out of which only seven layers yielded fossils. There were 58 benthic and 11 planktonic foraminifera species identified. The presence of predominantly smooth and striate forms of genus *Quinqueloculina* along with the presence of species like *Cibicides refulgens*, *Lobatula lobatula*, and *Elphidium crispum* indicate that the environment was a high energy cold temperate carbonate shelf sea. Moreover, the results from grain size analysis showed that the sediments are poorly sorted and extremely asymmetrical also indicates a prevailing high energy environment.

The appearance of *Globigerinella* obesa in all the strata and the presence of *Globigerinella pseudobesa* (4.37-5.20 Ma) in some suggest the deposits are from the early Pliocene epoch (Zanclean age).

Response of oxygen consumption and production of *Amphistegina lobifera* to temperature variations

Tina PALME[1], Petra HEINZ[1], Matthias NAGY[1]

[1] Department of Palaeontology, University of Vienna, Josef-Holaubek-Platz 2, 1090 Vienna, Austria; tina.palme@univie.ac.at, petra.heinz@univie.ac.at, matthias.nagy@univie.ac.at

Current rising temperatures in the oceans change marine habitats and faunal compositions. While thermal stress is potentially threatening existing benthic communities it can be advantageous for invasive species that are better adapted to high temperatures. One such example of a successfully expanding species is the symbiont-bearing large benthic foraminifera *Amphistegina lobifera* Larsen, 1976 originating from the Red Sea, that has spread throughout the coastal ecosystems of the eastern Mediterranean. Studies on *A. lobifera* have shown its high tolerance to increasing temperature with regards to survivorship and photochemistry in temperature ranges from 24 °C to 36 °C. Interestingly, little is known about the species' actual metabolic and photosynthetic activity with respect to oxygen consumption and production under different temperatures. This study intends to fill this gap. *A. lobifera* was cultivated in the laboratory at University of Vienna in Artificial Sea Water (ASW) at 24 °C and a salinity of 38 psu with a light exposure simulating day:night cycle (8:16 hours). A non-invasive method was used to analyse oxygen respiration rates. The method involved placing an Oxygen Sensor Spot in a small, 2 ml airtight glass vial filled with ASW alongside the foraminifera. Oxygen concentrations under dark and light conditions at different temperatures (24 °C, 28 °C, 32 °C, 36 °C) were documented using an Oxygen Microsensor. We used 10 cleaned, living individuals (triplicates measured) per trial that were allowed to acclimate to the elevated temperatures for 24 hours. Respiration rates are given in nmol O2/h calculated for biovolume (µm³) which was assessed for each individual specimen using photo microscopy. These results will give further insights into the ecological impacts and the contribution to biogeochemical cycles of *A. lobifera* in future ocean environments.

Moving away from the cliché of polluted harbours: unexpected high diversity of foraminiferal and macrofaunal communities in the harbour of Dunkirk, France

Jean-Charles PAVARD[1], Camille HENNION[1], Apolyne COURLEUX[1], Françoise HENRY[1], Laurent SEURONT[1,2,3], Vincent BOUCHET[1]

[1] Univ.Lille, CNRS, ULCO, IRD, UMR8187, LOG, Laboratoire d'Océanologie et de Géosciences, Station Marine de Wimereux, F-59000 Lille, France; jcharles.pavard@gmail.com, camille.hennion@univ-lille.fr, apolyne.courleux.etu@univ-lille.fr, francoise.henry@univ-littoral.fr, laurent.seuront@seuront.fr, vincent.bouchet@univ-lille.fr

[2] Department of Marine Resources and Energy and, Tokyo University of Marine Science and Technology, 4-5-Konan, Minato-ku, Tokyo, 108-8477, Japan

[3] Department of Zoology and Entomology, Rhodes University, Grahamstown, 6140, South Africa

Due to their strategic location between land and sea, harbours are critical societal and economic locations where industrialisation, trading and shipping drastically increased over the last decades, resulting in a cocktail of several types of pollution potentially affecting these highly modified transitional waters (TWs). Harbours have fundamentally been considered as highly polluted sites that were implicitly thought to host only poor species assemblages and then, were not considered in terms of conservation initiatives. Indeed, observations of faunal communities from harbours are rather focused on inventories of introduced species and little is still known on the diversity and functioning of these novel synthetic ecosystems. Ecological restoration in harbour is an emerging topic, and it requires a better knowledge of the structure and composition of benthic communities. In this context, the present work focused on both foraminiferal and macrofaunal assemblages

from the harbour of Dunkirk, lying at the crossroads between the English Channel and the North Sea, making it the fourth French harbour in terms of freight and hosting several industry plants. Environmental parameters showed that this harbour was characterised by a heavy metallic pollution (cadmium, copper, lead) and a high enrichment in total organic carbon (up to 10%). Both foraminiferal and macrofaunal assemblages showed unexpectedly high richness and diversity (respectively up to 23 and 20 species), noticeably higher than in Northeast (NE) Atlantic TWs less impacted by anthropogenic activities. Despite being driven by chlorophyll *a*, lead concentration and total organic carbon, the most abundant foraminiferal (e.g. *Ammonia confertitesta*, *Elphidium selseyense*, *Hopkinsina atlantica*) and macrofaunal species (e.g. *Capitella* spp., *Chaetozone gibber*) are typically encountered in NE Atlantic TWs, regardless their level of anthropisation. These results stress that, despite intrinsic important levels of pollution, harbours could be hotspot of biodiversity and should be considered as ecosystems *sensu stricto* and *de facto* more intensively monitored. Increasing the sampling effort in harbours in the future could fill the knowledge gap in our understanding of the drivers and structure of benthic communities in these peculiar environments.

The post-MECO period: paleoecological implications of changes in planktonic foraminifera assemblages (southern Adriatic region, Croatia)

Igor PEJNOVIĆ[1], Marina ČANČAR[1], Vlasta ĆOSOVIĆ[1]

[1] Department of Geology, University of Zagreb, Horvatovac 102b, Zagreb, Croatia; igor.pejnovic@geol.pmf.hr, marina.cancar@geol.pmf.hr, vcosovic@geol.pmf.hr

Following the transient warming event known as the Middle Eocene climatic optimum (MECO), there was a steady decline in temperature, known as the post-MECO period. This cooling trend affected the composition of planktonic foraminifera assemblages, leading to faunal adjustments from the late Eocene to the early Oligocene. We investigated these changes analyzing two flysch sections located in the southern Adriatic region (Pelješac peninsula and Slano, Croatia). This region was situated within a tectonically very active Dinaric foreland basin. Planktonic foraminifera indicate that the flysch deposition spanned the Late Bartonian to the Priabonian. The planktonic/benthic ratio (P/B) exceeded 80% in all studied samples suggesting deposition at bathyal depths. During the Bartonian, warm-water, mixed-layer dwelling genera, such as *Globoturborotalita*, *Globigerinatheka* and *Acarinina,* are the most abundant. Deeper-dwelling *Turborotalia* and deep-water genera like *Subbotina*, *Dentoglobigerina* and *Paragloborotalia* are less common, but consistently present. The beginning of the Priabonian, however, is marked by a compositional shift. Large muricate species (*Acarinina mcgowrani* and *Morozovelloides* sp.) became extinct, and the relative abundance of *Globigerinatheka* declined. Also, a slight increase in the relative abundance of cold-water genera *Subbotina* and *Dentoglobigerina*, as well as an increase in *Turborotalia*, particularly the cold-adapted species *T. increbescens* and *T. ampliapertura* occurred. In addition, Priabonian shows a rise in small-sized opportunistic taxa like *Chiloguembelina*, *Pseudohastigerina*, and *Streptochilus*. These changes suggest a gradual shift from warm and stable condition in the Bartonian towards cooler and potentially more variable condition in the Priabonian. This observed shift in foraminiferal composition aligns with documented global trends of cooling during this period.

This study was funded by Croatian Science Foundation through the BREEMECO project (IP-2019-04-5775).

Influence of cleaning protocols on Mn/Ca intra-test variability of benthic foraminifera assessed through SIMS

Jassin PETERSEN*[1], Hanna CIESZYNSKI[1], Patrick GRUNERT[1]

1 Institute of Geology and Mineralogy, University of Cologne, 50674 Cologne, Germany

* corresponding author: jassin.petersen@uni-koeln.de

High resolution sampling of individual foraminiferal tests is of great interest for understanding processes involved in defining elemental and isotopic carbonate compositions, and for paleoceanographic proxy calibrations. Such methods help documenting the variability of proxy signals within single tests, termed here intra-test variability. Manganese incorporation into benthic foraminiferal tests is thought to track changes in bottom water oxygenation (BWO) on varying time-scales. In fact, Mn/Ca intra-test variability has been proposed to serve as a proxy for seasonal BWO changes despite ontogenetic variability of the signal. Here we explore this idea further by studying the Mn/Ca intra-test variability of two genera of deep-sea benthic foraminifera from the SW Iberian Margin, *Melonis pompilioides* and *Gyroidinoides* spp. All specimens originate from sediments deposited during, and shortly before or after Heinrich stadials in the eastern North Atlantic (HS1 and HS11). Specimens of *M. pompilioides* were prepared with contrasting cleaning protocols: one batch was subject only to basic treatment for sediment removal, one batch was treated with sediment removal and oxidative cleaning steps, and one batch was treated with sediment removal, oxidative as well as reductive cleaning steps. Such an investigation of cleaning protocols specifically for Mn/Ca intra-test variability is novel, and is needed for proxy calibration. We used Secondary Ion Mass Spectrometry (SIMS) in order to analyse Mn/Ca of different parts of the foraminiferal tests. Then, we compared the results of Mn/Ca intra-test variability between specimens treated with different cleaning protocols based on SIMS and subsequent SEM imaging. We find an intra-test variability of ~30% regardless of the cleaning protocol applied. Furthermore, it seems that the reductive cleaning step reveals a decreasing ontogenetic trend in Mn/Ca for a majority of the specimens analysed. Such a trend was not dominant for specimens not subject to reductive cleaning. This highlights the importance of reductive cleaning steps in the detection of ontogenetic effects in Mn/Ca intra-test variability, and the application of this potential proxy for seasonal BWO changes.

Microfossil investigations as part of multiproxy analyses – the Roman Harbour of Ephesos versus the Hellenistic Harbour of Elaia

Anna PINT[1], Peter FRENZEL[1], Martin SEELIGER[2], Friederike STOCK[3], Helmut BRÜCKNER[4]

[1] Department of Earth Science, Friedrich-Schiller-Universität Jena, Burgweg 11, Jena, Germany; anna.pint@uni-jena.de

[2] Institute of Physical Geography, Goethe-University Frankfurt, Altenhöferallee 1, 60438, Frankfurt am Main, Germany; seeliger@em.uni-frankfurt.de

[3] Bundesanstalt für Gewässerkunde, Am Mainzer Tor 1, 56068 Koblenz, Germany; stock@bafg.de

[4] Institute of Physical Geography, Universität zu Köln, Albertus-Magnus-Platz, D-50923 Köln, Germany; h.brueckner@uni-koeln.de

Benthic foraminifers as part of multi proxy analyses are a powerful tool to reconstruct environmental changes, sea level fluctuations and coastal development. Especially in combination with ostracods it is possible to follow coastal evolution from open marine to coastal limnic environments. The method is also used in geoarchaeological studies, especially to present an active phase of an ancient harbour. Concerning the microfossil inventory, harbours are very similar to lagoons in habitat type and ecology due to their protected position. In harbour basins, eutrophication is common, caused by the input of human waste and the reduced exchange of water. This is reflected by a ubiquitous faunal association, adapted to temporary deficiency in

oxygen. Often, the sedimentation rate is higher than in natural lagoons. Silting up of a harbour leads to the separation from the sea followed by a freshening of the water body with a characteristic freshwater fauna during the final phase. This marked change in the faunal composition, including ostracod freshwater species and the rapid reduction of foraminifer species indicates the disconnection to the sea and the end of the harbour activity. In this study we present the Roman Harbour of Ephesos and the Hellenistic Harbour of Elaia regarding ostracod and foraminifer distribution, sedimentation processes, landscape evolution and human impact. The key difference between the two harbour sites are the various sedimentation rates. In Elaia the sedimentation rate was low that caused the present position of the harbour close to the coast, whereas Ephesos was subject of a very high sementation rate causing fast siltation and separation of the Roman Harbour from the sea.

Leisure boat harbours, metal pollution and alien foraminifera: a case study of Hinsholmskilen Harbour (Gothenburg, Sweden)

Irina POLOVODOVA ASTEMAN[1], Emilie JAFFRÉ[1, 2], Agata OLEJNIK[1], Maria HOLZMANN[3], Mary MCGANN[4], Kjell NORDBERG[1], Jean-Charles PAVARD[5], and Delia ROSELL[6]

[1] Department of Marine Sciences, University of Gothenburg, NATRIUM, Medicinaregatan 7B, 41390, Gothenburg, Sweden; irina.polovodova@marine.gu.se

[2] Laboratory of Planetology and Geosciences (LPG), University of Angers, Faculty of Sciences, University d'Angers, 2 boulevard Lavoisier, 49045 Angers Cedex 1, France, emilie.jaffre@etud.univ-angers.fr

[3] Department of Genetics and Evolution, University of Geneva, Quai Ernest Ansermet 30, CH-1211 Geneva 4; maria.holzmann@unige.ch

[4] United States Geological Survey, Pacific Coastal and Marine Science Center, P.O. Box 158, Moffett Field, CA 94035, United States of America; mmcgann@usgs.gov

[5] University of Lille, CNRS, Univ. Littoral Côte d'Opale, IRD, UMR 8187, LOG, Laboratoire d'Océanologie et de Géosciences, Station Marine de Wimereux F-59000, Lille, France; jcharles.pavard@gmail.com

[6] Department of Earth Sciences, University of Gothenburg, NATRIUM, Medicinaregatan 7B, 41390, Gothenburg, Sweden; delia.rosel@gu.se

Small leisure boat harbours have important aesthetic and recreational values in any country with a coastline. Sweden, with its long and complex coastline, is a particularly good example of a rich public boat life. It is estimated that there are about 860 000 leisure boats in Sweden, which is one of the highest numbers in the world in relation to the country's population. Yet, small boat harbours also present a wide range of environmental problems such as e.g. metal pollution and introduction of alien species. In this study we have investigated the ecological quality status (EcoQS) of the small boat harbour of Hinsholmskilen, located south-west of Gothenburg city (Sweden). We have analysed surface sediment (0-1 cm) samples, taken in 2019, for heavy metals (As, Cu, Zn, Pb, Co, Ni, Cr and Hg) and performed a reconnaissance survey of the harbour's previously unstudied benthic foraminiferal communities. The results showed that the harbour has good to high EcoQS corresponding to no or little deviation from reference conditions for Ca, Co, Ni and Pb distribution. Some of the metals (Pb, As, Zn and Cr) showed poor to bad EcoQS in the innermost harbour in proximity to high pressure cleaning plants, where boats are usually lifted up, cleaned, and prepared for winter storage on land. Finally, Cu and Hg showed consistently bad and poor EcoQS all over the harbour, reflecting use of both metals as biocides in antifouling boat paints. Based on the total fauna distribution, the benthic foraminiferal assemblages in the Hinsholmskilen Harbour represented a typical estuarine community with highly abundant *Ammonia* and *Elphidium* species, as documented elsewhere in European estuaries. Based on molecular and morphological data, we report two alien and putatively invasive species likely originating from Asia: *Trochammina hadai* and *Ammonia confertitesta* (phylotype T6). Both species have been recently identified elsewhere on the Swedish west coast based on molecular data but were not recorded by morphology-based studies yet.

Effects of artificial electric fields on the physiological state of *Amphistegina lessonii*: Insights from oxidative stress biomarkers and gene expression

Federica REBECCHI[1], Caterina CIACCI[2], Michele BETTI[2], Yoshiyuki ISHITANI[3], Davide LATTANZI[2], Sigal ABRAMOVICH[4], Patrizia AMBROGINI[2] Yurika UJIIÉ[5], Fabrizio FRONTALINI[1]

[1]Department of Pure and Applied Sciences, Urbino University, Via Ca' le Suore 2, Urbino, Italy; f.rebecchi@campus.uniurb.it, fabrizio.frontalini@uniurb.it

[2]Department of Biomolecular Science, Urbino University, Via Ca' le Suore 2, Urbino, Italy; caterina.ciacci@uniurb.it, michele.betti@uniurb.it, davide.lattanzi@uniurb.it, patrizia.ambrogini@uniurb.it

[3]Institute for Extra-Cutting-Edge Science and Technology Avant-garde Research (X-star), Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Yokosuka, Japan; ishitaniy@jamstec.go.jp

[4]Department of Earth and Environmental Sciences, Ben Gurion University of the Negev, P.O.B 653, Beer Sheva, Israel; sigalabr@bgu.ac.il

[5]Marine Core Research Institute, Kochi University, Nankoku, Kochi, Japan; yujiie@kochi-u.ac.jp

Many marine organisms have developed electroreceptive abilities to detect natural electric fields in their surroundings for vital functions such as movement, orientation, and foraging. With increasing energy inputs, such as subsea electrical cables, marine organisms, particularly benthic organisms, interact with the anthropogenic sources of electric fields. Little is known about the physiological responses of benthic organisms to electric stimulation and potential stress induced by artificial electric fields. Benthic foraminifera are widely used as bioindicators in marine environments due to their sensitivity and ability to respond to stressors. This study aims to evaluate the short-term effects of different electric current densities on the symbiont-bearing benthic foraminiferal species *Amphistegina lessonii* using biomarkers (i.e. proteins and enzymes). We also investigate the metabolic response to electrical stimulation based on single-cell transcriptome analysis, comparing gene expression patterns between the electric samples and control. Our findings reveal that exposure to an artificial electric field induces oxidative stress, as evidenced by the production of reactive oxygen species [ROS], and modifies protein synthesis. Specifically, electrical stimulation leads to the modulation of antioxidant-related enzymes (GST, GSR, GPx, and Se-GPx), directly related to a defence mechanism against ROS, and activates the p-p38 MAPK and p-PKC pathways, which may be involved in cellular responses to stressful stimuli. Electrical stimulation also leads to the upregulation of different genes (HSPA, RAB5, PPOX, SUOX, GPX, ACSL, SCD, EHD1). Our experiment successfully demonstrates metabolic changes related to electrical stimulation. The application of cellular biomarkers could represent an emergent approach to detect early warning signs of environmental stress in benthic foraminifera-based biomonitoring.

Southeast Pacific Water Mass Geometry since the Last Glacial Maximum: the evolution of the dense intermediate/deep carbon reservoir

Dharma REYES-MACAYA[1,2], Babette HOOGAKKER[1], Consuelo MARTÍNEZ-FONTAINE[3,4,5], Gema MARTÍNEZ-MENDEZ[6], Ricardo DE POL HOLZ[3], Mahyar MOHTADI[2], Claudia ARACENA[7], Elisabeth MICHEL[4,5], Francisco GARCIA-ARAYA[8], Natalie UMLING[9], Juan MUGLIA[10], Sofia MONTILLA[2], Thomas RONGE[11], William GRAY[4,5], Tapia RAUL[12], Alison JACOBEL[13], Jean LYNCH-STIEGLITZ[14], Henning KUHNERT[2], Giuseppe SIANI[3,4], Naoufel HADDAM[3,4], Nicolas GLOCK[15], Gulay ISGUDER[3,4], Silvana COLLADO[3], Victor MERINO[16], Andrea ITURRIA[17], Paola CARDENAS[17,18,19], Carina LANGE[19], Bruno MILLETME[3,4], Helen BOSTOCK[20], Eugenia M. GAYO[21], Dierk HEBBELN[2]

[1] Lyell Centre, Heriot-Watt University, Research Avenue, Currie, EH14 4BA, Edinburgh, UK; d.reyes_macaya@hw.ac.uk, b.hoogakker@hw.ac.uk

[2] MARUM - Center for Marine Environmental Sciences, University of Bremen, Leobener Str. 8, 28359, Bremen, Germany; d.reyes_macaya@hw.ac.uk, mmohtadi@marum.de, sbarraganmontilla@marum.de, hkuhnert@marum.de, dhebbeln@marum.de

[3] Geochronology laboratory, GAIA - Antártica, Universidad de Magallanes, Punta Arenas, Chile; consuelola.m.f@gmail.com, ricardo.depol@umag.cl, scolladofa@gmail.com

[4] Geosciences Paris-Saclay GEOPS/IPSL, UMR CNRS-Universite Paris-Saclay 8148, Bat 504 - Universite Paris-Saclay, 91405 Orsay Cedex, France; consuelola.m.f@gmail.com, elisabeth.michel@lsce.ipsl.fr, giuseppe.siani@universite-paris-saclay.fr, bruno.millet@lsce.ipsl.fr

[5] Laboratoire des Sciences du Climat et de l'Environnement LSCE/IPSL, UMR CEA-CNRS-UVSQ 8212, Bat 714 - CEA Saclay, piece 1034, Site de l'Orme des Merisiers Chemin de Saint Aubin - RD 128, F-91191 Gif sur Yvette Cedex, France; consuelola.m.f@gmail.com, elisabeth.michel@lsce.ipsl.fr, giuseppe.siani@universite-paris-saclay.fr, william.gray@lsce.ipsl.fr, gulay.isguder@lsce.ipsl.fr, bruno.millet@lsce.ipsl.fr

[6] Clima Protection Department, Stadt Delmenhorst, Stadthause II, Hans-Böckler-Platz 16, 27749 Delmenhorst, Germany; gema.martinezmendez@gmail.com

[7] Centro de Investigación en Recursos Naturales y Sustentabilidad, Universidad Bernardo O'Higgins, Avenida Viel 1497, Santiago, Chile/Laboratorio Costero de Recursos Acuáticos de Calfuco, Universidad Austral de Chile, Valdivia, Chile; claudiaaracenap@gmail.com

[8] Departamento de Ciencias de la Tierra, Facultad de Ciencias Químicas, Universidad de Concepción, Concepción, Chile. garcicia@gmail.com

[9] Rutgers University, New Brunswick, New Jersey, USA; nu53@marine.rutgers.edu

[10] Centro Nacional Patagonico, Centro para el Estudio de sistemas Marinos (CESIMAR), Puerto Madryn, Argentina; jmuglia@cenpat-conicet.gob.ar

[11] International Ocean Discovery Program (IODP), College Station, Texas, USA; ronge@iodp.tamu.edu

[12]Institute of Oceanography, National Taiwan University, No. 1 Sec. 4 Roosevelt Road, 106 Taipei, Taiwan; raul.tapia@upla.cl

[13] Deparment of Earth and Climate Sciences, Middlebury College, Vermont, USA; allison_jacobel@brown.edu

[14] School of Earth and Atmospheric Sciences, Georgia Institute of Technology, Atlanta, USA; jean@eas.gatech.edu

[15] University of Hamburg, Department of Earth System Sciences, Germany; nicolaas.glock@uni-hamburg.de

[16] Departamento de Biología, Universidad Nacional de Mar del Plata, Mar de Plata, Argentina; victormerino000@gmail.com

[17] Departamento de Ingeniería Ambiental y Recursos Naturales, Universidad Catolica de la Santísima Concepción, Alonso de Ribera 2850, Casilla 297, CP 4090541, Concepción, Chile; p.cardenas888@gmail.com, iturria.andrea@gmail.com

[18] Programa de Doctorado en Ciencias Mención en Biodiversidad y Biorecursos, Universidad Católica de la Santísima Concepción, Concepción, Chile; p.cardenas888@gmail.com

[19]Centro de Investigación Dinámica de Ecosistemas Marinos de Altas Latitudes (IDEAL), Universidad Austral de Chile, Valdivia, Chile; p.cardenas888@gmail.com, clange@copas.cl

[20] School of the Environment, The University of Queensland, Australia; h.bostock@uq.edu.au

[21] Departamento de Geografía, Universidad de Chile, Portugal 84, Santiago, Chile; eugenia.gayo@uchile.cl

Since 1750 cumulative carbon dioxide emissions unequivocally caused by human activities have induced rapid and widespread changes in all components of the climate system, provoking with high confidence global warming, more common periods of extreme weather events, ocean acidification, ocean deoxygenation and sea level rises. The ocean is an active carbon reservoir and plays a key role in regulating the atmospheric carbon during glacial/interglacials cycles. Evaluating ocean circulation and water mass distribution during past climates snapshots with evidence of strong variations in the global carbon cycle in a global and regional scale are crucial for improving past biogeochemical climate models' boundary parameters background information. Here we present the first high resolution coverage of $\delta^{13}C$ and $\delta^{18}O$ in the epibenthic (*Cibicidoides wuellerstorfi)* foraminifera from 20 marine sediment cores recovered between 537 and 3839 m water depth along the Chilean Continental Margin covering snapshots of the Last Glacial Maximum (LGM), Late Deglaciation (LD), Early Deglaciation (ED), and Early (EH), Middle (MH) and Late Holocene (LH). The data

was corrected by the reported main changes in carbon cycle and ice volume coverage during the specific time periods. Our $\delta^{13}C$ and $\delta^{18}O$ bottom waters reconstructions provide evidence of strong changes in the geometric configuration of the lower horizon of intermediate waters and deep waters as a result of declined ventilation and increase in water mass density during the LGM and LD from the Southern Ocean to the Equator. The upper horizon and the core of the intermediate waters show no changes in geometry; however the ventilation is enhanced during the LGM. For the LD/ED/EH/MH/EH the ventilation and configuration seems like modern conditions.

Naming clades of planktonic foraminifera

Susan L. RICHARDSON[1], Jon A. MOORE[1]

[1] Harriet L. Wilkes Honors College, Florida Atlantic University, Jupiter, FL, USA; richards@fau.edu, jmoore@fau.edu

Phylogenetic nomenclature is a rank-free system of biological nomenclature in which taxon names are explicitly defined by reference to phylogenetic trees, rather than by diagnostic characters. With the 2020 publication of the *PhyloCode*, new clade names can now be formerly established, and pre-existing names can be converted, separately from the rank-based codes (*i.e.*, ICZN, ICNafp, ICNP, etc.). The clade names *Rhizaria* T. Cavalier-Smith 2002 [A. G. B. Simpson] and *Foraminifera* C. E. Eichwald 1830 {S. L. Richardson & J. H. Lipps] were defined and established in the 2020 *Phylonyms* companion volume to the *PhyloCode*.
In this presentation, we will review the basic concepts of phylogenetic nomenclature and will propose phylogenetic definitions for *Globothalamea*, *Rotaliida*, and eleven crown clades of spinose planktonic foraminiferans by referring to recent molecular phylogenetic trees which, in most cases, portray extant species only. A crown clade is defined as a clade originating in the most recent common ancestor of two or more extant species (or organisms).
Panclade definitions for Pan-*Globothalamea*, *Pan-Rotaliida*, and eleven total clades of spinose planktonic foraminiferans will also be presented. A total clade is composed of the crown clade and all species that, including the extinct species that branch off the stem lineage, share a more recent common ancestor with the crown clade than any extant species that are not members of the crown clade. Understanding whether fossil species branch within the crown or off the stem lineage will be an important component to resolving the tree of life of spinose planktonic foraminiferans but will require integrating DNA and morphological data sets into future analyses.

Behavourial effects of heatwaves on *Haynesina germanica* enhanced by microplastic leachates

Julien RICHIRT[1,*], Vincent BOUCHET[1], Apolyne COURLEUX[1], Laurent SEURONT[1,2,3]

[1] Univ. Lille, CNRS, Univ. Littoral côte d'Opale, IRD, UMR8187, LOG, Laboratoire d'Océanologie et de Géosciences, Station Marine de Wimereux, 59000, Lille, France

[2] Department of Marine Resources and Energy, Tokyo University of Marine Science and Technology, Tokyo, Japan

[3] Department of Zoology and Entomology, Rhodes University, Grahamstown 6140, South Africa

* Corresponding author: richirt.julien@gmail.com

With huge amounts entering the marine environment, plastic is now acknowledged as a ubiquitous source of pollution in marine ecosystems. Substances released in the environment by plastic particles such as plasticisers

or adsorbed pollutants may represent a threat to organisms exposed to these leachates. Piling on other pollution types, plastic leachates effect(s) may interact with global warming, which threatens almost all ecosystems. To explore the combined effect of plastic leachates and temperature variations on Foraminifera, we incubated specimens of the common coastal benthic species *Haynesina germanica* in different experimental treatments and monitored their motion behaviour for 24h. The experiment consisted of exposition to temperature increase (simulated heatwave, from 12 to 30 and 36°C) or decrease (simulated coldwave, from 12 to 0°C) in the absence or presence of plastic (polyethylene) leachates from virgin (pristine, from factory) and aged (picked up on the beach) pellets. Then, temperature was returned to the in-situ temperature (i.e. 12°C) to investigate the motion recovery of individuals. Specimen positions were recorded every 10 min, and their distance travelled and velocity were compiled. Preliminary results indicated that:

- Individuals exposed to different plastic treatments in the control temperature condition (12°C) did not show velocity changes.
- Individuals exposed to 0° and 36°C strongly reduced their movements disregarding the plastic treatment and started to move again after the temperature returned to 12°C (temperature changes were not lethal).
- A strong difference was observed between plastic treatments after exposition to 30°C, with slightly reduced velocity in presence of leachates originating from aged pellets and strong velocity diminution in presence of plastic leachates issued from virgin pellets compared to the absence of plastic leachate condition where no change was observed.

These results suggest that the presence of plastic leachates may be deleterious when temperature is elevated, possibly decreasing the highest temperature tolerance for *H. germanica*, by unknown mechanism(s). This finding makes this study particularly relevant in an increasing plastic pollution in marine environment and global warming context.

Composite calcite and opal test in Foraminifera (Rhizaria)

Julien RICHIRT[1,2], Satoshi OKADA[1], Yoshiyuki ISHITANI[1], Katsuyuki UEMATSU[3], Akihiro TAME[3], Kaya ODA[1], Noriyuki ISOBE[4], Toyoho ISHIMURA[5], Masashi TSUCHIYA[6], Hidetaka NOMAKI[1]

[1] SUGAR, X-star, Japan Agency for Marine-Earth Science and Technology (JAMSTEC), 2-15 Natsushima-cho, Yokosuka 237-0061, Japan

[2] Univ. Lille, CNRS, Univ. Littoral côte d'Opale, IRD, UMR8187, LOG, Laboratoire d'Océanologie et de Géosciences, Station Marine de Wimereux, 59000, Lille, France

[3] Marine Works Japan Ltd., 3-54-1 Oppamahigashi-cho, Yokosuka, Kanagawa, 237-0063, Japan

[4] Research Institute for Marine Resources Utilization (MRU), Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Yokosuka, Kanagawa, 237-0061, Japan

[5] Graduate School of Human and Environmental Studies, Kyoto University, Yoshidanihonmatsu, Sakyo-ku, Kyoto 606-8501, Japan

[6] Research Institute for Global Change (RIGC), Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Yokosuka, Kanagawa, 237-0061, Japan

* Corresponding author: richirt.julien@gmail.com

We report for the first time a composite calcite/opal test in the cosmopolitan and well-studied benthic Foraminifera species *Bolivina spissa* (Rotaliida), sampled from the Sagami Bay in Japan. Based on comprehensive investigations including Scanning Electron Microscopy (SEM) coupled with Energy Dispersive X-ray Spectroscopy (EDS) and Fourier Transform Infrared Spectroscopy (FTIR), we inspect the morphology and composition of the novel opaline layer coating the inside part of the calcitic test. Using Scanning Transmission Electron Microscopy (STEM) and EDS analyses, we detected probable Silica Deposition Vesicles (SDVs), organelles involved in opal precipitation in other silicifying organisms, confirming that certain foraminifer may secrete opal. The layer was systematically found in all studied

individuals and had no apparent sub-structure. Its thickness showed an analogous growth pattern with the calcitic shell of *B. spissa*, being the thickest in the oldest chamber (proloculus) and becoming thinner toward the younger chambers (apertural side). Its absence in the youngest chambers indicates that silicification occurs subsequently to calcification, probably discontinuously. This finding poses the question of the origin of this composite test from an evolutionary point of view. We propose that the opal layer may serve as a protection barrier against predators using mechanical drilling or chemical etching of the calcitic test. Isotopic composition measurements performed separately on the proloculus part and the apertural side of *B. spissa* suggest that the precipitation of an opal layer may alter the calcitic isotopic signal and impact paleoenvironmental proxy using foraminifer's tests composition. If silicification in Foraminifera was found to be more widespread than previously thought, it could possibly have important implications for foraminiferal evolution, palaeoceanographic reconstructions, and the silica cycle at global scale.

Benthic foraminiferal assemblages through an environmental gradient at Heron Island, Australia

Angelique ROSA MARÍN[1], Pamela HALLOCK[1], Peter L. HARRISON[2]

[1] College of Marine Science, University of South Florida, 830 1st Street SE, Saint Peterburg, FL, United States of America; arosamarin@usf.edu; pmuller@usf.edu

[2] Marine Ecology Research Center, Southern Cross University, Military Rd, East Lismore NSW 2480, Australia; peter.harrison@scu.edu.au

Heron Island is a cay in the southern part of the Great Barrier Reef, Australia. The cay has rich terrestrial and marine biodiversity, including Green and Loggerhead turtles, birds, and fringing coral reefs. Global and local threats, including ocean acidification and global warming, have increased bleaching episodes, impacting coral reefs around the island. This study quantified distributions of benthic foraminiferal assemblages inshore to offshore of Heron Island reef flat and compared assemblages with benthic survey data to determine if such spatial distributions can inform the usefulness of foraminiferal assemblages as environmental indicators. We expect that foraminiferal assemblages will vary consistent with ecological conditions, including sediment texture, water-quality parameters, and coral cover. In 2019, two inshore-offshore transects of 20 m each were delineated on the southwestern side of the reef flat. Three sites were selected along each transect for a total of six sites: two inshore, two mid-zone, and two offshore. At each site, a perpendicular transect of 20 m was delineated, and three numbers were randomly selected. A quadrat of 1 m^2 was placed at each selected meter location, and three independent surficial sediment and water samples were collected for foraminiferal counting, sediment texture, and nutrient analysis. Temperature values were 24.25–26.35°C, pH from 8.15–8.30, and salinity from 36.95–38.10. Sand, scleractinian coral, and macroalgae were predominant macrobenthos at inshore and midzone sites, while turf algae, scleractinian coral, rubble, and dead coral, predominated at offshore sites. Three larger benthic foraminiferal species, *Calcarina hispida, Calcarina calcar* and *Baculogypsina shpaerulata,* dominated foraminiferal assemblages. The presence of algal symbiont-bearing taxa indicates appropriate water-quality conditions for reef health. Most specimens were broken and abraded dead tests, which is typical in very shallow, high-energy environments. This study provides baseline data on the implications of foraminiferal assemblages as bioindicators of reef health on Heron Island.

Productivity Proxy Calibration along the West Iberian margin: a multi-proxy approach

Emilia SALGUEIRO[1,2], Fátima ABRANTES[1,2], Carmen G. CASTRO[3], Antje H.L VOELKER[1,2], Lelia MATOS[1,2], Andreia REBOTIM[1,2]

[1] Instituto Português do Mar e da Atmosfera, I.P. (IPMA, IP), Av. Alfredo Magalhães Ramalho 6, 1495-165 Algés, Portugal; emilia.salgueiro@ipma.pt, fatima.abrantes@ipma.pt, antje.voelker@ipma.pt, lelia.matos@ipma.pt, andreia.rebotim@ipma.pt

[2] Centro de Ciências do Mar do Algarve (CCMAR), Universidade do Algarve, Campus de Gambelas, 8005-139 Faro, Portugal;

[3] Instituto de Investigacións Mariñas – CSIC, Eduardo Cabello 6, 36208 Vigo, Spain; cgcastro@iim.csic.es

Coastal upwelling regions are areas of significant biological productivity, representing 80 to 90% of the global new production. These areas are considered key locations to understand the linkage between the biological pump, or export productivity and climate in the past, which is essential to improve future scenario simulations. However, the accuracy of these paleoreconstructions depends on the data set and calibration quality. Several calibration efforts have been defining and improving the use of proxies for productivity and nutrient cycling parameters. Along the Iberian margin, however, combining present-day hydrographic and biogeochemical data with the past oceanic or climate conditions has rarely been done. In order to minimize the lack of information from the upper water column productivity, we investigate trace elements and stable isotopes in planktonic foraminifera (PF) species, PF fauna, Ba concentration, together with total organic carbon from a large set of core-top sediment samples from the West Iberian margin. Sediment data are compared with satellite derived chlorophyll a, and present-day water column data (e.g., trace elements, stable isotopes, phosphate concentration). In sediment samples, Cd/Ca shows only high values on G. *bulloides* (upwelling related species for the region) close to the coast, reflecting the intense upwelling (high chlorophyll a concentrations). Sediment records of *G. inflata*, and *N. incompta*, deep-dwelling species, display high Ba/Ca in agreement with water Ba/Ca, showing a clear increase in Ba/Ca from the surface to the deep water, that is correlated with spring/early fall phosphate concentrations. This study contributes to projects CALIBERIA, CARBO-ACID, IRMAPEx; and ICW3P.

Effect of pH on calcification and physiological responses of laboratory-cultured large benthic foraminifera (LBF), *Amphistegina lobifera*

Ajay Valiyaveettil SALIMKUMAR[1], Julie MEILLAND[2], Marion PERAL[1,3], Philippe CLAEYS[1]

[1]Archaeology, Environmental Changes and Geo-Chemistry (AMGC), Vrije Universiteit Brussel, Belgium; ajay.valiyaveettil.salimkumar@vub.be, phclaeys@vub.be

[2] MARUM - Center for Marine Environmental Sciences, University of Bremen, Germany; jmeilland@marum.de

[3] Department of Environnements et Paléoenvironnements Océaniques et Continentaux (EPOC), University of Bordeaux, France ; marion.peral@u-bordeaux.fr

Between 1750 and 2015, human activity significantly increased atmospheric CO_2 concentration ($[CO_2]$), driving global warming of the ocean. As a result, the surface ocean pH decreased by 0.1 units, and the $[H^+]$ increased by 26%. Decreasing pH or carbonate ion concentration have detrimental impacts on the delicate balance of marine life, particularly on organisms like corals, shellfish, and/or foraminifera that rely on calcium carbonate to build their shells and skeletons. Foraminifera are considered ideal model organisms that contribute to the marine carbon cycle because of their widespread distribution and abundance. However, the impact of ocean acidification on large benthic foraminifers remains unclear, in particular, their responsiveness to environmental changes. This study determines the pH effect on calcification and physiological responses of laboratory-cultured large benthic foraminifera (LBF), *Amphistegina lobifera*, under different pH treatments (pH 7.54, pH 7.78, pH 8.23, and pH 8.55). Our results show that *A. lobifera* displays the most significant shell

growth in pH treatments close to ambient levels (pH 8.05), whereas notably lower rates are found in treatments further from 8.05 (pH 7.54 and 8.55). A gradual declining locomotion in the treatment with the higher shell growth, suggest a metabolic trade-off driving their fast adaptive response to the fluctuating pH conditions. Besides these results, the cultured specimens also allow the determination of potential pH effect on classical ($\delta^{18}O$) and clumped (Δ_{47}) isotopes. Clumped isotope on foraminifera represents a promising thermometer allowing the reconstruction of both surface and bottom temperatures. By documenting the presence or absence of pH effects in isotopic measurements, we accurately reconstruct both ocean temperatures (Δ_{47}) and by extension (when combined with $\delta^{18}O$), the seawater $\delta^{18}O$, related to ice sheet volume changes.

Contrasting Natural And Anthropic Historical Changes In Two Estuarine Systems Along The Brazilian Coast: Implications On Benthic Foraminiferal Assemblages And Environmental Quality

Julia SAMBUGARO[1], Isabela S. KROPIWIEC[1], Luiz Gustavo PEREIRA[2], Joel Augusto S. SARMIENTO[3], Renê H. MAGALHÃES[4], Eduardo SIEGLE[1], Maria Virgínia A. MARTINS[5,6], Silvia H. M. SOUSA[1]

[1]Department of Physical, Chemical and Geological Oceanography, Oceanographic Institute, Universidade de São Paulo, Brazil. Praça do Oceanográfico, 191, CEP: 05508-120, São Paulo, SP, Brazil. sambugaro@usp.br, isabela.kropiwiec@usp.br, smsousa@usp.br

[2]Department of Geochemistry and Geotectonics, Geosciences Institute, Universidade de São Paulo, Brazil. Rua do Lago 562, CEP: 05508-080 São Paulo, SP, Brazil. luiz.gustavo.pereira@usp.br

[3]Earth Science Laboratory, School of Arts, Sciences and Humanities, Universidade de São Paulo, Brazil. Av. Arlindo Béttio, 1000, CEP: 03828-000 São Paulo, SP, Brazil. jsamanez@usp.br

[4]Paleoceanography and Paleoclimatology Laboratory, School of Arts, Sciences and Humanities, Universidade de São Paulo, Brazil. Av. Arlindo Béttio, 1000, CEP: 03828-000 São Paulo, SP, Brazil. rene.magalhaes@usp.br

[5]Department of Stratigraphy and Paleontology, Faculty of Geology, University of State of Rio de Janeiro. São Francisco Xavier Street, 524, CEP: 20550-013, Rio de Janeiro, RJ, Brazil

[6]Department of Geosciences, University of Aveiro, GeoBioTec, Campus de Santiago, 3810-193, Aveiro, Portugal. virginia.martins@ua.pt

The study investigates the historical changes of two estuarine systems, located along the Brazilian coast. The Santos estuarine system (SES) has been submitted to anthropogenic influences such as industrialization, urbanization and the Port of Santos. Conversely, the Caravelas estuarine system (CSE) has been subjected to natural-driven changes and by slight anthropogenic alterations. Sedimentological, geochemical, benthic foraminifera (BF) analysis, and multivariate statistics were used to investigate the distinct estuarine systems. The biotic indices applied were the Paleo-Ecological Quality Status (Paleo-EcoQS), calculated using the diversity index exp(H´bc) based on BF fauna, the Ecological Quality Ratio (EQR), to assess the Palaeo-EcoQS using local reference conditions, and the Enhanced Benthic Foraminifera Oxygen Index (EBFOI), to estimate bottom oxygenation.

Reference EcoQs conditions (1902), at SES are ‘good’, but through time it fluctuates between ‘moderate’ and ‘bad’, shifting to ‘poor’ in the latest years (2003-2012). While at CSE, EcoQs ranges between ‘moderate’ and ‘high’ conditions across the entire sedimentary record, with mean conditions assessed as ‘good’. The EBFOI at SES exhibits low values throughout the core, ranging from -40 to 18, indicative of suboxic and low oxic conditions, aligning to weak hydrodynamic conditions in the area. Conversely, the CSE values range from -11 to 66, suggesting a high oxic environment. The PCA highlights the contrasting response of the BF fauna between the systems. At CSE, the biotic indices exhibit an inverse relationship to the PLI, suggesting higher environmental quality, whereas these indices align closely with poorer environmental conditions at SES.

The study highlights the importance of sedimentary records to distinguish natural from human-induced historical changes in transitional areas. Moreover, it provides valuable information that contributes to environmental monitoring and informs conservation strategies.

Lateral distribution of benthic foraminifera at Moore Reef (Australia)

Marie SCHEEL[1], Patrick GRUNERT[1], Katharina E. FABRICIUS[2], Martin R. LANGER[3]

[1] Institute of Geology and Mineralogy, University of Cologne, Otto-Fischer Str. 14, Cologne, Germany; mscheel3@smail.uni-koeln.de , pgrunert@uni-koeln.de

[2] Australian Institute of Marine Science, 1526 Cape Cleveland Road, Townsville, Australia; K.fabricius@aims.gov.au

[3] Department for Palaeontology, University of Bonn, Kirschallee 3, Bonn, Germany; martin.langer@uni-bonn.de

Coral reefs are facing threats worldwide due to global and local stressors. Benthic foraminiferal assemblages can be used as markers for these stressors and utilized as indicators of environmental quality within the reef system. The Moore Reef study area is located east of Cairns (Australia) and represents an offshore reef within the central Great Barrier Reef.
Here, we study benthic foraminifera in a set of pilot samples from the front site of the reef, recovered from the sediment surface at water depths of 5 m and 15 m. For each water depth, we compare two samples from the same location, taken at an average lateral distance of 30 m. We aim to investigate the lateral variability of each sample pairing with respect to taxonomic composition and functional groups (symbiont-bearing, opportunistic, heterotrophic). The samples were washed and dried and the foraminifera were picked from each. The foraminifera were taxonomically identified at the genus and (if possible) species level. The relative abundances of taxa and functional groups were determined and compared within and between sample pairings. Preliminary results suggest an 87 and 84 percent similarity within the sample pairings. Among functional groups, heterotrophic foraminifers are the most abundant followed by the symbiont-bearing group. The opportunistic group is least abundant in all samples. Especially the samples from the shallower depth show a very high similarity in the composition of their functional groups. We conclude that samples collected at a certain lateral distance do not show significant differences in their foraminiferal assemblages.
Sample material and financial support were provided by the Australian Institute of Marine Science and by the PROMOS scholarship program of the Deutsche Akademischer Austauschdienst (DAAD).

Climate forcing of rapid foraminiferal diversity changes in oligotrophic deep-sea environments during the late Quaternary

Gerhard SCHMIEDL[1], Yvonne MILKER[1], Andreas MACKENSEN[2]

[1] Institute for Geology, Center for Earth System Research and Sustainability, Universität Hamburg, Bundesstraße 55, Hamburg, Germany; gerhard.schmiedl@uni-hamburg.de, yvonne.milker@uni-hamburg.de

[2] Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Am Alten Hafen 26, Bremerhaven, Germany; amackens@posteo.de

The biodiversity of deep-sea ecosystems is closely linked to climate changes during the late Quaternary as documented by the diversity and species composition of benthic foraminifera. The benthic foraminiferal diversity changes are mainly driven by variations in food fluxes and bottom- and pore-water oxygenation with distinct regional differences. Overall, the observed regional diversity patterns suggest that highly diverse deep-

sea ecosystems are more resilient to perturbations such as drops in oxygen than low-diverse ecosystems, supporting the Diversity-Stability Hypothesis. Seasonal phytodetritus pulses in oligotrophic and well-ventilated deep-sea ecosystems, such as the Nordic Seas, commonly result in a dominance of opportunistic taxa and low faunal diversity. The scarcity of potentially denitrifying foraminifera in oligotrophic deep-sea environments explains their high vulnerability to hypoxic conditions. In the ultraoligotrophic eastern Mediterranean Sea, warm and humid climate conditions during insolation maxima repeatedly result in a temporal reduction or cessation of deep-water formation with transient collapses of deep-sea ecosystems and slow recovery afterwards. Understanding the underlying processes of past changes in the diversity of deep-sea benthic foraminifera is useful for assessing the stability of modern deep-sea ecosystems with respect to potential impacts of future climate change and local anthropogenic perturbations.

Monitoring intertidal foraminifera on the German North Sea coast - a 23-year record of environmental change

Joachim SCHÖNFELD[1]

[1] GEOMAR Helmholtz Centre for Ocean Research Kiel, Wischhofstraße 1-3, 24148 Kiel; jschoenfeld@geomar.de

Tidal flats and coastal wetlands are under pressure by sea level rise, global warming and intensified storm surges. The response dynamics of marginal marine systems is constrained by dykes and human foreland management on the southern North Sea coast. No dyke has been built and human intervention is kept at minimum in the salt marsh at Schobüll, Germany, where the natural floral and faunal succession is still preserved. The long-term dynamics of benthic foraminiferal faunas was monitored here in response to environmental changes. Stations on the mudflat, in the pioneer vegetation zone, lower and upper salt marsh were annually sampled since 2000. The vegetation was assessed, sediment properties, elevation, and hydrographic parameters were measured. The station heights were tied to the German Reference Surface and revealed the successive silting-up of the mudflat with 1 cm a-1 on average, interrupted by strong storm surges eroding 8 to 22 cm of the sediment. The accretion rate in the upper saltmarsh was constrained to 1.3 cm a-1. The living (rose-Bengal stained) foraminiferal fauna of the 63-2000 µm size fraction was dominated by *Haynesina germanica* and an *Ammonia tepida* morphotype on the mudflat and the latter increased in abundance through time. *Elphidium williamsoni* was missing since 2015 and was only found in the lower salt marsh since then. The diversity increased through time while the population density showed a high variability and no clear trend. The fauna in the upper salt marsh was dominated by *Jadammina macrescens, Balticammina pseudomacrescens, Trochamminita irregularis* and *Trochammina inflata*. The latter became rare since 2014, and *Balticammina pseudomacrescens* was rare since 2019. *Trochamminita irregularis* decreased in abundance in 2022 while *Haplophragmoides wilberti* and *Miliammina fusca* were on the rise. The faunal dynamics in the upper salt marsh accords with the succession of exceptionally hot and dry summers since 2013.

Snapshot of benthic and planktonic foraminiferal diversities off the Iberian margin through environmental DNA (eDNA)

Magali SCHWEIZER[1], Sophie QUINCHARD[1], Kate F. DARLING[2,3], Lélia MATOS[4,5], Emilia SALGUEIRO[4,5]

[1] University of Angers, Nantes Université, Le Mans Université, CNRS, Laboratoire de Planétologie et Géosciences, LPG UMR 6112, 49000 Angers, France ; magali.schweizer@univ-angers.fr, sophie.quinchard@univ-angers.fr

[2] School of GeoSciences, University of Edinburgh, West Mains Road, Edinburgh EH, UK; kate.darling@ed.ac.uk

[3] Biological and Environmental Sciences, University of Stirling, Stirling FK9 4LA, UK

[4] Portuguese Institute for Sea and Atmosphere (IPMA), Rua Alfredo Magalhães Ramalho 6, 1495-165 Algés, Portugal ;

lelia.matos@ipma.pt, emilia.salgueiro@ipma.pt

[5] Center of Marine Sciences (CCMAR), Algarve University, Campus de Gambelas, 8005-139 Faro, Portugal

The CARBO-ACID research cruise (EUROFLEETS+ SEA02_10) was carried out in August 2022, departing from Vigo (Spain) and ending in Lisbon (Portugal). Plankton and sediment samples were collected during the upwelling season, along two transects coinciding with the two persistent upwelling filaments off the Iberian Margin: the Cape Finisterra (4 sampling sites) and the Cape Roca (3 sampling sites). Plankton filters were sampled at 3 to 7 different water depths (38 samples) and benthic samples taken at three different sediment depths (18 samples). Filters and sediment samples were extracted for environmental DNA (eDNA). The DNA extractions were amplified with foraminiferal specific primers and sequenced with high throughput sequencing (HTS) and a MiSeq device (Illumina) to get about 5.8 million of reads (sequences). After cleaning with bioinformatic tools to remove low quality reads and chimaeras, about 2.8 million of reads and 4000 ASVs (Amplicon Sequence Variants, a proxy for species) were retained. First results show that the identification of planktonic foraminifera works well, whereas the one of benthic foraminifera is much more difficult, with more than 50% of the ASVs unidentified. This is not surprising as the database used for recognition of planktonic foraminifera is almost complete, with most of the known morphospecies sequenced including cryptic species. On the contrary, the database to identify benthic foraminifera is far from complete. This is partly due to the higher diversity of benthic foraminifera: about 100 times more morphospecies than planktonic foraminifera. In addition, the endemism of benthic foraminifera is probably higher than for planktonic foraminifera and the Iberian margin has been little sampled for DNA barcoding and metabarcoding to date, adding to taxonomic uncertainties.

Deep environmental conditions in the Gulf of Genoa (western Mediterranean) since the last deglaciation

Mar SELVAGGI[1,2], Isabel CACHO[1], Pierluigi MARTINELLI[3], Sergi TRIAS-NAVARRO[1], Fabrizio LIRER[2], and Letizia DI BELLA[2]

[1] GRC Geociències Marines, Departament de Dinàmica de la Terra i de l'Oceà, Universitat de Barcelona, Barcelona, SPAIN.

[2] Dipartimento di Scienze della Terra, Università di Roma la Sapienza, Roma, ITALY.

[3] Dipartimento di Scienze della Terra, Università degli Studi di Torino, Torino, ITALY.

This study analyses benthic foraminiferal species assemblages to reconstruct environmental changes that occurred in the Gulf of Genoa over the last ~18 kyrs, based on the sediment core NDT-22-2016 (437 m water depth). The taxonomy data is complemented with oxygen stable isotopes measurements in the shallow infaunal foraminifer *Uvigerina mediterranea*. Our findings reveal significant changes in the benthic taxonomy during the Heinrich Stadial 1 event (HS1) and the first part of the Holocene period (11-9 kyr). These taxonomic changes suggest the occurrence of diverse circulation patterns in the region. We observe that a major influx of costal-derived benthic foraminifera, accompanied by cold and with moderate to strong bottom currents occurred during the HS1 event. We further propose that the changes detected during the first part of the Holocene period (11-9 kyr) represented a major re-organization of the water mass column structure. More precisely, the appearance of a newly formed water mass, probably originated in Gulf of Genoa region, occupied most of the space left by the reduced flow of Levantine Intermediate Water (LIW) due to the Eastern

Mediterranean stagnation associated to the last Sapropel event. These results prove the sensitivity of the studied site to regional climate variability.

µXRF Synchrotron analysis on genus *Subbotina* from the Tethyan Alano section (NE Italy) across the Middle Eocene Climatic Optimum (MECO)

Silvia SIGISMONDI[1], Giuseppe CRUCIANI[1], Valeria LUCIANI[1], Helena L. FILIPSSON[2]

[1] Department od Physics and Earth Sciences, University of Ferrara, Via Saragat 1, Italy; silvia.sigismondi@unife.it, giuseppe.cruciani@unife.it, valeria.luciani@unife.it

[2] Department of Geology, Sölvegatan 12, Lund University, 223 62 Lund, Sweden; helena.filipsson@geol.lu.se

The Middle Eocene Climatic Optimum (MECO; ~40 Ma), is still an enigmatic global warming event, which temporarily interrupted for ~500–600 kyrs, the long-term cooling trend initiated at the end of the early Eocene climatic optimum (~49 Ma). The absence of a clear trigger mechanism coupled with a complex $\delta^{13}C$ excursion makes this event mysterious, sometimes referred to as the middle Eocene "carbon cycle conundrum". While volcanism may represent a plausible excess carbon source inducing the MECO warming, the synchronicity of any single volcanic degassing event remains to be demonstrated. Moreover, the paleoenvironmental and biotic repercussions of the MECO are poorly constrained and still require comprehensive understanding. To investigate the biotic repercussion of this event and explore its driving mechanism we performed high resolution synchrotron-based (SR) techniques (µXRF) on planktic foraminifera (PF) from the Tethyan Alano section (NE Italy) where marked changes in species composition have been recorded during the MECO. This section is also of crucial interest for its paleogeographic position close to the recently identified source of volcanic emissions potentially triggering the MECO warming. We focus on genus *Subbotina*, as previous data from the Alano section display elevated percentage (up to 80%) of malformed tests within the MECO. High resolution SR techniques (µ-XRF) on fossil PF are proposed here as an innovative approach to unravel past oceanic conditions across this event. Synchrotron -XRF measurements allowed us to map the trace elements distribution and demonstrate that during the event PF were exposed to releases of bioactive metal cations (Mn, Cu, Ni, Ti and Zn) that their shells incorporated. In particular, the trace elements investigation shows specifical pattern, with significant difference in the pre and post MECO phase. We hypothesize that the MECO led to the development of shell abnormalities, possibly derived by heavy-metal input possibly deriving from volcanism.

Application of deformed tests of benthic foraminifera in the assessment of environmental quality of the Estuarine System of Santos, SP/Brazil

Beatriz S. M. SILVA [1], Cintia YAMASHITA [1], Silvia H. M. SOUSA [1]

[1] Department of Physical, Chemical and Geological Oceanography, Oceanographic Institute, Universidade de São Paulo, Brazil. Praça do Oceanográfico, 191, CEP: 05508-120, São Paulo, SP, Brazil; beatriz.saito28@usp.br, cintia.yamashita@usp.br, smsousa@usp.br

Benthic foraminifera are abundant unicellular protists in oceanic and coastal sediments and are excellent environmental indicators due to their rapid response to environmental variations. Therefore, these organisms have been used to study environments polluted by heavy metals, petroleum hydrocarbons, sewage effluents, and other pollutants. In response to variations in marine physicochemical parameters, benthic foraminifera

may exhibit changes in their abundance and diversity and develop deformities in their tests. Thus, the objectives of this work are: a) to understand the distribution of deformed foraminiferal tests in the estuarine system of Santos/Brazil; b) to evaluate the role of heavy metals detected in the calcareous shells and other abiotic factors in the development of deformities in foraminiferal tests; and c) to assess how deformities affecting foraminifera can be used in the environmental assessment of the Santos estuary, which has a history of pollution from toxic waste and liquid effluents since the beginning of industrial activities in São Paulo. For this purpose, different types of deformities in foraminiferal tests were identified and counted for the application of the FAI (Foraminiferal Abnormality Index - based on the relative abundance of deformed specimens per sample), that indicated a gradient in environmental quality across the study area, such that in the upper estuary region, characterized by higher environmental stress conditions, a high relative abundance of deformed specimens was observed, with this abundance progressively decreasing towards Santos Bay, an area with lower environmental impact. In order to deepen the investigation of the deformities affecting benthic foraminifera, Energy Dispersive Spectroscopy (EDS) analyses and microphotographs through Scanning Electron Microscopy (SEM) will be performed to compare the chemical composition and morphological aspects of deformed and non-deformed foraminifera. The results obtained will be compared with other abiotic data related to organic pollutants to verify the degrees of influence of these factors on the development of deformities in foraminiferal tests.

Planktic foraminiferal response to the variations in the Agulhas Current during Early Quaternary: Evidences from IODP Hole U1474A

Vikram Pratap SINGH[1], Shivani PATHAK[1], Rahul DWIVEDI[1]

[1] Department of Geology, Indira Gandhi National Tribal University, Amarkantak, India; vikram.singh@igntu.ac.in, shivani.jpathak@gmail.com, drahul17@gmail.com

The Agulhas Current (AC) ist he largest western boundary current that regulates the Atlantic Meridional Overturning Circulation (AMOC) by feeding the returning arm through the Agulhas Leakage via the Indo-Atlantic gateway. Over the last 2.6 million years, there have been several episodes of reduction in the AC, mostly in response to the waxing Antarctic Ice Sheet (AIS) due to glaciation.

In the present study spanning 2.6 to 1.2 Ma, we have identified four events of reduced AC on the basis of the relative abudnance of Southern Ocean Fauna (SOF) and Agulhas Fauna (AF) and $\delta^{18}O_{\textit{Gs. ruber}}$ from the IODP Hole U1474A. The SOF includes the cold temperate-subpolar forms, while the AF comprises of warm tropical and subtropical dwellers. The events of reduced AC are discovered at 2.45 My, 2.06 My, 1.59 My and 1.24 My.

The early Pleistocene started with lower SOF till 2.45 Ma, after which an abrupt rise of 30%, corroborated with extremely low AF and positive $\delta^{18}O$ indicate the first events of reduced AC. The onset of the intensification of Northern Hemisphere Glaciation (INHG) at 2.7 Ma seems to have triggered these changes, leading to an incursion of cold Southern Ocean waters at the site. Further, till 2.2 Ma there was no evident cooling as the SOF remained extremely low. A cooling trend started at 2.2 Ma which led to an extreme event at 2.06 Ma, marked by an abrupt rise of SOF, also supported by a positive excursion in the $\delta^{18}O$ values and extremely low AF. It was followed by two more events of abrupt rise in the SOF at 1.58 and 1.24 Ma. Of these two, the first event at 1.58 Ma was a severe glacial event as evident by the SOF constituting almost half oft he totla faunal population. Both these events are coincident with the cooling of southeast Atlantic Ocean between 1.6 and 0.9 Ma. These glacial events led to the weakening of the AC.

Textularia agglutinans, a cosmopolitan calcifying benthic foraminifera in disguise: A new geochemical recorder of coastal environments

Tamara SOSNITSKY[1], Vasilisa KREKOVA[1], Bar ELISHA[1], Aleksey SADEKOV[2], Adi TORPSHTEIN[5], Sigal ABRAMOVICH[1], Sarit ASHCKENAZI-POLIVODA[3,4*]

[1] Department of Earth and Environmental Sciences, Ben-Gurion University of the Negev, Beer Sheva 8410501, Israel; sosnitta@post.bgu.ac.il, sigalabr@bgu.ac.il, brelisha@gmail.com, vasilisa@post.bgu.ac.il

[2] The University of Western Australia, 35 Stirling Highway, 6009 Perth, Australia; aleksey.sadekov@uwa.edu.au

[3] Dead Sea and Arava Science Center, Masada National Park, Mount Masada, 86910, Israel

[4] Ben-Gurion University of the Negev, Eilat 8855630, Israel; sarit@adssc.org

[5] The Fredy & Nadin Herrman Institute of Earth Sciences The Hebrew University, The Edmond J. Safra Campus - Givat Ram, Jerusalem 9190401, Israel; adi.torf@mail.huji.ac.il

Calcifying foraminifera from the orders Rotaliida and Miliolida are widely used as geochemical recorders in paleoceanography and biomonitoring. Agglutinated foraminifera are generally overlooked in these studies because their shells are mostly composed of alien particles from the surrounding environment. The agglutinated species *Textularia agglutinans* d'Orbigny is exceptional. Its test (shell) consists of a thick internal self-precipitated calcitic wall covered externally by agglutinated practices, cemented by micritic calcite. This species is known for its widespread distribution, and its exceptionally long evolutionary record spanning into the Late Cretaceous.

The present study provides the first geochemical characterization of the inner calcitic layer of *T. agglutinans*, to establish its use as a recorder of both temperatures and heavy metal pollution. The study is based on specimens collected from the shallow Mediterranean coast of Israel, where the species has become extremely abundant. Laser ablation ICP-MS analyses were done on field specimens and compared to whole test ICP-MS measurements of jointly sampled two rotaliid species (*A. lobifera* and *P. calcariformata*) and the miliolid taxa *Lachlanella*. The Mg/Ca temperature calibration were based on LA-ICP-MS analyses of new chambers of specimens cultured in a mesocosm setup for a month, under 17°, 20°, 25 °C.

Textularia agglutinans is a mid Mg species ranging from ~30 to ~60 mmol/mol, showing a clear temperature sensitivity with trend that resembles those of high Mg species. The elements/Ca ratios of *T. agglutinans* are highly variable and range between milliolid and rotallids. The most unique geochemical feature of this species is its Sr/Ca ratios (2.7-7.8 mmol/mol) that are considerably higher all known foraminifera, coccolithophores, bivalves and are more similar to calcifying corals. These findings imply that *T. agglutinans* evolved an exclusive biomineralization mechanism for building its internal calcitic test, contradicting an expected synapomorphy with rotallids, derived from their close phylogenetic relationship.

Living (stained) benthic foraminifera from Southern Brazilian Margin: a comparative study of size fractions (63-125 µm and > 125 µm) and sedimentary strata (0-1 and 1-2 cm)

Silvia H. M. e SOUSA[1], Ana Cláudia A. SANTAROSA[1], Cintia YAMASHITA[1], Thaisa M. VICENTE[1], Maria Virginia A. MARTINS[2,3]

[1] Laboratório de Bioindicadores Ambientais. Instituto Oceanográfco, Universidade de São Paulo, Praça do Oceanográfco, 191, Cidade Universitária, São Paulo, SP, 05508-120, Brazil; smsousa@usp.br, ana.santarosa@usp.br, cintia.yamashita@usp.br, thaisamv@gmail.com

[2] Universidade do Estado do Rio de Janeiro - Faculdade de Geologia, Av. São Francisco Xavier, 524, Maracanã, Rio de Janeiro, SP, 20550-013, Brazil; virginia.martins@ua.pt

Living benthic foraminifera from deep-sea stations in the Santos Basin Southern Brazilian Margin, were studied to compare and comprehend distribution patterns across the 63–125 µm and >125 µm size fractions and two different sediment intervals (0-1 and 1-2 cm). The objective was to establish a method for analyzing benthic foraminifera applicable to environmental evaluation and bio-monitoring. Forty-five stations were collected at water depths ranging from 400 m to 2,400 m during the austral winter of 2019, using box corer sampling. Statistical tests, including ANOVA and Wilcoxon, conducted on benthic foraminifera density (D), total species (S), Pielou's evenness (J'), and Shannon diversity (H') confirmed the presence of significant differences between the two sediment layers and size fractions. The superficial level showed a higher D and S. The most abundant and frequent species in this layer were *Globocassidulina subglobosa*, *Epistominella exigua*, *Alabaminella weddellensis*, *Reophax* sp.1, *Seabrookia curta*, *Bolivina albatrossi*, *Reophax tortilis*, and *Trifarina bradyi*, while in the 1-2 cm layer were *Reophax* sp.1, *G. subglobosa*, *Aschemonella* sp.1, *Bolivina albatrossi*, *A. weddellensis*, *E. exigua*, and *Uvigerina auberiana*. Regarding the different size fractions, the larger one (>125 µm) showed lower D but higher S and higher values of the H'. The assemblages presented on average 65% agglutinated species and 33% calcareous species. In the 63-125 µm size fraction, are overall composed of 53% agglutinated and 43% calcareous species, showing that the proportions of agglutinated species decrease while calcareous species increase from the larger to the smaller size fraction. Based on the statistically different results of the diversity indices, as well as the distinctive composition of species between the two layers and size fractions, we recommend the use of the >63 µm size fraction and 0-2 cm for future studies on benthic foraminifera in oligotrophic deep-sea areas.

Coastal foraminifera dispersion dynamics into deep-sea sediments

Marleen STUHR[1], Francesca GIOVENZANA[2], Hildegard WESTPHAL[1,2,3], Fabio MARCHESE[2], Marco TAVIANI[4]

[1] Leibniz Centre for Tropical Marine Research (ZMT), Bremen, Germany; marleen.stuhr@leibniz-zmt.de, hildegard.westphal@leibniz-zmt.de

[2] King Abdullah University of Science and Technology (KAUST), Thuwal, Saudi Arabia; francesca.giovenzana@kaust.edu.sa, fabio.marchese@kaust.edu.sa

[3] Geosciences, Bremen University, Germany

[4] Istituto di Scienze Marine, Consiglio Nazionale delle Ricerche, Bologna, Italy; marco.taviani@bo.ismar.cnr.it

Benthic foraminifera are key indicators for environmental assessment in modern and fossil habitats, yet relocated specimens pose challenges in their application. In a recent survey focusing on the development of shallow- and deep-water carbonate-producing ecosystems systems offshore western Saudi Arabia in the northern Red Sea, we discovered large shallow-water foraminifera as a minor but recurring component in the skeletal assemblages of deep-sea sediments, mainly dominated by particles shed by pelagic factories. Taxonomy and abundance of these foraminifera reveal at least three symbiont-bearing taxa (e.g., Soritidae, Amphisteginidae and Nummulitidae) at depths ranging from 429 to 938 m. Typically associated with shallow seagrass and coral reef environments, their occurrence prompts speculation about displacement to bathyal depths from original habitats. We propose a process by means of passive rafting via floating seagrass transported offshore, from the Al Wajh shelf. Our hypothesis is supported by well-preserved seagrass leaves and rhizomes, along with their encrusting community, in sediment cores from a brine pool at 668 m depth—at least 20 km offshore from the nearest shallow-water habitat. The coastal abundance of seagrass emerges as a key facilitator, enabling the passive transport and dispersal of foraminifera and their propagules into distant environments. This dispersal may not only drive quick invasions into new habitats but also highlights potential displacement from original environments. These findings underscore the importance of careful foraminifera interpretation as bioindicators, given the complex dynamics of their dispersion and the influence of relocated specimens or alien species on environmental assessments.

Foraminiferal Perspectives on Coral Reef Health and Sedimentary Carbonate Production in the Chagos Archipelago

Marleen STUHR[1], Ines D. LANGE[2], Lea TA FUCHS[1,3], Aitana GEA NEUHAUS[1,4], Chris T. PERRY[2]

[1] Leibniz Centre for Tropical Marine Research (ZMT), Bremen, Germany; marleen.stuhr@leibniz-zmt.de

[2] Geography, University of Exeter, UK; i.lange@exeter.ac.uk, c.perry@exeter.ac.uk

[3] Geosciences, Bremen University, Germany; leafuchs@uni-bremen.de

[4] Institute for Chemistry and Biology of the Marine Environment (ICBM), Oldenburg University, Germany; aitana.geaneuhaus@plymouth.ac.uk

The ongoing degradation of coral reef ecosystems poses significant challenges to the geo-ecological functions they provide, particularly in terms of carbonate sediment production crucial for tropical beach and island formation. This study focuses on the contribution of benthic foraminifera to sedimentary carbonate production and their role as sensitive bioindicators, offering insights into the impact of environmental changes. Here we investigate spatial and temporal patterns in benthic foraminifera communities across the Chagos Archipelago, Indian Ocean, to a) quantify their contribution to sedimentary carbonate production states across reef zones and islands of three atolls, and b) to detect temporal and spatial variations potentially related to changes of the benthic community or local inputs of seabird-derived nutrient subsidies. Our findings indicate substantial variability in foraminiferal carbonate production across depths, with greater contributions observed in the lagoons compared to outer reef slopes. Furthermore, initial results suggest higher foraminiferal productivity around islands with large seabird populations, possibly linked to guano-derived nutrient runoff or enhanced microhabitat and substrate availability (e.g., more calcareous algae). Long-term analysis reveals shifts in foraminiferal communities between 1979 and 2021, reflecting changes in benthic communities following coral bleaching events, from species common in coral-dominated habitats (e.g., *Amphistegina* spp.) to those indicating more algae-dominated realms (e.g., *Neorotalia* spp.). However, the application of the FoRAM Index, a bioindicator metric for water quality derived from foraminiferal communities, indicates favorable conditions for reef calcification and high post-disturbance recovery potential in this marine protected area. This study contributes valuable insights into the dynamic relationship between benthic foraminifera, environmental change, and reef ecosystem health.

Clues for carbonate system dynamic in the southeast Brazilian continental margin

Jaime Y. SUÁREZ-IBARRA*[1], Tamiris ZARDIN[2], Stephanie LEONE[3], Maria A.G. PIVEL[4], Bruna B. DIAS[5], Sonia CHAABANE[6], Thibault de GARIDEL-THORON[6], Gerson FAUTH[2], Luigi JOVANE[3]

[1] Ustav Geologie a Paleontologie, Prirodovedecka Fakulta, Univerzita Karlova v Praze, Czechia

[2] Instituto tecnológico OCEANEON, Universidade do Vale do Rio dos Sinos, Brazil

[3] Instituto Oceanográfico, Universidade de São Paulo, Brazil

[4] Centro de Estudos de Geologia Costeira e Oceânica, Universidade Federal do Rio Grande do Sul, Brazil

[5] Escola de Artes, Ciências e Humanidades, Universidade de São Paulo, Brazil

[6] Aix-Marseille Université, CNRS, IRD, INRAe, CEREGE, France.

* corresponding author: jysuarezibarra@gmail.com

Different mechanisms have been proposed to account for the carbonate preservation history in the south Brazilian continental margin, western South Atlantic, during the late Quaternary. Some studies have documented a coupling between surface productivity and carbonate dissolution, in sites located at the mid and lower slopes for the southern region, linked with increased dissolution occurring during high productivity

intervals due to remineralisation of organic matter. Yet, this is not the case in the southeast Brazilian continental margin. Here, we study the changes in past surface productivity, and carbonate dissolution at the mid slope of the southeast Brazilian continental margin using 55 samples from core C2-GC3 (24°48' S, 44°00' W, 1287 mbsl). The preliminary age model, based on six benthic $\delta^{18}O$ tie points, suggests our core spans the 7-82 ka time interval (marine isotope stages, MIS, 1-5). Calcium carbonate content ($CaCO_3$ %) fluctuates between 10 and 40%, with minimal values during MIS4 and higher values during MIS1. The benthic $\delta^{13}C$ record follows similar changes as the carbonate content except for the MIS5 period when values are minimum. While planktonic foraminiferal $\delta^{13}C$ values on *Globigerina bulloides* suggest no changes in nutrient availability, the surface planktonic ratio of eutrophic *G. bulloides* to oligotrophic *Globigerinoides ruber* species from a nearby core records low values during MIS4 and 2. Both previous proxies for surface productivity suggest a decoupling with carbonate dissolution. Finally, our $CaCO_3$ (%) and benthic $\delta^{13}C$ records align with nearby deeper cores (~2000 mbsl), suggesting a connection between carbonate preservation and changes in bottom water masses geometry. Additional analyses, including conservative water masses tracers (e.g., εNd) and ongoing planktonic foraminifera counts in our core, will enhance our understanding of the carbonate system in the southeast Brazilian continental margin.

Examining the influence of contemporary climate change on foraminifera and their calcium carbonate production in a rapidly changing fjord.

Natalia SZYMAŃSKA[1], Magdalena ŁĄCKA[1], Marek ZAJĄCZKOWSKI[1]

[1] Institute of Oceanology, Polish Academy of Sciences, Powstańców Warszawy 55, 81-712 Sopot; natalia@iopan.pl, mlacka@iopan.pl, trapper@iopan.pl

Foraminiferal calcium carbonate production is an important aspect of global carbon burial. Planktic foraminifera are widely recognized as significant producers of calcium carbonate worldwide. However, benthic foraminifera have received relatively little attention in this context. Our research in Arctic fjords indicates that benthic foraminifera contribute substantially to sedimentary carbon in high latitudes. Changes in their species composition and abundance have the potential to significantly influence the amount of carbon sequestered in glacimarine sediments in the Arctic.

Our study reveals shifts in the composition of foraminiferal assemblages between sediments collected in 2002 and those taken in 2019 in an Arctic fjord. Both the concentration of foraminiferal tests and species diversity have declined. Currently, more opportunistic species such as *Cassidulina reniforme* and *Elphidium clavatum*, as well as agglutinated species like *Recurvoides turbinatus* and *Labrospira crassimargo*, are dominant. In contrast, larger, more specialized species like *Nonionellina labradorica* were more prevalent in the past (referring to the assemblage found in 2002). This has large implications for foraminiferal carbon contribution to the sedimentary carbon pool.

The changes observed in foraminiferal assemblages can be attributed to contemporary climate change. The location of the study, Hornsund fjord, is strongly affected by Atlantification, glacier loss, and reduction in sea ice cover. These processes are closely linked to contemporary climate change. Our study uncovers a strong correlation between climate, oceanography, and foraminiferal carbon production, and provides numerical data on foraminiferal carbon production from the most abundant species in the fjord.

This study was funded by project National Science Centre of Poland, grant no 2022/45/B/ST10/02033.

Exploring Cenozoic paleoenvironmental dynamics along the NW margin of South America: insights from benthic foraminiferal analysis

Raúl TREJOS-TAMAYO[1,2,3], Andrés PARDO-TRUJILLO[2,3,4], José-Abel FLORES[1]

[1] Departamento de Geología, Universidad de Salamanca, Plaza de los Caídos 37008, Salamanca, Spain; raul.trejos@ucaldas.edu.co; flores@usal.es

[2] Instituto de Investigaciones en Estratigrafía, Universidad de Caldas, Calle 65 No. 26-10, 170004, Manizales, Colombia

[3] Grupo de Investigación en Estratigrafía y Vulcanología (GIEV-Cumanday), Universidad de Caldas, Calle 65 No. 26-10, 170004, Manizales, Colombia.

[4] Departamento de Geología, Universidad de Caldas, Calle 65 No. 26-10, 170004, Manizales, Colombia; andres.pardo@ucaldas.edu.co

The NW margin of South America is strategically important, as it has been a key point in the intermittent connection between the Pacific and Atlantic oceans throughout the Cenozoic, significantly influencing global ocean circulation. Although its relevance, paleoenvironmental understanding in this region is limited.
To explore its paleoenvironmental evolution, we examined the abundance and diversity of benthic foraminifera in wells drilled by the oil industry along the Caribbean margin of Colombia from the lower Eocene to the Pliocene. We observe deep-water agglutinated assemblages in the lower Eocene, which indicate turbiditic settings. The upper Eocene shows two environments: one with abundant calcareous-walled foraminifera suggestive of well-oxygenated shallow waters and another marked by lower slope agglutinated indicative of poorly oxygenated bottoms. In the lower Oligocene, a significant increase of calcareous taxa indicative of slope and suboxic conditions represents a change in conditions. The Oligocene to middle Miocene sequences reflect predominantly oxygen-poor, nutrient-rich slope foraminifera, occasionally punctuated by coral reef assemblages. Upper Miocene and lower Pliocene samples show microfossils indicative of shelf environments influenced by fluvial inputs.
The tectonic complexity of the region poses challenges to micropaleontological studies, such as variable sedimentation rates, poor preservation of microfossils due to diagenetic processes, and difficulty distinguishing regional from global signals. Despite these, our research unveils the diverse paleoenvironments of the area, revealing a correlation between its evolution and tectonic processes. However, it is plausible that global climatic influences also play a role. Unraveling the extent of this influence is fundamental to understanding the development of marine environments in the region.

Mn lamination in shells of symbiont-bearing foraminifera linked to day-night cycle

Inge VAN DIJK[1], Christine BARRAS[1], Aurelia MOURET[1], Gert-Jan REICHART[2], Emmanuelle GESLIN[1]

[1] Laboratoire de Planétologie et Géosciences, CNRS, Univ. d'Angers, Nantes Université, Le Mans Université, Angers, France; inge.vandijk@univ-angers.fr

[2] NIOZ - Royal Netherlands Institute for Sea Research, Texel, the Netherlands

Previous studies on the micro distribution of manganese in the foraminiferal shell wall have shown broad bands of low and high Mn. The broad banding seems to correspond to lamination of secondary layers of calcium carbonate added on older chambers during chamber formation, suggesting the bioavailable Mn changed for different calcification events. This was previously observed in a controlled experiment at hypoxia, but only for symbiont bearing species, suggesting that in these conditions, presence of symbionts and their activity could have an impact on the Mn incorporation.
To further explore the impact of symbiont activity on Mn lamination of symbiont bearing foraminifera, an additional experiment was performed using symbiont-barren *Ammonia confertitesta* and symbiont-bearing

species *Amphistegina lessonii* and *Heterostegina depressa*. The experiment was performed using small culture vessels that receive different media during the day and night, synchronous with the change in light conditions (12h/12h). The experiment was performed with seawater with high [Mn] kept under hypoxic conditions (30% oxygen saturation). Group 1 received culture media+Sr spike during the night, and group 2 received the culture media+Sr spike during the day. The Sr spike ensured we could determine if the calcite was precipitated during the day or the night, to investigate the link between light conditions and the Mn misdistribution. After several days, the foraminifera were harvested, cleaned, polished to reveal shell cross sections, after which Ca, Mn, Sr and Mg was measured by an electron microprobe.
For *A. lessonii* from both groups we observe covariation of Sr and Mn values, where in both groups low Mn concentrations are found during the day calcite, i.e. the calcite with low Sr values for group 1, and high Sr values for group 2. This shows the Sr spike did not drive the changes in Mn incorporation, and that Mn lamination is linked to the moment of calcification, during the day or night. The same observations were found for the limited number of *H. depressa,* but not *A. confertitesta*, suggesting symbiont activity to be the dominant driver of this broad Mn lamination. Symbiont activity changes during the day cycle, and suggests that during the day, symbionts are changing the bioavailability of Mn in the microenvironment of the foraminifer.

Adaptions of foraminifera to low oxygen conditions: evidence from survival, growth rates, shell porosity, microbiome and chlorophyll content

Inge VAN DIJK[1], Christine BARRAS[1], Shai ORON[2,3], Mariandrea ROUSSELIN[1], Aurélia MOURET[1], Magali SCHWEIZER[1], Emmanuelle GESLIN[1]

[1] Laboratoire de Planétologie et Géosciences, CNRS, Univ. d'Angers, Nantes Université, Le Mans Université, Angers, France; inge.vandijk@univ-angers.fr

[2] Department of Marine Geosciences, Charney School of Marine Sciences, University of Haifa, Haifa, Israel

[3] The Interuniversity Institute for Marine Sciences, Eilat, Israel

Marine low-oxygen zones have been increasing since the 1960s affects the stability of marine ecosystems. We present data of foraminifera cultured under controlled oxygen concentrations to better understand their capability to adapt to future and past low oxygen conditions. We investigated different species of foraminifera, two symbiont-barren species *Ammonia confertitesta* (with big pores) and *Ammonia aberdovyensis* (with small pores) and two tropical symbiont-bearing species *Amphistegina lessonii* and *Operculina ammonoides*. The pore patterns of shells have been observed in foraminifera exposed to different conditions of oxygenation of the surrounding seawater, but so far this has not been tested nor calibrated in controlled laboratory conditions. We investigated changes in shell porosity and a range of different biological parameters, i.e. survival and shell growth rate, as well as microbiome and chlorophyll content of the symbiont bearing species.
For all species, the number of newly formed chambers decreased in anoxic conditions, while survival rates were not affected in all cases. This shows most foraminifera can survive short periods of lower oxygen conditions but will precipitate less $CaCO_3$. For both species of *Ammonia*, porosity gradually increased with lower oxygen, while for symbiont-bearing *Amphistegina lessonii,* porosity only increased at the lowermost tested oxygen conditions, suggesting symbiont activity might support the foraminifer until a certain hypoxia threshold is reached. Peculiarly, *Operculina ammonoides* does not adapt its porosity at low oxygen conditions and performs poorly in anoxic conditions in terms of survival and chamber addition. This suggests that not all species are capable of changing shell porosity, an ability needed to maintain metabolism at low oxygen conditions. We also observed changes in 16S and chlorophyll contents for both symbiont-bearing species, which suggests that variations in oxygen conditions impact the foraminiferal microbiome.
Together, our results might indicate that 1) species of foraminifera that have symbionts and are capable to change porosity, like *Amphistegina lessonii*, are more likely to survive low oxygen conditions, and that 2) shell porosity of symbiont-barren species, like *Ammonia* could be used as a proxy for past oxygen conditions.

Enigmatic early Pleistocene interglacial co-occurrence of *Neogloboquadrina pachyderma* with subtropical species at the southern Portuguese margin: Evidence for a "not (sub)polar" variant

Antje H.L VOELKER[1,2], Erin O'NEILL[1], Mónica DUQUE-CASTAÑO[1,2,3]

[1] Divisão de Geologia e Georecursos Marinhos, Instituto Português do Mar e da Atmosfera, Algés, Portugal; antje.voelker@ipma.pt

[2] Centre of Marine Sciences (CCMAR), Universidade do Algarve, Faro, Portugal

[3] Universidade do Algarve, Campus de Gambelas, Faro, Portugal; monica.duque.castano@gmail.com

The Gulf of Cadiz is a region influenced by surface waters from the subtropical gyre that are largely a advected by the Azores Current, as reflected by the strong contribution of subtropical species to the planktonic foraminifera fauna. However, the sediment records from the Gulf of Cadiz also revealed incursions of subpolar waters based on the presence of *Neogloboquadrina pachyderma* during abrupt stadial events when the Atlantic meridional overturning circulation was reduced and the subarctic front moved into the lower mid-latitudes of the North Atlantic. Whereas initial studies documented such occurrences during the Heinrich events of the last glacial cycle, recent studies at IODP Site U1387 (36°48´N, 7°43´W) have recorded their existence back into the early Pleistocene. So, occurrences of *N. pachyderma* in the Gulf of Cadiz were typically associated with subpolar surface waters and the (sub)polar variant of the species. Recently, when analyzing the planktonic foraminifera fauna during interglacial Marine Isotope Stage (MIS) 47 and MIS 31, we observed the co-occurrence of *N. pachyderma* with subtropical species. During MIS 47, when the subtropical species dominated the fauna (≥30 %), the presence of *N. pachyderma* specimens was observed in several samples. Also, during MIS 31, *N. pachyderma* was found in nearly all the samples, despite subtropical species having abundances of 25% and more, especially the early phase of MIS 31 when *N. pachyderma* percentages reached 10-25%. Given the strong influence of subtropical water reflected in the faunas, we believe that the *N. pachyderma* specimens found in the interglacial samples present not the subpolar variant, but one associated with temperate or even subtropical waters.

Heterochrony in the evolution of the *Globigerinoidesella fistulosa* (planktonic foraminifera)

Bridget WADE[1], Christopher POOLE[1], Thomas EZARD[2], Anieke BROMBACHER[2,3]

[1] Department of Earth Sciences, University College London, London, United Kingdom; b.wade@ucl.ac.uk, poolechris@live.co.uk

[2] School of Ocean and Earth Science, University of Southampton, Southampton, United Kingdom; t.ezard@soton.ac.uk

[3] Department of Earth & Planetary Sciences, Yale University, New Haven, United States of America; anieke.brombacher@yale.edu

Planktonic foraminifera are extremely well-suited to study evolutionary change in the fossil record due to their abundance deposits and global distribution. Species are typically conservative in their shell morphology with the same geometric shapes appearing repeatedly through iterative evolution, but the mechanisms behind the architectural limits on foraminiferal shell shape are still not well understood. To understand when and how these developmental constraints evolve, we study morphological change leading up to the origination of the unusually ornate species *Globigerinoidesella fistulosa*. This morphospecies is an important biostratigraphical marker for the Pliocene–Pleistocene. We measured the size and circularity of over 900 specimens of *G. fistulosa*, its ancestor the *Trilobatus sacculifer* plexus (*T. sacculifer, T. quadrilobatus, T. immaturus* and *T. trilobus*) and intermediate forms from a site in the western equatorial Pacific. Our results show that the origination of *G. fistulosa* from the *Trilobatus sacculifer* plexus involved a combination of two heterochronic expressions: earlier onset of protuberances (pre-displacement) and steeper allometric slope (acceleration) as compared to its ancestor. Our work provides a case study of the complex morphological and developmental changes required to produce unusual shell shapes and highlights the importance of developmental deviations in evolutionary origination.

Foraminifera from the 19th century as baselines for modern environmental change and invasion studies – insights from the Sicily Channel

Anna E. WEINMANN[1], Nicoletta MANCIN[2], Antonio CARUSO[3], Julian EVANS[4]

[1] Geological-Paleontological Department, Natural History Museum Vienna, Burgring 7, Vienna, Austria; anna.weinmann@nhm.at

[2] Dipartimento di Scienze Della Terra e Dell'Ambiente, Università di Pavia, Via Ferrata 1, Pavia, Italy; nicoletta.mancin@unipv.it

[3] Dipartimento di Scienze e Tecnologie Biologiche Chimiche e Farmaceutiche, Università di Palermo, Via Archirafi 18, Palermo, Italy; antonio.caruso@unipa.it

[4] Department of Biology, University of Malta, Msida, MSD 2080, Malta; julian.evans@um.edu.mt

Foraminifera have emerged as widely-used indicators for modern environmental change, *e.g.* pollution, rising temperatures, or the introduction of invasive alien species. The latter is a prominent perturbation in the Mediterranean Sea, where alien taxa like *Amphistegina* are expanding their abundance and distribution thus impacting local communities. Recently, extensive studies in the central Mediterranean, *e.g.* the northern Ionian Sea or the Sicily Channel, have documented the negative impacts of invasive species on diversity and community structure.

In order to evaluate the effect of recent invaders, a better understanding of the pre-invasion assemblages and their patterns is necessary. Therefore, we analyzed sediment samples from Malta and Sicily from the 19th century, which provide a unique peek into actual assemblages from pre-invasion times. Our goals for the present study were1) to establish an inventory of the historic foraminiferal assemblages that serves as a baseline for future environmental studies, and 2) to compare this baseline with modern assemblage data from the same area to evaluate the connection between pre-invasion communities and assemblages at varying stages of modern invasion by *Amphistegina* documented in the Sicily Channel.

We found diverse foraminiferal assemblages in the historic material with 137 benthic species in Malta, 101 species in eastern Sicily, and 98 species in northern Sicily. The historic assemblages showed high abundances of epiphytic foraminifera and small miliolids, which are particularly sensitive to the invasion of *Amphistegina*. A comparison with modern assemblage data from the Sicily Channel revealed that the historic communities are quite distinct and only show closer relations to assemblages from modern-day eastern Sicily, which has been categorized as still being in the early stages of invasion. On the other hand, assemblages from an advanced stage of invasion by *Amphistegina* in modern-day Malta had the largest differences in composition.

Our results will be useful in future invasion studies and can help to establish the status of indigenous, cryptogenic, or alien taxa. Further, they can be utilized as important baselines for the ongoing and future monitoring of the invasion stages in the area.

Distribution of *Neogloboquadrina pachyderma* morphotypes in the Central Arctic Ocean – first clonal schizont event observed in the wild

Tirza M. WEITKAMP[1,2], Flor VERMASSEN[1,2], Allison Y. HSIANG[1,2], Clare BIRD[3], Kate DARLING[3,4] & Helen K. COXALL[1,2]

[1] Department of Geological Sciences, Stockholm University, Stockholm, Sweden; tirza.weitkamp@geo.su.se flor.vermassen@geo.su.se allison.hsiang@geo.su.se helen.coxall@geo.su.se

[2] Bolin Centre for Climate Research, Stockholm University, Stockholm, Sweden; tirza.weitkamp@geo.su.se flor.vermassen@geo.su.se allison.hsiang@geo.su.se helen.coxall@geo.su.se

[3] Biological and Environmental Sciences, University of Stirling, Stirling FK9 4LA, UK; clare.bird2@stir.ac.uk kate.darling@ed.ac.uk

[4] School of Geosciences, University of Edinburgh, West Mains Road, Edinburgh EH9 3FE, UK; kate.darling@ed.ac.uk

The modern Arctic Ocean is dominated by a single species of planktonic foraminifera, *Neogloboquadrina pachyderma*. Sedimented *N. pachyderma* exhibit large morphological variability, resulting in recognition of 6 morphotypes, including a dextrally coiled form. Current hypotheses link these morphotypes to differences in ecology or life history, including the possibility of an asexual reproductive stage, although evidence from 'wild' populations is lacking. Here we explore how test morphology varies in living and sedimented *N. pachyderma*, using data from 8 plankton-net stations from the Central Arctic, 5 paired to seafloor sediments. Using high-throughput imaging (AutoMorph) to acquire large morphometric data sets (ca. 15.000 specimens), we present data on coiling direction, test size and degree of encrustation. Overall, living Arctic *N. pachyderma* populations are dominated (68-88%) by relatively small (80-125 µm) individuals referrable to the Nps-5 morphotype. Notably, 8-31% of the total standing stock is dextrally coiled Npd. The >125 µm size-category contains all 4 'Nps' morphotypes, but is also dominated by non-encrusted Nps-5 (52-68%), the remainder comprising the encrusted morphotypes Nps-1-4, familiar to palaeoceanographers. In contrast, seafloor sediments (>63 µm) are dominated by Nps 1-4 (40-70%), although still with significant proportions of Nps-5 (25-53%). Coiling is overall 5.5% dextral in the sediment. Our results show a mismatch in coiling direction, test size and degree of encrustation between the water column and the seafloor. We interpret the unusually high proportion of small Npd in the water column as the result of asexual reproduction events, fortuitously captured in our plankton hauls. Drawing on results from *N. pachyderma* culture studies, we propose this to be evidence of a schizont cloning cycle in *N. pachyderma*, which contributes numerous often dextrally-coiled offspring, and maybe a critical survival strategy in the ultra-seasonal Arctic.

Cumberland Bay (South Georgia) glacial evolution during the Holocene.

Jack WILKIN[1,2], Claire ALLEN[2], Erin McCLYMONT[3], Rowan DEJARDIN[4], Victoria PECK[2], George SWANN[5], James SCOURSE[1], Melanie LENG[6,7], Kate LITTLER[1,8], Kerry STRONG[4], Sev KENDER[1,6]

[1]Department of Earth and Environmental Sciences, University of Exeter, Penryn, United Kingdom; jw923@exeter.ac.uk, j.scourse@exeter.ac.uk, k.littler@exeter.ac.uk, s.kender@exeter.ac.uk

[2]British Antarctic Survey, Cambridge, United Kingdom; jw923@exeter.ac.uk, csall@bas.ac.uk; vlp@bas.ac.uk

[3]Department of Geography, Durham University, Durham, United Kingdom; erin.mcclymont@durham.ac.uk, k.a.strong@durham.ac.uk

[4]School of Geographical Sciences, University of Bristol, Bristol, United Kingdom, rowan.dejardin@bristol.ac.uk

[5]School of Geography, University of Nottingham, University Park, Nottingham, United Kingdom, george.swann@nottingham.ac.uk

[6]British Geological Survey, Nottingham, United Kingdom; mjl@bgs.ac.uk, s.kender@exeter.ac.uk

[7]School of Biosciences, University of Nottingham, Loughborough, United Kingdom, melanie.leng@nottingham.ac.uk

[8]Environment and Sustainability Institute, University of Exeter, Penryn, United Kingdom; k.littler@exeter.ac.uk

Today, South Georgia is heavily glaciated with glaciers often terminating into the ocean via steep-sided bay and U-shaped valleys. However, due to a low number of well-dated climate records from the island, there is uncertainty about how glaciers responded to Holocene climate variability. Here, we reconstruct the glacial evolution of Cumberland Bay from marine sediment core GC673 (ca. 9.7 cal. Kyr BP to Present; ca. 6 km from the nearest land) based on benthic foraminiferal and diatom assemblages, biogenic silica, alkenones and pXRF.

The relative abundance of the benthic foraminifera *Fursenkoina fusiformis* is interpreted as a proxy for more intense diatom blooms resulting from increased terrestrial runoff associated with the spring-summer melting of glaciers. The *F. fusiformis* abundance correlates well with diatom concentration accumulation rates and peaks in both proxies correspond to elevated (but low) abundance of sea ice diatom taxa.

A sequence of several glacial advances can be recognized. The high productivity of the early Holocene is associated with melt associated with the retreat of glaciers into the inner fjord during the early Holocene warm

period. Subsequent advances seem to have two different causes. The first mid-Holocene advance corresponds to a decrease in alkenone-derived palaeotemperatures from GC673. The two advances during the late Holocene correspond to increases in published LOI data suggested increased strength of the South Westerly Winds (SWW) at the latitude of South Georgia which would have increased winter snowfall aiding the growth of glaciers. Our proxies are aligned with, and build upon, published glacial trends previously constrained by plant macrofossil and pollen evidence from nearby peat bogs and dated glacial moraines. We conclude that the primary driver of productivity at site GC673 were diatom blooms associated with spring/summer melt of glaciers whose growth is partially associated with strengthened SSW.

LIST OF PARTICIPANTS

Alves Martins, Maria Virgínia	Universidade do Estado do Rio de Janeiro
Amaglio, Giulia	University of Milan
Armynot du Châtelet, Eric	University of Lille
Auderset, Alexandra	University of Southampton
Aze, Tracy	University of Leeds
Barragán-Montilla, Sofía	MARUM
Barras, Christine	University of Angers
Bellentani, Laura	Modena
Bieler, Aaron	Max Planck Institute for Chemistry
Boscolo Galazzo, Flavia	University of Bremen
Bouchet, Vincent	University of Lille
Bouhdayad, Fatima Zohra	University of Cologne
Brinkmann, Inda	Geological Survey of Denmark
Čančar, Marina	University of Zagreb
Cannings, Torin	University of Geneva
Capotondi, Lucilla	Italian National Research Council
Caridi, Francesca	Marche Polytechnical University
Choquel, Constance	University of Aix-Marseille
Chroustová, Markéta	Charles University Prague
Cotton, Laura	Natural History Museum Denmark
D'Onofrio, Roberta	Italian National Research Council
Dämmer, Linda Karoline	Bonn
Darling, Kate	Universities of Edinburgh and Stirling
de Nooijer, Lennart	Royal Netherlands Institute for Sea Research
Dettner-Schönfeld, Anke	Gettorf
Di Bella, Letizia	Sapienza University of Rome
Dimou, Grigoria Vasiliki	Aristotle University of Thessaloniki
Dissenha, Joicce	Federal University of Paraná
Domínguez-Samalea, Yaima	National Polytechnical Institute
Doubrawa, Monika	University of Leuven
Doutrelant, Manon	University of Lille
Dowari, Jumee	Assam University
Duque-Castano, Monica	University of Algarve
Dwivedi, Rahul	Indira Gandhi National Tribal University
Edgar, Kirsty	University of Birmingham
Ehmcke Espinosa, Isabel	University of Heidelberg
Eichner, Daniela	University of Hamburg

El Moutchou, Wiame	University Mohammed V
Fabbrini, Alessio	University of Galway
Fabritius, Jessica	University of Cologne
Falzoni, Francesca	Italian National Research Council
Fassihi, Shirin	University of Vienna
Fayolle, Florent	University of Southampton
Fentimen, Robin	University of Angers
Filippi, Giulia	University of Ferrara
Filipsson, Helena	Lund University
Fischer, Alexa	Mainz
Fluegeman, Richard	Ball State University
Friedrich, Oliver	University of Heidelberg
Fries, Morgane	French National Centre for Scientific Research
Fuchs, Julian	Urbach
FX Anjar, Tri Laksono	University of Pécs
Gardoki, Jon	University of the Basque Country
Garrido, Sebastian	Heriot-Watt University
Gaskell, Daniel	University of California Santa Cruz
Gennari, Rocco	University of Torino
Gerhard, Schmiedl	University of Hamburg
Geslin, Emmanuelle	University of Angers
Glock, Nicolaas	University of Hamburg
Goleń, Jan	Krákow
Govindankutty Menon, Anjaly	University of Hamburg
Haokip, T. Ngamlengin	Assam University
Hayat, Sikandar	University of Angers
Heins, Lena	Max Planck Institute for Chemistry
Hess, Silvia	Oslo
Holcová, Katarína	Charles University Prague
Hoogakker, Babette	Heriot-Watt University
Huber, Brian	Smithsonian Institution
Hyams-Kaphzan, Orit	Geological Survey of Israel
Jasper, Felix	University of Cologne
Jones, Chloe	University of Southampton
Kotthoff, Ulrich	Leibniz Institute for the Analysis of Biodiversity Change
Koukousioura, Olga	University of Cologne
Kozanoglou, Caterina	Hellenic Centre for Marine Research
Kranner, Matthias	University of Kiel Kiel
Kropiwiec, Isabela	University of São Paulo

Kucera, Michal	University of Bremen
Langer, Martin	University of Bonn
Leon Rodriguez, Lizette	Cushman Foundation / Ellington Geological Services
Licari, Laetitia	University of Aix-Marseille
Lintner, Michael	Polish Academy of Sciences
Lirer, Fabrizio	Sapienza University of Rome
Lopes, Ana	University of Salamanca
Lübbers, Julia	University of Algarve
Luciani, Valeria	University of Ferrara
Martinelli, Pierluigi	University of Torino
Martinez-Colon, Michael	Florida A&M University
Melliti, Sarra	University of Tunis
Mendes, Isabel	University of Algarve
Menezes Freire, Tiago	University of Cologne
Mikadze, Khatuna	I. Javakhishvili Tbilisi State University
Milker, Yvonne	University of Hamburg
Moore, Jon	Florida Atlantic University
Morard, Raphael	MARUM
Moura de Mello, Renata	PETROBRAS
Nardelli, Maria Pia	University of Angers
Nguyen, Ngoc-Loi	Polish Academy of Sciences
Ni, Sha	University of Hamburg
O'Brien, Phoebe	University of Gothenburg
Pai, Mahima	Polish Academy of Sciences
Palme, Tina	University of Vienna
Pavard, Jean-Charles	University of Lille
Pejnović, Igor	University of Zagreb
Petersen, Jassin	University of Cologne
Petrizzo, Maria Rose	University of Milan
Pint, Anna	University of Jena
Polovodova Asteman, Irina	University of Gothenburg
Rebecchi, Federica	Università di Urbino Carlo Bo
Reyes Macaya, Dharma Andrea	Heriot-Watt University & MARUM
Richardson, Susan	Florida Atlantic University
Richirt, Julien	University of Lille
Rollion-Bard, Claire	French National Centre for Scientific Research
Rosa Marín, Angelique	University of South Florida
Sabbatini, Anna	Marche Polytechnical University
Saito de Meneses Silva, Beatriz	University of São Paulo

Salgueiro, Emília	University of Algarve
Sambugaro, Júlia	University of São Paulo
Santarosa, Ana	University of São Paulo
Scheel, Marie	University of Cologne
Scheiner, Filip	Charles University Prague
Schönfeld, Joachim	GEOMAR Helmholtz Center for Ocean Research Kiel
Schweizer, Magali	University of Angers
Selvaggi Mallorquí, Mar	Sapienza University of Rome
Shah, Bhakti	Leibniz Centre for Tropical Marine Research
Sigismondi, Silvia	University of Ferrara
Singh, Vikram Pratap	Indira Gandhi National Tribal University
Sosnitsky, Tamara	Ben-Gurion University of the Negev
Sousa, Silvia	University of São Paulo
Speijer, Robert	University of Leuven
Stuhr, Marleen	Leibniz Centre for Tropical Marine Research
Suarez Ibarra, Jaime Y.	Charles University Prague
Subba, Rohan	Jadavpur University
Sunil, Sunil Kumar Das	Indian Institute of Technology Bhubaneswar
Susaya-Vicente, Krystel	University of Concepción
Szymańska, Natalia	Polish Academy of Sciences
Trejos-Tamayo, Raúl	University of Salamanca
Trevisan Disaró, Sibelle	Federal University of Paraná
Valiyaveetil Salimkumar, Ajay	Free University of Brussels
van Dijk, Inge	University of Angers
Voelker, Antje	Portuguese Institute for Sea and Atmosphere
Wade, Bridget	University College London
Weinmann, Anna	Natural History Museum Vienna
Weitkamp, Tirza	Stockholm
Wilkin, Jack	University of Exeter
Yamashita, Cintia	São Paulo