FORAMS 2023
June 26th–30th, 2023 - Perugia, Italy

Abstracts with program

Edited by:
C. A. Papazzoni
& M.R. Petrizzo
Scientific Committee

Pamela Hallock Muller: University of South Florida 140 Seventh Ave. S. St. Petersburg, FL 33701, United States of America.
Martin Langer: Universität Bonn, Nussallee 8, D-53115 Bonn, Germany.
Jan Pawlowski: Université de Genève, 4, Boulevard d’Yvoy, 1205, Geneva, Switzerland.
Maria Rose Petrizzo: Università degli Studi di Milano, Via Mangiagalli 34 - 20133 Milano, Italy.
Silvia Spezzaferri: Université de Fribourg, Ch. du Musée 6, 1700 Fribourg, Switzerland.
Katsumi Ueno: Fukuoka University, Fukuoka 814 - 0180, Japan.

Organizing Committee

Antonino Briguglio: Università degli Studi di Genova, Corso Europa 26 - 16132 Genova, Italy.
Giulia Margaritelli: CNR IRPI, Via Madonna Alta, 06128, Perugia, Italy.
Cesare Andrea Papazzoni: Università degli Studi di Modena e Reggio Emilia, Via Campi 103 - 41125 Modena, Italy.
Maria Rose Petrizzo: Università degli Studi di Milano, Via Mangiagalli 34 - 20133 Milano, Italy.
Roberto Rettori: Università degli Studi di Perugia. P.za Università - 06123 Perugia, Italy.

Secretariat

Forams2022@gmail.com www.forams2022.it

Sponsors

The contribution of Shell to the organization of FORAMS 2023 is warmly acknowledged.
Table of contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foreword</td>
<td>5</td>
</tr>
<tr>
<td>Map of Perugia</td>
<td>6</td>
</tr>
<tr>
<td>Code of conduct</td>
<td>7</td>
</tr>
<tr>
<td>Field Trips</td>
<td>8</td>
</tr>
<tr>
<td>Conference schedule</td>
<td>9</td>
</tr>
<tr>
<td>Opening Ceremony – Closing Ceremony</td>
<td>10</td>
</tr>
<tr>
<td>Oral Presentations – Monday 26</td>
<td>11</td>
</tr>
<tr>
<td>Oral Presentations – Tuesday 27</td>
<td>15</td>
</tr>
<tr>
<td>Oral Presentations – Wednesday 28</td>
<td>20</td>
</tr>
<tr>
<td>Oral Presentations – Thursday 29</td>
<td>23</td>
</tr>
<tr>
<td>Oral Presentations – Friday 30</td>
<td>27</td>
</tr>
<tr>
<td>Poster Presentations</td>
<td>30</td>
</tr>
<tr>
<td>Opening Ceremony: Decadal trends in Foraminifology</td>
<td>42</td>
</tr>
<tr>
<td>Abstracts</td>
<td>44</td>
</tr>
<tr>
<td>List of participants</td>
<td>276</td>
</tr>
</tbody>
</table>
Dear Friends and Colleagues,

FORAMS 2023 continues the tradition of the highly successful meetings previously held in Halifax (Benthos '75), Pau (Benthos '81), Geneva (Benthos '86), Sendai (Benthos '90), Berkeley (FORAMS '94), Monterrey (FORAMS '98), Perth (FORAMS 2002), Natal (FORAMS 2006), Bonn (FORAMS 2010), Concepción (FORAMS 2014), and Edinburgh (FORAMS 2018).

During the last meeting in Scotland, the general assembly voted to hold the next meeting, FORAMS 2022 (now FORAMS 2023), in Perugia, Italy.

It is with great pleasure and honour that Perugia hosts this important scientific event, which certainly will contribute to spread even further the knowledge and the science among all countries represented at the meeting.

FORAMS 2023 will see 223 oral presentations and 162 poster presentations hosted into 25 scientific sessions, with more than 330 participants. Two of the proposed field trips were activated to visit the Carso area (near Trieste, pre-congress) and the world-famous Bottaccione section (close to Gubbio, post-congress).

The presentations will cover any topics related to extant and fossil foraminifera, including biostratigraphy, taxonomy, evolution, mass extinctions, paleoclimatology, paleoceanography, paleogeography, geochemistry, biology, ecology, symbiosis, biomineralization, environmental monitoring, extreme environments, polar environments, automated recognition, molecular systematics, from all over the world.

We thank all the participants hoping this conference will be again an enjoyable place to exchange scientific knowledge, to stimulate younger researchers to build new collaborations, and to demonstrate the vitality of our scientific community.

The Organizing Committee of FORAMS 2023
Map of Perugia

with indications for the Conference venue, ice breaker party, city center, bus and train stations
Code of Conduct

This Code of Conduct applies to all FORAMS 2023 participants (students, professionals, accompanies, retired and emeritus status). FORAMS 2023 is committed to equality, diversity, inclusion and accessibility; all participants will receive equal treatment regardless of age, disability, gender reassignment, marital or civil partner status, pregnancy or maternity, race, colour, nationality, ethnic or national origin, religion or belief, gender or sexual orientation, as well as many other characteristics that can be discriminated against.

All FORAMS 2023 participants are expected to:

a) Be committed to quality, diversity and inclusion, and not act in a way that discriminates against any individual or group, for example knowingly disseminate material, which appears to encourage discrimination.

b) Help create a supportive, respectful, and inclusive environment for all. Whilst it is recognised that scientific debate should aim to challenge ideas, questions and discussions should be constructive and never demeaning, abusive or inflammatory.

c) Respect the private property and intellectual property of others, ask first permission to the corresponding author to record a presentation, or to take a picture of a poster. Requests not to disseminate content must always be respected.

d) Behave politely with all fellow participants as well as with all personnel involved in the conference organization. Alcoholic beverages will be available during lunchtime and during evening events. Alcohol misuse will be reported to the local authorities.

Allegations of behaviour that breaches the Code will be investigated by FORAMS 2023 Organizing Committee that will take appropriate action.
Field trips

Pre-Congress
(FT1) - Shallow water Cretaceous to Paleogene successions in NE Italy: the Carso Region.
2 days: June 2023, 23rd and 24th
Field leaders: Lorenzo Consorti (CNR-ISMAR, Trieste) - lorenzo.consorti@ts.ismar.cnr.it; Romana Melis (University of Trieste) - melis@units.it
This pre-congress field trip aims to unravel some key places in the surroundings of Trieste (NE Italy) including rock strata rich in larger Foraminifera as well as Recent depositional environments where benthic Foraminifera can be found as a living constituent. The Cretaceous to Eocene carbonate platform of the Classical Karst, together with the siliciclastic deposits associated to the Eocene Dinaric orogenic phase, host some of the traditional successions studied for larger Foraminifera. The Eocene deposits of Collio are moreover particularly known for releasing isolated Alveolina and Nummulites specimens. Recent intertidal rocky areas of the Trieste gulf host a wide array of niches in which benthic foraminifera, among Ammonia, Trochammina and Elphidium, thrive abundantly. During the morning of June 23rd, the field trip will run at Miramare Castle where Eocene olistoliths, rich in larger Foraminifera, are on stand. Then we will go for a sampling of living Foraminifera from an intertidal setting at the Villaggio del Pescatore, including a quick visit to the dinosaurs site, whereas the afternoon will be dedicated to collect fossil Larger Foraminifera nearby Cormons village. The second day (June 24th) will focus on the Cretaceous and Paleogene exposures at Aurisina (type locality of Keramosphaerina tergestina, Upper Cretaceous), Val Rosandra (lower to mid Eocene) and at the K-Pg bearing section of Padriciano (Maastrichtian to Thanetian). In June 25th participants should reach the conference venue at Perugia in time for the icebreaker party; train is the fastest option (Trieste->Florence->Perugia). More detailed info will be given in a next circular; for any particular request or more detailed info please contact the field leaders. The field trip mostly includes geological activity, hammers and hand lens are recommended. Follow the safe rules for excursions in the field, every participant should have a medical insurance policy or be covered by the own the national health program. The nearest international hub is Ronchi dei Legionari Airport, even the most of flight companies land at Venice airport, two hours by bus or train from Trieste. Ronchi dei Legionari Airport is connected to Trieste by train.

Post-Congress
(FT3) - Mesozoic sequences and the K/Pg boundary around Perugia.
1 day: July 1st
Field leaders: Michael Kaminski (KFUPM) - kaminski@kfupm.edu.sa; Fabrizio Frontalini (UniUrbino) - fabrizio.frontalini@uniurb.it
A one-day field excursion to Gubbio and Piobbico will visit the major stage boundaries and oceanic events in Cretaceous and Paleogene. A lunchtime visit to the historical city of Gubbio is included. Departure directly from Conference Venue, visit to Bottacione Gorge to view the Campanian GSSP and the Cretaceous/Paleogene boundary. Walk on the ancient aqueduct towards the city of Gubbio. Free Lunch in Gubbio / free time for shopping. Short trip to the Contessa Road section to view the PETM and the Cenomanian/Turonian boundary. 14:30 Departure to Piobbico to view OAE1a (the Selli Event). 18:00 Arrival in Perugia, back to Conference venue.
OPENING CEREMONY
Monday, June 26
HALL 1

9:00 Welcome from the FORAMS 2023 Organizing Committee
Invited speakers:
Maurizio Oliviero, Rector of the University of Perugia
Diego Perugini, Head of the Department of Physic and Geology of the University of Perugia
Leonardo Varasano, Councillor for Culture of the Municipality of Perugia

10:05 FORAMS 2023 Award for Career Achievement

10:15 Introductory talk by Mike Kaminski (King Fahd University of Petroleum & Minerals, Saudi Arabia) - Decadal Trends in Foraminiferology

CLOSING CEREMONY
Friday, June 30
HALL 1

16:00 Best Student Awards for Oral and Poster presentations
Presentation of the candidates and selection of the location for the next INTERNATIONAL SYMPOSIUM ON FORAMINIFERA - FORAMS 2027
Announcements of upcoming meetings and
Closing remarks and acknowledgments by the FORAMS 2023 Organizing Committee
### ORAL PRESENTATIONS

#### MONDAY June 26th

**HALL 1**

<table>
<thead>
<tr>
<th>Time</th>
<th>Speaker(s)</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>11:30</td>
<td>Kaminski Michael A., Hikmahtiar Syouma and Cetean Claudia G.</td>
<td>Turnover in agglutinated foraminifera across the Cretaceous/Paleogene boundary at Contessa, Umbria-Marche Basin, Italy: assessing the Signor-Lipps Effect</td>
</tr>
<tr>
<td>11:45</td>
<td>Gilabert Vicente, Arenillas Ignacio, Arz José Antonio, Batenburg Sietske J., Robinson Stuart A., Krahl Guilherme, Fauth Gerson, Regelous Marcel and Ferrer Daniel</td>
<td>Deccan volcanism, Chicxulub impact, orbital forcing, and changes in planktic foraminiferal assemblages across the Cretaceous/Paleogene boundary</td>
</tr>
<tr>
<td>12:00</td>
<td>Hsiang Allison Yi</td>
<td>A high-resolution morphological record of planktonic foraminifera across the K-Pg boundary</td>
</tr>
<tr>
<td>12:15</td>
<td>Macleod Kenneth G. and Huber Brian T.</td>
<td>Extremely rapid evolution of earliest Danian planktonic foraminifera? Evidence from the Brazos River Cretaceous-Paleogene boundary sequence</td>
</tr>
<tr>
<td>12:30</td>
<td>Schmidt Daniela N., Adebowale Monsuru, Flower Amy, Thomas Ellen, Ridgwell Andy, Cotton Laura J. and Witts James</td>
<td>Life in a dark environment –physiological response of benthic foraminifera to the environmental changes of the Paleogene</td>
</tr>
<tr>
<td>12:45</td>
<td>Lowery Christopher M., Standring Patricia, Borrelli Chiara, Routledge Claire, Villa Alexandra, McIntyre Andrew and the South Atlantic transect IODP Expedition 390 &amp; 393 Scientists</td>
<td>Eocene Evolution of Surface Circulation and Export Production in the Western South Atlantic</td>
</tr>
</tbody>
</table>

**LUNCH**

<table>
<thead>
<tr>
<th>Time</th>
<th>Speaker(s)</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>14:30</td>
<td>Gallagher Stephen, Wade Bridget, Qianyu Li, Holdgate Guy, Bown Paul, Korasidis Vera, Scher Howie, Houben Alexander, McGovran Brian and Allan Tony</td>
<td>Eocene to Oligocene high paleolatitude neritic record of Oi-1 glaciation in the Otway Basin southeast Australia</td>
</tr>
<tr>
<td>14:45</td>
<td>Takata Hiroyuki, Sakai Saburo, Nomura Ritsuo, Tsujimoto Akira, Nishi Hiroshi, Soo Lim Hyoun and Khim Boo-Keun</td>
<td>Biotic response of deep-sea benthic foraminifera at ODP Site 744 (Kerguelen Plateau) in the Southern Ocean during the early Oligocene</td>
</tr>
<tr>
<td>15:00</td>
<td>Friedrich Oliver, Brzelinski Swaantje, Bornemann André, Wilson Paul, Liebrand Diederik and Van Peer Tim</td>
<td>Short-term waxing and waning of Antarctic ice sheets during the late Oligocene – evidence from benthic foraminiferal geochemistry</td>
</tr>
<tr>
<td>15:15</td>
<td>Cannings Torin, Kroon Dirk, Robertson Alastair, Jung Simon, Barnet James</td>
<td>Insights into Middle to Late Miocene conditions in the eastern Mediterranean region (Cyprus) from stable isotope and trace element analysis</td>
</tr>
<tr>
<td>15:30</td>
<td>Miyamoto Yusei and Takagi Haruka</td>
<td>Vertical distribution of planktonic foraminifera and its controlling environmental factors in the eastern South Pacific</td>
</tr>
<tr>
<td>15:45</td>
<td>Spezzaferri Silvia, Samankassou Elias, Basso Daniela, Pisapia Chiara</td>
<td>Understanding coral thermal bleaching thresholds during past interglacial extremes: Insight into thermal stresses dynamics on tropical coral reef ecosystems (RESILIENCE)</td>
</tr>
</tbody>
</table>
## POSTERS AND COFFEE BREAK

### S11: Evolution, Stratigraphy, and Geological Crises

Conveners: Luka Gale, Rossana Martini, Katsumi Ueno

<table>
<thead>
<tr>
<th>Time</th>
<th>Author(s)</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>17:00</td>
<td>De Nooijer Lennart, Pacho Laura, Jorissen Frans, Pawlowski Jan, Rosenthal Yair, Dissard Delphine and Reichart Gert-Jan</td>
<td>Does the elemental composition of foraminiferal shells reflect their evolutionary history?</td>
</tr>
<tr>
<td>17:15</td>
<td>McCauley Chris, Nestell Galina, Nestell Merlynd and Barrick James</td>
<td>Late Silurian (Ludlow, Pridoli) and Earliest Devonian (Lochkovian) Foraminifers of South-Central Oklahoma, USA</td>
</tr>
<tr>
<td>17:30</td>
<td>Tremblin Clément M. and Haig David W.</td>
<td>Early evolution of trochamminoids (trochospiral organic-cemented agglutinated foraminifera)</td>
</tr>
<tr>
<td>17:45</td>
<td>Nestell Galina and Nestell Merlynd</td>
<td>Roadian foraminifers of the Williams Ranch Member of the Cutoff Formation (Guadalupian, Middle Permian), Delaware Basin, West Texas (USA)</td>
</tr>
<tr>
<td>18:00</td>
<td>Haig David W., Barros Isaias Santos and McCartain Eujay</td>
<td>Permian–Early Jurassic Nodosarians: Punctuated diversification but no mass extinction</td>
</tr>
<tr>
<td>18:15</td>
<td>Boscolo-Galazzo Flavia, Jones Amy, Dunkley Jones Tom, Crichton Katherine A., Wade Bridget S. and Pearson Paul N.</td>
<td>Late Neogene Evolution of modern deep-dwelling plankton</td>
</tr>
</tbody>
</table>

### S19: Modern and Past Tropical Belts Assessed by Foraminifera

Conveners: Mike Kaminski, Maria Virginia Alves Martins, Silvia Helena Mello Sousa

<table>
<thead>
<tr>
<th>Time</th>
<th>Author(s)</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>14:30</td>
<td>Alves Martins Maria Virgínia, Hohenegger Johann, Nunes Márcia, Damasceno Fabrício, Leandro, Figueira Rubens, Martínez-Colón Michael, Frontalini Fabrizio, Senez-Mello Thaise M., Pregnolato Leonardo Antonio, Duleba Wania, de Mello e Sousa Silvia marine and Geraldes Mauro César</td>
<td>Determining the toxicity of metals based on different extraction methods: a case study in the Guanabara Bay (SE Brazil)</td>
</tr>
<tr>
<td>14:45</td>
<td>Sousa Silvia Helena Mello, Damasio Bruno, Santos Felipe Rodrigues, Bonetti Carla, Siegle Eduardo, Martins Maria Virginia Alves and Bicego Marcia Caruso</td>
<td>Environmental compartmentation of the Santos estuary complex (SW Atlantic, Brazil): Response of biotic indices and pollutants</td>
</tr>
<tr>
<td>15:00</td>
<td>Vilar Amanda, Vicente Thaisa, Omachi Claudia, De Santis Wlademir, Sambugaro Julia, Nogueira Rafaela and Sousa Silvia Helena</td>
<td>Response of benthic foraminifera biomass on the slope and plateau of Santos Basin (South Atlantic, Brazil) to different carbon flux models</td>
</tr>
<tr>
<td>15:15</td>
<td>Turco Elena, Di Renzo Rosalia and Lourens Lucas</td>
<td>Planktonic foraminiferal quantitative record of the Burdigalian to Langhian interval at Site 1264 (Walvis Ridge, south-eastern Atlantic Ocean)</td>
</tr>
<tr>
<td>15:30</td>
<td>Disaró Sibelle T., Watanabe Silva and Totah Violeta I.</td>
<td>A new calcareous Globothalamia (Rhizaria, Foraminifera) from the northeastern Brazilian continental margin</td>
</tr>
</tbody>
</table>

### HALL 2

### S26: Phylogeny and taxonomy of Neogene and Quaternary Planktonic Foraminifera

Conveners: Tracy Aze, Helen Coxall

<table>
<thead>
<tr>
<th>Time</th>
<th>Author(s)</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
17:00  Lamyman Grace, Fordham Barry, Pearson Paul, Wade Bridget, Woodhouse Adam, Young Jeremy, and Aze Tracy - Phylogeny of the Cenozoic planktonic foraminifera

17:15  Crundwell Martin - Phylogeny of Late Neogene and Quaternary planktic foraminifera: a temperate Southwest Pacific perspective

17:30  Fabbrini Alessio, Greco Mattia, Kucera Michal, Ezard Thomas and Wade Bridget S. - Bridging the gap: unravelling the fossil record of extant Globigerina falconensis

17:45  Jones Chloe Louise, Brombacher Anieke and Ezard Thomas - Classification challenges from overlapping distributions of final whorl chamber numbers

18:00  Lamyman Grace and Aze Tracy - An in-depth study of macroperforate and microperforate Neogene planktonic foraminifera speciation events

18:15  Latas Marcin, Pearson Paul N., Poole Christopher, Fabbrini Alessio and Wade Bridget - A new species of pink pigmented Globigerinoides (planktonic foraminifera) from the Pleistocene

**HALL 3**

S17: Larger Foraminifera through time and space

Conveners: Lorenzo Consorti, Raquel Robles-Salcedo, Vicent Vicedo

11:30  Read Michael T. and Nestell Merlynd K. - Middle Pennsylvanian-Cisuralian (Early Permian) fusulinids from the Cache Creek Complex near Meadow Lake, southern British Columbia, Canada: An exotic fauna with Paleo-Tethyan affinities

11:45  Shi Yukun - Carboniferous-earliest Permian foraminifera radiation certificated by a high-resolution biodiversity analysis

12:00  Torres-Silva Ana I. and Hohenegger Johann - Objective identification of Lepidocyclina (Foraminifera) species from the Eocene of Cuba based on growth-invariant morphometric characters

12:15  Pignatti Johannes, Marianelli Diego and Oliverio Dalila - Trimorphism in Orbitolites complanata Lamarck, 1801 from the Lutetian of the Paris Basin (France)

12:30  Arena Luca, Briguglio Antonino, Giraldo-Gómez Victor M., Gandolfi Antonella, Baucon Andrea, Papazzoni Cesare Andrea, Pignatti Johannes, Baumgartner-Mora Claudia, Luciani Valeria and Piazza Michele - Depositional and paleontological consequences of the Middle Eocene Climatic Optimum (MECO) as recorded along a shallow-water succession near Olivetta San Michele (IM), NW Italy

12:45  Fujita Kazuhiro, Webster Jody M. and Yokoyama Yusuke - Response of large benthic foraminiferal assemblages to sea-level changes over the past 40,000 years in the Great Barrier Reef: IODP Expedition 325

**LUNCH**

S32: Biology, metabolisms and behavior: role of benthic foraminifera in ecosystem functioning

Conveners: Joan Bernhard, Vincent Bouchet, Emmanuelle Geslin, Edouard Metzger

14:30  Neumüller Katharina, Basu Subhajit, Schmidt Christiane, Stuhr Marleen, De Beer Dirk, Westphal Hildegard and Klatt Judith - Amphistegina lobifera as a sink for H₂O₂ in coral reef sediments from the Gulf of Aqaba

14:45  Masawa Jenipher, Winters Gidon, Kaminer Moran, Szitenberg Amir, Gruntman Michal and Ashckenazi-Polivoda Sarit - A matter of choice: The interactions between foraminifera and their seagrass host as a model ecosystem for biomonitoring environmental and anthropogenic stressors
<table>
<thead>
<tr>
<th>Time</th>
<th>Speakers and Titles</th>
</tr>
</thead>
<tbody>
<tr>
<td>15:00</td>
<td>Courtial Julia, Metzger Edouard, Lothier Jeremy, Choquel Constance, Limami M. Anis and Geslin Emmanuelle - Seasonal dynamics of respiration and photosynthesis of benthic kleptoplast foraminifera inhabiting an intertidal mudflat: what ecological roles?</td>
</tr>
<tr>
<td>15:15</td>
<td>Lintner Michael, Wildner Manfred, Lintner Bianca, Wanek Wolfgang and Heinz Petra - The use of VIS spectroscopy to detect kleptoplasts and food particles in foraminifera</td>
</tr>
<tr>
<td>15:30</td>
<td>Daviray Maxime, Geslin Emmanuelle, Risgaard-Petersen Nils, Scholz Vincent Valentin, Jorissen Frans, Fouet Marie and Metzger Edouard - Foraminiferal shell preservation under mudflats colonised by electrical cable bacteria</td>
</tr>
<tr>
<td>15:45</td>
<td>Langlet Dewi, Mermillod-Blondin Florian, Deldicq Noemie, Bauville Arthur, Duong Gwendoline, Konecny Lara, Hugoni Mylene, Denis Lionel and Bouchet M.P. Vincent - Benthic foraminifera mediate oxygen penetration and prokaryotic diversity in intertidal sediment</td>
</tr>
</tbody>
</table>

**POSTERS AND COFFEE BREAK**

<table>
<thead>
<tr>
<th>Time</th>
<th>Speakers and Titles</th>
</tr>
</thead>
<tbody>
<tr>
<td>17:00</td>
<td>Richirt Julien, Okada Satoshi, Glock Nicolaas, Ishitani Yoshiyuki and Nomaki Hidetaka - Correlative analyses of cellular structures and elemental distribution of soluble compounds: Cryo-SEM imaging coupled to EDS elemental mapping in the denitrifying species Bolivina spissa</td>
</tr>
<tr>
<td>17:15</td>
<td>Nomaki Hidetaka, Chen Chong, Oda Kaya, Tsuchiya Masashi, Tame Akihiro, Uematsu Katusyuki, Salonen lines S. and Isobe Noriyuki - Abundant chitinous structures in cytoplasm of Chilostomella and their potential functions</td>
</tr>
<tr>
<td>17:30</td>
<td>Glock Nicolaas, Nomaki Hidetaka, Woehle Christian, Algar Christopher, Govindankutty Menon Anjaly, Ishitani Yoshiyuki, Kienast Markus, Mutzberg Andre, Okada Satoshi, Rakshit Subhadeep, Richirt Julien, Schmiedl Gerhard, Steiner Zvi and Zhang Zhouling - Ubiquitous occurrence of phosphate storage in foraminifera – Another adaptation to anaerobic environments?</td>
</tr>
<tr>
<td>17:45</td>
<td>Nielsen Kurt Soren Svenson - Bio-erosional traces on the foraminiferal test</td>
</tr>
</tbody>
</table>
### TUESDAY June 27th

#### HALL 1

**S1: A Latin American and Caribbean cluster: gathering foraminiferal researchers**

<table>
<thead>
<tr>
<th>Time</th>
<th>Speaker(s)</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>09:00</td>
<td>Reyes-Macaya Dharma, Hoogakker Babette, Martínez Fontaine Consuelo, Glock Nicolaas, Tapia Raul, De Pol Holz Ricardo, Martínez – Méndez Gema, Erdem Zeynep, Garrido Sebastian, Michel Elisabeth, McCorkle Daniel, Yokoyama Yusuke, Mohtadi Mahyar, Tavera Laura, Marchant Margarita, Cardich Jorge, Flores Edgart, Ingle James, Cordova Kathy, Kuhnert Henning, Krause Stefan, Gayo Eugenia, Castillo Alexis, Hromić Tatiana, Lückge Andreas, Santamaria Pablo, Troncoso-Ojeda Rodrigo, Aguilera Victor, Davis Catherine, Vargas Cristian and Hebbeln Dierk</td>
<td>Stable isotopes of oxygen and carbon in benthic foraminifera: Proxy validation in the Southeast Pacific, an international collaborative endeavour</td>
</tr>
<tr>
<td>09:15</td>
<td>Suárez-Ibarra Jaime Y., Freire Tiago M., Battaglin Beatriz B.F., Dias Bruna B., Ballalai João, Chalk Thomas, Chaabane Sonia, Costa Karen, Tesla Felipe, Scheiner Filip, Holcová Katarina, de Garidel-Thoron Pivéal Marie, and Pivel Maria A.G.</td>
<td>Decoupling of productivity and carbonate dissolution in the western South Atlantic during MIS 5-4</td>
</tr>
<tr>
<td>09:30</td>
<td>Garrido Sebastián, Hoogakker Babette, Reyes-Macaya Dharma, Richirt Julien, Fouet Marie, Hebbeln Dierk, Gayo Eugenia M., Cardich Jorge, Muñoz Praxedes, Castillo Bruna Alexis, Michel Elisabeth and Jorissen Frans</td>
<td>Pore patterns of epifaunal benthic Foraminifera as a palaeoxygenation proxy in the South-East Pacific</td>
</tr>
<tr>
<td>09:45</td>
<td>Trejos-Tamayo Raúl, Garzón Darwin, Flores José-Abel, Pardo Andrés, Vallejo-Hincapié Felipe and Duque-Castaño Mónica</td>
<td>Paleoenvironmental changes during the late Paleogene – Early Neogene in the SW Caribbean Region (ANH-San Jacinto-1 well): inferences from benthic foraminifera</td>
</tr>
<tr>
<td>10:00</td>
<td>Kropiwiec Isabela S. and Disaró Sibelle T.</td>
<td>When rose Bengal fails to detect living foraminifers by simple observation through the tests – methodological approaches in the Santos Basin, Brazil (Southwestern Atlantic)</td>
</tr>
<tr>
<td>10:15</td>
<td>Samsonodar Sadie and Knappertbusch Michael</td>
<td>Revitalizing historic and iconic Trinidad type sections through archival research within Hans G. Kugler’s Legacy in Basel, Switzerland</td>
</tr>
</tbody>
</table>

---

**POSTERS AND COFFEE BREAK**

**S15: Foraminiferal records of climatic and oceanographic change across critical intervals during the Cretaceous**

<table>
<thead>
<tr>
<th>Time</th>
<th>Speaker(s)</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>11:30</td>
<td>Görög Ágnes and Zsiborás Gábor</td>
<td>A glimpse into the past of planktonic foraminifera: Aalenian (Middle Jurassic) forms and their phylogenetic relationships</td>
</tr>
<tr>
<td>11:45</td>
<td>Colpaert Clémentine, Reboulet Stéphane and Li Gang</td>
<td>The response of benthic foraminifera to disaerobic event – example of the Valanginian Weissert event based on the reference Vergol and La Charce sections, Vocontian Basin, Southeast France</td>
</tr>
<tr>
<td>12:00</td>
<td>Giraldo-Gómez Victor M., Petrizzzo Maria Rose, Bottini Cinzia and Erba Elisabetta</td>
<td>Bottom water conditions during the Ocean Anoxic Event 1a in the southern Tethys and central Pacific Ocean: the benthic foraminifer response</td>
</tr>
<tr>
<td>12:15</td>
<td>Wolfring Erik, Petrizzzo Maria Rose and Watkins David</td>
<td>Integrated biostratigraphy of the Albion of the Southern High Latitudes</td>
</tr>
</tbody>
</table>
12:30 Gutiérrez-Puente Nicté, Barragán Ricardo, Núñez-Useche Fernando, Enciso-Cárdenas Juan, Camacho-Ortegón Luis and Mesa-Rojas Julián - Microfossil events and planktic foraminifera response to Cretaceous Oceanic Anoxic Events in the Sabinas Basin, Northern Mexico

12:45 Petrizzo Maria Rose and Gale Andy S. - Planktonic foraminifera and paleoceanographic changes across the middle Cenomanian carbon-isotope excursion (MCE 1) in south-east England, UK

LUNCH

14:30 Kender Sev, Walker-Trivett Chloe, Edvardsen Trine, Bogus Kara, Littler Kate, Lacey Jack and Leng Melanie - Elevated productivity during Oceanic Anoxic Event 2 in the Mentelle Basin, Western Australia (IODP Expedition 369), indicated by benthic foraminifera and geochemical proxies

14:45 Amaglio Giulia, Petrizzo Maria Rose, Holbourn Ann, Kuhnt Wolfgang and Wolfgring Erik - Late Cretaceous benthic foraminifera responses across Oceanic Anoxic Event 2 at southern high latitudes (Mentelle Basin, SW Australia)

15:00 Falzoni Francesca, Petrizzo Maria Rose, Amaglio Giulia and MacLeod Kenneth G. - A causal link between re-organization of ocean circulation patterns during Oceanic Anoxic Event 2 and extinction of Rotaliporids

15:15 CP Sooraj and Punekar Jahnavi - Late Cretaceous foraminifera from Eastern Lower Narmada Valley as part of the marine seaway through Central India

15:30 Dameron Serena, Leckie R. Mark and MacLeod Kenneth G. - Re-evaluating Water Mass Influence on Late Cretaceous Deep-Sea Benthic Foraminifera

15:45 Kesen Kebenle and Punekar Jahnavi - The effect of the end-Cretaceous ocean acidification on the community structure of planktic foraminifera

POSTERS AND COFFEE BREAK

S33: Honoring Martin Buzas: Innovative approaches to analyzing distributions of benthic foraminifera

Conveners: Pamela A. Buzas-Stephens, Laurel S. Collins, Stephen J. Culver, Lee-Ann C. Hayek, Maria Rose Petrizzo

17:00 Buzas-Stephens Pamela, Culver Stephen J., Marchitto, Thomas M. Jr. and Buzas, Martin A. - Attributes allowing for long species duration in benthic foraminifera

17:15 Schmiedl Gerhard, Milker Yvonne and Mackensen Andreas - Benthic foraminiferal record of deep-sea biodiversity changes during the late Quaternary

17:30 Fentimen Robin, Depuydt Pauline, De Deckker Patrick and Mojtahid Meryem - Deep-sea response to interglacial-glacial variability on the South Australian margin over the last 94 ka

17:45 Hayward Bruce W., Sabaa Ashwaq T., Howarth Jamie D., Orpin Alan R. and Strachan Lorna J. - Foraminiferal evidence for the provenance and flow history of turbidity currents triggered by the 2016 Kaikōura Earthquake, New Zealand

18:00 Jorissen Frans, Fouet, Marie, Singer, David and Howa Hélène - Foraminiferal communities of intertidal estuarine mudflats – The MII and EFDI indices, a first step towards solving the estuarine quality paradox

18:15 Burkett M. Ashley - Using seafloor substrate experiments to acquire, assess, and describe populations of Cibicidoides wuellerstorfi recruiting to plastics over the course of months to years
### HALL 2

#### S13: Foraminifera in polar environments: problems of preservation, presence in different palaeoenvironments and related problem solving

Conveners: Lucilla Capotondi, Romana Melis, Caterina Morigi

<table>
<thead>
<tr>
<th>Time</th>
<th>Title</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>09:00</td>
<td>Bombard Samantha, Leckie R. Mark and IODP Exp. 374 Science Party - Middle Miocene Foraminifera of the Ross Sea Continental Shelf, IODP Exp. 374</td>
<td>Melis Romana, Colizza Ester, Del Carlo Paola, Di Roberto Alessio, Torricella Fiorenza and Capotondi Lucilla - The significance of foraminifera in Southern Ocean: examples from the west-central Ross Sea</td>
</tr>
<tr>
<td>09:15</td>
<td>Wilkin Jack, Kender Sev, Dejardin Rowan, Allen Claire, Peck Victoria, Swann George, McClymont Erin, Scourse James, Littler Kate and Leng Melanie - South Georgia palaeo-productivity and glacial evolution over the past 15 ka</td>
<td>Majewski Wojciech, Szczuciński Witold and Gooday J. Andrew - Benthic foraminiferal communities (stained) in sub-Antarctic fjords of South Georgia</td>
</tr>
<tr>
<td>09:30</td>
<td>Bartolini Annachiara, Sabbatini Anna, Andreo Antoine, Aleon Jérôme, Mostefăoui Smail, Morigi Caterina, Rollion-Bard Claire and Monti-Birkenmeier Marina - Looking for a geochemical imprinting of sea-ice environment in the planktic foraminiferal Neogloboquadrina pachyderma</td>
<td>Coxall Helen K., Vermassen Flor, Cronin Thomas M., Regnier Alexa, Darling Kate, West Gabriel, Husum Katrine, Huber Brian T., Voelker Antje H. L. and Matt O’Regan - The genus Turborotalita in the Arctic Ocean: quinqueloba, egelida and exumbilicata</td>
</tr>
<tr>
<td>10:00</td>
<td>Bartolini Annachiara, Sabbatini Anna, Andreo Antoine, Aleon Jérôme, Mostefăoui Smail, Morigi Caterina, Rollion-Bard Claire and Monti-Birkenmeier Marina - Looking for a geochemical imprinting of sea-ice environment in the planktic foraminiferal Neogloboquadrina pachyderma</td>
<td>Szymanska Natalia, Lacka Magdalena and Zajaczkowski Marek - Climate change induced decrease in foraminifera abundance in an Arctic fjord (Hornsund, Svalbard). Implications for carbon burial</td>
</tr>
<tr>
<td>11:45</td>
<td>Bartolini Annachiara, Sabbatini Anna, Andreo Antoine, Aleon Jérôme, Mostefăoui Smail, Morigi Caterina, Rollion-Bard Claire and Monti-Birkenmeier Marina - Looking for a geochemical imprinting of sea-ice environment in the planktic foraminiferal Neogloboquadrina pachyderma</td>
<td>Simonds Mike and Bidgood Mike - A critical review of Larger Benthic Foraminifera of the Cenomanian; planispiral (or near-planispiral) forms</td>
</tr>
<tr>
<td>12:00</td>
<td>Bartolini Annachiara, Sabbatini Anna, Andreo Antoine, Aleon Jérôme, Mostefăoui Smail, Morigi Caterina, Rollion-Bard Claire and Monti-Birkenmeier Marina - Looking for a geochemical imprinting of sea-ice environment in the planktic foraminiferal Neogloboquadrina pachyderma</td>
<td>Papazzoni Cesare Andrea, Fornaciari Beatrice, Giusberti Luca, Simonato Michela and Fornaciari Eliana - A new proposal for biozonation of the Paleocene: Shallow Benthic Zones (SBP) calibrated with calcareous nanofossils</td>
</tr>
</tbody>
</table>

### S3: Advances in larger foraminiferal biostratigraphy: a framework for reconstructing shallow-water events

Conveners: Cesare A. Papazzoni, Antonino Briguglio, Laura J. Cotton

<table>
<thead>
<tr>
<th>Time</th>
<th>Title</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>14:30</td>
<td>Simonds Mike and Bidgood Mike - A critical review of Larger Benthic Foraminifera of the Cenomanian; planispiral (or near-planispiral) forms</td>
<td>Papazzoni Cesare Andrea, Fornaciari Beatrice, Giusberti Luca, Simonato Michela and Fornaciari Eliana - A new proposal for biozonation of the Paleocene: Shallow Benthic Zones (SBP) calibrated with calcareous nanofossils</td>
</tr>
<tr>
<td>14:45</td>
<td>Simonds Mike and Bidgood Mike - A critical review of Larger Benthic Foraminifera of the Cenomanian; planispiral (or near-planispiral) forms</td>
<td>Kövecsi Szabolcs-Attila, Less György, Ples Georg, Binu-Haitonic Raluca and Silye Lóránd - The Albeşti nummulitic limestones: biostratigraphic, paleoenvironmental and paleogeographic remarks</td>
</tr>
<tr>
<td>15:00</td>
<td>Simonds Mike and Bidgood Mike - A critical review of Larger Benthic Foraminifera of the Cenomanian; planispiral (or near-planispiral) forms</td>
<td>Less György, Kövecsi Szabolcs Attilla and Silye Lóránd - The distribution of some numerical parameters of Nummulites perforatus (Montfort) A-forms from the Bartonian of Transylvania (W Romania): evidence for trimorphic life cycle in fossil foraminifera?</td>
</tr>
<tr>
<td>Time</td>
<td>Conveners/Authors</td>
<td></td>
</tr>
<tr>
<td>--------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>15:30</td>
<td>Dimou Grigoria Vasiliki, Koukousioura Olga, Less György, Triantaphyllou Maria, Dimiza Margarita and Syrides George - Exceptionally abundant Larger Benthic Foraminiferal fauna from the uppermost Eocene of Fanari (Thrace Basin, Greece)</td>
<td></td>
</tr>
</tbody>
</table>

**POSTERS AND COFFEE BREAK**

**S8: Evolutionary and environmental control on coiling direction and loss of algal photosymbiosis (bleaching) in the foraminiferal fossil and recent record**

Conveners: Valeria Luciani, Bridget Wade, Roberta D’Onofrio

<table>
<thead>
<tr>
<th>Time</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>17:00</td>
<td>Filippi Giulia, Luciani Valeria, Sigismondi Silvia, D’Onofrio Roberta, Dickens Gerald R., Wade Bridget S. and Westerhold Thomas - Disentangling implications of changes in morozovellids coiling direction at the Eocene Climatic Optimum (EECO, ca 53-49 Ma) (Pacific, Atlantic and Indian Oceans)</td>
</tr>
<tr>
<td>17:15</td>
<td>Gheiasvand Masoumeh, Bartolini Annachiara, Huber Brian T. and Fiorillo Denis - Response of morozovellid and acaraninid planktic foraminifera to early Eocene global warmth in a southern high-latitude site in the Indian Ocean</td>
</tr>
<tr>
<td>17:30</td>
<td>King David J., Wade Bridget S. and Miller C. Giles - Coiling direction and biostratigraphic utility of mid Miocene paragloborotaliids and globorotaliids (planktonic foraminifera)</td>
</tr>
<tr>
<td>17:45</td>
<td>Kenigsberg Chen, Pinko Doron Levin Sivan, Abdu Uri and Abramovich Sigal - An indoor thermal acclimation of symbiodinium endosymbionts within a foraminiferal host</td>
</tr>
<tr>
<td>18:00</td>
<td>Takagi Haruka and Saito Hiroaki - Responses to DCMU, high light, and high temperature in <em>Trilobatus sacculifer</em> photosymbiosis</td>
</tr>
</tbody>
</table>

**HALL 3**

**S12: Foraminifera as seawater oxygen proxies**

Conveners: Sebastian Garrido, Babette Hoogakker, Nicolaas Glock, Helena Filipsson, Madelyn Cook, Jeroen Groeneveld, Constance Choquel

<table>
<thead>
<tr>
<th>Time</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>09:00</td>
<td>Kranner Matthias, Harzhauser Mathias, Beer Christoph, Auer Gerald and Piller Werner E. - New approach to calculating dissolved marine oxygen values with the Enhanced Benthic Foraminifera Oxygen Index</td>
</tr>
<tr>
<td>09:15</td>
<td>Brinkmann Inda, Barras Christine, Jilbert Tom, Paul K. Mareike, Somogyi Andrea, Ni Sha, Schweizer Magali, Bernhard Joan M. and Filipsson Helena L. - Mn/Ca as a potential recorder for bottom-water oxygenation</td>
</tr>
<tr>
<td>09:30</td>
<td>Doherty Shannon, Davis Catherine and Fehrenbacher Jennifer - Anaerobic microbial metabolisms in particle microenvironments recorded by <em>Globorotaloides hexagonus</em></td>
</tr>
<tr>
<td>09:45</td>
<td>Alcorn Rachel, Davis Catherine and Ontiveros-cuadras Jorge Feliciano - Reconstructing Pacific oxygen minimum zone structure through deglacial warming using planktic foraminifera</td>
</tr>
<tr>
<td>10:00</td>
<td>Davis Catherine, Doherty Shannon, Fehrenbacher Jennifer and Wishner Karen - Potential for conventional trace elements in <em>Globorotaloides hexagonus</em> as proxies for the pelagic Oxygen Minimum Zone</td>
</tr>
<tr>
<td>10:15</td>
<td>Van Diik Inge, Barras Christine, Oron Shai, Mouret Aurelia and Geslin Emmanuelle - Biological adaptation of Foraminifera to low oxygen conditions</td>
</tr>
</tbody>
</table>

**POSTERS AND COFFEE BREAK**

<table>
<thead>
<tr>
<th>Time</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>11:30</td>
<td>Subba Rohan and Ghosh Anupam - Exploring the link between Pore Morphology in Benthic Foraminifera (Ammonia) and Dissolved Oxygen: Insights from Chilika Lagoon (INDIA)</td>
</tr>
<tr>
<td>11:45</td>
<td>Ford Trinity and Burkett Ashley - Test volume response to bottom water oxygen changes in <em>Cibicidoides wuellerstorfi</em></td>
</tr>
<tr>
<td>-------</td>
<td>---------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>12:00</td>
<td>Eichner Daniela, Schmiedl Gerhard, Titschack Jürgen, Triantaphyllou Maria, Ferreira Malu and Milker Yvonne - Dysoxia in shallow bathyal marine deposits of the island of Rhodes (Greece) during the Plio-Pleistocene</td>
</tr>
<tr>
<td>12:15</td>
<td>Pilade Francesco, Mancini Alan, Pellegrino Luca, Lozar Francesca, Schmiedl Gerhard and Gennari Rocco - Insights into the benthic foraminiferal response to precessional forcing and environmental changes across the Messinian Salinity Crisis onset in the Sorbas Basin (SE Spain)</td>
</tr>
<tr>
<td>12:30</td>
<td>Sutton Seth Reid and Kelly Daniel Clay - Neritic Benthic Foraminifers as Indicators of Ocean Deoxygenation in the Salisbury Embayment (U.S. Atlantic Coastal Plain) during the Mid-Miocene Climatic Optimum</td>
</tr>
<tr>
<td>12:45</td>
<td>Rosenthal Yair, HESS Anya V., Auderset Alexandra, Miller Kenneth G., Zhou Xiaoli, Sigman Daniel M. and Martinez-Garcia Alfredo - A well oxygenated eastern tropical Pacific during the warm Miocene</td>
</tr>
</tbody>
</table>

**LUNCH**
### WEDNESDAY June 28th

#### HALL 1

<table>
<thead>
<tr>
<th>Session</th>
<th>Title</th>
<th>Conveners</th>
<th>Presenters</th>
</tr>
</thead>
<tbody>
<tr>
<td>S10</td>
<td>Environmental monitoring with benthic foraminifera: assessing the Ecological Quality Status of coastal and marine systems</td>
<td>Michael Martínez-Colón, Irina Polovodova Asteman, Silvia Spezzaferri</td>
<td>Barras Christine, Labrune Céline, Hubert-Huard Raphaël, Lescure Lyvia, Madre Mathilde, Orts Ameline, Pruski Audrey, Quinchard Sophie, Vétion Gilles and Astruch Patrick</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Impact of sediment discharges on benthic faunas in coastal Mediterranean Sea</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gardoki Jon, García-artola Ane, Cearreta Alejandro, Irabien Maria Jesús, Gómez-arozamena José, Villasante-marcos Victor, Galaz-Samaniego Carlos and Bessa Filipa</td>
<td>Modern environmental conditions on an agriculture-impacted estuary (Mondego, N Portugal): a foraminiferal approach</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Golikova Elena, Korsun Sergei, Varfolomeeva Marina, Kursheva Anna and Morgunova Inna</td>
<td>Assessment of ecological quality status of Arctic salt marshes and adjacent tidal flats using foraminifera</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Joshi Neha, Saulnier Talbot Émilie and Montero-Serrano Jean-Carlos</td>
<td>Foraminifera as indicators of late Holocene sediment contamination in the Bay of Sept-Iles</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hoober Lin, Titelboim Danna, Abramovich Sigal, Herut Barak, Teutsch Nadya, Benaltabet Tal and Torfstein Adi</td>
<td>Establishing the baseline assessment levels for monitoring coastal heavy metals in seawater using benthic foraminiferal shells</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Krekova Vasilisa, Abramovich Sigal, Herut Barak and Torfstein Adi</td>
<td>Assessing Heavy Metal Contamination Along the Mediterranean Coast of Israel Using Foraminiferal Shell Geochemistry</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hess Silvia, Alve Elisabeth and Helland Aud</td>
<td>Retrospective benthic foraminiferal community studies: a sensitive method to determine early environmental changes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>O’Brien Phoebe A.J., Barrenchea Angeles Ínès, Pawlowski Jan, Nordberg Kjell, Alve Elisabeth and Polovodova Asteman Irina</td>
<td>Assessing the environmental quality of a historically-polluted fjord: a comparison of benthic foraminiferal eDNA and morphospecies proxy approaches</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rosa Marín Angelique and Martínez-Colón Michael</td>
<td>Benthic foraminifera as bioindicators of reef health in Jobos Bay, Puerto Rico</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Trubin Yaroslav S. and Langer Martin R.</td>
<td>Benthic foraminifera from shallow-water of Line Islands</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Schwing Patrick, Garrett Matthew, Hubbard Katherine, Lam Tristan, Mopps Gabe, Dauzvardis Geo, Inga Bailey, Cory Ariana, O’Malley Bryan, Larson Rebekka and Brooks Gregg</td>
<td>Harmful Algal Bloom (Red Tide) Monitoring Utilizing Benthic Foraminifera on the West Florida Shelf (USA)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>O’Malley Bryan, Schwing Patrick, Lam Tristan, Larson Rebekka, Brooks Gregg and Gooday Andrew</td>
<td>Patterns of foraminiferal diversity and species composition from a three-year time series in the Southeastern Clarion-Clipperton Zone, an area designated for deep sea mining</td>
</tr>
</tbody>
</table>

LUNCH
HALL 2

**S28: Recent benthic foraminifera in extreme environments**

**Conveners:** Luisa Bergamin, Letizia Di Bella, Elena Romano

**09:00** Bernhard Joan M., Rogers Daniel, Huang I-Ting, Powers Christopher, Zhang Ying, Utter Daniel R., Cavanaugh Colleen, Edgcomb Virginia P, Gomaa Fatma - Gene expression of in situ preserved kleptoplastidic *Nonionella stella* from an aphotic sulfidic anoxic setting

**09:15** Cosović Vlasta, Sanjek Rahela, Hadžić Eric, Rakarić Mihovil, Ištuk Željko, Sušmelj Kaja Čermeļ Branko And Žvab Rožić Petra - Submarine sulphur springs in Northern Adriatic (Koper Bay) and benthic foraminiferal assemblages: extreme conditions or not?

**09:30** Di Bella Letizia, Casalbore Daniele, Conte Aida Maria, Conti Alessia, Cornacchia Irene, D’Ambrosi Andrea, Gaglianone Giovanni, Ingrassia Michela, Spatola Daniele, Pierdomeno Martina, Provenzani Claudio, Ruspandini Tania and Chiocci Francesco Latino - The foraminiferal response to methane emissions in shallow water environments from the Scoglio d’Africa (Tuscan Archipelago, Northern Tyrrhenian Sea)

**09:45** Hyams-Kaphzan Orit, Almogi-Labin Ahuva, Zolotarvesky Sophia, Kitin Michael, Katz Oded, Torfstein Adi and Langer R. Martin - Under the south-eastern deep Mediterranean Sea: Benthic foraminifera serve as sentinels for various microhabitats definition

**10:00** Dissenha Joicce and Disaro Sibelle T - Attached and encrusting Foraminifera on mobile unconsolidated substrates in the Santos Basin (SE - S, Brazil): unexpected records

**10:15** Giovenzana Francesca, Mateus-Vicens Guillem, Westphal Hildegard, Petrovic Alexander and Vahrenkamp Volker - Mesophotic benthic foraminifera assemblages record the drowning of a carbonate platform in the northern Red Sea, Saudi Arabia

**POSTERS AND COFFEE BREAK**

**11:30** Guilhermic Corentin, Nardelli Maria Pia, Mouret Aurélia, Pusceddu Antonio, Baltzer Agnès and Howa Hélène - Difficult life under a tidal glacier terminus: Inteseasonal responses of benthic foraminifera close to the Kronebreen glacier front (Kongsfjorden, Svalbard)

**11:45** Koukousioura Olga, Georgiou Sofia, Dimiza D. Margarita, Triantaphyllou V. Maria and Langer R. Martin - When stress creates high diversity: the case of Thermaikos Gulf (NW Aegean Sea)

**12:00** Rohret Shari, Borda Elizabeth and Bernhard Joan M. - Assessing biodiversity of benthic foraminifera in an anoxic-hypoxic karst subterranean estuary of the Yucatan Peninsula, Mexico

**12:15** Romano Elena, Bergamin Luisa, Di Bella Letizia, D’Ambrosi Andrea, Di Fazio Melania, Medeghini Laura, Pierdomenico Martina, Provenzani Claudio, Rampazzo Romano, Rinaldi Sheila and Spagnoli Federico - Agglutinated foraminifera as early indicators of microplastic pollution in two Mediterranean marine caves

**12:30** deCuba Jeanette M., and Collins Laurel S. - Benthic Foraminiferal Response to the BP Deepwater Horizon Oil Spill in the Northeastern Gulf of Mexico

LUNCH

HALL 3

**S14: Foraminiferal geochemical proxies: novel approaches, unique applications and facing poorly-understood problems**

**Conveners:** Lennart de Nooijer, Gert-Jan Reichart, Howard Spero
<table>
<thead>
<tr>
<th>Time</th>
<th>Title</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>09:00</td>
<td>Controls on B/Ca in planktic foraminifera</td>
<td>Branson Oscar, Holland Katherine and Eggins Stephen</td>
</tr>
<tr>
<td>09:15</td>
<td>Diet controls foraminiferal nitrogen isotopes: a feeding experiment on T. sacculifer</td>
<td>Fang Wei-Ning, Branson Oscar, Yang Er-Wen, Spero Howard J., Fehrenbacher Jennifer S. and Ren Haojia</td>
</tr>
<tr>
<td>09:30</td>
<td>The effect of carbonate chemistry on the incorporation of trace elements into shells of benthic foraminifera: Paleoceanographic and biomineralization implications</td>
<td>Hauzer Hagar, Evans David, Müller Wolfgang, Rosenthal Yair, Erez Jonathan</td>
</tr>
<tr>
<td>09:45</td>
<td>Assessing the impact of different carbonate system parameters on benthic foraminifera from controlled growth experiments</td>
<td>Mojtahid Meryem, Depuydt Pauline, Mouret Aurélia, Le Houedec Sandrine, Fiorini Sarah, Chollet Simon, Massol Florent, Dohou Francis, Filipsson Helena L., Boer Wim, Reichart Gert-Jan and Barras Christine</td>
</tr>
<tr>
<td>10:00</td>
<td>The effect of $[\text{Mg}^{2+}]_{\text{sw}}$, $[\text{SO}<em>4^{2-}]</em>{\text{sw}}$, and temperature on Mg incorporation in cultured benthic foraminifera</td>
<td>Pacho Laura, de Nooijer Lennart, Nagai Yukiko, Toyofuku Takashi and Reichart Gert-Jan</td>
</tr>
<tr>
<td>10:15</td>
<td>Mg/Ca surface-water paleotemperatures at the Early Eocene Climatic Optimum from the Pacific Ocean: repercussions on planktic foraminiferal assemblages</td>
<td>Sigismondi Silvia, Filippi Giulia, D’Onofrio Roberta, Tiepolo Massimo, Cannaò Enrico, Dickens Gerald R., Wade Bridget S., Westerhold Thomas and Luciani Valeria</td>
</tr>
<tr>
<td>11:30</td>
<td>Geochemical and Mineralogical investigation of “foraminifera barren layer” in Maastrichtian carbonate ooze of Walvis ridge</td>
<td>Singh Brijesh, Sriwastava Piyush and Punekar Jahnavi</td>
</tr>
<tr>
<td>11:45</td>
<td>Reconstructing past changes in cloud cover from foraminifera population geochemistry – A testable hypothesis</td>
<td>Spero Howard</td>
</tr>
<tr>
<td>12:00</td>
<td>Nitrogen isotopic signals in tissue of planktic foraminifers in the northern South China Sea from the shelf to the open ocean and implications for the foraminifer-bound nitrogen isotope paleo-proxy</td>
<td>Bieler Aaron L., Schiebel Ralf, Martinez-Garcia Alfredo, Smart Sandi M., Eßmann Tobias, Heins Lena, Gaye Birgit, Waniek Joanne J., and Haug Gerald H.</td>
</tr>
<tr>
<td>12:15</td>
<td>The geochemistry of non-spinose foraminifera: What is it good for?</td>
<td>Fehrenbacher Jennifer, Lane Mary Kelsey, Fritz-Endres Theresa, Hupp Britanny, Davis Catherine, Branson Oscar, Ren Abby, Vetter Lael and Spero Howard</td>
</tr>
<tr>
<td>12:30</td>
<td>Trace elements through life and time of planktic foraminifera</td>
<td>Searle-Barnes Alex, Milton J. Andy, Standish Christopher, Foster Gavin and Ezard Thomas</td>
</tr>
</tbody>
</table>

LUNCH
## S2: Advances and challenges in modern and fossil benthic foraminifera research:
a session dedicated to Prof. John Murray

**Conveners:** Elisabeth Alve, Andrew Gooday, Babette Hoogakker, Malcolm Hart, Irina Polovodova Asteman

<table>
<thead>
<tr>
<th>Time</th>
<th>Speaker(s)</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>09:00</td>
<td>Stuhr Marleen, Gea Neuhaus Aitana, Fuchs Lea T.A., Perry Chris T. and Lange Ines D.</td>
<td>Foraminifera of the remote Chagos Archipelago – Community responses to local and global drivers and their effects on coral reef sediment production</td>
</tr>
<tr>
<td>09:30</td>
<td>Pavard Jean-Charles, Richirt Julien, Bouchet Vincent M.P., Holzmann Maria, McGann Mary, Armynot du Chatellet Eric, Pezy Jean-Philippe, Dauvin Jean-Claude and Seuront Laurent</td>
<td>Unexpected high records of non-indigenous foraminiferal species in the eastern English Channel</td>
</tr>
<tr>
<td>09:45</td>
<td>Polovodova Asteman Irina, Alve Elisabeth, Dolven Jane K., Eliassen Nicole, Ferraro Mattia, Hess Silvia, Morin Filip, Panova Marina, Rumpfbuber Nina, Schweizer Magali, Viechmann Marlene R., Maciute Adele, Choquel Constance, Filipsson Helena L., Sundberg Per, Bergström Per, Risebrobakken Bjørg and Aasgaard Sigrid</td>
<td>Spreading of an alien benthic foraminifer in the North Sea: a reason to be worried?</td>
</tr>
<tr>
<td>10:00</td>
<td>Schweizer Magali, Geslin Emmanuelle, Bird Clare, Filipsson Helena L., Jauffrais Thierry, LeKieffre Charlotte, Manero Florence, Metzger Edouard, Mouret Aurélia and Quinchard Sophie</td>
<td>Foraminifera and Other Organisms: Determination of Interactions and Ecology (project FOODIE) in two contrasting environments</td>
</tr>
<tr>
<td>10:15</td>
<td>Bowser Samuel, Bernhard Joan, Landing Ed, Andreas Amanda, Patrucco Reyes Sandra and Walker Sally</td>
<td>Rhizarian stercomata: Experimental notes on their potential for fossilization</td>
</tr>
</tbody>
</table>

### POSTERS AND COFFEE BREAK

<table>
<thead>
<tr>
<th>Time</th>
<th>Speaker(s)</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>11:30</td>
<td>Barragán-Montilla Sofia, Johnstone Heather J.H., Mulitza, Stefan and Pälike, Heiko</td>
<td>Benthic foraminiferal palaeothermometry in deglacial sediments off NW Africa: how accurately is Mg/Ca recording bottom water temperature changes in the past?</td>
</tr>
<tr>
<td>11:45</td>
<td>Ghosh Anupam, Dasgupta Utsha, Tsujimoto Akira, Nomura Ritsuo and Saraswati Pratul Kumar</td>
<td>Applying faunal indices to understand paleoenvironmental changes with benthic foraminifera: a case study from Chilika Lagoon, East coast of India</td>
</tr>
</tbody>
</table>

### LUNCH

## S27: Quaternary planktonic foraminifera: tool for paleoclimatic and paleoceanographic studies

**Conveners:** Giulia Margaritelli, Fabrizio Lirer, Francisco Javier Sierro, Lucilla Capotondi, Isabel Cacho Lascorz

<table>
<thead>
<tr>
<th>Time</th>
<th>Speaker(s)</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>14:30</td>
<td>Asioli Alessandra, Piva Andrea, Andersen Nils and Trincardi Fabio</td>
<td>Deep water production in Adriatic Sea during MIS3-MIS2 from foraminiferal and geochemical proxies</td>
</tr>
<tr>
<td>14:45</td>
<td>Havard Emily, Cherry Katherine, Davis Catherin, Tappa Eric and Benitez-Nelson Claudia</td>
<td>A changing response of planktic foraminifera to seasonality in the California Current Ecosystem: Updates from 2018-2021</td>
</tr>
<tr>
<td>Time</td>
<td>Name and Affiliation</td>
<td>Title</td>
</tr>
<tr>
<td>--------</td>
<td>----------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>15:00</td>
<td>Jackson, Rebecca</td>
<td>Quantifying oceanic regime shifts south of Iceland across glacial/interglacial transitions and millennial scale oscillations using the planktonic foraminifera record</td>
</tr>
<tr>
<td>15:15</td>
<td>Jonkers, Lukas</td>
<td>Using spatial patterns in planktonic foraminifera biodiversity to assess climate models</td>
</tr>
<tr>
<td>15:30</td>
<td>Li, Baohua</td>
<td>Seasonal variation of Planktonic Foraminifera in the South China Sea and its paleoceanographic implication</td>
</tr>
<tr>
<td>15:45</td>
<td>Singh, Vikram Pratap</td>
<td>Migration of the Subtropical Front over the Indian Ocean and its Impact on the Agulhas Current during Quaternary: Planktonic Foraminiferal Evidences</td>
</tr>
</tbody>
</table>

**POSTERS AND COFFEE BREAK**

<table>
<thead>
<tr>
<th>Time</th>
<th>Name and Affiliation</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>17:00</td>
<td>Tang, Hung Yung</td>
<td>The distribution of planktonic foraminifera from Central Locunia province, southern South China Sea</td>
</tr>
<tr>
<td>17:15</td>
<td>Telesiński, Maciej</td>
<td>A mid-Holocene cold spell in the Nordic Seas and its links to a global cooling event</td>
</tr>
<tr>
<td>17:30</td>
<td>Chaabane, Sonia</td>
<td>Exploring the distribution and diversity of modern planktonic foraminifers under multiple climatic stressors: FORCIS database</td>
</tr>
<tr>
<td>17:45</td>
<td>Woodhouse, Adam</td>
<td>Late Cenozoic cooling restructured global marine planktonic foraminiferal communities</td>
</tr>
<tr>
<td>18:00</td>
<td>Ying, Rui</td>
<td>Adaptive thermal niche of planktic foraminifera and the emergence of mechanistic model</td>
</tr>
</tbody>
</table>

**HALL 2**

### S9: Determining the processes involved in biomineralisation – how do foraminifera build their shells?

Conveners: David Evans, Jennifer Fehrenbacher

<table>
<thead>
<tr>
<th>Time</th>
<th>Name and Affiliation</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>09:00</td>
<td>Erez, Jonathan</td>
<td>Biomineralization and proxies in foraminifera</td>
</tr>
<tr>
<td>09:15</td>
<td>Meilland, Julie</td>
<td>Mass reproduction and multi-generation culture of planktonic foraminifera in laboratory</td>
</tr>
<tr>
<td>09:30</td>
<td>Procter, Frances</td>
<td>Using electron backscatter diffraction to investigate shell microstructure and preservation impacts on planktonic foraminiferal calcite</td>
</tr>
<tr>
<td>09:45</td>
<td>Arns, Anthea</td>
<td>Non-classical crystallisation mechanisms as a part of hyaline foraminifer biomineralisation</td>
</tr>
<tr>
<td>10:00</td>
<td>Jaques, Victory A.J.</td>
<td>Submicron Computed Tomography to analyse and quantify microstructures in <em>Uvigerina</em> spp.</td>
</tr>
<tr>
<td>10:15</td>
<td>Paolini, Tommaso</td>
<td>Composition of Foraminifera test</td>
</tr>
<tr>
<td>Time</td>
<td>Title</td>
<td>Authors</td>
</tr>
<tr>
<td>-------</td>
<td>----------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>11:30</td>
<td>Costanzi Elisa, Caridi Francesca, Bartolini Annachiara, Amici Adolfo, Zito Francesca and Sabbatini Anna - Preliminary study of proteins involved in the biocalcification of Rotaliid Foraminifera</td>
<td>Costanzi Elisa, Caridi Francesca, Bartolini Annachiara, Amici Adolfo, Zito Francesca and Sabbatini Anna</td>
</tr>
<tr>
<td>11:45</td>
<td>Ujiitė Yurika, Ishitani Yoshiyuki, Ulanova Dana, Inagaki Yuuka, Ikuma Issui, Yoshimura Toshihiro and Endo Hirotoshi - Transcriptome analyses unveil the molecular framework of calcification in Rotaliida, benthic and planktic foraminifers: What are the differences among species?</td>
<td>Ujiitė Yurika, Ishitani Yoshiyuki, Ulanova Dana, Inagaki Yuuka, Ikuma Issui, Yoshimura Toshihiro and Endo Hirotoshi</td>
</tr>
</tbody>
</table>

**POSTERS AND COFFEE BREAK**

**LUNCH**

**S25: Palaeo- and biogeographical dynamics of benthic foraminifera**

Conveners: Davide Bassi, Meena Förderer, Jere H. Lipps, Johannes Pignatti, Willem Renema

<table>
<thead>
<tr>
<th>Time</th>
<th>Title</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>14:30</td>
<td>Sappe Anna, Petersen Jassin, Schmidt Johanna, Bahr André and Grunert Patrick - Biogeography of benthic foraminifera in contourite drift systems</td>
<td>Sappe Anna, Petersen Jassin, Schmidt Johanna, Bahr André and Grunert Patrick</td>
</tr>
<tr>
<td>14:45</td>
<td>Langer R. Martin, Förderer E. Meena and Rödder Dennis - Biogeography of modern larger symbiont-bearing foraminifera: A fully revised update</td>
<td>Langer R. Martin, Förderer E. Meena and Rödder Dennis</td>
</tr>
<tr>
<td>15:00</td>
<td>Manda Sneha, Ashchenazi-Polivoda Sarit, Herut Barak, Rilov Gil, Kucera Michal and Abramovich Sigal - Hotspot pattern of benthic foraminifera in highly productive environments of the Levant</td>
<td>Manda Sneha, Ashchenazi-Polivoda Sarit, Herut Barak, Rilov Gil, Kucera Michal and Abramovich Sigal</td>
</tr>
<tr>
<td>15:15</td>
<td>Zsiborás Gábor and Görög Agnes - Pliensbachian–Aalenian (Jurassic) palaeobiogeographical patterns of the Neotethyan benthic foraminifera</td>
<td>Zsiborás Gábor and Görög Agnes</td>
</tr>
<tr>
<td>15:30</td>
<td>Leckie R. Mark, Parker Amanda, Dameron Serena N. and Bryant Raquel - A Neritic Record of Oceanic Anoxic Event 2 from Coastal Utah: New Insights into U.S. Western Interior Seaway Paleoceanography and Foraminiferal Paleoecology</td>
<td>Leckie R. Mark, Parker Amanda, Dameron Serena N. and Bryant Raquel</td>
</tr>
<tr>
<td>15:45</td>
<td>Doubrawa Monika, Stassen Peter, Robinson Marcî M. and Speijer Robert P. - Palaeoecological and biogeographical dynamics of the U.S. Atlantic Coastal Plain prior and during the Paleocene-Eocene Thermal Maximum</td>
<td>Doubrawa Monika, Stassen Peter, Robinson Marcî M. and Speijer Robert P.</td>
</tr>
</tbody>
</table>

**POSTERS AND COFFEE BREAK**

**HALL 3**

**S6: Automated image recognition in microscopic analysis for foraminifera studies**

Conveners: Emmanuelle Geslin, Morten Hald, Thibault de Garidel-Thoron, Steffen Aagaard Soerensen, Christine Barras

<table>
<thead>
<tr>
<th>Time</th>
<th>Title</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>Abstract</td>
<td></td>
</tr>
<tr>
<td>-------</td>
<td>--------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>09:15</td>
<td>Sørensen Steffen Aagaard, Myrvoll-Nilsen Eirik, Galata Stamatia, Johansen Thomas Haugland, Martinsen Iver, Hald Morten and Godtliebsen Fred - Automated image/video classification and object detection of foraminifera</td>
<td></td>
</tr>
<tr>
<td>09:30</td>
<td>Choquel Constance, Pirzamanbien Behnaz and Filipsson Helena L. - Addressing the segmentation challenge posed by 3D pore patterns and thickness of foraminiferal tests</td>
<td></td>
</tr>
<tr>
<td>09:45</td>
<td>Govindankutty Menon Anjaly, V. Davis Catherine, Nürnberg Dirk, Nomaki Hidetaka, Salonen Iines and Glock Nicolaas - Pore detection of the denitrifying benthic foraminifer Bolivina spissa through automated image analysis technique</td>
<td></td>
</tr>
</tbody>
</table>

**POSTERS AND COFFEE BREAK**

**S22: New threats on foraminifera from climate change to emerging environmental contaminants: innovative methodological approaches and opportunities**

Conveners: Vincent M.P. Bouchet, Fabrizio Frontalini, Hidetaka Nomaki

<table>
<thead>
<tr>
<th>Time</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>11:30</td>
<td>Sabbatini Anna, Caridi Francesca, Costanzi Elisa, Birarda Giovanni, Medas Daniela, Buosi Carla, Amici Adolfo and Mobbili Giovanna - Toxicological effects of CBs and nicotine as emerging pollutant for benthic foraminifera</td>
</tr>
<tr>
<td>11:45</td>
<td>Frontalini Fabrizio, Greco Mattia, Al-Enezi Eqbal, Amao Abduljamiu, Francescangeli Fabio, Cavaliere Marco, Bucci Carla, Toscanesi Maria, Trifugogi Marco and Pawlowski Jan - Evaluation of the effects of decabromodiphenyl ether BDE-209, a persistent organic pollutant, on benthic foraminiferal community using morphological and eDNA metabarcoding approaches</td>
</tr>
<tr>
<td>12:00</td>
<td>Lintner Michael, Schagerl Michael, Lintner Bianca, Nagy Matthias and Heinz Petra - Symbiont-bearing foraminifera Heterostegina depressa affected by sunscreens</td>
</tr>
<tr>
<td>12:15</td>
<td>Bouchet Vincent M.P., Bertile Fabrice, Muller Leslie, Deldicq Noémie, Deiss Alice, Tailliez Loïc and Seuront Laurent - Virgin or Aged does not matter: Microplastic leachates alter the behavior and the proteome of the kleptoplastidic foraminifera Haynesina germanica</td>
</tr>
<tr>
<td>12:30</td>
<td>Joppien Marlena, Westphal Hildegard, Chandra Viswasanthi, Doo Steve S. and Stuhr Marleen - Plastic particles can be mistaken as a food source and incorporated into benthic foraminifera tests</td>
</tr>
<tr>
<td>12:45</td>
<td>Ishitani Yoshiyuki, Ciacci Caterina, Ujiitê Yurika, Nomaki Hidetaka and Frontalini Fabrizio - Time-course analyses on foraminiferal strain Ammonia veneta reveal unique adverse physiological effects and metabolic changes when exposed to nanoplastics</td>
</tr>
</tbody>
</table>

**LUNCH**

<table>
<thead>
<tr>
<th>Time</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>14:30</td>
<td>Rebecchi Federica, Lattanzi Davide, Abramovich Sigal, Ambrogini Patrizia, Ciacci Caterina, Betti Michele, Schmidt Christiane and Frontalini Fabrizio - Evaluation of the effects and emerging perspectives of electric current stimulation on larger benthic foraminifera: a case study on the genus Amphis pegina</td>
</tr>
<tr>
<td>14:45</td>
<td>Martinez-Colón Michael, Ross Benjamin, Martins Maria V.A., Owens Jeremy, Fajemila Olugbenga T. and Bouchet Vincent M.P. - Comparative analysis of potential toxic element extractions in environmental micropaleontology: “Bioavailability” anyone?</td>
</tr>
<tr>
<td>15:00</td>
<td>Schmidt Christiane, Puerto Rueda Diana, Stuhr Marleen, Raposo Debora, Pochon Xavier and Davy Simon - Menthol-induced bleaching as an effective method to rear foraminifera aposymbiotic</td>
</tr>
</tbody>
</table>
### FRIDAY June 30th

#### HALL 1

**S29: Molecular advances in foraminiferal research: from phylogenomics and molecular systematics to environmental monitoring and paleogenomics**

<table>
<thead>
<tr>
<th>Time</th>
<th>Speaker(s)</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>09:00</td>
<td>Morard Raphael, Darling Kate F., Cordier Tristan, Henry Nicolas, Hassenrück Christiane, Vanni Chiara, Greco Mattia, Weiner Agnes K.M., Vollmar Nele M., Milivojevic Tamara, Rahlan Shirin N., Siccha Michael, Meilland Julie, Jonkers Lukas, Quillévéré Frédéric, Escarguel Gilles, Douday Christophe J., De Garidel-Thoron Thibault, De Vargas Colomban and Kucera Michal</td>
<td>The global genetic diversity of planktonic foraminifera</td>
</tr>
<tr>
<td>09:15</td>
<td>Pawlowska Joanna, Nguyen Ngoc-Loi and Pawlowski Jan</td>
<td>Foraminiferal diversity uncovered by sedaDNA metabarcoding</td>
</tr>
<tr>
<td>09:30</td>
<td>Nguyen Ngoc-Loi, Pawlowska Joanna and Pawlowski Jan</td>
<td>Foraminifera diversity from the ocean surface to the surface layer of sediments in Nordic Sea</td>
</tr>
<tr>
<td>09:45</td>
<td>Barrenechea Angeles Ines, Holm Villads, Holzmann Maria, Pawlowski Jan and Panieri Giuliana</td>
<td>Foraminifera eDNA assemblages from arctic methane cold seeps</td>
</tr>
<tr>
<td>10:00</td>
<td>Frontalini Fabrizio, Greco Mattia, Cavaliere Marco, Buresta Andrea, Barrenechea Angeles Ines, Montresor Marina, Martins Alves Maria Virginia and Pawlowski Jan</td>
<td>Benthic foraminiferal changes in hydrothermal areas around Ischia Island: the evaluation of the effects of ocean acidification through morphological and molecular ecology</td>
</tr>
<tr>
<td>10:15</td>
<td>Girard Elsa B., Didaskalou Emilie A., Rattner Carolina, Pratama Andi M. A., Morard Raphael and Renema Willem</td>
<td>Towards estimating community composition from metabarcoding output in large benthic Foraminifera</td>
</tr>
</tbody>
</table>

**POSTERS AND COFFEE BREAK**

<table>
<thead>
<tr>
<th>Time</th>
<th>Speaker(s)</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>11:30</td>
<td>Pawlowski Jan, Barrenechea Angeles Inès, Nguyen Ngoc-Loi, Holzmann Maria and Gooday Andrew</td>
<td>Monothalamous foraminifera: mapping the unknown diversity revealed by environmental genomics</td>
</tr>
<tr>
<td>11:45</td>
<td>Holzmann Maria, Siemensma Ferry, Pawlowski Jan and Gooday Andrew</td>
<td>Freshwater and soil foraminifera: an overview</td>
</tr>
<tr>
<td>12:00</td>
<td>Grow Adri K. and Katz Laura A.</td>
<td>Assessing freshwater foraminifera diversity in New England (USA)</td>
</tr>
<tr>
<td>12:15</td>
<td>Timmons Caitlin, Le Kristine, Rappaport Hannah, Sterner Elinor G., Maurer-Alcalá Xyrus X. and Katz Laura A.</td>
<td>The life cycle of <em>Allogromia laticollaris</em> has brief haploid and diploid phases followed by a 12,000 fold amplification of genome content and then Zerfall</td>
</tr>
<tr>
<td>12:30</td>
<td>Weinmann Anna E., Hassenrück Christiane, Raposo Débora, Goldstein Susan T., Langer Martin R., Li Qingxia, Triantaphyllou Maria V. and Morard Raphael</td>
<td>Tracking community turnover through time: A combined approach of propagule culture experiments and eDNA metabarcoding</td>
</tr>
<tr>
<td>12:45</td>
<td>Langlet Dewi, Ruppli Rahel, Suzuki H. Nicole, Phua Yong-Heng, Fujita Kazuhiko and Husnik Filip</td>
<td>Eukaryotic symbioses of large benthic foraminifera</td>
</tr>
</tbody>
</table>

**LUNCH**

<table>
<thead>
<tr>
<th>Time</th>
<th>Speaker(s)</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>14:30</td>
<td>Pinko Doron, Abramovich Sigal, Rahav Eyal, Belkin Natasha, Rubin Blum Maxim, Kucera Michal, Morard Raphael, Holzmann Maria and Abdu Uri</td>
<td>Shared ancestry of...</td>
</tr>
<tr>
<td>Time</td>
<td>Abstract</td>
<td></td>
</tr>
<tr>
<td>-------</td>
<td>---------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>14:45</td>
<td>Salonen Iines, Husnik Filip, Naumova Mariia, Ishitani Yoshiyuki, Richirt Julien and Nomaki Hidetaka - The ecology and evolution of the deep-sea foraminifer <em>Chilostomella ovoidea</em> and its enigmatic plastid</td>
<td></td>
</tr>
<tr>
<td>15:00</td>
<td>Takagi Haruka, Nakamura Yasuhide, Schmidt Christiane, Kucera Michal, Moriya Kazuyoshi and Saito Hiroaki - Photosymbiotic partnerships and evolution in planktonic foraminifera revealed by single-cell metabarcoding</td>
<td></td>
</tr>
<tr>
<td>15:30</td>
<td>Fordham Barry G. and Ogg James G. - Tappan &amp; Loeblich’s phylogeny of Foraminifera families: dusting it off for a closer look</td>
<td></td>
</tr>
</tbody>
</table>

**CLOSING CEREMONY**

**HALL 2**

**S5: Applying integrated foraminifera, sedimentology and stratigraphy to refine paleoenvironmental and paleoceanographic reconstructions**

<table>
<thead>
<tr>
<th>Time</th>
<th>Presenter</th>
</tr>
</thead>
<tbody>
<tr>
<td>09:00</td>
<td>Bergh Eugene - Strontium isotope and biostratigraphy of the Namibian continental shelf and associated palaeoenvironmental changes during the Neogene to Quaternary</td>
</tr>
<tr>
<td>09:15</td>
<td>Blake Gregg H. - Benthic Foraminiferal Faunal Response to The Middle Miocene Climatic Transition From Greenhouse to Icehouse Conditions Along Central California, USA</td>
</tr>
<tr>
<td>09:30</td>
<td>Bouhdadad Fatima, Freire Tiago, Auer Gerald, Carballeira Rafael, Herwartz Daniel, Scheidt Stephanie, Leicher Niklas, Wennrich Volker, Albert Richard, Gerdes Axel, Petersen Jassin, Nielsen Sven, Rivadeneira Marcelo and Grunert Patrick - Unlocking the paleoceanographic archives of the Humboldt Current System through the foraminiferal record: A case study from the Bahia Inglesa Formation, northern-central Chile</td>
</tr>
<tr>
<td>09:45</td>
<td>Charoentitrat Thasinee, Jitmahantrakul Sukonmeth, Tokiwa Tetsuya and Hara Hidetoshi - Age constraints of Fusulinid Foraminifers and U-Pb Detrital Zircon from Conglomerates in the western margin of Indochina Block, Thailand: Evidence of Paleogeography and Indosinian Orogenies</td>
</tr>
<tr>
<td>10:00</td>
<td>Cotton Laura J., Evans David and Schmidt Daniela N. - Shelf ecosystem response to the Eocene-Oligocene Transition</td>
</tr>
</tbody>
</table>

**POSTERS AND COFFEE BREAK**

<table>
<thead>
<tr>
<th>Time</th>
<th>Poster</th>
</tr>
</thead>
<tbody>
<tr>
<td>11:30</td>
<td>Gastaldello Maria Elena, Agnini Claudia, Westerhold Thomas, Drury Anna Joy, Sutherland Rupert, Drake Michelle K., Lam Adriane R., Dickens Gerald R., Dallanave Edoardo, Burns Stephen and Alegret Laia - Regional imprint and global signature of the Late Miocene-Early Pliocene Biogenic Bloom in the Tasman Sea (IODP Site U1506)</td>
</tr>
<tr>
<td>11:45</td>
<td>Hupp Brittany and Kelly D. Clay - ‘Unmixing’ Deep-Sea Sedimentary Records of Planktic Foraminifer Community Turnover during the PETM through Isotopic Filtering</td>
</tr>
<tr>
<td>12:00</td>
<td>Kearns Lorna E., Sánchez-Montes Maria Luisa, Jones Heather, Sepúlveda Julio and Lowery Christopher M. - Recovery of planktic ecosystems following the end-</td>
</tr>
<tr>
<td>Time</td>
<td>Session/Abstract</td>
</tr>
<tr>
<td>-------</td>
<td>-------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>12:15</td>
<td>Leon-Rodriguez Lizette, Jonk Rene, Knabe Keith, Kevin Bohacs Kevin and Davis J. Steve - The application of biostratigraphic studies in the energy and subsurface-storage industries. An example from the Ainsa Basin, Spain</td>
</tr>
<tr>
<td>12:30</td>
<td>Sayed Mostafa M., Heinz Petra, Abd El-Gaied Ibrahim M. and Wagreich Michael - Paleoclimate and paleoenvironment reconstructions from middle Eocene successions at Beni-Suef, Egypt: foraminiferal assemblages and geochemical approaches</td>
</tr>
<tr>
<td>12:45</td>
<td>Peñalver-Clavel Irene, Agnini Claudia, Bhattacharya Joyceeta, Dallanave Edoardo, Westerhold Thomas, Dickens Gerald, Sutherland Rupert and Alegret Laia - First record of deep-sea benthic foraminiferal response to the Late Lutetian Thermal Maximum in the Tasman Sea (IODP Site U1508, Southwest Pacific)</td>
</tr>
<tr>
<td></td>
<td>LUNCH</td>
</tr>
<tr>
<td>14:30</td>
<td>Roslim Amajida, Alfian Amirah, Briguglio Antonino, Goeting Sulia and Koceis László - Species distribution and biostratigraphic evaluation of fossil foraminifera from Miocene to late Pleistocene sediments obtained from deep wells offshore Brunei Darussalam</td>
</tr>
<tr>
<td>15:00</td>
<td>Lu Zhengbo and Fan Junxuan - Pattern of foraminiferal diversity change across the Eocene-Oligocene transition</td>
</tr>
<tr>
<td></td>
<td>CLOSING CEREMONY</td>
</tr>
<tr>
<td></td>
<td>HALL 3</td>
</tr>
</tbody>
</table>

**S18: Linking Morphogenesis and Biomineralization**

Conveners: Yukiko Nagai, Lennart de Nooijer, Takashi Toyofuku, Jaroslaw Tyszka

<table>
<thead>
<tr>
<th>Time</th>
<th>Session/Abstract</th>
</tr>
</thead>
<tbody>
<tr>
<td>09:00</td>
<td>Toyofuku Takash and Nagai Yukiko - Chamber of Secrets: Decoding the Formation Process of Foraminiferal tests</td>
</tr>
<tr>
<td>09:15</td>
<td>Goleń Jan, Tyszka Jaroslaw, Bickmeyer Ulf, Bijma Jelle, Godos Karolina, Nagai Yukiko and Toyofuku Takashi - Ectoplasmic control of calcium ion transport during chamber biomineralization in rotaliid Foraminifera: novel results from live fluorescent labelling of frothy pseudopodia</td>
</tr>
<tr>
<td>09:30</td>
<td>François Daniel, De Goeysie Siham, Reichart Gert-Jan, King Helen E. and De Nooijer Lennart J. - Proton pumping influences element incorporation in hyaline foraminifera</td>
</tr>
<tr>
<td>09:45</td>
<td>Charrieau Laurie M., Rollion-Bard Claire, Terbrueggen Anja, Wilson David J., Pogge von Strandmann Philip A.E., Misra Sambuddha and Bijma Jelle - Lithium incorporation and isotopic fractionation in large benthic foraminifera under decoupled pH/DIC conditions</td>
</tr>
<tr>
<td>10:00</td>
<td>Brombacher Anieke, Searle-Barnes Alex, Mulqueeney James, Stansish Chris, Watson Richard, Wilson Paul, Foster Gavin and Ezard Thomas - Environmental drivers of developmental plasticity distinguished from genetic change in the fossil record</td>
</tr>
<tr>
<td>10:15</td>
<td>Nagai Yukiko, Tsubaki Remi, Fujita Kazuhiko and Toyofuku Takashi - Ultrafine structure observation and pH imaging of site of calcification in <em>Sorites orbiculus</em></td>
</tr>
<tr>
<td></td>
<td>POSTERS AND COFFEE BREAK</td>
</tr>
<tr>
<td>11:30</td>
<td>Hohenegger Johann - Perspectives of growth in Foraminifera</td>
</tr>
<tr>
<td>11:45</td>
<td>Tyszka Jaroslaw, Godos Karolina, Goleń Jan and Radmacher Wiesława - Phylogenetic patterns of Foraminiferal Organic Linings</td>
</tr>
<tr>
<td></td>
<td>LUNCH</td>
</tr>
</tbody>
</table>
# POSTER PRESENTATIONS

<table>
<thead>
<tr>
<th>CODE</th>
<th>REFERENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>S1: A Latin American and Caribbean cluster: gathering foraminiferal researchers</strong></td>
<td></td>
</tr>
<tr>
<td>S1-1</td>
<td>Baumgartner-Mora Claudia, Baumgartner Peter O., Ferrández-Cañadell Carles and Buchs David M. - Larger benthic foraminifera from the Azuero Peninsula (SW-Panama) define Eocene accretionary events and an arc gap along the trailing edge of the Caribbean Plate</td>
</tr>
<tr>
<td>S1-3</td>
<td>King David J., Wade Bridget S. and Miller C. Giles - The influence of the Caribbean in Oligo-Miocene planktonic foraminifera taxonomy and biostratigraphy</td>
</tr>
<tr>
<td>S1-4</td>
<td>Zardin Tamires N., Kochhann Karlos, Krahl Guilherme, Martins Alisson, Roloff Greice, Fauth Gerson and Chiessi Cristiano - Integrated stratigraphy of the last glacial-interglacial transition in the Sergipe-Alagoas basin, South Atlantic Ocean</td>
</tr>
<tr>
<td>S1-5</td>
<td>Mendes Rafaela, Yamashita Cintia, Vicente Thaisa, Santa Rosa Ana, Fonseca Gustavo, Vieira Danilo, Martins Maria Virginia and Sousa Silvia Helena - Predicting deep-sea living (stained) benthic foraminifera from the continental slope and São Paulo Plateau, Santos Basin (SW Atlantic): Differences between genus and species data using machine learning</td>
</tr>
</tbody>
</table>

<p>| <strong>S2: Advances and challenges in modern and fossil benthic foraminifera research: a session dedicated to Prof. John Murray</strong> | |
| S2-1 | Barras Christine, Le Moigne Damien, Mojtahid Meryem, Labruné Céline, Mouret Aurélie, Metzger Edouard, Maillet Grégoire, Morisseau Célestine, Pruski Audrey, Vétion Gilles, Lescure lyvia and Vaz Sandrine - Distribution of benthic foraminifera in the Gulf of Lions, Mediterranean Sea: Response to trawling activity or natural variability? |
| S2-2 | Faizieva Kamila, Wollenburg Jutta, Heinz Petra and Wukovits Julia - Phytodetritus-colonising living (Rose Bengal stained) benthic foraminifera during a spring phytoplankton bloom in the Arctic Ocean |
| S2-3 | Francescangeli Fabio, Bouchet Vincent M.P., Milker Yvonne, Frontalini Fabrizio, Richard Xavier, Trentesaux Alain and Armynot du Chatelet Eric - Temporal changes in intertidal benthic foraminifera: a seasonal survey from the English Channel (France) |
| S2-4 | Tremblin Clément M., Holzmann Maria, Parker Justin H., Sadekov Aleksey and Haig David W. - Invasive <em>Trophammina</em> in a south-west Australian estuary |
| S2-5 | Markoglou Eleni Anastasia, Tsourou Theodora, Parinos Constantine, Gogou Aleka, Dimiza Margarita, Danelian Taniel and Triantaphyllou Maria - Modern agglutinated foraminifera in the surface sediments of NE Mediterranean environments |
| S2-6 | Bardis Dimitrios, Triantaphyllou Maria, Dimiza Margarita, Tsourou Theodora, Koukousioura Olga, Weinmann Anna, Langer Martin and Hallock Pamela - <em>Amphistegina lobifera</em> Larsen life cycle mode in a stressed coastal environment: The Vravron site, Aegean Sea Greece, revisited |
| S2-7 | Gfatter Christian, Martínez-Colón Michael and Owens Jeremy - Comparing flow-through culturing systems to investigate elemental uptake in the calcite tests of |</p>
<table>
<thead>
<tr>
<th>Abstract</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>benthic foraminifera</td>
<td>S2-8 Wukovits Julia, Wollenburg Jutta, Glock Nicolaas, Heinz Petra and Roy Alexandra-Sophie - A review and new observations on <em>Tholosina vesicularis</em> Brady (1879), an extraordinary monothalamous foraminifera</td>
</tr>
<tr>
<td></td>
<td>S2-9 Fentimen Robin, Rime Valentim, Francescangeli Fabio, Negga Haile, Attafu Balemwal and Foubert Anneleen - Fossil benthic foraminifera from the Danakil Depression (northern Ethiopia): avian transport within an active rift valley</td>
</tr>
<tr>
<td></td>
<td>S2-10 Bryant Raquel, Belanger Christina and Meehan Kim - Multivariate analyses on benthic foraminiferal assemblages: Two case studies from the Late Cretaceous Western Interior Seaway</td>
</tr>
<tr>
<td></td>
<td>S2-11 Nagy Matthias, Enge Annekatrin J., Heinz Petra and Albano Paolo G. - Documentation of the native shallow water benthic foraminiferal assemblage in a sediment core from the coastal region of Northern Israel</td>
</tr>
<tr>
<td></td>
<td>S2-12 Disaro Sibelle T, Dissenha Gonçalves Joicce, Kropiwiec Isabela S., Mendes Rafaela, Ribas Elis R., Pupo Daniel V. and Moreira Daniel L. - Benthic foraminifera from the continental shelf of the Santos Basin (SE-S, Brazil) - traditional and Machine Learning, integrated approach</td>
</tr>
<tr>
<td></td>
<td>S2-13 Brombacher Anieke, Butts Susan, Cheng Evan and Hull Pincelli - Studying morphological variation across space and through time using existing museum collections</td>
</tr>
<tr>
<td></td>
<td>S3: Advances in larger foraminiferal biostratigraphy: a framework for reconstructing shallow-water events</td>
</tr>
<tr>
<td></td>
<td>S3-1 Crobu Simone, Briguglio Antonino, Arena Luca, Giraldo-Gómez Victor M., Gandolfi Antonella, Baucon Andrea, Papazzoni Cesare Andrea, Pignatti Johannes and Piazza Michele - Biodiversity of Larger Benthic Foraminifera (LBF) from the Bartonian succession of Capo Mortola promontory (Liguria, NW Italy)</td>
</tr>
<tr>
<td></td>
<td>S3-2 Gheiasvand Masoumeh and Bartolini Annachiara - New morphotypes of <em>Balkhania balkhanica</em> Mamontova, 1966 from the upper Valanginian - lower Aptian of the northern Tethyan margin</td>
</tr>
<tr>
<td></td>
<td>S3-3 Papazzoni Cesare Andrea and Benedetti Andrea - Larger foraminiferal biodiversity from Paleocene to Miocene: possible relationships with climate changes</td>
</tr>
<tr>
<td></td>
<td>S5: Applying integrated foraminifera, sedimentology and stratigraphy to refine paleoenvironmental and paleoceanographic reconstructions</td>
</tr>
<tr>
<td></td>
<td>S5-1 De Almeida Fabiana K., de Mello Renata M., Rodrigues André R. and Bastos Alex C. - Factors controlling the benthic foraminiferal distribution on the Espírito Santo Basin slope, SW Atlantic</td>
</tr>
<tr>
<td></td>
<td>S5-2 De Almeida Fabiana K., de Mello Renata M. and Bastos Alex C. - The influence of submarine canyons processes in the benthic foraminiferal distribution on the Espírito Santo Basin, SW Atlantic</td>
</tr>
<tr>
<td></td>
<td>S5-3 Diz Paula, Sierro Francisco J., Groba Ricardo and Hernández-Almeida Iván - Surface drivers of deep-sea benthic foraminifera variability during the Mid-Pleistocene Transition in the subpolar North Atlantic</td>
</tr>
<tr>
<td></td>
<td>S5-4 Filippi Giulia, Schmidt Daniela, Barret Ruby, D’Onofrio Roberta, Westerhold Thomas, Brombin Valentina and Luciani Valeria - Planktic foraminiferal abundance and test-size record across the Early Eocene Climatic Optimum (EECO, ~53-49 Ma) at Shatsky Rise (Pacific Ocean)</td>
</tr>
<tr>
<td></td>
<td>S5-5 Gale Luka, KresniTjaša, Brajkič Rok and Košir Adrijan - Foraminiferal view on Toarcian environmental perturbations on the northern part of the Adriatic Carbonate Platform, Slovenia</td>
</tr>
<tr>
<td>S5-6</td>
<td>Gandolfi Antonella, Giraldo-Gómez Victor Manuel, Luciani Valeria, Piazza Michele, Papazzoni Cesare A., Pignatti Johannes and Briguglio Antonino - Planktic and benthic foraminifera across the Middle Eocene Climatic Optimum (MECO): the case study of the shallow-water Capo Mortola succession (Liguria, NW Italy)</td>
</tr>
<tr>
<td>S5-7</td>
<td>Goeting Sulia, Lee Huan Chiao, Kocsis László, Baumgartner Claudia and Marshall David J - Diversity and distribution of the benthic foraminifera on the Brunei shelf (Palawan/North Borneo ecoregion): effect of seawater depth</td>
</tr>
<tr>
<td>S5-8</td>
<td>Székely Adrienn and Görög Ágnes - Reconstruction of the Oligocene paleoenvironment in the Central Paratethys, North Hungarian Paleogene Basin</td>
</tr>
<tr>
<td>S5-9</td>
<td>Hernitz Kučenjak Morana, Pezelj Durdica, Marković Franjo, Kovačić Marijan and Matošević Mario - Middle Badenian foraminiferal assemblages from Papuk Mt, North Croatian Basin</td>
</tr>
<tr>
<td>S5-10</td>
<td>Bu Khamsin Ali and Kaminski Michael - New Bajocian shallow-water agglutinated foraminifera from the basal D1 member of the Dhrama Formation west of Riyadh, Saudi Arabia</td>
</tr>
<tr>
<td>S5-11</td>
<td>Standring Patricia, Lowery Christopher, Kearns Lorna and Martindale Rowan - Palaeoceanographic Changes and Ecological Impacts on Foraminifera during Eocene-Oligocene Transition in the Gulf of Mexico</td>
</tr>
<tr>
<td>S5-12</td>
<td>Koukousioura Olga, Puentes-Jorge Xabier, Panagiotopoulos Konstantinos, Diz Paula and Grunert Patrick - Paleoenvironmental changes in the Gulf of Corinth (eastern Mediterranean) during MIS 5 from benthic foraminifera and geochemical proxies</td>
</tr>
<tr>
<td>S5-13</td>
<td>Peñalver-Clavel Irene, Dallanave Edoardo, Westerhold Thomas, Dickens Gerald R., Sutherland Rupert and Alegret Laia - Benthic foraminiferal response to the Middle Eocene Climate Optimum in the Tasman Sea (IODP Site U1511, Southwest Pacific)</td>
</tr>
<tr>
<td>S5-14</td>
<td>Pezelj Durdica, Sabol Jurica, Kovačić Marijan and Marković Franjo - The Middle Miocene benthic foraminiferal assemblages from Krndija Mt. (Našice quarry, Croatia)</td>
</tr>
<tr>
<td>S5-15</td>
<td>Rodrigues André R., De Almeida Fabiana K., Mello Renata M. de , Grilo Caroline F., Quaresma Valéria da S. and Bastos Alex C. - Benthic foraminiferal assemblages of the Espírito Santo Continental Shelf, Southeastern Brazil (SW Atlantic)</td>
</tr>
<tr>
<td>S5-16</td>
<td>Ruschi Anita G., Rodrigues André R., Cetto Paulo H. and Bastos Alex C. - Paleoenvironmental evolution of Abrolhos Depression (Brazil - SW Atlantic) based on the distribution of benthic foraminiferal assemblages</td>
</tr>
<tr>
<td>S5-17</td>
<td>Trubin Yaroslav S., Marinov Vladimir A., Rudmin Maxim A., Smirnov Pavel V., Winkler Alina, Brit Vyacheslav A., Novoselov Andrey A. and Langer Martin R. - The Foraminifera of the Western Siberian Seas – with what sorts of treasures they filled their homes after life?</td>
</tr>
<tr>
<td>S5-18</td>
<td>Walsh Jared, Fietz Susanne and Bergh Eugene - Biostratigraphic and marine palaeoenvironmental change associated with the Plio-Pleistocene transition along the western continental shelf of southern Africa</td>
</tr>
<tr>
<td>S6: Automated image recognition in microscopic analysis for foraminifera studies</td>
<td></td>
</tr>
<tr>
<td>S6-1</td>
<td>Lichterfeld Yohan, De Garidel-Thibault, Leduc Guillaume, Dewilde Fabien, Vidal Laurence and Luciani Elise - Individual foraminifera analyses: comparison of morphometric and isotopic methods and application for the penultimate deglaciation</td>
</tr>
<tr>
<td>S6-2</td>
<td>Siciliano Julie, Russo Bianca, Barattolo Filippo and De Bonis Alberto - Analysis of</td>
</tr>
<tr>
<td>Abstract</td>
<td>Title</td>
</tr>
<tr>
<td>----------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>S6-3</td>
<td>Planktic foraminifera abundance in ceramic samples from Pian della Tirena (Calabria, southern Italy): Application of JMicroVision software</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>S6-4</td>
<td>Benthic foraminifera abundance in ceramic samples from Pian della Tirena (Calabria, southern Italy): Application of JMicroVision software</td>
</tr>
<tr>
<td>S6-5</td>
<td>Identification of environmentally relevant benthic foraminifera from the Skagerrak fjords by deep learning image modelling</td>
</tr>
<tr>
<td>S6-6</td>
<td>Identification of environmentally relevant benthic foraminifera from the Skagerrak fjords by deep learning image modelling</td>
</tr>
<tr>
<td>S8-1</td>
<td>Evolutionary and environmental control on coiling direction and loss of algal photosymbiosis (bleaching) in the foraminiferal fossil and recent record</td>
</tr>
<tr>
<td>S9-1</td>
<td>Determining the processes involved in biomineralisation – how do foraminifera build their shells?</td>
</tr>
<tr>
<td>S9-2</td>
<td>Determining the role of seawater vacuolisation in the biomineralisation process of the planktonic foraminifera using confocal microscopy</td>
</tr>
<tr>
<td>S10-1</td>
<td>Environmental monitoring with benthic foraminifera: assessing the Ecological Quality Status of coastal and marine systems</td>
</tr>
<tr>
<td>S10-2</td>
<td>Environmental monitoring with benthic foraminifera: assessing the Ecological Quality Status of coastal and marine systems</td>
</tr>
<tr>
<td>S10-3</td>
<td>Environmental monitoring with benthic foraminifera: assessing the Ecological Quality Status of coastal and marine systems</td>
</tr>
<tr>
<td>S10-5</td>
<td>Environmental monitoring with benthic foraminifera: assessing the Ecological Quality Status of coastal and marine systems</td>
</tr>
<tr>
<td>S10-6</td>
<td>Environmental monitoring with benthic foraminifera: assessing the Ecological Quality Status of coastal and marine systems</td>
</tr>
<tr>
<td>Abstract Reference</td>
<td>Title</td>
</tr>
<tr>
<td>---------------------</td>
<td>---------------------------------</td>
</tr>
<tr>
<td>S10-7</td>
<td>Goodwin Charles, Smith Christopher and Dellapenna Timothy - A down core analysis of foraminifera from Patrick Bayou (Galveston Texas) before and after hurricane disturbances</td>
</tr>
<tr>
<td>S10-8</td>
<td>Martínez-Colón Michael, Ross Benjamin, Shirey Benjamin, Chauhan Ashvini, Pathak Ahish, Owens Jeremy and Bouchet Vincent M.P. - Historical foraminiferal and microbial environmental health assessment of Guánica Bay (Puerto Rico)</td>
</tr>
<tr>
<td>S10-9</td>
<td>Fouet Marie P.A., Schweizer Magali, Singer David, Richert Julien, Quinchard Sophie and Jorissen Frans J. - How do morphological and eDNA data compare for biomonitoring? An example with the distribution of three Ammonia (Foraminifera, Rhizaria) species in estuaries of the French Atlantic coast</td>
</tr>
<tr>
<td>S10-10</td>
<td>Melis Romana, Figus Billy, Floreani Federico, Petranich Elisa and Terranova Kevin Gabriele - Living Benthic foraminifera as ecological and biomonitoring tools in the Marano and Grado Lagoon (northern Adriatic Sea, Italy)</td>
</tr>
<tr>
<td>S10-11</td>
<td>Khokhlova Anna, Gudnitz Maria N., Ferriot Pere, Tejada Silvia, Sureda Antonio, Pinya Samuel, Mateu-Vicens Guillem - Epiphytic Foraminifera in Posidonia oceanica Meadows as a Tool for Monitoring Heavy-Metal Pollution in the Balearic Islands (Spain)</td>
</tr>
<tr>
<td>S10-12</td>
<td>Elkin Adam, Lam Tristan, O’Malley Bryan, Quiambao Rafael and Schwing Patrick - Methods for Classification of Epilithic Benthic Foraminifera of the Southeastern Clarion-Clipperton Zone</td>
</tr>
<tr>
<td>S10-13</td>
<td>Hoff Marie, Argentino Claudio, Barrenechea Angeles Ines and Panieri Giuliana - The response of benthic foraminiferal assemblages to copper mine tailing deposits at the Repparfjord, Northern Norway</td>
</tr>
<tr>
<td>S11-1</td>
<td>Ueno Katsumi, Charoentitirat Thasinee and Kamata Yoshihito - Foraminiferal succession across the Permian–Triassic boundary in Northern Thailand</td>
</tr>
<tr>
<td>S11-2</td>
<td>Falzoni Francesca, Gale Luka, Rettori Roberto, Weinmann Anna, Parente Mariano - Taxonomic revision of some textulariinid benthic foraminifera of the Triassic-Jurassic boundary interval</td>
</tr>
<tr>
<td>S11-3</td>
<td>Rashall Jenny, Nestell Galina and Nestell Merlynd - Benthic Foraminifera of the Albion-Cenomanian (Cretaceous) Washita Group in North-Central Texas, USA</td>
</tr>
<tr>
<td>S11-4</td>
<td>Woodhouse Adam, Swain Anshuman, Fagan William F., Fraass Andrew J. and Lowery Christopher M - Multi-million-year lags between planktonic foraminiferal functional richness and community responses to Cenozoic climate perturbations</td>
</tr>
<tr>
<td>S12-1</td>
<td>Winkelbauer Helge, Hoogakker Babette, Anderson Robert, Melanie Leng, Hamilton Elliot and Chenery Simon - Research Avenue South, Edinburgh, EH14 4AP Planktic foraminifera iodine/calcium ratios and relationship to seawater oxygen content</td>
</tr>
<tr>
<td>S12-2</td>
<td>Aranyi Timea and Görög Agnes - Can we use milioline morphotype (miliolids and rzehakinids) foraminifera in pelagic environment as seawater oxygen proxies?</td>
</tr>
<tr>
<td>S12-3</td>
<td>Glock Nicolaas, Erdem Zeynep and Schönfeld Joachim - Foraminiferal pore densities reveal that the Peruvian oxygen minimum zone was similar in extent but weaker during the Last Glacial Maximum</td>
</tr>
<tr>
<td>S12-4</td>
<td>Groeneveld Jeroen, Palme Tina, Steinke Stephan and Lückge Andreas - Reconstructing the Oxygen Minimum Zone in the Arabian Sea using Mn/Ca in planktonic foraminifer</td>
</tr>
</tbody>
</table>
and isotopic fingerprinting of benthic foraminifera to distinguish contourites from turbidites

**S13: Foraminifera in polar environments: problems of preservation, presence in different palaeoenvironments and related problem solving**

<table>
<thead>
<tr>
<th>Session</th>
<th>Title</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>S13-1</td>
<td>Beneath the Ross Ice Shelf, Antarctica: A perspective of West Antarctic Ice Sheet History from Miocene Benthic Foraminifera</td>
<td>Dameron Serena and Leckie R. Mark</td>
</tr>
<tr>
<td>S13-2</td>
<td>Warm Water Incursions and Water Mass Changes on the Ross Sea Shelf (Antarctica) During the Plio-Pleistocene Based on Foraminifera from IODP Exp 374</td>
<td>Seidenstein, Julia L., Leckie, R. Mark, Harwood, David and IODP Exp. 374</td>
</tr>
<tr>
<td>S13-3</td>
<td>Pleistocene Foraminifera of the Ross Sea Continental Slope and Rise, IODP Exp. 374</td>
<td>Seidenstein, Julia L., Leckie, R. Mark and IODP Exp. 374 Science Party</td>
</tr>
<tr>
<td>S13-4</td>
<td>Benthic foraminifera as tools to reconstruct past tidewater glacier dynamics: A case study from Kongsfjorden (Svalbard)</td>
<td>Mojtaahid Meryem, Fossile Eleonora, Santoni Serena, Husum Katrine, Streuff Katharina, Forwick Matthias, Howa Hélène and Nardelli Maria Pia</td>
</tr>
<tr>
<td>S13-5</td>
<td>Environmental changes in the Barents Sea over the last millennia: benthic foraminifera evidence</td>
<td>Boretto Gabriella, Tesi Tommaso, Gulhermic Corentin, Dessandier Pierre Antoine, Panieri Giuliana and Capotondi Lucilla</td>
</tr>
<tr>
<td>S13-6</td>
<td>Seasonal dynamics of intertidal foraminifera of the subarctic White Sea</td>
<td>Golikova Elena, Chelkak Alexandra, Aristov Dmitriy, Stodolskaya Alyona and Korsun Sergei</td>
</tr>
<tr>
<td>S13-7</td>
<td>Recent benthic foraminifera from Marian Cove, King George Island, Antarctica</td>
<td>Lee Somin, Frontalini Fabrizio and Lee Wonchoel</td>
</tr>
</tbody>
</table>

**S14: Foraminiferal geochemical proxies: novel approaches, unique applications and facing poorly-understood problems**

<table>
<thead>
<tr>
<th>Session</th>
<th>Title</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>S14-1</td>
<td>Assessing the impact of diagenetic bias on sea-level reconstructions spanning the last full glacial cycle based on deep-sea benthic foraminiferal stable isotope records</td>
<td>Poirier Robert K., Borrelli Chiara, Fung Megan, Schaller Morgan F. and Kozdon Reinhard</td>
</tr>
<tr>
<td>S14-3</td>
<td>Barium incorporation of benthic foraminifera – high resolution proxy calibration from the natural laboratory of the Northern Aegean Sea</td>
<td>Petersen Jassin, Bouhdavad Fatima, Grunert Patrick, Schleinkofer Nicolai, Raddatz Jacek, Bahr Andre, Mojtabah Meryem, Pross Joerg, Jorissen Frans and Schmiedl Gerhard</td>
</tr>
<tr>
<td>S14-4</td>
<td>The High-Low: combined analytical approaches yield both high and low past ocean temperatures from the equatorial Indian Ocean across the Cenozoic</td>
<td>Nilsson-Kerr Katrina, Meckler Anna Nele, Pedersen Leif-Erik, Anand Pallavi and Garrido Sebastián</td>
</tr>
<tr>
<td>S14-5</td>
<td>ExploRarE: Exploring the potential of REEs as productivity indicators in planktonic foraminifera along western Iberian Margin</td>
<td>Rebotim Andreia, Salgueiro Emilia, Matos Lélia, Lopes Cristina, Voelker Antje H.L., Brito Pedro A. and Abrantes Fátima</td>
</tr>
<tr>
<td>S14-6</td>
<td>Recent benthic foraminifera from Marian Cove, King George Island, Antarctica</td>
<td>Rice Addison, Melis Bestard Neus, Frauenschuh Saskia, Ziegler Martin, Reichart</td>
</tr>
<tr>
<td>Session</td>
<td>Title</td>
<td>Authors</td>
</tr>
<tr>
<td>---------</td>
<td>----------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>S14-7</td>
<td>Assessing seasonal, size, and depth-related influences on planktic foraminiferal Mg/Ca ratios in the eastern Mediterranean Sea through comparison of sediment trap and surface sediment samples</td>
<td>Gert-Jan de Nooijer Lennart, Lourens Lucas, de Lange Gert, Peterse Francien and Sluijs Appy</td>
</tr>
<tr>
<td>S14-9</td>
<td>Impact of the Middle Eocene Climatic Optimum (MECO) on Atlantic planktic foraminiferal assemblages</td>
<td>Sigismondi Silvia, Luciani Valeria and Alegret Laia</td>
</tr>
<tr>
<td>S15-1</td>
<td>A new high resolution stable isotope record from the North Atlantic Ocean: a detailed insight into the mid-Maastrichtian event</td>
<td>Fischer Alexa, Friedrich Oliver, Bahr André and Voigt Silke</td>
</tr>
<tr>
<td>S15-2</td>
<td>Albian–Cenomanian planktonic foraminifera and the warm to hot Cretaceous greenhouse climate transition at southern high latitudes: Results from IODP Sites U1513, U1514, and U1516 (SE Indian Ocean)</td>
<td>Huber Brian T., Macleod Kenneth G., Petrizzo Maria Rose and Watkins David H.</td>
</tr>
<tr>
<td>S15-3</td>
<td>Turonian - Santonian paleoceanographic changes registered by planktonic foraminifera and stable isotopes at southern high latitudes</td>
<td>Petrizzo Maria Rose, MacLeod Kenneth G., Watkins David K., Wolfgring Erik and Huber Brian T.</td>
</tr>
<tr>
<td>S15-4</td>
<td>A Comparative Morphological Analysis of Planoheterohelix Across the Cretaceous Western Interior Seaway during Oceanic Anoxic Event 2</td>
<td>Holguin-Caldera Daniel and Bryant Raquel</td>
</tr>
<tr>
<td>S15-5</td>
<td>Benthic foraminiferal assemblages from the Lower Cretaceous of the Neuquén Basin, Argentina: paleoecological and paleoenvironmental constraints</td>
<td>Caratelli Martina and Archuby Fernando</td>
</tr>
<tr>
<td>S15-6</td>
<td>Early Cretaceous (Aptian–Albian) depositional environments of Sergipe-Alagoas Basin (northeastern of Brazil): microbiofacies and foraminiferal assemblages</td>
<td>Luft-Souza Fernanda, Terra Gerson José Salamani, Patarroyo German David and Fauth Gerson</td>
</tr>
<tr>
<td>S17-1</td>
<td>A new species of Eoparafusulina (Fusulinacea, Monodoexodininae) from the Lower Permian of the Northwest Peninsular Malaysia: Its significance to Sibumasu Block (Eastern Cimmerian Continent) palaeobiogeography and palaeoclimatology</td>
<td>Fassihi Shirin, Vachard Daniel, Heinz Petra and Hassan Meor Hakif Amir</td>
</tr>
<tr>
<td>S17-2</td>
<td>New insights on the benthic Foraminifera at the Cenomanian-Turonian boundary (OAE2) aftermath and the role of the genus Rotorbinella Bandy through the Late Cretaceous</td>
<td>Consorti Lorenzo, Krizova Barbora, Cardelli Sahara, Bagherpour Borhan, Franceschi Marco, Bonini Lorenzo and Friija Gianluca</td>
</tr>
<tr>
<td>S17-3</td>
<td>Benthic foraminiferal assemblages from the Lower Cretaceous of the Neuquén Basin, Argentina: paleoecological and paleoenvironmental constraints</td>
<td>Consorti Lorenzo, Fabbi Simone, Cipriani Angelo and Pampaloni Maria Letizia</td>
</tr>
<tr>
<td>S17-4</td>
<td>Cvetko Tešović Blanka, Schlagintweit Felix, Martinuš Maja and Vlahović Igor - New benthic foraminifera from the island of Brač (Croatia): further evidence for high foraminiferal diversity in Campanian inner platform settings</td>
<td></td>
</tr>
<tr>
<td>S17-5</td>
<td>Ferrández-Cañadell Carles, Baumgartner-Mora Claudia and Baumgartner Peter O. - Polyphyletism and parallel evolution in Foraminifera and their implications in biostratigraphy. Two new examples from the Priabonian of the Helvetic Alps</td>
<td></td>
</tr>
<tr>
<td>S17-6</td>
<td>Martens Lise, Stassen Peter, Steurbaut Etienne and Speijer Robert P. - Reconstructing Eocene mid-latitudinal environmental changes through <em>Nummulites</em> geochemistry</td>
<td></td>
</tr>
<tr>
<td>S17-7</td>
<td>Schlagintweit Felix, Xu Yiwei and Li Xianghui - Apparent Megadiversity of Tibetan Orbitolininae: Revision Overdue</td>
<td></td>
</tr>
</tbody>
</table>

**S18: Linking Morphogenesis and Biomineralization**

| S18-1 | Godos Karolina, Tyszka Jarosław, Goleń Jan and Radmacher Wiesława - Trends in the record of foraminiferal organic linings |
| S18-2 | Van Dijk Inge, Csíneros-Lazaro Deyanira, Raitzsch Markus, Brummer Geert-Jan, Moore Jo, Meibom Anders and Bijma Jelle - Cogwheel structures in foraminiferal shells |

**S19: Modern and Past Tropical Belts Assessed by Foraminifera**

| S19-1 | Alves Martins Maria Virginia, Damasceno Fabricio Leandro, Saibro Murilo Barros, da Silva Layla Cristine, Senez-Mello Thaise M., Frontalini Fabrizio, Santos Luiz Guilherme Costa, Mendonça Filho João Graciano, Castelo Wellen Fernanda Louzada, Duleba Wania, de Mello e Sousa Silvia Helena, and members of the project “Anthropized coastal systems”: Carvalho da Silva André Luiz, Ramos and Silva Carlos Augusto, Vilela Claudia Gutterres, Dias Fabio Ferreira, Cne Heloísa Helena Gomes, Castro João Wagner Alencar, Antonioli Luzia, Creaire Miirían Araújo Carlos, Damasceno Raimundo Nonato, Dino Rodolfó, Carelli Thiago Gonçalves, dos REIS Antonio Tadeu and Guerra Josefá Varela - Evaluation of the effectiveness of ballast water regulation in Brazil: benthic foraminiferal morphology and eDNA metabarcoding for the biosurveillance of invasive alien species |
| S19-2 | Damasceno Fabricio Leandro, Alves Martins Maria Virginia, Senez-Mello Thaise M. Frontalini Fabrizio, Pawlowski Jan, Cermakova Kristina, Anglees Inês Barrenechea, Santos Luiz Guilherme Costa, Mendonça Filho Joao Graciano, Castelo Wellen Fernanda Louzada, Duleba Wania, de Mello e Sousa Silvia Helena, Antonioli Luzia and members of the project “Anthropized coastal systems”: Carvalho da Silva André Luiz, Ramos and Silva Carlos Augusto, Vilela Claudia Gutterres, Dias Fabio Ferreira, Cne Heloísa Helena Gomes, Castro João Wagner Alencar, Creaire Miirían Araújo Carlos, Damasceno Raimundo Nonato, Dino Rodolfó, Carelli Thiago Gonçalves, dos Reis Antonio Tadeu and Guerra Josefa Varela - The response of benthic foraminifera to environmental impact in the Sepetiba Bay (SE Brazil): metabarcoding and morphology-based analyses |
| S19-3 | Giraldo-Gómez Víctor M., Arena Luca, Azzola Annalisa, Capello Marco, Cutroneo Laura, Montefalcone Monica and Briguglio Antonino - The taxonomy and taphonomy of modern Foraminifera in the Blue Hole of Faanu Madugau (Ari Atoll, Maldives) |
| S19-4 | Vilar Amanda, Vicente Thaisa, Sambugaro Julia, Nogueira Rafaela and Sousa Silvia Helena - Benthic foraminifera biomass on the continental slope and São |
### S19: Paulo plateau of Santos basin (South Atlantic, Brazil): Comparison between different cytoplasmic occupation in the test

Vizcaíno Maoli N., Hull Pincelli, Reynolds Caitlin and Richey Julie - Assessing the environmental drivers of seasonal-to-decadal shifts in planktonic foraminiferal assemblages in the Gulf of Mexico

### S22: New threats on foraminifera from climate change to emerging environmental contaminants: innovative methodological approaches and opportunities

<table>
<thead>
<tr>
<th>Session</th>
<th>Title</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>S22-1</td>
<td>Andreas Amanda and Bowser Samuel - Cytological and physiological impacts of lead and cadmium on the monothalamid foraminifer Astrammina rara</td>
<td></td>
</tr>
<tr>
<td>S22-2</td>
<td>Muller Elsa, Choquel Constance, Dupont Sam, Geslin Emmanuelle and Filipsson Helena L. - Response of Ammonia confertitesta (T6) to Triple Stressors: Ocean Acidification, Warming, and Deoxygenation</td>
<td></td>
</tr>
<tr>
<td>S22-3</td>
<td>Puerto Diana, Stuhr Marleen and schmidt Christiane - Menthol-induced bleaching of Amphistegina lobifera and investigation on diatom photosymbiotic flexibility</td>
<td></td>
</tr>
<tr>
<td>S22-4</td>
<td>Holzmann Maria and Megann Mary - First occurrence of the nonindigenous Asian foraminifera Ammonia confertitesta Zheng in the northeastern Pacific Ocean: Vancouver Island, British Columbia, Canada</td>
<td></td>
</tr>
<tr>
<td>S22-5</td>
<td>Mancin Nicoletta, Evans Julian, Guastella Roberta, Caruso Antonio and Marchini Agnese - Impact of the invasive foraminifer Amphistegina lobifera Larsen on infralittoral benthic foraminiferal assemblages in the Sicily Channel (Central Mediterranean)</td>
<td></td>
</tr>
<tr>
<td>S22-6</td>
<td>Goldstein Susan T. and Richardson Elizabeth A. - Growing Deformed Benthic Foraminifera from Propagules with Exposure to Zinc</td>
<td></td>
</tr>
</tbody>
</table>

### S24: Oceanographic records from K/Pg to Recent: A session dedicated to the research interests of Dick Kroon

<table>
<thead>
<tr>
<th>Session</th>
<th>Title</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>S24-1</td>
<td>Cotton Laura J., Thibault Nicolas, Śliwińska Kasia K., Sheldon Emma and Yasuara Moriaki - Pre-Middle Eocene Climatic Optimum warming in the North Sea Basin</td>
<td></td>
</tr>
<tr>
<td>S24-2</td>
<td>Doubrawa Monika, Stassen Peter, Robinson Marci M., Babila Tali L., Zachos James C. and Speijer Robert P. - The pre-onset excursion (POE) enigma of the U.S. Atlantic Coastal Plain: a prelude of the PETM environmental perturbation?</td>
<td></td>
</tr>
<tr>
<td>S24-3</td>
<td>Gilabert Vicente, Arenillas Ignacio, Arz José Antonio, Krahl Guilherme and Batenburg Sietske - Aberrant planktic foraminifera as biomarkers of environmental stress and/or chemical contamination across the Cretaceous/Paleogene boundary</td>
<td></td>
</tr>
<tr>
<td>S24-4</td>
<td>Hubert-Huard Raphaël, Schmiedl Gerhard and Andersen Nils - A benthic foraminiferal stable isotope record of changes in overturning circulation of the Red Sea during the Marine Isotope Stage 3</td>
<td></td>
</tr>
<tr>
<td>S24-5</td>
<td>Lowery Christopher M., Kearns Lorna E, Sánchez-Montes Maria Luisa, Jones Heath and Sepúlveda Julio - Integration of Multiple Data Types to Reconstruct the Whole Plankton Ecosystem After the K/Pg Mass Extinction</td>
<td></td>
</tr>
<tr>
<td>S24-6</td>
<td>Pejnović Igor and Ćosović Vlasta - Morphological variations in Pseudohastigerina micra from the upper Eocene flysch sediments of the island of Hvar, Croatia</td>
<td></td>
</tr>
<tr>
<td>S24-7</td>
<td>Singh Vikram Pratap, Singh Ashutosh K. and Sinha Devesh K. - Quaternary Episodes of Variation in the Western Pacific Warm Pool: Planktic foraminiferal evidences from the Sulu Sea (ODP Hole 769B)</td>
<td></td>
</tr>
<tr>
<td>S24-8</td>
<td>Takata Hiroyuki, Sakai Saburo, Nomura Ritsuo, Tsujimoto Akira, Nishi Hiroshi, Soo Lim Hyoun and Kim Boo-Keun - Faunal transition of benthic foraminifera</td>
<td></td>
</tr>
</tbody>
</table>
### S25: Palaeo- and biogeographical dynamics of benthic foraminifera

| S25-1 | Premec Fuček Vlasta, Hernitz Kučenjak Morana, Galović Ines, Matošević Mario, Mikša Goran, Hajek-Tadesse Valentina, Krizmanić Krešimir, Belak Mirko and Fuček Ladislav - Development of the Late Karpatian to Early Badenian benthic foraminifera assemblages in the Sava Sub-basin (Croatia), SW Central Paratethys |
| S25-2 | Bassi Davide, Iryu Yasufumi, Pignatti Johannes and Renema Willem - Disentangling biogeographical patterns through the integration of fossil data: *Alveolinella quoyi* in the western Indo-Pacific Warm Pool |
| S25-3 | Molina Giulia, Mega Aline, Schmiedl Gehard, Rodrigues Teresa and Voelker Antje - Paleoproductivity fluctuations at the seafloor in the Gulf of Cadiz during MIS 25-MIS 19: evidence from benthic foraminifera assemblages |
| S25-4 | Hosono Takashi, Fujita Kazuhiro, Kakumura K. Azusa, Azuma Shuko, Kishimoto Azusa, Matsuda Shoko, Fusho Ayana, Sonoda Akira and Fujikura Katsunori - Use of a standard format (DarwinCore) on an information system (BISMaL) to integrate recent foraminifera data and to estimate recent past habitat condition |
| S25-5 | Weinmann Anna E. - Historic sediment samples as early-Lessepsian baselines for the biogeography and diversity of benthic foraminifera in the Mediterranean Sea |

### S26: Phylogeny and taxonomy of Neogene and Quaternary Planktonic Foraminifera

| S26-1 | Weitkamp Tirza M., Pearson Paul N. and Coxall Helen K. - Upper Oligocene to Holocene planktonic foraminifera from DSDP Site 407, Reykjanes Ridge: towards a revised taxonomy of Neogene high-latitudes species |
| S26-2 | Fabbrini Alessio, Petrizzo Maria Rose, Premoli Silva Isabella, Foresi Luca M. and Wade Bridget S. - On the traces of the forgotten marker *Globigerina bollii*: an endemic species from the Mediterranean Langhian? |

### S27: Quaternary planktonic foraminifera: tool for paleoclimatic and paleoceanographic studies

<p>| S27-1 | Copete Mª Fernanda, Diz Paula, Pérez-Arlucea Marta, Estrada Ferrán, Alejo Irene, Mena Anxo, Nombela Miguel Ángel and Francés Guillermo - Planktonic foraminifera assemblage in the Bight Fracture Zone during the last glaciation |
| S27-2 | Crundwell Martin and Woodhouse Adam - Biostratigraphically constrained Quaternary chronologies from the Hikurangi margin of north-eastern Zealandia |
| S27-3 | Del Gaudio Arianna V., Pillar Werner E., Auer Gerald and Kurz Walter - Pleistocene planktonic and benthic foraminifera assemblages from Fantangisña seamount in the NW Pacific Ocean (IODP Expedition 366) |
| S27-4 | Duque-Castaño Monica, Voelker Antje H.L. and Rodrigues Teresa - Surface water variations during MIS 44 to MIS 50 (1.36-1.5 Ma) on the Southern Portuguese Margin – evidence from planktonic foraminifera and biomarker data |
| S27-5 | Lopes Ana, Salgueiro Emília, Rodrigues Teresa, Padilha Mária, Abrantes Fátima and Alonso-García Montserrat - Late Pliocene-Early Pleistocene surface ocean conditions at the SW Iberian margin |
| S27-6 | Millo Christian, Stasevskas Kujawski Rita and Badaraco Costa Karen - Reconstruction of calcification depths of Quaternary planktonic foraminifera from the Espirito Santo Basin (southwestern Atlantic) using stable isotopes |
| S27-7 | Myers Savannah, Aiudi Laura, Caridi Francesca, Donders Timme, Grant Katharine, de Groot Michelle, Morigi Caterina, Rohling Eelco, Sabbatini Anna, Sangiorgi |</p>
<table>
<thead>
<tr>
<th>Abstract ID</th>
<th>Authors</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>S27-8</td>
<td>Salgueiro Emilia, Voelker Antje H.L., Siervo Francisco J., Hodell David, Rodrigues Teresa, Rebottim Andreia and Abrantes Fátima</td>
<td>Oceanographic condition on the southwestern Portuguese Margin during the Marine Isotope Stage 35: an atypical interglacial</td>
</tr>
<tr>
<td>S27-9</td>
<td>Voelker Antje H.L., Mega Aline, Duque Castaño Monica, Salgueiro Emilia and Rodrigues Teresa</td>
<td>Nature of cooling events on the southern Iberian margin point to extreme contraction of the North Atlantic’s subtropical gyre during the early Pleistocene</td>
</tr>
<tr>
<td>S27-10</td>
<td>Zhang Shuai, Yu Zhoufei, Chang Fengming and Li Tiegang</td>
<td>The evolution of the barrier layer in the centre of the western Pacific warm pool during the last deglacial based on planktonic foraminifera surface species</td>
</tr>
<tr>
<td>S27-11</td>
<td>Doherty Shannon, McCarthy Matthew, Havard Emily, Christensen Stephanie and Davis Catherine</td>
<td>Investigating the ecology of planktic foraminifera species with compound-specific stable isotope analysis of amino acids</td>
</tr>
<tr>
<td>S27-12</td>
<td>Hupp Brittany and Fehrenbacher Jennifer</td>
<td>Geochemical differences between alive, uncrusted and dead, crusted shells of the planktic foraminifera <em>Neogloboquadrina pachyderma</em>: Implication for paleoreconstruction</td>
</tr>
<tr>
<td>S27-13</td>
<td>Martinelli Pierluigi, Gennari Rocco, Lirer Fabrizio and Cascella Antonio</td>
<td>Nature of cooling events on the southern Iberian margin point to extreme contraction of the North Atlantic’s subtropical gyre during the early Pleistocene</td>
</tr>
<tr>
<td>S28-1</td>
<td>Milker Yvonne, Schönfeld Joachim and Schmiedl Gerhard</td>
<td>Recent foraminiferal assemblages in terrestrial salt ponds and meadows in Central Germany</td>
</tr>
<tr>
<td>S28-2</td>
<td>Prayudi Sinatrya D., Amao Abduljamiu O., Tawabini Bassam S., Korin Asmaa and Kaminski Michael A.</td>
<td>Can benthic foraminiferal morphological deformities be considered lethal in a natural hypersaline environment? Case studies at several localities of the western Arabian Gulf</td>
</tr>
<tr>
<td>S28-3</td>
<td>Schmidt Christiane, Morard Raphael, Rapp Sophia K., Amao Abduljamiu O., Rahman Shirin Nurshan, Vaughan Grace, Farrell Oliver M., and Burt John A.</td>
<td>Local biodiversity of recent foraminifera in three coral reefs in the extremely warm Persian/Arabian Gulf</td>
</tr>
<tr>
<td>S28-4</td>
<td>Rohret Shari and Bernhard Joan M.</td>
<td>Inhabitation of bathyal hydrocarbon seeps by basal benthic foraminifera evidenced by ultrastructural observations</td>
</tr>
<tr>
<td>S28-5</td>
<td>Katz Oded, Abramovich Sigal, Ashkenazi Leeron, Torfstein Adi, Moshe Naomi, Leshno-Afriat Yael and Hyams-Kaphzan Orit</td>
<td>Analysing source and transport of submarine mass wasting along the continental margins of southeastern Mediterranean Sea using assemblages and taphonomy of benthic foraminifera</td>
</tr>
<tr>
<td>S28-6</td>
<td>Moisathid Meryem, Michel Elisabeth and De Deckker Patrick</td>
<td>From “source to sink” - a new perspective on the past dynamics of the Murray Canyon Group from benthic foraminiferal communities</td>
</tr>
<tr>
<td>S29-1</td>
<td>Bird Clare, Darling Kate, Thiessen Rabecca and Pieńkowski Anna</td>
<td>Microbiome analysis of Baffin Bay <em>Neogloboquadrina pachyderma</em> reveals the first evidence for kleptoplasty in planktonic foraminifera</td>
</tr>
<tr>
<td>S29-2</td>
<td>Courtial Julia, Lothier Jeremy, Cukier Caroline, Limami M. Anis and Geslin Emmanuella</td>
<td>Metabolome of foraminiferal species from Bourgneuf bay</td>
</tr>
</tbody>
</table>
characterized by GC-MS approach

S29-3 Grow Adri K., Sterner Elinor G. and Katz Laura A. - A phylogenomic approach to understanding population level processes in benthic foraminifera

S29-4 Lane M., Kelsey, Fehrenbacher Jennifer, Bird Clare, Branson Oscar, LeKieffre Charlotte, Ren Abby and Crump Byron - Planktonic foraminifera microbial associations in the subtropical Pacific

S29-5 Maeda Ayumi, Hamamoto Kohei, Nishijima Miyuki, Iguchi Akira and Suzuki Atsushi - Depth-influenced variation of symbiont relationship between large benthic foraminifera and Symbiodiniaceae

S29-6 Renema Willem, Girard Elsa B. and Macher Jan-Niklas - (Meta)Barcoding all forams - An invitation to contribute to the Foraminifera Reference Database ForamBase

S29-7 Cote-L’Heureux Auden, Sterner Elinor G., Maurer-Alcalá Xyrus and Katz Laura A. - Foraminifera maintain consistent amino acid usage despite extreme codon usage bias in multiple non-monophyletic clades

S29-8 Sterner Elinor G., Leleu Marie and Katz Laura A. - Differential gene expression over the life cycle of Allogromia laticollaris CSH to understand complex nuclear dynamics

S29-9 Renema Willem, Girard Elsa B. and Macher Jan-Niklas - (Meta)Barcoding all forams - An invitation to contribute to the Foraminifera Reference Database ForamBase

ForamBase

S32: Biology, metabolisms and behavior: role of benthic foraminifera in ecosystem functioning

S32-1 Bouchet Vincent M.P., Deldicq Noémie, Langlet Dewi, Denis Lionel, Mermillod-Blondin Florian and Seuront Laurent - Single cells ecosystem engineers: foraminiferal role in bioturbation processes

S32-2 Choquel Constance, Geslin Emmanuelle, Mouret Aurélie, Jesus Bruno, Schweizer Magali, Houlié Emile, Jauffrais Thierry and Metzger Edouard - Trophic interactions between foraminifera and diatoms in a French mudflat using a long monitoring period

S32-3 Manda Sneha, Ashckenazi-Polivoda Sarit, Herut Barak, Rilov Gil, Kucera Michal and Abramovich Sigal - Symbiont-bearing foraminifera and their potential as major carbonate producers in coastal environments undergoing global warming

S32-4 Palme Tina, Heinz Petra, Wukovits Vital, Maier Andreas, Polovodova Asteman Irina, Nagy Matthias and Glatzel Stephan - Laboratory feeding experiments - investigating respiration rates of the benthic foraminifer Nonionella sp. T1

S32-5 Polovodova Asteman Irina, Choquel Constance, Mouret Aurélia, Schweizer Magali, L. Filipsson L. Helena, Scozzina Eva, Metzger Edouard and Geslin Emmanuelle - Distribution of the putative invasive species Nonionella sp. T1 in the Gullmar Fjord – What is its potential contribution to biogeochemical cycles?

S32-6 Richirt Julien, Matsuzaki Takuya, Ishitani Yoshiyuki, Tame Akihiro, Oda Kaya and Nomaki Hidetaka - Vacuoles size and abundance in Foraminifera: new insight about their metabolic adaptation to low oxygen environments

S33: Honoring Martin Buzas: Innovative approaches to analyzing distributions of benthic foraminifera

S33-1 Jonkers Lukas, Strack Anne, Huber Robert and Kucera Michal - Towards FAIRer micropalaeontological data
It is interesting to speculate what the next fifty years will bring…

...systematics, because the scientific community will require another compilation to supplement Loeblich and Tappan's book.

...these organism to these changes needs to be investigated. Nevertheless we ought not de-emphasize studies on the...

...doubt that foraminifera respond to changes in the environment, whether natural or human-related, and that the response of...

...embraced new directions in our area of research over the past 50 years. We see evidence of an increasing focus on studies...

...first morphogroup papers in the mid 1980's.

...published in Palaeontology that still focus on the basics such as taxonomy and XYZ. Coincidentally, several uptrends and...

...downtrends in our findings seem to overlap with some recognisable events such as the publication of Loeblich & Tappan's...

...has fluctuated, although in general within stable limits during the entire time period, even if they later faced a considerable...

...by a decline starting after 1990. On the other hand, the bulk of XYZ and taxonomic research published in Palaeontology...

...displays a higher level of diversity than Palaeontology during their 50-year history. In comparison to XYZ and taxonomy, which both have percentages above 30% in Palaeontology, ecological studies have formed the major proportion of articles (31.8%), with the other categories almost sharing equal portions (ranging from 5% to 15%, apart from taphonomy and molecular biology) in the JFR. While determining which subjects see considerable increase, we discovered that ecological studies have formed the major proportion of articles.

...have witnessed many keystone findings in foraminiferal research as well as the establishment of new directions within the broad framework of foraminiferal studies. Although fundamental knowledge in foraminiferal research is still strongly connected with traditional knowledge about documenting the fossil record and reporting new discoveries (as we know from the perspective of Palaeontologists), the actual reality is that our field may not operate under the same restrictions. One question has yet to be addressed: do we still operate within the same boundaries as the typical palaeontologist, or have we already branched out beyond the scope of our initial studies? The easiest way to answer to this question is to compare our body of foraminiferal literature with the vast body of knowledge in the broader field of Palaeontology.

...address this problem, we make a comparisons by examining two of the top journals in our respective fields that embody a cross-section of current research: The leading journal in the study of foraminifera is the Journal of Foraminiferal Research (JFR), and the other representing a wider based journal for palaeontological studies (Palaeontology, published by the Palaeontological Association). From 1975 through 2020, we sampled the papers in each journal at intervals of five years, examining their titles and internal content to determine what they mostly covered. Research topics were classified into broad 11 categories: XYZ (i.e., documenting fossils from a specific age and place), ecology, biostratigraphy, palaeoceanography, paleogeography, taxonomy, systematics, methodology, evolution, taphonomy, and molecular biology. We plotted our findings in order to portray the relative proportions of papers belonging to a given category, and how the research emphasis has changed over time.

...our assessment, which was based on the proportions of each research category in the two journals, the JFR displays a higher level of diversity than Palaeontology during their 50-year history. In comparison to XYZ and taxonomy, which both have percentages above 30% in Palaeontology, ecological studies have formed the major proportion of articles (31.8%), with the other categories almost sharing equal portions (ranging from 5% to 15%, apart from taphonomy and molecular biology) in the JFR. While determining which subjects see considerable increase, we discovered that ecological studies have skyrocketed during the lifetime of the JFR, with a large jump occurring after 1995. Another unexpected discovery is that systematic investigations published in the JFR show a considerable increase from 1980 to 1985, followed by a decline starting after 1990. On the other hand, the bulk of XYZ and taxonomic research published in Palaeontology has fluctuated, although in general within stable limits during the entire time period, even if they later faced a considerable reduction after 2005. In Palaeontology, ecological and evolutionary studies fluctuated over the period but showed growing percentages after 2005.

...Considering our comparison between the leading journals within our research areas, i.e., foraminiferology (JFR) and the wider scope journal that also covers our research area (Palaeontology), our fundamental knowledge and research areas in foraminiferology appear to be more advanced with a more diverse selection of research topics. Aside from the growth in traditional study area, we have witnessed new research topics such as molecular biology and ecological aspects of foraminifers, which have grown significantly across the timespan of almost five decades – compared with the articles published in Palaeontology that still focus on the basics such as taxonomy and XYZ. Coincidentally, several uptrends and downtrends in our findings seem to overlap with some recognisable events such as the publication of Loeblich & Tappan’s book in 1987, the growth of studies based on ODP samples, and the growth of ecological studies after the publication of the first morphogroup papers in the mid 1980’s.

...If we compare our scientific output with that of the Paleontologists, it is obvious that Foraminiferologists have embraced new directions in our area of research over the past 50 years. We see evidence of an increasing focus on studies dealing with ecology and paleoceanography, at the expense of studies of the systematics of the foraminifera. There is no doubt that foraminifera respond to changes in the environment, whether natural or human-related, and that the response of these organisms to these changes needs to be investigated. Nevertheless we ought not de-emphasize studies on the systematics, because the scientific community will require another compilation to supplement Loeblich and Tappan’s book. It is interesting to speculate what the next fifty years will bring…
Reconstructing Pacific oxygen minimum zone structure through deglacial warming using planktic foraminifera

ALCORN Rachel1*, DAVIS Catherine1 and ONTIVEROS-CUADRAS Jorge Feliciano2

1Department of Marine, Earth and Atmospheric Sciences, North Carolina State University, 2800 Fayetteville Dr, Raleigh, USA; ralcorn@nccsu.edu
2Oceanic and Coastal Processes Unit, National Autonomous University of Mexico, Av. Universidad 3004, Mexico City, Mexico;
jonitiveros@cmarl.unam.mx
*Corresponding author

Oxygen minimum zones (OMZs) are areas of the ocean with consistently low levels of oxygen (<0.5 mL L⁻¹) driven by high productivity and low ventilation. OMZs are expanding globally due to modern climate change with implications for ecosystem function and biogeochemical cycling. However, significant uncertainties exist in how OMZs respond to climate change on longer than decadal timescales. Planktic foraminiferal assemblages, pore size, and ventilation ages are used here to reconstruct potential drivers of OMZ change (productivity and water source) in the Eastern Tropical North Pacific (ETNP) through the most recent period of rapid warming (~20-9 ka). We focus on core MAZ1-E04 (22°54.29’N, 106°54.59’W; 1463 m depth) from the Mexican Margin where there is evidence that the OMZ intensified into the Holocene relative to the Last Glacial Maximum (LGM). We show that the relative abundance of subpolar foraminifera (primarily Neogloboquadrina incompota) dominates through most of the Pleistocene until a dramatic drop ~13 ka where transitional foraminifera (primarily Globigerina bulloides) simultaneously increased and dominated into the early Holocene (~9 ka) suggesting an increase in upwelling conditions during the Younger Dryas (~13-12 ka). Ventilation ages record relatively old bottom waters during both the LGM (~20 ka) and the Bolling-Allerod (~15-13 ka) indicating input from older, less oxygenated, southern source water during these periods. Porosity of planktic Orbulina universa will provide an additional proxy for OMZ position and intensity within the photic zone. Using these multiple approaches, we demonstrate that this site likely experienced lower productivity but poorly ventilated bottom waters during the LGM and the Bolling-Allerod. Conversely, the beginning of the Younger Dryas experienced well-ventilated bottom waters but higher productivity. We hypothesize that the ETNP OMZ expanded during deglacial warming due to an increase in surface productivity alongside the input of older southern source waters.

Evaluation of the effectiveness of ballast water regulation in Brazil: benthic foraminiferal morphology and eDNA metabarcoding for the biosurveillance of invasive alien species

ALVES MARTINS Maria Virginia1,2*, DAMASCENO Fabricio Leandro1,2, SAIBRO Murilo Barros1,2, DA SILVA Layla Cristine1,2, SENEZ-MELLO Thaise M.1,2, SANTOS Luiz Guilherme Costa1,2, MENDONCA FILHO João Graciano1,2, CASTELO Wellen Fernanda Louzada1,2, DULEBA Wania3, DE MELLO & SOUSA Silvia Helena4,5, and members of the project “Anthropized coastal systems”: CARVALHO DA SILVA André Luiz1,2, RAMOS E SILVA Carlos Augusto1,2, VILELA Claudia Gutterres1,2, DIAS Fabio Ferreira1,2, COE Heloisa Helena Gomes1,2, CASTRO João Wagnner Alencar8, ANTONIOLI Luzia1,2, CRAPEZ Mirian Araújo Carlos1,2, DAMASCENO Raimundo Nonato6, DINO Rodolfo7, CARELLI Thiago Gonçalves8, DOS REIS Antonio Tadeu4 and GUERRA Josefa Varela1

1Universidade 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; fabricioleandro@id.uff.br; murilosaiбро@id.uff.br; laylageologiauerj@gmail.com; thaise_senеz@id.uff.br; wellenfle@yahoo.com.br; luantonioli8@gmail.com; andrelessilvageouerj@gmail.com; heloisaco@gmail.com; dinoauerj@gmail.com; tadeu.reis@gmail.com; josie.guerra@gmail.com
2Universidade de Aveiro, GeoBioTec, Departamento de Geociências, Campus de Santiago, 3810-193 Aveiro, Portugal; virginia.martins@ua.pt
3Federal Fluminense University (UFF), Rio de Janeiro, Brazil; thaise_senеz@id.uff.br; caugusto_99@yahoo.com; fabiofgeo@yahoo.com.br; miriancrapez@id.uff.br; rdamasceno@id.uff.br
4Department of Pure and Applied Sciences, Università degli Studi di Urbino “Carlo Bo”, 61029, Urbino, Italy; fabrizio.frontalini@uniurb.it
5Università Federal do Rio de Janeiro – UFRJ, Dpto Geologia - Instituto de Geociências, Brazil; guilherme@lafo.geologia.ufrj.br; gracianodol@geoliga.ufrj.br; vilеla@geoliga.ufrj.br; castro@mn.ufrj.br
6Escola de Artes, Ciências e Humanidades da Universidade de São Paulo. Rua Arlindo Bettio, 1000, Vila Guaraciaba, São Paulo - SP, Brazil; waduleba@gmail.com
7Instituto Oceanoográfico, Universidade de São Paulo (IOUSP). Address: Pça. do Oceanoográfico, 191, Butantã, São Paulo, Brazil. silviahelenamello@gmail.com
8Universidade Federal do Estado do Rio de Janeiro – UNIRIO, Av. Pasteur 458, s. 500, Urca, Rio de Janeiro, Brazil; thiagiocarelli@unirio.br
*Corresponding author
Today, one of the environmental concerns for the civil and scientific community is the intentional or accidental introduction of pollutants and exotic species into the marine environment that may cause significant and harmful changes in coastal ecosystems. To tackle and regulate this problem, since 2005, Brazil has issued a legal and mandatory procedure for all ships sailing in Brazilian waters: NORMAM-20 of the Maritime Authority on water pollution caused by vessels, platforms, and their support facilities. It states that the oceanic exchange of ballast water should occur at least 200 miles away from the coast in places with a minimum water depth of 200 meters. However, the analysis of the living and dead assemblages present in the surface sediments of 50 sites distributed in the inner and outer sector of the Sepetiba Bay (SB, SE Brazil) reveals the occurrence of species such as *Trochammina hadai* Uchino 1962 and *Ammonia bazasi* Hayward and Holzmann, 2021 (identified by eDNA metabarcoding in 16 sites and morphological analysis) that have never been reported in this coastal ecosystem. Analysis of the sedimentary record along cores collected in several regions of the SB (SP1-SP6, SP8, SP11) reveals that these species disappear below the first few centimeters of the sediment record. It should be noted that *T. hadai* was also recently considered as an invasive species in the Flamengo Inlet, Ubatuba, São Paulo State (Brazil). These species, which may have been introduced into the SB by the discharge of ballast water from ships that dock in the region’s ports to load ore, are currently a component of the living foraminiferal assemblages of this ecosystem, reacting and responding to environmental stress in this bay, a highly anthropized and heavily polluted environment by potentially toxic elements (PTEs). While *T. hadai*, which mainly thrives in fine sand bottoms, seems to prefer low polluted conditions, *A. bazasi*, as well as *Ammonia tepida*, *Ammonia rolhaussenii*, and *Cribrariophilum excavatum*, seem to tolerate the environmental stress caused by increasing of organic matter levels, and PTEs (mainly Cd and Zn), where the diversity of foraminiferal species considerably declines (and when all the other species reduce their abundance). Thus, this work shows the importance of better knowledge of endogenous species so that invasive species and their ecological role in coastal ecosystems are known.

**Determining the toxicity of metals based on different extraction methods: a case study in the Guanabara Bay (SE Brazil)**

**ALVES MARTINS Maria Virgínia**1,2*, **HOHENEGGER Johann**3, **NUNES Márícia**1, **DAMASCENO Fabricio Leandro**1, **FIGUEIRA Rubens**4, **MARTINEZ-COLÓN Michael**1, **FRONTALINI Fabrizio**6, **SENEZ-MELLO Thaise** M.1,7, **PREGNOLATO Leonardo Antonio**1, **DULEBA Wanika**8, **DE MELLO E SOUSA Silvia Helena**3 and **GERALDES Mauro César**1

1Universidade 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; marianunesgeologia@gmail.com; fabricioleandro@id.uff.br; thaise_senez@id.uff.br; leopregnolato@outlook.com; mauro.gerais@gmail.com
2Universidade de Aveiro, GeoBioTec, Departamento de Geociências, Campus of Santiago, 3810-193 Aveiro, Portugal; virginia.martins@ua.pt
3Universität Wien, Institut für Paläontologie, Althanstrasse 17, A 1090 Wien, Austria; johann.hohenegger@univie.ac.at
4Instituto Oceográfico, Universidade de São Paulo (IOUSP), Pça. do Oceanográfico, 191, 05508 120 Butantã, São Paulo, Brazil; rfigueira@usp.br; silviahelenamello@gmail.com
5School of the Environment, Florida A&M University, 1515 S Martin Luther King Jr. Blvd, FSH Science Research Center, Tallahassee, FL 32307, Florida, USA; michael.martinez@famu.edu
6Department of Pure and Applied Sciences, Università degli Studi di Urbino “Carlo Bo”, 61029, Urbino, Italy; fabrizio.frontalini@univur.it
7Marine Geology Lab – LAGEMAR, Federal Fluminense University (UFF), Rio de Janeiro, Brazil; thaise_senez@id.uff.br
8Escola de Artes, Ciências e Humanidades da Universidade de São Paulo. Rua Arlindo Bettio, 1000, Vila Guaraciaba, São Paulo - SP; Brazil; waduleba@gmail.com
*Corresponding author

The scientific community has made an effort to improve methods and techniques aiming at the adequate characterization of natural ecosystems and the response of organisms to environmental stress. This effort extends to the application of foraminifera as bioindicators of environmental quality. Many works have shown the applicability of these organisms as bioindicators of ecological quality status (EcoQS). Recently, the EcoQS of impacted areas in Guanabara Bay (GB; SE Brazil) has been assessed based on foraminiferal and sedimentological data. This bay, located in the metropolitan region of Rio de Janeiro State, is highly anthropized, and some areas are polluted by potentially toxic elements (PTEs). Thus, it is important to understand if geochemical methods based on total digestion of sediment (TD) or sequential chemical extraction (SQE) allow you to effectively assess the concentrations of PTEs that most affect living organisms and, in particular, benthic foraminifera. Thus, in this work, the data of living foraminifera from 33 sites in the margins of the GB, in more or less impacted regions, were statistically compared with concentrations of PTEs obtained by TD and SQE in three phases (dissolved in water, adsorbed on organic matter, and Mn oxy-hydroxides). The main pollutants in the samples studied are Cu, Zn, and Pb, an evaluation made from TD. The principal component analysis shows an overall negative response of most species and ecological indices to metal enrichment. Despite it, the correlations between the species and the ecological indices and the concentrations of PTEs obtained by TD are generally low and not significant, even with the metals considered major pollutants. However, negative and significant correlations between species and PTEs (Cd, Zn and Ni) dissolved in water and associated with organic matter are found. Additionally, diversity and several species are significantly and negatively correlated with the PTEs associated with Mn oxy-hydroxides, probably because this is a dynamic sedimentary phase. This work sheds light on the importance of SQE to properly evaluate the effects of PTEs, to determine their bioavailability, and
ultimately, to provide measures of toxicity in marine sediment based on effects range low (ERL) and effects range median (ERM).

**Late Cretaceous benthic foraminifera responses across Oceanic Anoxic Event 2 at southern high latitudes (Mentelle Basin, SW Australia)**

AMAGLIO Giulia 1*, PETRIZZO Maria Rose 1, HOLBORN Ann 2, KUHNT Wolfgang 2 and WOLFGRING Erik 1,3

1Dipartimento di Scienze della Terra “Arildo Desio”, Università degli Studi di Milano, via Mangiagalli 34, I-20133 Milano, Italy; giulia.amaglio@unimi.it; mrose.petrizzo@unimi.it
2Institut für Geowissenschaften, Christian-Albrechts-Universität, Oldenaustrasse 40, 24118 Kiel, Germany; wolfgang.kuhnt@ifg.uni-kiel.de; ann.holbourn@ifg.uni-kiel.de
3Department of Geology, University of Vienna, Althanstraße 14, Vienna 1090, Austria; erik.wolfgang@univie.ac.at
*Corresponding author

Oceanic Anoxic Event 2 (OAE 2), across the Cenomanian-Turonian boundary interval, shows global environmental perturbations in the carbon cycle that also affect marine biota. International Ocean Discovery Program (IODP) Sites U1513 and U1516 in the Mentelle Basin (offshore SW Australia) document a continuous benthic foraminiferal record suitable to reconstruct the paleoenvironmental conditions at the seafloor. At both sites, the benthic foraminiferal assemblages generally show low diversity with dominance of deep-water calcareous taxa, whereas agglutinated foraminifera are rare. The most abundant genera are *Gavelinella*, *Stensioeina*, *Gyroidinoides*, *Conorboides*, *Tappanina*, *Praebulimina* and the agglutinated genus *Clavulinoides*. High latitudinal diagnostic taxa *Pseudopatellinella howchinii* and *Scheibnerova protindica* are found through the stratigraphic section, with the disappearance of the latter above a low carbonate interval registered within OAE 2. Paleobathymetry of both sites is interpreted at upper-middle bathyal depths.

Below OAE 2, *Gavelinella* sp., *Gyroidinoides* sp., *Stensioeina* sp. 1 and *Tappanina laciniosa* are the most abundant species. Infaunal *Laevidentalina* sp. and *Lenticulina* sp. are moderately frequent. The presence of the agglutinated cosmopolitan and opportunistic taxa *Glomospira* and *Ammodiscus* suggests low organic matter concentrations at the seafloor. The lowermost part of OAE 2 is dominated by *Gavelinella* sp., *Gyroidinoides* sp., *Stensioeina* sp. 1 and *Lingulogavelinella frankei*. *Stensioeina truncata* appears just in this interval. Infaunal taxa gradually decrease in abundance probably showing a deterioration of environmental conditions. The interval of low CaCO\(_3\) content is characterized by radiolarians and calcispheres and by the absence of benthic and planktonic foraminifera. Dominance of siliceous sediments identifies an extremely eutrophic environment with a reduced water mass stratification.

Above this interval, an environmental change is registered based on the occurrence of highly diversified foraminiferal assemblages showing different composition compared to the underlying interval. The presence of the agglutinated foraminifera *Clavulinoides gautinicus* and *Spiroplectinata annectens* probably indicates increased nutrients at the seafloor. The first occurrences of *Conorboides claytonensis*, *Bulmina triangularis*, *Stensioeina* sp. cf. *S. infrarosa* are identified in this interval. Infaunal taxa, such as *Astacolus* sp., *Lenticulina* sp., *Planularia* sp., *Pleurostomella subnodosa* and *Colomia cretacea*, show a consistent increase in abundances. The assemblage indicates mesotrophic regimes with moderate oxygen conditions at the seafloor that alternates to more eutrophic episodes. The latter conditions are suggested by the high abundance of the opportunistic taxa *Praebulimina elata* and *Gavelinella* sp.

In general, the OAE 2 interval is characterized by an eutrophic regime with dominance of the opportunistic taxa *Gavelinella*, *Gyroidinoides* and *Stensioeina*, whereas infaunal taxa show low occurrences. The environmental change observed above the low carbonate interval coincides with the occurrences of a benthic foraminiferal assemblage characterized by increased species diversity, indicating enhanced nutrients influx at the seafloor and a return to a mesotrophic regime with episodic eutrophic pulses.

**Cytological and physiological impacts of lead and cadmium on the monothalamid foraminifer Astrammina rara**

ANDREAS Amanda 1,2 and BOWSER Samuel 1,2*

1Wadsworth Center, New York State Department of Health, P.O. Box 509, Albany, NY 12201-0509 USA; amanda.andreas@gmail.com; samuel.s.bowser@gmail.com
2Department of Environmental Health Sciences, University at Albany School of Public Health, 1 University Place, Rensselaer, NY 12144, USA; amanda.andreas@gmail.com; samuel.s.bowser@gmail.com
*Corresponding author

For decades, researchers have used foraminifera as bioindicators of heavy metal pollution in marine environments. Multichambered calcareous and agglutinated forams are the primary focus of such ecotoxicological studies; less is known about how heavy metals affect the physiology and shell microarchitecture of monothalamid agglutinated species. The research reported here exploits unique attributes of *Astrammina rara*, an agglutinated Antarctic monothalamid, as a model system to study the exposure effects of heavy metal toxicants, lead and cadmium. This species (1) is readily collected in Explorers Cove, which is a major hub of marine research in McMurdo Sound; (2) is comparable other Clade I
monothalamids inhabiting polar and deep-sea settings; (3) is well-suited for biochemical and morphological studies due to its large size (>1mm) and ease of isolating protoplastic and shell matrix fractions; (4) can be maintained in the lab for years, and (5) has been used extensively in past in vitro studies.

In this study, specimens of *A. rara* were removed from their shells and placed in growth chambers with normal, Pb- or Cd-spiked artificial seawater and artificial sediment (plastic beads) for 5 weeks. At all sublethal exposure levels (determined by our prior respirometry measurements), these isolated cell bodies constructed shells, which were subsequently removed, rinsed with deionized water, and then either pooled for inductively coupled plasma-mass spectrometry (ICP-MS) analysis or processed for scanning electron microscopy (SEM) imaging. For ICP-MS, shells were nitric acid-digested and analysed to determine Pb and Cd concentrations in the nascent bioadhesive fraction. These data were compared to background levels adsorbed to plastic bead controls. We found that Pb bound to the bioadhesive at concentrations significantly above the bead control exposure levels, while Cd did not, suggesting that Pb has a more direct effect on matrix assembly/binding. At the ultrastructural level, the matrix appeared ‘moth-eaten’ in the exposure treatments, which was likely due to failure of the bioadhesive to withstand surface tension forces experienced during our ethanol fixation/air drying protocol. These findings show that Pb and Cd impact agglutinated shell morphogenesis differentially. We suggest that more emphasis be placed on monothalamids with fibrous adhesive matrices in environmental toxicology and monitoring studies.

Can we use milioline morphotype (miliolids and rzehakinids) foraminifera in pelagic environment as seawater oxygen proxies?

ARANYI Timea* and GÖRÖG Ágnes1

1Department of Geology, Eötvös Loránd University, Pázmány Péter sétány 1/C, Budapest, Hungary 1117; timea.aranyi3@gmail.com
2Hamtkan Foundation, Detrekő utca 1/B, Budapest, Hungary 1022; ag.gorog@gmail.com
*Corresponding author

Miliolids have an important role in interpreting ancient marine environments, it is assumed that they indicate oxic conditions and shallow water depth (inner shell). The agglutinated rzehakinids are bathyal-abyssal forms and can tolerate fluctuating oxygen levels. Our study shows that miliolids and rzehakinids occur together in a hypoxic environment indicating that several mid-Cretaceous miliolid species were euryoxic.

The studied material comes from moderate to well-preserved isolated foraminiferal assemblages of the Pénzeskút Marl Formation (Jásd-42 borehole, Bakony Hill, Hungary). This 463 m succession records the local response of the microfauna to the environmental changes of the late Albian OAE1d and the Albian-Cenomanian transition within a pelagic environment. The formation consists of dark-grey marl, calcareous marl with glauconite content at the lower part, and sandstone and siltstone intercalations at the upper part. Rock samples were soaked in a 3% solution of H2O2, the harder calcareous rocks were treated with 99% acetic acid. From the washed residues at least 300 foraminifera specimens were picked. Quantitative analyses of foraminiferal assemblages were performed from 88 samples on the >125 µm size fraction. The co-occurrence of *Thalmanninella appenninica* and *Planomalina buxtorfi* in the lowermost samples indicates the late Albian age. The first occurrence (FO) of *Th. globotruncanoides* can be detected, which is the primary criterion for defining the Albian-Cenomanian boundary. The P/B ratio has values between 27 % and 95 %, with a decreasing tendency to the top of the section indicating an open marine environment. Non-keeled shallow-dwelling forms are the most common (70-95 % of the fauna) and are represented by hedbergellids, and there is much less half-keeled intermediate taxon *Praeglobotruncanina* and keeled deep-dwelling *Thalmanninella*. The associated fauna is represented by calcareous nannofossils, calcisphaeres, ostracodes, juvenile gastropods, and ammonite embryos. Ostracoda assemblages are characterized by the high dominance of *Cytherella ovata* and *C. parallela* (35-85 %, typical “platycopa-signal”) associated with the opportunistic *Schuleridea jonesiana* (2-55 %), a total of 55-98 % indicate a hypoxic environment of a deep sublittoral-bathyal bottom through the entire section.

The isolated miliolids and rzehakinids were studied by stereomicroscope in reflected and transmitted light to measure the biometrical parameters. Oriented thin-sections were made to examine their inner structures and the texture of the wall. The miliolids are represented by *Quinqueloculina moremani*, *Q. stolleyi*, *Massilina* sp., and *Adelosina* sp., while rzehakinids by *Psamminopelta bowsheri* and *P. sp.*. At the lower part of the section (Pl. buxtorfi Subzone) milioline morphotype is rare (only *Q. sp.* and *P. bowsheri*), this coincides with the late Albian OAE1d. In the Th. appenninica and Th. globotruncanoides zones, these forms occur in almost every sample and have a ratio up to 14%. *Q. moremani* is dominant following *Q. stolleyi*, *Massilina* sp., *Adelosina* sp., and *P. spp.* has low values. The most common associated benthic genera are *Gavelinella*, *Gyroidinoidea*, *Osangularia*, *Lenticulina*, *Tritaxia*, *Præbulimina*, and *Bolivina*.

The relatively fragile rzehakinids are exceptionally well preserved, even the previously unknown long tube-shaped, non-agglutinated aperture of *P. bowsheri* was preserved, indicating that the fauna was not transported. The lack of shallow-water fauna, such as ostracods, also supports this.

Contrary to the previous views we found that miliolids were relatively common and diverse in the hypoxic, pelagic mid-Cretaceous environment. Two scenarios can be considered: 1) they could tolerate the constantly low oxygen level...
Depositional and paleontological consequences of the Middle Eocene Climatic Optimum (MECO) as recorded along a shallow-water succession near Olivetta San Michele (IM), NW Italy

ARENA Luca1, BRIGUGLIO Antonino1,2, GIRALDO-GÓMEZ Víctor M.1,3,4, GANDOLFI Antonella3,4, BAUCON Andrea1,5,6, PAPAZZONI Cesare Andrea2,5,6, PIGNATTI Johannes3,4, BAUMGARTNER-MORA Claudia4,5,6,7, LUCIANI Valeria3 and PIAZZA Michele1

1Dipartimento di Scienze della Terra, dell’Ambiente e della Vita, Università degli Studi di Genova, Corso Europa 26, I-16132 Genova, Italy; antonino.briguglio@unige.it; victormanuel.giraldoomez@edu.unige.it; lucaarenza95@libero.it; antonella.gandolfi@edu.unige.it; michele.piazza@unige.it
2School of Ocean and Earth Science, University of Southampton, European Way SO14 2EY, Southampton, UK; d.evans@soton.ac.uk
3Institute of Inorganic and Analytical Chemistry, Goethe University Frankfurt, Max-von-Laue-Straße 7, 60438 Frankfurt a.M., Germany; markus.mezger@univie.ac.at
4Institute of Geosciences, Goethe University Frankfurt, Altenhöferalle 1, 60438 Frankfurt a.M., Germany; Linckens@em.uni-frankfurt.de
5Institute of Geosciences, Johannes Gutenberg University Mainz, Johann-Joachim-Becher-Weg 21, 55128 Mainz, Germany; jantschke@uni-mainz.de
6Dipartimento di Scienze della Terra, Università di Ferrara, Via Giuseppe Saragat, 1, 44100, Ferrara, Italy; lev@unife.it
7*Corresponding author

This work focuses on the carbonate-siliclastic sediments of the middle Eocene (Bartonian) Capo Mortola Calcarenite Formation from a sedimentary succession cropping out near the village of Olivetta-San Michele (Liguria, NW Italy). The succession is very rich in larger benthic foraminifera such as nummulitids and sporadic orthophragmines. Nummulitid dominance is very unstable throughout the succession and this seems to be linked with short- to long-term variations of the depositional environment. Along the succession, we observe significant paleoecological changes, likely triggered by the variation in neritic input as consequence of tectonic and climatic instabilities. The increase in water turbidity caused stressful conditions, especially for the mixotrophic taxa, which reduced their size and abundance considerably until they became rare and in the middle to upper part of the succession they almost completely disappear. However, the filter feeders, such as turritellid gastropods and bivalves (particularly oysters), became dominant, thus suggesting an increase of nutrients in suspension, favoring their development. The presence of an oyster bed indicates a significant increase in fluviatile supply, which is ideal for the survival of these taxa.

In the upper part of the succession, we have recorded an alternation between gravity flow deposits and marly sediments that are interpreted as short-term alternations between calm and intense precipitations. The gravity flows display evident erosional bases and are characterized by much more competent lithologies than the surrounding marly sediments. The gravity flows yield transported LBF (i.e., orthophragmines and nummulitids), smaller benthic and planktonic foraminifera, molluscs, and corals. In turn, marls display only few LBF and abundant smaller benthic and planktonic foraminifera. In these intervals, the increase of planktonic foraminifera suggests a deepening of the carbonate ramp coinciding with a reduction of light that did not favour the development of the LBF.

Within the marly samples, the planktonic foraminifera indicate biozone E12, which is chronostratigraphically related to the MECO event, and a dedicated isotope stratigraphy dataset confirms the climatic perturbation. The sedimentary changes registered in the uppermost part of the successions are therefore related to the climatic dynamics that occurred in the Bartonian in the western Tethys.

Non-classical crystallisation mechanisms as a part of hyaline foraminifer biomineralisation

ARNS Anthea1,2, EVANS David3,4, SCHIEBEL Ralf1,5, FINK Lothar3,4, MEZGER Markus1,4, ALIG Edith1,4, LINCKENS Jolien5,6, JOCHUM Klaus Peter1,6, SCHMIDT Martin7, JANTSCHEK Anne8 and HAUG Gerald1,7

1Max Planck Institute for Chemistry, Hahn-Meitner-Weg 1, 55128 Mainz, Germany; anthea.arns@mpic.de; ralf.schiebel@mpic.de; k.jochum@mpic.de; gerald.haug@mpic.de
2School of Ocean and Earth Science, University of Southampton, European Way SO14 EHZ, Southampton, UK; d.evans@soton.ac.uk
3Institute of Inorganic and Analytical Chemistry, Goethe University Frankfurt, Max-von-Laue-Straße 7, 60438 Frankfurt a.M., Germany; fink@chemie.uni-frankfurt.de; c.alig@chemie.uni-frankfurt.de; M.Schmidt@chemie.uni-frankfurt.de
4Faculty of Physics, University of Vienna, Währinger Straße 38-42,1090 Vienna, Austria; markus.mezger@univie.ac.at
5Institute of Geosciences, Goethe University Frankfurt, Altenhöferalle 1, 60438 Frankfurt a.M., Germany; Linckens@em.uni-frankfurt.de
6Institute of Geosciences, Johannes Gutenberg University Mainz, Johann-Joachim-Becher-Weg 21, 55128 Mainz, Germany; jantschke@uni-mainz.de
7Department of Earth Sciences, ETH Zurich, Sonneggstrasse 5, 8092 Zurich, Switzerland; gerald.haug@mpic.de
8*Corresponding author

The exact mechanism of foraminifer biomineralisation is a matter of ongoing debate, yet establishing this is vital for confidently linking environmental parameters and proxy signals. It is, for example, not resolved in detail whether metastable phases such as amorphous CaCO₃ or vaterite are part of the process of crystallising a calcite test, or how organic matter is
involved in controlling calcification. To approach this question, we investigated a set of hyaline foraminifer tests on a micro-
to nanometre scale. We show that the chamber walls exhibit nanogranular fracture surfaces along with a crystallite domain 
size of approximately 100 nm, with regions of crystallographic orientation towards the outside chamber surface on a 
micrometre scale. From this, we conclude that hyaline foraminifer tests are made of mesocrystals, which strongly indicates 
the presence of particle-mediated, non-classical crystallisation mechanisms during foraminifer biomineralisation. Given that 
non-classical crystallisation pathways have been observed to involve metastable carbonates along with phase transitions to 
stable phases, and organic matter in diverse functions, a biomineralisation mechanism via a precursor phase is likely to 
distinctly influence isotopic fractionation and trace element incorporation into the shell. As such, this pathway needs to be 
considered when mechanistically understanding proxy signal formation.

These conclusions highlight the necessity to explicitly investigate non-classical processes in the organism as well as in 
experimental models, to reduce uncertainties arising from vital effects, and to enable accurate and precise reconstructions.

A multiproxy study by means of quantitative analysis of planktic and benthic foraminifer assemblages, O and C stable 
isotopes measured on planktic (G. bulloides) and epibenthic (C. pachyderma) taxa has been carried out in Southern Adriatic 
in core SA03-11 (1126 m w.d.) and SA03-03 (470 m. w.d.), collected on the up and the down current limbs, respectively, of sediment waves generated on the 
western flank of the southern Adriatic margin by the dense water cascading, and PRAD1-2 borehole, drilled in the Middle 
Adriatic Pit at 187 m w.d. The chronology integrated 33 (published and new) 13C datings, O and C stratigraphy, 
tephrochronology and foraminifer bioevents (event stratigraphy) and allowed to investigate the time interval since 37 to 12 
kyrs BP.

The interstadials (up to GI-5) are marked by increase of warm water planktic taxa (G. ruber) and by low values benthic 
13C, interpreted as intervals with lower production of dense water, coherent with the increase of low-oxygen and organic 
matter tolerant benthic species. The LGM (chronozone) displays a moderate warming phase (increase of warm planktic taxa) 
punctuated by short-term oscillations, while the deep-water production seems to reach its maximum strength (highest benthic 
13C values and highest benthic oxygen index) in all the southern Adriatic sites, differently from the previous interval when 
the deepest site showed a relatively minor ventilation in comparison with the slope sites. Considering the low-sound sea level 
at that time the main site of deep-water production was probably limited to the southern Adriatic area. The interval 
corresponding to the HS1 event is characterized by a cold water planktic assemblage, although a modest warming is visible 
starting at 16.2 kyr BP, just preceding the abrupt decrease of bottom ventilation (decrease of 13C benthic values and peak of 
low oxygen benthic taxa in all the southern sites), a well-known event occurring within HS1 in the western Mediterranean 
and corresponding to HE1. A strong peak in low oxygen benthic taxa (Bolivina-Brizalina) is also present at the base of HS1 
event in both the slope and deep southern Adriatic sites and we interpret it as the result of a rapid burial, rather than a 
decrease of general ventilation, considering the high sedimentation rate obtained by the chronology. However, HS1 interval 
shows, in the slope site, also the occurrence and increase of shelf benthic taxa, considered as a proxy of the cascading 
process. This may be interpreted as the beginning of the reactivation of dense water production in northern Adriatic 
(NADDW) after LGM, as consequence of a sea level rise during HS1 event. We do not rule out a Levantine Intermediate 
Water intensification concuring to this high sedimentation rate. In the central Adriatic, evidence of diffuse riverine runoff 
confirms the surrounding glaciers melting. After the abrupt warming at the base, the GI-1 interval displays the general 
cooling trend coherent with the known literature, as well as a quite intense cascading process in the slope site. However, 
in the southern Adriatic the ventilation appears stronger in the slope site rather than in the deep site, where 13C values still 
decrease in the deep site since the middle HS1 event (switching between northern and southern Adriatic dense water 
production?). During the GS-1 event the sluggish ventilation at the base and its strong recovery at the top are confirmed by 
13C and benthic assemblages along with the cascading proxy. This recovery is not coherent with 13C signal of the western 
Mediterranean records (activation of NADDW production because of sea-level rise drowning the northern area and/or more 
influence from the Siberian High?). At last, HS3 and HS2 events show an articulated structure, showing an abrupt decrease 
in ventilation in the middle of the interval (H3).
Amphistegina lobifera Larsen life cycle mode in a stressed coastal environment: The Vravron site, Aegean Sea Greece, revisited

BARDIS Dimitrios1, TRIANTAPHYLLOU Maria1*, DIMIZA Margarita1, TSOUROU Theodora1, KOUKOUSIOUARA Olga2, WEINMANN Anna3, LANGER Martin1 and HALLOCK Pamela1
1Department of Historical Geology and Palaeoentology, Faculty of Geology and Geoenvironment, National and Kapodistrian University of Athens, Panepistimioupolis 15784, Athens Greece; mtriant@geol.uoa.gr; mdimiza@geol.uoa.gr; ts sourou@geol.uoa.gr
2Department of Geology and Palaeontology, Faculty of Geology, University of Thessaloniki, Panepistimioupolis 54124, Thessaloniki Greece; okoukous@geo.auth.gr
3Geological-Paleontological Department, Natural History Museum Vienna, Burgring 7, 1010, Vienna, Austria; Anna.Weinmann@NHM-WIEN.AC.AT
*Corresponding author

Representatives of the Amphisteginidae family are nearly omnipresent contributors to shelf carbonate facies through most of the Cenozoic. Amphistegina lobifera Larsen, 1976 is one of the most successful invasive species in coastal ecosystems of the eastern Mediterranean, being a significant carbonate producer of shoreline sediments as well as an ecosystem quality indicator.

This study reports a year-long (November 2021–October 2022) study of an Amphistegina lobifera population collected monthly from algal samples (mostly Halopteris scoparia, Amphiroa and Jania) in the Vravron/Attica rocky substrate coastal ecosystem of the south Evoikos Gulf (Aegean Sea). Comparison with a previous study performed over a decade ago at the same site (2008–09) indicates higher sea-surface temperatures consistent with the Mediterranean’s general warming trend during the last decades. Prominent variations in salinity (38.50-35.50) and pH values mostly below 8 are associated with both natural and anthropogenically stressed environmental conditions. Our results show two major peaks of A. lobifera dead specimens observed with simultaneous decrease of living individuals in March and June/July; the latter time interval is featured by the restricted presence of white (reproducing) specimens and is followed by a slight increase of juvenile individuals (less than 0.5 mm in diameter) in August. An increasing trend of dead specimens is also observed in November. Overall, the juvenile individuals are prominently reduced when compared to the over a decade ago data, slightly exceeding 10%, in respect to the juvenile abundances of up to 60% during the summer reproduction period over a decade ago. Abundance of A. lobifera living specimens was remarkably prominent in February 2022 (more than 380 living specimens/100 cm²). The associated epiphytal foraminiferal fauna revealed notable contribution of miliolids and Textularia agglutinans d’Orbigny, 1839 in the assemblages, with the latter practically exceeding A. lobifera abundances in most of the monthly samplings. Peneroplis spp. and particularly P. planatus (Fichtel & Moll, 1798) are clearly increased when A. lobifera was almost absent, e.g., during June/July, implying the outcompeting role of the latter vs. the native Peneroplis species in the Aegean ecosystems.

Although A. lobifera has been recorded to reproduce primarily during the summer in the coastal ecosystems of the Aegean Sea, when sexual and reproductive processes take place simultaneously, the present study indicates a noted reproduction mostly in size classes previously considered pre-adult implying potential failure/mortality of embryos and/or successive asexual generations of megalospheric forms that are better adjusted in environmentally stressed conditions.

Benthic foraminiferal palaeothermometry in deglacial sediments off NW Africa: how accurately is Mg/Ca recording bottom water temperature changes in the past?

BARRAGÁN-MONTILLA Sofía1, JOHNSTONE Heather J.H.1, MULITZA, Stefan1 and PÅLIKE, Heiko1
1MARUM – Center for Marine Environmental Sciences, University of Bremen, Bremen, Germany; sbarraganmontilla@marum.de; hjohnstone@marum.de; smulitza@marum.de; hpailike@marum.de
*Corresponding author

The need to reconstruct deep water temperatures to understand the role of ocean circulation in the climate system has drawn growing interest in using Mg/Ca of benthic foraminifera as a paleotemperature proxy. There are now several bottom water temperature (BWT) records published for timescales of thousands to millions of years. Many of these records are based on the common deep-sea infaunal foraminifera genus Uvigerina, with numerous core top calibrations from different areas of the Atlantic and Pacific oceans.

However, low recovery and poor preservation of this genus in shallower sites, or specific environmental conditions in the geological record that limit the occurrence of Uvigerina, make it necessary to investigate other species groups as potential bottom water paleothermometers. Intermediate to deep infaunal foraminifera like Cassidulina spp., Nonion spp., Globobulimina spp., and Melonis barleeanus have been used in paleotemperature reconstructions of the (mainly western) North Atlantic and the Nordic seas.

Benthic foraminifera Mg/Ca is sensitive not just to temperature, but also to other environmental parameters and parallel records may isolate confounding factors. In this research, we tested the potential of Mg/Ca ratios of common intermediate
infaunal *Melonis barleeanus* and deep infaunal *Globobulimina turgida* from site GeoB9512-5 (water depth 794 m) in the tropical East Atlantic, to reconstruct BWT changes at intermediate depths during the last deglaciation. In the process, we evaluated the possible correlation of other paleoenvironmental factors affecting Mg/Ca uptake from these species that could influence paleotemperature reconstructions.

The comparison of Mg/Ca ratios and BWT estimates from *Melonis barleeanus* and *Globobulimina turgida* with *Uvigerina mediterranea* records, show that *M. barleeanus* does not record the same Mg/Ca-based paleotemperatures as *U. mediterranea* and *G. turgida*, furthermore no fixed offset can be calculated. Our Mn/Ca data suggests, that as *U. mediterranea* and *G. turgida*, remain at relatively constant depths in the sediment, *M. barleeanus* seem to have migrated vertically due to bottom water oxygenation and trophic levels variability, potentially affecting Mg uptake during calcification. Moreover, a strong correlation between Mn/Ca and Mg/Ca from *M. barleeanus* and low correlation of these two parameters in *U. mediterranea* supports our findings. This suggests that *M. barleeanus* is not a suitable species for paleotemperature reconstructions in the NE Atlantic and highlights the importance of local Mg/Ca calibrations and multispecies measurements in paleoceanographic studies.

**Impact of sediment discharges on benthic faunas in coastal Mediterranean Sea**

BARRAS Christine1, LABRUNE Céline2, HUBERT-HUARD Raphaël2, LESCURE Lyvia3, MADRE Mathilde1, ORTS Amelie4, PRUSKI Audrey5, QUINCHARD Sophie2, VÉTION Gilles5 and ASTRUCH Patrick4

1Université d’Angers, Nantes Université, Le Mans Université, CNRS, Laboratoire de Planétologie et Géosciences, LPG UMR 6112, 2 boulevard Lavoisier, 49000 Angers, France; christine.barras@univ-angers.fr; mathilde.madre@etad.univ-angers.fr; sophie.quinchard@univ-angers.fr
2CNRS, Laboratoire d’Écogéochimie des Environnements Benthiques, Sorbonne Université, LECOB UMR 5222, 1 avenue Pierre Fabre, 66650 Banyuls-sur-Mer, France; celine.labrune@obs-banyuls.fr; lyvia.lescure@obs-banyuls.fr; audrey.pruski@obs-banyuls.fr; vetion@obs-banyuls.fr
3Institute of Geology, Universität Hamburg, Bundesstraße 55, 20146 Hamburg, Hamburg Germany; raphael.hubert-huard@uni-hamburg.de
4GIS Posidonie, OSU Institut Pythéas, Aix-Marseille Univ., Campus de Luminy, 163 Avenue de Luminy, 13288, Marseille, France; ortsimeliane13@gmail.com; patrick.astruch@univ-amu.fr
5*Corresponding author

Since the 1950’s, benthic foraminifera are more and more widely used as marine bio-indicators of ecosystem quality. For this purpose and in the context of the Water Framework Directive, biotic indices have been developed to define the ecological quality status of water masses. Biotic indices based on indicative species, such as Foram-AMBI, TSI-Med and FSI, are currently used in the Mediterranean Sea. They are based on the classification of the different species of foraminifera into 1 to 5 ecological groups according to their sensitivity to a gradient of organic matter enrichment. However, this kind of indices may not be suitable for detecting physical or chemical perturbations.

In this study, we focus on the impact of sediment discharges from dredging activities on soft bottom ecosystems. The study area, located in the Gulf of Lions close to Port la Nouvelle, was subject to two types of dredging activities at the time of sampling: 1) regular dredging for the maintenance of access channels and sufficient water depth in harbour basins, and 2) temporary dredging for the harbour expansion works due to the future installation of offshore wind farm. Comparing these two types of sediment discharge areas was interesting since their localisation, volume, frequency and grain size characteristic were different. In this context, we studied the living foraminiferal fauna at 10 stations located along a transect at ~25-30 m water depth parallel to the coast, crossing two different dumping zones and reference conditions. Other parameters such as quantity and quality of organic matter, grain size analyses, macrofauna communities, sediment interface pictures and videos of the seafloor were studied for the same stations.

The impact of sediment discharges on benthic ecosystem was highlighted by the different parameters studied. For foraminiferal faunas, diversity indices and densities were significantly lower in the dumping zones compared to the reference zones and assemblages were different as well. It was also possible to detect faunal differences between impacted stations according to the total volume of sediment discharged in the last months before sampling. Not surprisingly, the biotic indices based on the sensitivity of species to eutrophication were not adapted to identify the impact. However, the GPBI (General-Purpose Biotic Index) proposed for macrofauna, based on the loss of abundance of sensitive species in impacted sites compared to reference sites, gave promising results with regards to the assessment of physical disturbances such as sediment discharges.

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

BARRAS Christine1, LE MOIGNE Damien1, MOJTAHID Meryem1, LABRUNE Céline2, MOURET Aurélie1, METZGER Edouard1, MAILLET Grégoire1, MORISSEAU Célestine1, PRUSKI Audrey2, VÉTION Gilles3, LESCURE Lyvia2 and VAZ Sandrine3

1Université d’Angers, Nantes Université, Le Mans Université, CNRS, Laboratoire de Planétologie et Géosciences, LPG UMR 6112, 2 boulevard Lavoisier, 49000 Angers, France; christine.barras@univ-angers.fr; damien.lemoigne@univ-angers.fr; meryem.mojtahid@univ-angers.fr; aurelia.mouret@univ-angers.fr; edouard.metzger@univ-angers.fr; gregoire.maillet@univ-angers.fr; celestinenморisseau09@gmail.com

2Raphael Hubert-Huard, Universität Hamburg, Bundesstraße 55, 20146 Hamburg, Germany; raphael.hubert-huard@uni-hamburg.de

3GIS Posidonie, OSU Institut Pythéas, Aix-Marseille Univ., Campus de Luminy, 163 Avenue de Luminy, 13288, Marseille, France; ortsimeliane13@gmail.com; patrick.astruch@univ-amu.fr

*Corresponding author
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 thanks to the Vessels Monitoring Systems (VMS) 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 of soft-bottom habitats in this area.

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, at around 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, which can be used to complement and/or precise the monthly abrasion maps available. 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 aculeata), 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.

Foraminifera eDNA assemblages from arctic methane cold seeps

BARRENECHEA ANGELES Ines1*, HOLM Villads1, HOLZMANN Maria2, PAWLOWSKI Jan3 and PANIERI Giuliana1

1Department of Geosciences, UiT the Artic University of Norway, 9010 Tromsø, Norway; ines.a.angeles@uit.no; vho037@post.uit.no; giuliana.panieri@uit.no
2Department of Genetics and Evolution, University of Geneva, 1205 Geneva, Switzerland; maria.holzmann@unige.ch
3Institute of Oceanology, Polish Academy of Sciences, 81-712 Sopot, Poland; janpawlowski@iopan.pl
*Corresponding author

The foraminiferal communities in methane seeps have been characterized based on the morphology of living or dead assemblages. These assemblages generally included hard-shelled (calcareous and agglutinated) multi-chambered foraminifera. However, little work has been done on the single-chambered (monothalamous), usually soft-walled (organic or finely agglutinated) foraminifera that can be abundant in methane seeps. Here, we present the first eDNA metabarcoding study of the methane seeps foraminiferal fauna encompassing both multi- and single-chambered taxa. Samples were collected from shallow sites in the Barents Sea and deep active pockmarks off NW Svalbard. The sampling focused on typical seep microhabitats, such as sediment with methane bubbling, microbial mats, tubeworm, and gastropod zone. In addition, reference samples within and outside the pockmarks were also recovered. The eDNA metabarcoding data provide an overview of the foraminiferal community, including soft-walled and small sized species not comprised in traditional studies. This study also identifies potential methane-tolerant species that could be used as indicators of methane seepage. Monothalamous species, which were the most abundant in all samples and some of which were present only in the microbial mat, are potential candidates to be methane indicators. As expected, in addition to differences in water depth and geographical conditions from the selected areas, each microhabitat has a different composition.

Looking for a geochemical imprinting of sea-ice environment in the planktic foraminiferal Neogloboquadrina pachyderma

BARTOLINI Annachiara1*, SABBATINI Anna2, ANDREO Antoine1, ALEON Jérôme1, MOSTEFAOUI Smail3, MORIGI Caterina3, ROLLION-BARD Claire3 and MONTI-BIRKENMEIER Marina6

1CR2P-Center for Research on Palaeontoloy - Paris, UMR 7207 MNHN CNRS SU, Muséum national d’Histoire naturelle, 8 rue Buffon, 75005 Paris, FRANCE; annachiara.bartolini@mnhn.fr, antoine.andreo3@orange.fr
Polar sea-ice is a unique habitat for virus, bacteria, microalgae and zooplankton, which are enclosed in an ice matrix at low temperature (down to -20°C) and low light levels, where the only liquids are high salinity brines (up to 82 PSU) in channels and pockets. Survival in these conditions requires a complex series of physiological and metabolic adaptations, but organisms thrive in the sea-ice, and their prolific growth play a fundamental role in polar ecosystems and carbon cycle.

The planktic foraminifer Neogloboquadrina pachyderma (Ehrenberg, 1861) is the only taxon among sea-ice zooplankton to secrete a calcareous test (= shell). At present, N. pachyderma specimens are abundant in the Antarctic sea-ice, but very rare in the Arctic sea-ice. They have likely adopted different test-building and biocalcification strategies depending on whether they grow in the seawater column or sea-ice. Recent culture experiments with juvenile and pre-adult N. pachyderma collected from sea-ice during the austral winter in the Antarctic Weddell Sea (ANT-XXIX/6 of RV Polarstern in 2013) have shown that they can actually biocalcify in extreme salinity conditions mimicking those of the sea-ice brines. Trace element analyses on these cultured N. pachyderma specimens, reveal increased values of test Mg/Ca, Sr/Ca and Na/Ca ratios at higher salinities and stress the strong influence of high salinity brines on the Mg/Ca paleothermometer. Consequently, the temperatures of this proxy may be overestimated.

We analyzed specimens from the upper and lower layers of sea-ice cores collected during the austral winter in the Weddell Sea (ANT-XXIX/7 of RV Polarstern in 2013) and from seawater column sampled during a subsequent cruise during the austral autumn (Polarstern PS112 in 2018). We performed NanoSIMS (MNHN, Paris) intra-test mapping with nanoscale lateral resolution (<100 nm) of Ca, Mg, Na, K and Sr following the sub-micrometric growth structure of the test’s chambers, characterized by an alternation of organic and calcitic layers. We found a heterogeneous distribution of Mg/Ca, Na/Ca, K/Ca, Sr/Ca ratios within the test, characterized by alternating enriched and depleted bands parallel to the test surface. The Na and K banding are highly correlated, whereas there is no obvious correlation between the banding of the other trace elements. Na and K enrichments are observed around thin organic layers interspersed with calcitic layers, associated with the sequential chamber formation of the test. Mg enrichments are observed both around the organic layers between the calcitic layers and within the calcitic layers, the latter being possibly related to the continuous thickening of the calcitic layers once formed. In addition to the impact of high salinity, the intra-test distribution of Mg in the analyzed individuals also shows a significant biological control on Mg incorporation during test construction.

Comparison of intra-test distribution patterns of Mg/Ca, Sr/Ca, K/Ca and Na/Ca between specimens collected from sea-ice and the seawater column confirms that N. pachyderma appears to be able to calcify in Antarctic sea-ice within brine pockets and channels, and that their test has a characteristic geochemical sea-ice signature. Furthermore, the comparison of Mg/Ca, Na/Ca, K/Ca and Sr/Ca ratios between the last and first chambers may provide new insights into the life cycle of this fascinating species of planktic foraminifera that thrives in polar environments, including sea-ice. A better understanding of the incorporation of these key trace elements in N. pachyderma tests taken from sea-ice may help to use them as multiproxies of sea-ice palaeoenvironments and their evolution in the past.

Disentangling biogeographical patterns through the integration of fossil data: Alveolinella quoyi in the western Indo-Pacific Warm Pool

BASSI Davide1, IRYU Yasufumi2, PINNATTI Johannes3 and RENEMA Willem4, 5

1Dipartimento di Fisica e Scienze della Terra, Università di Ferrara, 44122 Ferrara, Italy; bsd@unife.it
2Institute of Geology and Paleontology, Graduate School of Science, Tohoku University, Aobayama, Sendai 980-8578, Japan; yasufumi.iryu.d8@tohoku.ac.jp
3Dipartimento di Scienze della Terra, Università ‘La Sapienza’, P.le A. Moro 5, 00185 Rome, Italy; Johannes.Pignatti@uniroma1.it
4Naturalis Biodiversity Center, P.O. Box 9517, 2300 RA, Leiden, The Netherlands; willem.renema@naturalis.nl
5University of Amsterdam, Institute for Biodiversity and Ecosystem Dynamics (IBED), P.O. Box 94240, 1090 GE Amsterdam, The Netherlands; willem.renema@naturalis.nl

*Corresponding author

In present-day Indo-Pacific coral-reef settings, only Alveolinella H. Douvillé, 1907 (Early Miocene–Recent) and Borelis de Montfort, 1898 (late Eocene–Recent) represent the alveolinoid larger foraminiferan. Three present-day species of Alveolinella and Borelis have been identified: A. quoyi (d’Orbigny, 1826), B. pulchra (d’Orbigny, 1839) and B. schlumbergeri (d’Orbigny, 1839). Alveolinella quoyi occurs in the Central Indo-Pacific Ocean (CIP) with its northernmost record from the shallow-water settings in Okinawa Jima (central Ryukyu Islands, Japan).
We collected literature data of the long-known *Alveolinella quoyi* of the western Pacific area. Besides assessing its fossil record and their palaeobiogeographical distributions, we investigate its range over the past c. 10 Myr and investigated when this species plausibly appeared in the Ryukyu Islands, its northernmost Indo-Pacific record.

*Alveolinella quoyi* possibly first appeared in the Tortonian of Indonesia. During the Pliocene *A. quoyi* was constrained within the CIP. After the initiation of the Kuroshio current in the latest Pliocene, the northward migrants arrived in the central Ryukyu Islands in the Calabrian–Chibanian (Early–Middle Pleistocene). The northward dispersal route of *A. quoyi* was constrained by complex coastlines and numerous islands. The Kuroshio current favoured the migrants arriving in the shallow-water carbonate settings of Okinawa Jima where the species is still thriving. Likely, during the Late Pleistocene, following the unrestricted stronger Indonesian Throughflow that connected the western Indo-Pacific Warm Pool with the Indian Ocean and Western Australia, the westward *A. quoyi* migrants moved into the western CIP giving rise to the present-day Maldivian and Réunion occurrences.

Did Upper Eocene short-lived corallinacean-foraminiferal carbonates form in mesotrophic paleoenvironments along the Alpine convergent margin?

**BAUMGARTNER Peter O.**, **BAUMGARTNER-MORA Claudia**, **FERRÀNDEZ-CÀÑADELL Carles**, **GOETING Sulia**, **EPARD Jean-Luc** and **ANDIJC Goran**

1 Institut des sciences de la Terre, Université de Lausanne, Géopolis, CH-1015 Lausanne, Suisse; peter.baumgartner@unil.ch
2 Département Dinàmica de la Terra i de l'Oceà, Facultat de Ciències de la Terra, Universitat de Barcelona, Martí i Franquès s/n, Barcelona, 08028, Spain; carlesferrandez@ub.edu

*Corresponding author*

The actualist paradigm of restricting large forms of hyaline larger benthic foraminifera (LBF) to oligotrophic environments is challenged by their rock forming occurrence in short-lived, Upper Eocene corallinacean carbonates of the external, sedimentary nappes of the Alps (Helvetic, Chaines Subalpines and Lombardian Southern Alps).

Abundant large forms of orthophragminids, nummulitids and other rotaliids occur with over 20 species in grey limestones recently attributed by us to SBZ 19 and 20 (Priabonian, Sanetsch Formation) in several Helvetic and N-Helvetic nappes of Western Switzerland and the Haute Savoie, France. In this deepening upwards formation, the upper lithofacies (Pierredar Limestone Member) are largely dominated by coralline rhodophyceans: melobesian and peyssonneliacean crusts, rhodoliths and abundant bioclasts of geniculate rhodophytes. The matrix of the bioclastic limestones contains variable amounts of fine-grained lithics, such as quartz, feldspars, mica and some charcoal fragments. The darkest lithologies give off a smell of kerogen, contain <10 µm framoidal pyrite, as well as larger pyrite aggregates, frequent in the matrix, indicating dysoxic conditions in bottom waters and/or beneath the sediment surface. In sections weakly affected by alpine burial diagenesis, LBF reveal a pristine, intrinsic cathodoluminescence unlike recrystallized specimens from shallow water environments. Hence, there is evidence of displacement of LBF, exhumed from shallower, well-oxygenated domains into the dysoxic depositional sites. On the other hand, even the lowest, shallowest, cross-bedded parts of the sections show oxidized pyrite, charcoal fragments, and abundant quartzo-feldspathic material.

Modern coralline rhodophyceans occupy a wide range of habitats from tropical to temperate zones. They dominate in the “marginal reefs” or “turbid reefs” recently described from many mesophotic and mesotrophic shelfal areas of the Atlantic and elsewhere, alas, without mention of LBF.

Prevailing mesotrophic conditions during formation of the Priabonian carbonates are suggested by the occurrence of extensive pavements of the large oyster *Pycnodonte gigantica*, common irregular echnoids, bryozoans, serpulids and solitary corals, while hermatypic scleractinian corals are rare and restricted to genera, at present-day tolerant to mesotrophic and/or mesophotic, soft sediment conditions, such as *Cladophora*, *Porites* and *Caulastrea*. Except for miliolids, porcelaneous LBF are rare.

Mesotrophic and probably turbid conditions prevailed, because Upper Eocene carbonates formed off estuarine/deltaic areas shedding terrestrial material from the north (Black Forest, Vosges) into the Helvetic realm and from the advancing South Alpine nappes into the Lombardian South Alpine Realm, where Priabonian shallow water carbonates are known from deep-water resediments only (Ternate Formation).

While Eocene orthophragminids have no recent representatives, modern nummulitids, such as *Opeculina* ssp. have been dredged off Brunéi Darussalam (NW-Borneo) under the mesotrophic fringe of the South China Sea from depths down to the shelf edge (140 m) where they lived on muddy substrates under mesophotic/mesotrophic conditions. Further investigations of deeper mesotrophic shelf areas may perhaps reveal modern equivalents of the Upper Eocene corallinacean, LBF-rich carbonates.
Larger benthic foraminifera from the Azuero Peninsula (SW-Panama) define Eocene accretionary events and an arc gap along the trailing edge of the Caribbean Plate

BAUMGARTNER-MORA Claudia1*, BAUMGARTNER Peter O.1, FERRÀNDEZ-CAÑADELL Carles2 and BUCHAR David M.3

1Institut des sciences de la Terre, Université de Lausanne, Moulle 11-Géopolis, CH-1015 Lausanne, Suisse; claudia.baumgartner@unil.ch; peter.baumgartner@unil.ch
2Department Dinamica de la Terra i de l'Oceà, Facultat de Ciències de la Terra, Universitat de Barcelona, Marti i Franquès s/n, Barcelona, 08028, Spain; carlesferandez@ub.edu
3School of Earth and Ocean Sciences, Cardiff University, Main Building, Cardiff, CF10 3AT, United Kingdom; BuchsD@cardiff.ac.uk
*Corresponding author

The Azuero Plateau, the trailing edge of The Caribbean Large Igneous Province (CLIP), is overlain by ribbon-cherts dated by radiolarians as Coniacian-Santonian. Proto-arc dikes crosscut the Azuero Plateau and the unconformably overlying Upper Cretaceous sediments. The latter consist of hemipelagic carbonates, the Ocú Formation (Fm.), and of volcanioclastics, the Quebrada Quema Fm., both dated by globotruncanids as Late Campanian to Maastrichtian. Upper Cretaceous larger benthic foraminifera (LBF) and rudist fossils were reported by early workers in the Ocú area, suggesting the presence of carbonate shoals on early arc volcanic edifices. A recently published crystallization 206Pb/206Pb-age of zircons dates the oldest (Cerro Montuoso) batholith of W-central Azuero as 66.4±0.3 Ma (latest Maastrichtian).

The Azuero Plateau is bounded towards the SW by the Azuero-Soná Fault Zone and the adjacent Azuero Subduction Mélange that contains fragments of oceanic seamounts dated by globotruncanids as early Maastrichtian.

The Azuero Accretionary Complex occupies the SW-corner of the Azuero Peninsula. It is principally composed of two well-preserved oceanic seamounts. The Hoya seamount to the W is made of intrusives, subaerial and submarine lava flows with interbedded carbonates. Pelagic carbonates yielded Morozovella sp. indicate a late Paleocene – early Eocene age. Shallow water carbonates yielded the association of Neodiscocyclina barkeri, Euconuloides sp. cf. E. welsi and Amphistegina undecima, indicating an early Eocene age.

The Punta Blanca Seamount to the E is characterized by a several km thick sequence of submarine/subaerial basaltic lava flows regularly interbedded with carbonates. Most shallow water facies only contain rhodophytes and bivalve bioclasts. Only one calcarenite yielded Pseudophragminina anconensis and orthophragminids suggesting an early-middle Eocene age.

The Covachón Fm. is the first overlap sequence in which chaotic deposits with up to 50 m sized blocks document the accretion of the seamounts. LBF collected from several localities indicate a middle Eocene age of the accretionary events. These resulted in a shutdown of the arc between 49 and 36 Ma (late Ypresian – earliest Priabonian), reflected by a lack of 206Pb/206Pb zircon ages from intrusives. Covachón facies range from distal volcanioclastic turbidites to chaotic megaflows and up to nearshore conglomerates, documenting fast tectonic uplift.

At Puerto Escondido, a stratigraphic base of the Covachón Fm., is formed by cross-bedded detrital limestones unconformably on seamount basalts. They contain winnowed small LBF: Eoconuloides sp., Amphistegina grimsdalei, A. praegrimsdalei and Pseudophragminina sp. suggesting a Middle Eocene age. In the chaotic facies at Covachón Beach the matrix of the debris flows yielded Asterocyclina ssp., Neodiscocyclina marginita, Lepidocyclina ssp. and Polyphildida sp. suggesting a middle Eocene maximum age. Detrital zircons form the turbiditic facies yielded a 42 Ma minimum age (late Lutetian).

The Tonosi Fm. represents a several 100 m thick deepening upwards forearc series that ranges from paralic to turbiditic facies of late Eocene to Oligocene age. Its base onlaps time-transgressive on older formations and basalts documenting progressive drowning of the Azuero Arc Complex. The youngest zircons of the upper Tonosi yielded 206Pb/206Pb ages around 36 Ma (Priabonian). The Rio Pedregal paralic facies include polymict conglomerates and encroach unconformably on accreted seamount rocks and deformed packages of Covachón Fm. The conglomerates contain pavements of oysters (Pycnodonte sp.) and a detrital matrix with abundant large Lepidocyclina ssp., pseudophragminids and Asterocyclina ssp. indicating a late Eocene age.

The Guerita River exposes herringbone cross-bedded bioclastic limestones, unconformably overlying the Upper Cretaceous Rio Quema Fm. They are made of abundant Operculinoides ssp., suggesting an Oligocene age. Another inland outcrop is rich in large Lepidocyclina ssp., among them L. tournoueri and L. undosa with an Oligocene age.

Strontium isotope and biostratigraphy of the Namibian continental shelf and associated palaeoenvironmental changes during the Neogene to Quaternary

BERGH Eugene1*

1Geology Department, Unit for Environmental Sciences and Management, North-West University, Hoffman Street, Potchefstroom, South Africa; eugene.bergh@nwu.ac.za
*Corresponding author

The Namibian continental shelf is rich in phosphorite with large economic potential. The stratigraphy, ages and palaeoenvironments of these deposits have previously not received much attention. An understanding of how
palaeoenvironments changed over time under changing oceanographic conditions of the Northern Benguela Upwelling System along the margin also lacked.

Exploration and environmental studies rely on accurate stratigraphic information. Foraminifera provide an excellent proxy to determine the stratigraphy through isotopes and biostratigraphy. This study investigated 20 cores from the northern and central Namibian continental shelf (199 to 400 m). Lithological units were studied, and sedimentary components identified under binocular microscopy. Samples from the cores were analysed for strontium isotopes in sedimentary components such as foraminifera, mollusc shell, cetacean and fish bone, as well as in phosphorite grains to determine ages for the different lithological units. Faunal analyses were conducted to determine how the environments changed during the identified ages obtained from strontium isotope stratigraphy and biostratigraphy.

The sediments from the cores were found to largely be biogenic in the older olive-green mud units, containing mostly foraminifera. Phosphatic material dominated the sedimentation in the darker, younger sediments with an increase in large biogenic components to the top of the cores. Foraminifera formed minor to moderate components in the darker phosphatic units. Foraminiferal taxa and indicator species were identified and used to determine the biostratigraphy. Results from the study indicated the oldest age at the base of these cores to be in the Langhian (middle Miocene), between 15.2 and 14.1 million years ago, confirmed by both strontium isotope stratigraphy and biostratigraphy (indicator species *Globoquadrina dehiscens* and *Trilobatus bisphericus*). The foraminiferal assemblages indicated the palaeoenvironment to have shifted from a deep-water, oligotrophic environment, with warm tropical-subtropical-like conditions during the middle Miocene to shallower colder and more nutrient-rich environments during the Pleistocene-Holocene. The ages of major phosphatisation with an increase in productivity were found to be in the Pleistocene-aged darker sediments when Benguela upwelling intensified. Foraminiferal faunal analyses also indicated different assemblages during the early, middle and late Pleistocene, related to increasing amplitude sea level changes.

This study therefore provided ages to the different lithological units on the northern and central continental shelf and its associated palaeoenvironmental conditions, which can be associated with global and regional climate and oceanographic changes.

---

**Gene expression of in situ preserved kleptoplastidic Nonionella stella from an aphotic sulfidic anoxic setting**

BERNHARD Joan M.1,*, ROgers Daniel2, Huang I-Ting3, Powers Christopher4, Zhang Ying4, Utter Daniel R.5, Cavanaugh Colleen5, Edgcomb Virginia P.1 and Gomaa Fatma1,3

1Department of Geology and Geophysics, Woods Hole Oceanographic Institution, 266 Woods Hole Road, MS52, Woods Hole, MA 02543, USA; jbernhard@whoi.edu; vedgcomb@whoi.edu; Fatma.gomaa@gmail.com
2Chemistry Department, Stonehill College, 320 Washington Street, Easton, MA 02375, USA; d Rogers2@stonehill.edu
3Department of Organismic and Evolutionary Biology, Harvard University, 16 Divinity Avenue, Cambridge, MA 02138, USA; ihuang@g.harvard.edu; cavanaugh@fas.harvard.edu; fatma.gomaa@gmail.com
4Department of Cell and Molecular Biology, University of Rhode Island, Center for Biotechnology and Life Sciences, 120 Flagg Road, Kingston, RI 02881, USA; c-11060@uri.edu; yingzhang@uri.edu
5Division of Geological and Planetary Sciences, California Institute of Technology, 1200 E. California Blvd, MC 100-23, Pasadena, CA 91125, USA; dutter@caltech.edu
*Corresponding author

*Nonionella stella* (known by some as *Nonionella* sp. T4) is a benthic foraminifer thriving in euxinic marine sediments in the Santa Barbara Basin (Southern California, USA). *N. stella* maintains functional diatom chloroplasts, sequestered from *Skeletonema pseudocostatum* or its close relative, despite inhabiting the aphotic zone (~560–595-m water depth). While we have documented *N. stella*’s gene-expression previously, those specimens had been exposed to sunlight briefly during the sampling effort and also during the isolation process. To identify the metabolic capabilities mediated by both the kleptoplasts and host cells never exposed to sunlight, we collected *N. stella*-laden sediments that were preserved *in situ* on seafloor. Thus, the data accurately represents the biology and gene expression of the host and their chloroplast endosymbionts while in their natural environment. At the time of collection, the bottom-water oxygen concentrations were undetectable, sunlight was undetectable (via PAR), and the *Beggiaota* (bacterial) mat spanned many square km of the seafloor. We sequenced and assembled metatranscriptomes and metagenome-assembled genomes (MAGs) to determine *in situ* gene expression and genomic context for genes of interest, respectively. Our data analysis confirms prior observations that *N. stella* is capable of respiring both nitrate and oxygen but also reveals novel insights into the adaptations that make this benthic foraminifer so successful in such an extreme habitat.

Funded by NASA Award #80NSSC21K0478 to JMB, FG, VPE, and DR.
Preliminary data on the application of artificial intelligence to the identification of Ammonia species from scanning electron microscopy images

BICCHI Erica1,2*, SCHWEIZER Magali2 and RASTI Pejman1,3

1ESAIP LA SALLE-18, rue du 8 mai 1945 - CS 80022 - 49180 Saint-Barthélemy d'Anjou, Cedex, France; ebicchi@esaip.org
2Université d'Angers, Nantes Université, Le Mans Université, CNRS, Laboratoire de Planétologie et Géosciences, LPG UMR 6112, 49000 Angers, France; magali.schweizer@univ-angers.fr
3Laboratoire Angevin de Recherche en Ingénierie des Système (LARIS), Université d’Angers, 62 Avenue Notre Dame du Lac, 49000 Angers, France; prasti@esaip.org
*Corresponding author

Ammonia is one of the most abundant cosmopolitan taxa among foraminifera dwelling in neritic environments. The high morphological variability of this genus led to a confused and controversial taxonomy at the species level, challenged by molecular studies in the two last decades.

From an inventory at the global scale, the DNA based data delineated more than fourteen phylotypes, different enough to be considered as separate species. Three phylotypes (T1, T2 and T6) found along the European Atlantic coast in intertidal areas are morphologically very close and still difficult to distinguish without molecular analyses. Unfortunately, these analyses are expensive, time-consuming and may represent drawbacks in routine taxonomical recognition. In addition, molecular analyses are usually bound to living individuals and are more difficult to apply to Holocene/Pleistocene fossil material.

Hence, the researchers have attempted to combine molecular and morphological approaches to achieve fast and reliable identification of species based on selected morphological characters, which can be applied to present and fossil foraminifera. Recently, by combining morphometric and molecular analyses, two discriminant morphological characters were identified to clearly distinguish the three species of Ammonia commonly found in European mudflats: Ammonia veneta (T1), A. aberdoveyensis (T2) and A. confertitesta (T6). These two morphological criteria are (i) the pore size of the penultimate chamber based on semi-automated standardized measurement (pore number, pore area and porosity), and (ii) the raised or flush character of the sutures on the spiral side. Therefore, the direct observation of these morphological characteristics allows recognizing these different species under a stereomicroscope without the need for molecular analysis.

Although these new criteria make it possible to avoid using DNA analysis, it is still rather time-consuming as one must analyse the scanning electron microscopy (SEM) images of each specimen.

With recent advances in computer software, automated identification processes have become possible. These processes help reduce the cost and time of studies while also enhancing their reproducibility. In this study, deep learning algorithms were developed and used to identify various Ammonia species based on SEM images. The algorithms were tested on two groups of images from Ammonia specimens collected from the Northeast Atlantic Ocean (SEM images of sequenced specimens) and coastal sites in Western Madagascar (SEM images of not sequenced specimens).

Deep learning addresses complex prediction problems using neural networks with high capacity. These networks are highly non-linear functions with numerous parameters, and their estimation usually requires a large amount of annotated training data. Transfer learning or domain adaptation is a common solution to this problem. The idea is to learn high-capacity models on large alternative source data sets whose content is sufficiently correlated with the target application and then transfer the learned knowledge to the target data.

This study performed a supervised transfer using classical weight freezing and fine-tuning. The knowledge was transferred from the well-known image classification task ILSVRC 2012 (ImageNet). Model architectures optimised for this task were used, and the hyper-parameters were optimized over a validation set. The deep network optimised for the data set was small compared to the knowledge encoded in the source data (ILVSRC). Therefore, "classical" and well-known high-capacity models for the ILVSRC task, namely VGG16, and ResNet50, were used. Among all possible combinations of freezing layers that were tested, the model with freezing at the first 3 layers and fine-tuning the other layers on the validation dataset returned the best performance of 98.3%.

Nitrogen isotopic signals in tissue of planktic foraminifers in the northern South China Sea from the shelf to the open ocean and implications for the foraminifer-bound nitrogen isotope paleo-proxy

BIeler Aaron L.1,2, SChIEbel Ralf7, MartINEZ-GARcIa Alfredo1, SMART Sandi M.3, ESmann Tobias1, HEINs Lena1, GayE BirGit2, WanIEK JoAnna J.4 and Haug Gerald H.4,5

1Max Plank Institute for Chemistry, Hahn-Meitner-Weg 1, Mainz, Germany; aaron.bieler@mpic.de; ralf.schiebel@mpic.de; a.martinez-garcia@mpic.de; t.essemann@mpic.de; lena.heins@mpic.de; gerald.haug@mpic.de
2Department of Geological Sciences, The University of Alabama, 7th Avenue 201, Tuscaloosa, USA; sandi.smart@alumni.uct.ac.za
3Institute of Geology, Hambourg University, Bundesstrasse 55, Hamburg, Germany; birgit.gaye@uni-hamburg.de
4Leibniz Institute for Baltic Sea Research, Seestraße 15, Rostock, Germany; joanna.waniek@io-warnemuende.de
5Department of Earth Sciences, ETH Zurich, Sonneggstrasse 5, Zurich, Switzerland; gerald.haug@erdw.ethz.ch
*Corresponding author
Marine nitrogen (N) cycling is key to reconstructing ecosystems in past oceans and directly links to global climate feedbacks through the marine carbon pump and CO₂ sequestration. Information on marine ecosystems is encoded in the N isotopic composition (δ¹⁵N) of organic matter produced by organisms such as planktic foraminifers. A part of the organic matter is preserved within foraminifer tests, which makes fossil shell-bound δ¹⁵N a valuable tool to investigate past changes in surface ocean nitrogen cycling.

The interpretation of the planktic foraminifer shell-bound δ¹⁵N requires comprehensive knowledge about ecosystem parameters and processes relevant for the formation of this signal in living foraminifer biomass. To investigate the imprint of N cycling processes in different environments on δ¹⁵N of planktic foraminifer biomass, we collected planktic foraminifers, seawater, and organic particulates (particulate organic N, PON) from the water column in the northern South China Sea during late summer monsoon at locations from the shelf near the Pearl River Estuary to the open ocean. The δ¹⁵N of tissue from three different species, *Trilobatus sacculifer*, *Globigerinoides ruber albus*, and *Globigerinita glutinata* were analyzed from the surface to 80 m water depth in combination with the isotopic composition of nitrate and the δ¹⁵N of PON.

We find that the δ¹⁵N in planktic foraminifer tissue is distinctly lower (by ≥ 2 ‰) than the nitrate at thermocline depth at open ocean stations, which we interpret to be associated with ammonium recycling. In comparison, on the inner shelf and the shelf edge, the δ¹⁵N of the foraminifer tissue is higher and more variable than the open ocean stations. This implies that a complex interplay of smaller scale processes may be more relevant for shelf than open marine environments. Further, we show species-specific and depth-resolved δ¹⁵N signals, which are consistent with the different trophic niches and habitats of these species. The results allow to refine our understanding of the connection between ecosystem parameters and δ¹⁵N in foraminifer biomass and provide a foundation for accessing traces of past N cycling contained in the sedimentary planktic foraminifer record in this region and beyond.

Microbiome analysis of Baffin Bay *Neogloboquadrina pachyderma* reveals the first evidence for kleptoplasty in planktonic foraminifera

**BIRD Clare**¹, **DARLING Kate**¹,², **THIENSEN Rabecca**³ and **PIEŃKOWSKI Anna**⁴,⁵

¹Biological and Environmental Sciences, Cottrell Building, University of Stirling, Stirling, FK9 4LA, UK; clare.bird2@stir.ac.uk
²School of Geosciences, Grant Institute, James Hutton Road, King’s Buildings, University of Edinburgh, Edinburgh, EH9 3FE, UK; kate.darling@ed.ac.uk
³Department of Physical Sciences, MacEwan University, 10700 104th Ave NW, Edmonton, AB, Canada, T5J 4S2; rabeccathiessen@gmail.com
⁴Institute of Geology, Adam Mickiewicz University, Bogumila Krygowskiego 10, 61-680 Poznań, Poland; anna.pienkowski@amu.edu.pl
⁵Department of Arctic Geology, UNIS (University Centre in Svalbard), P.O. Box 156 N-9171 Longyearbyen, Svalbard, Norway; anna.pienkowski@amu.edu.pl

*Corresponding author

*Neogloboquadrina pachyderma* is the only true polar species of planktonic foraminifera. It therefore plays a crucial role in the calcite flux, and in reconstructions and modelling of seasonality and environmental change within the high latitudes. The rapidly changing environment of the (sub)polar regions of the North Atlantic and Arctic Oceans poses survival challenges for this species in terms of temperature, sea ice melt, calcite saturation and ocean pH, and competition from Atlantic species. To model the potential future for this important high latitude species, it is vital to investigate the modern ocean community structure throughout the annual cycle of the Arctic to understand the inter-dependencies of *N. pachyderma*. We use 16S rDNA metabarcoding and transmission electron microscopy (TEM) to identify the microbial interactions of *N. pachyderma* during the summer ice-free conditions in Baffin Bay. We demonstrate that the *N. pachyderma* diet consists of bacteria and diatoms. The core microbiome is defined as the 16S rDNA amplicon sequencing variants (ASVs) found in 80% of individuals investigated. This core microbiome consists of two diatom ASVs and seven bacterial ASVs and accounts for, on average, 50% of the total ASVs in any individual. The bacterial ASVs represent hydrocarbon degrading bacteria, and those found routinely in the diatom phycosphere. On average the two chloroplast ASVs compose 40% of the core microbiome. However, significantly, on average 55.7% of all ASVs in any individual are of chloroplast origin. TEM highlights the importance of diatoms to this species, by revealing that chloroplasts are sequestered in the foraminiferal cytoplasm in large numbers, indicating potential kleptoplasty. Whilst some species of benthic foraminifera are known to be kleptoplast, utilising diatom chloroplasts in this way, this adaptation has never been observed in planktonic foraminifera. However, the close association between *N. pachyderma* and diatoms in the pelagic Arctic realm provide an ideal opportunity for kleptoplasty to develop, where diatoms are a significant component of the phytoplankton population. Such an adaptation is likely to confer advantage to this species but could become an Achilles heel if the diatom species utilised are restricted to a small pool of species, that become impacted by climate change.
Benthic Foraminiferal Faunal Response to The Middle Miocene Climatic Transition From Greenhouse to Icehouse Conditions Along Central California, USA

BLAKE Gregg H. 1*

1Blake Geological Services LLC, 481 Chimney Cove Dr., Marble Falls, TX, 78654 USA; Ghblake51@gmail.com
*Corresponding author

The Monterey Formation, consisting of siliceous and calcareous biogenic sediments, was deposited during the transition from a relatively warm greenhouse climate in the early Miocene to the cooler temperatures of icehouse climatic conditions during the early middle to late Miocene. This cooling event is associated with global paleoclimatic and oceanic changes assumed to be related to the deposition of organic carbon-rich sediments into the marginal basins of California.

The distribution of benthic foraminiferal assemblages found in the middle to late Miocene benthic foraminiferal faunas was controlled by both local tectonic, environmental, and depositional events and global variations associated with the climatic transition from greenhouse to icehouse conditions, including changes in water mass stratification, changes in productivity, and eustatic cycles.

The local and regional environmental parameters changed in space and time related to the Neogene evolution of the continental margin basins along central and southern California. Comparing faunal distributions across the continental margin benthic foraminiferal assemblages occurring in the outer and inner margin basins will establish the possible relationship between climatic-controlled oceanic events and faunal responses.

At the end of the Middle Miocene Climatic Transition (MMCT) in the mid-Serravalian (~ 13.1 Ma), there is a distinctive faunal change in the benthic foraminiferal assemblages readily recognized by a change in several species and genera common in the MMCT and have their highest stratigraphic occurrence immediately below the contact between a change in sedimentation between an older calcareous clay-dominated section to siliceous-dominated deposition in the Monterey Formation. This faunal turnover is related to the climatic and oceanographic changes associated with the onset and further expansion of the East Antarctic Ice Sheet.

Middle Miocene Foraminifera of the Ross Sea Continental Shelf, IODP Exp. 374

BOMBARD Samantha1*, LECKIE R. Mark1,2 and IODP Exp. 374 Science Party2

1Department of Earth, Geographic, and Climate Sciences, University of Massachusetts Amherst, 627 North Pleasant St., Amherst, MA 01003, USA; smecomb@umass.edu; leckie@umass.edu
2International Ocean Discovery Program, Texas A&M University, 1000 Discovery Drive, College Station, TX 77845, USA; leckie@umass.edu
*Corresponding author

The Miocene paleoclimatic record of the Ross Sea can provide crucial insight into the Antarctic ocean-cryosphere system. The Miocene Climate Optimum (MCO, ~16.9-14.7 Ma) was a global warming event with atmospheric CO₂ concentrations higher than today, followed by the Middle Miocene Climate Transition (MMCT, ~14.7-13.8 Ma) marking the shift to colder conditions and major growth of the East Antarctic Ice Sheet. The MCO and MMCT would have had a profound impact on the ice sheet dynamics, continental shelf evolution (i.e., progradation), water mass behavior, and productivity in the Ross Sea. One way to determine the degree of impact on the Ross Sea system is by examining the foraminifera from the continental shelf. Here we investigated the early to middle Miocene foraminiferal assemblages from IODP Site U1521 located on the central Ross Sea continental shelf to: 1) identify distinct benthic biofacies; 2) constrain the timing of the continental shelf evolution; and 3) compare the recorded assemblages with other Ross Sea Paleogene and Neogene drill sites.

The preliminary late early Miocene to middle Miocene foraminiferal assemblages from Site U1521 are variable in composition and abundance, shifting between and within lithologic units. Lithologic unit IV is a sandy diamict (upper-lower Miocene, MCO) containing a diverse assemblage including high abundances of *Uvigerina*, *Globocassidulina*, and *Melonis*, as well as rare *Antarcticella antarctica*. We infer high continuous percentages of *Uvigerina*, found in unit IV, can be used as a tracer for the continental shelf edge suggesting that the continental shelf prograded northward during the early Miocene. Unit III is a diatom bearing/rich mudstone (lower middle Miocene, MCO) has a low and variable foraminiferal recovery with only ~30% of the examined samples containing foraminifera. We suggest the low recovery may be due to dissolution associated with open water and high productivity. The transition into unit II, a muddy diamict (middle Miocene, MMCT), records an increase in foraminiferal preservation with *Globocassidulina* and *Elphidium* as the dominant genera. This may represent a sub-ice shelf assemblage. High abundances of these two genera suggest the presence of modified Circumpolar Deep Water (*Globocassidulina*) on a shallower, prograded (*Elphidium*) continental shelf. In addition to assemblage differences between lithologic units, muddy intervals inferred by high gamma ray values contain more foraminifera than intervals rich in biogenic silica (low gamma ray values) where foraminifera are typically rare to absent.
Pleistocene Foraminifera of the Ross Sea Continental Slope and Rise, IODP Exp. 374

BOMBARD Samantha1*, LECKIE R. Mark2* and IODP Exp. 374 Science Party2

1Department of Earth, Geographic, and Climate Sciences, University of Massachusetts Amherst, 627 North Pleasant St., Amherst, MA 01003, USA; smecomb@umass.edu; leckie@umass.edu
2International Ocean Discovery Program, Texas A&M University, 1000 Discovery Drive, College Station, TX 77845, USA; leckie@umass.edu
*Corresponding author

The Ross Sea continental margin provides a dynamic setting for studying the ocean-climate history of Antarctica. Multiple processes along the slope and rise potentially influenced the abundance and diversity of foraminiferal assemblages, including depositional modes, current activity, sea ice coverage, productivity, and changes in water masses. Here we investigated the Pleistocene foraminifera from IODP Sites U1525 and U1524 to learn more about the glacial-interglacial depositional and oceanographic processes along the continental margin. We were interested in determining: 1) what controlled foraminiferal presence and absence during the Pleistocene; 2) when foraminifera are present, what can they tell us about the environmental conditions along the eastern Ross Sea continental margin; 3) if the benthic assemblages defined by previous Ross Sea studies can be recognized at these deeper continental margin sites, and 4) whether specific benthic foraminiferal biofacies are useful tracers of discrete water masses. Foraminifera from Holes U1525A and U1524A are uncommon. Rare occurrences of subpolar and temperate planktic species (Neogloboquadrina inompta, Globigerina bulloides, Globigerina falconensis, Turborotalita quinqueloba, and Globococcolina inflata), suggest periods of open marine, high productivity, and possible incursions of the warmer Ross Sea Gyre into the Ross Sea. Peaks in benthic foraminifera (at least 20 specimens), observed in only 10 samples, were used to define four benthic biofacies; Globocassidulinida, Globocassidulinida-Eponides, Epistominella, and Miliammina. The Miliammina biofacies represents open marine conditions, high productivity, and High Salinity Shelf Water (HSSW) exported off the continental shelf via the Hillary Canyon. The Epistominella biofacies, the only biofacies recognized at both sites, indicates less sea ice and open marine conditions in response to the spring bloom of phytoplankton. The Globocassidulinida biofacies suggests possible incursions of Circumpolar Deep Water (CDW) into the Ross Sea. The Globocassidulinida-Eponides biofacies suggests high productivity associated with the spring bloom of phytoplankton in addition to the influence of CDW. Together, these biofacies illustrate the dynamic interplay between deposition, climate, water masses, and the Antarctic ice sheet during the Pleistocene.

Living and dead Foraminiferal as the basis for environmental diagnosis in a mesotidal tropical estuary: Cachoeira River Estuary, Bahia-Brazil

BOMFIM Isabel1*, CAMARA Gabriel1, COUTO Erminda C.G.2, BONETTI Carla1, SOUZA Silvia Helena M.3, MARTINS Maria Virginia A.4, SEMENASATO Jr. Décio L.5*, DISARO Sibelle T.6, BELART Pierre1, PEREIRA Kettollen1, DIAS Andriu1, CARELLI Thiago1 and LAUT Lazaro1

1Laboratório de Micropaleontologia – LABMICRO, Departamento de Ciências Naturais, Instituto de Biotecnologias; Universidade Federal do Estado do Rio de Janeiro – UNIRIO. Av. Pasteur, 458, IBIO/CCET, Ueuc, CEP 22.240-490, Rio de Janeiro, Rio de Janeiro, Brazil; isabela.garcia@edu.unirio.br; gabriel.kauaicamara@gmail.com; phelart@gmail.com; kettollen@gmail.com; andriu.dias@edu.unirio.br; tgearelli@gmail.com; lazaro.laut@gmail.com
2Institute of Geosciences, Federal University of São Carlos – UFSC, Trindade Campus, Florianópolis, SC – Brazil; carla.bonetti@ufsc.br
3Institute of Oceanographic, University of São Paulo – USP, Oceanographic Square, 191, University City, São Paulo, SP – Brazil; smsousa@usp.br
4Department of Geology, University of the of State of Rio de Janeiro – UERJ, Av. São Francisco Xavier, 524, sala 2020A Maracanã – Rio de Janeiro, RJ – Brazil; virginia.martins@iu.pt
5Laboratory of Micropaleontology, Federal University of Parana – UFPR, Av. Beira Mar s/n’- Pontal do Parana, PR – Brazil; stdisaro@ufpr.br
*Corresponding author

The Cachoeira River Estuary is the largest in southern Bahia (Brazil) and hosts a rich biodiversity, including extensive mangrove areas. However, the region has a well-known history of environmental impacts from industrial, urban, and rural (cocoa cultivation) sources that have affected the ecosystem’s health and made it one of the most vulnerable in the country. Under this scenario, identifying and mapping impacted areas are extremely important to support future environmental monitoring plans. Thus, aiming to contribute to the scientific knowledge in the region, this study applied the benthic foraminifera fauna (bio- and taphocenosis), supported by sedimentological and physicochemical parameters as a tool for ecological and hydrodynamic characterization to establish a database that can be used in environmental management and biomonitoring of Cachoeira River Estuary. The sediment sampling was carried out in November 2016, with an Ekman Grab, in triplicates, in 30 pre-established stations scattered from the river mouth to the innermost part of the estuary. The physicochemical parameters were measured using a portable probe at the water-sediment interface. As a result, 80 species of benthic foraminifera were identified, of which 57 taphocenosis species in the (D – 9 agglutinated and 48 calcareous) and 49 in the biocenosis (L - 19 agglutinated and 30 calcareous). The Detrended Correspondence Analysis pointed out that the
distribution of L species is related to sanity, alkaline pH, and total dissolved solids (Quinqueloculina spp., Textularia spp., Miliolinella subrotunda, Bulimina elegansissima, Nonionella auris, and Pseudononion japonicum) as well as chlorophyll and turbidity (Elphidium excavatum, Ammonia parkinsoniana, Trochammina inflata, and Haynesina germanica). Dead species were positively correlated to organic matter (T. inflata, Paratrochammina closei, and Quinqueloculina seminulum) and salinity, turbidity, alkaline pH, and dissolved oxygen (P. japonicum, B. elegansissima, Fissurina agassizi, M. subrotunda, Quinqueloculina milletti, Bolivina transluens, and Rosalina bradyi) were the most important. The cluster analysis showed few similarities between the analysed assemblages, which may be related to the hydrodynamic conditions and seasonal environmental variations. At the same time, the high hydrodynamics is evidenced by the distribution of Assemblage A (B. elegansissima_D and N. auris_D), which corresponds to inner-shelf organisms transported throughout the entire estuary. The boundary of the inner estuary, pointed by Assemblage C (Discorbis peruvianus_L and D), occurs 5 km from the river mouth. A region with higher chlorophyll concentration and more turbid waters can be identified 10 km from the mouth and is marked by assemblages D (A. parkinoniana_L) and G (A. tepida_L), representing the region under the greatest influence of the waste from the sewage treatment plant and corresponds to the middle estuary. The disturbance caused by the treatment plant did not allow us to identify the middle estuary end boundary and the upper estuary beginning. The results allowed the identification of estuarine compartments and regions of higher organic matter accumulation. These data indicate foraminifera as a proxy for coastal environmental characterization and, possibly, biomonitoring tools.

Environmental changes in the Barents Sea over the last millennia: benthic foraminifera evidence

BORETO Gabriella1,2*, TESI Tommaso1, GUILERMIC Corentin3, DESSANDIER Pierre Antoine4, PANIERI Giuliana5 and CAPOTONDI Lucilla6

1Istituto di Scienze Polari, Consiglio Nazionale delle Ricerche ISP-CNR, Via P. Gobetti, 101 – 40129, Bologna, Italy; gabriella.boretto@isp.cnr.it; tommaso.tesi@cnr.it
2Joint Research Center - ENI-CNR Aldo Pontremoli, Via Monteroni s.n.c., Lecce, 73100, Italy; gabriella.boretto@isp.cnr.it
3Universidad d’Angers, Nantes Université, Le Mans Université, CNRS, Laboratoire de Planétologie et Géosciences, LPG UMR 6112, 49000 Angers, France; corentin.guilermic@etud.univ-angers.fr
4UMR BEEP Biologie et Ecologie des Ecosystèmes marins Profonds et du Laboratoire Environnement Profond, Ifremer - Centre Bretagne, France; Pierre.Antoine.Dessander@ifremer.fr
5Department of Geosciences, UiT The Arctic University of Norway, Dramsvegen 201, N-9037, Tromsø, Norway; giuliana.panieri@uit.no
6Istituto di Scienze Marine, Consiglio Nazionale delle Ricerche ISP-CNR, Via P. Gobetti, 101 – 40129, Bologna, Italy; lucilla.capotondi@bo.ismar.cnr.it
*Corresponding author

Characterising natural climate-environment variability is essential to evidence the recent anthropic impact and to simulate realistic projections. This is particularly relevant for the Barents Sea, a unique and highly sensitive shallow water polar ecosystem that is one of the world’s most productive. Over the last decades, this region experienced a warming of sea surface temperature (SST) related to the expansion of the warmer Atlantic Water (AW) into the area, a phenomenon commonly referred to as “Atlantification”. Moreover, the Arctic region stored in its sediment methane gas hydrates which are sensitive to climatic variations. These large gas reservoirs also depend on tectonic activity and climate change. In this regard, benthic foraminifera represent a handy proxy to reconstruct paleoecological and paleoenvironmental changes as their diversity and distribution are strongly related to environmental parameters. Here we combined foraminiferal data and stable isotope analyses to reconstruct the paleoenvironmental history in the Barents Sea over the last millennia. The study is based on sediment samples from the cores HH1141 and HH1118 (74.015533° N 21.071100° E, -285 m depth, and 74.081600° N 21.362300°E, -298 m depth, respectively), collected during the cruise CAGE 18-4 (on July-August 2018) on the R/V Helmer Hanssen. The distributional pattern of benthic microfauna commonly related to the AW water mass inflow (Trifarina angulosa, Melonis barleeanus, Epistominella nipponica, Buccella frigida, Nonionella labradorica, Adercotryma elegans, Buliminella elegantissima) as well as chlorophyll concentration and more turbid waters can be identified 10 km from the mouth and is marked by assemblages D (A. parkinoniana_L) and G (A. tepida_L), representing the region under the greatest influence of the waste from the sewage treatment plant and corresponds to the middle estuary. The disturbance caused by the treatment plant did not allow us to identify the middle estuary end boundary and the upper estuary beginning. The results allowed the identification of estuarine compartments and regions of higher organic matter accumulation. These data indicate foraminifera as a proxy for coastal environmental characterization and, possibly, biomonitoring tools.

Probing Melonis barleeanus agglutinating strategy: an experimental approach

BORRELLI Chiara1, LITTLE Emma1, SCHOLER Margaret1, JASAPARA Aditi1, NAGY Matthias2, HEINZ Petra2, BOWSER Samuel1 and PANIERI Giuliana4

1Department of Earth and Environmental Sciences, University of Rochester, 120 Trustee Road, Rochester, USA; cborrelli@ur.rochester.edu; elittle6@u.rochester.edu; mcscholer@u.rochester.edu; ajasapara@u.rochester.edu
2Department of Palaeontology, University of Vienna, Josef-Holubek-Platz 2, 1090 Vienna, Austria; matthias.nagy@univie.ac.at; petra.heinz@univie.ac.at
3School of Public Health, Environmental Health Sciences, University of Albany, 1400 Washington Avenue, Albany, USA; foramdude@hotmail.com

FORAMS 2023, June 26th–30th, 2023, Perugia, Italy – Abstract Book
Melonis barleeanus is a calcareous benthic foraminifer often used in paleoceanographic reconstructions. Recently, it was demonstrated that sedimentary particles were present within the test of this species making *M. barleeanus* a calcareous and agglutinated species. Interestingly, this is not an isolated case among calcareous foraminifera. Similar observations were made on other benthic foraminiferal genera, such as *Cibicides*, *Stomatoboria*, and *Uvigerina*, suggesting that an agglutinated strategy might be more common than initially thought among rotaliids.

This study aims to start tackling the unusual biomineralization strategy of *M. barleeanus* using an experimental approach. In particular, here we present the results of culturing experiments designed to investigate the selectivity of *M. barleeanus* towards sedimentary grain size and mineralogy. Sediments collected in the Barents Sea at ~1200 m depth were sieved at 63 µm and placed in two separate beakers. To one of these beakers, glass (quartz) beads ranging 0.5-11 µm were added to the sediment. The experiments were run in parallel for about five months under controlled pH, salinity, oxygen, and temperature conditions. Calcein was introduced in the experimental medium (i.e., artificial seawater) to help identify the calcite deposited by foraminifera while in culture. Dead *Phaeodactylum tricornutum* was used as the food source and added once a week.

For each experiment (with and without glass beads), ~100 specimens were isolated and analyzed. An epifluorescence microscope was used to identify those individuals that deposited one or more chambers during the experiments. Scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDS) were performed to investigate the presence of sedimentary particles within *M. barleeanus* tests and to collect qualitative chemical data on those grains. Our results showed that many of the specimens examined grew under controlled conditions and contained sedimentary particles within their tests. These results confirmed the previous finding that *M. barleeanus* is a calcareous and agglutinated foraminifer and shows a certain degree of selectivity towards the grains incorporated within the calcite frame of its test.

**Mid Oligocene climate and Antarctic ice-sheet instability: evidence from clumped-isotope thermometry**


Ice-volume reconstructions derived from deep-sea oxygen isotope records suggest large fluctuations in East Antarctic ice volume between 29 to 26 million years ago (Ma), in the mid Oligocene. According to these reconstructions, changes in ice-volume were primarily paced by 100-kyr eccentricity cycles. The largest fluctuations involved complete melting of a modern-sized East Antarctic ice-sheet, while smaller fluctuations suggest reduction to one third to one half of the peak volume attained during glacial intervals. Sea-level reconstructions support large variations in ice volume in the mid Oligocene, but such cyclical large-scale fluctuations are difficult to reconcile with our understanding of ice-sheet dynamics. Even when ice-sheet models are forced with large changes in atmospheric CO$_2$ (>700 ppm), a full melting of a modern-sized ice-sheet is not reached due to strong hysteresis.

A major limitation of oxygen isotope-based ice-volume reconstructions is that the oxygen isotope signal in calcite is also controlled by seawater temperature. To address the behaviour of the Antarctic ice-sheet, we measured clumped isotope ($\Delta^{47}$) temperatures on benthic foraminifera at ODP Site 699, in the Atlantic sector of the Southern Ocean, between 27.2 and 28.2 Ma at a 34 thousand year (kyr) resolution. Clumped isotope thermometry is independent from the oxygen isotope composition of seawater, hence the temperature component in the foraminiferal $\delta^{18}$O signal can be isolated. With our new record, we are able to track the 100 kyr-eccentricity cycles and test whether deep ocean temperature can explain the large fluctuations in $\delta^{18}$O observed in the mid Oligocene, which would eliminate the need for continental-scale waxing and waning of the East Antarctic ice-sheet.

**Late Neogene Evolution of modern deep-dwelling plankton**

**BOSCOLO-GALAZZO Flavia**, **JONES Amy**, **DUNKLEY JONES Tom**, **CRICHTON Katherine A.**, **WADE Bridget S.** and **PEARSON Paul N.**

1MARUM, University of Bremen, Leobener strasse 8, 28359 Bremen, Germany; fbosocolagalazzo@marum.de

*Corresponding author*
The fossil record of marine microplankton provides insights into the evolutionary drivers which led to the origin of modern deep-water plankton, one of the largest components of ocean biomass. We use global abundance and biogeographic data, combined with depth habitat reconstructions, to determine the environmental mechanisms behind speciation in planktonic foraminifera over the past 15 Myr. We also obtain similar data for calcareous nannofossils, another major component of ocean plankton. We compare our microfossil datasets with water column profiles simulated in an Earth system model. We show that deep-living planktonic foraminiferal (zooplankton) and calcareous nannofossil (mixotroph phytoplankton) species were virtually absent globally during the peak of the middle Miocene warmth. The evolution of deep-dwelling planktonic foraminifera started from subpolar–mid-latitude species, during late Miocene cooling, via allopatry. Deep dwelling species subsequently spread towards lower latitudes and further diversified via depth sympathy, establishing modern communities stratified hundreds of meters down the water column. Similarly, sub-euphotic zone specialist calcareous nannofossils become a major component of tropical and sub-tropical assemblages during the latest Miocene to early Pliocene. Our model simulations suggest that increased organic matter and oxygen availability for planktonic foraminifera, and increased nutrients and light penetration for nannoplankton, favoured the evolution of new deep-water niches. These conditions resulted from global cooling and the associated increase in the efficiency of the biological pump over the last 15 Myr.

Virgin or Aged does not matter: Microplastic leachates alter the behavior and the proteome of the kleptoplastidic foraminifera Haynesina germanica

BOUCHET Vincent M.P.1*, BERTILE Fabrice2,3, MULLER Leslie2,3, DELDICQ Noémie1, DEISS Alice1, TAILLIEZ Loïc1 and SEURONT Laurent1,4,5

1Univ. Lille, CNRS, ULCO, UMR8187, LOG, Laboratoire d’Océanologie et de Géosciences, Station Marine de Wimereux, F-59000 Lille, France; vincent.bouchet@univ-lille.fr; noemie.deldicq@outlook.fr; alice.deiss.rta@univ-lille.fr; loic59199@gmail.com; laurent.seuront@seuront.com
2Université de Strasbourg, CNRS, IPHC UMR 7178, 23 rue du Loess, 67037 Strasbourg Cedex 2, France; fbertile@unistra.fr; lmuller-schmitt@inoviem.com
3Infrastructure Nationale de Protéomique (ProFI) – FR2048, Strasbourg, France; fbertile@unistra.fr; lmuller-schmitt@inoviem.com
4Department of Marine Energy and Resource, Tokyo University of Marine Science and Technology, 4-5-7 Konan, Minato-ku, Tokyo, 108-8477, Japan; laurent.seuront@seuront.com
5Department of Zoology and Entomology, Rhodes University, Grahamstown, 6140, South Africa; laurent.seuront@seuront.com
*Corresponding author

Plastic pollution in marine environments was first reported in 1970, with concern growing until the mid-1980s. The 5 to 13 Mt of plastic dumped into the oceans each year is expected to grow to as much as 90 Mt/year by 2030 if nothing changes, due to the exponential growth in plastic production (from 1.5 Mt in 1950 to 368 Mt in 2019) and the mismanagement of plastic waste (in 2010, one third of the plastic waste (32 Mt) from 93% of the world’s population was considered to be mismanaged in 2010). Plastic debris are persistent in the environment and are dispersed over great distances by winds and ocean currents due to their intrinsic durability. They can then sink to the seafloor and are often buried in unvegetated and vegetated sediments in subtidal and intertidal coastal environments where they become a potential threat to biodiversity. Their toxicity comes from additives, i.e., primary leachates (e.g. plasticizers, flame retardants, UV stabilizers, antioxidants, and antistatic molecules) incorporated into plastic during the manufacturing process to modify the physical properties and durability of the polymers (hereafter called virgin plastics), but also from contaminants already present in seawater, i.e., secondary leachates (from another source of pollution) that are adsorbed onto the surface of the plastic debris when they are exposed to weathering processes (hereafter called aged plastics). Thus, benthic species in soft-bottom sediments face a new threat that may hinder their survival. In this work, we studied the kleptoplanktic benthic foraminifera Haynesina germanica, a key species in intertidal European mudflats. The effects of virgin and aged microplastics (MPs) leachates (at environmentally relevant concentrations) were evaluated at different levels. Firstly, at the behavioral level, the pseudopodial was significantly impaired in the presence of aged MPs leachates. Secondly, at the cellular level, significant alterations in the proteome of the foraminiferal individual and the stolen plastids were observed upon exposure to virgin and aged MPs leachates. This work confirms the potential hazard of plastic leachates to benthic foraminifera and the urgent need to address this issue for soft-bottom meio- and macro-benthic organisms.
Single cells ecosystem engineers: foraminiferal role in bioturbation processes

BOUCHET Vincent M.P.1, DELDICOQ Noémie1, LANGLET Dewi1,2, DENIS Lionel1, MERMILLOD-BLONDIN Florian1 and SEURONT Laurent1,4,5

1Univ.Lille, CNRS, UMR8187, LOG, Laboratoire d’Océanologie et de Géosciences, Station Marine de Wimereux, F-59000 Lille, France; vincent.bouchet@univ-lille.fr; noemie.deldicoq@outlook.fr; dewi.langlet@oist.jp; lionel.denis@univ-lille.fr; laurent.seuront@seuront.com
2Evolution, Cell Biology, & Symbiosis Unit, Okinawa Institute of Science and Technology, 1919-1 Tancha, Onna-son, Kunigami-gun, Okinawa, 904-0495, Japan; dewi.langlet@oist.jp
3Univ. Lyon, Université Claude Bernard Lyon 1, CNRS, ENTPE, UMR 5023 LEHNA, Laboratoire d’Ecologie des Hydrologies Naturelles et Anthropisés, F-69622, Villeurbanne, France; Florian.mermillod-blondin@univ-lyon1.fr
4Department of Marine Energy and Resource, Tokyo University of Marine Science and Technology, 4-5-7 Konan, Minato-ku, Tokyo, 108-8477, Japan; laurent.seuront@seuront.com
5Department of Zoology and Entomology, Rhodes University, Grahamstown, 6140, South Africa; laurent.seuront@seuront.com

*Corresponding author

The role of benthic foraminifera in the benthic ecosystem functioning, and the associated functional diversity is an untapped question. The movement ability of intertidal foraminifera suggests that they may have a role, yet to be quantified, in benthic-pelagic coupling through their movement on the sediment surface, at the sediment-water interface and within the sediment. Based on the literature, we hypothesized that foraminiferal vertical movements may (i) have major impacts on the stability and erodibility of the surficial sediment layer, (ii) produce a substantial downward transport of particles and (iii) enhance fluxes of dissolved oxygen and solutes at the sediment-water interface.

Our laboratory experiments over the last years, investigating the behavioral traits of 5 benthic foraminiferal species typical of European temperate mudflats (Ammonia tepida, Haynesina germanica, Quinqueloculina seminulum, Miliammina fusca and Cribroelphidium williamsoni), revealed an unexpected functional diversity in benthic foraminifera. Specifically, C. williamsoni belongs to the epifaunal-biodiffusers, A. tepida belongs to the surficial-biodiffusers, and H. germanica, Q. seminulum and M. fusca are considered gallery-biodiffusers. The classification of benthic foraminifera in these functional groups implies that they would contribute differently to benthic-ecosystem functioning. For instance, although C. williamsoni is larger than H. germanica and that both species displayed similar travelled distance, the latest was more efficient to rework the surface sediment.

In details, the specific experiment conducted with H. germanica showed that its infaunal behaviour leads to the creation of one-end tube within the first centimetre of sediment. In addition, a vertical trail following behaviour was described for the first time in foraminifera, which may be linked to the sustainability of the biogenic sedimentary structures. Therefore, H. germanica produces a vertical transport of both mud and fine sediment fractions. Furthermore, the potential link between the intensity of sediment reworking and the functional group of a species is not straightforward; suggesting we are still at the very early beginning in our understanding of bioturbation processes in benthic foraminifera. Noticeably, we also observed that features like velocity, activity, tortuosity, and density may mediate sediment-mixing intensity.

We also showed that foraminifera motion-behaviour increased the oxygen penetration depth and decreased the total organic content. Their activity in the top 5 mm of the sediment affected the prokaryotic community structure. Indeed, in bioturbated sediment, bacterial richness was reduced and sulfate reducing taxa abundance in deeper layers was also reduced, probably inhibited by the enhanced oxygen penetration depth. Since they can affect both particulate and dissolved fluxes, foraminifera should be considered as bioturbators. They are further able to mediate the prokaryotic community, suggesting that they play a major role in the benthic ecosystem functioning and may be the first described single-celled eukaryotic ecosystem engineers.

Unlocking the paleoceanographic archives of the Humboldt Current System through the foraminiferal record: A case study from the Bahía Inglesa Formation, northern-central Chile

BOUHDAYAD Fatima1*, FREIRE Tiago1, AUER Gerald2, CARBALLEIRA Rafael1, HERWARTZ Daniel1, SCHEIDT Stephanie1, LEICHER Niklas1, WENNRICHL Volker1, ALBERT Richard1, GERDES Axel1, PETERSEN Jassin1, NIENSEN Sven1, RIVADEIRENA Marcelo1 and GRUNERT Patrick1

1Institute of Geology and Mineralogy, University of Cologne University of Cologne, Otto-Fischer-Str. 14, 50674 Cologne, Germany; bouhdayad.fatima@uni-koeln.de; tiagomefreire@gmail.com; d.herwartz@uni-koeln.de; stephanie.scheidt@uni-koeln.de; n.leicher@uni-koeln.de; vwenrich@uni-koeln.de; jassin.petersen@uni-koeln.de; pgrunert@uni-koeln.de
2Institute of Earth Sciences, University of Graz, Universitätsplatz 2/2. Stock 8010 Graz, Austria; gerald.auer@uni-graz.at
3Cavanilles Institute of Biodiversity and Evolutionary Biology, University of Valencia, Calle Catedrático José Beltrán Martínez, n2 46980 Paterna, Valencia, Spain; raf.carballeira@gmail.com
4Institute of Geoscience, University of Frankfurt, Altenhöferallee 1, 60438 Frankfurt am Main, Germany; RichardAlbert@fierce.uni-frankfurt.de; gerdes@em.uni-frankfurt.de
5Instituto de Ciencias de la Tierra, Universidad Austral de Chile, Avenida Eduardo Morales Miranda, Campus Isla Teja, Edificio Emilio Pugio, 5090000 Valdivia, Chile; sven.nielsen@uach.cl
6El Centro de Estudios Avanzados en Zonas Áridas (CEAZA), Avenida Ossandon 877, Región de Coquimbo, Chile; marcelo.rivadeirena@ceaza.cl

*Corresponding author
The Atacama Desert has experienced long periods of hyperarid conditions which possibly date back to the early Miocene. Reduced landward moisture flux due to the northward transport and upwelling of cold waters by the Humboldt Current System (HCS) has been identified as one of the main drivers of hyperaridity in today’s Atacama Desert. However, the evolution of paleoclimatic variability and the paleoceanographic conditions are poorly constrained. The microfossil content of marine sediments exposed along the Chilean coastline provide a unique palaeoceanographic archive of the HCS that allows us to study drivers of paleoclimate in the Atacama Desert during the Neogene.

Miocene to Pliocene marine deposits in Chile 26°45'-28°S are summarized as Bahía Inglesa Formation. These sediments, in particular thick successions of diatomaceous mud, potentially allow the characterization of Neogene HCS properties at orbital-scale resolution. However, the depositional age of the Bahía Inglesa Formation is not sufficiently well constrained, and quantitative studies on the microfossil content are missing. Here we present a refined integrated stratigraphic framework for the Bahía Inglesa Formation at Quebrada Tíburón (27°S) and a preliminary palaeoceanographic assessment based on planktic and benthic foraminifera.

The marine sediments exposed at Quebrada Tíburón are composed of ac. 9m-thick succession of laminated diatomaceous muds with intercalated sandy deposits. Preliminary results from bio- (planktonic foraminifera, calcareous nannoplankton, diatoms), chemo- ($\delta^{18}O$ of benthic foraminifera, Sr isotopes), tephro- and magnetostratigraphy suggest a late Tortonian age of c. 8.7 Ma for the initial transgression and a late Messinian (< 6 Ma) to early Pliocene (> 3.6 Ma) age for the intermittent emplacement of the diatomaceous muds.

Benthic foraminiferal assemblages and test morphology reveal a shift from trochospiral and planospiral (predominantly epifaunal) to serial (infaunal) morphotypes between sands and diatomaceous muds, respectively. Together with plankton assemblages dominated by diatoms and the planktonic foraminifera *Globigerina bulloides* and *Neogloboquadrina pachyderma*; the diatomaceous muds reflect a highly productive coastal upwelling regime and low oxic, eutrophic conditions at the seafloor. However, occasional layers of bioturbation within the diatomaceous succession also imply phases of relaxed upwelling conditions. In the next step, the quantitative assessment of planktic and benthic foraminiferal assemblages and shell geochemistry will allow a more detailed characterization of sea surface temperatures and bottom water oxygenation. These integrated results will highlight the significant changes in the Neogene palaeoceanographic properties of the upwelling system which will allow us to better understand the variability of the prevailing hyperaridity in this area and to relate it to the long-term climatic forcing, which may have been experienced, and which is thought to concomitantly control marine deposition.

This study contributes to CRC 1211 “Earth-Evolution at the dry limit”, funded by the Deutsche Forschungsgemeinschaft (DFG).

**Rhizarian stercomata: Experimental notes on their potential for fossilization**

**BOWSER Samuel**1,2*, BERNHARD Joan3, LANDING Ed4, ANDREAS Amanda1,2, PATRUCCO REYES Sandra1 and WALKER Sally5

1Wadsworth Center, New York State Department of Health, P.O. Box 509, Albany, New York, USA; samuel.s.bowser@gmail.com; amanda.andreas@gmail.com; spatrucco21@gmail.com
2Department of Environmental Health Sciences, University at Albany School of Public Health, 1 University Place, Rensselaer, New York, USA; samuel.s.bowser@gmail.com; amanda.andreas@gmail.com
3Geology and Geophysics Department, 266 Woods Hole Road, MS 52, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, USA; jbernhard@whoi.edu
4New York State Museum, 222 Madison Avenue, Albany, New York 12230 USA; ed.landing@nysed.gov
5Department of Geology, University of Georgia, Athens, Georgia USA; swalker@gly.uga.edu

*Corresponding author

Stercomata are micrometer-scale, intra-test agglomerations of fine particulate waste. They are typically composed of mineral grains, clay particles, and fragments of biogenic materials (diatom frustules, sponge spicules, invertebrate body parts). Stercomata are cytoplasmic and/or extracellular features of all *Gromia* spp. studied to date, as well as certain benthic Foraminifera (e.g., *Bathysiphon* spp.), especially the Xenophyophorea and Komokiacea. The function(s) of stercomata are poorly understood; possibilities include buoyancy control and the reduction of food value to predators.

We report here the results of experiments designed to test the resistance of stercomata to agents known to solubilize cytoplasm or disaggregate shale. The source of stercomata resulted from a happy accident: Twenty-five years ago, a laboratory environmental room failed and warmed to room temperature for one week, resulting in the death of ~1,000 specimens of cold-adapted *Gromia* sp. collected from McMurdo Station, Antarctica. Since that time, stercomata sourced from the decayed gromiid remains have been stored refrigerated in 120ml polystyrene tubes. Despite long-term storage in oxygenated, bacterized seawater, these stercomata retain all the structural features of those seen in live specimens. The source of stercomata resulted from a happy accident: Twenty-five years ago, a laboratory environmental room failed and warmed to room temperature for one week, resulting in the death of ~1,000 specimens of cold-adapted *Gromia* sp. collected from McMurdo Station, Antarctica. Since that time, stercomata sourced from the decayed gromiid remains have been stored refrigerated in 120ml polystyrene tubes. Despite long-term storage in oxygenated, bacterized seawater, these stercomata retain all the structural features of those seen in live specimens. The parameters examined include ultrastructure, size and aspect ratio, and close association with refractile granules (xenosomes). We found that stercomata are resistant to disaggregation by sonication, overnight dissolution in 5% sodium hypochlorite, boiling in 5% hydrogen peroxide, and ashing for 24 hours at 500°C. Sonication in surfactant/detergent solutions (Triton X-100, NP-40, Quaternary O) also failed to disrupt stercomata. The only agent tested that disaggregated stercomata was
sodium dodecyl sulphate (SDS). These findings indicate that stercomata are highly refractory, and are likely to be useful markers for identifying microfossils of putative Rhizarian protists.

### Controls on B/Ca in Planktic Foraminifera

**BRANSON Oscar**1*, **HOLLAND Katherine**2 and **EGGINS Stephen**2

1Department of Earth Sciences, University of Cambridge, Downing Street, Cambridge CB2 3EQ, UK; ob266@cam.ac.uk
2Research School of Earth Sciences, Building 142, Mills Road, Acton, ACT 2601, Australia; Stephen.Eggins@anu.edu.au
*Corresponding author

The B/Ca ratio of foraminifera shells has been developed as a proxy for past ocean carbon chemistry. However, despite numerous culturing studies investigating this proxy system, there is little consensus as to which physical or chemical environmental parameter exerts the strongest control on foraminifera B/Ca, particularly in planktic species. Suggestions include dependencies on B(OH)2/HCO3, CO32-, pH, light intensity, shell size/mass, phosphate concentration, seawater saturation state and temperature. If B/Ca is to be used as a seawater carbonate proxy, it is vital to identify the primary controls on B/Ca in foraminifera.

We present B/Ca data from a comprehensive culturing study of *Orbulina universa*, grown under conditions where DIC, pH, CO32-, temperature, [Mg] and [Ca] are independently varied. Within this broad matrix of conditions, we show that *O. universa* B/Ca is most strongly correlated with seawater B(OH)2/(CO32-)0.5. This variable alone predicts 96% of the variance in the data and including additional experimental variables offered no improvement in the ability to predict B/Ca. B(OH)2/(CO32-)0.5 alone is sufficient to predict B/Ca across a wide range of temperature and seawater chemistry conditions. Our ability to identify this as the main predictor of B/Ca is made possible by the wide range of conditions and decoupled of seawater carbonate chemistry considered in these experiments, which allow us to exclude proposed dependencies on other aspects of carbon chemistry, temperature, [Mg] and [Ca].

We further assess whether this relationship is also able to explain trends in previously published culture and core-top data. We find that B(OH)2/(CO32-)0.5 is the best predictor of B/Ca in all studies of cultured planktic foraminifera to date, but that the relationship is less clear core-top data. This is likely attributable to the variability in additional environmental factors (light intensity, shell size/mass, phosphate concentration) that were not varied in culture studies.

### Mn/Ca as a potential recorder for bottom-water oxygenation

**BRINKMANN Inda**1,2, **BARRAS Christine**3, **JILBERT Tom**4, **PAUL K. Mareike**4, **SOMOGYI Andrea**3, **NI Sha**5,6, **SCHWEIZER Magali**3, **BERNHARD Joan M.**7 and **FILIPSSON Helena L.**1*

1Department of Geology, Sölvegatan 12, Lund University, 223 62 Lund, Sweden; inda.brinkmann@geol.lu.se; sha.ni@geol.lu.se; Helena.filipsson@geol.lu.se
2current address: Department of Glaciology and Climate, Geological Survey of Denmark and Greenland, Øster Voldgade 10, 1350 Copenhagen Denmark; inda.brinkmann@geol.lu.se
3Université d’Angers, Nantes Université, Le Mans Université, CNRS, Lab. de Planétologie et Géosciences, LPG UMR 6112, 49000 Angers, France; christine.barras@univ-angers.fr; magali.swiezer@univ-angers.fr
4Department of Geosciences and Geography, University of Helsinki, Helsinki, Finland; tom.jilbert@helsinki.fi; mareike.paul@helsinki.fi
5Nanoscopium Synchrotron SOLEIL Saint-Aubin, 91192 Gif-sur-Yvette Cedex, France; andrea.somogyi@synchrotron-soleil.fr
6current address: Institute for Geology, University of Hamburg, Germany; sha.ni@geol.lu.se
7Department of Geology and Geophysics, Woods Hole Oceanographic Institution, Woods Hole, MA, USA; jbernhard@whoi.edu
*Corresponding author

Deoxygenation is currently one of the most significant environmental challenges facing marine ecosystems. This issue is primarily caused by warming, increased water stratification, and higher biological oxygen demand, with future warming likely to exacerbate the problem, particularly in temperate and subpolar regions. In addition, human-induced eutrophication, increased freshwater input, and hydrographic changes in coastal zones also contribute to declining dissolved oxygen concentrations, resulting in the expansion of hypoxia. As a result, there is a pressing need for a framework to understand the severity and potential outcomes of these changes and to develop evidence-based strategies for managing the environment. This framework can be derived from paleoenvironmental records during periods when comparable events happened in the past, but to develop this context there is a pressing need to expand and further advance proxies for bottom-water oxygenation to accurately reconstruct past [O2] in marine settings. However, it is challenging to obtain accurate quantitative proxies for [O2], and efforts are ongoing to improve and expand such proxies. One potential approach involves using manganese-to-calcium ratios (Mn/Ca) in biogenic calcium carbonates such as benthic foraminifera tests to determine bottom-water oxygenation conditions.

To explore the feasibility of this approach, we analyzed the Mn/Ca ratios of two living benthic foraminifera species (*Bulimina marginata* and *Nonionellina labradorica*) in Gullmar Fjord, Swedish west coast, which offers a range of
oxygenation conditions. Our data suggest that *Bulimina marginata* has the potential to be a useful proxy for low-oxygen conditions, while *Nonionella labradorica* was found to be less sensitive to environmental variability. We also used synchrotron-based scanning X-ray fluorescence (XRF) nanoinaging to explore Mn distribution across *B. marginata* tests, revealing Mn/Ca shifts by chambers that reflect bottom-water oxygenation history and/or ontogeny-driven life strategy preferences. We further investigate the potential biologically controlled mechanisms that could explain the species-specific response observed in this study.

Overall, our findings suggest that selecting sensitive candidate species can help to further develop the Mn/Ca proxy for quantitative oxygen reconstructions in the low-oxygen range, which is critical for understanding the past and present state of marine ecosystems.

**Studying morphological variation across space and through time using existing museum collections**

BROMBACHER Anieke¹, BUTTS Susan², CHENG Evan¹ and HULL Pincelli³

¹Department of Earth and Planetary Sciences, Yale University, 210 Whitney Avenue, New Haven CT-06511, USA; Anieke.Brombacher@yale.edu; evan.cheng@yale.edu; pincelli.hull@yale.edu
²Division of Invertebrate Paleontology, Yale Peabody Museum, 170 Whitney Avenue, New Haven CT-06511, USA; susan.botts@yale.edu
³*Corresponding author

Museum collections provide unique opportunities to generate large, global datasets. This is particularly valuable for planktonic foraminifera, where sample collection and identifying and picking of specimens is a time-consuming process that limits the size of a dataset that can be generated by individual researchers. Here, we present the first results of a new project that will digitise the planktonic foraminifera collection housed at the Yale Peabody Museum. This collection contains picked assemblage slides from hundreds of core-top samples from all over the world. Slides are imaged at high resolution and made publicly available for morphological analysis. We showcase the first results of variation within and among species around the world and highlight opportunities for future research.

**Environmental drivers of developmental plasticity distinguished from genetic change in the fossil record**

BROMBACHER Anieke¹², SEARLE-BARNES Alex¹, MULQUEENEY James¹, STANDISH Chris¹, WATSON Richard³, WILSON Paul¹, FOSTER Gavin¹ and EZARD Thomas¹

¹Institute for Life Sciences, University of Southampton, Highfield Campus, Southampton SO17 1BI, UK; Anieke.Brombacher@yale.edu; C.J.A.Searle-Barnes@soton.ac.uk; J.M.Mulqueeney@soton.ac.uk; c.d.standish@soton.ac.uk; paul.wilson@noc.soton.ac.uk; Gavin.Foster@noc.soton.ac.uk; t.ezard@soton.ac.uk
²Department of Earth and Planetary Sciences, Yale University, 210 Whitney Avenue, New Haven CT-06511, USA; Anieke.Brombacher@yale.edu
³Division of Invertebrate Paleontology, Yale Peabody Museum, 170 Whitney Avenue, New Haven CT-06511, USA; susan.botts@yale.edu

*Corresponding author

The fossil record holds the most direct evidence of large-scale biodiversity change on Earth, but fundamental paleontological-gaps limit our ability to interrogate the processes involved. A particular issue concerns the role of environmentally induced phenotypic variation, which is ubiquitous in contemporary populations but typically undetected using traditional paleontological methods. Here we develop a novel method to reconstruct reaction norms in deep time by comparing multiple morphological and environmental measurements made on the same individual. We studied macroperforate planktonic foraminifera, which preserve their entire ontogeny in their fossil remains and record environmental conditions at the time of calcification. We developed high throughput x-ray micro-CT and Laser Ablation Inductively Coupled Plasma Mass Spectrometry protocols to reconstruct coupled morphological and environmental change records from the same specimens. Generalised additive mixed effect models show that growth rates are inversely correlated with calcification temperature, as reconstructed from Mg/Ca, across three sister species of the Pliocene *Menardella* genus, but reaction norms vary among species. By contrast, architectural traits such as shell trochospirality and the angle between subsequent developmental stages are driven by across-species developmental constraints not environmental variation. Our results show for the first time that studying developmental plasticity in deep time is feasible. Integrated data protocols shed new light on developmental plasticity in the fossil record and help establish a framework to better understand the mechanisms by which environmentally induced trait variation led to the generation and proliferation of life on Earth.
Multivariate analyses on benthic foraminiferal assemblages: Two case studies from the Late Cretaceous Western Interior Seaway

BRYANT Raquel1*, BELANGER Christina2 and MEEHAN Kim1

1Department of Earth and Environmental Sciences, Wesleyan University, 265 Church St, Middletown, CT, USA; rbryant@wesleyan.edu
2Department of Geology and Geophysics, Texas A&M University, 611 Ross St, College Station, TX, USA; christina.belanger@tamu.edu
*Corresponding author

The fossil record of benthic foraminifera is widely used to reconstruct environmental conditions across marine settings but studies limited to a single stratigraphic section often muddle the interplay between local, regional, and global drivers of environmental conditions. Moreover, they alone cannot lead to a better understanding of basin-wide dynamics or ecological trends, which are useful for untangling local and regional drivers of change. In contrast, multivariate analyses allow for sediment samples from various stratigraphic sections to be co-analyzed on a common scale, facilitating inter-basin comparisons.

Here we present two case studies from the Cretaceous Western Interior Seaway (WIS) that exemplify the utility of multivariate techniques for co-analyzing benthic foraminiferal assemblages across a single basin. To prepare each dataset, proportional abundance data was collected from previously published studies and taxonomically standardized. Then, species or genus concepts were summarized into taxonomically agnostic groups of morphotypes or guilds to test ecological coherence in the absence of taxonomic information. The datasets were subjected to multivariate techniques most appropriate for the proposed research objective. In the first case study, we employ Principle Components Analysis (PCO) to test for spatial patterns in the response to environmental change associated with late Cenomanian Oceanic Anoxic Event 2 (OAE2). We found that benthic forams were primarily affected by changes in the availability of oxygen and food at the seafloor, conditions driven by water mass change. This study underscores how local environmental changes overshadow the expression of global events. In the second case study, we use distance-based redundancy analysis (db-RDA), a constrained ordination, to test whether benthic foraminifer assemblages from Campanian to Maastrichtian seep environments are distinct.

This study showed that although seep environments draw their benthic foraminiferal faunas from the surrounding metacommunity, assemblages reflect the environmental conditions present at individual seeps. This study also emphasizes the significance of local drivers in ecological signals. Importantly, both studies also show ecological coherence between the taxonomic, morphotype and guild-level analyses. This coherence suggests that morphotypes are a good substitution when species concepts might disagree or be poorly established due to preservation. The use of unconstrained (PCO) versus constrained (db-RDA) ordinations demonstrates how useful multivariate methods are for testing multiple hypotheses about what controls the distribution of benthic foraminifera. These case studies show that multivariate techniques are an important tool for leveraging the extensive and detailed fossil record of benthic foraminifera.

New Bajocian shallow-water agglutinated foraminifera from the basal D1 member of the Dhruma Formation west of Riyadh, Saudi Arabia

BU KHAMSIN Ali1 and KAMINSKI Michael2*

1Saudi Aramco, Geological Operation Department, Dhafran, 31311, Saudi Arabia; ali.bukhamsin@gmail.com
2Geoscience Department, College of Petroleum Engineering and Geoscience, King Fahd University of Petroleum & Minerals, PO Box 5070, Dhafran, 31261, Saudi Arabia; kaminski@kfupm.edu.sa
*Corresponding author

The Dhruma Formation is part of the middle Jurassic succession in Saudi Arabia. The formation is subdivided into seven members and assigned an age of Bajocian–Bathonian based on ammonites. This study concentrates on the agglutinated foraminifera from the basal member, the Balum (D1) Member of early Bajocian age (upper part of the Discites Zone to lower part of the Laeviuscula Zone). We previously reported a new Ammobaculoides species (Ammobaculoides dhrumaensis Kaminski, Malik and Setoyama, 2018) from the green shale of the D1. This study represents a continuation of this preliminary study concentrating on the smaller agglutinated foraminiferal assemblage of the basal Dhruma Formation.

For the purpose of this study, we sampled the basal part of the Dhruma Formation near Hafirat Nisah, southwest of Riyadh. At this locality the thickly bedded limestones of the overlying D2 member forms a prominent ridge that is visible from a distance. A total of 30 samples were collected bed-by-bed from the green shales and marls exposed in a small man-made excavation dug by local farmers. The entire stratigraphic sequence exposed at the locality was sampled up to the base of the D2 member. Samples from the basal shale subunit were disaggregated by gently boiling in water with a small amount of dishwashing liquid. Marly samples were disaggregated using the acetic acid method. Samples from the basal part of the exposure are clay-rich, and the majority of samples contain a rich benthic assemblage consisting of gastropods, echinoderm fragments, holothurian sclerites, and smaller benthic foraminifera.
The foraminiferal assemblage has been previously mentioned as the “smaller agglutinated fauna”. We describe nine new smaller agglutinated benthic foraminiferal species (Haplophragmoides sp. 1, Pseudobolivina? sp. 1, Trochammina sp. 1, Trochammina sp. 2, Gaudryinopsis sp. 1, Gaudryinopsis sp. 2, Gaudryinopsis sp. 3, Gaudryinopsis sp. 4, and Gaudryinopsis sp. 5) from the lowermost Balum (D1) Member of the Dhruma Formation. The assemblage at the studied locality is comprised of 70–80% of agglutinated species, while the remaining species mainly consist of calcareous nodosariids and polymorphinids. The newly reported species are well preserved and accounted for less than 5% of the assemblage.

The Middle Jurassic sediments of Saudi Arabia are renowned for the presence of endemic species of ammonites, foraminifera, gastropods, and echinoids. It therefore comes as no surprise that the basal unit of the Dhruma Formation also contains smaller agglutinated foraminifera that are new to science. The taxonomic composition of the whole assemblage will be the subject of future work.

**Attributes allowing for long species duration in benthic foraminifera**

BUZAS–STEPSHES Pamela1*, CULVER Stephen J.2, MARCHITTO, Thomas M. Jr.1 and BUZAS, Martin A.3

1Department of Geological Sciences, University of Colorado UCB 399, Boulder, Colorado USA; pamela.stephens@colorado.edu; thomas.marchitto@colorado.edu
2Department of Geological Sciences, East Carolina University, Graham 101, Greenville, North Carolina, USA; CULVERS@ecu.edu
3Department of Paleobiology, National Museum of Natural History, Smithsonian Institution, Washington, D.C., USA.

*Corresponding author

Benthic foraminifera have flourished throughout the Phanerozoic and are abundant today, ranging from barely brackish coastal waters to the deep-sea abyss. Their species durations can be relatively long, on the order of 40 my for deeper water species. In marine invertebrates with a fossil record, macroevolution has been effectively studied by looking at genus or species duration compared to factors such as abundance and geographic distribution. Not surprisingly, ecological versatility has also been recognized as a main contributor to longevity. But in the benthic foraminifera, it has been shown that neither
abundance, geographic range, nor frequency of occurrence have a significant positive relationship with duration, which is perplexing. Why do benthic foraminifera have such longevity; what makes them so successful through time? This paper reviews past work and provides some new data to address these questions. One overriding attribute ensuring survival of species is dispersal method. Living benthics can disperse through the use of resting propagules, and ensuing populations exhibit a log series distribution in space and time. The fossil record shows that dispersal is very rapid, and characteristic biogeographic and evolutionary patterns can be observed in shallow and deeper water communities. Another important attribute of benthic foraminifera promoting species survival is their ability to tolerate extreme and/or changing environmental conditions. For example, some living benthic species can prosper in oxic or anoxic environments, switching from aerobic to anaerobic respiration when needed. Shallow water forms may be abundant during vast changes in temperature and salinity, and some can easily tolerate pollutants. Even with high levels of heavy metals in their shells, as seen in new test analysis data presented herein, species can thrive.

Insights into Middle to Late Miocene conditions in the eastern Mediterranean region (Cyprus) from stable isotope and trace element analysis

CANNINGS Torin1*, KROON Dirk1, ROBERTSON Alastair1, JUNG Simon1, BARNET James2, RAE James2 and MARK Darren3

1School of GeoSciences, Grant Institute, University of Edinburgh, James Hutton Road, Edinburgh EH9 3FE, UK; torin.cannings@ed.ac.uk; Alastair.Robertson@ed.ac.uk; simon.jung@ed.ac.uk
2School of Earth and Environmental Science, University of St Andrews, St Andrews, KY16 9AL, UK; jdb24@st-andrews.ac.uk; jwbr@st-andrews.ac.uk
3Scottish Universities Environmental Research Centre, Rankine Avenue, Scottish Enterprise Technology Park, East Kilbride, G75 0QF, UK;
Darren.Mark@glasgow.ac.uk
*Corresponding author

Dynamic climate changes and regional tectonic convergence/collision were fundamental factors in the formation of the earth, ocean and climate systems during the Middle to Late Miocene. CO2-driven global warming of the Middle Miocene Climatic Optimum (MMCO) has been proposed as an analogue for future anthropogenic climate change. However, the nature and extent of both the MMCO and the subsequent Middle to Late Miocene cooling are poorly constrained in the eastern Mediterranean region. This region was affected by the closure of key ocean gateways to the Indian Ocean during the Middle Miocene and to the Atlantic Ocean during the Late Miocene. New planktic foraminiferal stable isotope and trace element/Ca records provide fresh insights into the evolution of sea surface temperature and ocean chemistry. Two main Middle-Upper Miocene sections in Cyprus (Kottaphi Hill and Lapatza Hill) were sampled at 5–25 cm resolution and correlated using calcareous nannofossil biostratigraphy and bulk rock stable isotope data, supported by field observations, x-ray diffraction and x-ray fluorescence data. Our new data reveal how both global climate changes and the local to regional effects of ocean gateway closures affected the eastern Mediterranean during this time interval. An improved understanding of Middle to Late Miocene conditions in the eastern Mediterranean highlights how ‘two-phase’ reef development in Cyprus was controlled by a complex interplay of climate, tectonic events and related sea-level changes. Our research further demonstrates how sampling of pelagic sediment outcrops, such as those on Cyprus, can yield effective geochemical records.

Benthic foraminiferal assemblages from the Lower Cretaceous of the Neuquén Basin, Argentina: paleoecological and paleoenvironmental constraints

CARATELLI Martina1,2* and ARCHUBY Fernando1,3

1CONICET, Consejo Nacional de Investigaciones Científicas y Técnicas, Argentina; mcaratelli@unrn.edu.ar; farkchuby@gmail.com
2Instituto de Investigación en Paleobiología y Geología (Universidad Nacional de Río Negro and CONICET). Avenida Roca 1242, 8332, General Roca, Río Negro, Argentina; mcaratelli@unrn.edu.ar
3Centro de Estudios Integrales de La Dinámica Exógena, Universidad Nacional de La Plata. Diagonal 113 Nro 469, 1900, La Plata, Buenos Aires, Argentina; farkchuby@gmail.com
*Corresponding author

The Agua de la Mula Member of the Agrio Formation (Neuquén Basin, Argentina) represents shallow marine environments and consists of high-frequency sedimentary sequences characterized by mixed siliciclastic-carbonate deposition. Five stratigraphic section encompassing the Agua de la Mula Member were analyzed across the Neuquén Basin, revealing differences between proximal and distal sectors. An integrated approach based on the benthic foraminiferal record (species composition, morphgroups, alpha diversity analysis, epifaunal/infaunal ratio) and multivariate statistical methods (cluster analysis, RDA, partial-RDA, PERMANOVA, PCoA), allowed to evaluate the paleosynecological and paleoenvironmental significance of the foraminifer fossil associations (FFAs) identified. Relative sea-level changes influenced variations in sedimentation rate, oxygenation and food availability, and are here considered as main controlling factors in the distribution of benthic FFAs. A total of 7,709 specimens of benthic foraminifera were identified, distributed into 52 species in 31 genera, 15 families and 5 suborders. Calcareous tests dominate the foraminiferal assemblages with
The distribution and diversity of modern planktonic Foraminifera are affected by different environmental stressors such as the anthropogenically forced ocean and climate change. Up to now, historical changes in the distribution of planktonic foraminiferal species have not yet been assessed at the global scale.

The FORCIS (FORaminifera Response to Climatic Stressors) project aims to collect information from published and unpublished data since 1910 to today regarding the planktonic foraminiferal diversity and distribution from the global ocean and compile a comprehensive database. The FORCIS database is composed of more than 180,000 samples, including ~157,000 Continuous Plankton Recorder (CPR), ~16,500 net tow, and ~7,000 sediment trap samples.

Our database provides a first insight into the distribution patterns of planktonic foraminifers in the global ocean at different scales over the past decades. The relationships between the abundance of the modern planktonic Foraminifera species and the different size classes and water depth ranges have been assessed. It enables us to model the total abundance in the test size fraction larger than 100 µm. Historical changes in the distribution patterns indicate a poleward increase of foraminifer abundances during the past 30 years. In the low latitudes, spinose symbiont barren deep dwelling species showed a vertical and latitudinal migration toward higher latitudes due to the deepening of the thermocline. However, most of the spinose symbiont-bearing species presented a northward migration only. In the mid latitudes, herbivorous symbiont barren species migrated northward following the food availability. While omnivorous and carnivorous symbiont-bearing species migrated to greater water depth and to higher latitudes. Other species seem not affected by the changes in the environment and do not show any habitat changes such as *Pullenia obliquiloculata* and *Globigerinoides ruber ruber*. Second, a decrease of tropical and subtropical species occurred in the mid latitudes. A loss in equatorial species seems to be compensated by an increase in diversity in mid latitudes. Finally, an abundance decrease in almost all species was recorded over the past decade that could be related to several abiotic and biotic factors. The response of the planktonic Foraminifera to these factors is species-specific and leads to a redistribution of the planktonic Foraminifera ecological niche, and new assemblages have emerged. However, the poleward migration of species is a striking feature since the *Ω* × *w* in higher latitude is predicted to decrease to unsuitable values for Foraminifera to calcify.
Age constraints of Fusulinid Foraminifers and U-Pb Detrital Zircon from Conglomerates in the western margin of Indochina Block, Thailand: Evidence of Paleogeography and Indosinian Orogenies

CHAROENTITIRAT Thasinee 1*, JITMAHANTRAKUL Sukonmeth 1, TOKIWA Tetsuya 2 and HARA Hidetoshi 3

1M.Sc. Program in Petroleum Geoscience, Faculty of Science, Chulalongkorn University, 254 Phayathai, Bangkok 10330, Thailand; thasinee@gmail.com; sukonmethj@gmail.com
2Faculty of Science, Shinshu University, 3-1-1 Asahi, Matsumoto, Nagano, 390-8621, Japan; tokiwa@shinshu-u.ac.jp
3Geological Survey of Japan, AIST, 1-1-1 Umezono, Tsukuba, Ibaraki, 305-8560, Japan; hara-hide@aist.go.jp
*Corresponding author

This research aims to reconstruct paleogeography, depositional environment and to define the provenance of conglomerates from the Huai Hin Lat Formation. This formation is generally represented the succession of Triassic conglomerates which have been widely exposed in the western margin of Indochina Block, Thailand. Unfortunately, the detailed studies on these conglomerates are not well examined. In order to achieve those goals, many attempts such as detailed field survey, paleontology and sedimentology analyses, clast-morphometric measurements, detrital zircon U-Pb dating, and tectonic concepts must be integrated. The exposures of conglomerate in this area form as undulating terrane, high and small hills. Conglomerates from two localities were collected: conglomerate area A and area B.

The succession of conglomerate area A is about 500 meters thick. Conglomerate area A is prominently clast-supported, polymictic conglomerate with reddish brown, very fine to coarse-grained sandstone as a matrix. Conglomerate area A’s clasts are composed of mainly limestone, sandstone, chert and silicified rock, petrified wood and some volcanic rocks. Conglomerate area B is also represented by clast-supported, polymictic conglomerate and reddish brown, fine to coarse-grained sandstone as a matrix. Its clasts consist mainly of volcaniclastic rocks with few limestone, sandstone and mudstone clasts. Fusulinid limestone pebbles were collected for age and original depositional environment studies. Two and one samples of fine-grained sandstone in conglomerate’s matrix from area A and B, respectively were collected for U-Pb detrital zircon age dating. Sedimentary structure such as bedding, lamination, cross bedding, channelling feature can be clearly observed. No fossils have been seen in the matrix. Based on fossil study from limestone conglomerates in areas A and B, they do not show the different in age. Limestone clasts from both areas contain fusulinids (Pro fusulinella, Nankinellina, Pseudofusulina Chalaroschwagerina, Presumatolina, Parafusulina, Yangchienia), coral, bryozoan, crinoid, sponge, ostracod etc. showing various ages of Pennsylvanian to Middle Permian. The rock type of limestone clasts contains oolitic grainstone, peloidal packstone-grainstone, calcareous mudstone, wackestone and calcirudite sandstone. However, detrital zircon separated from sandstone samples in area A shows 242-229 Ma (YSC), 243 Ma (YC) and 261 Ma (unmix age). The ones from sandstone sample in area B displays 211 Ma (YSC), 237 Ma (YC) and 216 Ma (unmix age). U-Pb detrital zircon age from sandstone sample in area B is younger than the ones from area A.

Based on the studies of fusulinid-limestone pebbles show that carbonate platforms existed during Middle Permian and were composed of several sub-environments such as intertidal, lagoon, reef and slope environments. Carbonate platforms started to uplift and erode at least or after Middle Permian time. These events have caused the major unconformity (or Indosinian I unconformity) which was represented by the presence of conglomerate area A derived from collapsed Permian carbonates. The detrital zircon age (242-229 Ma; YSC) from area A shows that the conglomerates were deposited during late Middle to early Late Triassic (Anisian to Carnian). This age is also implied to the time of Indosinian I characterized by the compression tectonic between South China and Indochina blocks. Moreover, the age of U-Pb detrital zircon from sandstone sample in area B; 211 Ma (YSC) is represented the depositional age of conglomerate area B around Late Triassic (Norian) and can be referred to the Indosinian II unconformity.

Lithium incorporation and isotopic fractionation in large benthic foraminifera under decoupled pH/DIC conditions

CHARRIEAU Laurie M.1*, ROLLION-BARD Claire2, TERBRUEGGEN Anja1, WILSON David J.3, POGGE VON STRANDMANN Philip A.E.3,4, MISRA Sambuddha5 and BJMA Jelle1

1Biogeosciences section, Alfred Wegener Institute (AWI), Am Handelshafen 12, 27570 Bremerhaven, Germany; laurie.charrieau@awi.de
2Rollion-Bard@awidejile.jelles@awi.de
3Laboratoire des Sciences du Climat et de l’Environnement (LSCE), Université Paris-Saclay, 91919 Gif-sur-Yvette, France; claire.rollion-bard@lsce.ipsl.fr
4London Geochemistry and Isotope Centre (LOGIC), University College London, 5 Gower Place, London WC1E 6BS, UK; david.j.wilson@ucl.ac.uk;
poggevo@uni-mainz.de
5Mainz Isotope Geochemistry (MIGHTY), Institute for Geosciences, Johannes Gutenberg University Mainz, Saarstrasse 21, 55122 Mainz, Germany;
poggevo@uni-mainz.de
*Corresponding author

The chemical weathering of continental silicate rocks removes CO2 from the atmosphere and exerts a fundamental control on the Earth’s climate over geological timescales. Characterizing silicate weathering in the past is therefore crucial for understanding the climate system. The lithium isotopic composition (δ7Li) of carbonates is considered to be a reliable
archive of past seawater δ^7Li values, which are useful as a tracer of silicate weathering. However, the Li isotopic fractionation during biogenic carbonate formation is complex, and local conditions such as carbonate system parameters could impact δ^7Li values in marine calcifiers. For example, δ^7Li values have been shown to be dependent on either pH or DIC in two studies using large benthic foraminifera. Those results are enigmatic, since both studies used similar species of the genus Amphistegina but reported differing controls on δ^7Li values.

The aim of this study was to address the earlier contradictory results on the Li isotope behaviour in the hyaline species Amphistegina lessonii. We performed culture experiments under decoupled pH/DIC conditions, and analysed the δ^7Li values and Li/Ca ratios in the foraminifera tests. Two different light treatments (light/dark and dark) were also implemented to investigate the potential role of the symbionts.

Contrary to the two previous studies, no links between either pH or DIC and δ^7Li or Li/Ca values were observed for any of the treatments in our experiments. Additionally, growth rates also did not seem to influence the Li incorporation or isotopic fractionation. However, an effect of different light treatments was observed, probably due to different physiological processes of the symbionts occurring in dark conditions. Overall, these findings appear to support the use of Li isotopes in large benthic foraminifera to reconstruct past seawater chemistry and to infer changes in chemical weathering during carbon cycle perturbations over the last several hundred million years of Earth history.

**Trophic interactions between foraminifera and diatoms in a French mudflat using a long monitoring period**

CHOQUEL Constanțe1,2*, GLESLIN Emmanuelle2, MOURET Aurélie2, JESUS Bruno3, SCHWEIZER Magali4, HOUILIEZ Emilie4, JAUFFRAIS Thierry2 and METZGER Edouard6

1Geology Department, Lund University, Sölvegatan 12, SE 22362 Lund, Sweden; constance.choquel@geol.lu.se; helena.filipsson@geol.lu.se

2Université d’Angers, Nantes Université, CNRS, UMR 6112, LPC, F-49000 Angers, France; constance.choquel@geol.lu.se; emmanuelle.gleslin@univ-angers.fr; aurelia.mouret@univ-angers.fr; magali.schweizer@univ-angers.fr; edouard.metzger@univ-angers.fr

3Nantes Université, Institut des Substances et Organismes de la Mer, ISOMER, UR 2160, F-44000 Nantes, France; bruno.jesus@univ-nantes.fr

4Université de Lille, Laboratoire D’océanologie et de Géosciences, CNRS, UMR 8187, Station Marine de Wimereux, 28 Avenue Foch, 62930 Wimereux, France; emilie.houillez@outlook.fr

5Ifremer, IRD, Univ. Nouvelle-Caïdénolle, Univ. La Réunion, CNRS, UMR 9220 ENTROPIE, New Caledonia; Thierry.Jauffrais@ifremer.fr

*Corresponding author

The ecological significance of mudflat meiofauna to the marine ecosystem functioning is increasingly recognized, particularly for abundant meiobenthic populations such as foraminifera. Due to their small size, high turnover rate, and specific ecological requirements, mudflat foraminifera may be used as bioindicators to detect both natural seasonal variations and anthropogenic pressures across the surface sediment record. Foraminifera have intricate trophic strategies and a broad range of mechanisms for adapting to carbon and nitrogen resources from primary producers such as diatoms. These complex trophic interactions play major roles in the food web, and biogeochemical cycles and thus may drive mudflat ecosystems and biodiversity. Previous experimental and metabarcoding studies have revealed that foraminifera (grazers) - diatom (preys) relationships have more specific interactions than previously thought. However, there is still no evidence that the dynamics of foraminiferal populations can be explained by the population dynamics of various diatom species due to the challenge of counting and identifying the species over a long monitoring period.

This study benefits from the MUDSURV program which, aimed to generate decadal time-series of sediment geochemistry, microphytobenthos, and foraminifera data, at a pilot site located south of the Loire estuary in the Bourgneuf Bay mudflat (French Atlantic Coast). Specifically, we observed seasonal patterns regarding the four main foraminiferal species living there: Ammonia confertitesta (T6) and Haynesina germanica which reproduced twice per year almost at the same periods in spring and autumn, whereas Elphidium oceanense was abundant in autumn and Elphidium selseyense was present only in late spring. Here, we investigated the seasonal dynamics of these foraminifera regarding the major diatoms species through a DistLM (Distance-based Linear Models) analysis over 27 months. The DistLM routine uses the best possible combination of predictor variables (i.e., the relative abundance of diatoms species) that could significantly explain variations in foraminifera abundances. This analysis highlighted trophic relationships between foraminifera and diatoms and showed that the presence of specific diatom combinations could serve as indicators of foraminifera abundance. We showed that Ammonia confertitesta preferentially feeds on six diatom species characterized by different sizes (large, medium, and small), elongated shapes, and two life forms (epipelagic and epipsammic). Haynesina germanica showed a restrictive diet, feeding on four large elongated epipelagic diatom species. Elphidium oceanense presented the most varied diet, preferentially feeding on nine diatom species of different sizes, simple and complex shapes, and three life forms (epipelagic, epipsammic, and pelagic). No diatom species correlated with Elphidium selseyense temporal variability, perhaps due to its non-optimal habitat or non-diatom food preferences.

Our work suggests that the temporal dynamics of the most common foraminifera species in temperate mudflats can be explained by the seasonal variability of diatom species. Interestingly, we noted that some diatoms were preferentially preyed by only one foraminiferal species while others consumed by different foraminiferal species, which might suggest competition for food.
Addressing the segmentation challenge posed by 3D pore patterns and thickness of foraminiferal tests

CHOQUEL Constance1*, PIRZAMANBIEN Behnaz2 and FILIPPSON Helena L.1

1Geology Department, Lund University, Sölvegatan 12, SE 22362 Lund, Sweden; constance.choquel@geol.lu.se, helena.filipsson@geol.lu.se
2Statistics Department, Lund University, Tycho Brahes väg 1, 22363 Lund, Sweden; behnaz.pirzamanbien@stat.lu.se
*Corresponding author

Over the past two centuries, coastal regions have experienced various anthropogenic environmental stressors such as ocean acidification, pollution, warming, and deoxygenation that have impacted benthic marine life. Understanding the severity and potential outcomes of such changes is crucial for supporting effective environmental management strategies. Benthic foraminifera, protists with calcite tests, have long been recognized as excellent recorders of past bottom-water conditions. Morphological parameters of the shell, such as thickness and pore patterns, are of great interest for environmental reconstruction. Shell thinning is a known consequence of ocean acidification, and pore patterns are increasingly used as a proxy for bottom water oxygenation. However, the relationship between these two parameters is not well defined due to challenges posed by species-specific traits, shell curvature, and limited access to test thickness or pore blockage.

Recent advances in morphological analysis of foraminiferal tests using microcomputed tomography (μCT) have led to significant progress in generating 3D reconstruction tests. The 3D approach enables a non-destructive study of the morphology, which is beneficial for further geochemical analyses or studying legacy museum collections. To draw statistically valid conclusions, it is necessary to scan as many tests as possible and work at sub-micrometer resolution for measurement accuracy. Synchrotron light-based approaches can be used to achieve these objectives. However, extracting the required parameters from 3D tests remains challenging due to the limitations of image processing and computational capacity; therefore, optimizing post-data analysis is crucial.

Previously, it was described a post-data routine for analyzing entire tests in 3D from Elphidium clavatum specimens that recorded environmental conditions in the Baltic Sea entrance from the early industrial (the 1800s) and present-day (the 2010s) conditions. The 3D time series of morphological parameters revealed that modern specimens have on average 28% thinner tests and 91% more pores than their historical counterparts. These morphological changes were interpreted as the result of gradual environmental changes in the Baltic Sea inlet that have intensified since the start of the industrial era, linked in particular to a decline in pH and an increase in the duration and severity of hypoxia in the region.

Here, we have extended the analyses to Elphidium clavatum specimens to explore changes in their pore patterns from a selected chamber. The challenge of achieving 3D pore patterns remains, particularly concerning cropping a chamber from an image stack and segmenting and reconstructing pores in 3D. We detail the following parameters: porosity (%), pore area (μm²), crop area (μm²), number of pores, pore density, maximum pore size, minimum pore size, standard deviation of pore sizes, and average pore size. Thus, the main interest is therefore to continue to gain efficiency in image processing and to rapidly generate large databases of 3D morphological parameters. To accelerate the adoption of this semi-automated approach, we developed a routine using open-source software in ImageJ and Matlab (student version). The perspectives of this work are multiple, as it would allow for a better understanding of how the morphology of the shell varies during ontogeny or culture experiments under controlled conditions.

The response of benthic foraminifera to disaerobic event – example of the Valanginian Weissert event based on the reference Vergol and La Charce sections, Vocontian Basin, Southeast France

COLPAERT Clémentine1,2*, REBOULET Stéphane3 and Li Gang4

1Institut für Geowissenschaften Ruprecht-Karls-Universität Heidelberg, im Neuenheimer Feld 234 D-69120 Heidelberg, Germany; Clementine.Colpaert@geow.uni-heidelberg.de
2State Key Laboratory of Palaeobiology and Stratigraphy, Center for Excellence in Life and Environment, Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, 39 East Beijing Road, Nanjing 210008, China; Clementine.Colpaert@geow.uni-heidelberg.de; gangli@ngpas.ac.cn
3Univ Lyon, Univ Lyon 1, ENSL, CNRS, LGL-TPE, F-69022, Villeurbanne, France; stephane.reboulet@univ-lyon1.fr
*Corresponding author

The Valanginian sequence of the Vocontian basin is revisited based on a foraminiferal study of material collected in the Vergol and La Charce sections. The Vergol Section consists in a good sedimentological record of the Valanginian Weissert event, whereas the outcrop of the La Charce locality is more favourable to observe the uppermost Valanginian succession. The Weissert Event is the earliest major perturbation of the global cycle of the Cretaceous System. The event occurred after a long period of relative quiescence and displays a significant positive δ13C anomaly. The causes for the Valanginian carbon isotope excursion and associated paleoenvironmental changes are still a matter of debate. This research aims to analyse the structure and composition of the foraminiferal assemblages using the modern knowledge and methodological approaches about the ecological affinities of the selected taxa and their evolution across the different intervals of the Weissert Event. To
do so, the great sensibility of the microfauna to environmental changes, was used to enable the identification of variations of the sea-level, as well as nutrient and oxygen availabilities.

During most of the Early Valanginian, the negative $\delta^{13}$C$_{\text{carb}}$ excursion and the major sea-level lowstand was associated with the abundance of agglutinated, erected infaunal to semi-infaunal suspension feeders and detritivores. These forms are mainly found in poorly oxygenated deep-water environments, located beyond the shelf break. As suggested by the succession of deep-water assemblages, alternating with rich outer shelf – epibathyal and mesobathyal / infrabathyal forms, the late Early Valanginian to earliest Hauterivian was characterized by a major second-order lowstand during which multiple high-amplitude transgressions flooded the platform. Starting from the *N. platycostatus* subzone, *K. inostranzewi* zone, the basis of the Weissert event is represented by a negative excursion of $\delta^{13}$C$_{\text{carb}}$ following by evenly increasing values of $\delta^{13}$C$_{\text{carb}}$ and $\delta^{13}$C$_{\text{org}}$ reaching their maximum in the *S. verrucosum* Zone/Subzone. This period is associated with the abundance of poorly diversified infaunal morphogroups evolving detivorous feeding strategies. It suggests high influx of organic matter on the sediment-water interface and associated disaerobic conditions. A bloom of *Lenticulina*, usually considered as an opportunistic taxon, was observed at the basis of the *S. verrucosum* zone, associated with higher fertility of marine waters. During the latest Valanginian, the $\delta^{13}$C$_{\text{carb}}$ excursion contains many returns to less positive values. Synchronously, the occurrence of agglutinated, elongated, infaunal detritivore (dorothinids) together with diversified calcareous, elongated, infaunal active deposit feeders, herbivores, and bacterial scavengers, suggests sporadic increase in oxygen concentration (moderate dysoxic conditions), which favoured the recolonization of bottom waters.

The reason for fluctuations in the composition and diversity of foraminiferal assemblages are complex. Indeed, the Valanginian was a period of major climate changes. Enhanced atmospheric CO$_2$ and subsequent climate warming associated to the development of volcanic activity is assumed as a trigger for the Weissert event. During the Valanginian, an increase in continental weathering and run-off, probably due to humid conditions and low sea-level, may have been the consequence of higher marine productivity, enhanced level of organic matter and disaerobic conditions on the sea-floor. During the latest Valanginian, short-term ameliorations of bottom waters were concomitant with decreased pelagic carbonate production in a context of cooler marine temperatures, development of polar ice caps and subsequent sea-level fall.

Benthic foraminiferal bioevents through the Italian geological sheet N. 377 “Trasacco” (CARG Project)

CONSORTI Lorenzo$^{1,3}$, FABBì Simone$^{2,3}$, CIPRIANI Angelo$^{3}$ and PAMPALONI Maria Letizia$^{3}$

$^1$Institute of Marine Sciences (CNR ISMAR), Italian National Research Council, area Science Park Basovizza, Edificio Q2, strada Statale 14, km 163.5, 34149, Trieste, IT; lorenzo.consorti@ts.ismar.cnr.it
$^2$Department of Earth Sciences, “Sapienza” University of Rome, Piazzale Aldo Moro 5, 00185, Rome, IT; simone.fabbi@uniroma1.it
$^3$Department for the Geological Survey of Italy (ISPRA), Via Vitaliano Brancati 60, 00144, Rome, IT; angelo.cipriani@isprambiente.it; marialetizia.pampaloni@isprambiente.it

*Corresponding author

Geological mapping represents a valuable tool to understand the past settings and future evolution of the Earth system. Through the several activities involved for the final release of an official geological survey, biostratigraphy may have a pivotal role. This is true in particular when fossil-rich rock succession crops out into the studied area, and even more when shallow-water carbonate units have to be characterized and mapped in detail. The lithostratigraphy of the Mesozoic and Cenozoic units of carbonate platform is, usually, intimately related with the fossil content, benthic foraminifera among others, and to the relative stratigraphic extension for each taxon or assemblages. We present an example coming from the succession cropping out into the Apennines (Central Italy), included into the geological sheet n. 377 “Trasacco” (CARG Project), that has been characterized by applying a micropaleontological analysis based on benthic foraminifera and algae. Even not completely calibrated against the chronostratigraphic scale, the shallow-water zones here used help to define the relative position of taxa through time, supporting the characterization of the biostratigraphic units and the recognition of stratigraphic gaps. The observation of foraminifera by hand lens has first permitted to establish some unit boundaries in the field, whereas refined biostratigraphy by using thin sections helped to solve problems at the mesoscale.

The shallow-water succession encompasses great part of the Jurassic and Cretaceous with ‘Bahamian-type’ facies, over lain by Lower Miocene succession made of heterozoan carbonates. This has helped to broadly resume the bioevents recorded through the platform, especially during the Mesozoic. Through the Lower Jurassic only oligotrophic foraminiferal associations developed, constrained by the environmental conditions of supratidal and near-emersion settings. The Middle to Upper Jurassic succession records a recovery of larger foraminiferal species included into the family Pfenderinidae, among others. Through the Lower Cretaceous some larger agglutinated and porcelaneous foraminifera typify the benthic association, among representative of the genera *Akcaya*, *Mesorbitolina*, *Praechrysalidina*, *Cribellopsis* and *Archeaeoalveolina*, associated with green algae and the bivalve *Chondrodonta*. The Cenomanian records high diversity with *Cisalveolina*, *Sellialveolina*, *Rotorhinella*, several foraminifera agglutinated and paraceamidiforme typify the benthic association, among representative of the genera *Akcaya*, *Mesorbitolina*, *Praechrysalidina*, *Cribellopsis* and *Archeaeoalveolina*, associated with green algae and the bivalve *Chondrodonta*. The Cenomanian records high diversity with *Cisalveolina*, *Sellialveolina*, *Rotorhinella*, several foraminifera agglutinated and paraceamidiforme, among others, which underwent mostly extinguished soon after at the Cenomanian-Turonian boundary (related to the Oceanic Anoxic Event 2). The following Upper Cretaceous succession records a post OAE2 diversification of several groups of larger benthic foraminifera such as the lamellar perforated rotaideans whose evolution started by small representatives that likely survived to the Cenomanian-
New insights on the benthic Foraminifera at the Cenomanian-Turonian boundary (OAE2) aftermath and the role of the genus *Rotorbinella* Bandy through the Late Cretaceous

**CONSORTI Lorenzo**, **KRIZOVA Barbora**, **CARDELLI Sahara**, **BAGHERPOUR Borhan**, **FRANCESCHI Marco**, **BONINI Lorenzo** and **FRIJIA Gianluca**

1Institute of Marine Sciences (CNR ISMAR), Italian National Research Council, area Science Park Basovizza, Edificio Q2, strada Statale 14, km 163.5, 34149, Trieste, IT; lorenzo.consorti@is.smar.cnr.it

2Department of Physics and Earth Sciences, University of Ferrara, Via Saragat 1, 44122, Ferrara, IT; krzbr@unife.it, saharamaria.cardelli@edu.unife.it; frijg@unife.it

3Department of Earth Sciences, School of Science, Shiraz University, Ghasro Dasht street, Shiraz, Iran; borhan.b@gmail.com

4Department of Mathematics and Geosciences, University of Trieste, Via Weiss 2, 34128, Trieste, IT; mfranceschi@units.it; lbonini@units.it

*Corresponding author

The Late Cretaceous was characterized by extremely high temperatures. The modeled CO₂ concentration in the atmosphere is among the highest of the entire Phanerozoic and it has been considered the main driver of such trend. The gradual warming started in the Albain and culminated during the Late Cenomanian and early Turonian where sea-surface temperatures reached ≥30 °C in the tropics and ≥20 °C in the southern mid- to high latitudes. This has produced the flooding of large portions of continents and created shallow water environments suitable for the development of carbonate platforms and their associated benthic biota.

Data at our disposal on rotaliodean Foraminifera place their very first appearance in shallow-water platforms shortly before the KTM, in the early Cenomanian, or during the late Albain. They were represented by small *r*-strategist *Rotorbinella* and *Pararotalia*, thought later extinct at the Cenomanian-Turonian Oceanic Anoxic Event 2 (OAE2), along with all the Cenomanian larger foraminifera. The KTM was followed by a long-term gradual cooling which lasted until the Maastrichtian, where Tethys benthic foraminifera experienced a striking diversification. Rotaloideans evolved and diversified independently, following biprovincial and/or endemic patterns. The genus *Rotorbinella* is known in the Santonian-Campanian of the central-western Atlantic Tethys (Pyrenean gulf) and central Tethys (e.g. isolated platforms of the Apennines and Adriatic area) occurring along with other several rotaloidians. In the eastern Tethys (Arabian platforms) and westernmost Tethys (Caribbean) an apparently hybrid association with endemic species is recorded in the Santonian-Campanian timespan. Several species are also described from the uppermost Cretaceous of the Caribbean, southern Spain and the Arabian platform.

Such an outstanding richness of rotaloideans was poorly known, and several of these morphotypes have been systematically described in recent decades only. The high diversity roots on the possible survival of some small Cenomanian *r*-strategist across the OAE2 with capability to survive or stay in quiescence. It is thus of a key aspect to understand what was the evolutionary history of the group nearby the Cenomanian-Turonian boundary (OAE2) and how really this event impacted or boosted on its evolution. To do so we have sampled a Cenomanian-Turonian shallow-water succession cropping in the Friuli region (Adriatic Carbonate Platform), and performed a detailed temperature trends with absolute estimations at a very high temporal resolution. Furthermore, we have also collected inedited data from the very poorly known “assemblage of the Coniacian-Santonian of Iran (Arabian platform).

Results show that i) in the Adriatic, *Rotorbinella* occurs in the late early Turonian, along with several Late Cretaceous ‘newcomers’, including the genus *Rotalispira*, once temperatures started dropping; ii) in the Arabian platform, *Rotorbinella* thrived along with a species closely related to the genus *Orbitokathina*, which represents a further Late Cretaceous ‘newcomer’.

The pervasive occurrence of *Rotorbinella* in the Cenomanian, late early Turonian, as well as in the rest of Late Cretaceous represents a key aspect that highlight the fundamental role of such a basic morphotype as a pioneer for the recovery and diversification of benthic foraminifera after the most impactful global events, such as the Cenomanian-Turonian. A pattern comparable with that here observed is also displayed through the end-Cretaceous and Paleogene (K-Pg) times.

Planktonic foraminifera assemblage in the Bight Fracture Zone during the last glaciation

**COPETE Mª Fernanda**, **DIZ Paula**, **PÉREZ-ARLUCEA Marta**, **ESTRADA Ferrán**, **ALEJO Irene**, **MENA Anxo**, **NOMBELA Lorenzo**

1Centro de Investigaciones Marinas, Universidad de Vigo, Fac. Ciencias del Mar, 36310, Vigo España; mariafernanda.copete@uvigo.es; pdiz@uvigo.es; marlucea@uvigo.es; tallejo@uvigo.es; anxomena@uvigo.es; mnombela@uvigo.es; gfrances@uvigo.es

2Instituto de Ciencias del Mar (ICM-CSIC). Pg. Maritim de la Barceloneta, 08003, Barcelona, España; festrada@icm.csic.es

*Corresponding author
Oceanographic changes in the North Atlantic Ocean during the Pleistocene have been well documented by many works. Nevertheless, past circulation across deep-ocean passages and their associated sedimentary processes are relatively few known. In this study, planktic foraminifera assemblages from a core retrieved at Bight Fracture Zone (BFZ) are presented to infer surface water dynamics during Marine Isotope Stages (MIS) 3 and 2.

The BFZ, which is a deep and narrow passage situated at the southwestern of Reykjanes Ridge (57° 54.26' N; 32° 44.448' W), is connecting the Iceland basin with the Irminger and Labrador basins. The main water masses through this passage are the North Atlantic Central Water (NACW), Sub-Artic Water (SAW) and Sub-Artic Intermediate Water (SAIW) as surface waters, intermedial waters like the Labrador Sea Water (LSW) and the deep Iceland-Scotland Overflow Water (ISOW). The last constitute one of the most important branches of the North Atlantic Deep Water (NADW), which is formed in high latitudes of the Norwegian Sea. It is expected that dynamic interaction between these water masses is going to determine sedimentation processes at the bottom of this passage, as well as fluctuations of the Polar Front and marine ice coverage determine the composition of the planktonic foraminiferal community.

The core BFZ21-GC01 was obtained in the westernmost end of the BFZ (57° 7.06’ N; 35° 16.354’ W) onboard the B/O Sarmiento de Gamboa during the cruise BOCATS2-BFZ21 in 2021. Parametric echosounder records reveal the presence of channel-related contourite deposit and frequent slide or resedimented bodies.

The combined use of AMS 14C age model, the stable oxygen isotope record in Neogloboquadrina pachyderma (syn.), planktonic foraminiferal assemblage analysis, and sedimentary and tomographic facies identification allowed us to reconstruct surface water conditions and the paleo-circulation in the BFZ during Marine Isotope Stages (MIS) 3 and 2 and the deglaciation.

During the analyzed interval Neogloboquadrina pachyderma (syn.) is the dominant species, but it is represented by five sinistral coiling morphotypes, analogous to those previously described in other regions of the Northern North Atlantic. Other frequent individuals are the dextral coiling forms that many works have considered as Neogloboquadrina incompta (Cifelli, 1961).

The main results of this research indicate that during the relatively colder intervals, the assemblages were dominated (80-90%) by the polar specie N. pachyderma, with the subpolar Turborotalita quinqueloba secondary specie (10-15%), while the subpolar species N. incompta corresponded low to 5%. Furthermore, the spherical and compact morphotypes of N. pachyderma were predominant, suggesting the influence of nutrient laden Arctic waters. In contrast, during the relatively milder intervals, the assemblages show an increment of subpolar and transitional species T. quinqueloba (30%), Globigerina bulloides and Globigerinita glutinata (30-40%), as well as the increment of transitional and subtropical species Globocassida inflata and Orbulina universa (10 %), respectively. During these relatively warm intervals, the abundance of the elongated and lobulated morphotypes of N. pachyderma increases. This is interpreted as indicative of the influence of low-nutrient surface Atlantic waters.

Submarine sulphur springs in Northern Adriatic (Koper Bay) and benthic foraminiferal assemblages: extreme conditions or not?

Northern Adriatic, a shallow-water basin (less than 50 m in deep), is considered a vulnerable area to climate or anthropogenic caused changes. The submarine sulphur springs offshore of Izola (Koper Bay) where samples were taken have been known since the 17th century for the healing characteristics of the warm water. In this study, we correlated the spatial distribution of benthic foraminifera in the Žumrove kotanje area, water depth between 25 and 32 m to the physicochemical properties of the surrounding water and the mineralogical, granulometric and geochemical properties of the sediments. The objective was to (1) determine the composition of the benthic foraminiferal assemblages as a function of distance from the springs, (2) compare the differences between the “living” (rose-bengal-stained foraminifera) and total assemblages and (3) interpret relation between sedimentological, geochemical, and paleontological data. Three categories of indices were considered: biodiversity (species richness, Shannon H’, dominance), Ammonia-Elphidium (IAE), and sensitive-tolerant species occurrences (Foram-AMBI, EcoQs).

The studied revealed moderately diverse, species rich, and structurally monotonous benthic foraminiferal assemblages. With 61 bentic species, the species richness fits well with the distribution of a typical shallow-water benthic foraminiferal fauna in the eastern Adriatic and exceeds previous species counts for stressful environments. Representatives of the genera Ammonia and Elphidium, which are known to tolerate a broad range of salinity, temperature, oxygen concentration, and low
Biomineralization expresses the ability of organisms to construct and assemble inorganic material in an organized way. Foraminifera, as unicellular shell-producing microorganisms, perform this function with extreme efficiency. Biominerals are produced under strict biological control, so it is important to consider the role of the foraminiferal macromolecules in determining shell structure. In rotaliids, the biocalcification process begins with the eversion of the pseudopods from the posterior side of the cell, and the shell is then built on the pseudopod plasma membrane proteins. We may assume 1) the presence of membrane cytoplasmatic proteins in the shell organic matrices and 2) the engagement of these proteins in the biocalcification process.

The preliminary results revealed the presence of Annexin A13 in the organic shell matrix of several foraminiferal species. The involvement of Annexin A13 in the biocalcification process is supported by the presence of calcium-binding proteins in the shell organic matrices. Annexins are a family of membrane proteins generally involved in physiological mineralization in humans and other multicellular organisms. The presence of Annexin A13 in foraminiferal shells suggests a role in the biocalcification process, particularly in the formation of the shell organic matrices.

Foraminiferal maintain consistent amino acid usage despite extreme codon usage bias in multiple non-monophyletic clades

COTE-L’HEUREUX Auden, ESTERNER Elinor G., MAURER-ALCALA Xyrus and KATZ Laura A.

\[1\text{Department of Life and Environmental Science, Università Politecnica delle Marche, via Brecce Bianche, 60122, Ancona, Italy; elisa.costanzi@iusspavia.it; f.caridi@staff.univpm.it; a.sabbatini@staff.univpm.it} 
\[2\text{University School for Advanced Studies IUSS Pavia; elisa.costanzi@iusspavia.it} 
\[3\text{Museum National d'Histoire Naturelle, Histoire de la Terre, CP 38 CR2P UMR 7207 du CNRS, 8 rue Buffon, Paris, France; bartolini@mnhn.fr} 
\[4\text{Department of Clinical Sciences (DISCO), Section of Biochemistry, Politecnic University of Marche, via Tronto 10/a, 60020 Torrette di Ancona, Italy; a.amici@staff.univpm.it} 
\[5\text{Laboratoire de Biologie Physico-Chimique des Protéines Membranaires UMR 7099 – IBPC, 13 rue Pierre et Marie Curie F-75005 Paris, France; francesca.zito@ibpc.fr} 
\[6\text{Corresponding author}
Codon usage varies widely across the eukaryotic tree of life, though the forces driving codon usage have primarily been investigated in model organisms for which complete genome sequence data are available. Prior to our work, members of the genus *Plasmodium* exhibited the most extreme compositional bias, where composition is largely driven by mutation bias generating an AT-rich genome. Other organisms, such as *Saccharomyces cerevisiae*, have relatively unbiased overall genome composition, but show strong codon preferences in highly expressed genes. Here, we combine single-cell transcriptomics and phylogenomics to explore patterns of molecular evolution in uncultivable Foraminifera. We sample broadly from all major clades of Foraminifera, and after careful curation, generate a dataset of 1,044 gene families from 49 individuals representing 27 diverse genera. We find extreme codon bias among multiple non-monophyletic clades, with average GC-content at silent sites in some organisms well below 10%. Despite this extreme bias, amino acid usage remains highly constrained, showing little variation across all taxa. This contrasts to patterns in biased *Plasmodium* species, which are more likely to use amino acids whose codons are more AT-rich (e.g. the FYMINK amino acids) compared to their less biased relatives. Codon usage correlates with expression in a complex manner that may hint at underlying transcriptional and translational mechanisms. Together, our analyses demonstrate a remarkable consistency in amino acid usage among Foraminifera despite highly variable codon usage and lead to broad insights on the evolution of translational mechanics and the genetic code.

**Shelf ecosystem response to the Eocene-Oligocene Transition**

COTTON Laura J.1*, EVANS David 2 and SCHMIDT Daniela N.1

1Natural History Museum Denmark, Øster Voldgade 5 - 7, 1350 København K, Denmark; laura.cotton@smn.ku.dk.
2School of Marine and Environmental Science, University of Southampton, Southampton, SO14 3ZH; D.Evans@soton.ac.uk
3School of Earth Sciences, University of Bristol, Wills Memorial Building, Bristol BS8 1RJ, UK; D.Schmidt@bristol.ac.uk
*Corresponding author

The Eocene-Oligocene transition (EOT) is one of the most dramatic climate shifts of the Cenozoic with severe consequences for reef ecosystems. The onset of continental Antarctic glaciation is associated with widespread environmental change, resulting in a global peak in biotic turnover. Whilst numerous studies of the biotic response to the changes at the EOT have been carried out, most high-resolution studies consist of open ocean records of foraminifera and nannofossils. However, this is not representative of the ocean system as a whole. The shelf seas and reefs are some of the most diverse and fundamentally important ecosystems of the oceans. Long-term diversity loss across the EOT has been shown in several macrofossil studies, but mainly at low resolution, and recovery is not well understood. Larger benthic foraminiferal records provide a higher resolution insight to this event, both in terms of biodiversity, physiology and shallow water geochemical records. Additionally when integrated with records of other shelf organisms (e.g. molluscs, algae, bryozoans) this provides a powerful overview of whole ecosystem response. Many shelf species are ecosystem engineers whose loss and recovery have profound implications for the entire ecosystem. Understanding these interactions will provide insights into shallow marine ecosystems and their response to major climate perturbations.

The Tanzanian Drilling Project EOT record (TDP 11, 12, 17) is recognised globally for its completeness and exceptionally preserved calcareous microfossils. It is most importantly, though, a rare record of both shallow water organisms and open ocean plankton. Here we draw together a unique dataset of high-resolution larger benthic foraminifera, planktonic foraminifera, molluscs, Dasycylnadaceae, bryozoan, coral, shallow water trace element and isotope records from the EOT. The response and recovery of these species is compared with known, modern physiology of each group to provide a complete picture of the shallow marine ecosystem response. These assemblage changes are coincident with a period of more positive values in δ13C of planktonic foraminifera and changes in trace element values. Comparison with the open ocean record of planktonic foraminiferal, pteropod, and nannofossils confirm fossil increases are a biological, rather than sedimentological response and additionally support a transition to more eutrophic conditions during the transition. The interaction of these groups, within an environmental framework of traditional and novel geochemistry indicate that increased nutrient fluxes, rather than the temperature change directly, played a pivotal role in restructuring shelf ecosystem dynamics, and offer new insights into our understanding of the EOT.

**Pre-Middle Eocene Climatic Optimum warming in the North Sea Basin**

COTTON Laura J.1*, THIBAULT Nicolas2, ŚLIWIŃSKA Kasia K.3, SHELDON Emma3 and YASUHARA Moriaki4

1Natural History Museum Denmark, Øster Voldgade 5 - 7, 1350 Copenhagen K, Denmark; laura.cotton@smn.ku.dk.
2Department of Geosciences and Natural Resource Management, Copenhagen University, Øster Voldgade 10, Copenhagen K, Denmark; nt@ign.ku.dk
The Middle Eocene Climatic Optimum (MECO) is a rapid global warming event that occurred ~40 Myr ago and lasted ~500 kyr. It induced major biotic and seasonal changes across high to low latitudes, the extent and nature of which have not yet been fully assessed, particularly with in shallower settings. The MECO is characterized by a significant negative anomaly in both δ13C and δ18O values of benthic and planktonic foraminifera, indicating up to 6°C warming in sea surface waters. Recently, a work on Ocean Drilling Project Site 647 in the Southern Labrador Sea recognised an additional, likely regional, pre-MECO warming event associated with an incursion of the planktonic foraminiferal genus *Hantkenina*. However, until now this has not been identified outside of this northerly region.

The Kysing-4 borehole is located in the eastern part of the North Sea Basin and provides a near continuous record of the Eocene to Oligocene sediments, including the MECO. The longer borehole record is tied to global stratigraphy by magneto-, calcareous nanoplankton, foraminiferal and marine palynomorph stratigraphy. Here we present preliminary high-resolution, integrated records of planktonic foraminiferal size and assemblage data, ostracode assemblage data, biostратigraphy, Tex86 and XRF analyses across the Middle Eocene. Tex86 records indicate a spike in temperatures of up to ~30°C in the lower part of magnetochron C18r, with corresponding changes in the XRF and foraminiferal datasets, followed by a second temperature increase within C18n. We interpret these as the pre-MECO warming, followed by the MECO itself. The earlier event correlates well with the timing of the *Hantkenina* incursion event and warming seen in the Labrador Sea. Though preliminary, this data suggests this pre-MECO event extends into the North Sea Basin and therefore may be less localized than previously thought.

**Metabolome of foraminiferal species from Bourgneuf bay characterized by GC-MS approach**

**COURTIAL Julia**, **LOTHERI Jeremy**, **CUKIER Caroline**, **LIMAMI M.Anis** and **GESLIN Emmanuelle**

Foraminifera are present in all types of environments, though most foraminifera are marine benthic and are found from the deep ocean to the intertidal zone, exposed to various environmental stresses. They stand out for their rapid response to stresses and their resistance to extreme living conditions. However, little is currently known about their biology, and specifically their metabolism and physiology.

In order to better understand foraminiferal lifestyle strategy in a coastal mudflat environment, we studied the metabolome of kleptoplastic and non-kleptoplastic species from Bourgneuf bay. To this end, gas chromatography-mass spectrometry (GC-MS)-based experiments were set up. It is a method of separation of analytes by gas chromatography and analysis by mass spectrometry allowing for both qualitative and quantitative analysis of polar and semi-polar low molecular weight organic compounds (amino acids, sugars…). The critical step in the protocol that required adjustment was optimization of the sample size. Indeed, on the one hand, it is necessary to work on enough cells so that the extracted metabolites reach a detectable concentration. On the other hand, foraminifera specimens collection from sediment samples is a very low process. Foraminifera are collected individually with the help of a brush under the binocular microscope which causes a drift in concentration. On the other hand, foraminifera specimens collection from sediment samples is a very low process.

Foraminifera are collected individually with the help of a brush under the binocular microscope which causes a drift in concentration. On the other hand, foraminifera specimens collection from sediment samples is a very low process. We carried out the experiment with samples at different sizes 600, 300 and 200 foraminiferal cells for each species, we have found that 200 individuals might be enough to observe most of the molecules detectable by this technique. We manage to create a foraminiferal library of more than one hundred compounds (amino acids, sugars…). The critical step in the protocol that required adjustment was optimization of the sample size. Indeed, on the one hand, it is necessary to work on enough cells so that the extracted metabolites reach a detectable concentration. On the other hand, foraminifera specimens collection from sediment samples is a very low process. Foraminifera are collected individually with the help of a brush under the binocular microscope which causes a drift in concentration. On the other hand, foraminifera specimens collection from sediment samples is a very low process.
Seasonal dynamics of respiration and photosynthesis of benthic kleptoplast foraminifera inhabiting an intertidal mudflat: what ecological roles?

COURTIAL Julia1, METZGER Edouard1, LOTHIER Jeremy2, CHOQUEL Constance3, LIMAMI M. Anis2 and GESLIN Emmanuelle1

1LPG UMR 6112, Université d’Angers, Nantes Université, Le Mans Université, CNRS, Laboratoire de Planétologie et Géosciences, 2 Boulevard de Lavoisier, 49000 Angers, FRANCE; julia.courtial@univ-angers.fr; edouard.metzger@univ-angers.fr; emmanuelle.geslin@univ-angers.fr
2UMR1345 IRHS, INRAE, Institut Agro, Université d’Angers, 42 rue Georges Morel - CS 60057, 49071 Beaucouzé, FRANCE; jeremy.lothier@univ-angers.fr; anis.limami@univ-angers.fr
3Geology Department, Lund University, Sölvegatan 12, SE 22362 Lund, Sweden; constance.choquel@geol.lu.se

*Corresponding author

Foraminifera display varied trophic strategies, from opportunistic to highly specialized (selective herbivory with few diatom species), as well as complex life strategies including symbioses and mixotrophy. For instance, some foraminiferal species are known to retain in their cytoplasm chloroplasts from diatom prey, a phenomenon called kleptoplasty. However, the precise function of kleptoplasts in foraminiferal metabolism is still poorly understood. Photosynthetic activity has been demonstrated in some kleptoplastic foraminiferal species such as *Haynesina germanica* inhabiting photic zones. Here, we compare the metabolism of kleptoplastic and non-kleptoplastic species to better understand the mixotrophic lifestyle strategy and the advantages provided to foraminifera by kleptoplasty in a coastal mudflat environment.

This study is based on the MUDSURV project (Mudflat survey, OSUNA, LPG), initiated in 2016 and aimed to monitor over a decade the foraminiferal assemblages and sediment geochemistry of Bourgneuf Bay (French Atlantic Coast). We conducted a monthly monitoring of respiration and photosynthesis of kleptoplastic (*Elphidium oceanense*-phylotype S3-, *Elphidium selseyense*-phylotype S5-, and *Haynesina germanica*) and non-kleptoplastic foraminiferal species (*Ammonia sp.*, morphogroup tepida mainly phylotype T6). For this purpose, oxygen productions or consumptions were measured by oxygen microelectrodes in light and darkness conditions at field temperature. The results suggest that each foraminiferal species exhibited seasonal variation in respiration, with a significant correlation to temperature. Throughout the study period (september. 2020 to may 2022), the oxygen rates observed in light conditions for *Ammonia sp.*, *E. selseyense* and *E. oceanense* were very close to those observed in the dark indicating an absence of photosynthesis. Although *E. oceanense* and *E. selseyense* are known to have kleptoplasts, no photosynthetic activity was detected during our monitoring. Therefore, it is assumed that sequestered plastids are not necessarily photosynthetically functional. Conversely, *H. germanica* showed photosynthetic activity, with a greater variation in oxygen rate in light than in darkness until net photosynthesis was reached. However, the photosynthetic activity of *H. germanica* varied seasonally, with almost no activity observed in late summer/early autumn and early spring, while net oxygen production was observed in late autumn and early winter. In addition, we observed that *H. germanica* was more abundant when photosynthetically active, suggesting that active kleptoplasty is beneficial probably when food competition is high. Our results suggest that 1) kleptoplasts are not necessarily used for acquiring photosynthetic function in the photic zone; 2) photosynthetically active kleptoplast species show a seasonal variation of their net photosynthesis; 3) the ability to use actively kleptoplasts is an advantage; 4) different foraminiferal species adopt different life strategies which may play different roles in the ecosystem. This study improves the understanding of foraminiferal ecology and highlights the importance of long-term monitoring in elucidating the complex interactions between species and their environment.

The genus *Turborotalita* in the Arctic Ocean: *quinqueloba, egelida and exumbilicata*

COXALL Helen K.1*, VERMASSEN Flor1, CRONIN Thomas M.2, REGNIER Alexa1, DARLING Kate4,5, WEST Gabriel1, HUSUM Katrine6, HUBER Brian T.7, VOELKER Antje H. L.2 and MATT O’Regan1

1Department of Geological Sciences & Bolin Centre for Climate Research, Stockholm University, Svanen Arthenius väg 8, Sweden; helen.coxall@geo.su.se; flor.vermassen@geo.su.se; gabriel.west@geo.su.se; matt.oregan@geo.su.se
2School of Earth Sciences, Ohio State University, 275 Mendenhall Laboratory, 125 South Oval Mall, Columbus, Ohio, USA; regnier.7@buckeyemail.osu.edu
3School of Geosciences, University of Edinburgh, Geography Building, Drummond Street, Edinburgh, UK, kate.darling@ed.ac.uk
4Biological and Environmental Sciences, University of Stirling, Stirling, UK; kate.darling@ed.ac.uk
5Norwegian Polar Institute, Fram Centre, Hjalmar Johansensgt 14, Tromsø, Norway; katrine.husum@npolar.no
6Department of Paleobiology, National Museum of Natural History, Smithsonian Institution, 10th St. & Constitution Avenue NW, Washington, DC, USA; huberb@si.edu
7Instituto Português do Mar e da Atmosfera, Divisão de Geologia e Georecursos Marinhos, Av. Doutor Alfredo Magalhães Ramalho 6, Alges, Portugal; antje.voelker@ipma.pt

*Corresponding author

Planktonic foraminifera assemblages in the modern Arctic Ocean north of 80°N are composed almost exclusively of the polar species *Neogloboquadrina pachyderma*. Incursions of the subpolar genus *Turborotalita* at several horizons in multiple
Central Arctic Ocean (CAO) sediment cores are, therefore, anomalous and allude to significantly warmer-than-modern conditions during the past one million years. This finding is important palaeoclimatologically; however, unclear taxonomy is complicating progress with applications. Crucially, the stratigraphically ‘upper’ and ‘lower’ Turborotalita incursions to the CAO, which have been associated with Marine Isotope Stage (MIS) 5 and MIS 11 respectively, involve two different Turborotalita morphotypes: *T. quinqueloba* s.s in MIS 5 and ‘*T. egelida*’ during MIS 11. There are two issues with this. First, clear taxonomic concepts and reference images needed to distinguish these morphospecies, both from each other and from a deceptively similar morphotype of *N. pachyderma*, are unsatisfactory or lacking, leading to misidentification and misinterpretation. Second, the taxonomic concept of *T. egelida* itself is problematic, leaving questions about its usage.

To address these problems, we conducted taxonomic, morphometric and wall texture analysis of extant and fossil Quaternary planktonic foraminifera belonging to the ‘*T. quinqueloba* plexus’, from the northern North Atlantic, subarctic seas and CAO through the intervals of interest. We conclude that the stratigraphically upper turborotalitids from the CAO (morphotype-1) can be assigned to *T. quinqueloba* s.s., having a tightly coiled test and a tear drop-shaped final chamber, although the CAO forms are smaller than typical and lack gametogenetic thickening. Morphotype-2 (stratigraphically deeper horizon), is shown also to be spinose, thus supporting a *Turborotalita* affiliation; however, it deviates from *T. quinqueloba* s.s. in having more evolute coiling, an open umbilicus surrounded by relict apertural lips, and a more rounded final chamber that does not extend into the umbilical region. Morphotype-2 also commonly dominates assemblages across all size fractions, with only scarce *N. pachyderma*, unlike the younger *T. quinqueloba* s.s.-rich intervals in which *N. pachyderma* reaches 40-70%. Furthermore, we show that a loosely coiled thin-walled morphotype of *N. pachyderma* that has 5 chambers in the final whorl, has previously been confused with *Turborotalita* morphotype-2. Differences in test shape and wall reflectiveness can help distinguish the latter using optical microscopy but the two are most clearly differentiated under SEM, which reveals the non-spinose wall of the thin-walled *N. pachyderma* morphotype.

We conclude that *Turborotalita* morphotype-2 is sufficiently different morphologically and stratigraphically from *T. quinqueloba* s.s to warrant taxonomic distinction. However, we expose confusion surrounding application of the currently used name ‘*egelida*’, which was defined from the living plankton (thus sub-mature specimens) recovered in plankton net hauls. We argue that a more appropriate name for morphotype-2 is ‘*exumbilicata*’, described from a core sample from Alpha Ridge, CAO in 1974. These taxonomic clarifications provide an improved framework for recognizing modern and fossil morphospecies of *Turborotalita* useful for Quaternary biostratigraphic and paleoceanographic reconstructions in the CAO. It remains unclear whether (i) *T. exumbilicata* exists within modern populations outside the CAO, (ii) what its true relationship is to *T. quinqueloba*, and (iii) if the ‘*T. exumbilicata zone*’ is equivalent to MIS 11c or, if it is older. More broadly, this study emphasizes the need for publishing quality images to underpin all biostratigraphy, assemblage and palaeoclimate studies, which must be considered as primary data.

Late Cretaceous foraminifera from Eastern Lower Narmada Valley as part of the marine seaway through Central India

CP Sooraj* and PUNEKAR Jahnavi1

1Department of Earth Sciences, Indian Institute of Technology Bombay, Powai, Mumbai 400076, India; soorajpetro@iitb.ac.in; jpunekar@iitb.ac.in

*Corresponding author

The Late Cretaceous marine transgression resulted in a ~800 km long seaway through the ENE-WSW trending Narmada rift basin in India. The relics of this marine incursion are preserved in the highly fossiliferous Bagh Group of rocks (Turonian–Coniacian) in the lower Narmada valley. Most of the paleoenvironmental reconstructions of this marine incursion are based on macrofossils such as echinoids, gastropods, bivalves, brachiopods, and ammonites. The present study focuses on a quantitative analysis of benthic and planktic foraminifera of Bagh Group to infer marine paleoenvironmental conditions during Turonian-Coniacian in the Eastern part of Lower Narmada Valley.

Twelve isolated patchy outcrops were explored in the Bagh-Jeerabad area, Dhar district of Madya Pradesh, India. Four of studied outcrops (Soyla, Jeerabad, Rampura, and Avral) yield friable lithologies (Hence, easy to extract microfossils) and were investigated for foraminiferal assemblages. The typical marine carbonate succession of the studied sections consists of an older Nodular limestone Formation (NLF; mudstone-wackestone) overlain by the Bryozoan limestone Formation (BLF; packstone-planar laminated rudstone). The clay/marl horizons in the NLF yield benthic foraminifera including agglutinated-walled genera such as *Ammobaculites, Hoplofragmoides, Ammodiscus, Lagenammina, Bathysiphon*, hyaline-walled genera such as *Gavelinella, Cibicides, Gyroidinoids, Dentalina, Nonionella, Praebulimina, Lenticulina, Planularia, Bolivina, Fursenkoina*, and porcelaneous-walled forms such as *Quinqueloculina* and *Spiroloculina*. The planktic assemblages consist of opportunistic shallow-water genera of *Planoheterohelix, Muricodiabergella*, and *Whiteinella*. The lower part of NLF was likely deposited during Lower-Middle Turonian in a low-energy, upper intertidal-supratidal depositional environmental conditions in an epicontinental, semi-enclosed sea. The upper NLF was deposited during Late Turonian in a warm, low-energy, shallow subtidal (open-marine) condition. These inferences are consistent with the previously reported invertebrate fossil and sedimentological evidence. Other coeval records (e.g., Benue trough, Nigeria; Bight Basin. Australia; Bohemian
Cretaceous Basin, Central Europe; Turonian drill site, Tanzania) record variability in foraminiferal assemblages likely linked to paleoenvironmental changes regulated by eustasy, local tectonics and/or sediment supply.

**Biodiversity of Larger Benthic Foraminifera (LBF) from the Bartonian succession of Cape Mortola promontory (Liguria, NW Italy)**

CROBU Simone1*, BRIGUGLIO Antonino1, ARENA Luca1, GIRALDO-GÓMEZ Victor M.1, GANDOLFI Antonella1, BAUCON Andrea1, PAPAZZONI Cesare Andrea2, PIGNATTI Johannes1 and PIAZZA Michele1.

1Dipartimento di Scienze della Terra, dell'Ambiente e della Vita, Università degli Studi di Genova, Corso Europa 26, I-16132 Genova, Italy; simojump@gmail.com; antonino briguglio@unige.it; lucaarena95@libero.it; victormanuel.giraldogomez@edu.unige.it; antonella.gandolfi@edu.unige.it; michele.piazza@unige.it; andrea@tracemaker.com

2Dipartimento di Scienze Chimiche e Geologiche, Università di Modena e Reggio Emilia, Via Campi 103, 41125 Modena, Italy; papazzoni@unimore.it

3Dipartimento di Scienze della Terra, Università degli Studi di Roma “La Sapienza”, Piazzale Aldo Moro 5, 00185, Roma; johannes.pignatti@uniroma1.it; *Corresponding author

The present study focuses on the taxonomic description of the LBF from the Cape Mortola Calcarenite Formation cropping out along the Cape Mortola promontory in Liguria (NW Italy). The promontory is within a protected area and rock sampling is only permitted by concession of the local authorities that granted us access for this study.

We measured almost 50 meters of sedimentary log, from its basal contact with the Cretaceous limestone of the Trucco Formation, to the contact with the overlying Olivetta San Michele Silty Marl Formation, which crops out (poorly) at the top of the succession. From the entire section, we treated 48 samples to retrieve loose material from which we collected isolated LBF tests. We sectioned along the equatorial plane 175 nummulitids (i.e., Assilina and Nummulites) and 53 orthophragmines (as yet, only belonging to the genus Discocyclina).

The species retrieved throughout most of the section point to an early Bartonian age, specifically SBZ 17 according to the most recent biozonational scheme. The assemblages are dominated by relatively few taxa, such as Nummulites perforatus, N. biarritzensis and N. bronngnarti, which are most abundant in the lower to middle part of the section. All the Assilina specimens belong to the A. exponens, they are more abundant in the middle to upper part of the succession, and lack in the uppermost part of the section. Their disappearance may correspond to the SBZ 17/SBZ 18 boundary.

Orthophragmines abound in the uppermost part of the succession and all of them belong to the genus Discocyclina; the following species and subspecies are most abundant: D. pulcra baconica, D. dispensa sella, D. dispensa ex. interc.-dispansa-sella, D. pratti pratti, D. augustae olianae and D. trabayensis elazigensis. The orthophragminid assemblages point to a Bartonian age, specifically to the orthophragminid zones OZ 12, OZ 13, OZ 14 and to the shallow benthic zones SBZ 17 and SBZ 18a, according to the most recent biozonations.

**Phylogeny of Late Neogene and Quaternary planktic foraminifera: a temperate Southwest Pacific perspective**

CRUNDWELL Martin1*

1Mapping and Stratigraphy Team, GNS Science, PO Box 30368, Lower Hutt 5010, NZ; m.crundwell@gns.cri.nz

*Corresponding author

The Subtropical Frontal Zone (STFZ) in the Southwest Pacific has been an incubator for Late Neogene and Quaternary temperate planktic foraminiferal evolution. It is also a region where morphometric studies have been used to distinguish species on the basis of simple features, such as the number of chambers in the outer whorl, and the presence or absence of a peripheral keel. For example, morphometric studies in the 1980’s demonstrate that populations of Globoconella punctulata (unkeeled 4-chambered forms) evolved in the early Pliocene from late Miocene populations of Gc. conomiozea (keeled <4.5 chambered forms), via transitional populations of Gc. sphericomiozea, and in turn gave rise to late Pliocene populations of Gc. inflata (inflated <4 chambered forms). More recent studies have identified other keeled globoconellid species (G. mons and Gc. pliozea) and transitional early Pliocene globoconellid populations, but they do not support the taxonomic validity of Gc. sphericomiozea, because the ratio of keeled and unkeeled specimens shows “glacial–interglacial” scale variations and the number of keeled specimens does not always decrease. In this respect, the presence of transitional globoconellid populations is possibly an artefact caused by the mixing of unkeeled subantarctic and keeled subtropical populations within the STFZ.

Local biostatigraphic studies also support the presence of transitional globoconellid populations between Ge. punctulata and Ge. inflata, but the identification of new unkeeled species, early Pliocene populations of Gc. puncticoeides (moderately compressed 4-chambered forms), Ge. pseudospinosa (subangular 4-chambered forms) and Gc. triangula (subangular <3.5 chambered forms), and late Pliocene populations of Gc. cf. triangula (inflated subangular <4.5 chambered forms) means the concept of a simple morphological transformation between these species needs to be reviewed. Based on the range of morphological variation amongst these globoconellids, and local biogeographic and biostratigraphic data, two
phylogenetic groups are recognized: 1) \textit{Gc. inflata} group, that first appears in the Miocene and evolves within the STFZ (\textit{Globoconella punctuloides} – \textit{Gc. punctulata} – \textit{Gc. inflata}); and 2) \textit{Gc. triangula} group, that colonizes the STFZ in the early Pliocene and evolves in the Pliocene (\textit{Globoconella pseudospinosa} – \textit{Gc. triangula} – \textit{Gc. cf. triangula}). Both groups include morphospecies with high-arched apertures and a partially pustulose surface ultrastructure – distinctive features that are diagnostic of the clade \textit{Globoconella}.

The clade \textit{Truncorotalia}, that is characterized by morphospecies with low slit-like apertures and a distinctive pustulose surface ultrastructure, is also a major contributor to Late Neogene and Quaternary planktonic foraminiferal assemblages in the Southwest Pacific. Local biostratigraphic studies suggest unkeeled Pliocene populations of \textit{Tr. crassaformis} (ventrally extended 4-chambered forms) evolved from late Miocene populations of \textit{Tr. juanai} (biconvex 4-chambered forms), via transitional populations of \textit{Tr. neojuanai}, and in turn gave rise to keeled Quaternary populations of \textit{Tr. crassacarina} (ventrally extended 4-chambered forms). This group invades the STFZ at least three times in the late Miocene, before it colonizes the STFZ permanently and evolves. Another group of truncorotalids is also recognized that is comprised of Pliocene populations of \textit{Tr. crassaconica} (weakly keeled ventroconical forms with 4-chambers in the outer whorl) and Quaternary populations of \textit{Tr. truncatulinoides} (keeled ventroconical forms with >4.5 chambers in the outer whorl). The juxtaposition of these morphospecies contrasts with the North Atlantic, where biostratigraphic studies suggest keeled populations of \textit{Tr. truncatulinoides} evolved from unkeeled populations of \textit{Tr. tosaensis}, and it suggests the evolution of \textit{Tr. truncatulinoides} is more complex than we thought.

Biostratigraphically constrained Quaternary chronologies from the Hikurangi margin of north-eastern Zealandia

\textbf{CRUNDWELL \textit{Martin}1* and WOODHOUSE \textit{Adam}2}

1\textit{Mapping and Stratigraphy Team, GNS Science, PO Box 50368 Lower Hutt 5010, NZ; m.crundwell@gns.cri.nz}
2\textit{University of Texas Institute for Geophysics, University of Texas at Austin, Austin, TX, 78758, USA; adam.woodhouse@austin.utexas.edu}

Highly resolved biostratigraphically constrained chronologies have been developed to help elucidate the complex stratigraphy of tectonically deformed Quaternary sediments from the Hikurangi subduction margin of north-eastern Zealandia. The biostratigraphic framework that underpins the dating is based on well documented and dated 0–1.2 Ma planktic foraminiferal records from ODP Site 181–1123 on the Chatham Rise, just north of the Subtropical Frontal Zone. Biostratigraphic subdivision is derived from the tops and bases of short-lived climatically tempered influxes of \textit{Hirsutella hirsuta}, \textit{Hr. praehirsuta}, \textit{Truncorotalia truncatulinoides}, \textit{Tr. crassacarina}, \textit{Globigerinoides ruber}, and \textit{Neogloboquadrina pachyderma}. Most of these biostratigraphic markers are not unique, but sequences of markers that are unique to each marine isotope stage provide an unprecedented level of biostratigraphic detail and chronological dating when they are used within the contextual chronological framework of keystone biostratigraphic markers.

The detailed biostratigraphic framework has been used to date three sites on the mid to lower slope of the accretionary prism (IODP Site 372-U1517, 375-U1519, 375-U1518) and two sites east of the deformation front (Hikurangi Trough Site 375-U1520 and Tūranganui Seamount Site 375-U1526). The dating indicates sedimentation rates are very high and variable on the accretionary prism (0.2–9.6 m/kyr), especially during the Last Glacial Maximum (LGM) when downslope redeposition from the continental shelf and upper slope is very common. Sedimentation rates at Hikurangi Trough Site 375-U1520 are also variable (0.01–3.0 m/kyr) and they increase markedly as the incoming site approached the deformation front, especially during the LGM, in tandem with increased downslope redeposition from the inner to mid shelf. The incoming Quaternary section at Tūranganui Seamount Site 375-U1526, is characterised by low sedimentation rates (0.04–0.4 m/kyr) and the sequence is punctuated by hiatuses that shorten in duration as the site approached the deformation front. The shorter hiatuses are attributed to the site moving away from the core flow of the Deep Western Boundary Current and closer to the supply of clastic sediment from the hinterland.

New benthic foraminifera from the island of Brač (Croatia): further evidence for high foraminiferal diversity in Campanian inner platform settings

\textbf{CVETKO \textit{TEŠOVIĆ} \textit{Blanka}1*, SCHLAGINTWEIT Felix2, MARTINUŠ Maja1 and VLAHOVIĆ Igor3}

1\textit{Department of Geology, Faculty of Science, University of Zagreb, Horvatovac 102a, Zagreb, Croatia; bevetko@geol.pmf.unizg.hr; maja.martinus@geol.pmf.unizg.hr}
2\textit{Lerchenauerstr. 167, D-80935 München, Germany; felix.schlagintweit@gmx.de}
3\textit{Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Pierottijeva ul. 6, Zagreb, Croatia; igor.vlahovic@rgn.unizg.hr}

*Corresponding author

The informal group of larger benthic foraminifera (LBF) generally exhibits a high potential for biostratigraphy, palaeoenvironmental interpretations, and palaeobiogeographic comparisons in Neotethys especially during the Cretaceous
greenhouse period. They comprise representatives from the three main high order ranks, lamellar-perforate rotiliids, porcelaneous miliolids, and agglutinated taxa.

The so-called Late Cretaceous Global Community Maturation Cycle (GCMC) encompasses the Turonian–Maastrichtian interval, and represents a special period of increasing diversity of LBF in shallow water settings. The LBF suffered seriously from the palaeoenvironmental disturbances associated with the Cenomanian–Turonian boundary event (OAE-2) leading to an almost complete extinction of the group. Among the few survivor taxa, not all can be considered as LBF due to comparably small size and simple test structure. Generally, Turonian shallow water carbonates are characterized by very poor assemblages of benthic foraminifera among nezaazzatids, cuneolinids, dicyclinids and a few others. In the Coniacian–Santonian, the LBF of various groups already underwent a remarkable diversification in a wider area from Spain, southern France, Italy, Croatia, Greece to Turkey associated with widely distributed extensive platform carbonate evolution. From Campanian inner platform facies, numerous taxa of LBF have been reported especially from Spain, S-Italy, Greece and Croatia, here namely the island of Brač, a central Dalmatian island situated alongside the eastern Adriatic coast. From here five taxa (including four new genera) have been described from thin section material of these outcropping strata: Neobalkhania bignoti, Fleuryana adriatica, Reticulinella fleuri, Cretaciellavulina gusici, and Braciana jelaskai.

Ongoing studies have revealed additional four new taxa (including one new genus) of LBF described from lower-middle Campanian inner-platform carbonates of the island of Brač, Croatia. Two of the new taxa are also reported from time-equivalent strata of the Gavrovo-Tripolitza Platform (SW Greece) providing further evidence for the pronounced Campanian diversification within the Late Cretaceous Global Community Maturation Cycle of larger benthic foraminifera in inner platform facies of the Mediterranean Adriatic Carbonate Platform.

The response of benthic foraminifera to environmental impact in the Sepetiba Bay (SE Brazil): metabarcoding and morphology-based analyses

DAMASCENO Fabrício Leandro1*, ALVES MARTINS Maria Virginia 1,2, SENEZ-MELLO Thaise M.1,3, FRONTALINI Fabrizio4, PAWLOWSKI Jan5,6,7, CERMAKOVA Kristina6, ANGELES Inês Barrenechea4, SANTOS Luiz Guilherme Costa8, MENDONÇA FILHO João Graciano8, CASTELO Wellen Fernanda Louzada8, DULEBA Wania8, DE MELLO E SOUSA Silvia Helena9, ANTONIOLI Luzia1 and members of the project “Anthropized coastal systems”: CARVALHO DA SILVA André Luiz1, RAMOS E SILVA Carlos Augusto8, VILELA Claudia Gutteres8, DIAS Fabio Ferreira1, COE Heloisa Helena Gomes8, CASTRO João Wagner Alencar8, CRAPEZ Mirian Araújo Carlos5, DAMASCENO Raimundo Nonato7, DINO Rodolfo5, CARELLI Thiago Gonçalves12, DOS REIS Antonio Tadeu1 and GUERRA Josefa Varela1

1Universidade do Estado do Rio de Janeiro, UERJ, Av. São Francisco Xavier, 524, Maracanã. CEP: 20550-013 Rio de Janeiro, RJ, Brazil. fabrilocleandro@id.uff.br; virginia.martins@ua.pt; thaise_senez@id.uff.br; wellenflc@yahoo.com.br; luantonioli7@gmail.com; andrecsiilvageo@gmail.com; heloisacoe@gmail.com; dinouerj@gmail.com; josefa@uerj.br
2Universidade de Aveiro, GeoBioTec, Departamento de Geociências, Campus de Santiago, 3810-193 Aveiro, Portugal
3Federal Fluminense University (UFF), Rio de Janeiro, Brazil; caugusto_99@yahoo.com; fabiogeo@yahoo.com.br; miriancrapecz@id.uff.br; rdamasceno@id.uff.br
4Department of Pure and Applied Sciences, Università degli Studi di Urbino “Carlo Bo”, 61029, Urbino, Italy, fabrizio.frontalini@univurb.it
5Department of Genetics and Evolution, University of Geneva, Geneva, Switzerland, Jan.Pawlowski@unige.ch
6ID-Gene ecodiagnostics, Chemin du Pont-du-Centenaire 109, 1228 Plan-les-Ouates, Switzerland, kristina.cermakova@id-gene.com
7Institute of Oceanology, Polish Academy of Sciences, 81-721 Sopot, Poland, janpawlowski@iopan.pl
8Department of Geosciences, The Arctic University of Norway, Dramsvegen 201, N-9037, Tromso, Norway ines.a.angeles@uit.no
9Universidade Federal do Rio de Janeiro – UFRJ, Dpto Geologia - Instituto de Geociências. guilherme@laf0.geologia.ufrrj.br, graciano@geologia.ufrrj.br; vilela@geologia.ufrrj.br; castro@mm.ufrrj.br
10Escola de Artes, Ciências e Humanidades da Universidade de São Paulo. Rua Arlindo Bettio, 1000, Vila Guaraciaba, São Paulo - SP, Brazil. waduleba@gmail.com
11Instituto Oceanográfico, Universidade de São Paulo (IOUSP). Address: Pca. do Oceanográfico, 191, Butantã, São Paulo, Brazil. silviahelenamello@gmail.com
12Universidade Federal do Estado do Rio de Janeiro – UNIRIO, Av. Pasteur 458, s. 500, Urca, Rio de Janeiro, Brazil. thiago.carelli@unirio.br
*Corresponding author

The Sepetiba Bay (SB, western region of Rio de Janeiro State, SE Brazil) is an estuarine system bordered by the Maranhaúba barrier island. In recent years, SB has been an area of intense economic exploitation in response to ore transport, industrial and port activities, and expansion of population growth. The intense anthropic activities have affected this ecosystem with the discharge of organic and inorganic pollutants and the alteration of the sediment substrate. In the present work, we analyze the response of benthic foraminifera to such environmental quality deterioration. For this purpose, 16 samples of bottom sediment collected from the inner and outer sectors of the SB were analyzed for foraminiferal diversity using the morphology-based approach and eDNA-based metabarcoding sequencing. Sediment samples were also characterized with grain-size and geochemical data (total organic carbon, elemental concentrations). The number of taxa inferred through metabarcoding (518 amplicon sequence variants - ASVs) is much higher than that identified through the standard morphological approach (310 species). Monothalamous (soft-walled single-chambered) species largely dominate the eDNA dataset. Since no genetic database of foraminiferal species has been developed for the South Atlantic, only a minor
part of the ASVs has been assigned. The statistical results on living foraminifera assemblages based on the morphological dataset (principal component analysis and cluster analyses) show that the highest diversity of foraminifera tends to occur in areas less impacted by organic matter and metal pollution, namely Zn and Cd, the two main pollutant metals in the SB. Both analyses reveal that Ammonia species dominate the foraminiferal communities (i.e., morphological and molecular) in the most polluted areas. However, the eDNA analysis reveals that the most impacted areas contain large numbers of reads of monothalamous species, rarely reported in other coastal environments. Thus, this work reinforces the importance of using molecular analysis and morphological methods in environmental impact assessment studies.

**Beneath the Ross Ice Shelf, Antarctica: A perspective of West Antarctic Ice Sheet History from Miocene Benthic Foraminifera**

**DAMERON Serena** and **LECKIE R. Mark**

1Department of Earth, Geographic, and Climate Sciences, 233 Morrill Science Center, University of Massachusetts Amherst, 627 North Pleasant St Amherst, MA 01003-9297 Amherst, MA, USA; sdameron@umass.edu; leckie@umass.edu

*Corresponding author

In 1977-78 and 1978-79, the Ross Ice Shelf Project (RISP) recovered sediments from beneath the ice shelf at Site J9, 450 km from the calving front and open marine waters at ~82°S, 168°W. This is one of the most southern sites for marine sediment recovery in Antarctica. One important finding was discovering no benthic meiofauna, but an active pelagic macrofauna sustained below the ice shelf so far from open waters. The sediment has a thin, unconsolidated upper unit (up to 20-cm thick) and a lower unit (~1-m thick) containing reworked early and middle Miocene diatom and calcareous benthic foraminiferal assemblages. A post-LGM unconformity separates the upper unit (~7 kya–modern?) agglutinated foraminiferal assemblage, from the lower unit consisting mostly of reworked Miocene calcareous species, including Trifarina fluens, Elphidium magellanicum, Globocassidulina subglobosa, Gyroidina sp., and Nonionella spp. The presence of Neogloboquadrina pachyderma and Antarcticella antarctica supports the late Miocene diatom age for the matrix of the lower unit. The microfossil assemblages indicate periods of ice sheet collapse and open water conditions south of site J9 during parts of the early, middle, and late Miocene.

The upper unit foraminiferal assemblage is unique to the Ross Sea and is found in two other areas of West Antarctica. Cyclammina is dominant in the proximal grounding line in the western Antarctic Peninsula (Bellinghausen Sea) that contains a low diverse assemblage of mostly agglutinated species and only occurs when the total foraminiferal counts are low. This potentially serves as an analogue to RISP. Low diversity and low foraminiferal abundance in the western Antarctic Peninsula and RISP indicate a stressed environment, which could potentially be related to the position of the grounding line and extent of the ice shelf. Under conditions where the grounding line is more distal from the edge of the ice shelf, low organic carbon Availability would be expected where Cyclammina is one of the few taxa that could tolerate and survive such conditions. Cyclammina is also dominant along the continental slope of the eastern Ross Sea, directly north of RISP. Today Cyclammina is known as a deep benthal to abyssal taxon. At the LGM, the seafloor was about 500 meters deeper at ~1000 m, and the ice sheet was grounded at the edge of the continental shelf. Following the LGM, Cyclammina likely followed the retreating grounding line to RISP before isostatic rebound. Alternatively, Cyclammina at Site J-9 may be associated with corrosive High Salinity Shelf Water derived from the western Ross Sea. An absence of live meiofauna in the surface sediment suggests that the agglutinated assemblage at RISP may be a relict post-LGM assemblage.

**Re-evaluating Water Mass Influence on Late Cretaceous Deep-Sea Benthic Foraminifera**

**DAMERON Serena** and **MACLEOD Kenneth G.**

1Department of Earth, Geographic, and Climate Sciences, 233 Morrill Science Center, University of Massachusetts Amherst, 627 North Pleasant Street, Amherst, MA 01003; USA; sdameron@umass.edu; leckie@umass.edu

2Department of Geological Sciences, University of Missouri–Columbia, 101 Geological Sciences Building, Columbia, MO 65211, USA; MacLeodK@missouri.edu

*Corresponding author

The unique physical and chemical properties of water masses (e.g., NADW, AABW) were once thought to control the composition of foraminiferal assemblages found in the deep-sea. Over time, that idea was abandoned in favor of more localized parameters, such as the flux of food to the seafloor and dissolved oxygen content. We re-evaluated this concept by looking at a ~13-myr late Campanian – early Danian benthic foraminiferal assemblage record at Shatsky Rise in the northwest Pacific. Stable carbon and oxygen isotopes reveal at least 12 water mass changes that likely originated from the northwest Pacific, Southern Ocean, and perhaps the Indian Ocean (Tethys) and/or Caribbean.

Q-mode cluster analyses of the assemblages show 12 distinct and sharply defined groupings that are closely correlated with shifts in oxygen isotopes. Of note is the start of long-term cooling beginning in the latest Campanian (~74 Ma), with
major assemblage changes around the Campanian-Maastrichtian Biotic Event (CMBE, ~72 Ma) marked by a sharp increase in infaunal taxa (Præbulimina, Aragonia), followed by further cooling during the early Maastrichtian and an elevated abundance of inoceramid clams (71 Ma; Inoceramid Acme Event, IAE). The mid-Maastrichtian Event (MME; 70 Ma) was an abrupt warming that terminated the presence of inoceramids at Shatsky Rise followed by another rapid cooling event during the late Maastrichtian (68 Ma), culminating in a two-step warming during the end-Maastrichtian (~67 Ma). This is followed by a slight cooling at the K/Pg boundary and further warming in the early Danian.

One take away from this study is that specific taxa are not diagnostic of individual warming or cooling trends, although the changes in the cluster packages are highly indicative of changes in water mass. Many of the clusters are defined by abrupt shifts in taxa abundance, including the decline of P. elevata, O. umbonatus, and G. pyramidata at the MME, and the emergence of Trixia, sharp increases in G. becariiformis, and Reussella, followed by P. hillebrandti and Adercotryma. Assemblage changes were subtle, but associated with both cooling and warming events, likely driven by water mass buoyancy flux changes and vertical migrations of intermediate and deep water masses over Shatsky Rise, as well as changes in sources of deep/intermediate water masses during the study interval.

**Foraminiferal shell preservation under mudflats colonised by electrical cable bacteria**

DAVIRAY Maxime1*, GESLIN Emmanuelle1, RISGAARD-PETERSEN Niils2, SCHOLZ Vincent Valentin1, JORISSEN Frans1, FOUET Marie3,4 and METZGER Edouard1

1Université d’Angers, Faculté des Sciences, 2 Bd de Lavoisier, 49100 Angers, France; maxime.daviray@univ-angers.fr; emmanuelle.geslin@univ-angers.fr; frans.jorissen@univ-angers.fr; marie.fouet@u-bordeaux.fr; edouard.metzger@univ-angers.fr
2Aquatic Biology, Department of Biology, Aarhus University, Ny Munkegade 114-116, 8000 Aarhus C, Denmark; niils.risgaard-petersen@bio.au.dk
3Center for Electromicrobiology, Department of Biology, Aarhus University, 8000 Aarhus C, Denmark; vincent.scholz@bio.au.dk
4at present: UMR EPOC, Université de Bordeaux, CNRS, UMR 5805, Station Marine d’Arcachon, 2 rue du Professeur Jolyet, 33120, Arcachon, France; marie.fouet@u-bordeaux.fr
*Corresponding author

Cable bacteria activity (CBA) redesigns diagenetic processes generating strong pH gradients within the first few centimetres of sediment. Since their discovery ten years ago, their environmental distribution has been documented from freshwaters to coastal and seabed environments. The impact of sediment acidification induced by this bacterial activity on living benthic foraminifera and the preservation of their tests were investigated in intertidal mudflats. In September 2020, sediment cores were collected from three stations on the macrotidal estuary of the Auray river (Atlantic coast, France). Contrasted CBA were observed by oxygen and pH microprofiling with values ranging from 6.8 to 5.8. Cable bacteria density was assessed by q-PCR analyses that showed CB densities from 7 to 75 m.cm⁻³. According to a dissolution scale based on SEM observations of Ammonia spp. and Haynesina germanica, sediment acidification below the oxic zone led to dissolution of the shells of living calcareous foraminifera, ranging from slight test alterations to complete exposure of the inner organic lining. Therefore, foraminiferal test dissolution can be used as a CBA indicator. Samples from other estuarine intertidal mudflats were also shown test dissolution features, suggesting the active CB occurrence. Similarly, re-investigation of 1995-96 samples in the Auray estuary did not show foraminiferal test dissolution, suggesting recent colonisation of these mudflats by CB. Furthermore, in mudflats inhabited by CB, dead foraminiferal assemblages revealed a strong calcareous-test loss with an organic lining accumulation throughout depth. CBA past episodes may be tracked by examining the foraminiferal preservation state, possibly back to their first occurrence in the environment. Ecological monitoring and archival studies using foraminifera as bioindicators and paleoproxies should take account of CBA by considering these changes in both living and dead foraminiferal assemblages.

**Potential for conventional trace elements in Globorotaloides hexagonus as proxies for the pelagic Oxygen Minimum Zone**

DAVIS Catherine1*, DOHERTY Shannon1, FEHRENBACKER Jennifer1 and WISHERN Karen3

1Department of Marine, Earth, and Atmospheric Sciences, North Carolina State University, 2800 Fauxette Dr, Raleigh, USA; catherinedavis@ncsu.edu; sdoher@ncsu.edu
2School of Earth, Ocean, and Atmospheric Sciences, Oregon State University, Ocean Administration Building, 104, 101 SW 26th St, Corvallis, OR; jennifer.fehrenbacher@oregonstate.edu
3Graduate School of Oceanography, University of Rhode Island, 215 South Ferry Rd, Narragansett, RI, USA; kwishner@uri.edu
*Corresponding author

Conditions within the low-oxygen, low-pH regions known as Oxygen Minimum Zones (OMZ) play a key role in global climate and marine nutrient cycles. However, a scarcity of proxies for the pelagic OMZ frequently limits our understanding of how OMZ environments have changed in the past. Here we present multiple trace element to calcium ratios from the shells of the foraminifer Globorotaloides hexagonus, recovered live from discrete depth (MOCNESS) tows through the
upper oxycline and OMZ in the Eastern Tropical North Pacific (21°N, 118°W). Laser ablation ICP-MS was used to obtain individual foraminifera mean values of Mg/Ca, Sr/Ca, Mn/Ca, and Zn/Ca. We discuss temperature, oxygenation, and carbonate chemistry as potential drivers of geochemical variability. Low oxygen correlates with low Sr/Ca, high Mn/Ca, and high Zn/Ca. We hypothesize that the trends in Mn/Ca and Zn/Ca result from decreasing oxygen and pH deeper within the OMZ. A strong correlation with Sr/Ca is likely mediated by shelf growth rate in response to low oxygen. Results suggest that all three elements, especially Sr/Ca, have potential for reconstructing the intensity of paleo-OMZs. Some applications of these potential proxies are complicated by diagenesis, and we present G. hexagonus trace element data from the deglacial Eastern Equatorial Pacific (TR163-33; 0°24.6' N, 92°9.6' W; 2,730 m depth) that exemplifies this problem. However, Sr/Ca is less susceptible to post-depositional alteration and Sr/Ca records from G. hexagonus at TR163-23 would indicate an intensification of the pelagic OMZ over the last deglaciation.

The influence of submarine canyons processes in the benthic foraminifera distribution on the Espírito Santo Basin, SW Atlantic

DE ALMEIDA Fabiana K.1*, DE MELLO Renata M.2 and BASTOS Alex C.1

1Laboratory of Marine Geosciences (LabGeo), Postgraduate Program in Environmental Oceanography, Department of Oceanography and Ecology, Universidade Federal do Espírito Santo, Av. Fernando Ferrari, 514, Goaiabeiras, CEP 29075-910, Vitoria, ES, Brazil; fabiana.dealmeida@gmail.com; alexcardosobastos@gmail.com
2PETROBRAS S.A. Headquarters, Av. Henrique Valadares, 28, Centro, CEP 20231-030 Rio de Janeiro, RJ, Brazil; renatamouramello@yahoo.com.br

*Corresponding author

Submarine canyons are features with a more complex topography than the adjacent slope, which may result in differences in the composition of the benthic assemblages. In order to understand how trophic, hydrological and sedimentological conditions in submarine canyons can influence the distribution of benthic foraminifera, and to use this information to corroborate paleoenvironmental interpretations for the Holocene, we investigated recent benthic foraminiferal assemblages (total fauna > 63 µm) and sedimentological data in two canyons (CANWN and CAND) in the Espírito Santo Basin (ESB) between 18°20' and 21°20' S. Eighteen surface sediment (0-2 cm) samples were collected inside the canyons (150 to 1300 m water depth) and in shelf-slope adjacent transects (50 to 1300 m water depth) during an oceanographic cruise in 2013. After sample collection, the sediment was not stained which only allowed a total benthic foraminiferal census. The assemblage composition of benthic foraminifera varies according to depth and location. The Q-mode cluster analysis allowed us to recognize five major groups (I, II, III, IV, and V) that represent five benthic foraminiferal assemblages, which reflect a depth gradient and a heterogenous bottom morphology at the ESB. Three groups (V, III, and I) are present in different bathymetric sectors; Group V: outer shelf (50 m), Group III: upper, and middle – lower slope (150 to 400 m), and Group I: middle – lower slope (1000 to 1300 m). Groups II and IV show no characteristic bathymetric distribution and are present only in CAND and in CANWN, respectively. Group V consists of species that are almost limited to the outer shelf, such as Hanzawaia boueana, Peneroplis planatus, and Quinqueloculina lamarecki. In Group III Globocassidulina rossensis is dominant, and Trifarina spp. is more abundant. The species that contribute most to Group I are Globocassidulina crassa, Bolivina lowmani, Gavelinopsis versiformis, Alabaminella weddellensis, and Epistominella exigua. The main species related to Group II are Trifarina angulosa, Globocassidulina subglobosa, and Discorbis vilardeboanus. Group IV (middle – lower CANWN, 1000 to 1300 m) consists of agglutinated species Glomospira charoides, Rhabdammina abyssorum, and Pseudomonastra fusca. Our data suggest that the quantity (and quality) of food supply, hydrodynamic conditions, and sediment properties are the main drivers controlling the bathymetric distribution of benthic foraminiferal assemblages in both canyons. The CANWN and CAND host distinct benthic foraminiferal assemblages, especially from 1000 to 1300 m water depth, confirming that submarine canyons-related processes induce different ecological niches on the slope. The middle – lower CANWN revealed unstable trophic conditions, related to terrigenous sediment input due to turbidity currents. The increased abundance of opportunistic, shallow infaunal benthic foraminiferal species in CAND indicates that this submarine canyon trapped enough organic matter that favors species establishment and diversity, indicating a more productive and less unstable environment than in CANWN.

Factors controlling the benthic foraminiferal distribution on the Espirito Santo Basin slope, SW Atlantic

DE ALMEIDA Fabiana K.1*, DE MELLO Renata M.2, RODRIGUES André R.1 and BASTOS Alex C.1

1Laboratory of Marine Geosciences (LabGeo), Postgraduate Program in Environmental Oceanography, Department of Oceanography and Ecology, Universidade Federal do Espírito Santo, Av. Fernando Ferrari, 514, Goaiabeiras, CEP 29075-910, Vitoria, ES, Brazil; fabiana.dealmeida@gmail.com; alexcardosobastos@gmail.com
2PETROBRAS S.A. Headquarters, Av. Henrique Valadares, 28, Centro, CEP 20231-030 Rio de Janeiro, RJ, Brazil; renatamouramello@yahoo.com.br

*Corresponding author
In order to understand the main environmental factors driving the benthic foraminiferal distribution along continental slopes, and corroborate paleoenvironmental interpretations in the Holocene, we investigated recent benthic foraminiferal assemblages (total fauna >63 μm) and sedimentological data along six transects on the continental slope of the Espirito Santo Basin (ESB) between 18°20′ and 21°20′ S. The ESB is an important region for the oil and fishing industries. The ESB shelf-slope system is known due to a significant variation in the continental shelf width, changes in sedimentation regimes, variation of the shelf-break orientation, and the presence of complex morphological structures on the slope, built in response to relative sea-level fluctuations over geological time. Surface sediment samples (0–2 cm) were collected perpendicularly to the coast, from the upper (400 m) to the lower slope (3000 m) using a box-corer. The density, taxonomic diversity and assemblage composition change with depth and location. The genus *Globocassidulina* dominates the upper and lower slope, whereas *Bolivina* is the most abundant taxon in the deepest lower slope. The Q-mode cluster analysis allowed us to recognize five major groups, which reflect the distinct ecological preferences of the most abundant taxa. These groups are distributed in three main bathymetric sectors: upper, middle – lower, and lower slope. Group I (upper slope, 400 m) is characterized by the highest mean relative abundances of *Globocassidulina rossensis*, *Trifarina* spp. and *Trifarina angulosa*. Group II (middle – lower slope, 1000 to 1300 m) shows the highest mean relative abundances of *Globocassidulina subglobosa*, *Bolivina albatrossi*, *Bulimina aculeata* and *Uvigerina peregrina*. Group III (middle – lower slope, 1000 to 1300 m) is characterized by the highest mean relative abundances of *Globocassidulina crassa*, *Gavelinopsis versiformis*, *Epistominella exigua* and the unilocular group. Group IV (lower slope, 1900 m) shows the highest mean relative abundances of *Alabaminella weddellensis*, *Bolivina inflata* and *E. exigua*. Group V (lower slope, 2500 to 3000 m) is dominated by the genus *Bolivina* (*B. lowmani*, *B. pseudoplicata* and *Bolivina* spp). The most abundant taxa along the ESB slope are ecologically associated with the organic matter flux, bottom water oxygen concentration, and hydrodynamics conditions. Our data suggest that the quantity (and quality) of food supply is the primary factor controlling the distribution of recent benthic foraminiferal assemblages, which varies with depth. Group I (400 m) indicates that the organic flux is higher on the upper slope than on the middle and lower slope. The abundance of opportunistic benthic foraminiferal species of Groups II, III, IV and V (1000–3000 m), which feed on phytodetritus pulses, confirms the influence of the quasi-stationary Vitoria Eddy, as well as the seasonality of primary productivity in the ESB. Secondary factors include the physical-chemical properties of water masses (especially AAIW and NADW), and intermediate and deep boundary currents (IWBC and DWBC). The increased fragmentation of benthic and planktic foraminifera tests (>125 μm) on the upper and middle – lower slope is related to abrasion during transport from shallower regions to the slope. The distribution of recent benthic foraminifera assemblages found in this study reflects a more integrated picture of the population dynamics and the prevailing environmental conditions in the EBS during the Late Holocene (Biozone Z).

Benthic Foraminiferal Response to the BP Deepwater Horizon Oil Spill in the Northeastern Gulf of Mexico

**DECUBA Jeanette M.***1  and **COLLINS Laurel S.1**

1Department of Earth and Environment, Florida International University, 11200 Southwest 8th Street, AHC5 360, Miami, Florida 33199 USA; jdecu001@fiu.edu; collinsl@fiu.edu

*Corresponding author

The largest known marine oil spill, in 2010, was the BP Deepwater Horizon Oil Spill at the Macondo well in the northeastern Gulf of Mexico. From April until July 2010, approximately 206 million gallons of unrefined oil were discharged at a depth of 1,544 m. Shortly after the initial blowout, both physical and chemical agents were applied to remediate and mitigate potential environmental and human health impacts. As a result of the combined effects of the spill, response efforts, and natural biological and physical processes, marine snow formed, and pulses of sediment led to the transport of weathered Macondo oil and other contaminants to the seafloor across the northern Gulf of Mexico. At the end of 2010, cores were collected in the vicinity of the Macondo wellhead for geochemical and benthic foraminiferal analysis.

In this study we analyze foraminifera from sediment core WB-1110-DSH10-ISO collected in the DeSoto Canyon, about 55 km northeast the Macondo well head. Previous geochemical studies of the core provide insight on the benthic environment at the time, including the accumulation of hydrocarbons and pulses of sediment associated with the Deepwater Horizon Spill. Benthic foraminiferal diversity and changes throughout the core were analyzed to investigate a response to the presence of the material transported to the seafloor during and immediately after the spill. Findings reveal a significant faunal shift in the presence of dark particulate matter in the top portion of the core. Notably, diversity increased with an increase in concentration of this material. Also, agglutinated foraminifera and tubular agglutinated foraminifera were more abundant in the layers in which dark particulate matter concentrations increased. Multivariate statistical analyses and assemblage turnover calculations show a distinct shift in faunal assemblages before and after the presence of the weathered dark sediments in the top portion. Ultimately, this study compares the observed pattern of foraminiferal changes associated with the BP Deepwater Horizon Oil Spill and the occurrence of the oiled sediments and marine snow to assess the potential of benthic foraminifera as indicators of oil spills.
Principles and applications of automated recognition and picking of microfossils using the Microfossil Sorter (MiSo) automaton

DE GARIDEL-THORON Thibault1*, ADEBAYO Michael1, BOLTON Clara1, CHAABANE Sonia1, GODBILLOT Camille1, LICARI Laetitia1, LICHTERFELD Yohan1, MAZUR Jean-Charles1, SUAREZ-IBARRA Jaime Yesid1, LE THANG1,2, CHEVALIER Cristele2, PÉREZ-ASENSIO Jose Noël1,2, THIAM Malick1, WALLA Tobias1, BARRAS Christine1, GESLIN Emmanuelle2 and MARCHANT Ross1

1CEREGE, Aix-Marseille Université, CNRS, IRD, INRAe, Technopôle de l'Arbois BP80, 13545 Aix-en-Provence CEDEX 4, France; garidel@cerge.fr; adebayo@cerge.fr; bolton@cerge.fr; godbillot@cerge.fr; licari@cerge.fr; lichterfeld@cerge.fr; mazur@cerge.fr; suarez@ird.fr; luz@natur.cuni.cz; ldqthang@gmail.com; jnperezasensio@gmail.com; ross.g.marchant@gmail.com
2MIO, Aix-Marseille Université, Université de Toulon, CNRS, IRD, Bât. Méditerranée, Campus de Luminy-Oceanomé, 13009 Marseille, France; ldqthang@gmail.com; cristele.chevalier@mio.osuptheas.fr
3Universidad de Granada, Department of stratigraphy and paleontology, Facultad de Ciencias, Avenida de la Fuenta N/S, 18071 Granada, Spain; jnperezasensio@gmail.com
4Université Cheikh Anta Diop de Dakar, Département des Sciences de la Vie et de la Terre, Faculté des Sciences et Technologies de l'Éducation et de la Formation, Boulevard Habib Bourguiba BP 5036 Dakar-Fann, Sénégal; malick22.thiam2@ucad.edu.sn
5Université d'Angers, LPG-BIAF, Université d'Angers, 2 Boulevard de Lavoisier, 49045 Angers CEDEX 01, France; twalla1@gmail uni-koeln.de; christine.barras@univ-angers.fr; emmanuelle.geslin@univ-angers.fr
*Corresponding author

Together with the development of genetics, high-throughput imaging is emerging as a powerful technique to explore the biodiversity, and within the species, explore morphological traits at a massive scale. Yet, high-throughput foraminifera imaging systems have been lagging compared to other bionuclear nanoparticles imaging systems, for several reasons such as the complex sedimentary matrix, their diverse types, their fragility, and their 3-dimensional complex structure. A pioneering system at the Scripps Institute of Oceanography was devised in the late 1970s to automate their imaging (System of Automated Micropaleontology), though it was never fully operational.

In this presentation, we will present the state-of-the-art microfossil picking machine developed at CEREGE, together with ATG-Technologies, named Microfossil Sorter (MiSo). This automaton handles sedimentary coarse fractions, singles out sedimentary particles including foraminifera (benthic and planktonic), images them through a motorized-Z camera stage, identifies them using Convolutional Neural Network (CNN) techniques, and depending on its classification sort them into different microtubes or vials for subsequent geochemical analyses. Typically, this automaton processes close to 10k particles per day, and its processing principle has been recently patented.

The identification of microparticles, based on 2-stack images is based on a CNN classifier, and has been recently improved by the inclusion of image features, to improve both the accuracy and recall of the classification. We will show the most recent progresses of our Particle-Trieur software, which integrates the current workflow, from segmentation to annotation, classification to biometrical analyses, and discuss the limitations of current approaches.

Last, we will present and discuss a set of core-top and downcore applications for which this machine, and a cheaper exploratory system, have shown its usefulness, from foraminiferal sorting for isotopic analyses (see Y. Lichterfeld abstract); Nd geochemical analyses; foraminiferal imaging for trait-based analysis of planktonic foraminifera; benthic foraminifera identification in both recent sediments from coastal settings, but also in older Paleogene time intervals.

Pleistocene planktonic and benthic foraminifera assemblages from Fantangisña seamount in the NW Pacific Ocean (IODP Expedition 366)

DEL GAUDIO Arianna V.1*, PILGER Werner E.1, AUER Gerald1 and KURZ Walter1

1Institute for Earth Sciences, NAWI Graz Geocenter, University of Graz, Heinrichstraße 26, 8010 Graz, Austria; arianna.del-gaudio@uni-graz.at; werner.piller@uni-graz.at; gerald.auer@uni-graz.at; walter.kurz@uni-graz.at
*Corresponding author

The Izu-Bonin-Mariana (IBM) trench-arc system, in the northwestern Pacific Ocean (12° N to 35° N) is, to date, the only known setting where active serpentinite mud volcanism takes place. The southern sector of the IBM (the Mariana forearc) comprises a large number of serpentinite mud volcanoes, situated between the trench and the Mariana volcanic arc. Among them, Fantangisña seamount was drilled during International Ocean Discovery Program (IODP) Expedition 366. Lithologies comprise serpentinite mud deposits with ultramafic clasts from the subducting Pacific Plate, forearc crust and mantle, blanketed by pelagic sediments containing few ultramafic clasts. Additionally, the base of the seamount includes nanofossil-bearing silty to sandy volcanic ash deposits.

Fantangisña seamount is situated at low latitudes (16° N) in the tropical Pacific sector, under the influence of the North Equatorial Current (NEC). The NEC is a warm, oligotrophic, wind-drifted current, which moves westward in the tropical Pacific Ocean.
In this study, we analysed benthic and planktonic foraminifera assemblages at Site U1498A, cored on the southern, more stable side of Fantangisña seamount edifice. The investigated interval mainly spans the Early to Late Pleistocene, as defined by our previous biostratigraphic analysis on this site.

Cluster analyses performed on planktonic foraminifera provided significant insights on the water column dynamics during the Pleistocene. Specifically, two major sample clusters were identified based on the ratio between thermocline-dwelling species (e.g., *Globorotalia* spp.) and mixed-layer dwellers (e.g., *G. ruber*, *G. rubescens*, *G. glutinata*, *Trilobatus* spp.), inferring variations in the depth of the thermocline. We considered these fluctuations of the thermocline as related to variations in the NEC intensity. Precisely, our results showed that during the Early-Middle Pleistocene Transition (EMPT), the intensity of the NEC decreased, favouring the presence of a deep thermocline. In contrast, planktonic foraminifera assemblages recorded a weaker thermocline following the EMPT, which in turn can be related to a reduction in the strength of the NEC. We suggested that the strengthening/weakening of the NEC could be linked to ENSO climate phases (El Niño/La Niña).

Additionally, planktonic foraminifera diversity indices suggested that the serpentinite mud activity in the region does not affect the ecological distribution of the planktonic taxa. Interestingly, our data indicate that the production of serpentinite mud flows could enhance the preservation of the planktonic tests, allowing a fast burial after deposition.

Benthic foraminifera showed high diversity pre- and post-serpentinite mud volcanism and indicate oligotrophic and well oxygenated bottom-water conditions. Conversely, benthic forms are extremely rare within the serpentinite mud deposits as they severely suffered from the mud flows activity and gas outpouring.

**Does the elemental composition of foraminiferal shells reflect their evolutionary history?**

DE NOOIJER Lennart1*, PACHO Laura1, JORISSEN Frans2, PAWLOWSKI Jan3, ROSENTHAL Yair4, DISSARD Delphine5 and REICHART Gert-Jan1,6

1NIOZ - Royal Netherlands Institute for Sea Research, 1t Landsdiep 4, 1797 SZ, Texel, The Netherlands; lennooijer@nioz.nl; laura.pacho@nioz.nl; gert-jan.reichart@nioz.nl
2UMR CNRS 6112 LPG-BIAF, Angers University and Nantes Université, 2 boulevard Lavoisier 49045 Angers Cedex 1 (FRANCE) France; frans.jorissen@univ-angers.fr
3Institute of Oceanology, PAS, Powstańców Warszawy 55, 81-712, Sopot, Poland; janpawlowski@iopan.pl
4Rutgers, The State University of New Jersey 57 US Highway 1. New Brunswick, NJ 08901-8554.USA; rosenthal@marine.rutgers.edu
5IRD/UMR LOCEAN, IRD, BP A5, 98848, Nouméa, New Caledonia; Delphine.Dissard@locean.ipsl.fr
6Utrecht University, Princktonlaan 8a, 3584 CD, Utrecht, The Netherlands; gert-jan.reichart@nioz.nl
*Corresponding author

Ongoing ocean acidification affects marine calcification, although the scope and magnitude of this impact is essentially unknown. Here, we investigate the evolutionary origin of shell building in foraminifera to understand the long-term interplay between ocean carbon chemistry and calcification. Our analysis of shell chemical composition reveals multiple, independent origins for foraminiferal calcification throughout the Phanerozoic. With the long timespan involved, variability in seawater chemistry provided contrasting environments for calcification to arise, resulting in the diverse calcification strategies that exist today. This, in turn, explains the opposite responses of shell building to carbon perturbations. Our results call for adopting an evolutionary perspective when predicting the impact of perturbations on marine calcification and thereby, on the global carbon cycle.

**Holocene sea ice dynamics and paleoenvironments on the southwest Svalbard shelf reconstructed using a multiproxy approach**

DEVENDRA Dhanushka1,2, ŁĄCKA Magdalena1, SZYMAŃSKA Natalia1, SZYMCZAK-ZYŁA Małgorzata1, KRAJEWSKA Magdalena1, WEINER Agnes K.M.2, DE SCHEPPER Stijn3, HILDEGARD SIMON Margit4 and ZAJĄCZKOWSKI Marek1

1Department of Paleooceanography, Institute of Oceanology, Polish Academy of Sciences, Sopot 81-712, Poland; devendra@iopan.pl; mlacka@iopan.pl; natalia@iopan.pl; szymanska@iopan.pl; mkrajewskaa@iopan.pl; trapper@iopan.pl
2NORCE Norwegian Research Centre, Bjerknes Centre for Climate Research, Bergen, 5007, Norway; agwe@norceresearch.no; stde@norceresearch.no; msim@norceresearch.no
*Corresponding author

Although the general patterns of Atlantic Water (AW) inflow into the Arctic during the Holocene are well known, the development of ocean currents and induced environmental changes following the previous deglaciation are still not fully understood. We present a multiproxy record from core OCE2019-HR7-GC from the southwestern Svalbard inner shelf, a highly dynamic frontal area influenced by various ocean currents and local water masses, in order to better understand past water mass dynamics and their effects on sea ice cover and the environment throughout the Holocene. We focus on the foraminifera assemblages along with sea ice (IP23) and phytoplankton biomarkers, Alkenones, and Mg/Ca for reconstric
surface and bottom water conditions, and the dominant water masses. We observe extensive sea ice cover before 10.2 kyr BP, which was likely linked to the Preboreal Oscillation. Based on our reconstructions, the period between 10 and 7 kyr BP was characterized by the warmest Holocene conditions on the SW Svalbard shelf. This interval is associated with high surface water productivity and an increased AW influx that drove strong erosive activity at the bottom. After 6.5 kyr BP, the SW Svalbard shelf was characterized by a dynamic environment with cold and unstable conditions that lasted until 3.5 kyr BP. After 3.5 kyr BP, we observe an increase in sea ice cover and iceberg rafting over our site, which likely indicates seasonally fluctuating ice margins, with low AW influx, which lasted until 2.2 kyr BP. A brief warm period accompanied by strong bottom currents occurred between 2.2 and 1.8 kyr BP, which may correspond to the Roman Warm Period. The environment returned to a colder state with the presence of sea ice until 1.5 kyr BP, which was followed by warmer conditions between 1.5 and 1 kyr BP, an interval that corresponds to the Medieval Warm Period.

The research work was financially supported by the Norwegian Financial Mechanism for 2014-2021, project no 2019/34/H/ST10/00682 and by National Science Centre in Poland through project 2019/33/B/ST10/00297.

Foraminifera and tecamoebians from Oiapoque River Estuary, Brazil-French Guiana

DIAS Andriu1*, PEREIRA Kettollen1, CAMARA Gabriel1, BONFIM Isabela1, BELART Pierre1, CARELLI Thiago1, FERREIRA Valdenira2 and LAUT Lazaro1

1Laboratory of Micropaleontology – LABMICRO, Department of Natural Sciences, Federal University of the State of Rio de Janeiro – UNIRIO, Av. Pasteur 458, Rio de Janeiro, Brazil; andriu.dias@edu.unirio.br; kettollen@gmail.com; gabriel.kauaicamara@gmail.com; isabela.garcia@edu.unirio.br; pbelart@gmail.com; tgearelli@gmail.com; lazaro.laut@gmail.com

2Institute of Scientific and Technological Research of the State of Amapá – IEPA, Av. Feliciano Coelho 1509, Amapá, Brazil; valdeniraferreira@gmail.com

*Corresponding author

Tropical estuaries are important ecosystems that serve not only as critical habitats for a wide range of aquatic species (including fish, crustaceans, and mollusks), but also as breeding and nursery grounds for many commercially important species. In addition, they provide a range of ecosystem services (e.g., nutrient cycling, sediment trapping, water purification, and others) and their mangrove vegetation plays a significant role in carbon sequestration and storage, which can help mitigate the impacts of climate changes. However, it is known that tropical regions have been highly impacted by climate change, mainly due to changes in precipitation, which reinforces the importance of studies to understand and monitoring these ecosystems. In this context, the foraminifera assemblages can play a great role in the environmental diagnosis and recognition of short-term changes in tropical ecosystems. Nevertheless, knowledge about the ecology of foraminifera in the Amazon Coast is scarce, which demands studies in this region. Thus, this work aimed to evaluate the living benthic foraminifera distribution during two distinct seasons through a combined approach using physical-chemical parameters and granulometric analysis along the Oiapoque River Estuary (2º - 4º N and 51º - 52º W). This estuary is located in a binational basin with ~32,000 km², being ~17,000 km² in French territory and ~15,000 km² belonging to Brazil with a long history of mercury pollution resulting from gold extraction. In the lower Oiapoque River is located the Cabo Orange National Park that is one of the oldest Brazilian conservation units for the integral protection of nature which present a rich biodiversity and several indigenous communities.

As a result, 22 foraminifera species (dominance of *Ammobaculites dilatatus, Milliamma fusca, and Ammobium morenoi*) and 07 tecamoebians species (dominance of *Diffugia globularis* and *Diffugia oblonga*) were identified. In the wet season (December-May), the foraminifera assemblage showed a very restricted distribution, which includes only the estuary mouth. The analysis of physical-chemical and sedimentological parameters measured in both seasons pointed to significant changes in the lower estuary. The dry period (September-November) is characterized by low rainfall rates and a higher influx of oceanic waters (up to 21% salinity) into the estuary. By contrast, in the wet period, the oceanic water influx is extremely reduced due to the higher rainfall rates (300-400 mm/month, with some areas showing rates up to 500 mm/month) that promote an increase in the fresh waters contribution from Amazonian rivers, thus resulting in a salinity decreasing (2‰ salinity) and increase of suspended sediment in the environment. In both analyzed seasons, the occurrence of living calcareous foraminifera (*Elphidium excavatum* and *Ammonia tepida*) were restrict to the river mouth at the French Guiana margin that is recovered by red mangrove. The anthropic impact was identified by the high percentages of total organic carbon and sulfur that has a depocenter near Saint Georges OYapock City.

The Detrended Correspondence Analysis showed that most foraminifera species had their distribution correlated to salinity, total dissolved solids, and dissolved oxygen corresponding to lower estuary region. On the other hand, thecamoebians had their distribution correlated to less turbulent areas, with silty sedimentation and colder waters corresponding to the innermost region of the estuary. The results allowed distinguishing microenvironments inside the Oiapoque estuary with a strong interannual variation that must be considered for future management and monitoring plans. The foraminifera were important for recognizing the regions under coastal water influence in Oiapoque River and these methodologies can be applied to other Amazon estuaries. However, more studies must be carried out to understand the seasonal patterns in Oiapoque Estuary, especially in the mouth region.
The foraminiferal response to methane emissions in shallow water environments from the Scoglio d’Africa (Tuscan Archipelago, Northern Tyrrhenian Sea)

Di Bella Letizia1, Casalbore Daniele1, Conte Aida Maria2, Conti Alessia2, Cornacchia Irene3, D’Ambrosi Andrea4, Gaglianone Giovanni1, Ingrassia Michela1, Spatola Daniele1, Pevzdomeno Martina4, Provenzani Claudio2, Rusopandi Tania1 and Chioeci Francesco Latino1

1Department of Earth Sciences, Sapienza University, Piazzale Aldo Moro 5, Rome, Italy; letizia.dibella@uniroma1.it, daniele.casalbore@uniroma1.it; giovanni.gaglianone@uniroma1.it; daniele.spatola@uniroma1.it; tania.rusopandi@uniroma1.it; francesco.chioeci@uniroma1.it
2Research Council of Italy, Institute of Environmental Geology and Geoenengineering (CNR-IGAG), UOS, Department of Earth Sciences, Sapienza University, Piazzale Aldo Moro 5, Rome, Italy; aidamaria.conte@cnr.it; alessia.comiti@cnr.it; michela.ingrassia@cnr.it
3Istituto di Geoscienze e Georisorse (IGG), Consiglio Nazionale delle Ricerche (CNR), Via Giuseppe Moruzzi 1, 56124 Pisa, Italy; irene.cornacchia@igg.cnr.it
4BigBlueXplorers ASD. Via S. Fabiano 20, 00165 Rome, Italy; andrea.dambrosi@outlook.it; elaprov64@gmail
5Istituto per lo studio degli impatti Astropechi e Sostenibilità in ambiente marino, Consiglio Nazionale delle Ricerche (IAS-CNR), Department of Earth Sciences, Sapienza University, Piazzale Aldo Moro 5, Rome, Italy; martina.pierdomenico@ias.cnr.it
*Corresponding author

In this research benthic foraminiferal response to shallow water methane (CH₄) emissions located in the area around Scoglio d’Africa (Tuscan Archipelago, Northern Tyrrhenian Sea) was investigated. Methane (CH₄) is an important greenhouse gas, with a global warming potential about 20 times as large as carbon dioxide (CO₂) on a 100-year horizon. In the marine environment, coastal areas represent methane hotspots highly exceeding emissions from the open ocean. In this view, Scoglio d’Africa may represent a much-promising site for multidisciplinary marine research (carbon capture and storage, geochemistry of hydrothermal fluids and ocean acidification vs. benthic and pelagic organisms). The study area is located in the southernmost part of the Elba-Pianosa Ridge, a mainly submarine, north-south elongated morpho-structural high separating the Tuscany Shelf to the east from the Corsica Basin to the west. In the study area, submarine methane emissions have been studied since the 1960s and they are linked to the combined action of two processes: biogenic (microbial process called methanogenesis) and thermogenic origin. The gas emissions affect an area characterized by widespread Posidonia oceanica meadows occurring primarily between 10 and 40 m water depth. Two sampling surveys were conducted during 2021 and 2022: in the first (2021) thirteen sample grabs were collected while in the second, sediments and Posidonia samples were collected around two main mounds by scuba. The microfaunal analyses were carried out from samples coming from 11-16 m depth. The Posidonia were sampled 5-10 m from the emission points while sediment samples (grab and 50 ml syringe samples) were collected both at the Posidonia and no plant covering sites. The preliminary results of this research highlighted a very patch distribution and variability in density and biodiversity probably linked to the irregular distribution of the venting activity on the ground floor. The complexity of the interaction of the ecological factors characterizing extreme environments such as shallow hydrothermal vents did not allow us to carry out a real pattern of biota responses in situ. Around the muddy mounds, a strong loss of biodiversity and collapse in faunal density are recorded due to the combined effect by the CH₄ emissions and the mud flow setting. The rare living specimens are represented by agglutinated species like Lepidodenterammina ochracea and Ammodiscus sp. Contrarily to sediment samples, the epiphytic foraminiferal assemblages (living on Posidonia leaves and rizhomes) are abundant, mainly dominated by rosalinds (Neocorina posidonicola and Rosalina spp.). EDS microanalysis and isotopic analyses will be conducted both on the foraminiferal test and Posidonia leaves to highlight the isotopic signatures of living benthic foraminifera from methane rich environments. The aim of the research is to increase the knowledge on the of microfaunal response in this extreme environment as a proxy to improve reconstructions of methane release in the past and better predict the impact of future climate warming on methane seepage.

Exceptionally abundant Larger Benthic Foraminiferal fauna from the uppermost Eocene of Fanari (Thrace Basin, Greece)

Dimou Grigoria Vasiliki1, Koukousioura Olga1, Less Gyoergy2, Triantaphyllou Maria3, Dimiza Margarita4 and Syrides George1

1School of Geology, Aristotle University of Thessaloniki, 54124, Thessaloniki, Greece; dimouvaso@geo.auth.gr; okoukous@geo.auth.gr; syrides@geo.auth.gr
2Department of Geology and Mineral Resources, University of Miskolc, H-3515, Miskolc-Egyetemváros, Hungary; gyorgy.less@uni-miskolc.hu
3Faculty of Geology and Geoenvironment, National and Kapodistrian University of Athens, Panepistimiopolis, 15784, Athens, Greece; mtriant@geol.uoa.gr; mdimiza@geol.uoa.gr
4Corresponding author

An uppermost Eocene site very rich in Larger Benthic Foraminifera (LBF) was discovered in the coastal zone of Fanari village, 30 km southwest of Komotini city (NE Greece). It consists of molassic-type deposits of the Trace basin. Its importance lies to three main reasons. Primarily, it represents one of the few sites in the Greek peninsula where isolated
micro- and macrofossils were recovered. Secondly, these fossils are well preserved and thirdly and most importantly this site constitutes one of the most abundant in LBF sequences in the Tethyan realm. Two stratigraphical sections (FAN A-lower part, FAN B-upper part), which consist of shallow marine deposits have been sampled. They comprise in general fossiliferous sandstones and siltstones that are rather continuous, and their displacement is related to a fault system. The objectives of this research are: (1) to determine the LBF assemblages of the latest stage of Eocene, in accordance with biometric analysis and morphological features (internal/external), (2) to provide a biostratigraphic framework and finally (3) to reconstruct the paleoenvironmental conditions.

A total of 21 samples from the sandstone and siltstone were collected. The macro- and microfaunal content was extracted after soaking in water and H$_2$O$_2$ (70%) and wet sieving. Subsequently, plethora of the recovered LBF specimens were submitted to the standard preparation techniques for their dichotomy. More than 1000 specimens have been elaborated (thin sections/bisected). Morphometrical measurements were performed on the bisected specimens to support and amplify the taxonomic identification of LBF.

Twenty-four taxa, among which six (chrono)subspecies, belonging to twelve genera were subsequently identified. FAN A section is characterized mainly by nummulitids, unlike FAN B, which is represented by a diverse and very rich micro-fauna. The most common species, present almost in the whole sequence, is *Nummulites fabiani*. However, the most abundant species are *Pellatispira madaraszi* and *Spirolyceus carpaticus*, displaying their mass abundancies in the upper part of the sequence. It is worth mentioning that their accumulations show a quite opposite trend. Moreover, noteworthy is the increase of the proloculus size of *S. carpaticus*, detected also in the upper part of the sequence, leading to the distinction of two groups. Orthophragmines are abundant and occur only in the upper part of the sequence.

The whole sequence was placed within the stratigraphic framework based on the first occurrence of both *Heterostegina gracilis* and *Spirolyceus carpaticus*, documented already from the lower layers of the sequence and occur through the top ones. This fact enabled us to assign both sections to the upper part of the Priabonian, to the SBZ 20 larger benthic foraminiferal zone.

Finally, the paleoenvironmental evolution and reconstruction of Fanari area took place, according to the composition and distribution of foraminiferal assemblages. Three main depositional marine shelf facies were distinguished that operated along the carbonate platform before its demise took place. In particular, a low-energy water, shelf environment limited to the shallowest parts of the upper slope shift to open marine settings is concluded.

**Benthic foraminifera from the continental shelf of the Santos Basin (SE-S, Brazil) - traditional and Machine Learning, integrated approach**

**DISARÓ Sibelle 1, DISENENHA GONÇALVES Joicce1**, **KROPIWIEC Isabela S.1, MENDES Rafaela2, RIBAS Elis R.1, SILVA Thiago G.1, PUPO Daniel V.2 and MOREIRA Daniel L.3**

1Foraminifera and Quaternary Micropaleontology Laboratory (LaFMA) MCN-SCB, Federal University of Paraná, Av. Cel Francisco Heráclito dos Santos 100, Curitiba (PR), CEP 81.530-000 BRAZIL; stdisaro@ufpr.br; joicce@ufpr.br; isabelasksk@gmail.com; elisribas@ufpr.br; thiagogomes@ufpr.br
2Laboratório de Bioindicadores Ambientais – IOUSP, Universidade de São Paulo, Instituto Oceanográfico, Praça do Oceanográfico, 191, Cidade Universitária. 05058-120 São Paulo, SP, Brazil; dvpupo@gmail.com
3Petrobras S.A., Centro de Pesquisas Leopoldo Américo Miguez de Mello, CENPES/PDIDMS/TSMS/Tecnologias para Meio Ambiente; danielmoreira@petrobras.com.br

*Corresponding author

The constant expansion in the exploitation of renewable and non-renewable resources in the coastal zones and deep sea generates a growing concern in the scientific community, which wants to correctly estimate the regional natural habitats and their biodiversity before human interventions. It is essential to avoid the loss of species or damages that might threaten them.

Currently, new and promising approaches are being incorporated into traditional ecological studies, with notable advances in processing large amounts of data to understand complex causal relationships, contributing to current diagnostic studies and future predictions. Foraminifers have a wide geographical and bathymetric distribution being abundant in all marine areas and are susceptible to environmental variations. The structure of benthic foraminiferal assemblages results from the interaction of multiple factors. Aiming to improve the application of foraminifera as proxies of climate and anthropogenic changes, their relationship with abiotic parameters has been intensely investigated. Among our objectives within the scope of the "Santos Project – Regional Environmental Characterization of the Santos Basin (PCR-BS)," coordinated by PETROBRAS, was the survey of foraminiferal species that live on the Santos Basin's (SB) continental shelf, gathering information about the structure of their associations and which are the most critical factors responsible for their distribution. The structure of their assemblages was analysed (density, richness, diversity, dominance, and uniformity), hierarchical clustering and Canonical Correspondence Analysis (CCA) were performed, and four main groups were identified, correlated to the following data: (i) the inner southern platform (25 m) has foraminifera positively correlated with a higher temperature, finer sediments, the influence of Mixture Water (MW) and Coastal Water (CW), and probable by the Plata Plume Water influence; (ii) the northern inner shelf has coarser sediments and many attached foraminifera; (iii) the middle shelf (50 to 100 m) is under the influence of South Atlantic Central Water (SACW), silt and clay sediments dominate.
and retain nutrients (mainly chlorophyll-a and pheophytin-a), and is dominated by infaunal foraminifera with many opportunistic species; and (iv) the outer shelf (150 m) is dominated by gravel and high carbonate content, where epifaunal species less responsive to nutrient fluxes dominate.

Finally, we compared these results with Machine Learning (ML) approaches using self-organized maps (SOM), hierarchical dendrogram (CH), and random forest (RF) algorithms. The results of the SOM analysis, followed by the hierarchical clustering analysis with the WardD2 algorithm, separated the network into 28 neurons in four distinct groups of foraminifers. Furthermore, based on the results of the machine learning models, 21 environmental variables proved significant in explaining foraminifers' spatial distribution patterns giving precise predictions. Finally, RF analysis allowed for estimating the distribution of foraminifera associations with approximately 80% accuracy. Both traditional statistics analyses and machine learning showed similar results in characterizing the SB continental shelf. The integration of new approaches proved promising, allowing the processing of large amounts of data and the production of environmental models. They may generate forecasts to predict the consequences of ecological changes and, perhaps, implement mitigation measures in advance.

The contribution of different sediment layers to foraminiferal assemblages' characterization in distinct habitats from Santos Basin (Southwestern Atlantic)

Dissaró Sibelle T1, Dissenha Joicce1, Santa-Rosa Luciana C. C.2, Kropiwiec Isabela S.1', Pupo Daniel V.2, Guimarães Ana Tereza B2 and Leite Daniel M.3

1Laboratório Foraminíferos e Micropaleontologia Ambiental, Federal University of Paraná, Av. Cel Francisco Heráclito dos Santos 100, Curitiba, Brazil; stdissaro@ufpr.br; jois.digion@gmail.com; luyahue@gmail.com; isabelaksk@gmail.com; dv.pupo@gmail.com
2Universidade Estadual do Oeste do Parana (Unioeste), Centro de Ciências Biológicas e da Saúde (CCBS), Cascavel, PR, Brazil; anathguimaraes@gmail.com
3Petrobras S.A., Centre de Pesquisas Leopoldo Américo Miguez de Mello, CENPES/PDIDMS/TSMS/Tecnologias para Meio Ambiente; danielmoreira@petrobras.com.br
*Corresponding author

The Santos Basin is Brazil's most significant offshore sedimentary basin, ranging for over 350,000 km², from Cabo Frio (Rio de Janeiro) to Florianópolis (Santa Catarina). The first investments in exploration and production studies for this basin date back to the 1970s. Today it is one of the largest pre-salt oil reservoirs in the world, with an estimated recoverable oil reserve of 21.6 billion barrels of oil, extending into water depths of around 3,000 m. Operations in the Santos Basin pre-salt area began on May 1, 2009, a milestone for the company and the country. A year later, the Definitive Production System went on stream at the Tupi Field, deployed about 280 km from the coast and in waters with a depth of 2200 meters.

Exploration activities must be carefully planned to ensure environmental quality and maximum longevity and safety of the infrastructure. Responsible management involves anticipating planning and continuous monitoring based on scientific knowledge. Research must go hand in hand with industry activities, trying to maximize efforts and best practices to increase production safety.

Small details in the sample design can provide the necessary information without spending unnecessary time. Aiming to optimize the working time in the analysis of samples from the studies of characterization and environmental monitoring, we analyzed two strata of different depths: 0-1 and 0-2 cm, to verify which one is sufficient for environmental characterization. Benthic foraminifera are considered good indicators of environmental changes and are usually used to estimate marine ecosystems' health. They are single-celled organisms that live in direct contact with the sediment and its components at the water-sediment interface, up to several centimeters deep in marine and transitional sediments. The distribution of foraminifera in the sedimentary column depends on the chemical, physical, and biological conditions; they can move according to favorable or adverse conditions.

In Brazil, environmental characterization and monitoring studies usually use the first two centimeters due to the prevailing sedimentary characteristics of the Brazilian continental margin. International protocols suggest the first surficial centimeter of the sedimentary column be studied for environmental monitoring based on foraminifers; however, it is necessary to test how the foraminifera assemblages are distributed in different environments. Within the scope of the Santos Basin Environmental Characterization project, coordinated by PETROBRAS, we studied foraminiferal assemblages at four different habitats from the continental shelf, investigating the living benthic foraminiferal assemblages at the 0-1 cm and 1-2 cm depths, from different grain sizes and bathymetric zones. The assemblages’ composition and parameters, especially the density, richness, and diversity indexes, were evaluated. In addition, a Student's T-test was performed to assess the density of living foraminifers among the two layers. The surficial layer (0-1 cm) has a higher density than the 1-2 cm layer (p = 2,2-16). The richness at the surficial layer was 319, while at the 1-2 cm layer, it was 281.

The most effective layer for studying foraminifera is discussed, aiming at the environmental characterization and monitoring activities.
The atlas “Biodiversidade Marinha da Bacia Potiguar – Foraminifera” is a volume from the series “Marine Biodiversity of the Potiguar Basin”, a product of the Marine Environmental Characterization and Monitoring projects from Potiguar Basin, coordinated by Petrobras. It was elaborated by the “Laboratório Foraminífera e Micropaleontologia Ambiental” (LaFMA) from the Universidade Federal do Paraná (Curitiba-PR, Brazil) and two researchers from the Laboratorio de Foraminíferos of the Museo Argentino de Ciencias Naturales “Bernardino Rivadavia” – CONICET (Buenos Aires, Argentine). We work together on a formal and productive partnership, and in the scope of the projects, 1,100 species of benthic foraminifera have been recorded in northern Rio Grande do Norte, in one or more of the following regions from the Brazilian northeastern continental margin: inner continental shelf, mid-outer continental shelf, and/or continental slope.

The atlas presents 132 living species of benthic foraminifera collected in different samplings: (i) 2nd Potiguar Basin Environmental Characterization Campaign, carried out in 2003; (ii) four Regional Environmental Monitoring Campaigns in the Potiguar Basin, carried out in 2009, 2010, and two in 2014; (iii) ten campaigns for Monitoring the Submarine Outfall of the Effluent Treatment Station of the Industrial Pole of Guamaré, carried out between 2008 and 2015, and (iv) two campaigns for Characterization of the Continental Slope of the Potiguar Basin, carried out between 2009 and 2011. Scanning electron and optical microscopy images show different aspects of the tests; in some cases observations on the direct comparison with type-specimens were included, and also images of the holotype or another type when available, and some observations on the regional occurrence of the species (bathymetry, sedimentary data together with organic matter and carbonate content). A map with the distribution of the species in the study area and their registration in different world regions are presented to complement. Finally, at the end of the atlas, an illustrated glossary intended for non-specialists can help to understand the technical terminology.

This publication aims to awaken interest in foraminifera, making their study more accessible and attractive.

A new calcareous Globothalamea (Rhizaria, Foraminifera) from the northeastern Brazilian continental margin

1Laboratório Foraminíferos e Micropaleontologia Ambiental, Federal University of Paraná, Av. Cel. Francisco Heráclito dos Santos 100, Curitiba, BRAZIL; stdisaro@ufpr.br; elisribas@ufpr.br; dvpupo@gmail.com
2Laboratório de Foraminíferos – Museo Argentino de Ciencias Naturales “Bernardino Rivadavia” – CONICET, Av. Patricia Argentinia 480, C1405DJB, Buenos Aires, ARGENTINA; vtotah@macn.gov.ar; silviawata.8@gmail.com
*Corresponding author

Studying living benthic foraminifers from the northeastern Brazilian continental margin for several years, we have recorded around 1,100 species with a tremendous foraminiferal richness. Many researchers were active in the last century on the Tropical Southwest Atlantic. The possibility of being involved in this research brings us a new understanding of the regional foraminiferal biodiversity and promotes the discovery of a new species presenting now. Searching publications for similar species we had no success. Another difficulty was placing this new form in an adequate genus due to certain distinctive features; therefore, we probably have a new genus, too; for now, we will call it Discorbinella (??) sp. nov.

The test was frequently attached to bioclasts or lithoclasts but also free; it presents a low trochospiral arrangement, subcircular to oval outline, slightly lobed with a rounded periphery. It has a calcareous wall semi-transparent with milky white color. The dorsal side is convex with 2.5 to 3 whorls, partially evolute. The sutures are gently curved and slightly depressed with a peculiar chamber overlapping due to how the proximal portion of the subsequent chambers lays over the distal portion of the anterior one. It has 6 to 8 falciform to subrectangular chambers per whorl, increasing in size as added. Another notable characteristic is the large pores distributed over most of the spiral side, not uniform in size but almost uniformly distributed, following the sutural direction on the dorsal side, giving a coarse appearance to the test. The umbilical side is involute and slightly concave; sutures are sinuous, visible but obscured by the extensive development of papillae almost even in size, though they cover most of the umbilical face except for the periphery, which shows a smooth stripe with pores, little ones. Umbilicus is covered by papillae from the chambers of the previous coil. The aperture is a small, simple opening on the periphery at the base of the last chamber, another one on the umbilical side, under the wide flap projected towards the umbilicus. The height (mean ± SD) is 50.46 µm ± 16.36, and the diameter is 166.20 µm ± 47.40. They live between 4 and 49 meters deep. Considering the narrow continental shelf, they are found from the inner to the outer shelf on variable sediments: lithobioclastics, lithoclastics, biolithoclastics, and bioclastics.
Attached and encrusting Foraminifera on mobile unconsolidated substrates in the Santos Basin (SE - S, Brazil): unexpected records

DISENHA Joicel1 and DISARÓ Sibelle T.1

1Foraminifera and Quaternary Micropaleontology Laboratory (LAFMA) MCN-SCB, Federal University of Paraná, Av. Cel Francisco Heráclito dos Santos 100, Curitiba (PR), CEP 81.530-000 BRAZIL; joi.ddg@gmail.com; stdisaro@ufpr.br

*Corresponding author

Benthic foraminifera have an intimate connection with the substrate and different life habits. They can live free on the surface of the substrate (epifaunal) or bury themselves in the sediment (infaunal); they can move across the environment or be attached or encrusting with little or no mobility (sessile) fixed to rocks, lithoclast, bioclast, living plants or animals remaining temporary or permanently set. About 15.5% of 284 living agglutinated foraminifer genera are sessile; most benthic are well-known and recorded worldwide. Still, studies on attached forams are rare or restricted to fossils and naturally consolidated substrates such as corals, areas with metallic nodules, or constructions such as oil platforms, artificial reefs, or distinct substrates offered in experiments. A literature search referring to attached or encrusting genera and species indicates that these foraminifers have been neglected or sparsely recorded in distributional and ecology studies. There is also a shortage of their images. Believing that the abundance and richness of adhered or encrusting foraminifers might be underestimated in the literature, we present unexpected data from these organisms from unconsolidated mobile sediments of the inner shelf of the Santos Basin (SE and S Brazil). Despite the lack of records in previous studies, samples collected from 3 to 25 m deep in surficial sediments presented high density and richness of attached forams. Unfortunately, many sessile species were either not recorded on the Brazilian coast or in few numbers. In mobile studied substrates, these “sessile” foraminifers compose up to 96% of the total fauna on the shallow inner shelf of the Paraná coast and up to 82% of the living forams collected at 25m depth; these areas are constantly disturbed by the wave action and currents, a striking feature of some parts of this coast. They have agglutinated or calcareous tests; most are permanently attached, but some may be temporarily attached. A free-living agglutinated foraminifera genus was also abundant, although it was not recorded in nearby regions. Some species were never mentioned, others were recorded, but their identity is controversial. This study provides information on attached and encrusting benthic foraminifera and agglutinated species poorly known. We believe that the images might help their recognition, and our data can subsidize regional paleoenvironmental interpretation, supporting the recognition of similar areas, especially those under intense wave action. Their record may also improve environmental characterization and monitoring studies. Future researchers should be sure that this group of foraminifera is really absent from the study area; otherwise, they will remain almost invisible, as they have been until now.

Surface drivers of deep-sea benthic foraminifera variability during the Mid-Pleistocene Transition in the subpolar North Atlantic

DIZ Paula1*, SIERRÓ Francisco, J.2, GROBA Ricardo1 and HERNÁNDEZ-ALMEIDA Iván3

1Centro de Investigaciones Marinas, Universidade de Vigo, Campus Lagoas-Marcosende s/n, 36310 Vigo, Spain; pauladiz@uvigo.gal, puaatteam@hotmail.com
2Department of Geology, Faculty of Sciences, University of Salamanca, Plaza de Los Caídos, s/n, 37008 Salamanca, Spain; sierro@usal.es
3Geological Institute, ETH Zürich, Someggstrasse 5, 8092 Zurich, Switzerland; ivan.hernandez@erdw.ethz.ch

*Corresponding author

Deep-sea benthic foraminiferal assemblages from the Mid-Pleistocene Transition (MPT) (1060-780 ka) have been investigated at high-resolution at IODP Site U1314, located in the subpolar North Atlantic (56.36°N, 27.88°W, 2820 m water depth) in the southern Gardar Drift. The downcore benthic foraminifera assemblages are compared to existing multiproxy data (sedimentological, isotopic, geochemical and surface ocean faunal census counts data) from the same core, and to modern distribution of benthic foraminifera assemblages in the subpolar North Atlantic, to understand the drivers of benthic faunal assemblage composition and diversity through the MPT.

The most common benthic foraminifera species at Site U1314 are Epistominella exigua (Brady), Oridorsalis umbonatus (Reuss), Pusillina osloensis Feyling-Hanssen, Melonis pompilioides (Fichtel & Moll) and Astronion echolsi Kennett. Other, less abundant species, are Gyroidina polia (Pfleger & Parker), Gyroidina umbonata (Silvestri), Quadrimorphina laevigata (Pfleger & Parker), Pusillina bulboides (d’Orbigny) and a group of species indicative of low oxygen in pore waters (Globobulimina spp., Chilostomella spp. and Stainforthia spp.). High relative abundances of E. exigua (up to 60%) generally occurred during ice-rafted debris events. Therefore, we interpret peaks in E. exigua at U1314 as increases of seasonal primary productivity during iceberg discharges. Astronion echolsi shows high fluctuations (10-25%) between 780-830 ka and 930-1060 ka being nearly absent in between those periods. This is the first time that A. echolsi is found in high abundances (up to 25%) at Site U1314 and in other North Atlantic Pleistocene and Holocene cores. The ecology of this species in the subpolar North Atlantic is not well known, and consequently its paleoenvironmental interpretation is still uncertain.
The Shannon diversity index of the benthic foraminifera assemblage at Site U1314 ranges from 1.8 to 3.4 and covaries at the millennial and orbital scale with sea surface temperatures (SST) reconstructed from planktonic foraminifera assemblages (high SST, high benthic diversity, and vice versa). The observed relationship suggests a strong benthic-pelagic coupling likely through increased/decreased organic carbon supply during latitudinal shifts in the position of the Arctic front, which marks the boundary between cold polar and warmer Atlantic surface waters in this region.

Anaerobic microbial metabolisms in particle microenvironments recorded by *Globorotaloides hexagonus*

DOHERTY Shannon1*, DAVIS Catherine1 and FEHRENBACHER Jennifer2

1Department of Marine, Earth, and Atmospheric Sciences, North Carolina State University, 2800 Faucette Dr, Raleigh, NC, USA 27607; sdohert@ncsu.edu; cdavis24@ncsu.edu
2School of Earth, Ocean, and Atmospheric Sciences, Oregon State University, 104 CEOAS Admin. Bldg. Corvallis, OR, USA 97331; jennifer.fehrenbacher@oregonstate.edu
*Corresponding author

In the ocean, microenvironments inside organic particles can harbour lower oxygen conditions than ambient water. These microenvironments can host anaerobic microbes even outside of ocean anoxic zones. We present evidence that the planktic foraminifer *Globorotaloides hexagonus* inhabits a particle microenvironment and records the chemistry of anaerobic microbial metabolisms inside particles. Intrashell trends in Ba/Ca, Mn/Ca, and Zn/Ca ratios in *G. hexagonus* are interpreted as signatures of denitrification, Mn respiration, and sulphate reduction. We use *G. hexagonus* samples from discrete depth horizons in the Eastern Tropical North Pacific (ETNP) to examine vertical distributions of anaerobic metabolisms inside particle microenvironments through the ETNP oxygen minimum zone (OMZ). Geochemistry of individual specimens suggests that denitrification occurred inside particles throughout the water column, regardless of macroenvironmental oxygen concentrations, Mn respiration occurred in particles throughout the OMZ, and sulphate reduction occurred inside particles only in the core of the OMZ. We discuss the application of these intrashell trends to proxies for oxygen concentration as well as nitrogen, sulphur, and trace element cycling in OMZs.

Investigating the ecology of planktic foraminifera species with compound-specific stable isotope analysis of amino acids

DOHERTY Shannon1*, MCCARTHY Matthew2, HAVARD Emily1, CHRISTENSEN Stephanie2 and DAVIS Catherine1

1Department of Marine, Earth, and Atmospheric Sciences, North Carolina State University, 2800 Faucette Dr, Raleigh, NC, USA 27607; sdohert@ncsu.edu; ehavard@ncsu.edu; cdavis24@ncsu.edu
2Department of Ocean Sciences, University of California, Santa Cruz, 1156 High Street, Santa Cruz, CA, USA 95064; mmdmccar@ucsc.edu; stchrist@ucsc.edu
*Corresponding author

Foraminiferal proxies must be interpreted in the context of foraminifera ecology, including depth habitat, the presence/absence of symbionts, and diet. Stable isotope ratios and test morphology have traditionally been used to infer the ecological traits of both extant and extinct foraminifera species, but many uncertainties remain. Compound-specific stable isotope analysis of amino acids (CSIA-AA) has been used widely as a tool to untangle trophic ecology and carbon and nitrogen sources in organisms. CSIA-AA methodology is well established in many marine organisms but has only recently become feasible for small samples such as foraminifera tests. We present a new method for the application of CSIA-AA to foraminifera test-bound organic matter and present the results of CSIA-AA in three species of modern planktic foraminifera from Santa Barbara Basin sediment traps: *Globigerina bulloides*, *Turborotalita quinqueloba*, and *Neogloboquadrina incompta*. These results include the trophic position, or location in the food web, of each species, as well as dietary sources of carbon to each species. For example, CSIA-AA results from the spinose foraminifer *G. bulloides* indicate that this species was herbivorous (trophic position ~2) and feeding primarily on diatom aggregates in Santa Barbara Basin. We compare these data to observational evidence of ecological traits to expand upon current knowledge in modern foraminifera. Another goal of this work is to apply CSIA-AA to fossils; we discuss the application of methods to sediment-recovered and extinct species. Despite the potential, we also discuss the challenges of this method, such as the large sample size requirements.
The pre-onset excursion (POE) enigma of the U.S. Atlantic Coastal Plain: a prelude of the PETM environmental perturbation?

Doubrawa Monika1, STASSEN Peter1,2, ROBINSON Marc M.3, BABILA Tali L.,4 ZACHOS James C.5 and SPEIJER Robert P.1

1KU Leuven, Earth and Environmental Sciences, Celestijnenlaan 200E, 3001 Leuven, Belgium; Monika.Doubrawa@kuleuven.be; Robert.Speijer@kuleuven.be
2Royal Belgian Institute of Natural Sciences, OD Earth and History of Life, Vautier Street 29, 1000 Brussels, Belgium; Peter.Stassen@kuleuven.be
3U.S. Geological Survey Florence Bascom Geoscience Center, 12201 Sunrise Valley Drive, 20192 Reston, Virginia, USA; mmrobinson@usgs.gov
4University of Southampton, School of Ocean and Earth Science, European Way, S014 3ZH Southampton, UK; t.babila@soton.ac.uk
5University of California Santa Cruz, Earth and Planetary Sciences, 1156 High Street, 95064 Santa Cruz, USA; jzachos@ucsc.edu

*Corresponding author

The Paleocene-Eocene Thermal Maximum (PETM), is a short, transient global warming event, that took place ~56 Myr ago. It is the most pronounced of a series of hyperthermals that punctuated Earth’s long-term warming trend spanning the late Paleocene to the early Eocene. The PETM was caused by a major injection of 13C-depleted carbon into the ocean-atmosphere reservoirs, causing a greenhouse driven global temperature rise of 5–8°C. Associated with it are among others surface ocean acidification, shoaling of the carbonate compensation depth and regional changes in the hydrological cycle. The exact cause and trigger of the PETM is still under debate, ranging from influences from long-term mechanisms like orbital-variability based cycles and volcanic intrusions to instantaneous events like a bolide impact. Isotope data from the U.S. Atlantic Coastal Plain (site South Dover Bridge, Maryland) show additional small, but distinct, δ13C and δ18O excursions just below the base of the PETM, coined as the “pre-onset excursion” (POE). Their relationship with the PETM is still undetermined, but it may indicate that the latest Paleocene climate was not as stable as previously assumed and experienced a more gradual or stepwise change towards the PETM-onset in association with an enigmatic disturbance in the carbon cycle.

In this study we combine foraminiferal taxonomical data, grain size data and clay mineralogy with geochemical proxies (δ13C, δ18O, δ11B) to confine the POE at South Dover Bridge, investigate connected environmental changes and potential connections to the PETM. In this region, the PETM interval on the shelf is characterized by a distinct shift in grain size to a silty-clayey composition, with a high kaolinite content. The POE sediments also exhibit a fining trend, but to a lesser degree, and with no noticeable change in the clay mineralogy suite. The base of the POE coincides with a lowered pH at the seafloor, indicated by a δ11B excursion recorded in benthic foraminifera tests, likely impacting the foraminiferal assemblages as a decrease of hyaline, thin-walled foraminifera is observed (Bulimina virginiana, Paradlabamina lunata). While the thin-walled taxa increase in numbers throughout the POE again, other species fully disappear from the record (e.g., Bolivinopsis emmendorferi), or gradually diminish to eventually disappear at the onset of the PETM (e.g., Cibicidoides alleni, Pseudovigerina triangularis). Taxa that would become the most dominant species during the PETM phase, appear during the POE (e.g., Pulphosphinina prima, Anomaloides acutus), although the assemblage remains diverse. During the PETM Atlantic coastal bottom water currents are reduced and riverine input may have increased, causing finer grained sediments to be transported wider into the basin and/or to settle at the seafloor. While the δ13C excursion recovers between the POE and the onset of the PETM, environmental conditions show a slow and incomplete recovery, as reflected in the benthic foraminiferal assemblage, with noted changes persisting up to and throughout the PETM. Bottom-water temperatures (δ18O) start to increase by 2–4°C at the base of the POE, towards the PETM. The grain size record indicates that bottom water currents increased and/or riverine input decreased immediately after the POE.

We additionally report changes associated with the POE from two more sites in Maryland. While the δ13C excursion is not as distinct, the biotic shifts, grain size and δ18O suggest a potential stratigraphic correlation between those sites. The gradual changes after the POE, as well as the more transient changes, such as the POE, indicate that conditions on this late Paleocene Atlantic shelf were not as stable as commonly presumed, at least on this regional scale.

Paleoecological and biogeographical dynamics of the U.S. Atlantic Coastal Plain prior and during the Paleocene-Eocene Thermal Maximum

Doubrawa Monika1, STASSEN Peter1,2, ROBINSON Marc M.3 and SPEIJER Robert P.1

1KU Leuven, Earth and Environmental Sciences, Celestijnenlaan 200E, 3001 Leuven, Belgium; Monika.Doubrawa@kuleuven.be; Peter.Stassen@kuleuven.be; Robert.Stassen@kuleuven.be
2Royal Belgian Institute of Natural Sciences, OD Earth and History of Life, Vautier Street 29, 1000 Brussels, Belgium; Peter.Stassen@kuleuven.be
3U.S. Geological Survey Florence Bascom Geoscience Center, 12201 Sunrise Valley Drive, 20192 Reston, Virginia, USA; mmrobinson@usgs.gov
*Corresponding author

The Paleocene-Eocene Thermal Maximum (PETM) is a short, transient global warming event, known as hyperthermal, that took place ~56 Myr ago. It is the most pronounced of a series of hyperthermals taking place in front of a long-term warming trend spanning the late Paleocene to the early Eocene. The PETM is characterized by a distinct carbon isotope...
excursion (CIE) in marine and non-marine carbon-bearing sediments and fossils worldwide, caused by a major injection of $^{13}$C-depleted carbon into the ocean-atmosphere reservoirs. This injection led to a greenhouse driven global warming of 5–8°C. Associated with it are, among others, surface ocean acidification, shoaling of the carbonate compensation depth, and regional changes in the hydrological cycle.

Here, we investigated the regional paleoenvironmental evolution of shallow shelf sites from the late Paleocene into the PETM, climate-triggered changes connected to the PETM and corresponding biotic responses of benthic foraminifera. Shelf environments are unique habitats, bridging terrestrial and coastal to deep-sea environments, and are influenced by both inland hydrological conditions and oceanographic processes. Sedimentation rates are potentially high, providing a high time resolution. Hence, shelf environments represent optimal settings to study extreme climate events, like the PETM, and adjunct background conditions.

We combine benthic foraminiferal assemblage and grain size data from multiple drill sites along the U.S. Atlantic Coastal Plain (New Jersey & Maryland) to reconstruct environmental conditions across a late Paleocene shelf transect. Assemblages were diverse and heterogeneous. The sites were prone to river-influence, decreasing from the south-western sites, where a typical opportunistic, lower diverse river outflow assemblage is present (dominated by *Epistominella* spp. and *Bulimina virginiana*), to the south-eastern sites, where a more open marine, stable setting allowed for a high diverse assemblage (*Cibicidoides* spp., *Alabamina midwayensis*, *Anomalinoides compressus*, *Bulimina* spp., *Paralabamina lunata*), to the northern, distal sites, which offer a deeper, more open marine environment (presence of *Bulimina hornerstownensis* and *Gavelinella beccariformis*). The southern domain is strongly influenced by high food availability, indicated by high occurrences of *Bulimina virginiana,* which is relatively reduced in the northern domain. Bottom waters are oxic throughout the shelf, as shown by the constant occurrence of various *Cibicidoides* species and/or *Anomalinoides compressus*.

In contrast, the PETM shelf assemblage is poorly diverse and more homogeneous. During the PETM, the shelf becomes river-dominated with strongly reduced currents, resulting in the accumulation of fine-grained, silty-clayey sediments with high foraminiferal abundances in excellent preservation. Episodic low-oxygen conditions, caused by river-induced stratification allowed the less diverse, but opportunistic PETM fauna to thrive (*Pulsipherinona prima*, *Anomalinoides acutas*, *Pseudouvginerina wilcoxensis*, *Tappanina selimens*, and *B. virginiana*), while the Paleocene assemblage nearly vanishes from the record. Some of the typical PETM taxa show environmental preferences of river influence and water depth for their habitat (*Spiroplectinella laevis*, *Tappanina selimens*, *A. acutas*) in their distribution across the shelf transect. The food input remains high, but may evolve to a more pulsed input. During the recovery phase of the PETM, a renewal of bottom currents lead to better oxygenated bottom waters, with a more continuous food supply. Late Paleocene taxa (*Cibicidoides* spp., *Paralabamina lunata*) together with new taxa (*Bulimina callahani*) gradually reappear in the assemblage, while the dominant taxa of the PETM start to decrease in abundances. Despite the great environmental perturbation, no increased extinction rate is observed, hinting towards the presence of refugia along the shelf.

### Surface water variations during MIS 44 to MIS 50 (1.36-1.5 Ma) on the Southern Portuguese Margin – evidence from planktonic foraminifera and biomarker data

**DUQUE-CASTAÑO Monica1,2*, VOELKER Antje H.L.1,2 and RODRIGUES Teresa1,2**

1Divisão de Geologia e Georecursos Marinhos, Instituto Português do Mar e da Atmosfera, Rua Alfredo Magalhães Ramalho, 6, Lisboa; monica.duque@ucaldas.edu.co; antje.voelker@ipma.pt; teresa.rodrigues@ipma.pt
2Centro de Ciências do Mar (CMAR), Universidade do Algarve, Campus de Gambelas, Faro, Portugal; monica.duque@ucaldas.edu.co; antje.voelker@ipma.pt; teresa.rodrigues@ipma.pt

*Corresponding author

Planktonic foraminifera are commonly used as paleoclimatic tracers and have enabled millennial-scale reconstructions of climate variability, particularly in the Quaternary. So far little is known how climatic variations in the 41 kyr world, especially prior to the Mid-Pleistocene Transition, affected the planktonic foraminifera fauna. We are, therefore, generating early Paleocene planktonic foraminiferal assemblage data for IODP Site U1387 (36°48.321′N 7°43.132′W), drilled into the Faro Drift on the southern Portuguese margin (Gulf of Cadiz) at a water depth of 559 m during IODP Expedition 339 (Meditteranean Outflow Water). Besides the faunal data itself, changes in the coiling direction of *Globorotalia truncatulinae* are recorded to infer subtropical gyre strength variations. The assemblage data is combined with *G. bulloides* and epibenthic foraminifera stable isotope data and sea-surface temperature (SST) data derived from alkenones to assess glacial/interglacial and millennial-scale climate and ecosystem changes. Here we present centennial-to-millennial-scale records for the interval from Marine Isotope Stage (MIS) 44 to MIS 50 (1.36-1.5 Ma).

The faunal data reveals the presence of subtropical to subpolar water masses at the southern Portuguese margin. Species related to subtropical surface waters are abundant throughout the record, conform with the observed alkenone SST that in general were warmer than today. During interglacial MIS 47, tropical species like *Pulleniatina obliquiloculata*, *Globorotalia crassafornis*, *Trilobatus trilobus*, and *Sphaeroidinella dehiscens* also contributed to the fauna indicating a stronger influence of tropical waters. On the other hand, the terminal stadial event of MIS 48 was marked by a high percentage (up to 60%) of *Neogloboquadrina pachyderma* accompanied by increases in the percentage of *Turborotalita quinqueloba*. This is evidence that subpolar surface water penetrated as far south as the Gulf of Cadiz and that the subtropical gyre contracted significantly.
in the eastern North Atlantic. Ongoing analysis will reveal if the same pattern can be observed for the MIS 50 to MIS 49 and MIS 46 to MIS 45 transitions and how strong the cooling was during stadial events of glacial MIS 48, MIS 46, and MIS 44. The already available assemblage data also revealed the presence of extinct species Neogloboquadrina atlantica dextral and Globigerinoides obliquus and their extinction dates and ecological preferences will be further explored in the future.

**Dysoxia in shallow benthal marine deposits of the island of Rhodes (Greece) during the Plio-Pleistocene**

EICHER Daniela1*, SCHMIEDL Gerhard1,2, TITSCHACK Jürgen3,4, TRIANTAPHYLLOU Maria5, FERREIRA Malu1 and MILKER Yvonne1,2

1Institute for Geology, University of Hamburg, Bundesstrasse 55, 20146 Hamburg, Germany; daniela.eicher@uni-hamburg.de; gerhard.schmiedl@uni-hamburg.de; malu.ferreira@uni-hamburg.de; yvonne.milker@uni-hamburg.de;
2Center for Earth System Research and Sustainability (CEN), University of Hamburg, Bundesstrasse 55, 20146 Hamburg, Germany; gerhard.schmiedl@uni-hamburg.de; yvonne.milker@uni-hamburg.de;
3MARUM·Center for Marine Environmental Sciences, Leobener Straße 8, 28359 Bremen, Germany; jitschack@marum.de;
4Senckenberg am Meer, Marine Research Department, Südstrand 44, 26382 Wilhelmshaven, Germany; jitschack@marum.de;
5Faculty of Geology and Geoenvironment, University of Athens, Panepistimioupolis 15784, Athens, Greece; mtriant@geo1.uoa.gr;
*Corresponding author

During the Plio-Pleistocene, the eastern Mediterranean Sea was influenced by orbital-driven climate changes, and sapropel formation occurred periodically during the minima in the precession cycle and associated shut-down of deep-water formation. The fossiliferous marine sediments of the Lindos Bay Formation, outcropping along the east coast of the island of Rhodes, provide an excellent fossil record to analyse to what extent the marine environments off the island of Rhodes were influenced by the oceanographic changes during the Plio- and Pleistocene.

Here, we present two new Late Pliocene to Early Pleistocene benthic foraminiferal records from the Plimiri section, located at the south-east coast of the island of Rhodes. Indicated by the recurrent dominance of eutrophic indicator species (genera Brizalina, Rectuvigerina, Stainforthia) and a decline in foraminiferal diversity, we found evidence of a periodic occurrence of dysoxic conditions at the seafloor, which can be linked to the sapropel events of the deep eastern Mediterranean basins. While the Late Pliocene record shows three dysoxic layers with up to one meter thickness each, the younger Early Pleistocene record shows only one event of a few centimetres thickness. Increased fresh-water and nutrient inputs from the island are likely responsible for enhanced primary productivity, resulting in the evolution of oxygen-deficient conditions in bottom-waters of the highly tectonically-structured island shelf. This onshore influence can be related to a river system fitted along NW-SE trend lineaments that are more prominent in the south-eastern part of the island.

The deposition of the dysoxic Plimiri sediment layers likewise reflect periods of restricted water exchange with the open ocean due to the deposition in a bay or semi-enclosed basin, which further fostered the establishment of bottom water oxygen deficiency.

**Methods for Classification of Epilithic Benthic Foraminifera of the Southeastern Clarion-Clipperton Zone**

ELKIN Adam1, LAM Tristan1*, O’MALLEY Bryan1, QUIAMBAO Rafael1 and SCHWING Patrick1

1Marine Science and Geoscience Disciplines, Eckerd College, 4200 54th Ave S, St. Petersburg FL, 33711, USA; amelkin@eckerd.edu; tslam@eckerd.edu; bjomaline@eckerd.edu; mrquiamb@eckerd.edu; schwintp@eckerd.edu
*Corresponding author

The Clarion-Clipperton Zone (CCZ) in the equatorial Pacific Ocean is home to a diverse community of undescribed foraminifera and foraminifera-like lifeforms that rely on polymetallic nodules for habitat. Encrusting and attached foraminifera are dominant components of all biological size classes (meio-, macro-, mega-) in nodule fields. However, despite increased exploration and sampling efforts in the CCZ, the characterization of nodule associated foraminifera remains poor. It is necessary to characterize these epilithic communities to establish baseline taxonomic knowledge of the CCZ. Additionally, epilithic organisms, such as encrusting foraminifera, komokiaceans, and xenophyophores, are vulnerable to deep-sea mining (DSM) impacts, namely direct removal of hard substrate and burial from sediment plumes. Ecological baselines are necessary in understanding natural abundances and variabilities in foraminiferal assemblages, as well as impacts of DSM.

Nodule assemblages from multicore sites in the NORTI-D lease area were analyzed using photography, microscopy, and morphological taxonomy. Whole nodules were photographed at sea using a DSLR camera, while individual foraminifera and quadrats of nodules were captured in the laboratory using a stereomicroscope equipped with a digital camera. Sets of photos were taken at varying depths of field by incrementally adjusting the camera or microscope focus. These photos were then fed into focus stacking software to create images with a greater depth of field and to ensure that the entire nodule/foraminifera was in focus. The resulting images were then incorporated into an interface that enables the user to select specific individuals within a whole nodule image bringing them to the microscope photo. This is particularly useful in determining life mode, size, and morphological characteristics. Using these photos, all foraminifera found on the nodule were identified and classi-
Biominalization and proxies in foraminifera

EREZ Jonathan1*, HAUZER Hagar1,2, MOR-KHALIFA Gal3, BENTOV Shmuel1 and EVANS David4

1The Freddy & Nadine Herrmann Institute of Earth Sciences, The Hebrew University of Jerusalem, Givat-Ram, Jerusalem 91904, Jerusalem, Israel; Jonathan.erez@mail.huji.ac.il
2Israel Oceanographic and Limnological Research, National Institute of Oceanography, Haifa, 3108000, Israel; Hagar.hauzer@mail.huji.ac.il
3Ellalemelbaum institute for Immuno-oncology, Sheba Medical Center, Derech Sheba 2, Ramat Gan, Israel; galmor26@gmail.com
4School of Ocean and Earth Science, University of Southampton, Southampton, SO14 3ZH, UK; D.Evans@soton.ac.uk
*Corresponding author

Biominalization and proxy incorporation in hyaline (calcitic radial, perforated) foraminifera is of great scientific interest because they are major CaCO3 producers in the ocean and play a significant role in determining the carbonate chemistry of the oceans and hence atmospheric CO2. A substantial portion of the information we have on paleoceanographic and paleoclimatic changes for the Cenozoic (the last 65 Ma) is based on the sedimentary archive of planktic and benthic foraminifera in ocean drillings and in a few geological land sections. In addition to being important for stratigraphy and paleo-ecology the most crucial quantitative information is obtained from geochemical proxies in foraminifera shells (i.e. δ18O, δ13C, Δ147, δ11B, Mg/Ca, and other trace and minor elements). The use of these proxies was, and still is, largely based on empirical field calibrations. Very few laboratory calibrations on live foraminifera were performed during the last 50 years and these were able to narrow more precisely the effects of specific environmental conditions (i.e. temperature, water chemistry etc.) on the shell chemistry and isotopes. Regardless of the methods used, it is clear that vital effects are observed in foraminifera and other biogenic archives such as coccolithophores and corals. Therefore, knowledge of the mechanisms of biominalization is essential in order to extract more reliable environmental information from proxies in foraminiferal archives.

In the past 30 years, modern methods including electron microscopy, fluorescent confocal microscopy and microanalysis were developed and used to investigate the biominalization of foraminifera using specific preparations (ameboids and recovering individuals) mainly of Amphistegina lobifera and several species of planktic foraminifera. The most important finding of these studies is that the main pathway for ions (Ca, CO3, trace and minor elements) for calcification is seawater endocytosis, which is a key process in these large unicellular organisms. Seawater vacuoles (SWV), contain ~10 mM of Ca and ~2 mM DIC. To maximize the efficiency of calcite precipitation from seawater these organisms elevate the pH of the SWV and accumulate DIC from CO2 diffusion into the SWV. This requires continuous alkalinity increase which is most probably achieved by proton/sodium exchangers. In some cases, Ωcalcite in the SWV is so high that amorphous CaCO3 (ACC) is precipitated and the SWV shrinks (by a factor of 500-1000) to form numerous ACC vesicles. These ACC vesicles are rich in trace elements (particularly Mg), and the large bentic foraminifera (e.g. Operculina ammonoides) are using this pathway to make shells of high Mg calcite. Other species including the planktic and deep benthic species use similar SWV but remove the Mg to lower concentrations and elevate the pH and DIC, thus precipitating low Mg calcite. Some species (e.g. Amphistegina spp.) probably use both strategies. We will show microscopic and geochemical evidence to support the mechanisms described above for hyaline foraminifera.

In contrast, a completely different strategy is taken by coccolithophores that channel and pump the ions needed for their intracellular calcification through their membrane and into the coccolith vesicle. This was directly observed using TEM and geochemical information although the function of their shells remains unresolved. The difference between these two groups of calcareous plankton, which both emerged in the Mesozoic, highlights the diverse pathways that evolution has used to cope with past changes in seawater chemistry.

Determining the role of seawater vacuolisation in the biominalisation process of the planktonic foraminifera using confocal microscopy

EVANS David1 and EREZ Jonathan2*

1School of Ocean and Earth Science, University of Southampton, SO14 3ZH, UK; d.evans@soton.ac.uk
2The Freddy & Nadine Herrmann Institute of Earth Sciences, The Hebrew University of Jerusalem, Jerusalem 91904, Israel; jonathan.erez@mail.huji.ac.il
*Corresponding author
The principal mode of delivery of the ions necessary for calcification to the biomineralisation site of foraminifera is poorly constrained, and may differ between different species. Specifically, much research in the last two decades has focused on determining whether the Ca\(^{2+}\) required for shell formation is delivered via trans-membrane ion transport or seawater vacuoles, with the importance of both processes having been argued for. In addition, amorphous and/or metastable precursor phases have been implicated in foraminifer biomineralisation, but their presence and role in calcification is yet to be conclusively shown. The vast majority of the direct observational evidence for these transport processes is derived from shallow-dwelling benthic foraminifera, yielding an enormous amount of valuable information, yet it is not clear whether these observations are applicable to the planktonic species widely used in palaeoceanography.

In order to address these knowledge gaps, we conducted a set of experiments designed to understand the importance of seawater vacuolisation in the planktonic foraminifera using confocal microscopy coupled with membrane-impermeable fluorescent probes (calcein, FITC, SNARF). We applied this technique to both intact specimens and recovering individuals that were decalcified using EDTA, the latter in order to more easily examine intra-cellular processes using confocal microscopy.

Our results demonstrate that at least two species of planktonic foraminifera, *Globigerinoides ruber* and *Globigerinella siphonifera*, vacouls large quantities of seawater (tens of percent of the volume of the cell may consist of these vacuoles), and that the vacuoles have a residence time in the cell of a few hours. The quantity and residence time of these vacuoles is consistent with the hypothesis that seawater vacuolisation is the dominant or only source of Ca\(^{2+}\) for calcification. Over the course of ~1 day, these vacuoles are replaced by smaller, non-polarising, strongly fluorescent (calcein) vesicles, which may thus consist of amorphous carbonate. In both recovering/decalcified individuals and intact specimens, we observe that the shell is calcein/FITC-labelled, demonstrating the presence of seawater and/or metastable/amorphous precursor phases precipitated from seawater at the biomineralisation site. These observations are the same, or very similar, to those of several species of benthic foraminifera, highlighting that diverse groups of foraminifera with contrasting shell chemistry (e.g. high/low-Mg calcite) are characterised by similar transport mechanisms.

Overall, our data demonstrate that seawater vacuolisation is very likely to be the dominant ion transport process in the planktonic foraminifera, and that the shells of planktonic foraminifera are excellent recorders of their environment because seawater transport is a major component of the calcification process.

**Bridging the gap: unravelling the fossil record of extant *Globigerina falconensis***

FABBRINI Alessio\(^1\), GRECO Mattia\(^2\), KUCERA Michal\(^3\), EZARD Thomas\(^4\) and WADE Bridget S.\(^1\)

\(^1\)Department of Earth Sciences, University College London, Gower Street, London, WC1E 6BT, UK; a.fabbrini@ucl.ac.uk; b.wade@ucl.ac.uk;
\(^2\)Institute of Oceanology, Polish Academy of Sciences, 81-712, Sopot, Poland; mgreco@iopan.pl;
\(^3\)MARUM – Center for Marine Environmental Sciences, University of Bremen, Leobener Str. 8, D-28359, Bremen, Germany; mkucera@marum.de;
\(^4\)National Oceanography Centre, Waterfront Campus European Way, Southampton, SO14 3ZH, UK; t.ezard@soton.ac.uk

*Corresponding author

The fossil record of planktonic foraminifera is full of numerous riddles, which need to be addressed to fully understand the evolution and phylogeny of this group of protists. We studied extant and fossil specimens of the planktonic foraminifera *Globigerina falconensis* plexus using an integrated approach combining biometry and genetic data. Morphological inconsistencies emerge between the fossil and extant populations which require taxonomical clarifications, since *Globigerina falconensis* is widely used in palaeoceanographic studies in conjunction with its sister taxon *Globigerinella bulloides*.

Morphologically *G. falconensis* and *G. bulloides* are similar, with the main difference being the distinctive apertural lip present in *G. falconensis*, still making their classification challenging. Thus, we selected cores covering the entire stratigraphic range of *G. falconensis*, from the early Miocene to modern, from oceanic sites at high latitudes in the North Atlantic Ocean and the southern Indian Ocean to sites in equatorial regions. The inconsistent morphology of the modern populations distinguishes them clearly from the Miocene holotype of *Globigerina falconensis* Blow described from lower Miocene sediments in Venezuela. The fossil types do not belong to the same taxon as the living species. A more lobate morphology evolved in the late Miocene, thus requiring a new name for the modern individuals. We thus suggest and describe a new morphospecies, which evolved in the late Miocene and still inhabiting the modern oceans. The morphological inconsistencies affect potentially the higher level of classification of these species, presenting a pseudocancellate wall texture. We used the molecular sequences from the PR2 database to reassess the generic attribution of the *G. falconensis* lineage, confirming its close relationship with *G. bulloides* and its retention in the genus *Globigerina*.

**On the traces of the forgotten marker *Globigerina bollii*: an endemic species from the Mediterranean Langhian?**

FABBRINI Alessio\(^1\), PETRIZZO Maria Rose\(^2\), PREMOLI SILVA Isabella\(^2\), FORESI Luca M.\(^3\) and WADE Bridget S.\(^1\)

\(^1\)Department of Earth Sciences, University College London, Gower Street, London, WC1E 6BT, UK; a.fabbrini@ucl.ac.uk; b.wade@ucl.ac.uk;
Globigerina bollii Cita & Premoli Silva was described from middle Miocene sediments in 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 it was only reported for a short and limited 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 ending its use in biostratigraphic schemes, and no longer utilised by authors working in the Mediterranean and Paratethys. We present here a reassessment of Globigerina bollii, showing for the first time a full collection of high quality SEM and optical images of the type series of specimens, and a comparative study with Mediterranean individuals from the Langhian of Cretaccio Section (Italy) and extra-Mediterranean individuals from ODP Site 747 in the Kerguelen Plateau (Indian Ocean). We document the stratigraphic range of all the occurrences cited in the scientific literature from 1960 to the present day, and all the references including images of the taxon.

We compare here G. bollii to other morphyspecies inhabiting the oceans during the middle Miocene, providing a detailed discussion of their morphological differences, which allow us to retain G. bollii a valid taxon and to cancel its synonymy with Globigerina falconensis. Our taxonomical observations also allow us to conclude that Globigerina bollii should be reassigned to the genus Globoturborotalita, due to its strong affinities with other members of that genus such as G. eolabiocrassata Spezzaferri & Coxall, and G. ouachitaensis Wallace. We present a direct visual comparison with the other representatives of the potentially related plexus. An additional comparison is also discussed with Globigerina bollii lentiana Rogl, which was retained the ancestor of G. bollii and endemic of the Paratethys. We conclude that the presence of G. bollii in the Mediterranean during such a confined stratigraphic range (Mediterranean Zone MMi4c-MMi4d), coeval to other biostratigraphic events, such as Paragloborotalia siakensis acme, and the evolution of Orbulina suturalis, might be an indicator of the tropicalisation of the Mediterranean faunas during the Langhian. This time interval coincides with the Miocene Climatic Optimum (MCO) and the Monterrey Excursion, thus we suggest that G. bollii represents a regional occurrence of warmer globoturborotalids.

Phyodetritus-colonising living (Rose Bengal stained) benthic foraminifera during a spring phytoplankton bloom in the Arctic Ocean

FAIZIEVA Kamila1*, WOLLENBURG Jutta2, HEINZ Petra1 and WUKOVITS Julia1

1Department of Palaeontology, University of Vienna, Josef-Holubek-Platz 2 (UZA II), 1090, Vienna, Austria; kamila.faizieva@univie.ac.at; petra.heinz@univie.ac.at; julia.wukovits@univie.ac.at
2Alfred Wegener Institute for Polar and Marine Research, Handelshafen 12, 27570, Bremerhaven, Germany; jutta.wollenburg@awi.de
*Corresponding author

The Arctic Ocean represents a highly sensitive area subjected to ongoing drastic environmental shifts, for instance, atlantification, an increasing influence of advected Atlantic waters due to gradually rising temperatures and salinities. The change in physical properties of Atlantic waters is causal for a thinning sea-ice cover impacting the timing of spring phytoplankton blooms which develop progressively earlier and often as under-ice blooms. The occurrence of spring phytoplankton blooms leads to episodic export pulses of detrital organic material to the seafloor. Exported and cryogenic mineral ballasted algae aggregates are observed on the seafloor as a phytodetrital layer. The phytodetritus serves as a food source and habitat for marine benthos, especially benthic foraminifera (BF). They represent primary consumers of fresh phytodetritus, and certain species of BF are able to colonise the layer actively. Here we present results on the foraminiferal faunal composition in freshly accumulated phytodetritus and surface sediments during a spring phytoplankton bloom in the Arctic Ocean.

During the expedition PS92 of the research vessel POLARSTERN (19/05/2015-28/06/2015), surface sediments with associated phytodetritus samples were collected on the northern marginal shelf of Svalbard, Yermak Plateau, and Sophia Basin. Sampling water depths ranged from 219 m to 2175 m. For analysis of living (Rose Bengal stained) BF from the pure phytodetritus, a one-way pipette was used to take volume-defined phytodetritus samples of 1 to 2 ml. At the same site, a total volume of 84.8 ml of surface sediments was collected from 0-1 cm sediment depths. Living benthic foraminifera of both sample sets were investigated in the >63 μm size fraction; the sediments were separated into size fractions 63 μm-2 mm and >2 mm. The results from the phytodetritus are compared to the sediment.

Faunal composition, species dominance and abundance in the phytodetritus and sediments vary depending on the sampling location. The standing stock of BF in the phytodetritus was around 15 times higher than in the surface sediments, and the composition between both was very different. The phytodetritus was populated in total by 84 species belonging to 61 genera, and species richness ranged from 33 to 57. Well-known phytodetritus epifaunal species (e.g., Alabaminella weddelensis, Epistominella arctica), as well as shallow infaunal ones (e.g., Cassidulina reniforme) colonised and thrived in the phytodetritus. The number of living species in sediment samples was significantly less diverse than in the phytodetritus.
Thus, in total, the sediments yielded 58 species. The fine fraction (63 μm-2 mm) was mostly populated by deep-infaunal living species (e.g., Melonis zaandami), and epifaunal specimens (e.g., Nonionella iridea, Ioanella tumidula). The epizoic species with high numbers of presumably juvenile Crithionina cushmani were found in the coarse fraction (>2 mm). The presence of various fragments of “primitive” living BF (e.g., Archimerismus, Aschemonella, Bathysiphon, and others) was also documented in the sediments.

The comparative investigations showed that the phytodetritus accumulated on the Arctic Ocean seafloor was rapidly invaded by a large number of BF that are uncommon in the underlying sediment. In addition, the phytodetritus is populated by epibenthic and endobenthic specimens that nourish on it based on bright green protoplasm observations.

**Taxonomic revision of some textulariinid benthic foraminifera of the Triassic-Jurassic boundary interval**

**FALZONI Francesca**1,2, GALE Luca3,4, RETTORI Roberto5, WEINMANN Anna6, PARENTE Mariano7

1Dipartimento di Scienze della Terra, dell’Ambiente e delle Risorse (DISTAR), Università degli Studi di Napoli Federico II, via vicinale cupa Cinta 21, 80126 Napoli, Italy; francesca.falzoni@unina.it; mariano.parenre@unina.it
2Istituto di Geologia Ambientale e Geoginegneria, Consiglio Nazionale delle Ricerche, via Mario Bianco 9, 20131 Milano, Italy; francesca.falzoni@igag.cnr.it
3Department of Geology, University of Ljubljana, Alkerčeva 12, 1000 Ljubljana, Slovenia; luka.gale@ntf.uni-lj.si
4Geological Survey of Slovenia, Dimičeva 14, 1000 Ljubljana, Slovenia; luka.gale@geo-zs.si
5Department of Fisica e Geologia, Università degli Studi di Perugia, Palazzina di Scienze, Piazza Università, Perugia, Italy; roberto.rettori@unipg.it
6Department of Geology & Paleontology, Natural History Museum Vienna, Burgring 7, 1010 Vienna, Austria; anna.weinmann@nhm-wien.ac.at
7*Corresponding author

Textulariinid benthic foraminifera represent an important component of Mesozoic assemblages and are found in the marine realm from carbonate platform to deep-water settings. However, the taxonomic classification of several taxa and their phylogenetic relationship are uncertain, because several species are described in thin section and the diagnostic features of the wall texture (e.g., the presence of pores) and of the primary aperture (position, morphology) are often not visible. Vice versa, problems with the determination also arise when species are described from washed residues, and the isolated type specimens are compared with morphotypes encountered in thin section studies.

The species belonging to the Duotaxis-Tetrataxis morphogroup and to the genus Trochammina described from Triassic levels are among the taxa that require taxonomic revision. The type species of the genus Tetrataxis (i.e., Tetrataxis conica Ehrenberg) was described from Carboniferous strata and shows a calcareous microgranular double-layered wall typical of fusulinids, whereas Late Triassic Tetrataxis species (T. inflata Kristan, T. humilis Kristan, T. nanus Kristan-Tollmann) are characterized by an agglutinated wall typical of the textulariinids. The range of Carboniferous and Triassic species is also separated by a significant stratigraphic gap. It has been suggested, but not yet supported by taxonomic studies, that these species should rather be placed in the genus Duotaxis Kristan, which currently comprises two species both described from the Triassic. Similar discrepancies exist for the genus Trochammina. Its type species, Trochammina inflata Montagu (type level: Recent) has a finely agglutinated and organic cemented imperforate wall and its primary aperture is an arch covered by a narrow lip in extraumbilical-umbilical position. In contrast, the holotype of the only Triassic species, Trochammina alpina Kristan (type level: Rhaetian) described from washed residues, has an agglutinated wall that is likely cemented by calcite, and the primary aperture is fully umbilical in position and has no arch. The other “Trochammina” species described from Triassic levels (e.g., Trochammina almtalensis Koehn-Zaninetti, Trochammina tabasensis Bronnimann, Zaninetti, Moshtagian and Huber) were described from thin sections.

The aim of this study is to re-illustrate the type specimens of the Triassic species of Duotaxis, Tetrataxis and Trochammina previously known only from the original drawings or low-quality microphotographs, with high-resolution stereo-, optical, and Scanning Electron Microscope (SEM) images. Furthermore, we compare these images with specimens from thin sections and washed residue samples collected from several Tethyan localities (Valle Agricola and Mt. Sparagio in Southern Italy, Mt. Messapion in Greece, Western Black Sea Shelf in Romania, Fonsjoch in Austria) and from different depositional environments (carbonate platform to shelf) with the aim to evaluate their external and internal morphologic variability.

Results of this study will produce a taxonomic revision of several textulariinid lineages and will better constrain the species stratigraphic ranges across the Triassic-Jurassic boundary interval, with the ultimate goal of providing new information to more accurately estimate the biodiversity loss across the end-Triassic mass extinction and the evolution of new taxa during the following recovery phase.
A causal link between re-organization of ocean circulation patterns during Oceanic Anoxic Event 2 and extinction of Rotaliporidae

FALZONI Francesca1°, PETRIZZO Maria Rose2, AMAGLIO Giulia3 and MACLEOD Kenneth G.3

1Istituto di Geologia Ambientale e Geoingegneria, Consiglio Nazionale delle Ricerche, via Mario Bianco 9, 20131 Milano, Italy; francesca.falzoni@igag.cnr.it
2Department of Geoscience della Terra “A. Desio”, Università degli Studi di Milano, via Mangiagalli 34, 20133 Milano, Italy; mrose.petrizzo@unimi.it; giulia.amaglio@unimi.it
3Department of Geology, University of Missouri–Columbia, 101 Geological Sciences Building, Columbia, Missouri; MacleodK@missouri.edu
*Corresponding author

The Cenomanian–Turonian Oceanic Anoxic Event 2 (OAE 2) is a severe perturbation of the global carbon cycle induced by enhanced volcanic activity within one or more Large Igneous Provinces (LIPs) that injected huge amounts of volcanogenically derived greenhouse gases in the ocean-atmosphere system and likely coincided with the highest sea-surface temperatures of the Late Cretaceous. The greenhouse mode of OAE 2 was temporarily interrupted by a 5 to 11°C drop in sea-surface temperatures known as Plenus Cold Event (PCE) recognized in several European epicontinental basins, in the Western Interior Seaway (WIS) and in the Atlantic Ocean. Broadly coeval to the PCE, a repopulation event of benthic foraminifera (Benthonic Zone) in the WIS and a geochemical fingerprint for oxidation in several European epicontinental basins suggest a re-oxygenation phase of bottom waters that temporarily interrupted dysoxia/anoxia at the sea floor.

Planktonic foraminifera extinctions during OAE 2 involved the large-sized, deep-dwelling rotaliporids, which were common in late Cenomanian, oligotrophic tropical-subtropical assemblages. The cause(s) for this extinction is still poorly constrained. Candidates include expansion of the oxygen minimum zone (OMZ), ocean acidification, collapse of the thermocline under global warming during OAE 2, or cooling and water-mass reorganization in northern Europe during the PCE combined with expansion of the OMZ at lower latitudes.

This study documents quantitative changes in planktonic and benthic foraminiferal from two European key-localities, Eastbourne (Anglo-Paris Basin, SE England) and Clot Chevalier (Vocontian Basin, SE France). Results are combined with published micropaleontological (planktonic and benthic foraminifera) and geochemical data (e.g., TEX, δ18O, εNd) resulting in a highly-resolved reconstruction of biotic and oceanographic changes in sea-surface and at the water-sediment interface at upper bathyal depth within OAE 2. The data demonstrate synchronicity between sea-surface cooling (PCE), oxygenation of bottom waters (Benthonic Zone), changes in sea-surface and intermediate circulation patterns (εNd shifts) and extinction of rotaliporid planktonic foraminifera throughout the European epicontinental seas, Tethyan, Atlantic Ocean, and Western Interior Seaway. We suggest that the southward expansion of cool, relatively low saline and mesotrophic Boreal waters in the Northern Hemisphere during the PCE disrupted sea-surface thermal stratification at tropical latitudes and critically contracted the ecological niche occupied by rotaliporids playing a fundamental role in their extinction.

Diet controls foraminiferal nitrogen isotopes: a feeding experiment on T. sacculifer

FANG Wei-Ning1°,2, BRANSON Oscar1, YANG Er-Wen2, SPERO Howard J.3,4 and FEHRENBACKER Jennifer S.3

1Department of Earth Sciences, University of Cambridge, Downing Street, Cambridge, UK; wnf21@cam.ac.uk; ob266@cam.ac.uk
2Department of Geosciences, National Taiwan University, No. 1 Sec. 4 Roosevelt Road, Taipei, Taiwan; erwenyang.1997@gmail.com; abbyren@ntu.edu.tw
3Departmen Earth & Planetary Sciences, University of California Davis, 1 Shields Avenue, Davis, USA; hjspero@ucdavis.edu
4College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, 104 CEOAS Administration Building, Corvallis, USA; jennifer.fehrenbacher@oregonstate.edu
*Corresponding author

The isotopes of organic nitrogen (N) preserved in foraminiferal shells have been developed as a proxy for past ocean nutrient conditions. This proxy is based on the assumption that the N isotopes (δ15N) incorporated into the tests of heterotrophic foraminifera track the N isotopic composition of their diet. This is supported by modern seasonal covariations of δ15N between foraminifera and particulate organic matter. However, little is known about the underlying mechanisms that translocate N from diet into foraminiferal soft tissue, and finally embedded into their mineralised shells.

We investigated the mechanism of N incorporation into foraminiferal tests by feeding living planktic, dinoflagellate-bearing Trilobatus sacculifer with two strains of brine shrimp (Artemia) with different naturally 15N-enriched isotopic compositions. The evolution of δ15N through the feeding experiment was examined by dissecting individual chambers and grouping them by the order of their growth sequence. The δ15N of the dissected chambers and remaining soft tissue were measured. Both feeding groups show that the shell δ15N and the soft tissue δ15N are elevated, representing a mixing of original biomass N and new N from the food intake. However, the shell-bound and the soft tissue N show different mixing behaviours: shell δ15N rapidly approaches diet δ15N, while soft-tissue δ15N represents a mixed signal between the original
biomass and total diet intake. This observation suggests that the N-rich biomineralising organics incorporated into the shell are sourced from N in recently metabolised food particles, rather than the average soft-tissue N pool in the foraminifera. These results will be presented and discussed in context of foraminiferal N metabolism, and the use of $\delta^{15}$N as a tracer for past nutrient conditions.

A new species of Eoparafusulina (Fusulinacea, Monodexodininae) from the Lower Permian of the Northwest Peninsular Malaysia: Its significance to Sibumasu Block (Eastern Cimmerian Continent) palaeobiogeography and palaeoclimatology

FASSIHI Shirin1*, VACHARD Daniel2,3, HEINZ Petra1 and HASSAN Meor Hakif Amir4

1University of Vienna, Department of Palaeontology, Althanstrasse 14, UZA II Geozentrum, 1090 Vienna, Austria; fassihis22@univie.ac.at; petra.heinz@univie.ac.at
2University of Lille-Sciences and Technologies, UMR CNRS 8198 Evo-Eco-Paléo, 59655 Villeneuve d’Ascq cedex, France; Daniel.Vachard@free.fr
3CIRCAS, 1 rue des Tilleuls, 59152 Gruson, France; Daniel.Vachard@free.fr
4Department of Geology, University of Malaya, Faculty of Science, Department of Geology, 50603 Kuala Lumpur, Malaysia; meorhakif@um.edu.my
*Corresponding author

A new species of Eoparafusulina, i.e., *Eoparafusulina perlisensis* sp. nov. is described from the Lower Permian sandy limestone in the Kubang Pasu Formation in Perlis of the Northwest Peninsular Malaysia. Previous Malaysian authors reported the occurrence of *Monodexodina shiptoni* and *Monodexodina satschanica* from the same area. The findings of this study, nevertheless, enabled us to have a better overview on the Early Permian fusulinoidae fauna found in this region. The described new species has an almost symmetrical, and elongated subcyindrical shell somewhat similar to *Monodexodina* described by Sosnina, 1956. Owing to its proloculus, juvenarium, and septal folding, however, this species corresponds to an advanced species of *Eoparafusulina* (sensu lato). These lines of evidence suggest that the specimens reported before in the Kubang Pasu Formation are morphologically transitional forms to *Monodexodina*, and they are not really a *Monodexodina* (sensu stricto). Therefore, they should be included in the genus *Eoparafusulina*, too.

The late Sakmarian–early Yakhtashian (Late Cisuralian; late Early Permian) age of the investigated biozone is clearly indicated by the presence of fusulin-markers like *Alaskanella*, *Eoparafusulina*, and *Pseudo fusulina*. The genus *Eoparafusulina* is generally the characteristic element to determine the early Asselian–early Yakhtashian (= Artinskian) age in many sections world-wide. However, owing to the presence of *Alaskanella* which its age is considered to be late Early Permian close to the Sakmariian/Yakhtashian boundary, the age of the Kubang Pasu Formation is defined as the late Sakmarian–early Yakhtashian, not the late Yakhtashian–Bolorian that was previously suggested by the Malaysian workers.

The impoverished genera diversity in the Kubang Pasu Formation reveals that during the Asselian (early Early Permian), the Northwest Peninsular Malaysia was still part of the Gondwana continental shelf. It probably rifted from the Gondwana margin and started to drift towards equatorial regions during the late Asselian or early Sakmarian. The northward movement of Sibumasu Block during the late Early Permian is especially evident in the development of the found fusulindis in this work. During the late Early Permian, besides, the Northwest Peninsular Malaysia was located not far from the East Malaya (the Central and Eastern belts), but in the higher paleolatitudes subtropical region.

The microfacies analysis of the Kubang Pasu Formation suggests a very high-energy shallow marine warm environment, more likely of the sand shoal.

Long-Term Evolutionary Trends within Benthic Foraminifera

FAULKNER Katherine1*, LOWERY Christopher2, MARTINDALE Rowan3, SIMPSON Carl1 and FRAASS Andy4

1Department of Geological Sciences, The University of Texas at Austin, 2275 Speedway, Austin, Texas, 78712, USA; katherinefaulkner@utexas.edu; Martindale@jsg.utexas.edu
2University of Texas Institute for Geophysics, Jackson School of Geosciences, University of Texas at Austin, Austin, TX, USA; cmlowery@utexas.edu
3University of Colorado Museum of Natural History and Department of Geological Sciences, University of Colorado Boulder, Boulder, CO, USA; Carl.Simpson@Colorado.edu
4School of Earth and Ocean Sciences, University of Victoria, Victoria, BC V8P 3E6, Canada; andyfraass@uvic.ca
*Corresponding author

Foraminifera are important archives of paleo-oceanographic information that have evolved and diversified throughout the Phanerozoic. Their tests’ mineralogy may reflect significant changes in global climate and ocean conditions. These organisms originated as organic walled and agglutinated forms before evolving calcareous tests in the early Silurian. It is logical to expect test wall type to vary through time as a result of global environmental and evolutionary changes. In this project, genus-level information was aggregated from *Foraminifera Genera and their Classification*, published by Loeblich and Tappan in 1988, the most recent and commonly used reference literature for foraminiferal genera. Our dataset includes the accepted name, wall type, first occurrence, and last occurrence information for 3,114 taxa. Using this data, we specified
2,442 genera, binned by Epoch level, tracked wall-type diversity, compared the ratios of calcareous versus agglutinated foraminifera, and contextualized foraminiferal responses to geologically significant events. Major findings include a high relative proportion of organic foraminifera from the Cambrian to the Ordovician Period. Calcareous foraminifera evolved in the Early Silurian and increased in relative proportions from the Silurian to the Devonian. There are notable decreases in relative abundance of calcareous foraminifera during the mid-Carboniferous warming, the Early Triassic Epoch, and the Triassic/Jurassic mass extinction event. Despite documented climatic fluctuations throughout the Cenozoic, calcareous foraminifera remain stable around 80% diversity from the Eocene through the Pleistocene. Comprehensive datasets such as this are essential for research about faunal diversity and paleoclimate records, ocean chemistry, and conservation. This data has the potential to inform global trends of benthic foraminifera and ocean chemistry throughout the Phanerozoic.

The geochemistry of non-spinose foraminifera: What is it good for?

FEHRENBACHER Jennifer1, LANE Mary Kelsey1, FRITZ-ENDRES Theresa1,2, HUPP Brittany3,4,5, DAVIS Catherine6, BRANSON Oscar6, REN Abby7, VETTER Lael8 and SPERO Howard9

1School of Earth, Ocean, and Atmospheric Sciences, Oregon State University, 101 SW 26th Street, Corvallis, OR 97330; jennifer.fehrenbacher@oregonstate.edu
2Pacific Ecological Systems Division, US EPA, 200 SW 35th St., Corvallis, OR 97330; fritzendres.theresa@epa.gov
3NOAA Climate and Global Change Postdoctoral Fellowship Program, CPAESS, UCAR, P.O. Box 3000, Boulder, CO 80307, USA; bhupp@gnu.edu
4Department of Atmospheric, Oceanic and Earth sciences, George Mason University, 4400 University Drive, Fairfax, VA 22030; bhupp@mu.edu
5Department of Marine, Earth, and Atmospheric Sciences, North Carolina State University, Jordan Hall, 2800 Faucette Dr., Raleigh, NC 27607; cdavis24@ncsu.edu

Over the last decade, culture experiments with non-spinose planktonic foraminifera have been performed to understand controls on trace element incorporation into shell calcite. When grown in culture, non-spinose planktonic foraminifera have relatively homogenous intrashell trace-element geochemistry for elements such as Mn, Ba and Sr. Yet, plankton tow, sediment trap, and fossil specimens from seafloor sediments have more heterogeneous trace element compositions, both intrashell and between individuals, including highly variable Zn, Mg, Mn, Ba, Sr, and likely others. Apart from Zn and Mg, this type of intrashell variability is generally absent in the spinose planktonic species. Here, we present results from the foraminifera culture experiments and specimens that completed their lifecycle in the ocean and discuss potential mechanisms responsible for the intrashell TE variability. Elevated Ba and Mn suggest many non-spinose species calcify within organic marine snow microhabitats, and thus may be useful for tracking changes in the production of particulate organic matter in the past. If non-spinose species do occupy this unique niche, it raises the question: Does the particulate microhabitat complicate the utility of other trace element proxies? We will share intrashell trace element data collected by laser ablation ICP-MS, discuss potential mechanisms related to their incorporation, and consider complications related to microhabitat environments.

Deep-sea response to interglacial-glacial variability on the South Australian margin over the last 94 ka

FENTIMEN Robin1,2, DEPUYDT Pauline1, DE DECKKER Patrick1 and MOJTAHID Meryem1

1Université d’Angers, Nantes Université, Le Mans Université, CNRS, Laboratoire de Planétologie et Géosciences, LPG UMR 6112, 49000 Angers, France; robin.fentimen@univ-angers.fr; pauline.depuydt@univ-angers.fr; meryem.mojtahid@univ-angers.fr
2Research School of Earth Sciences, The Australian National University, Canberra ACT, 2601, Australia; Patrick.DeDeckker@anu.edu.au

The continuous record offered by deep-sea sediments has been extensively used to constrain shifting continental and oceanographic conditions. Yet, past fluctuations in deep-sea benthic conditions and bottom-currents are in numerous parts of the globe scarcely documented, one such example being the South Australian margin. Indeed, though variations in surface water and terrestrial conditions in this area are well documented, little is known about benthic environments and their dynamics over the last interglacial-glacial cycle. We focus here on benthic foraminiferal assemblages sampled from a sediment core recovered at 2420 m depth from a small plateau south of Kangaroo Island within the underwater Murray Canyons Group (South Australian margin). Benthic foraminiferal assemblages show a distinct separation between interglacial and glacial periods over the last 94 ka, which can be linked to water-mass variations, shifting surface and benthic currents, together with variations in the River Murray’s input and relative position across the Laccopede Shelf. Our results show that the lowest sea-levels, markedly during the Last Glacial Maximum, coincide with the highest oxygen content at the seafloor and with the transport of allochthonous benthic foraminifera from shallow-water areas due to the relative proximity
of the River Murray’s mouth. Good seafloor oxygenation inferred from high abundances of miliolids possibly results from a greater influence of oxygen-rich Antarctic Bottom Water during the last glacial period. In contrast, fewer miliolids and greater numbers of epibenthic and phytodetritus-feeding benthic foraminiferal species during warm interglacial periods suggest a shift in benthic conditions in the area. We propose that the Deep Boundary Current, which transports low-oxygen, carbon-rich Indian Deep Water, strengthened during interglacials and favoured the proliferation of the observed assemblage. This significant change in the deep-sea domain mirrors the intensified circulation of Leeuwin Current at the surface.

Fossil benthic foraminifera from the Danakil Depression (northern Ethiopia): avian transport within an active rift valley

Robin Fentimen1*, Valentin Rime2, Francesc Angeli Fabio3, Haila Negga4, Balemwal Auma5 and Anneleen Foubert2

1Université d’Angers, Nantes Université, Le Mans Université, CNRS, Laboratoire de Planétologie et Géosciences, LPG UMR 6112, 49000 Angers, France; robin.fentimen@univ-angers.fr
2Department of Geosciences, University of Fribourg, Chemin du Musée 6, 1700 Fribourg, Switzerland; valentin.rime@unifr.ch; fabio.francescangeli@unifr.ch; haileyesussemu.negga@unifr.ch; anneleen.foubert@unifr.ch
3Department of Earth Sciences, School of Earth and Planetary Sciences, College of Natural Sciences, Addis Ababa University, P.O. Box 1176, Addis Ababa, Ethiopia; balemwal.atnafu@geol.aau.edu.et

*Corresponding author

The Danakil Depression, a rift valley reaching elevations of 125 m below sea level situated between the Ethiopian Plateau and the Danakil Alp, is one the hottest places on Earth. Evaporites precipitate within the rift basin and have done so at least since the late Pleistocene. Artisanal mining of the evaporites of the salt plain has been known since centuries. In contrast and unsurprisingly, much less knowledge has been gathered about foraminiferal faunas during past times. During the mid- to late Pleistocene, marine incursions flooded the depression at least four times, leading to the formation of fringing coral-algal reefs topped by gypsum. The two most recent marine incursions date back to MIS 5e (approximately 129 ka ago) and MIS 7 (approximately 200 ka ago). The study of a 625 m long commercial core (DAN003D) drilled by BHP Billiton in the centre of the basin allowed for a palaeoenvironmental reconstruction of the area. The core is believed to cover approximately the last 100 ka and is essentially made up of thick halite deposits, testimony of a warm and dry climate. However, two clastic-rich and clayey intervals are found within the top and bottom parts of the core, corresponding respectively to the late Pleistocene and late MIS 5e. Benthic foraminifera, essentially Ammonia spp. and Elphidium spp., and ostracods, were retrieved from these intervals and illustrated by Scanning Electron Microscopy. This microfaunal assemblage is typical of modern-day coastal shallow water environments and would suggest that the Danakil Depression was wetter than nowadays and subject to marine incursions. Yet, as evidenced by various proxies, no marine incursions took place during the deposition of Pleistocene foraminiferal-bearing sediments. We hence propose that during the late Pleistocene, benthic foraminifera and/or their propagules were carried by avian transport from the neighbouring Red Sea within the saline lakes of the Danakil Depression, in turn pointing to a possible important ecological role of the area for migratory birds.

Polyphyletism and parallel evolution in Foraminifera and their implications in biostratigraphy. Two new examples from the Priabonian of the Helvetic Alps

Carles Añade 1, Mora Claudia2 and Peter Baumgarter O.3

1Departament Dinàmica de la Terra i de l'Oceà, Facultat de Ciències de la Terra, Universitat de Barcelona, Martí i Franquès s/n, Barcelona, 08028, Spain; carlesferrandie@ub.edu
2Institut des sciences de la Terre, Université de Lausanne, Moulle 11 Géopolis, CH-1015 Lausanne, Switzerland; claudia.baumgarter@unil.ch; peter.baumgarter@unil.ch
3Corresponding author

Recurrent evolution of similar or equivalent forms through geologic time is common in Foraminifera. We show two examples from the Priabonian Sanetsch Fm in the Helvetic Nappes of the Swiss Alps: one dealing with polyphyletism and the other with parallel evolution.

1- Rotorbinella, a polyphyletic genus

Rotorbinella is a small hyaline foraminiferal genus with the simplest rotalid architecture: a simple umbilical plate delimiting a spiral canal around an umbilical plug. It appears in the Cenomanian and has a discontinuous stratigraphical range with species known from the Cenomanian, Coniacian-Santonian, Paleocene-Ilerdian and Miocene-Recent time intervals.

We identified a new species from the Sanetsch Fm, Rotorbinella sp. 1. The differences with other Rotorbinella species are subtle and refer to quantitative characters. These differences, together with the hiatuses in the stratigraphical record of Rotorbinella, point to a polyphyletic origin of Rotorbinella. This simplest rotalid architectural model would have originated
During the EECO, the different species were able to preferentially adopt sinistral coiling as a result of changed conditions in the mixed-layer. Whether sinistral and dextral Morozovella were the result of cryptic speciation, our record implies an evolutionary through and its δ13C data suggest greater flexibility giving evidence of major resilience to the EECO perturbance. Moreover, at ocean drilling sites in the tropical Pacific (1209-1210), and the Indian Ocean (762) morozovellids display a switch from dominantly dextral coiling preceding the EECO, to sinistral coiling within the EECO, as previously recorded in Atlantic Ocean sites (1051, 1258, 1263). This happens close to the carbon isotope excursion known as K/X or ETM-3 (~52.8 Ma), which also provides a new biostratigraphic tool for correlation.

Orthophragmimids are a group of orbitoidiform larger foraminifera that thrived during the Eocene. They consist of several genera of two different families, Discocyclinidae and Orbitoclypeidae, both originated in the Caribbean. In the Thetanian (late Paleocene) the discocyclind Discocyclina and the orbitoclypeid Orbitoclypeus reached the Tethys. During the Eocene both groups evolved separately in the two bioprovinces. Orbitoclypeus gave rise to equivalent stellar ribbed forms, assigned to the genus Asterocyclina, which has the same stratigraphical range in the two bioprovinces. However, from the data available, it is not possible to ascertain if Asterocyclina evolved in parallel in the two bioprovinces or migrated from one to the other.

In the Caribbean, some species of Asterocyclina developed a new character, which we have named rods: radial thickennings of imperforate calcite along the ribs. This was a feature known only in middle-upper Eocene Caribbean species. Now we have found this character in a late Eocene Tethyan species, A. ferrandezii. Furthermore, rods are found in two new subspecies (=phylogenetic chronospecies), which occur in Shallow Benthic Zones 19 and 20 respectively. A revision of own samples and of the literature showed that they occur in different basins of the western Tethys. Apart of their interest as new biostratigraphical markers for the Priabonian, these two new subspecies are relevant because they demonstrate the occurrence of parallel evolution in larger foraminifera. While in the Caribbean species of Asterocyclina with rods appeared yet at the early middle Eocene, in the Tethyan realm they originated during the late Eocene. In this case, parallel evolution is made evident because it is diachronous, but this is rather the exception. Biochronostratigraphical correlation based on equivalent species from different bioprovinces should have to be considered with the utmost caution. It can easily lead to either erroneous biostratigraphical correlations between different bioprovinces or to misinterpretations of the timing or direction of migration.

**Disentangling implications of changes in morozovellids coiling direction at the Eocene Climatic Optimum (EECO, ca 53–49 Ma) (Pacific, Atlantic and Indian Oceans)**

FILIPPI Giulia1*, LUCIANI Valeria1, SIGISMONDI Silvia1, D’ONOFRIO Roberta1, DICKENS Gerald R.2, WADE Bridget S.3 and WESTERHOLD Thomas 5

1Dipartimento di Fisica e Scienze della Terra, University of Ferrara, Via Saragat 1, Ferrara, Italy; giulia.filippi@unife.it; valeria.luciani@unife.it; silvia.sigismondi@unife.it; roberta.donofrio@unife.it
2Department of Geology, Museum Building, Trinity College Dublin, College Green, Ireland; DICKENSG@tcd.ie
3Department of Earth Sciences, University College of London, UK; b.wade@ucl.ac.uk
4MARUM – Center for Marine Environmental Sciences, University of Bremen, Loebener Str. 8, Bremen, Germany; twesterhold@marum.de
*Corresponding author

A major change in planktic foraminiferal populations occurred at the start of the Early Eocene Climatic Optimum (EECO), the interval of peak Cenozoic warmth from between ~53–49 million years ago (Ma). The symbiont-bearing genus Morozovella suffered an abrupt and permanent decline in abundance and taxonomic diversity after dominating tropical-subtropical early Paleogene assemblages. Conversely, the genus Acarinina markedly increased in abundance and diversity.

Moreover, at ocean drilling sites in the tropical Pacific (1209-1210), and the Indian Ocean (762) morozovellids display a switch from dominantly dextral coiling preceding the EECO, to sinistral coiling within the EECO, as previously recorded in Atlantic Ocean sites (1051, 1258, 1263). This happens close to the carbon isotope excursion known as K/X or ETM-3 (~52.8 Ma), which also provides a new biostratigraphic tool for correlation.

To interpret the observed changes, we measured the δ13C composition of dextral and sinistral morozovellid and acarinid morphotypes spanning the start of EECO. Carbon isotope data reveal that sinistral morphotypes belonging to the same morphospecies typically have lower δ13C values. The dominance of sinistral morphotypes, at the expense of dextral forms within the EECO, coupled with the lower δ13C signatures of the former, suggests that the sinistral forms were less dependent on their photosymbiotic partnerships, possibly moving slightly down in the mixed-layer, and thus able to adapt more readily to paleoceanographic change at the EECO. Remarkably, the genus Acarinina does not display coiling preferences throughout and its δ13C data suggest greater flexibility giving evidence of major resilience to the EECO perturbance. Whether sinistral and dextral morozovellids were the result of cryptic speciation, our record implies an evolutionary selection favouring sinistral forms. Alternatively, whether the coiling changes were exclusively environmentally controlled, the different species were able to preferentially adopt sinistral coiling as a result of changed conditions in the mixed-layer during the EECO.
Planktic foraminiferal abundance and test-size record across the Early Eocene Climatic Optimum (EECO, ~53-49 Ma) at Shatsky Rise (Pacific Ocean)

FILIPPI Giulia1*, SCHMIDT Daniela2, BARRET Ruby2, D’ONOFRIO Roberta1, WESTERHOLD Thomas3, BROMBIN Valentina2 and LUCIANI Valeria1

1Department of Physics and Earth Sciences, University of Ferrara, Via Saragat 1, Ferrara, Italy; giulia.filippi@unife.it; roberta.dono@unife.it; valentina.brombin@unife.it; valeria.luciani@unife.it
2School of Earth Sciences, Cabot Institute, University of Bristol, Queens Road, Bristol, UK; D.Schmidt@bristol.ac.uk; ruby.barrett@bristol.ac.uk
3MARUM, University of Bremen, Loebener Str. 8, Bremen, Germany; twesterhold@marum.de
*Corresponding author

The dynamic early Paleogene climate presents the crucial opportunity to detect relationships among calcareous plankton productivity, past carbon cycle perturbations and climate. We focus on the Early Eocene Climatic Optimum (EECO, ~53-49 Ma) as it is associated with peak temperature and pCO2 of the Cenozoic and therefore offers a long-term perspective of global warming impacts on marine biota. We investigate the Pacific sites 1209-1210, complementing evidence that the EECO markedly impacted planktic foraminiferal assemblages at the Atlantic Oceans. The selected sites have an excellent age model and stable isotope constraints that document the carbon isotope excursions that are the expression of the several hyperthermals events superimposed on the long-term warming. We record an abrupt and permanent abundance decline of more than one-third for the symbiont-bearing genus, Morozovella, from the beginning of the EECO (J event, ~53 Ma) at sites 1209-1210, whereas Acarinina concomitantly increased in agreement with Atlantic sites. One possible cause of the morozovellid abundance decline is a negative impact on their photosymbiotic relationships with algae, as suggested by the lower △13C values exhibited by survivors. Symbiosis is advantageous in the oligotrophic mixed-layer habitat and increases growth and final size. Therefore, we hypothesise that the morozovellid decline may have reduced planktic foraminiferal productivity and test-size. We evaluated the Coarse Accumulation Rate (CFAR) as an approximation of the planktic foraminiferal accumulation rate. The >38 m dominantly consists of planktic foraminifera in pelagic sediments and here is not significantly affected by dissolution which would reduce CFAR. In addition, we perform a test-size analysis on planktic foraminiferal assemblages across the EECO. Changes in the size of marine calcifiers can be caused by evolutionary mechanisms or environmental perturbation, both of which represent potential consequences of extreme warmth. Earlier work has shown that morozovellids are generally larger than acarininids, hence suggesting that size should decrease when morozovellid abundance drops. Samples were split into aliquots of 1000–1500 specimens and imaged at 160x magnification. The morphological parameters were analysed in Olympus Stream Motion, and the 95th percentile of the maximum diameter was calculated. Unexpectedly, our results show that the planktic foraminiferal assemblages do not display test-size reduction. Overimposed to a long-term general test size increase trend, we recorded test-size fluctuations across the short-term hyperthermals. The increase of planktic foraminiferal sizes across the hyperthermals may be linked to increases in the abundance of acarininids and decreases of morozovellids, which is the common pattern across these events. CFAR decreases across the EECO during the morozovellid abundance reduction, suggesting that this decline impacted overall planktic foraminiferal productivity and was seemingly not balanced by the acarininids. Future test-size analysis of the two groups involved will help to unravel a more exhaustive response to the EECO perturbation of planktic foraminiferal assemblages.

A new high resolution stable isotope record from the North Atlantic Ocean: a detailed insight into the mid-Maastrichtian event

FISCHER Alexa1*, FRIEDRICH Oliver1, BAHR André1 and VOIGT Silke2

1Institute of Earth Sciences, Heidelberg University, Im Neuenheimer Feld 234, Heidelberg, Germany; alexa.fischer@geow.uni-heidelberg.de; oliver.friedrich@geow.uni-heidelberg.de; andre.bahr@geow.uni-heidelberg.de
2Institute of Geosciences, Goethe University, Altenhöferallee 1, Frankfurt, Germany; s.voigt@em.uni-frankfurt.de
*Corresponding author

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 characterized by two positive δ13C excursions with an overall magnitude of 0.6% to 1.5% separated by a negative inflection. The δ13C excursions are accompanied by the extinction of inoceramid bivalves, an abrupt increase in deep-sea and sea-surface temperatures as well as 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 identified to be one of the main drivers of the MME. Nevertheless, the driving mechanisms, timing, character, and consequences of the circulation change are still up for debate. In this study, a 2 Myr-time interval of the Mid to Late Maastrichtian has been analyzed at ~2.5 to 5 kyr-resolution with the aim to improve the understanding of the climatic patterns leading to the MME. For IODP Core U1403 in the North Atlantic (J-Anomaly Ridge), XRF core scanning, wt% CaCO3 analyses, and stable oxygen and carbon isotope records of benthic foraminifera were generated. Bottom-water temperatures were reconstructed through Mg/Ca measurements of the same
foraminiferal tests. Preliminary data reveal a warming of North Atlantic deep-sea temperatures by ~2–3°C between ~68.5 and 69 Ma, accompanied by several CaCO$_3$ dissolution events as well as δ$^{13}$C excursions of up to 0.8 %. These findings point towards a major perturbation in the global carbon cycle accompanying the overall change in ocean circulation whose causes appear to be more complex than previously thought.

Test volume response to bottom water oxygen changes in *Cibicidoides wuellerstorfi*

FORDHAM Barry G. and BURKETT Ashley

1Boone Pickens School of Geology, Oklahoma State University, 105 Noble Research Center, Stillwater, Oklahoma, USA; trentity.ford@okstate.edu; ashley.burkett@okstate.edu

Benthic foraminiferal test morphologies and morphometrics have been used as proxies for paleoceanographic reconstructions based on the observation that variations in test formation record changes and stresses affecting the organisms. Test volumes have been thought to be sensitive to variations in available oxygen with some evidence showing an inverse correlation between foraminifera test size and aqueous oxygen availability. However, there is still a large amount of uncertainty in this relationship and its broad applicability to reconstruction efforts.

In an effort to further elucidate the relationship between test volume and bottom water oxygen in epibenthic foraminifera, volumetric analysis will be performed on a set of *Cibicidoides wuellerstorfi* specimens from different bottom water oxygen environments. These samples will be imaged via micro-computed tomography (micro-CT). Three-dimensional models derived from the micro-CT reconstructions will then be used to assess whole test volume of each specimen in the data set.

This work will be done in conjunction with pore surface area and I/Ca ratio analysis. Both pore surface area and I/Ca ratios have shown a strong correlation with bottom water oxygen levels and will be correlated with whole test volumes to assess the idea that reduced volume, and consequently surface area, is beneficial to the foraminifera inhabiting low oxygen environments, and is thus indicative of such environments.

If validated, this relationship would make for an attractive proxy when using foraminifera from the fossil record as it would be less susceptible to diageneric factors that could potentially limit the quality of other proxy methods. This would be especially beneficial in observing changes in oxygenation through paleoceanographic events such as the Paleocene-Eocene Thermal Maximum (PETM) or the Cretaceous-Paleogene (K-Pg) boundary when combined with other proxies such as BFOI (Benthic Foraminifera Oxygen Index), I/Ca ratios, or pore surface area.

Tappan & Loeblich’s phylogeny of Foraminifera families: dusting it off for a closer look

FORDHAM Barry G. and OGG James G.

1Research School of Earth Sciences, Australian National University, Canberra, ACT 2601, Australia; barry.fordham@anu.edu.au

2Department of Earth and Atmospheric Sciences, Purdue University, Indiana IN 47907-2051, USA and State Key Laboratory of Oil and Gas Reservoir Geology and Exploitation, Institute of Sedimentary Geology, Chengdu University of Technology, Chengdu 610059, China; jogg@purdue.edu

A digital version of the tree of foram families by Helen Tappan Loeblich and Alfred Loeblich, Jr. published in 1988 has provided a platform by which to better access and newly assess the Loeblichs’ last word on foram origins, of ancestor–descendant relationships. Their phylogeny has been calibrated stratigraphically (against GTS2020) and this can now be maintained into future time scales. Reported stratigraphic occurrences and the conjectured intervals implied by their phylogenetic proposals are made graphically distinct. Pop-ups of ancillary information, such as basic taxonomy and stratigraphic distribution, higher and included taxa, and representative images, has allowed an alternative and, in some ways more easily accessible, means by which to tap the rich knowledge contained in the Loeblichs’ *Treatise* and *Genera* tomes. Thumbnail images for each family on the tree have been carefully size-transformed to reflect actual size, despite the several orders of size represented across all forams. All of this information has been encapsulated in a back-end relational database, which can provide transparent documentation and be available for scrutiny and sharing by the specialist community.

At the suborder level the Loeblichs were able to almost fully implement their vision of 12 monophyletic groups (in the context of evolutionary taxonomy) recognised by wall composition and microstructure. Their more diverse choice of features applied to define 98 superfamilies proved more challenging for their phylogenetic thinking and so, despite their wish to express evolutionary relationships through classification, they implied that around 20% of these superfamilies were probably polyphyletic in terms of family origins, some with 3 or even 4 different ancestral families. Then, at the level of family, a quarter of the phylogenetic relationships they proposed were not supported by the stratigraphic distributions that they themselves had compiled. They clearly, as they had often stated, were juggling a number of aspects when considering phylogeny, not only stratigraphic order.
It would, therefore, be misguided to consider the interplay between the Loeblichs’ classifying and their phylogenetic thinking, made from the benefit of multidecadal hindsight, as a criticism of their work. Their attempts were surely heroic in the context of a massive life-long program to provide a coherent account of all forams, living and fossil, down to genus. What emerges rather is a rich and sophisticated approach taken by the Loeblichs to forams, albeit one that we would these days expect to be more explicitly documented, but which cannot be dismissed as in any way simplistic. This would of course, for example, argue against any suggestion that they, as representatives of so-called evolutionary paleontologists, applied stratigraphic order as some straightforward connecting framework for stitching together phylogenic trees.

**How do morphological and eDNA data compare for biomonitoring? An example with the distribution of three Ammonia (Foraminifera, Rhizaria) species in estuaries of the French Atlantic coast**

FOUET Marie P.A., SCHWEIZER Magali*, SINGER David, RICHARD Julien, QUINCHARD Sophie and JORISSEN Frans J.

1 Université d’Angers, Nantes Université, Le Mans Université, CNRS, Laboratoire de Planétologie et Géosciences, LPG UMR 6112, 2 bd de Lavoisier, 49000 Angers, France; marie.fouet@gmail.com; magali.schweizer@univ-angers.fr; david.singer.bio@outlook.com; sophie.quinchard@univ-angers.fr; jorissen@wanadoo.fr

2 Soil Science and Environment Group, CHANGINS, HES-SO University of Applied Sciences and Arts Western Switzerland, Route de Duillier 50, 1260 Nyon, Switzerland; david.singer.bio@outlook.com

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

*Corresponding author

Assessing the distribution of species in a given environment is essential to understand their ecology and disentangle natural and anthropic influences. In this study, we investigate three pseudocryptic species formerly mixed in the morphospecies Ammonia tepida: Ammonia veneta (phytotype T1), A. aberdoveyensis (phytotype T2) and A. confertitesta (phytotype T6). These pseudocryptic species are major constituent of foraminiferal assemblages in intertidal and shallow waters environments along the European coasts, with A. confertitesta usually being considered as an exotic species originating from eastern Asia. Their morphological discrimination has only become possible recently, allowing us to assess potential differences in their ecological characteristics. To understand the distribution of these species, we used a combined morphological and molecular approaches at 64 sites in seven estuaries along the French Atlantic coast.

While the combination of morphological and molecular methods confirmed the presence of the three species in all seven estuaries, the two methods showed discrepancies in their distribution. Ammonia confertitesta was present in all estuaries in the eDNA data set but was rare or absent in the morphological inventory of the northern estuaries (Elorn, Aulne, Odet, Crac’h and Auray) dominant in the southern Vilaine estuary and common in the Vie estuary further south. The large variability in absolute and relative densities (morphological data) of the supposedly invasive A. confertitesta suggests an opportunistic behaviour for this species. It appears that despite the widespread presence of genetic material (including adults, juveniles and propagules), the A. confertitesta population has not yet fully developed everywhere. The seven investigated estuaries represent different stages of replacement of the autochthonous species A. veneta and A. aberdoveyensis by A. confertitesta. Favourable conditions for such a replacement could be created by major river floods, creating temporarily vacant ecosystems. These would be preferentially colonised by A. confertitesta, because of its more opportunistic behaviour and perhaps a higher tolerance to low salinity. Our study demonstrates that the combination of morphological and eDNA approaches is optimal to reveal the current and potential spreading of possible invasive species in estuaries and allows a better understanding of the natural distribution of species in the different estuaries.

**Temporal changes in intertidal benthic foraminifera: a seasonal survey from the English Channel (France)**

FRANCESCANGELI Fabio¹*, BOUCHET Vincent M.P.², MILKER Yvonne³, FRONTALINI Fabrizio⁴, RICHARD Xavier⁵, TRENTESAUX Alain⁶ and ARMYNOT DU CHATELET Eric⁷

¹ Department of Geosciences, University of Fribourg, Chemin du Musée 6, 1700 Fribourg/Freiburg, Switzerland; fabio.francescangeli@unifr.ch

² University of Lille, CNRS, Univ. Littoral Côte d’Opale, UMR 8187, LOG, Laboratoire d’Océanologie et de Géosciences, Station Marine de Wimereux, 8 Av. du Maréchal Foch, 62930 Wimereux, France; vincent.bouchet@univ-lille.fr

³ University of Hamburg, Institute for Geography, Centre for Earth System Research and Sustainability; Bundesstrasse 55, 20146, Hamburg, Germany; yvonne.milker@uni-hamburg.de

⁴ University of Urbino, Dipartimento di Scienze Pure e Applicate (DiSpeA), Localita’ Crocicchia, 61029 Urbino, Italy; fabrizio.frontalini@univr.it

⁵ Department of Mathematics, University of Fribourg, Chemin du Musée 23, 1700 Fribourg/Freiburg, Switzerland; xavier.richard@unifr.ch

⁶ University of Lille, CNRS, Univ. Littoral Côte d’Opale, UMR 8187, LOG, Laboratoire d'Océanologie et de Géosciences, Cité Scientifique, Bât. SN5 - 59655 Villeneuve d’Ascq, France; alain.trentexaux@univ-lille.fr; eric.armynot@univ-lille.fr

*Corresponding author

Intertidal ecosystems are fragile environments that are naturally stressed by high spatial and temporal variability of physico-chemical parameters. In addition, these environments have been increasingly affected by the consequences of global
warming and the associated rise in mean sea level, heatwaves. The intertidal areas of the Hauts-de-France (English Channel, France) stand out for the occurrence of vulnerable ecosystems that have experienced natural and human–induced stresses. Over the last two centuries, the northern part of this region has been exposed to a strong human pressure, with the development of numerous activities (i.e., metallurgic factories, fisheries, embankments). On the contrary, its southern part includes less impacted areas. The objectives of this study are: 1) to characterise the seasonal variations in abundance (i.e., foraminiferal density, FD) and diversity of benthic foraminifera and 2) to identify which species are the most frequent and their temporal variations in this region based on a one-year survey. Sixteen sampling stations were selected from five sampling areas along the intertidal zones of Hauts-de-France with different levels of humanisation. At each of the four seasons (spring 2014; summer 2014; autumn 2014; and winter 2015), four replicated sediment samples were collected at each station. Three replicates were used for the foraminiferal analysis and the fourth was used to measure abiotic parameters (i.e., grain-size, total organic carbon, C/N ratio), collecting 256 samples (192 for foraminifera and 64 for sediment properties). Statistical analyses (i.e., Krustal-Wallis test and PERMANOVA) were carried out to reveal any significant influence of seasonality on foraminiferal assemblages. Significant seasonal variations were observed for FD although it did not show a clear temporally trend across the region. The diversity showed a significant seasonal influence with the highest values commonly found during spring and summer. For both FD and diversity, different patterns were exhibited in natural and human–altered stations. *H*aynesina germanica and *Elphidium selsevense* were the most frequent species differently distributed across the region. They both showed significant seasonal variations. The overall outcomes of this survey shed light on complex seasonal patterns in benthic communities of intertidal environments. Furthermore, this study evidences the importance of baseline and temporal investigations to plan further environmental monitoring of ongoing climate and human-related changes in the intertidal settings.

**Proton pumping influences element incorporation in hyaline foraminifera**

FRANÇOIS Daniel1, DE GOEYSE Siham1, REICHART Gert-Jan1,2, KING Helen E.2 and DE NOOIJER Lennart J.1

1Department of Ocean Systems, NIOZ Royal Netherlands Institute for Sea Research and Utrecht University, Texel, the Netherlands; daniel.do.nascimento.silva@nioz.nl; siham.de.goeyse@nioz.nl; Gert-Jan.Reichart@nioz.nl; Lennart.de.Nooyer@nioz.nl

2Department of Geosciences, Faculty of Geosciences, Utrecht University, Utrecht, the Netherlands; Gert-Jan.Reichart@nioz.nl; H.E.King@uu.nl

*Corresponding author

Despite sharing similar calcification pathways, the amount of Mg incorporated by hyaline foraminiferal species varies significantly (from ~100 to as low as 1-5 mmol/mol). Such variability is determined by biological factors, for which the underlying mechanisms remain only partly known. In this study, we show that the functioning of cellular V-type H⁺ ATPases, interpreted by external H⁺ fluxes outwards, are stronger in species with low Mg/Ca ratios. In order to maintain charge neutrality, increased activity of H⁺ transporters correlates with inward Ca²⁺ fluxes and thereby decreases Mg/Ca values in the fluid from which foraminifera calcify. This confirms the importance of transmembrane transporters on calcium accumulation and thereby their role in element to calcium ratios in foraminiferal shells. We furthermore show strong modulation of mitochondrial distribution during biomineralization, helping to clarify where enzyme-mediated H⁺ transport occurs. As they are densely distributed at the calcification site, mitochondria may also serve as a (temporary) storage site for the Mg²⁺ extracted from the site of calcification as well as providing the energy for H⁺/Ca²⁺ ion exchange.

**Short-term waxing and waning of Antarctic ice sheets during the late Oligocene – evidence from benthic foraminiferal geochemistry**

FRIEDRICH Oliver1, BRZELINSKI Swaantje1, BORMEANN André2, WILSON Paul1, LIEBRAND Diederik and VAN PEER Tim4

1Institute of Earth Sciences, Heidelberg University, Im Neuenheimer Feld 234-236, 65120 Heidelberg, Germany; oliver.friedrich@geow.uni-heidelberg.de; swaantje.brzelinski@geow.uni-heidelberg.de

2Bundesanstalt für Geowissenschaften und Rohstoffe, Stilleweg 2, 30655 Hannover, Germany; Andre.Bormemann@bgr.de

3University of Southampton, Waterfront Campus, National Oceanography Centre Southampton, European Way, SO14 3ZH Southampton, UK; paul.wilson@noc.soton.ac.uk; diederik.liebrand@noc.soton.ac.uk

4School of Geography Geology and Environment, University of Leicester, University Road, LE1 7RH Leicester, UK; T.E.vanPeer@soton.ac.uk

*Corresponding author

Sandwiched between the early Paleogene greenhouse and Neogene icehouse climates, the Oligocene epoch (33.9–23.03 Ma) represents what is arguably the most important transitional phase of Cenozoic climate evolution, with the first major expansion of Antarctic ice sheets (AIS). Temporally highly resolved paleoclimatic and paleoceanographic proxy records for the Oligocene therefore are a prerequisite for obtaining deeper insight into the fundamental mechanisms and processes involved in the waxing and waning of continental ice sheets. Whereas the long-term evolution of Oligocene glaciations is rather well known, current knowledge about short-term (i.e., orbital to suborbital scale) ice-sheet dynamics is still very limited and a matter of ongoing debate. Therefore, the focus of this project is to elucidate short-term ice-sheet dynamics.
Evaluation of the effects of decabromodiphenyl ether BDE-209, a persistent organic pollutant, on benthic foraminiferal community using morphological and edna metabarcoding approaches

FRONTALINI Fabrizio1*, GRECO Mattia2, AL-ENEZI Eqbal3, AAMO Abduljamiu4, FRANCESCHANGETI Fabio5, CAVALIERE Marco1, BUCCI Carla6, TOSCANESI Maria7, TRIFUOGLI Marco8 and PAWLSKI Jan9

1Department of Pure and Applied Sciences, Urbino University, Campus Scientifico, via Ca le Suore 2/4, 61029 Urbino, Italy; fabrizio.frontalini@uniurb.it; m.cavaliere6@campus.uniurb.it; carla.bucci@uniurb.it
2Institut de Ciències del Mar, Passeig Marítim de la Barceloneta, 37-49, Barcelona, Spain; mgrego@icm.csic.es
3Environment & Life Sciences Research Center, Kuwait Institute for Scientific Research, P.O. Box 24885, Safat 13109, Kuwait; genezi@kISR.kw
4Center for Integrative Petroleum Research, College of Petroleum Engineering and Geosciences, King Fahd University of Petroleum and Minerals, PO Box 5070, 31261 Dhahrnan, Saudi Arabia; amao@kfupm.edu.sa
5Department of Geosciences, University of Fribourg, Chemin du Musée 6, 1700 Fribourg/Freiburg, Switzerland; fabio.francescangeli@unifr.ch
6Department of Chemical Sciences, University of Naples Federico II, Via Cinta 21, 80126 Naples, Italy; marco.trifuoggi@unina.it; maria.toscanesi@unina.it
7ID-Gene ecodiagnostics Ltd, 109 ch. du Pont-du-Centenaire, 1228 Plan-les-Ouates, Switzerland; jan.pawlowski@unige.ch
8Institute of Oceanology, Polish Academy of Sciences, Powstańców Warszawy 55, 81-712 Sopot, Poland; janpawlowski@iopan.pl
9*Corresponding author

Persistent Organic Pollutants (POPs) are organic compounds that are resistant to environmental degradation. Among them, the polybrominated diphenyl ethers (PBDEs) are known for their toxicity, lipophilicity, persistence, and resistance to degradation and bioaccumulation potential. Many studies have recently reported that BDE-209 (decabromodiphenyl ether) could be accumulated in the environment and has been found to exhibit toxic effects on organisms. The BDE-209 is among the most common and the widest occurring POPs in some coastal-industrial areas of Kuwait posing serious threats to human health and the environment. A mesocosm experiment was conducted to evaluate the impact of BDE-209 on benthic foraminiferal communities. Sediments bearing such communities were incubated in mesocosms, exposed to varying levels of BDE-209 and monitored for up to 12 weeks. Relatively high concentrations of BDE-209 affected benthic foraminiferal communities (i.e., molecular and morphological ones) by reducing their diversity and changing their composition. No CTG-labelled (i.e., living) foraminiferal specimens were identified at high concentrations, namely 10 and 20 mg/L after 8 weeks of treatment, whereas ASVs were found at the highest concentrations even at the end of the experiment. Despite the significant difference in the composition of the two communities, the response of the foraminiferal molecular community well mirrored that of the morphological one. The present investigation evidences that BDE-209 pollution has detrimental effects on benthic foraminifera. This spiked-sediment toxicity approach may represent a valid complementary tool by which the effect on the biota of a single pollutant or a set of mixed organic or inorganic pollutants can be studied over time under controlled environmental conditions (i.e., micro- and mesocosms). These findings emphasize the importance of using foraminiferal communities in laboratory experiments to assess cause-and-effect relationships to allow for the validation of field study outcomes and test the sediment quality guidelines and thresholds.

Benthic foraminiferal changes in hydrothermal areas around Ischia Island: the evaluation of the effects of ocean acidification through morphological and molecular ecology

FRONTALINI Fabrizio1*, GRECO Mattia2, CAVALIERE Marco1, BURESTA Andrea1, BARRENECHEA ANGELES Ines3, MONTRESOR Marina3, MARTINS ALVES Maria Virginia4 and PAWLSKI Jan5

1Department of Pure and Applied Sciences, Urbino University, Campus Scientifico, via Ca le Suore 2/4, 61029 Urbino, Italy; fabrizio.frontalini@uniurb.it; m.cavaliere6@campus.uniurb.it
2Instituto de Ciencias del Mar, Passeig Maritim de la Barceloneta, 37-49, Barcelona, Spain; mgrego@icm.csic.es
3Urbino University, via Saffi 2, 61029 Urbino, Italy; a.buresta3@campus.uniurb.it
4Department of Geosciences, The Arctic University of Norway, PO Box 6050 Langnes, N-9037 9010 Tromsø, Norway; ines.a.angeles@uit.no
5Stazione Zoologica Anton Dohrn, Villa Communale, 80121 Naples, Italy; marina.montresor@szn.it
Since the beginning of the Industrial Revolution, the use of fossil fuel has resulted in an atmospheric increase in carbon dioxide ($pCO_2$) and a concurrent alteration of ocean chemistry with a decrease in ocean pH and of the carbonate saturation state. These changes in water chemistry, referred to as Ocean Acidification (OA), are also leading to biodiversity loss and an impact on key marine organisms that rely on calcium carbonate for building their skeletons or shells. Future OA scenarios can be studied and modelled in hydrothermal areas, particularly in corollary of vents such as in Ischia Island (NW sector of the Gulf of Naples, Southern Italy) that represents one of these natural laboratories. In this research, the variations of benthic foraminiferal (i.e., morphological and molecular) communities were investigated in fourteen samples collected along two transects at North and South of the Castello Aragonese bridge, where clear pH gradients were reported. The sites with the lowest pH values are dominated by agglutinated specimens that are less to not prone to dissolution. On the other hand, calcareous specimens, both hyaline and porcelaneous, are mostly found at sites with normal marine pH values. Variations of benthic foraminiferal parameters such as density or living/dead specimens are not only driven by pH values but also by the occurrence of the *Posidonia oceanica*, a seagrass, and the sediment grain-size (i.e., mud). The wall-type changes of the morphological community along the pH gradients correspond well to those identified in the molecular community. These observations suggest that OA negatively affects the benthic foraminiferal communities and support the application of the foraminiferal metabarcoding even in the assessment of the effects of climate changes.

Response of large benthic foraminiferal assemblages to sea-level changes over the past 40,000 years in the Great Barrier Reef: IODP Expedition 325

Fujita Kazuhiko1*, Webster Jody M.2 and Yokoyama Yusuke3

1Department of Physics and Earth Sciences, University of the Ryukyus, Senbaru 1, Nishihara, Okinawa 903-0213, Japan; fujitaka@sci.u-ryukyu.ac.jp
2Geocoastal Research Group, School of Geosciences, The University of Sydney, Sydney, NSW 2006, Australia; jody.webster@sydney.edu.au
3Atmosphere and Ocean Research Institute, University of Tokyo, Chiba 277-8564, Japan; yokoyama@aoori.u-tokyo.ac.jp

*Corresponding author

To understand sea-level changes since the Last Glacial Maximum (LGM) and their effects on coral reef systems, shelf-edge slopes of the Great Barrier Reef (GBR) were cored during the Integrated Ocean Drilling Program (IODP) Expedition 325. Recovered unconsolidated sediments beneath the submerged shelf edge reefs contain abundant foraminiferal tests, which record changes in depositional environments and paleo-water depth. Here we present a record of these changes obtained by foraminiferal analyses. A total of 177 sediment samples were collected from 17 drill holes along three transects located within two geographical areas (Noggins Pass and Hydrographers Passage), and were analysed to determine stratigraphic changes in benthic foraminiferal assemblages (2-0.5mm size fraction). Results show that four foraminiferal assemblages (A, B, C and D) are delineated by multivariate analyses (Q-mode cluster analysis and non-metric multidimensional scaling: NMDS), and these assemblages correspond to a back-reef to reef margin zone (0–10 m deep; Assemblage A), an upper photic zone (10–30 m deep) associated with hard substrates (Assemblage B), an intermediate to lower photic zone (30–90 m deep) characterized by soft substrates (Assemblage C), and a lower photic zone (90–130 m deep) only found in modern shelf slopes (Assemblage D). Gradual shifts in these four foraminiferal assemblages mainly reflect a water-depth gradient and the relative dominance of substrate types (hard and soft substrates). The lack of Assemblage D in pre-LGM deposits from all transects could be related to lowering temperature and/or increasing terrestrial sediment flux (i.e. more light attenuation).

Sedimentological and foraminiferal analyses of unconsolidated reef sediments recovered in cores 111–140 m below sea level at Hydrographers Passage revealed the occurrence of a benthic foraminiferal assemblage dominated by the genera *Calcarina* and *Baculogypsina*, which is common in modern reef-flat and back-reef environments in the Great Barrier Reef and elsewhere. This assemblage is associated with higher foraminiferal proportions in reef sediments and higher proportions of well-preserved *Baculogypsina* tests in the same intervals, which also characterize reef-flat environments. Radiocarbon ($^{14}$C–accelerator mass spectrometry) ages of reef-flat dwelling foraminifers, which indicate the time when these foraminifers were alive, are consistent with the timing of two-step sea-level falls into the LGM. This foraminiferal evidence suggests the development of geomorphologically mature fringing reefs with shallow back-reef lagoons during the LGM.

The lower part of cores drilled on the shelf edge slopes of Hydrographers Passage, consisting of lime (carbonate) sand with bioclastic grains, cover periods from late Marine Isotope Stage 3 (MIS 3) to the LGM. During a period from 35 to 29 ka, the proportion of soft-bottom-dwelling *Operculina* spp. decreased, whereas that of fore-reef-dwelling *Amphistegina lessonii* increased. Shallow-reef-dwelling *Baculogypsina sphaerulata* and *Calcarina* spp. also increased at a shallower site, indicating the gradual proximity of reef-flat habitats. Decreased planktonic foraminiferal ratio in a fine sand fraction.
indicates a gradual decrease in open-water influence. These foraminiferal trends indicate a shallowing upward pattern from 35 to 29 ka, recording rapid sea-level fall and full glaciation into the LGM.

**Foraminiferal view on Toarcian environmental perturbations on the northern part of the Adriatic Carbonate Platform, Slovenia**

Gale Lukáš1,2, Kresnik Tjaša1, Brajkovič Rok2 and Košir Adrijan3

1Department of Geology, Faculty of Natural Sciences and Engineering, University of Ljubljana, Aškerčeva cesta 12, Ljubljana, Slovenia; luka.gale@stf.uni-lj.si
2Geological Survey of Slovenia, Diničeva ulica 14, Ljubljana, Slovenia; luka.gale@geo-zs.si; rok.brajkovic@geo-zs.si
3Ivan Rakovec Institute of Palaeontology, Research Centre of the Slovenian Academy of Sciences and Arts, Novi trg 2, Ljubljana, Slovenia; adrijan.kosir@zrc-sazu.si
*Corresponding author

The Toarcian (late Early Jurassic) is marked by environmental perturbations caused by volcanism. Most notable is the spreading of marine anoxia and deposition of organic-rich facies in epicontinental seas, known as the Toarcian oceanic anoxic event (TOAE, ~183 Ma). The effects of climate changes, increased weathering and primary marine productivity, and a decrease in bottom oxygen levels are poorly understood in the case of carbonate platforms.

The Lower Jurassic succession from the Adriatic Carbonate Platform (AdCP) of the western Tethys comprises Hettangian peritidal carbonates, Sinemurian subtidal facies, upper Sinemurian-Pliensbachian lagoonal, oolite shoal and lithothid “buildups” facies, and Toarcian middle/outerramp facies. The latter is represented by nodule and mottled carbonate mudstone and wackestone, known as Spotted limestone, vertically and laterally alternating with crinoid and/or oolite grainstone facies. The Pliensbachian-Toarcian succession indicates relative deepening caused by tectonics. Due to their dependence on oxygen levels and supply of organic matter, benthic foraminifera might offer important insight into palaeoenvironmental conditions on the AdCP during the Toarcian. Transition from the Pliensbachian to Toarcian was recorded in the Radensko Polje section (northern Dinarides, central Slovenia). Thin sections were used for investigation of facies changes and foraminiferal assemblage. Besides taxonomic determination, diversity, the proportion of opportunistic species, and the proportion of epifaunal, shallow infaunal, and potentially deep infaunal morphotypes were determined.

The lower 7 m of the Radensko Polje section consists of packstone and grainstone with intraclasts, peloids and bioclasts, presumably late Pliensbachian in age. Skeletal grains are common, comprising fragments of molluscs, corals, crinoids, calcimicrobes, and foraminifera. The latter comprise 16 determined and 4 undetermined species. Foraminifera are relatively common, with often more than 24 specimens in an area of 4.5 cm². Shannon-Wiener diversity index in a single sample is up to 1.5. Epifaunal forms represent 55–70% of the specimens, shallow infaunal 25%, and potentially deep infaunal 5–20%. Opportunists and ecological specialists are equally represented. The succession continues with 7 m of mudstone and bioclastic wackestone, subordinately peloid-bioclastic grainstone. Bioclasts are rare in this part, comprising undetermined skeletal fragments and sponge spicules. Foraminifera are rare or absent. Opportunist *Meandrovoluta* and small nodosariids represent epifauna and shallow infauna. The diversity index is 0.10. The Spotted limestone is overlain by oolite wackestone–grainstone, subordinately bioclastic wackestone. Grading, lenses of bioclastic packstone/grainstone, amalgamation, and vertical burrows are present. Radial ooids and crinoids are characteristic, as well as foraminifera attached to ooids. Bioclasts locally represent 85% of grains. The number of foraminifera per thin section is up to 51 per 4.5 cm². Ten determined and eight undetermined species were recognized, of both specialists and opportunists. Epifaunal forms represent 45–85% of the specimens, shallow infauna 15–45%, and potentially deep infauna 0–15%.

The presence of foraminifera throughout the succession, including the entire Spotted limestone unit, testifies against a dependence on oxygen levels and supply of organic matter, benthic foraminifera might offer important insight into palaeoenvironmental conditions on the AdCP during the Toarcian. Possible explanations are lower stability of the environment, food availability diminution and depleted oxygenation.

**Eocene to Oligocene high paleolatitude neritic record ofOI-1 glaciation in the Otway Basin southeast Australia**

Gallagher Stephen1, WADE Bridget2, QIANYU Li3, HOLDGATE Guy1, BOWN Paul2, KORASIDIS Vera1, SCHER Howie4, Houben Alexander1, McGOWRAN Brian4 and ALLAN Tony4

1School of Geography, Earth and Atmospheric Sciences, University of Melbourne, Melbourne Victoria 3010, Australia; sjgall@unimelb.edu.au; guy.holdgate@gmail.com; vera.korasidis@unimelb.edu.au
2Department of Earth Sciences, University College London, Gower Street, London, WC1E 6BT, United Kingdom; b.wade@ucl.ac.uk; p.bown@ucl.ac.uk.
3School of Ocean and Earth Sciences, Tongji University. Shanghai China 200092; qi01@mail.tongji.edu.cn
4School of the Earth, Ocean and Environment, University of South Carolina, 701 Sumter Street, EWS 617 Columbia, SC 29208, USA; hscher@geol.sc.edu

The presence of foraminifera throughout the succession, including the entire Spotted limestone unit, testifies against a dependence on oxygen levels and supply of organic matter, benthic foraminifera might offer important insight into palaeoenvironmental conditions on the AdCP during the Toarcian. Possible explanations are lower stability of the environment, food availability diminution and depleted oxygenation.
Multiple foraminiferal stable isotope investigations from upper Eocene to lower Oligocene deep-water marine sequences record the transition from global greenhouse to the icehouse conditions (Oi-1 glacial). While Southern Ocean high latitude deep sea records of this transition are well known, their shallow marine equivalents are rare and have the potential to record the eustatic and oceanic consequences of Paleogene glacial variability. The well-known high paleolatitude (~55°S) neritic carbonate sequence at Browns Creek and Castle Cove in the Otway Basin in southeast Australia spans the Eocene-Oligocene boundary. During this time the area lay on the northeastern margin of the Australo-Antarctic Gulf facing the evolving Southern Ocean. The importance of this record has been hampered by a lack of a consistent stratigraphy and contradictory foraminiferal interpretations. To reconcile these issues we combine new foraminiferal and nannofossil bio-, chemo- and lithostratigraphic analyses of the outcrops and a new core (Colac-2) with pre-existing data to revise the stratigraphy. This confirms the middle/upper Eocene boundary is near the base of the section. The overlying upper Eocene siliciclastic strata are truncated by an unconformity (of ~0.8 Ma in duration) and overlain by glauconitic sand (the *Notrostrea* greensand) deposited after ~35.9 Ma. Subsequently deepening to outer to inner neritic depths deposited cycled carbonates. Shallowing after ~35 Ma deposited laterally variable calcareous siliciclastic facies. These strata were tilted and eroded prior to 34 Ma leading to shallow water facies that may have been subaerially exposed during uplift. Brachiopod stromium isotope dates and an 0.5‰ carbon isotope excursion above this unconformity suggests the top of the Browns Creek and the base of the Castle Cove section correlate to Eocene-Oligocene transition (EOT-1) at ~34 Ma. The subsequent persistence of positive C/O isotope values above this level records the transition to the Oi-1 glaciation at ~33.7 Ma. Strong cyclicity in the inner shelf Castle Cove limestone is interpreted to record the commencement of obliquity dominated glacio-eustacy during the Oi-1 glacial phase. The shallowing from outer to inner shelf palaeodepths from the late Eocene to the early Oligocene is likely related to the onset of cryosphere expansion, however, palaeodepth estimates are complicated by the onset of regional compressional tectonism at the Eocene/Oligocene boundary. The subsequent persistence of positive C/O isotope values above this unconformity suggests the top of the Browns Creek and the base of the Castle Cove section correlate to Eocene-Oligocene transition (EOT-1) at ~34 Ma. The subsequent persistence of positive C/O isotope values above this level records the transition to the Oi-1 glaciation at ~33.7 Ma. Strong cyclicity in the inner shelf Castle Cove limestone is interpreted to record the commencement of obliquity dominated glacio-eustacy during the Oi-1 glacial phase. The shallowing from outer to inner shelf palaeodepths from the late Eocene to the early Oligocene is likely related to the onset of cryosphere expansion, however, palaeodepth estimates are complicated by the onset of regional compressional tectonism at the Eocene/Oligocene boundary that caused localized tilting and an unconformity with possible antisiphoning effects in this near-field site.

Resilience of microbenthic and planktic foraminiferal across the Middle Eocene Climatic Optimum (MECO) along the shallow-water Sealza succession (Liguria, NW Italy)

GANDOLFI Antonella1*, GIRAALDO-GÓMEZ Victor Manuel2, LUCIANI Valeria1, PIAZZA Michele1, ARENA Luca1 FORNACIARI Eliana1, KOCIS Laszlo4 and BRIGUGLIO Antonino1

1Dipartimento di Scienze della Terra, dell’Ambiente e della Vita, Università degli Studi di Genova, Corso Europa 26, I-16132 Genova, Italy; antonella.gandolfi@edu.unige.it; victormanuel.giraldoomez@edu.unige.it; michele.piazza@unige.it; lucaarena95@libero.it; antonino.briguglio@unige.it;
2Dipartimento di Fisica e Scienze della Terra, Università di Ferrara, Via Giuseppe Saragat, 1, 44100, Ferrara, Italy; lv@unife.it
3Dipartimento di Geoscienze, Università di Padova, Via Giotto, 1, 35137 Padova, Italy; eliana.fornaciari@unipd.it
4Institut des dynamiques de la surface terrestre - Faculté des Géosciences et Environnement, Université de Lausanne, Quartier Mouline 1015, Lausanne, Switzerland; laszlo.kocis@unil.ch
*Corresponding author

This study focuses on the Middle Eocene Climatic Optimum (MECO, centered at ~40 Ma) which is one of the major Eocene global warming events, characterized by ~4–6°C warming, shifts in the global carbon cycle and rise in atmospheric pCO2. Even though the MECO is a still enigmatic event, studies on its paleobiotic effects are yet rather limited, and exclusively focused on deep water settings.

We present here new quantitative analyses of planktic and benthic foraminifera to assess the effect of the MECO on the biotic groups studied along the shallow-water section of Sealza in Liguria (NW Italy). This succession is interpreted as the product of a drowning ramp influenced by continuous tectonic activity and provides an exceptional chance to compare biotic variations in shallow-water assemblages with deep-water communities across the MECO. At Sealza section, the MECO interval is constrained by stable isotope oxygen data and the presence of the species *Orbulinoides beckmannii*, defining the Total Range Zone E12 which range largely corresponds to the MECO event.

The succession is over 200 meters thick, and we subsampled almost 15 meters (SE25-SE41) for foraminifera and nannofossil extractions. In addition, over 50 bulk samples as well as selected isolated planktic and benthic foraminifera were analyzed for stable isotopic composition.

Around 300 foraminiferal shells were picked from each sample to evaluate the resilience of different planktic and benthic species. The abundance of planktic foraminifera is generally scarce, as expected from a shallow-water succession. The most abundant genus is the cold index *Subbotina*, which however records its lowest abundance within MECO interval.
The most abundant genera among benthic foraminifera that are well-preserved and easily recognizable, are the epifaunal *Cibicidoides* and *Anomalinoides*, but the genera *Uvigerina* and *Bolivina* were also observed. The results different from the majority of published materials that deal with deep water settings, as most of the taxa retrieved are shallow water dwellers. The data obtained clearly separate those taxa that are more resilient from those that are heavily affected by the MECO. We assume that MECO enhanced the runoff from the onshore riverine system and that produced more material deposited into the shallow offshore, thus modifying the substrate and reducing the irradiation on the seafloor.

**Planktic and benthic foraminifera across the Middle Eocene Climatic Optimum (MECO): the case study of the shallow-water Capo Mortola succession (Liguria, NW Italy)**

GANDOLFI Antonella1*, GIRALDO-GÓMEZ Victor Manuel1, LUCIANI Valeria2, PIAZZA Michele1, PAPAZZONI Cesare Andrea3, PIGNATTI Johannes4 and BRIGUGLIO Antonino1

1Dipartimento di Scienze della Terra, dell’Ambiente e della Vita, Università degli Studi di Genova, Corso Europa 26, I-16132 Genova, Italy; antonella.gandolfi@edu.unige.it; victormanuel.giraldo@gomez@edu.unige.it; michele.piazza@unige.it; antonino.briguglio@unige.it
2Dipartimento di Fisica e Scienze della Terra, Università di Ferrara, Via Giuseppe Saragat, 1, 44100, Ferrara, Italy; lv@unife.it
3Dipartimento di Scienze Chimiche e Geologiche, Università di Modena e Reggio Emilia, Via Campi 103, 41125 Modena, Italy; papazzoni@unimore.it
4Dipartimento di Scienze della Terra, Università degli Studi di Roma “La Sapienza”, Piazzale Aldo Moro 5, 00185, Roma; johannes.pignatti@uniroma1.it

*Corresponding author

The early Paleogene is characterized by several warming episodes that are evaluated as analogues to the ongoing climate change. Herein, we focus on the Middle Eocene Climatic Optimum (MECO, centered at ~40 Ma), which is one of the major Eocene global warming events, characterized by a ~4–6°C warming, shifts in the global carbon cycle and rise in atmospheric $pCO_2$. Even though the MECO is still an enigmatic event, studies on biotic effects across this interval are yet rather limited. Herein, we present new data on planktic and benthic foraminifera of the carbonate terrigenous section of Capo Mortola (Liguria, NW Italy). This historical succession is very rich in larger foraminifera, such as nummulitids and orthophragmines, and offers the exceptional opportunity to compare biotic variations across the MECO in shallow-water assemblages with the record of planktic foraminifera. The section shows conspicuous paleoecological variations, brought on by the variance in neritic input because of tectonic and climatic instability.

The first purpose of our work is to refine the biostratigraphic framework of the section by correlating the Shallow Benthic Zones with the calcareous plankton zonal schemes. In addition, we provide a quantitative analysis to evaluate the impact of the MECO on the investigated biotic groups. Preliminary data on the Capo Mortola section, despite the evident dominance of benthic over planktic forms, allow us to recognize *Orbulinoides beckmannii*, and thus the E12 total range Zone, broadly corresponding to the MECO interval. The MECO constraint is substantiated by the negative shift in bulk oxygen stable isotopes.

It is very interesting to observe that lithological variations along the Capo Mortola succession do not show similarities with analogue successions investigated in the region also spanning the MECO. At Capo Mortola, deposits that register the MECO event are characterized by an elevated dominance of Larger Benthic Foraminifera (LBF), and the environment is not at all affected by enhanced riverine or deltaic activity, as instead expected during a major warming event that has been generally connected with enhanced precipitation. Increased dominance of oligophotic LBF (i.e., discocyclinids) may be related to a strong irradiation of the seafloor coupled with very limited sedimentary rates and very reduced neritic input from nearby deltas.

**Modern environmental conditions on an agriculture-impacted estuary (Mondego, N Portugal): a foraminiferal approach**

GARDOKI Jon1*, GARCÍA-ARTOLA Ane1, CEARRETA Alejandro1, IRIBIEN María Jesús2, GÓMEZ-AROZAMENA José2, VILLASANTE-MARCOS Víctor2, GALAZ-SAMANIEGO Carlos3 and BESSA Filipa4

1Departamento de Geología, Universidad del País Vasco UPV/EHU, Barrio Sarriena s/n, Leioa, Spain; jon.gardoqui@ehu.eus; ane.garcia@ehu.eus; alejandro.cearreta@ehu.eus; mariajesus.iribien@ehu.eus
2Laboratorio de Magnetismo de Materiales y Magnetismo Ambiental, Instituto Geográfico Nacional, C/Alfonso XII 3, Madrid, Spain; vallasante@mitma.es
3Departamento de Investigaciones Científicas y Tecnológicas, Universidad de Sonora, Blvd. Luis Encinas y Rosales, Hermosillo, Mexico; carlos.galar@unison.mx
4Universidade de Coimbra, MARE - Marine and Environmental Sciences Centre / ARNET – Aquatic Research Network, Department of Life Sciences, Calçada Martim de Freitas, Coimbra, Portugal; afbessa@uc.pt

*Corresponding author
The Mondego estuary is an Atlantic, mesotidal and relatively small coastal water-body (21 km in length, 8.6 km²), located in the central coast of Portugal, that is divided into two arms both separated by the island of Morraceira. This estuary has historically been impacted by agricultural activities upstream (maize, potatoes and rice production), receiving a significant volume of effluents with high loads of total nitrogen and phosphorus. Moreover, its water and surface sediments are characterized by the presence of diverse and abundant pesticides, some of them exceeding the maximum values established by European legislation. Therefore, it is an excellent example of an eutrophic coastal environment that can be considered a natural-laboratory to analyse the possible agricultural impact on benthic microfaunal communities from western Iberia. The aim of this work is twofold: i) To characterize, for the first time, the topographic and longitudinal zonation of benthic foraminifera in its modern sediments and ii) To determine the possible ecological response of benthic foraminifera to agricultural pollution.

Twenty-two surface samples were collected in May 2022 across four transects in salt marsh and tidal flat settings from the southern arm of the Mondego estuary, the only arm that still preserves its original subenvironments, since the northern arm is continuously dredged. Samples were stained with Rose Bengal to distinguish the biocoenosis (living individuals) from the thanatoocoenosis (dead tests). Standing crop values are total number of individuals/80cm².

Lower and upper estuary salt marshes are made up of the typical agglutinated species *Troccharmina inflata* and *Entzia macrescens* both in the living and dead assemblages, whereas *Millimmina fusca*, *Tiphrophora comprimata*, *Haplophragmoides wilberti*, *Scherochorella moniliformis* and *Siph trocharminna lobata* appear as secondary and accessory taxa. The hyaline taxon *Elphidium williamsoni* presents high abundances only in salt marshes from the lower estuary. Upper estuary salt marshes exhibit elevated frequencies of brackish hyaline taxa, involving *Ammonia tepida*, *Haynesina germanica* and *Elphidium oceaneense*, possibly in response to a lower slope that facilitates tidal inundation. In general terms, salt marsh living and dead assemblages are similar, although slightly higher to higher abundances of living hyaline species are recorded. Alternatively, tidal flats are dominated by the autochthonous brackish species *H. germanica*, *A. tepida*, *E. oceaneense* and *Quinqueloculina seminula* in the living assemblage, with clear increasing abundances of dead marine tests (e.g., *Quinqueloculina bicornis*, *Lobatula lobatula*, *Bolivina spp.* and *Elphidium spp.*) towards the main channel of the estuary and seaward. These compositional changes in benthic foraminiferal assemblages across topographic and longitudinal gradients are the response to tidal inundation and marine influence. The foraminiferal diversity is consistent with similar coastal areas from the northern and western Atlantic Iberian margin (Shannon index: 0.33-1.2, Alpha index: 0.83-13.67).

The observed standing crop values range from high to very high in all sampling stations, with an average of 6250 individuals/80cm² (650-33,120 individuals/80cm²). Contrary to what is observed in polluted coastal areas, none of the sampling stations presented low abundance or “azoic spots”, suggesting current good environmental conditions.

Therefore, we can preliminarily conclude that, at present, there is no apparent ecological stressor derived from agricultural pollution inhibiting stable and diverse populations of benthic foraminifera in the Mondego estuary. However, future multidisciplinary studies, involving geochemical-compositional proxies in core and surface samples may help achieve geographic and historical perspectives of the possible impact of agriculture-related activities that led to the recent environmental transformation of this coastal area.

**Pore patterns of epifaunal benthic Foraminifera as a palaeoxygenation proxy in the South-East Pacific**

**GARRIDO Sebastián¹**, **HOOGAKKER Babette¹**, **REYES-MACAYA Dharma¹,²,³**, **RICHIRT Julien⁴**, **FOUET Marie⁵**, **HEBBELN Dierk⁶**, **GAYO Eugenia M.⁷,⁸**, **CARICH Jorge⁴,⁷**,**⁶**, **MUÑOZ Praxedes⁶**, **CASTILLO BRUNA Alexis⁷,⁸**, **MILCHEL Elisabeth¹⁰** and **JORISSEN Frans⁹**

¹Lyell 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
²ANID - Millennium Science Initiative Program Nueclo Milenio UPWELL, Raúl Bitrán 1305, La Serena, Chile; sag15@hw.ac.uk; d.reyes_macaya@hw.ac.uk; kenagayoh@gmail.com; acastillo@ucm.cl
³MARUM - Center for Marine Environmental Sciences, University of Bremen, Leobener Str. 8, 28359, Bremen, Germany; d.reyes_macaya@hw.ac.uk; dhebbeln@marum.de
⁴Institute 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
⁵UMR CNRS 6112 LPG-BIAF, Angers University, 2, Boulevard Lavoisier 49045, Angers, France; marie.fouet@gmail.com; frans.jorissen@univ-angers.fr
⁶Departamento de Geografía, Universidad de Chile, Portugal 84, Santiago, Chile; kenagayoh@gmail.com
⁷Universidad Peruana Cayetano Heredia (UPCH), Av. Honorio Delgado 430 SMP, 15102, Lima, Perú; jorge.cardich.s@upch.pe
⁸Universidad Peruana Cayetano Heredia (UPCH), Av. Honorio Delgado 430 SMP, 15102, Lima, Perú; jorge.cardich.s@upch.pe
⁹Facultad de Ciencias del Climat y de l’Environnement (LSCE), Laboratoire CNRS-CEA-UVSQ, Orme des Merisiers, Bat 714, 91190 Saint-Aubin, Gif-sur-Yvette, France; elisabeth.michel@lsce.ipsl.fr
*Corresponding author

Benthic Foraminifera (BF) have developed structures through the test wall for gas exchange between the living cell and the surrounding seawater. These structures are tubular holes (pores) perpendicular to the wall surface, and their patterns can...
be explained by adaptations to environmental parameters such as temperature, oxygen, or nitrate concentrations. The pore density and/or pore surface in some infaunal and epifaunal BF taxa relates inversely to bottom water oxygen concentration (BWO\textsubscript{o}), where total porosity increases to enhance oxygen uptake. Hence, it has been proposed that pore patterns could serve as a proxy for past BWO\textsubscript{o} and redox conditions.

To validate the use of the pore pattern proxy for reconstructing paleoceanographic conditions in the South-East Pacific (Peru-Chile; 12-44°S), we analysed epifaunal BF taxa (Cibicidoides wuellerstorfi, C. lobatulus, Cibicides akkerianus, Planulina limbata, P. ariminensis) from surface marine sediment samples collected at 24-3,190 m water depth. The sediments are dated early Holocene to recent times (\textsuperscript{14}C age). We measured the pore number, area, radius, density, and porosity on the penultimate and antepenultimate chambers and the whole test area of both ventral and dorsal sides. These are compared to BWO\textsubscript{o} and other bottom water hydrological variables such as temperature, salinity, and nutrients.

We verify an inverse correlation between BWO\textsubscript{o} and pore density only on the ventral side for penultimate and antepenultimate chambers and the whole test area for C. wuellerstorfi. Still, BWO\textsubscript{o} correlates inversely with porosity instead of pore density on the dorsal side. In the case of C. lobatulus, the BWO\textsubscript{o} varies inversely and more strongly with pore density for all measurements on both sides. For C. akkerianus, the correlation between pore density and BWO\textsubscript{o} is still present on both sides but not as strong as for C. lobatulus or C. wuellerstorfi. Our results indicate a negative correlation between BWO\textsubscript{o} and pore density on both sides but only for the whole test area in P. ariminensis. Pore patterns of P. limbata, however, are not related to BWO\textsubscript{o}.

The relationships between epifaunal pore patterns and BWO\textsubscript{o} established in this study support using epifaunal BF pore patterns as a locally calibrated proxy in the South-East Pacific to reconstruct regional changes in subsurface ocean oxygenation throughout the geological record.

Regional imprint and global signature of the Late Miocene-Early Pliocene Biogenic Bloom in the Tasman Sea (IODP Site U1506)

GASTALDELLO Maria Elena\textsuperscript{1,2}, AGNNINI Claudia\textsuperscript{1}, WESTERHOLD Thomas\textsuperscript{2}, DRURY Anna Joy\textsuperscript{3}, SUTHERLAND Rupert\textsuperscript{5}, DRAKE Michelle K.\textsuperscript{6}, LAM Adriane R.\textsuperscript{3}, DICKENS Gerald R.\textsuperscript{3}, DALLANAVE Edorado\textsuperscript{8}, BURNS Stephen\textsuperscript{10} and ALEGRET Laia\textsuperscript{2,11}

\textsuperscript{1}Dipartimento di Geoscienze, Università degli Studi di Padova, Via Gradenigo 6, Padova, Italy; mariaelena.gastaldello@phd.unipd.it; claudia.agnnini@unipd.it
\textsuperscript{2}Departamento de Ciencias de la Tierra, Universidad de Zaragoza, Calle de Pedro Curbuna 12, Zaragoza, Spain; mariaelena.gastaldello@phd.unipd.it; laia@unizar.es
\textsuperscript{3}MARUM - Center for Marine Environmental Sciences, University of Bremen, Loebener Str. 8, Bremen, Germany; twesterhold@marum.de
\textsuperscript{4}Department of Earth Sciences, University College London, 5 Gower Place, London WC1E 6BS, UK; a.j.drury@ucl.ac.uk
\textsuperscript{5}Victoria University of Wellington, Kelburn, Wellington 6012, New Zealand; rupert.sutherland@vuw.ac.nz
\textsuperscript{6}Ocean Sciences Department, University of California, Santa Cruz, CA, USA; mkdrake@ucsc.edu
\textsuperscript{7}Department of Geological Sciences and Environmental Studies, Binghamton University, 4400 Vestal Pkwy E, Vestal, NY, USA; alam@binghamton.edu
\textsuperscript{8}Trinity College Dublin, Dublin, College Green, Dublin 2, Ireland; dickensg@tcd.ie
\textsuperscript{9}Faculty of Geosciences, University of Bremen, Klagenfurter Str. 2-4, Bremen, Germany; edoardo@uni-bremen.de
\textsuperscript{10}Department of Geosciences, University of Massachusetts Amherst, Morrill Science Center, Amherst, MA, USA; sburns@geo.umass.edu
\textsuperscript{11}Instituto de Investigación en Ciencias Ambientales de Aragón, Universidad de Zaragoza, Calle de Pedro Curbuna 12, Zaragoza, Spain; laia@unizar.es
\textsuperscript{*}Corresponding author

The Late Miocene-Early Pliocene Biogenic Bloom was a major paleoceanographic event marked by increased marine biological productivity. At multiple ocean sites, especially beneath upwelling regions in the Indian and Pacific oceans, increased mass accumulation of biogenic deposits (i.e. opal and CaCO\textsubscript{3}) has been documented between 9 and 3.5 Ma. Two hypotheses have been proposed to explain the anomalously high primary productivity during the Biogenic Bloom that is further supported by diatom-based proxies and benthic foraminiferal assemblages. This event has been related to either increased nutrient availability in the oceans (triggered by enhanced continental weathering and increased input of sediment through rivers), or to a major redistribution of nutrients due to the reorganization of ocean circulation. The widespread signal and common patterns of the Biogenic Bloom point to global forcing, however palaeoceanographic studies provide evidence for regional differences in its expression and timing. These findings underline the importance of studying regional scale processes to fully understand this event.

We investigated the expression of the Biogenic Bloom at Integrated Ocean Drilling Program (IODP) Site U1506 in the Tasman Sea, combining paleontological and geochemical data. The new age model based on orbital tuning of the Natural Gamma Radiation (NGR), benthic foraminiferal oxygen isotopes, and calcareous nannofossil biostratigraphy, was integrated with quantitative analyses of benthic foraminiferal assemblages and other independent proxies (benthic and planktonic carbon stable isotopes, mass accumulation rates of CaCO\textsubscript{3} and seismic data) to understand and possibly disentangle the regional signal from global imprint of the Biogenic Bloom at Site U1506.

Benthic foraminifera indicate two different productivity regimes within the study interval, which spans from the Tortonian (Late Miocene) to the Zanclean (Early Pliocene), and covers the middle part of the Biogenic Bloom, from 7.4 to 4.5 Ma. A high seasonal food supply to the seafloor, well-oxygenated bottom waters and strong current activity have been
inferred between 7.4 and 6.7 Ma. In contrast, benthic foraminiferal assemblages between 6.7 and 4.5 Ma are dominated by dysoxic taxa, indicating lower oxygen conditions and a continuous food supply to the seafloor. This change in productivity regime at 6.7 Ma coincides with a major stratigraphic change visible on the seismic profiles, which has been related to a weakening of the bottom current strength.

Our results point to a diverse expression of the Biogenic Bloom event at Site U1506, related to a regional change in oceanography during the Late Miocene. This study highlights the value of high-resolution studies in identifying the regional and global imprint of this event.

The potential of changing coiling directions of the planktic foraminifer *Globorotalia bykovae* (Aisenstat) for stratigraphic correlation in the Central Paratethys

**GEBHARDT Holger**1* and **HLAVÁTÁ HUDÁČKOVÁ Natália**2

1Geosphere Austria, Paleontology and Collections, Neulinggasse 38, 1060 Vienna, Austria; holger.geborahd@geosphere.at
2Dpt. of geology and paleontology, Faculty of Natural Sciences, Comenius University Bratislava, Ilkovičova 6, Mlynská Dolina, 842 15 Bratislava, Slovak Republic; natalia.hudackova@uniba.sk

*Corresponding author

Changing coiling trends of certain species can be used to distinguish time intervals on various scales. However, this attempt has been largely neglected in the last decades. Triggered by the need of alternatives for frequently missing index species in the marginal seas of the Paratethys with its instable environmental conditions, we tested the potential of changing coiling directions in *Globorotalia bykovae* (Aisenstat) for the correlation of strata. We chose *G. bykovae* because it is planktic and therefore widely distributed, easy to identify in the foraminiferal assemblages of the Central Paratethys, and occurs rather regular in late Karpatian to Badenian (late early to middle Miocene) samples. Furthermore, it is the morphologically most similar species to those used by Bolli in his 1971-paper to demonstrate the shift from the 50/50-ratio to the dominance (90% or more) of sinistrally coiled planktic foraminifera at the early to middle Miocene transition.

In order to test the potential of this method, we counted coiling directions in three well dated drill cores in Austria (Krems Embayment of Alpine Foreland Basin, Lower Austria) and three cores in the Slovak Republic (Danube Basin). Our preliminary results show not only the general shift towards sinistrally coiled specimens at the Karpatian-Badenian boundary, but show the possibility of much more detailed subdivisions. During the early to middle Badenian, several short lasting changes in the prevailing coiling direction opens the possibility to use the causing (probably) paleoecological events as stratigraphic tool for the correlation of sections. Distinct trends in coiling directions can be correlated within biostratigraphic zones (e.g., M5b, M6) and paralleled lithologic marker beds.

Therefore we propose the application of this method in section (or drill core) correlation at least as additional evidence or if index species are missing or just occur sporadically. Intra-basinal correlation appears possible if *G. bykovae* is present in the samples in sufficiently high amounts. This is probably the case during phases with normal marine conditions and environmental changes do not let to the (local) disappearance of this species.

Comparing flow-through culturing systems to investigate elemental uptake in the calcite tests of benthic foraminifera

**GFATTER Christian**1*, **MARTÍNEZ-COLÓN Michael**2 and **OWENS Jeremy**1

1Department of Earth, Ocean and Atmospheric Science, Florida State University, 1011 Academic Way, Tallahassee, FL, USA; egfatter@fsu.edu; jdowens@fsu.edu
2School of the Environment, Florida A&M University, 1515 South MLK, Tallahassee, FL, USA; michael.martinez@famu.edu

*Corresponding author

Elemental seawater concentrations of many trace elements have been collected through the analyses of benthic foraminiferal calcite. In addition, laboratory experiments have been conducted to determine the effect of various concentrations of these elements. Furthermore, analyses of foraminiferal calcite for many redox-sensitive transition metals, used to historically study the redox state of oceans, remain under constrained. Due to their low concentrations in seawater and the potential biological impact on the calcifying organisms studied, attention should be given to adsorption, contamination, and other interfering effects in such experimental studies using flow-through devices. Here, we examine the benefits and drawbacks of three such systems used to study the incorporation of trace elements into benthic foraminiferal calcite.

Three flow-through culturing systems are discussed: system 1) an apparatus using a plastic culture tray, system 2) a modified scheme utilizing a customized block of polytetrafluoroethylene (PTFE) instead of the plastic culture tray, and system 3) a serial system of synthetic perfluoralkoxy alkane (PFA) vials connected using PTFE tubing. Elements have variable affinities to adsorb onto surfaces and seawater trace metal concentrations are very low. Accordingly, particular
attention should be given to materials incorporated by devices utilized to examine trace metal effects. Notwithstanding, adjustments and compromises are often considered, depending on limitations and experimental objectives. The experimental designs presented can be adapted to a range of disciplines that study calcifying organisms, possibly for ocean acidification research and especially for tracking oceanic concentrations of trace metals.

**New morphotypes of Balkhania balkhanica Mamontova, 1966 from the upper Valanginian - lower Aptian of the northern Tethyan margin**

GHEIASVAND Masoumeh*1, and BARTOLINI Annachiara1

1CR2P-Center for Research on Palaeontology - Paris, UMR 7207 MNHN CNRS SU, Muséum national d’Histoire naturelle, 8 rue Buffon, 75005 Paris, FRANCE; masoumehgheiasvand@gmail.com, annachiara.bartolini@mnhn.fr

*Corresponding author

Balkhania balkhanica is one of the valuable species that has been used for the biostratigraphy of the Barremian-Aptian interval along the Tethyan carbonate platforms. This species is recorded from the Tethyan margins such as Russia, Lebanon, Iran, Afghanistan and Turkmenistan. B. balkhanica type species in Turkmenistan includes discoidal and evolved test, less than 5 mm to more than 15 mm in diameter, and megalospherid and microspheric forms. This species presents a choffatellid-like and calcite microgranular-agglutinated test. Pseudochoffatella gigantica also introduced as a synonymy of B. balkhanica.

Here, two Lower Cretaceous formations deposited on a carbonate platform along the Iranian Tethyan margin (Kopet-Dagh Basin, NE Iran and Yazd Block, Central Iran) have been studied. We found the first appearance of Balkhania balkhanica in the upper Valanginian beds of the Tirgan formation in the Kopet-Dagh Basin. They show small-size specimens of microspheric forms, very similar to those described for B. balkhanica type specimens described from Turkmenistan. The main difference is a much smaller test size, which ranges from 0.7 to 1.5 mm. They are therefore considered as a small-size morphotype of B. balkhanica species, which range from the upper Valanginian to the upper Hauterivian. The megalospheric forms were probably too small and thus difficult to observe and/or to preserve in the sedimentary record. B. balkhanica specimens have also been found in the upper Barremian-lower Aptian deposits of the Tirgan formation and upper Barremian of the Taft formation in the Yazd Block. Morphometric measurements show similarity to the type species, but most of them have a different wall composition, namely an agglutinated wall characterised by the presence of large quartz grains. Hence, we name them Balkhania balkhanica arenaceous morphotype. We also call Balkhania balkhanica sensu stricto for specimens of both of the forms that show nature and size-range of the tests identical to typical specimens in Turkmenistan, and have been recorded in this study and previously.

First appearance of the small-size morphotype of Balkhania balkhanica may be interpreted as basal morphotype of an evolutionary trend of this species from smaller to larger sized morphotypes at the Barremian-Aptian interval. This trend of increasing size has also been shown in other foraminifera. The nature of the grains in the composition of the wall is not always a taxonomic criterion for distinguishing agglutinated foraminifera at species level. The arenaceous morphotype could be an ecomorphotype adapted to peculiar ecological conditions and using quartz for building its wall according to its availability in the environment.

We gratefully acknowledge Annie Arnaud-Vanneau for all information on samples and identified ages, and financial support of the French Ministry for Europe and Foreign Affairs (MOPGA Fellowship).

**Response of morozovellid and acaraninid planktic foraminifera to early Eocene global warmth in a southern high-latitude site in the Indian Ocean**

GHEIASVAND Masoumeh*, BARTOLINI Annachiara1, HUBER Brian T.2 and FIORILLO Denis1

1CR2P-Center for Research on Palaeontology - Paris, UMR 7207 MNHN CNRS SU, Muséum national d’Histoire naturelle, 8 rue Buffon, 75005 Paris, FRANCE; masoumehgheiasvand@gmail.com, annachiara.bartolini@mnhn.fr
2Smithsonian Institution, Department of Paleobiology, MRC-121, Washington, DC 20013, USA; huberb@si.edu
*Corresponding author

Foraminiferal assemblages from Ocean Drilling Program (ODP) Hole 738C are analysed to assess the response of photosymbiont-bearing planktic foraminifera (morozovellids and acarininids) during the early Eocene, a time of extreme and sustained warming associated with high pCO2. This site is located on southeast Kerguelen Plateau at southern high-latitude (62°42.54'S, 82°47.25'E), which makes it ideal for the study of past climatic fluctuations in the circum-Antarctic surface waters.

We studied the diversity, abundance and test size of planktic foraminifera based on quantitative analysis of 300 specimen counts. In addition, morphometric analyses were performed on three species, including Subbotina velascoensis, Acarinina
soldadoensis and Morozovella subbotinae, from ten horizons spanning 244.80 to 283.40 meters below seafloor (mbsf). Following published interpretations, we consider S. velascoensis as an asymbiotic species and A. soldadoensis and M. subbotinae as a symbiotic species. Published oxygen isotope data on Acarinina from the lower Eocene of Hole 738C indicate decreasing values in the studied interval, suggesting increased warming of surface waters. The lowest δ¹⁸O values have been observed around 277 mbsf. Our data reveal an important planktic foraminiferal morphologic shift during this early Eocene surface seawater warming involving the symbiotic Morozovella and Acarinina foraminifera, as has been observed in several other oceanic sites (e.g., ODP Sites 1258, 1051 and 1263).

From 277.80 mbsf on, the abundance of Morozovella begins to decrease and finally M. subbotinae disappears at 264.36 mbsf, whereas Acarinina remains relatively abundant and diverse throughout the interval from 264.36 to 277.80 mbsf. Subbotina abundance increases beginning at 277.80 mbsf. In addition, the maximum size of both target symbiotic species, Acarinina soldadoensis and Morozovella subbotinae, begins to reduce (from 300 µm to 224 µm and from 250 µm to 200 µm, respectively) and after a depth of 255.32 mbsf, A. soldadoensis recovers its maximum size. Interestingly, despite the fact that the asymbiotic species Subbotina velascoensis shows a major decline in abundance from 264.6 to 244.8, it exhibits a mostly constant maximum size (~224 µm) throughout the studied interval.

The relationship between size increase of planktic foraminifera and photosymbiotic activity has already been demonstrated using test size relative to δ¹³C gradients. We propose that during the increased warming of the early Eocene the reduction in size of Morozovella and Acarinina in the southern Indian Ocean was due to a reduction in symbiotic activity (‘bleaching events’) driven by extreme environmental stress, as suggested for other oceanic sites. Morphometric and carbon isotope analyses are underway to test this hypothesis. Correlation of the early Eocene biostratigraphy, stable isotope analyses and relative abundance of morozovellids at Site 738 with the observations from Sites 1258, 1051 and 1263 of the Atlantic Ocean suggests that the first permanent decline in abundance of morozovellids was probably earlier in the southern Indian Ocean relative to the south Atlantic and then western Equatorial Atlantic Ocean. Moreover, at Site 738, the maximum test sizes of M. subbotina and M. gracilis were small (~250 µm) before their decline in abundance compared to other oceanic sites (e.g., Site 1051) where the maximum test sizes were much larger (~470 µm). An even more drastic reduction in size for these species is then observed at Site 738 in the course of the early Eocene increasing warming, coinciding with the decrease in their abundance just prior to their last occurrence, suggesting that the southern Indian Ocean ecosystem may have been more vulnerable to the warming event.

We gratefully acknowledge financial support of the French Ministry for Europe and Foreign Affairs (MOPGA Fellowship) to carry out this research.

**Applying faunal indices to understand paleoenvironmental changes with benthic foraminifera: a case study from Chilika Lagoon, East coast of India**

**GHOSH Anupam**¹*, **DASGUPTA Utsha**², **TSUIMOTO Akira**³, **NOMURA Ritsu**¹ and **SARASWATI Pratul Kumar**⁴

¹Department of Geological Sciences, Jadavpur University, 188 Raja S.C. Mallick Road, Kolkata 700032, India; anupam.ghosh@jadavpuruniversity.in
²Government Gramya Bharti College Hardibazar, Korba, Chattisgarh 495466, India; utshadasgupta93@gmail.com
³Faculty of Education, Shimane University, 1060 Nishikawatsu-cho, Matsue-shi, Shimane, 690-8504, Japan; tsuimoto@edu.shimane-u.ac.jp; nomura@edu.shimane-u.ac.jp
⁴Department of Earth Sciences, IIT Bombay, Powai, Mumbai – 400075, India; pratul56@gmail.com
*Corresponding author

Coastal areas have suffered environmental changes over the past few centuries, and floral and faunal assemblages have also changed. As foraminifera have the advantage of possessing mineralized tests preserved in the sediment compared to other organisms, they are a powerful tool for assessing (palaeo-) environmental changes. Chilika Lagoon (19°28′–19°54′ N; 85°06′–85°35′E), the largest brackish lagoon in Asia, has been studied in detail for the last few decades by using different environmental proxies such as physical and chemical parameters. In this work, we interpret the paleoenvironmental history of the lagoon in response to the artificial opening of the sand bar with diversity indices, bivariate plots, and Murray’s Ternary plot and try to find out the potentials of these tools in reconstructing paleoenvironments.

In the present study, cores were collected from two sites in the outer channel of the lagoon. The cores were sliced into 1 cm and divided into half ~ one for chronological and geochemical analysis and another for microfossil analysis. For micropaleontological analysis, the samples were wet sieved through a 63 µm sieve and dried at 50°C. The sediment samples were split with the help of a micro splitter, and benthic foraminifera from 1 gram of each split sediment sample was counted. A total of 3323 benthic foraminifera, including 15 species of Textulariida and seven species of Rotaliida, have been identified from both cores. The species of Rotaliida include Ammonia sobrina, Ammonia parkinsoniana, Ammonia tepida, Ammonia sp. 1, Ammonia sp. 2, Cribroelphidium hispidulum and Cribroelphidium sp. and Textulariida includes Ammobaculites exigus, Ammobaculites agglutinans, Ammobaculites dilatatus, Ammotium directum, Ammotium fragile, Ammotium salmii, Ammotium sp., Millimmina fuscic, Millimmina petilia, Textularia agglutinans, Textularia earlandi, Trochammina advena, Trochammina hadai, Trochammina sp. and Haplophragmoides sp.

With the Pb-210 dating method, four different intervals of environmental changes have been recognized. Very low foraminiferal abundance, including calcareous and agglutinated foraminifera ones, was noticed during the early 1900s, when
salinity fluctuations may have led to the survival problems of these species. With the opening of the artificially dredged mouth in 2000, the foraminiferal abundance and diversity value increased due to a rapid increase in salinity level. Further opening of new mouths in 2008 and widening of this mouth in 2010 and 2012, opportunistic uniserial agglutinated foraminiferal assemblages appeared and dominated, indicating the development of high salinity and low oxygenic condition in the outer channel over the last few decades. The reconstruction of the history of the environmental changes in the coastal marine ecosystem is essential to learn how the present environment formed and anthropogenically stressed ecosystems originated and to evaluate how they might evolve soon.

### Deccan volcanism, Chicxulub impact, orbital forcing, and changes in planktic foraminiferal assemblages across the Cretaceous/Paleogene boundary

**Gilabert Vicente**1,2*, ** Arenillas Ignacio**2, **Arz José Antonio**2, **Battenburg Sietske J.**, **Robinson Stuart A.**, **Krahul Guilherme**3, **Fauth Gerson**4, **Regelous Marcel**5 and **Ferrer Daniel**2

1Departament de Dinàmica de la Terra i de l'Oceà, Facultat de Ciències de la Terra, Universitat de Barcelona, C/ Martí i Franquès, 08028, Barcelona, Spain; vicengeo@gmail.com; sbattenburg@ub.edu
2Departamento de Ciencias de la Tierra, Universidad de Zaragoza-Instituto de Ciencias ambientales de Aragón-IUCA, C/ Pedro Cerbuna 12, 50009 Zaragoza, Spain; vicengeo@gmail.com; ias@unizar.es; josearz@unizar.es; danielferrer26795@gmail.com
3Department of Earth Sciences, University of Oxford, South Parks Road, OX1 3AN, Oxford, United Kingdom; stuart.robinson@earth.ox.ac.uk
4Technological Institute for Paleooceanography and Climate Change (IT OCEANEON), Unisinos University, Av. Unisinos, 950, 93022-750 São Leopoldo, Brazil; geounikrahil@gmail.com; GERSOFN@unisinos.br
5GeoZentrum Nordbayern, Universität Erlangen-Nürnberg, Schlossgarten 5, 91054 Erlangen, Germany; marcel.regelous@fau.de

*Corresponding author

The 1 Myr interval (66.4-65.4 Ma) across the Cretaceous/Paleogene boundary (KPB) is a brief period of Earth's history during which remarkable two events took place: the Chicxulub impact (~66 Ma) and the massive volcanism of the Deccan Traps (~66.3–65.6 Ma). Determining the contribution of either asteroid impact or massive volcanism to the KPB mass extinction event (~66 Ma) has fuelled and continues to fuel an intense scientific debate. In addition to the global climate disturbance that occurred just after the Chicxulub impact, others global and regional paleoclimatic events, such as the Late Maastrichtian Warming Event (LMWE; 66.25-66.10 Ma), the Dan-C2 (65.8-65.7 Ma), and the Lower-C29n event (LC29n; 65.48-65.41 Ma), have been recognized across the KPB in different localities. These events have been linked to climate changes induced by both Deccan volcanism and/or orbital forcing.

We carried out high-resolution planktic foraminiferal studies (including quantitative analyses, aberrant index, fragmentation index, and test morphometries) and carbonate geochemical analyses (bulk δ13C, bulk δ18O‰, CaCO3%) from well-known KPB sections, such as Caravaca and Zumaia (Spain), El Kef (Tunisia), and ODP Site 1262 (South Atlantic). Integrating all these proxies together with both major and trace elements (e.g., Hg, Ir, Zr, Ba, and Te, among others), may help to unravel the causes of the climatic, environmental, and biological changes across the studied interval and their relationship with the Deccan volcanism, the Chicxulub impact, and the orbital cycles. All proxies have been calibrated with an orbitally tuned age model and compared with the latest eruptive models proposed for the Deccan Traps.

No extinctions but small paleobiological changes have been recognized across the LMWE at Caravaca, such as moderate but transient changes in planktic foraminiferal assemblages, an increase in the fragmentation index tentatively related to ocean acidification, and dwarfism in Contusotruncana contusa tests. At Zumaia, the LMWE is synchronous with the last 405 kyr eccentricity maximum of the Maastrichtian, and we hypothesize that raised CO2 levels through Deccan outgassing during the late Maastrichtian may have amplified climate sensitivity to the orbital forcing, resulting in the enhanced global climatic response of the LMWE. No relevant changes have been recorded in all the studied sections during the last 100 kyr of the Maastrichtian. This suggests latest Maastrichtian environmental, climatic, and evolutionary stability was disrupted by the sudden mass extinction of > 95% of the planktic foraminiferal species at the KPB. During the Dan-C2 event, planktic foraminiferal assemblages show a rapid recovery. However, changes in planktic foraminiferal assemblages were virtually non-existent during the LC29n. Both early Danian events are robustly linked to extreme orbital configurations. Conversely, in all the studied localities, we have identified a bloom of opportunistic triserial guembelitrid Chiloguembelitria in the early Danian (~65.9 Ma), which covariates with an increase in aberrant planktic foraminifers. These increase in aberrant tests only was outnumbered for that recorded at the KPB, suggesting a resurgence of environmental stress in the sea surface. According to our first results in major elements, this environmental stress episode is temporally well-correlated with an anomaly in the Hg/TOC ratio (~65.9 Ma) at ODP Site 1262, supporting a cause-effect relationship with the Deccan Traps mega-eruptions that occurred during the emplacement of the Ambenali Fm. in the early Danian.
Aberrant planktic foraminifera as biomarkers of environmental stress and/or chemical contamination across the Cretaceous/Paleogene boundary

GILABERT Vicente1,2*, ARENNILAS Ignacio2, ARZ José Antonio2, KRAHL Guilherme3 and BATENBURG Sietske1

1Departamento de Dinámica de la Terra i de l’Oceà, Facultat de Ciències de la Terra, Universitat de Barcelona, C/ Martí i Franqués, 08028, Barcelona, Spain; vicengeo@gmail.com; sbatenburg@ub.edu
2Departamento de Ciencias de la Tierra, Universidad de Zaragoza-Instituto de Ciencias ambientales de Aragón-IUCA, C/ Pedro Cerbuna 12, 50009 Zaragoza, Spain; vicengeo@gmail.com; ias@unizar.es; josearz@unizar.es
3Technological Institute for Paleoceanography and Climate Change (itt OCEANEON), Unisinos University, Av. Unisinos, 950, 93022-750 São Leopoldo, Brazil; geounikral@gmail.com

*Corresponding author

The foraminiferal abnormality index (FAI = % in aberrant foraminifera) with benthic foraminifera has been proven useful in recognizing stressed and/or polluted environments in recent sediments. However, using this proxy with planktonic foraminifera is becoming more common, being used as a biomarker to identify events and episodes of greater environmental stress or chemical contamination from the distant past as well. A good example are the high values in FAI recorded across the Cretaceous/Paleogene boundary (KPB) that are tentatively linked to the environmental effects of the Chicxulub impact and/or Deccan massive volcanism. Various types of abnormalities in the test morphology have been described during this time interval, including protuberances near the proloculus, abnormal chambers, double or twinned ultimate chambers, multiple ultimate chambers, abnormal apertures, distortion in test coiling, morphologically abnormal tests, attached twins or double tests, and general monstrosities.

The first high-resolution study on the planktic FAI evolution across the KPB was carried out at El Kef and Aïn Settara sections (Tunisia; Tethys). At these two localities, a FAI peak (~18-20%) was recognized within the dark clay bed immediately above the KPB. It contrasts with the low values of FAI (usually ~2%) across the uppermost Maastrichtian, suggesting relatively stable environmental conditions during the last ~50–100 ka of the Cretaceous. The dark clay bed of the KPB is well-known for registering high values in heavy metals (e.g., Cr, Ni, Cu, P), and thus the increase in aberrant tests was linked to increased environmental stress and heavy metal pollution from the Chicxulub impact. A second peak in FAI was recognized in the early Danian, which was initially related to both the Dan-C2 and Deccan volcanism.

In this study, we carried out a quantitative study of the FAI from several well-known KPB sections, such as Caravaca (Spain; Tethys), Zumaia (Spain; North Atlantic), and ODP Site 1262 (South Atlantic), integrating it in a robust age model. The objective is to evaluate how the FAI behaves in different environments and establish cause-effect relationships with some of the environmental events reported across the KPB. The values reached by the FAI vary between sections, with the lowest values recorded at ODP Site 1262 and the highest at Aïn Settara. However, all the sections display similar FAI trends. The highest values within the KPB dark clay bed (i.e., the first ~10 ka of the early Danian) are related to the immediate environmental aftermath of the Chicxulub impact (i.e., ocean acidification, heavy metal pollution, toxic phytoplankton blooms). A decrease in FAI characterizes the following 70 kyr, although average values remain relatively high, suggesting that environments are still stressed but trending towards recovery. The environmental stabilization was abruptly interrupted ~100 kyr after the KPB, coinciding with the onset of the second FAI peak. According to geochemical and taphonomic proxies, this second peak does not correlate with changes in sea-surface temperature and/or ocean acidification. The second FAI peak occurred ~100 ka before the onset of the Dan-C2 climatic event (~65.8 Ma), but it correlates well with the Ambenali Formation emplacement (~65.9 Ma) of the Deccan Traps. The coeval bloom in opportunistic planktic foraminifera (triserial guembelitrids) and the high Hg values reinforce the hypothesis of the high input of volcanogenic nutrients and a higher concentration in heavy metals (e.g., Hg) during this interval. The weak biological pump conditions in the early Danian oceans may have enlengthened the residence time of the volcanogenic nutrients and elements on the sea surface, causing the FAI to remain high. More studies in other localities on the FAI evolution across the KPB are required to decipher whether it was linked to Deccan chemical contamination and/or other environmental stressors.

Mesophotic benthic foraminifera assemblages record the drowning of a carbonate platform in the northern Red Sea, Saudi Arabia

GIOVENZANA Francesca1,2, MATEU-VICENS Guillem1,4, WESTPHAL Hildegard3,5,6, PETROVIC Alexander1,2 and VAHRENKAMP Volker1,2

1Ali I. Al-Naimi Petroleum Engineering Research Center (ANPERC), King Abdullah University of Science and Technology (KAUST), 23955, Thuwal, Saudi Arabia; francesca.giovenzana@kaust.edu.sa; alexander.petrovic@kaust.edu.sa; volker.vahrenkamp@kaust.edu.sa
2Red Sea Research Center (RSRC), King Abdullah University of Science and Technology (KAUST), 23955, Thuwal, Saudi Arabia; francesca.giovenzana@kaust.edu.sa; hildegard.westphal@kaust.edu.sa; alexander.petrovic@kaust.edu.sa; volker.vahrenkamp@kaust.edu.sa
3Catedra Guillem Colom, University of the Balearic Islands, Ctra. Valldemossa km 7.5, E-07122 Palma de Mallorca, Spain; guillem.mateu@uib.es
4Interdisciplinary Ecological Group, University of the Balearic Islands, Ctra. Valldemossa km 7.5, E-07122 Palma de Mallorca, Spain; guillem.mateu@uib.es
5Leibniz Centre for Tropical Marine Research (ZMT), Fahrenheithstraße 6, 28359, Bremen, Germany; hildegard.westphal@kaust.edu.sa
6Department of Geosciences, University of Bremen, Bibliothekstraße 1, 28359, Bremen, Germany; hildegard.westphal@kaust.edu.sa
Mesophotic coral ecosystems (MCEs) are peculiar ecosystems characterized by low-light levels and typically occur between 30 and 150 m water depth in tropical and subtropical regions. They can develop on top of drowned carbonate platforms, since these provide high rugosity and three-dimensional structural complexity that result in great niche diversification. Benthic foraminifera are an important component of the mesophotic community and since they are optimal environmental indicators, they can be used to characterize and further understand this relatively understudied ecosystem. Through the analysis of benthic foraminifera assemblages, this study aims to describe a MCE developed on an isolated, partially drowned carbonate platform located to the south of Al Wajh lagoon (northern Red Sea, Saudi Arabia). Ultimately, constraining biological assemblages vs depth will help to develop criteria to recognize and quantify accommodation space increase caused by rapid sea level rise and/or salt tectonic-related drowning.

Al Wajh is a rift-basin land-attached carbonate platform characterized by an arid climatic setting. Its geological evolution has been influenced by tectonics, delta-top deposits, and salt tectonics. The southern margin is undergoing a fragmenting process related to the plasticity of the thick evaporitic layer deposited during mid-Miocene restricted conditions, which underlies the Plio-Pleistocene shallow-marine carbonates. The platform blocks are rafting towards the center of the basin and some of them have slid down partially or completely below the euphotic zone, including the one selected for this study. This platform rises to a height of 650 m above the seafloor, and it has been investigated during a joint research cruise between KAUST and JAMSTEC in February 2022, where hydroacoustic data, CTD profiles, seafloor images, and water and sediment samples were acquired. A total of 11 sediment samples have been collected between 40 and 130 m water depth for benthic foraminifera assemblages’ analysis.

The current depth profile of the platform is reflected in the taxonomic composition of the foraminiferal assemblages. Shallowerr samples are characterized by abundant epiphytic taxa such as *Cibicides* and shallow *Amphistegina* species such as *A. lessonii*, with rounded and thick tests. Deeper samples are dominated by infaunal, mud-dwelling taxa such as *Bolivina, Bulimina, Heterolepa*, and the deep, flat-shaped *A. papillosa, A. radiata* and *A. bicirculata*. *Operculina ammonoides* is a major component of all the assemblages and can occur both in its microspheric and megaspheric form. Small miliolids are present in shallower samples, while at deeper locations this group is only represented by reworked specimens. Reworked and broken tests of rotaliids are abundant in all samples.

This study establishes a clear depth-dependent trend in benthic foraminifera assemblages on a drowning carbonate platform. The way the platform drowning affects the benthic foraminifera assemblages is comparable with the changes expected in the biota community caused by a relative sea-level rise during deglacial phases. Moreover, in this mesophotic environment, a considerable proportion of reworked specimens indicates a mechanism of sediment transport by relatively strong currents. Hence, correlation of benthic foraminifera assemblages with water depth has to consider only *in situ* specimens, while excluding reworked ones. Future investigations on the paleoenvironmental evolution of this platform through the study of benthic foraminifera assemblages along sediment cores will provide further details on the combined effect of drowning/accommodation space increase related to subsidence due to salt tectonic movement and eustatic sea-level rise.

**The taxonomy and taphonomy of modern Foraminifera in the Blue Hole of Faanu Madugau (Ari Atoll, Maldives)**

**GIRALDO-GÓMEZ Victor M.**, **ARENA Luca**, **AZZOLA Annalisa**, **CAPELLO Marco**, **CUTRONEO Laura**, **MONTEFALCONE Monica** and **BRIGUGLIO Antonino**

1 Dipartimento di Scienze della Terra, dell’Ambiente e della Vita, Università degli Studi di Genova, Corso Europa 26, I-16132 Genova, Italy; victormanuel.giraldogomez@edu.unige.it; lucaarena95@libero.it; annalisa.azzola@edu.unige.it; marco.capello@unigea.it; laura.cutroneo@edu.unige.it; monica.montefalcone@unige.it; antonino.briguglio@unige.it

*Corresponding author

The Blue Hole of Faanu Madugau (Ari Atoll, Maldives) has a depth of about 80 m, and according to physical and chemical data measured along a depth profile from the surface to the bottom, suggests the complete absence of any water circulation below a depth of 50 m. Acidic pH, high concentration of H2S, and anaerobic conditions point to a very limited biotic window. To check for the historical record of the sedimentary succession deposited at the bottom of the Blue Hole, a shallow core was sampled by hand from the seafloor at 80 m ca. depth. The sediment observed at the bottom was extremely porous and oversaturated several centimetres beneath the surface, thus making core penetration relatively easy. The sampled core was around 1 m thick, but during the long ascensions, most of the sediment settled at the base of the core, thus producing only an 18 cm thick sediment interval. The core was immediately sliced into 2-cm intervals on the support vessel. Samples were dried and picked for biotic remains among the sediment particles.

The fauna retrieved is almost exclusively composed of foraminifera shells; a few molluscs and ostracods are also present, along with rare sponge spicules. The foraminiferal distribution is dominated by benthic taxa, while planktonic taxa are scarce. Among the benthic foraminiferal assemblages, the genus *Amphistegina* is the most abundant in all samples, with the species *A. bicirculata, A. lessonii*, and *A. radiata*. Other common taxa identified are *Neoassilina ammonoides, Operculina complanata, Elphidium cf. gunteri, Heterostegina depressa, Palaeonummulites venosus, Borelis pulchra, B. schlumbergeri,*
and *Neorotalia calcarea*, *Quinqueloculina* spp., *Spiroloculina* sp., and some agglutinated tests such as *Textularia* sp. are sporadically observed.

Since most of the retrieved assemblages are solely limited to the photic zone and inhabit mostly shallow reefs and lagoons, this study showed that all the retrieved foraminifera are transported from the surrounding environments to the greatest depths.

This interpretation leaves several questions to be answered in the future with more focused studies. One of the major questions should address how it is possible that the Blue Hole of Faanu Madugau has never been filled like the rest of the surrounding lagoon. Our data points to the interpretation that, since the entire material retrieved is the product of transportation from the nearby lagoon and reefs, only a diminished production rate can result in a reduced sedimentation rate, but that seems unplausible given the extent of the reefs in the region. This issue leads to the need to extrapolate the sedimentation rate of the deposit retrieved, which will be done in the future by measuring the C\(^{14}\) data from the foraminiferal fauna.

**Bottom water conditions during the Ocean Anoxic Event 1a in the southern Tethys and central Pacific Ocean: the benthic foraminiferal response**

GIRALDO-GÓMEZ Victor M.\(^1,2\)*, PETRIZZO Maria Rose\(^3\), BOTTINI Cinzia'and ERBA Elisabetta\(^1\)

1Dipartimento di Scienze della Terra “Ardito Desio”, Università degli Studi di Milano, Via Mangiagalli 34, 20133 Milano, Italy; victor.giraldo@unimi.it; morose.petrizzo@unimi.it; cinzia.bottini@unimi.it; erba@unimi.it

2Dipartimento di Scienze della Terra, dell’Ambiente e della Vita (DISTAV), Università degli Studi di Genova, Corso Europa 26, I-16132 Genova, Italy; victormanuel.giraldogomez@edu.unige.it

*Corresponding author

The environmental impact of the Ocean Anoxic Event 1a (OAE 1a) has been intensively studied in the Cismon core (Tethys, Italy) and DSDP Site 463 (central Pacific Ocean) by using different geochemical and micropaleontological proxies, but the benthic foraminiferal response reflected in the bottom waters had not been documented until now. Here we present new benthic foraminiferal assemblage data across the upper Barremian-Upper Aptian from the Cismon core (Tethys Ocean) and DSDP Site 463 (central Pacific Ocean). Based on changing taxa distribution through different benthic foraminiferal intervals (BFI), a reconstruction of bottom water conditions was addressed to distinguish the paleoenvironmental changes across the OAE 1a. In the pre-OAE 1a interval, a shift from relatively stable oxygenated conditions (upper Barremian) to more depleted oxygen conditions (lowermost Aptian) on the seafloor at the Cismon core has been observed. As a prelude to OAE1a, a considerable decrease in benthic foraminifera (crisis phase) suggests a marked deterioration of the bottom waters under a dysoxic regime in both stratigraphic sections. Within the OAE 1a interval, benthic foraminifera, especially in the Cismon core, evidence two distinctive short-term changes in the bottom waters. A lack of benthic foraminifera (barren phase), indicative of anoxic water conditions, is followed by a slight and scarce occurrence of benthic foraminifera (repopulation phase), suggesting the presence of at least very low concentrations of oxygen at the seafloor under a dysoxic-anoxic setting. In turn, at DSDP Site 463, there was a deprivation of benthic foraminifera (barren phase), indicating the depleted-oxygen conditions characteristic of an anoxic environment. Benthic foraminiferal taxa in the post-OAE 1a 1a interval coincide with a transition phase as the seafloor experienced a slight improvement in the oxygen concentration in the bottom waters. Finally, the benthic foraminifera at Cismon and DSDP Site 463 reflect extreme paleoenvironmental and climatic conditions during the Barremian-early Aptian associated with the oceanic perturbations resulting from the activity of the Ontong Java Plateau, including increased volcanogenic CO\(_2\) emissions and enhanced greenhouse climatic conditions.

**Towards estimating community composition from metabarcoding output in large benthic Foraminifera**

GIRARD Elsa B.\(^1,2\)*, DIDASKALOU Emilie A.\(^3\), RATTNER Carolina\(^1\), PRATAMA Andi M. A.\(^4\), MORARD Raphaël\(^5\) and RENEMA Willem\(^1,2\)

1Naturalis Biodiversity Center, Darwinweg 2, 2333 CR Leiden, the Netherlands; elsa.girard@naturalis.nl; carolina.rattner@naturalis.nl; jan.macher@naturalis.nl; willem.renema@naturalis.nl

2IBED, University of Amsterdam, Sciencepark 904, 1098 XH Amsterdam, the Netherlands

3Environmental Biology Department, Institute of Environmental Sciences, CML, Leiden University, Einsteinweg 2, 2333 CC Leiden, the Netherlands; e.a.didaskalou@cml.leidenuniv.nl

4Marine Science Department, Faculty of Marine Science and Fisheries, Hasanuddin University, Jl. Perintis Kemerdekaan Km. 10 Tamalilena, Makassar, 90245, Indonesia; agungpratama0515@gmail.com

5MARUM Center for Marine Environmental Sciences, University of Bremen, Leobener Strasse 11, 28359 Bremen, Germany; rmorard@marum.de

*Corresponding author

Describing living community compositions is essential to answer basic ecological questions; however, it is a challenging task. Continuous progress is being made in foraminiferal research to improve taxonomy, species identification and
community composition based on genetic information. Metabarcoding is a recent tool that could be used instead of traditional specimen counting under the microscope, which is time consuming and can lead to species misidentification. Quantitative metabarcoding has the potential to allow for more informative environmental monitoring, by rapidly producing outputs similar to specimen counting with higher taxonomic accuracy, in presence of a good reference database.

However, estimating molecularly foraminiferal community composition is challenging. Metabarcoding results provide relative abundance, which can be biased from a technical level (e.g., DNA extraction, amplification) or from a biological level (e.g., number of gene copies differing between species). Our work focuses on advancing metabarcoding methods to better understand these biases and correct for them, using a recently developed mitochondrial marker (COI). This marker has decreased genetic variability compared to the well-known nuclear marker (SSU 18S). Correcting these biases will provide a more accurate assessment of the species community composition and therefore permits the use of this data to answer ecological questions.

We are interested in monitoring large benthic foraminifera (LBF) assemblage composition in coral reefs, because they are good bioindicators of environmental conditions associated with coral growth. To achieve this, we used single specimens of LBF in combination with bulk sediment samples. We compared chamber volume, surface area and the number of COI gene copies in seven LBF species. First results show a positive correlation between surface area and number of COI gene copies was found in six of the seven species, but especially strong for *Amphisorus*, *Heterostegina depressa*, *Neorotalia guinardi* and *Operculina ammonoides*. Most calculations of gene copy density lay between 0.1 and 0.5 million copies/mm$^2$, but for *H. depressa* reaching up to 15 million copies/mm$^2$.

Based on these preliminary results, we expect that species composition can be extracted from the number of reads, proportional to the number of specimens and the space taken in a sample. Quantitative metabarcoding of species composition still needs to be demonstrated and validated by comparing our results with mock communities and sediment samples, both analysed morphologically and molecularly.

**Foraminiferal pore densities reveal that the Peruvian oxygen minimum zone was similar in extent but weaker during the Last Glacial Maximum**

**GLOCK Nicolaas$^1$, ERDEM Zeynep$^2$ and SCHÖNFELD Joachim$^3$**

$^1$Institute for Geology, University of Hamburg, Bundestrasse 55, 20146 Hamburg, Germany; nicolaas.glock@uni-hamburg.de
$^2$GEO MAR Helmholtz Centre for Ocean Research Kiel, Wischhofstr. 1-3, 24148 Kiel, Germany; jschoenfeld@geomar.de
$^3$Corresponding author

Quantifying past oxygen concentrations in oceans is crucial to improve understanding of currently ongoing global ocean deoxygenation. The use of porosity and pore density of aerobic epifaunal foraminifera as proxies for quantitative O$_2$ reconstructions is evolving. In this study, we tested four different methods to determine the pore density of epifaunal Planulina limbata in core top samples from the Peruvian Oxygen Minimum Zone (OMZ) between 7 and 12$^\circ$S. The strongest correlation between pore density and near-bottom water O$_2$ concentrations ([O$_2$]$_{bw}$) has been found when the pore density was determined on a size-normalized area of the spiral side. Subsequently, we used the novel calibration and a record of pore density of the epibenthic foraminifer *P. limbata* from the Peruvian OMZ to reconstruct oxygen concentrations in near-bottom waters from the Last Glacial Maximum to the Late Holocene at 17.5$^\circ$S about 500 meters water depth. We found that [O$_2$]$_{bw}$ levels were 40% lower during the Last Glacial Maximum than during the Late Holocene (about 6.7 versus 11.1 µmol/kg, respectively). A comparison with other reconstructions of oxygen concentrations in the region reveals a shallow OMZ during the Last Glacial Maximum that was similar in water depth and extent but weaker than during the Late Holocene. Increased glacial oxygen concentrations are probably related to lower temperatures (higher oxygen solubility), decreased nutrient and increased oxygen supply by source waters, and a decrease in coastal upwelling.

**Ubiquitous occurrence of phosphate storage in foraminifera – Another adaptation to anaerobic environments?**

**GLOCK Nicolaas$^1$, NOMAKI Hidetaka$^2$, WOEHLE Christian$^3$, ALGAR Christopher$^4$, GOVINDANKUTTY MENON Anjaly$^1$, ISHIKAWA Yoshiyuki$^2$, KIENAST Markus$^4$, MUTZBERG André$^4$, OKADA Satoshi$^2$, RAKSHIT Subhadeep$^3$, RICHIRT Julien$^2$, SCHMIEDL Gerhard$^1$, STEINER Zvi$^2$ and ZHANG Zhouling$^3$**

$^1$Institute for Geology, University of Hamburg, Bundestrasse 55, 20146 Hamburg, Germany; nicolaas.glock@uni-hamburg.de; anjaly.govindankutty.menon@uni-hamburg.de; gerhard.schmiedl@uni-hamburg.de
$^2$SUGAR, X-star, Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Yokosuka 237-0061, Japan; nomaki@jamstec.go.jp; okadasa@jamstec.go.jp; richirt.julien@jamstec.go.jp
$^3$Former address: Institute of Microbiology, Kiel University, 24118 Kiel, Germany; Current address: Miltenyi Biotec B.V. & Co. KG, 51429 Bergisch Gladbach, Germany; woehle@gmail.com
$^4$Dept. of Oceanography, Dalhousie University, 1355 Oxford St, Halifax, Nova Scotia, B3H 4R2, Canada; Chris.Algar@dal.ca; markus.kienast@dal.ca; Subhadeep.Rakshit@dal.ca

FORAMS 2023, June 26th–30th, 2023, Perugia, Italy – Abstract Book
Benthic foraminifers are ubiquitous marine protists that possess specific adaptations to the partly extreme environments in their ecological niche. Ocean deoxygenation due to climate warming and anthropogenic eutrophication is an ongoing threat for marine organisms that are not well adapted to O₂ depletion. Nevertheless, several benthic foraminifera species might benefit from ocean deoxygenation, since they are well adapted to O₂ depletion due to their capacities to denitrify or the ability to stay dormant during periodic hypoxia. In addition, their high abundances in O₂ depleted environments make them key players in marine nutrient cycling.

Recently, we found that foraminifera can accumulate large amounts of phosphate in their cells. New data show that this is a widespread phenomenon and occurs in diverse environments such as tidal flats, hypoxic fjord basins, oxygen minimum zones and the Mid-Atlantic Ridge. The high intracellular phosphate storage in foraminifera has previously been overlooked in benthic phosphorylating systems. It constitutes an important mobile reservoir in benthic ecosystems and might facilitate phosphogenesis in some environments. Foraminifera encode the genes required for both a polyphosphate, as well as a creatine phosphate metabolism. Both creatine phosphate and polyphosphates are good energy carriers that can rapidly regenerate ADP to ATP, when electron acceptors are depleted. Coupled TEM-EDS and cryo-SEM-EDS reveal intracellular phosphorous accumulations that are associated with vesicles of ~2-5 μm in diameter. These vesicles are possibly acidocalcisomes that are typically used to store polyphosphates in eukaryotic cells and are similar in size and shape. These results indicate, that the high intracellular phosphate storage is likely another adaptation to O₂ depletion and used to stay mobile, when their preferred electron acceptors are depleted in the environment.

Trends in the record of foraminiferal organic linings

GODOS Karolina¹, TYSZKA Jarosław³*, GOLEN Jan¹ and RADMACHER Wiesława¹

¹Institute of Geological Sciences, Polish Academy of Sciences in Kraków, St. Senacka 1, 31-002 Kraków, Poland; ndgodos@cyf-kr.edu.pl; ndtyszka@cyf-kr.edu.pl; ndgodos@cyf-kr.edu.pl; ndgodos@cyf-kr.edu.pl; ndgodos@cyf-kr.edu.pl; ndgodos@cyf-kr.edu.pl; ndgodos@cyf-kr.edu.pl; ndgodos@cyf-kr.edu.pl; w.radmacher@ingpan.krakow.pl
*Corresponding author

Foraminiferal organic linings still present nearly unexplored potential for learning evolutionary trends within the phylum Foraminifera. We recognize that the fossil record of organic linings is highly scattered and limited. Therefore, we decided to create a catalogue of all foraminiferal linings available in the scientific literature so far. The first version of Global Database of Foraminiferal Organic Linings (ForamL Version 1.2) has been based on 155 scientific publications that illustrated 614 linings (see ForamL, Version 1.2, doi: 10.17632/xw7w5ns649.3). All foraminiferal organic linings have been grouped following the supraordinal classification that divides Foraminifera into 3 large groups: (1) a paraphyletic monothalamids, as well as two classes (2) Globothalamea and (3) Tubothalamea, while phylogenetic position of an order Lagenida is still uncertain. These taxonomic groups of foraminifera are distinguished based on morphology and arrangement of chambers analyzed within the database. The database covers the whole Phanerozoic, divided into the Cenozoic, Mesozoic, Paleozoic, and then to systems/periods. The purpose of gathering the data is to extend scientific knowledge on the origin, taphonomy, and phylogenetic patterns of these fossilizable organic foraminiferal structures. The ForamL database is also linked to the most recent review of the knowledge on foraminiferal organic linings published by the authors. It will be further supplemented by available records of foraminiferal organic linings.

Our quantitative analysis of the database, shows a chronostratigraphic upward trend revealing an increase in the amount of linings from the lower to upper units (systems and erathems). The highest amount of foraminiferal organic linings calculated per time unit is found in the Cenozoic, then lower in the Mesozoic and the lowest in the Paleozoic. This phenomenon seems to be associated with accessibility of the data due to better access to younger sediments and greater interest in studying sediments representing younger geological periods that results in a larger number of published studies from younger strata. Another, partly complementary, explanation comes from the Triassic vs Jurassic and Cretaceous record. A high increase in the number fossil linings since the Jurassic may indicate the evolutionary proliferation of new globothalamean taxa that belong to Rotaliida and Textulariida. In this case, we can argue that we are dealing with the evolutionary trend. The analysis of the overall morphotypes of multilocular linings indicate a domination of spiral tests that include low trochospiral and planispiral chamber arrangements. This trend might reflect absolute dominance of spiral tests in the fossil record. Furthermore, we should note a consistent occurrence of biserial foraminiferal organic linings that appeared in the Jurassic and exist in the fossil record in all higher stratigraphic units. This pattern also appears to be related to the evolutionary trends known from the biserial globothalamean foraminifera.

Our research is supported by the Polish National Science Center (Grant 2020/37/B/ST10/01953).
Diversity and distribution of the benthic foraminifera on the Brunei shelf (Palawan/North Borneo ecoregion): effect of seawater depth

GOETING Sulia1*, LEE Huan Chiao2, KOCSIŚ Łąszłó1, BAUMGARTNER Claudia1 and MARSHALL David J2

1University of Lausanne, Faculty of Geosciences and Environment, Institute of Earth Sciences, Geopolis, CH 1015 Lausanne, Switzerland; Sulia.HajiMohamedSalim@unil.ch; laszlko.kocsis@unil.ch; Claudia.baumgartner@unil.ch
2Universiti Brunei Darussalam, Faculty of Science, Environmental and Life Sciences, Jalan Tungku Link, BE1410, Bandar Seri Begawan, Brunei Darussalam; 22m1413@ubd.edu.bn; david.marshall@ubd.edu.bn
*Corresponding author

The marine benthic diversity of Palawan/North Borneo ecoregion is relatively poorly known despite its implied unique high species richness within the Coral Triangle. The present study aimed to better understand the diversity and distribution of the benthic foraminifera on the Brunei continental shelf of this region. We documented the species collected in sediment samples from 11 sites extending 75 km from the coastline along a depth gradient ranging between 10 and 200 m. To understand how distribution is related to environmental factors, we undertook preliminary carbon and oxygen stable isotope analyses of selected species from three families (Rotaliina, Miliolina, Lagenina). In view of anticipated widely-varying, depth-related environmental conditions, we assessed foraminifera assemblage patterns and the existence of different biotopes. We found a total of 99 species belonging to 31 families and 56 genera, of which 52 species represented new records for Brunei and probably the ecoregion. The oxygen isotope data reflected strong positive correlations with depth that links to anticipated colder temperature at greater depths. The carbon isotope data showed some species-specific separation among the different taxa, especially for some rotaliid and miliolid, that may link to different habitat, food-source, and/or biomineralization effects. Three assemblages were distinguished relating to specific depths of ~10-40 m, 70-100 m and 200 m (shelf edge), indicating the presence of two benthic marine biotopes on the Brunei shelf. Overall, this study adds significant understanding to the local and regional patterns of benthic foraminifaran diversity and distribution.

Porosity in Ammonia sp. as an indicator of hypoxia in Long Island Sound, USA

GOETZ Eleanor1*, HULL Pincelli1 and THOMAS Ellen1,2

1Department of Earth and Planetary Sciences, Yale University, 210 Whitney Avenue, New Haven, CT, 06511, USA; elly.goetz@yale.edu; pincelli.hull@yale.edu; ellen.thomas@yale.edu
2Department of Earth and Environmental Sciences, Wesleyan University, 265 Church St., Middletown, CT, 06459, USA; ellen.thomas@yale.edu
*Corresponding author

Long Island Sound (LIS), between Connecticut and Long Island, NY, called 'The Urban Sea', is a relatively small body of water with sharply declining water quality from East to West, due to varying levels of population density and industrialization, and dominant water exchange with the Atlantic Ocean at its eastern end. Western LIS, closest to New York City, is characterized by overall high levels of pollution, including, heavy metal contamination and eutrophication due to input of nutrients from wastewater treatment plants.

Coincident with increasing eutrophication, there has been a turnover in the composition of benthic foraminiferal assemblages in western LIS. These had been dominated by the diatom-using Elphidium excavatum since the establishment of LIS as an estuary during the Younger Dryas, but became dominated by the omnivorous Ammonia sp. in the 1980s-1990s. The cause of this replacement is not clear: it may have been hypoxia, though E. excavatum as well as Ammonia sp. are hypoxia-resilient in cultivation, and/or caused by changes in phytoplankton communities due to increased N/Si. However, abundant Ammonia sp. could also be an invasive species, which outcompeted native Elphidium species in the most polluted regions.

We collected Ammonia sp. from Black Rock Harbor (Bridgeport, CT), next to a sewage outfall pipe, and from the Richard’s Property (Bradford, CT), a site with better water quality. Cells were picked and imaged on a Keyence light microscope to measure porosity before extracting and sequencing SSU. We use ImageJ to measure 2-dimensional area and maximum diameter of the test on the spiral side, and average pore size and porosity.

Ammonia spp. been shown to have inter- and intraspecies variability in pore size, with intraspecies variability corresponding to oxygen levels: larger pores may aid in gas exchange and/or house ectobionts for survival under hypoxia. Genetically, Ammonia is one of the best-studied genera of benthic foraminifera, but there is little sequence data from LIS, with specimens limited to two phylotypes (T1, T9). In our phylogeny, new data on LIS Ammonia grouped with clade T6 (Ammonia confertitesta) with 100% bootstrap support, a phylotype until now found only in Europe and Asia. We will sequence more specimens from both locations to determine what phylotypes are present and compare phylotypes and morphology.
Growing Deformed Benthic Foraminifera from Propagules with Exposure to Zinc

GOLDSTEIN Susan T.1* and RICHARDSON Elizabeth A.2

1Departments of Geology and Marine Sciences, University of Georgia, Athens, GA, U.S.A. 30602; sgoldst@uga.edu
2Georgia Electron Microscopy, University of Georgia, Athens, GA, U.S.A. 30602; bethrichardson@uga.edu
*Corresponding author

Deformed tests in benthic foraminifera have been widely reported in both calcareous and agglutinated, multi-chambered taxa. These abnormalities have been attributed to a broad range of stressors, both naturally occurring (e.g., fluctuating salinities or temperatures, shell repair, infestations) and human induced (heavy-metal or organic pollution, and related conditions). Identifying the underlying causes and mechanisms of morphological abnormalities in field-based studies alone is difficult because a specific site may experience multiple contaminants as well as brief temporal changes in environmental conditions. Controlled laboratory experiments are therefore invaluable in assessing the effects of environmental conditions and contaminants on foraminiferal assemblages and the responses of individual taxa.

Previous work has shown that growth from propagules in the presence of zinc produces high proportions of calcareous foraminifera with abnormal morphologies. The levels of zinc used in these experiments exceeded the U.S. Environmental Protection Agency’s maximum safe concentration for saltwater, but were below the threshold that prohibited foraminiferal growth and/or killed propagules. By growing deformed foraminifera in the lab, we can better examine biological responses to individual contaminants and how they perturb calcification and growth.

To determine conditions that repeatedly produce foraminifera with deformed tests, assemblages were grown from propagules using different sets of conditions. Those that produced the most consistent results for our study site include: constant temperature (between 18 and 23°C), ambient salinity at the collection site (between 30 and 32‰ artificial seawater), and exposure to a total initial concentration of 50 mg/L Zn (using ZnCl₂). The concentration of zinc in the artificial seawater typically declines over the course of the experiment as it adheres to sediment particles, organics and perhaps the container walls. The propagules used for this experiment were sourced from an extensive mudflat or the adjacent saltmarsh surface located on the southern end of Sapelo Island, Georgia, U.S.A. Overall, monothalamid foraminifera (Psammophaga sapela, Ovammina opaca) grew abundantly over the initial few weeks with no evidence of morphological abnormalities or other deleterious effects. Over the weeks that followed, populations of the calcareous perforate foraminifera, Haynesina germanica and Ammonia “tepida” grew, both with high abundances of deformed tests (5 – 48%). In addition, the agglutinated miliolid, Miliammina fusca, grew from sediments from the marsh surface with abundant deformed tests.

Living deformed Haynesina germanica and Ammonia “tepida” were able to extend pseudopodial nets. H. germanica however lacked the deep olive coloration that is characteristic of healthy individuals with abundant sequestered chloroplasts. A. “tepida” likewise lacked the characteristic golden color but were able to feed on Dunaliella. Abnormal morphologies range from slight to grossly malformed, and the types of abnormalities are comparable to many of those reported in field-based studies. Here, abnormalities in calcareous species include: fragility, abnormal chamber arrangement, enlarged or diminutive chambers, abnormal openings in the test, crenulations in the test, exfoliation of the test surface, abnormal pores, abnormal surface textures, and enlarged or out-of-place apertures. The primary deformity in Miliammina fusca is an abnormal chamber arrangement where new chambers become loosely coiled and appear nearly planispiral.

Ectoplasmic control of calcium ion transport during chamber biomineralization in rotaliid Foraminifera: novel results from live fluorescent labelling of frothy pseudopodia

GOLEŃ Jan1*, TYSZKA Jarosław1, BICKMEYER Ulf2, BUMA Jelle2, GODOS Karolina1, NAGAI Yukiko3 and TOYOFUKU Takashi3

1ING PAN – Institute of Geological Sciences, Polish Academy of Sciences, Research Centre in Cracow, Senacka 1, 31-002 Kraków, Poland; ndgolen@cyf-kr.edu.pl; ndtyszka@cyf-kr.edu.pl; ndgodos@cyf-kr.edu.pl
2Alfred-Wegener-Institut, Helmholtz-Zentrum für Polar- und Meeresforschung, Bremerhaven, Germany; ulf.bickmeyer@awi.de; Jelle.Bijma@awi.de
3Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Natsumashima-cho 2-15, Yokosuka, 237-0061, Japan; nagai.y@jamstec.go.jp; toyofuku@jamstec.go.jp
*Corresponding author

Our aim is to present the results of new actualistic studies on microstructure and biomineralization in calcareous Foraminifera. We explored the organization of the ectoplasmic structures and the process of seawater vacuolisation during chamber formation in rotaliid Foraminifera represented by Amphistegina lessonii d’Orbigny and Ammonia confertitesta Zheng. We employed live fluorescence staining and confocal microscope observations. Two distinctly different fluorescent dyes were used, i.e. (1) Calcein Red-Orange AM, a cell-permeable dye, to visualise the ectoplasm, and (2) Calcein, a calcium-binding, cell-impermeable, green dye, to observe seawater vacuolisation. Our results show that during the biomineralisation stage of chamber formation, Calcein Red-Orange AM stains the outer and inner lamellipodia, but also
Assessment of ecological quality status of Arctic salt marshes and adjacent tidal flats using foraminifera

GOLIKOVA Elena1, KORSUN Sergei2*, VARFOLOMEeva Marina1, KURSHEVA Anna3 and MORGUNOVA Inna3

1Department of Invertebrate Zoology, St-Petersburg University, Universitetskaya nab. 7/9, St-Petersburg, Russia; e.golikova@spbu.ru;
marina.varfolomeeva@gmail.com
2Paleoecology and Biostratigraphy Laboratory, Shirshov Institute of Oceanology, Nakhimovskiy pr. 36, Moscow, Russia; s_korsun@mail.ru
3FSBI “VNIIOkeangeologia”, Angliyskiy pr. 1, St-Petersburg, Russia; a.kursheva@mail.ru; mik@list.ru
*Corresponding author

Over past decades, diversity- and sensitivity-based foraminiferal indices have been widely applied on shelves and in shallow subtidal waters to assess ecological quality status (EcoQS). However, the application of these indices in the intertidal zone still poses a challenge, and only a few attempts have been made. Here, we present a modified approach to assess EcoQS in intertidal environments based on bias-corrected Shannon diversity of foraminifera. We characterized the distribution of polycyclic aromatic hydrocarbons (PAHs) in the intertidal sediments at seven study sites along the northern coast of Fennoscandia. We described diversity and distribution of intertidal foraminifera in relation to several abiotic factors and PAH concentrations. In addition, we also examined whether foraminiferal shell growth abnormalities correlated with these factors (and did not find out any obvious relationship). The EcoQS based on the effective number of foraminiferal species matched the PAH-based EcoQS. This opens new perspectives of using foraminifera as a biomonitoring tool in naturally stressed intertidal environments. Supported by RFBR grant 18-54-20001 (St-Petersburg University Pure ID: 62876031).

Seasonal dynamics of intertidal foraminifera of the subarctic White Sea

GOLIKOVA Elena1, CHELKAK Alexandra2, ARISTOV Dmitry3, STODOLSKAYA Alyona1 and KORSUN Sergei1,4

1Department of Invertebrate Zoology, St. Petersburg University, Universitetskaya nab. 7/9, St. Petersburg, Russia; e.golikova@spbu.ru,
stodolskaya99@mail.ru
2Anichkov Lycee, Nevsky pr. 39, St. Petersburg, Russia; a.d.chelkak@gmail.com
3Zoological Institute, Universitetskaya nab. 1, St. Petersburg, Russia; aamaursis@gmail.com
4Paleoecology and Biostratigraphy Laboratory, Shirshov Institute of Oceanology, Nakhimovskiy pr. 36, Moscow, Russia; s_korsun@mail.ru
*Corresponding author

Seasonality in intertidal assemblages of foraminifera have been documented from low- and temperate- latitudes but remains undereexplored in high latitudes. We aimed to track seasonal changes in foraminiferal populations inhabiting tidal flats in the subarctic White Sea. The study was designed for two tidal flats different in their sediment facies – one dominated by silt, the other by sand. Each tidal flat was transected by four stations from mid to lower intertidal elevations. Each station was sampled in triplicate (10 cm apart) in March (fast ice saved), May, August, and November 2015. The sediment samples (20 cm², 0-1 cm) were preserved in 80% ethanol with Rose Bengal stain (2 g/L). The 0.125–0.5 mm size fraction was used for foraminiferal analysis. Thirteen species of foraminifera were found in all samples with living (stained) individuals...
representing six species. Living foraminifera were present at all stations on both flats in all seasons. The abundance of living individuals was consistently higher on the silty flat (100 ind. in average, max ~400 ind./10 cm²) as compared to the sandy flat (15 ind. in average, max ~45 ind./10 cm²). Three species, the calcareous Elphidium williamsoni, the soft-walled Ovammina opaca, and the arenaceous Miliammina fusca, dominated both flats. The abundance of E. williamsoni did not show a clear seasonal pattern. The maximum abundance of O. opaca occurred in May at all stations on both flats. By contrast, the abundance of M. fusca peaked in November on both flats. The observed increase in abundance of these species may be related to their diet. Ovammina opaca has been reported to feed on diatoms. In the White Sea, the first and most pronounced phytoplankton bloom occurs in late April or early May. This bloom is dominated by diatoms and is associated with the melting of fast ice and high concentration of mineral nutrients near-shore. On the contrary, in late autumn, when photosynthesis wanes but the remineralization of organic matter accumulated during the vegetation season still continues, the conditions seem favorable for deposit feeders (bacterial feeders) such as M. fusca.

This study was supported by RSF grant 21-17-00235.

A down core analysis of foraminifera from Patrick Bayou (Galveston Texas) before and after hurricane disturbances

GOODWIN Charles1, SMITH Christopher1 and DELLAPENNA Timothy1

1Texas A&M University at Galveston, Marine and Coastal Environmental Sciences; 200 Seawolf Parkway Galveston, TX, 77554, USA; cgg528@tamu.edu; smithcw@tamug.edu; dellapet@tamug.edu

*Corresponding author

Foraminifera have been used as proxies for pollution for decades due to their sensitivity to potentially toxic elements or PTEs. This study sampled foraminifera from a core taken from Patrick Bayou, a location known to suffer from severe mercury pollution. This core was taken in early 2018 after Hurricane Harvey, visibly indicated by the sudden shift in sediment regime of the core slightly above 50 cm in depth. Above the 50 cm discontinuity, sediments consist mostly of silt-sized particles while below this point the core is comprised mainly of fine sand. The density and diversity of the foraminiferal assemblage was analyzed at different levels of the Patrick Bayou core. Large shifts in density and diversity on either side of the Harvey divide in the core could potentially be linked to an increase in PTEs in Galveston Bay. Mercury in particular is a common trace metal that can have a large impact when taken in by biota as methyl-mercury. Mercury has been shown to negatively affect both the relative abundance and the biodiversity of benthic foraminifera. When Hurricane Harvey remobilized the sediment in Patrick Bayou, PTEs that had been bound and sequestered were released, making them bioavailable again. The foraminifera sampled from the top of the Patrick Bayou core, from the post Harvey deposit, are dominated by very few species. Meanwhile, the foraminifera sampled from sediments undisturbed by Harvey are much more diverse. This observable shift in foraminiferal assemblage is presumably due to an increase in pollutants in the sediments following Hurricane Harvey. This demonstrates the ability of foraminifera to be a reliable proxy for pollution levels in Patrick Bayou.

A glimpse into the past of planktonic foraminifera: Aalenian (Middle Jurassic) forms and their phylogenetic relationships

GÖRÖG Ágnes1 and ZSIBORÁS Gábor1

1Hantken Foundation, H-1022 Budapest, Detrekő utca 1/b, Hungary; ag.gorog@gmail.com; zsgbedavies@gmail.com

*Corresponding author

The planktonic foraminifers most probably already appeared in the Late Triassic, nearly the same time or shortly after we know the fossil of other calcareous shell-bearing planktonic microorganisms as dinoflagellates, nannoliths and coccolithophores. In contrast to these forms, early planktonic foraminifera – also known as protoglobigerinids – only became widespread in the late Bajocian (Middle Jurassic). At this time, they often appeared en masse (ooze) in the neritic and pelagic environments of the Neotethys with different taxon compositions, in which 2–8 taxa could be identified. The number of described species reached 15, and all 8 morphotypes of the protoglobigerinids appeared.

Until this time, the knowledge about the early period of their evolution is very poor due to the extremely rare and incomplete fossil records. We only know internal moulds from the Triassic, and they were mentioned from a total of 7 areas from the Lower Jurassic, but isolated specimens are known from only two sites. Additionally, the only proved Aalenian (most probably lower Aalenian, Opalinum Zone) protoglobigerinids were documented from Domuz Dag, Turkey. The large (up to 320 µm) specimens, often with a thick outer wall known only from thin sections. For this reason, these forms could only be classified tentatively into species or even genera. Therefore, the recent discovery of these forms in well-dated Aalenian successions of the Transdanubian Central Range, Hungary, is of great importance for understanding their evolution.
The studied protoglobigerinids came from condensed successions built up of red and grey nodular flaser-bedded, Ammonitico Rosso-type limestones. More precisely, they were yielded from the Nagy-Pisznicz section (Opalinum and Comptum subzones of the Opalinum zone, lower Aalenian, and Concaum Zone, upper Aalenian) and the Tölgýhát B section (Comptum Zone, lower Aalenian) of Gerecse Ms., and the Bakonycsernye section (Murchisonae Zone, middle Aalenian and Concavum Zone, upper Aalenian) of Bakony Ms. During the Aalenian, this area was situated in the Mediterranean Biome of the Boreal-Atlantic-Caucasian Province.

The planktonic foraminifers were studied in thin-section and isolated specimens, extracted with pure acetic acid. The associated microfauna contained fragmented thin bivalve shells, foraminifera, ostracods, radiolarians, echinoderms, globochoanetes, and juvenile ammonites. The foraminiferal fauna were dominated by spirillinids (60–80%), lagenids (mostly smooth-walled nodosarids and lenticulinds (up to 10%), and conical forms (trocklinoids and paalzowellids), besides these epistominids and a few agglutinated forms, also occurred.

The protoglobigerinids were poorly to moderately preserved and gave the 1–2 % of the foraminifera fauna with 2–3 taxa, except the oldest sample, where their proportion reached nearly 30 % and 7 taxa could be identified. All forms were thin-walled and relatively small, less than 250 μm. The tests have a low to medium-high trochospire with 2.5–3 whorls and 3 or 4 chambers on the last whorl. All of them have an umbilical aperture, sometimes bordered by a lip. The morphology and the wall structure of the tests are more similar to the Toarcian association from Domuz Dag, Turkey than to the Aalenian one from the same area. This could also mean that the deep-dweller forms with cortex appeared earlier in the eastern part of Neotethys. Based on the isolated specimens the following taxa could be identified: Globuligerina oxfordiana, G. bathoniana, G. glinskikhi, G.? hungarica, G. dagestanica, G. aff. dagestanica, and Conoglobigerina? avariformis forma sphaerica. These forms were previously only known from the upper Bajocian or younger layers.

Our results filled an entire stage gap in the knowledge about the evolution of the protoglobigerinids. Contrary to the previous perceptions, these forms showed great diversity (7 out of 8 morphotypes already occurred) and frequency already in the lowermost Aalenian.

**Pore detection of the denitrifying benthic foraminifer Bolivina spissa through automated image analysis technique**

**GOVINDANKUTTY Menon Anjaly**¹, V. DAVIS Catherine², NÜRNBERG Dirk¹, NOMAKI Hidetaka³, SALONEN lines⁴ and GLOCK Nicolaas¹

¹Centre for Earth System Research and Sustainability, Institute for Geology, University of Hamburg, Bundesstrasse 55, D-20146, Germany; anjaly.govindankuty.menon@uni-hamburg.de; nicolaas.glock@uni-hamburg.de
²Department of Marine, Earth, and Atmospheric Sciences, North Carolina State University, 2800 Fucette Dr, Raleigh, NC, 27695, United States; cdavis24@ncsu.edu
³GEOMAR Helmholtz Centre for Ocean Research Kiel, Wischhofstr. 1-3, Geb. 8c, Raum 20148 Kiel, Germany; dnuernberg@geomar.de
⁴SUGAR, X-star, Japan Agency for Marine-Earth Science and Technology (JAMSTEC), 2-15 Natsushima-cho, Yokosuka 237-0061, Japan; nomakihi@jamstec.go.jp; isaloneni@jamstec.go.jp
*Corresponding author

Global warming driven by human activities accelerate ongoing ocean deoxygenation and the expansion of oxygen minimum zones. This is amplified by large-scale use of chemical nitrogenous fertilizers, which alter the marine nitrogen cycle. Nitrate (NO₃⁻) is the main reactive nitrogen compound in the ocean and an important macronutrient that can be limiting in some environments. The slowest infaunal foraminiferal species Bolivina spissa is abundant in oxygen depleted environments all around the Pacific. This species can denitrify and most likely takes up NO₃⁻ as an electron acceptor through the pores, making its pore density an empirical proxy for NO₃⁻ concentrations. In our study, we tested the application of a newly developed automated image analysis technique to detect pores in the tests of B. spissa using a deep learning algorithm. For our study, we utilized downcore samples taken from the Gulf of Guayaquil (M77/2-059-1), Mexican Margin (MAZ-1E-04), Sea of Okhotsk (MD01-2415), and modern core top samples from Central Sagami Bay (Japan), and Costa Rica (SO206-43-MUC). We investigated the interdependence between pore parameters such as the pore density (number of pores per unit area), porosity (% of area of the tests occupied by the pores) and the average pore size on specimens of B. spissa. Our study showed that the fully automated technique allows an efficient measurement of pore parameters producing statistically robust results. We found a significant difference in porosity among the studied locations. The porosity in samples from the Gulf of Guayaquil was mainly controlled by the size of the pores, while the porosity at other locations showed a stronger correlation to the pore density. We compared the pore density and porosity of four different closely related Bolivina species as a potential NO₃⁻ proxy. Bolivina spissa and Bolivina subadvena showed the same correlation between pore density and bottom water NO₃⁻ concentrations ([NO₃⁻]BW), while the pore density of Bolivina argentea and Bolivina subadvena acuminata was much higher and did not fit into this correlation. In addition, preliminary results indicate that there is a stronger correlation of [NO₃⁻]BW to pore density than to porosity. We speculate that this could be related to the electron acceptor uptake mechanism of denitrifying foraminifera, since NO₃⁻ is a charged ion and can be actively taken up through the pores, using ion channels. This is different compared to oxygen, a neutral molecule whose uptake is completely limited to passive diffusion, which makes the total porosity a more important factor for the exchange of neutral gases.
Reconstructing the Oxygen Minimum Zone in the Arabian Sea using Mn/Ca in planktonic foraminifera

GROENEVELD Jeroen,1,2* PALME Tina,3,4 STEINKE Stephan5 and LUÈCKGE Andreas6

1Institute of Oceanography, National Taiwan University, No. 1, Section 4, Roosevelt Road, Da’an District, 10617 Taipei City, Taiwan (R.O.C.); jgroeneveld@ntu.edu.tw
2Department of Geology, Hamburg University, Bundesstrasse 55, 20146 Hamburg, Germany; jgroeneveld@ntu.edu.tw
3Department of Geosciences, Bremen University, Klagenfurterstrasse 2-4, 28359 Bremen, Germany; tina.palme@uniciv.ac.at
4Institute of Paleontology, Vienna University, Josef-Holubek-Platz 2 (UZA II), 1090 Vienna, Austria; tina.palme@uniciv.ac.at
5Dep. of Geological Oceanography and State Key Laboratory of Mari. Environ. Sciences, College of Ocean and Earth Sciences, Xiamen University, Xiang’ an South Road, Xiang’an District, Xiamen, 361102 China; ssteinke@xmu.edu.cn
6Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Stilleweg 2, 30655 Hannover, Germany; andreas.lueckge@bgr.de
*Corresponding author

The Arabian Sea contains one of the most intense Oxygen Minimum Zones (OMZ) worldwide that may have been present for millions of years, triggered by lower oxygen water masses and high productivity along its edges. Understanding and reconstructing the OMZ is an essential part for predicting how future changes in its intensity may be, not only in the Arabian Sea but also worldwide. Although many reconstructions have been done, most are giving indirect estimates, i.e. reconstructing absolute dissolved oxygen concentrations in the past is not very accurate yet.

Foraminifera may provide a solution to this using the incorporation of redox-sensitive elements like manganese (Mn) into their calcite shells. It has already been shown that Mn/Ca in benthic foraminifera is sensitive to the dissolved oxygen concentration in the micro-environment they calcify in. When dissolved oxygen concentrations decrease, the amount of Mn available in the pore/bottom water to be incorporated into the calcite shells increases when Mn-(oxy)hydroxides are reduced. Similarly, the shells of those species of planktonic foraminifera that (partly) live in the OMZ may have higher shell Mn/Ca than those that stay in well-oxygenated water masses.

Here we present the first results to explore how Mn/Ca in the shells of different species of planktonic foraminifera varies related to different dissolved oxygen concentrations from a series of 68 core tops from the Arabian Sea taken during research expeditions SO-90 and SO-130 with RV Sonne. We selected species that occur under different circumstances that are also characterized by different dissolved oxygen concentrations. Globigerinoides ruber is a mixed layer species that continually occurs under well-oxygenated conditions. Globigerina bulloides also occurs in the mixed layer but prefers those periods when productivity increases. Neogloboquadrina dutertrei and Pulleniatina obiliguiloculata live deeper in the water column, likely (partly) well within the OMZ. And Uvigerina peregrina is an endo-benthic foraminifera that has already been studied previously in the Arabian Sea showing increased Mn/Ca when the overlying OMZ is intense.

Traditionally, Mn/Ca in foraminifera is used as an indicator for the presence of diagenetic coatings that are formed in the sediment. Our results suggest that these coatings are not present in our samples as 1) Mn/Ca is generally very low for all species with average values of 0.034-0.11 mmol/mol; 2) different species show significantly different average Mn/Ca. Specifically P. obiliguiloculata shows up to three times higher Mn/Ca than the other species. In a next step seasonal variations in the occurrence of the different species will be compared with dissolved oxygen concentrations at their respective locations and habitat depth to determine possible relationships with Mn/Ca. This will identify the species that are most suitable to reconstruct past variations of dissolved oxygen concentrations within the water column.

Assessing freshwater foraminifera diversity in New England (USA)

GROW Adria K.1,2* and KATZ Laura A.1,2

1Department of Biological Sciences, Smith College, 44 College Lane, Northampton, Massachusetts, USA; agrow@smith.edu; lkatz@smith.edu
2Program in Organismic and Evolutionary Biology, University of Massachusetts Amherst, 230 Stockbridge Road, Amherst, Massachusetts, USA; agrow@smith.edu; lkatz@smith.edu
*Corresponding author

Despite traditional textbook definitions of foraminifera as marine protists, foraminifera also occur in freshwater habitats, with first reports roughly 150 years ago. Yet, to date, very few freshwater foraminifera have been described in part because these fragile organisms are currently uncultivable. There are fewer than 15 freshwater foraminifera species described both morphologically and molecularly, and only one species has had its whole genome sequenced (Reticulomyxa filosa). In this study, we use foraminifera-specific primers designed to amplify a portion of the 18S rRNA gene as a means of characterizing freshwater foraminifera community diversity in different settings. Our focus is on exploring trends in the species composition of freshwater foraminifera in low-pH bogs, carnivorous pitcher plants, and a freshwater tank, with all sites sampled in Massachusetts and Maine (USA). Our preliminary results indicate the existence of a low-diversity of freshwater foraminifera in these environments, which is in striking contrast to the tremendous diversity found among marine lineages. We also find lineages (i.e. OTUs) that are widespread and others that are site-specific, and we identify several clades of “unknown” freshwater foraminifera that may be specific to the locations we sampled. Together, these data help to...
expanding our understanding of freshwater foraminifera biogeography through analyses of extreme habitats such as low-pH peatlands.

**A phylogenomic approach to understanding population level processes in benthic foraminifera**

GROW Adri K., STERNER Elinor G. and KATZ Laura A.

The widespread distribution of foraminifera morphospecies coupled with the observation of numerous cryptic species makes these lineages ideal candidates for population genomics studies. Open questions in this field include the nature of species boundaries, patterns of gene flow, and estimates of effective population size. Molecular work on population biology in Foraminifera is hampered by the fact that most are uncultivable and most come with complex associated microbiomes; however, we are building a pipeline to analyze the nucleotide polymorphisms that mark species boundaries and provide signals on gene flow. Primarily targeting benthic lineages in mudflats and tide pools sampled along the eastern coast of the United States, we are using single-cell transcriptomics to ask population level questions about patterns within and between sites. Starting with an initial dataset of single-cell transcriptome data from 107 marine and 8 freshwater cells, we are: extracting rDNAs as preliminary ‘identification’ and assessing foraminiferal genes (as opposed to contaminants and symbionts) using a taxon-rich phylogenomic approach. From here, we will use standard ‘omics tools to evaluate single nucleotide polymorphisms (SNPs) and calculate population statistics (e.g. Tajima’s D, dN/dS ratios). Together these data will address genomic and evolutionary features that allow foraminifera to proliferate and explore the nature of cryptic species in these diverse lineages.

**Difficult life under a tidal glacier terminus: Inteseasonal responses of benthic foraminifera close to the Kronebreen glacier front (Kongsfjorden, Svalbard)**

GUILHERMIC Corentin, NARDELLI Maria Pia, MOURET Aurélie, PUSCEDDU Antonio, BALTZER Agnès and HOWA Hélène

Arctic fjords are transitional areas between glacier-covered land and the ocean, characterized by strong environmental gradients. In addition to global changes affecting Arctic coastal environments, spatial and seasonal variabilities of physical and geochemical conditions in fjords affect benthic ecosystem, particularly living foraminiferal microhabitats. It is urgent to understand the functioning of these complex environments, to better monitor their modifications under the current global warming conditions.

Kongsfjorden (Svalbard) has entered in an intense phase of warming and ice melting, which have prevented the formation of extensive sea-ice since 2009 in winter. Therefore, the present evolution of this fjord now represents a first phase of transition from subpolar to future temperate conditions. In summer, it is characterised 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. Therefore, close to the glacier terminus, high detrital sedimentation and limited organic matter exported towards the seabed are supposed to affect both lateral and vertical foraminiferal distribution on a seasonal scale.

Two sampling campaigns were carried out in May and August 2021 to characterize seasonal environmental changes along a longitudinal transect from the Kronebreen glacier front to around 10 km far from it. Our research focused on the seasonal effect of physico-chemical gradients on foraminiferal communities, their spatial distribution, and microhabitats. Organic matter quantity and quality, sediment grain size, and physical parameters of the water masses were investigated as possible driving parameters for benthic ecosystem responses.

In May, the water column was well mixed throughout the fjord, and the environmental gradient was mainly driven by the organic matter content in the sediment, with a strong increase of biopolymeric carbon (BPC) and phytopigments from the glacier front to distal locations. In August, the water column stratification with surface turbidity induced a lowering of organic matter content in the sediment near the glacier front. In the proximal area, foraminiferal assemblages were
characterised by the dominance of the pioneer species *Capsamma bowmani* in the top sediment layers in August, and very low abundances to total absence of foraminifera in May. Food limitation and substrate instability induced by the turbid plume seem to be the major factors driving the summer foraminiferal distribution. In the distal area, foraminiferal assemblages were mainly represented by *Nonionellina labradorica* and *Adercotryma glamoratum* associated with a higher diversity in both seasons. However, in May, foraminiferal abundances were generally lower, due to food limitation. Interestingly, despite the occurrence of different bottom water masses at the two seasons, similar species compositions were observed, suggesting that the water masses do not directly influence the presence or absence of a species. However, a change in main microhabitat distribution was observed for both species, with a peak in superficial layers in summer and more infaunal behaviour in May. This change could be the response to different feeding regimes in the two seasons and/or possibly to enhanced downward transport of foraminifera by macrofaunal bioturbation in spring.

Our results clearly show that physical and geochemical gradients induced by melting waters and sediment discharges originating from the tidewater glacier during summer are the main factors that drive foraminiferal distribution at the local (10 km) scale. This finding induces that foraminifera can be used to monitor the effects of ongoing climate change on the benthic ecosystems of Arctic fjords and have the potential to be proxies for reconstructing glacier front positions in the recent past.

**Microfossil events and planktic foraminifera response to Cretaceous Oceanic Anoxic Events in the Sabinas Basin, Northern Mexico**

**Gutiérrez-Puente Nicte**1*, Barragán Ricardo**2, Núñez-Useche Fernando**2, Enciso-Cárdenas Juan**1, Camacho-Ortega Luis**3 and Mesa-Rojas Julián**1

1Posgrado en Ciencias de la Tierra, Universidad Nacional Autónoma de México, Ciudad Universitaria, Coyoacán, Ciudad de México 04510, México; nierceandrea@gmail.com; julian.leonardo.mesa@gmail.com
2Instituto de Geología, Universidad Nacional Autónoma de México, Ciudad Universitaria, Coyoacán, Ciudad de México 04510, México; ricardor@geologia.unam.mx; fernandomo@geologia.unam.mx
3Centro de Investigación en Geociencias Aplicadas, Universidad Autónoma de Coahuila, Boulevard Simon Bolívar 303 A, Independencia, Nueva Rosita 26800, Coahuila, México; jenciso@uadec.edu.mx; luis_camacho@uadec.edu.mx

*Corresponding author

During the Late Cretaceous, Oceanic Anoxic events represent major global perturbations in the carbon cycle, characterized by extensive deposits of organic-rich sediments distinguished by pronounced carbon isotopes excursions (CIE), reflecting an enhanced organic carbon burial during a time of global greenhouse climate and improved volcanic activity that promoted changes in the water chemistry, marine productivity, and structure of planktic communities. In Mexico, few studies incorporate geochemical proxies and microfossil data to interpret palaeoenvironmental evolution throughout the Cretaceous, a time in which the paleogeographic position of Mexican basins represented a linking area between the Western Interior Sea and the equatorial Atlantic water mass.

Here, we analyze a 193 m-thick interval of the IRME-2 core from the Sabinas Basin in northern Mexico to reconstruct palaeoenvironmental conditions using geochemical proxies, planktic foraminifera events, and abundance fluctuations of microfossils (foraminifers, calcispherulinds, radiolarians, echinoderms, and bivalves).

The succession, mainly represented by micritic limestone interbedded with shaly limestone and bentonites, encloses the transition between the Buda Limestone, the Eagle Ford and the Austin formations deposited under open marine conditions below the storm wave base. According to first and last occurrences of planktic foraminifera markers, this interval can be assigned to the upper Cenomanian to Santonian, encompassing the *Rotalipora cushmani* to the *Dicarinella asymetrica* zones. The carbon isotope curve (d<sup>13</sup>Corg) shows two levels with pronounced positive excursions. The first one, between *Rotalipora cushmani* and *Whiteinella archaeopectacea* zones, correlating with the OAE-2 in the Cenomanian/Turonian transition, and the second within the *Dicarinella asymetrica* Zone related to the OAE-3 in the Coniacian-Santonian interval. Before the emplacement of the OAE-2, the IRME-2 core records levels of filaments and infaunal benthic foraminifera increment. Then, accompanying the rise of d<sup>13</sup>Corg (~4.1‰), productivity-sensitive trace elements (PSTE) such as Ni and Cu showed enrichment levels, followed by an increment of 30% in biserial planktic foraminifera abundance probably related to the "Heterohelix shift." Moreover, mixed layer and intermediate dwellers represent the most abundant forms of planktic foraminifera assemblages, while thermocline dwellers are almost absent. In contrast, the interval recording the positive CIE in *D. asymetrica* Zone did not present significant enrichment of PSTE, and thermocline dwellers planktic foraminifera increased slightly.

Fluctuations observed in the enrichment factor of redox and productivity-sensitive trace elements, along with the prevalence of mixed layer and intermediate dwellers in the upper *R. cushmani* Zone of the Sabinas Basin, points to variable oxygen levels and mesotrophic-eutrophic conditions in the water column during the emplacement of OAE-2. Whereas the presence of thermocline dwellers and low values in enrichment factors of trace elements indicate a well-oxygenated water column and mesotrophic-oligotrophic conditions throughout the OAE-3.
Permian–Early Jurassic Nodosarians: Punctuated diversification but no mass extinction

HAIG David W.1*, BARROS Isaías Santos2,3 and MCCARTAIN Eujay4,5

1Oceans Institute, University of Western Australia, Perth, Australia; david.haig@uwa.edu.au;
2School of Earth Sciences, University of Western Australia, Perth, Australia; ibarros@ipg.tl;
3Instituto do Petróleo e Geologia-Instituto Público, Dili, Timor-Leste; southwananak@hotmail.com; ibarros@ipg.tl
4Corresponding author

Thick basinal mud successions in Permian to Early Jurassic basins of the East Gondwana interior rift system in Australia and Timor provide an excellent record of Nodosarian evolution ranging from the Early Permian (Sakmarian) to the Early Jurassic (at least, Pliensbachian). The foraminifera belong to assemblages extracted from friable mudstone and, unlike in thin-sections, full morphological features can be observed in the tests. The Australian successions are relatively undeformed with stage correlations based on rare ammonoids and conodonts and with local palynomorph zonations linking sections. Additional age control is provided by some isotopic dating of zircons from volcanic ash beds. Because the sections in the Timor orogenic belt, at the edge of the present-day Australian continent, are structurally deformed, the reconstructed basinal mud succession is based mainly on conodont (Permian-Triassic) and palynomorph biostratigraphy with some additional control from ammonoids and zircon dating.

This presentation outlines preliminary observations on the Nodosarians in the basinal mud facies. Although a continuous reconstructed section through the mud facies is not yet available, sufficient stratigraphic details exist to outline the broad evolution of the subclass in this depositional setting. Modifications to the "family" classification are suggested based on progressive stratigraphic appearances of genera, mode of chamber addition (e.g., rectilinear, arcuate curved backward, arcuate curved forward, planispiral, polymorphine, and combined modes), chamber shape, and the inception of new morphological features (e.g., apertural types, ornament). Fine details of wall ultrastructure are not included in the classification at this stage because many specimens have partly recrystallized walls and no consistent stratigraphic analysis of the significance of the wall structure can be made. The families and genera discussed here are: Syzraniidae (Syrania, Tezequina); Dentalinidae (Vervilleina, Laevidentalina, Dentalina); Nodosaridae (Protonodosaria, Nodosaria, Pseudonodosaria, Pyramulina); Lingulinae (Cryptoseptida, Lingulina, Paralingulina); Frondicularidae (Lumacaminna, Howchinella, Ichthyolaria, Frondicularia; Dagysina); Tristixidae (Tristix, Quadratina); Vaginulinae (Eocrystellaria, Astacolus, "striate/costate Astacolus", Lenticulina, Spinuterles, Enantiomarginulina, Marginulina, Marginulinopsis, Sarcenaria); Palmulinidae ("Laevipalmula", Palmula); Plectofrondiculariidae (Berthelinella); and Polymorphinidae (Ramulina, Eoguttulina).

The Permian to Early Jurassic interval includes two major mass extinction levels affecting the global biota (i.e., the Permian–Triassic and the Triassic–Jurassic boundaries). These events appear not to have severely affected Nodosarian evolution, at least at genus level. In contrast, major diversifications took place during the Early Permian, late Early to Middle Triassic and Early Jurassic. By the Late Triassic, most Nodosarian morphotypes recognized throughout the Mesozoic and Cenozoic had been established. During the Early Jurassic, while test morphology remained the same, many species acquired striate or costate ornament.

The reason why Nodosarians exhibited such conservative evolution may be related to an infaunal life within sea-floor mud and the ability to adapt to rapidly changing conditions in shallow-water estuarine-like interior seas. While the Middle Triassic and Early Jurassic diversifications took place after major mass extinctions, the Early Permian diversification (involving the first appearance of radiate apertures in different generic groups) came with warming after the melting of the Gondwana ice sheets. Perhaps the diversifications were associated with compositional changes in food (organic detritus and bacterial/algal micro-organisms) that were concomitant with the major climate or extinction events.

The effect of carbonate chemistry on the incorporation of trace elements into shells of benthic foraminifera: Paleoceanographic and biomineralization implications

HAUZER Hagar1,2*, EVANS David1, MÜLLER Wolfgang4,5, ROSENTHAL Yair6, EREZ Jonathan1

1The Fredy & Nadine Herrmann Institute of Earth Sciences, The Hebrew University of Jerusalem, The Edmond J. Safra Campus - Givat Ram Jerusalem 9190401, Israel; Hagar.hauzer@mail.huji.ac.il; Jonathan.erez@mail.huji.ac.il
2Israel Oceanographic and Limnological Research, National Institute of Oceanography, Tel Shikmona, Haifa 3109701, Israel; Hagar.hauzer@mail.huji.ac.il
3School of Ocean and Earth Science, University of Southampton, University Road Southampton SO17 1BJ, UK; D.Evans@soton.ac.uk
4Institute of Geosciences, Goethe University Frankfurt, Riedberg Campus Altenhoferallee 1 Frankfurt Am Main 60438, Germany; w.muller@em.uni-frankfurt.de
5FIERCE, Frankfurt Isotope & Element Research Center, Johann Wolfgang Goethe-Universität Frankfurt am Main, Altenhoferallee 1, 60438 Frankfurt am Main, Germany; w.muller@em.uni-frankfurt.de
6Department of Marine and Coastal Sciences and Department of Earth and Planetary Sciences, Rutgers University, 71 Dudley Road, New Brunswick NJ 08901, USA; rosentha@marine.rutgers.edu
7*Corresponding author

139
Na/Ca in biogenic CaCO$_3$ has recently been introduced as a proxy for past seawater Ca$^{2+}$ concentrations. This proxy was calibrated for the large benthic foraminifer Operculina ammonoides, an extant relative of the fossil Nummulites. Additional calibrations were performed for the planktonic foraminifera Globigerinella siphonifera, Trilobatus sacculifer, Globigerinoides ruber, and Orbulina universa, and also for hermatypic corals. These experiments demonstrate significant positive correlations between seawater and shell Na/Ca (as well as for other major and trace elements), when the main variable in these experiments was Ca$^{2+}$ concentration in seawater. In contrast, the influence of salinity on Na/Ca in *O. ammonoides* was shown to be very small. However, other possible parameters could potentially influence the Na/Ca ratio in foraminifera. Here we present a set of carbonate system experiments to test the effects of pH and dissolved inorganic carbon (DIC) on the incorporation of Na$^+$, Li$^+$, Mg$^{2+}$, and Sr$^{2+}$ into the shells of the high-Mg foraminifer *O. ammonoides*. Foraminifera were cultured under constant DIC (~2170 µmol kg$^{-1}$) with varying pH (7.5-8.4 NBS scale), and under varying DIC (830-2470 µmol kg$^{-1}$) with constant pH (~7.9). Based on alkalinity depletion, the foraminiferal growth was assessed and linearly correlated with pH, DIC, and calcite saturation state (Ω). The lowest pH and DIC treatments showed low population growth, and some of the specimens died during the experiments and their shells were partially dissolved.

Na/Ca$_{shell}$ and Li/Ca$_{shell}$ in *O. ammonoides* are positively correlated with seawater carbonate chemistry (CO$_2^-$ and Ω), while Sr/Ca$_{shell}$ and Mg/Ca$_{shell}$ are much less sensitive to these factors. Low-Mg planktonic foraminifera (and possibly some benthic species), did not show any sensitivity of Na/Ca$_{shell}$ to the carbonate system. However, the sensitivity of Na (and Li) in *O. ammonoides* to the carbonate system does not compromise the use of this proxy to reconstruct past seawater Ca concentrations, given that past changes in seawater Ω were probably small and can be reconstructed, thus allowing a small correction for this proxy over timescales of the Cenozoic. Thus, the Na/Ca proxy in the extinct *Nummulites* may be utilized for Ca$^{2+}$ reconstructions. The distribution coefficients of multi-element and isotope systems (e.g., Li, Sr, Mg, K, B, δ$^{18}$O, and possibly others) may therefore provide new insights for reconstructions of past ocean chemistry. Furthermore, based on this information we propose a modified biomineralization model for hyaline foraminifera where seawater vacuolization is the main source for major, trace and minor elements incorporated into low and high-Mg foraminiferal species.

A changing response of planktic foraminifera to seasonality in the California Current Ecosystem: Updates from 2018-2021

HAVARD Emily*, CHERRY Katherine1, DAVIS Catherine1, TAPPA Eric2 and BENITEZ-NELSON Claudia2

1Department of Marine, Earth, and Atmospheric Sciences, North Carolina State University, 2800 Faucette Dr., Raleigh, NC 27606, USA; ehavard@ncsu.edu; kscherry@ncsu.edu; cdavis24@ncsu.edu
2School of the Earth, Ocean, and Environment, University of South Carolina, 701 Sumter St., Columbia, SC 29208, USA; tappa@geol.sc.edu; benitezr@mailbox.sc.edu
*Corresponding author

The rapid response of foraminiferal assemblages to a changing climate makes their fossil shells an invaluable geological record of past ecological conditions. The drivers of planktic foraminifera presence and abundance, however, are complex and involve a combination of oceanographic and ecological processes. Seasonal and interannual variability affect the interpretation of foraminiferal records throughout geologic time. For example, if a species is most abundant in one season, the geochemical records from that species will be skewed towards that season. The Santa Barbara Basin sediment trap, located off the coast of California, USA, provides a record of sediment and foraminifera flux to the basin since 1993. The region experiences strong seasonal cycles due to changing winds and ocean currents. We present data on planktic foraminiferal assemblages collected between 2018-2021, at two-week intervals (> 75 samples) and compare results to previously published data collected between 1993-1998. We focus on the seasonality of flux and relationships to seasonally variable conditions. The most abundant species between 2018-2021 are Globigerina bulloides, Neogloboquadrina incompta, and Turborotalita quinqueloba, with the greatest flux in the spring and late summer. Peaks in both total foraminiferal flux and abundance of *G. bulloides* and *T. quinqueloba* frequently follow the onset of upwelling conditions but also occur independently of apparent upwelling. The winter season is characterized by low foraminiferal flux and an assemblage dominated by *G. bulloides* and *N. incompta*. Flux of Globigerinita glutinata peaks in winter. We also find that some species’ seasonalities (Globigerinoides ruber, Globigerina rubescens, Orbulina universa) may have changed over the past decades. Understanding how modern foraminifera, including classic upwelling species (*G. bulloides*), respond to seasonal changes can inform palaeontological interpretations and help to place foraminifera in a broader ecological context.

Foraminiferal evidence for the provenance and flow history of turbidity currents triggered by the 2016 Kaikōura Earthquake, New Zealand

HAYWARD Bruce W.*, SABAA Ashwaq T.1, HOWARTH Jamie D.2, ORPIN Alan R.3 and STRACHAN Lorna J.4

1Geomarine Research, 19 Debron Ave, Remuera, Auckland 1050, New Zealand; b.hayward@geomarine.org.nz, ashwaqsabaa@gmail.com
2School of Geography, Environment and Earth Sciences, Victoria University, Wellington 6140, New Zealand; jamie.howarth@vuw.ac.nz
3NIWA, Private Bag 14901, Kilbirnie, Wellington 6241, New Zealand; Alan.Orpin@niwa.co.nz
4Corresponding author
The planktonic/benthos ratio reaches up to 94% in the upper part of the section and suggests an increase of planktonic foraminifera dominance. Along the entire section, a similar trend is observed with the gradual increase of deepwater species within the benthic assemblage indicating a continuing deepening of the depositional environment.

The planktonic foraminifera association consists of representatives of the genera Trilobatus, Praeorbulina, Orbulina, Paraglobototalia, Globigerinella, and Globigerina. Among them, the most important species are Trilobatus trilobus (Reuss), T. quadrilobatus (d’Orbigny), T. sicanus (De Stefani), Praeorbulina curva (Blow), P. glomerosa (Blow), P. circularis (Blow), Orbulina sucturalis Brönnimann, Globigerinella obesa (Bolli), Paragloborotalia mayeri (Cushman & Ellisor), and Globigerina tarchanensis Subbotina & Khutsieva. The planktonic foraminifera association indicates the Middle Badenian age (Orbulina sucturalis Zone or M6 planktonic foraminifera zone).

The North Croatian Basin (NCB) in the southwestern part of the Pannonian Basin System (PBS) paleogeographically belongs to the area of the Central Paratethys. The Nježić outcrop is in the central part of the NCB, on the southwestern slopes of Papuk Mt, where five lithofacies were distinguished within the 140 m thick sequence: metagabbro, algal limestones, marl, bioclastic limestone, and tuff.

Marls contain a rich fossil assemblage of benthic and planktonic foraminifera. Micropaleontological analyses were performed on 40 samples prepared using a standard washing procedure (sieve fractions – 0.5; 0.25; 0.2; 0.125; 0.09; 0.063 mm).

The gradual increase of planktonic assemblage in the total foraminiferal community going upwards of the Nježić section and the gradual increase of deepwater species within the benthic assemblage indicate a continuing deepening of the depositional environment. The plankton/benthos ratio reaches up to 94% in the upper part of the section and suggests an increase of planktonic foraminifera dominance.
upper bathyal environment. At the same time, the gradient analysis, based on the overlap of benthic foraminifera depths, points to an outer shelf marine environment (with a water depth of about 200 m).

Determined planktonic and benthic foraminifera biozones are in accordance with \textsuperscript{40}Ar/\textsuperscript{39}Ar dating on volcanic glass fragments from the oldest tuff layer in the Nježić section, which yielded an age of 14.40 ± 0.03 Ma.

**Retrospective benthic foraminiferal community studies: a sensitive method to determine early environmental changes**

Hess Silvia\textsuperscript{1}, Alve Elisabeth\textsuperscript{1} and Helland Aud\textsuperscript{2}

\textsuperscript{1}Department of Geosciences, University of Oslo, P.O. Box 1047, Blindern, 0316 Oslo, Norway; silvia.hess@geo.uio.no; elisabeth.alve@geo.uio.no

\textsuperscript{2}COWI AS, Karvesvingen 2, 0579 Oslo, Norway; auhd@cowi.com

*Corresponding author

Two short sediment cores (< 50 cm), taken in the Sørfjord and Veafjord (Southwest Norway), were analyzed for benthic foraminifera, as well as geochemical (bulk TOC, \text{C}_\text{org}/\text{TN}, stable \text{δ}^{13}\text{C} isotopes and heavy metals) proxies. In addition to the core samples, living (rose Bengal-stained) benthic foraminifera were examined to determine the current ecological status at the study sites. The purpose of the study was to define the natural ecological condition in the Sørfjord and Veafjord, two sheltered inland fjords with restricted deep-water exchange with open coastal areas. An assessment of the development of the local environmental status over the last centuries was required in connection with plans for the disposal of road and railway track construction residues in the fjord systems.

The sediment cores were radiometrically dated by \textsuperscript{208}Pb and \textsuperscript{137}Cs back to the mid-19th and 20th centuries. Foraminiferal diversity was relatively high in the first half of the 20th century and earlier, indicating ‘very good’ ecological quality status (EcoQS) at both sites, according to the Norwegian ecological classification system. The EcoQS only showed minimal changes over time and was still ‘very good’ in the youngest sediments, which was also reflected by the living assemblages. Benthic foraminiferal accumulation rates increased from the 1960s to 1970s; however, this increase was more evident in the Sørfjord than in the Veafjord core. The foraminiferal assemblages showed increasing abundances of *Brizalina skagerrakensis*, *Bulimina marginata* and *Stainforthia fusiformis* during the same time period, which might indicate a general increase in primary production triggered by higher nutrient supply in the area.

Corresponding to the faunal changes, the organic carbon accumulation rates indicate increasing organic matter flux to the sea floor during the last 50 to 60 years. Both \text{δ}^{13}\text{C} and \text{C}_\text{org}/\text{TN} ratio showed a shift to slightly lower values at the same time, supporting the interpretation of higher nutrient supply and related primary production in the area.

Based on our study, we propose to carefully evaluate whether existing ecological indicators, required by the authorities’ environmental monitoring guidelines, are sensitive enough to detect early changes or deterioration of the environment. The study underlines the potential of using benthic foraminiferal assemblages in environmental monitoring programs.

The response of benthic foraminiferal assemblages to copper mine tailing deposits at the Repparfjord, Northern Norway

Hoff Marie\textsuperscript{1}, Argentino Claudio\textsuperscript{1}, Barrenechea Angeles Ines\textsuperscript{1} and Panieri Giuliana\textsuperscript{1}

\textsuperscript{1}Department of Geosciences, UIT – The Arctic University of Norway. Dramsveien 201, Tromsø, Norway; mho216@uit.no; claudio.argentino@uit.no; giuliana.panieri@uit.no; ines.a.angeles@uit.no

*Corresponding author

Benthic foraminiferal assemblages at a historical mine tailings deposit site provided new insight into the utility of foraminifera as biomonitoring tool. Copper mine tailings in a subarctic fjord in Northern Norway were found to affect recent sediment layers up to the sediment-water interface by leaching processes, exposing benthic communities to high copper concentrations over the last four decades.

We assessed the current diversity and composition of the benthic foraminiferal community at the Repparfjord, Northern Norway, as well as a retrospective reconstruction from sediment layers of a period prior to the mine tailings discharge. The ecological quality index based on the diversity of the assemblage (EcoQS) and the percentage of abnormal tests (FAI) was compared to the concentration of trace metals in the sediment pore water.

We identified three clusters of similar composition: (1) historical assemblages below the mine tailing layer in the sedimentary record; (2) more recent assemblages from the uppermost 5 cm of sediment in the mine tailing disposal area; (3) a pristine assemblage from the outer fjord. Our results show that the original benthic foraminiferal community disappeared almost entirely during the disposal period and is now dominated by stress-tolerant and opportunistic species. Against previous assumptions, the community composition changed, while the overall diversity (\text{ExpH}’bf) and the formation of abnormalities (FAI) were unaffected by elevated copper concentrations. EcoQS classes based on benthic foraminifera were generally lower than at other sites due to naturally lower diversity in the Subarctic region.
The improved understanding of the dependency of the benthic foraminiferal community structure and their diversity on physical disturbance and heavy metal concentrations will be helpful in the development of an indicator variable, allowing for the use of benthic foraminifera as biomonitoring tool in high-latitude ecosystems.

Perspectives of growth in Foraminifera

HÖHENEGGER Johann

1Institut für Paläontologie, Universität Wien, Josef Holoubek Platz 2, A 1090 Wien, Austria; johann.hohenegger@univie.ac.at
*Corresponding author

Growth in foraminifera can be continuous or discontinuous showing growth steps. Continuous growth is typical for monothalamous foraminifera and ends when the growth ratio is minimum in biomass production against the maintenance used for the organisms’ life. Protection of the monothalamous cell is performed by simple structured tests with organic or agglutinated walls.

Growth steps (intercepts) characterize the discontinuous growth in testate foraminifera. At the end of a growth intercept, test walls cover the new segment. Primarily, test walls can form either tubes or spheres leading to the molecular-genetically supported main separation in testate foraminifera between Tubothalamea and Globothalamea.

Growing tubes can be open at both ends (unilocular tests) or start with a spherical initial chamber (bilocular tests). Growth steps are undetectable at the test outside or can be found as weak, often irregularly positioned constrictions leading to pseudosepta.

Constricting the open tube segments creates chambers with small openings (apertures). The chamber front becomes a septum by the superposition of the following chamber, and the aperture transforms to a foramen. Growth based on spherical chambers automatically leads to the development of septa characterizing the grade of chambers’ overlapping. Tests based on tubular or spherical chambers are called multilocular.

Multilocular foraminifera show unlimited or limited growth. The former can be modelled by linear or exponential functions, while sigmoidal functions characterize the latter. Maturation is size dependent in linear and exponential growth, while the inflection point in sigmoidal functions separating increasing from decreasing growth rates determines maturation. Replacing the independent variable time \( t \) by the chamber number \( n \), test (cell) growth can be modelled by mathematical functions, where the Gompertz and Richards functions render the best fitting of sigmoidal functions. While test growth is modelled by the growth functions, the first derivatives of these functions characterizing the volumes of chambers determine chamber growth.

The timing of chamber construction depends on the growth ratio between biomass production and maintenance. The growth ratio decreases monotonically with increasing test size. Time intervals in chamber construction keeps constant in linear growth and increase in exponential and sigmoidal growth. This decrease can be modelled by the Michaelis-Menten function, where the inverse function allows estimation of the individuals’ birthday based on the number \( n \) of chambers.

The combination of chamber growth with the chamber-building rate leads to the time dependent mean growth function. Deviations from the mean growth rate can be calculated using standardized residuals. Decomposition into sinusoidal periods allows the interpretation of time dependent environmental influences (tides, raining seasons, etc.) on growth.

Chamber form determined by the morphogenetic program keeps constant during growth, affected by environmental disturbance only in chamber size. Deviation from optimal light conditions reduces chamber growth of symbiont-bearing larger foraminifera kept in cultures, while the chamber-building rate is extended in comparison to natural conditions, which can be experienced also under optimal conditions. Further, the effects of acidification and recovery as well as recovery after predation are demonstrated.

A Comparative Morphological Analysis of Planoheterohelix Across the Cretaceous Western Interior Seaway during Oceanic Anoxic Event 2

HOLGUIN-CALDERA Daniel* and BRYANT Raquel

1Department of Earth and Environmental Sciences, Wesleyan University, 265 Church Street, Middletown, CT USA; dholguincald@wesleyan.edu; rbryant@wesleyan.edu
*Corresponding author

As foraminifera grow, they sequentially add chambers to accommodate their expanding cellular material such that their tests record their full ontogeny. The intraspecific variation of tests, referred to here as trait plasticity, documents the physiological response of foraminifera to environmental stimuli. As heterotrophs, changing oxygenation and trophic conditions influence their metabolism, their body size, and the shape of the test’s constituent chambers. Therefore, trait plasticity observed in fossil foraminifera tests may be used to reconstruct paleoenvironmental conditions. However, recent
morphological studies on foraminifera have revealed that the phenotypic expression of foraminifera is not fully understood, especially in terms of the morphological variation resulting from changes in oxygenation. In order to test multiple drivers of morphological variation, we employ a comparative analysis of morphological variation of the same taxa at different localities in a single basin during an interval of global environmental change. Oceanic Anoxic Event 2 (OAE2) represents a major perturbation to the marine carbon cycle as evidenced by the globally observed positive carbon isotope excursion, in both organic carbon and carbonates, that defines the event. During OAE2, the Western Interior Seaway (WIS) was generally dysoxic and highly productive, but regional differences, such as water mass mixing, caused distinct local environmental conditions. The planktic foraminifera genus *Planoheterohelix* thrives during periods of dyoxia and was ubiquitous in the WIS during OAE2. This variability in local conditions during a global event presents a unique opportunity to test how foraminiferal trait plasticity changes across a geographically constrained area. In this study, specimens of *Planoheterohelix* from central New Mexico and northeastern Kansas will be compared to observe how trait plasticity varies on the western and eastern margins of the WIS throughout OAE2. Specimens of *Planoheterohelix* from both localities have been picked and prepared on microfossil slides. The New Mexico slides were imaged and preliminary results showed significant changes in final chamber size associated with the OAE2 interval. Differences and similarities in trait expression between the two sites would reveal important information about what conditions trigger intraspecific test variation in *Planoheterohelix*. In particular, a stronger understanding of the response to low oxygen conditions can be applied to other foraminiferal assemblages, both past and present, to test and predict how their test morphology reflects their environment. Furthermore, this study leverages previously picked slides and provides an example of the use of 2D morphometric techniques. This study demonstrates a potential mechanism for how foraminifera cope with differing environmental conditions, the utility of foraminiferal morphology as a geologic archive, and the potential impact of future hypoxic events on foraminiferal communities.

**First occurrence of the nonindigenous Asian foraminifera Ammonia confertitesta Zheng in the northeastern Pacific Ocean: Vancouver Island, British Columbia, Canada**

HOLZMANN Maria¹ and MCGANN Mary²

¹Department of Genetics and Evolution, The University of Geneva, 30 Quai Ernest Ansermet, CH-1211 Geneva, Switzerland; maria.holzmann@unige.ch
²U.S. Geological Survey, Pacific Coastal and Marine Science Center, Menlo Park, California 94025, USA; mmcgann@usgs.gov

*Corresponding author*

In May 2022, the U.S. Geological Survey conducted sampling operations (USGS Field Activity 2022-625-FA) along the coast of western North American to update the evidence of occurrences of the nonindigenous Asian foraminifera *Trocchanmina hadai* Uchio 1962. An effort was made to sample bays and harbors that were either subject to large ship operations (bulk carriers and tankers) or exclusively small boats to provide a better understanding of the vectors responsible for the species’ introduction. During sampling along the central-eastern coast of Vancouver Island, British Columbia, Canada, it was noted that in addition to the presence of *T. hadai*, a species of *Ammonia* with taxonomic features distinct from those associated with the native species *Ammonia kitazatoi* Hayward and Holzmann 2021 was observed. These new observations of foraminiferal faunas at three localities along the central-eastern side of Vancouver Island, British Columbia, Canada, as well as molecular analyses, document the first occurrence of the nonindigenous Asian species *Ammonia confertitesta* Zheng in the northeastern Pacific Ocean. The species was present at these localities: 1) dead specimens at a subtidal site (2022-625-1; 49°10′16″N, 123°56′03″W; 4 m water depth) off the end of the Swy-A-Lana Lagoon Fishing Pier in the Port of Nanaimo where the species comprised 0.6% of the benthic foraminiferal assemblage; and 2-3) living specimens at intertidal sites on the southern (2022-625-3; 48°57′50″N, 123°46′26″W) and northern (2022-625-4; 48°57′52″N, 123°46′25″W) sides of Highway 1A at Davis Lagoon, south of the town of Ladysmith, where the species comprised 4% of the benthic foraminiferal assemblage in the lagoon and 49% of the beach assemblage, respectively. The vector of introduction of this nonindigenous species is thought to be the release of ballast water and associated sediment from foreign bulk carriers and tankers. These releases probably occurred in the Port of Vancouver, which were then transported by means of the cyclonic circulation across the Strait of Georgia to Vancouver Island, or from local anchorages on the island close to the sampling sites. The timing of the introduction is impossible to determine because no stratigraphic record is presently available. However, foraminiferal studies in the late 1980s near the Port of Vancouver that recovered calcareous taxa did not report the presence of this species.

**Freshwater and soil foraminifera: an overview**

HOLZMANN Maria¹, SIEMENSMA Ferry², Pawlewski Jan³ and GoDaday Andrew⁴,⁵

¹Department of Genetics and Evolution, University of Geneva, 1205 Geneva, Switzerland; maria.holzmann@unige.ch
²Julianaweg 10, 1241VW Kortenhoef, Netherlands; ferry.siemensma@gmail.com
³Institute of Oceanology, Polish Academy of Sciences, 81-712 Sopot, Poland; janpawlewski@iopan.pl
Establishing the baseline assessment levels for monitoring coastal heavy metals in seawater using benthic foraminiferal shells

HOOBER Lin1*, TITELBOIM Danna2, ABRAMOVICH Sigal1, HERUT Barak1, TEUTSCH Nadya1, BENALTABET Tal3,4,5 and TOREFSTEIN Adi5,6

1Ben-Gurion University of the Negev, Beer Sheva, Israel; hoober.lin@gmail.com
2Department of Earth Sciences, University of Oxford, Oxford, UK; dannati@post.bgu.ac.il
3Israel Oceanographic and Limnological Research, Haifa, Israel; barak@ocean.org.il
4Geological Survey of Israel, Jerusalem, Israel; nadya.teutsch@gai.gov.il
5The Fredy and Nadine Herrmann Institute of Earth Sciences, The Hebrew University of Jerusalem, Jerusalem, Israel; tal@benaltabet@mail.huji.ac.il; adi.torf@mail.huji.ac.il
6Interuniversity Institute for Marine Sciences in Eilat, Israel; tal@benaltabet@mail.huji.ac.il; adi.torf@mail.huji.ac.il
*Corresponding author

A considerable growth of industrial facilities has been taking place along coastal environments over the past century. Some of these facilities have major economical and national importance, yet their operation can introduce a wide range of potentially harmful chemicals, such as heavy metals (HM), that might impact local ecosystems and human health. Efforts to monitor the presence of HM at low concentrations before damaging the ecosystem are contingent for protecting and conserving these coastal environments.

Many recent studies have shown the applicability of benthic foraminiferal shell chemistry for monitoring HM in coastal environments. Foraminiferal shells grow by sequential addition of chambers, thereby yielding a chronological record of HM concentrations in ambient seawater. This study introduces a new concept of defining a HM baseline assessment levels (BAL) in coastal seawater environments using foraminiferal shells. The BAL provide an absolute reference for documenting the temporal variation in HM that can be used to quantify the magnitude and duration following pollution events.

We demonstrate the potential of this approach by examining a pristine site in a nature reserve along the Mediterranean coast of Israel. Our previous investigation of this site in 2013-14 using foraminiferal single chamber LA-ICPMS created a large dataset that consisted of HM measurements in the last few chambers of two species Lachlanella and Pararotalia calciformata. This database was used to establish the BAL metals/Ca ratios of Zn, Cu and Pb, three HM associated with anthropogenic sources.

The BAL of each metal was defined as the 5th lower percentile value from the LA-ICPMS dataset of each species. To encompass the natural variability of non-contaminant natural sources in the BAL, 2 STDEV (in RSD%) of the observed variation of the alkaline earth metal Sr/Ca ratios were added. The potential biological variations between specimens to the resulting ratios based on laboratory culturing experiments of the two species added.

In February 2021, a significant oil spill event affected the entire Mediterranean coast of Israel, and included a considerable out wash of tar onto the shore. The event provided a unique opportunity to test the applicability of foraminiferal BAL by revisiting the previously studied site. Our strategy was to compare whole shell ICP-MS measurements of the two species collected shortly after the event and six months later, and compare them with the established BAL values. Our results revealed a significant increase (2-20 folds) in Zn/Ca, Cu/Ca, Pb/Ca ratios between 2013-14 and 2021. Among these, the increase in Pb/Ca is the most substantial and observed in both species. This implies a possible linkage between the oil spill event and the substantially elevated metals/Ca ratios measured by the foraminifera in 2021. Our study also demonstrates that bulk ICP-MS analyses will most likely yield similar ratios as those of average values of single chamber LA analyses of shells from the same location and period. This observation confirms that once BAL values are established, the analysis of bulk shell ICP-MS is effective for monitoring HM contamination of coastal environments.
Use of a standard format (DarwinCore) on an information system (BISMaL) to integrate recent foraminifera data and to estimate recent past habitat condition

HOSONO Takashi1*, FUJITA Kazuhiko2 KAKUMURA K. Azusa1, AZUMA Shuko1, KISHIMOTO Azusa1, MATSUDA Shoko1, FUSHO Ayana2, SONODA Akira1 and FUJIKURA Katsunori1

1Global Oceanographic Data Center, Japan Agency for Marine-Earth Science and Technology, Showa-machi 3173-25, Kanazawa-ku, Yokohama-city, Kanagawa, Japan; hosonot@jamstec.go.jp; kakumura_kinjoa@jamstec.go.jp; akiras@jamstec.go.jp; fujikura@jamstec.go.jp
2Department of Physics and Earth Sciences, Faculty of Science, University of the Ryukyus, Okinawa, Japan; fujitaka@sci.u-ryukyu.ac.jp
3Marine Works Japan LTD, Toyohara 224-3, Nago-shi, Okinawa, Japan; azumas@jamstec.go.jp; kishimotoa@jamstec.go.jp; matsudasy@jamstec.go.jp; fushoa@jamstec.go.jp
*Corresponding author

Due to growing concerns about effects of climate change on ecosystems, many scientific projects to collect biodiversity information on a global scale have been launched. Oceanographic Biodiversity Information System (OBIS, https://obis.org/) is one of the major data collecting project on marine biodiversity information, which has integrated and published over about 100 million biological occurrence records covering the entire ocean. In terms of detecting marine ecosystem changes, foraminifera could become the best sensitive indicator organism, because they distribute all over the ocean from shallow to deep water zones. However, only 0.1 million occurrence records of foraminifera are available in OBIS. This number is much lower than that would be expected from their wide distribution compared with 30.5 million records in Actinopterygii, and 10.3 million records in Crustacea (data accessed on March 31, 2023). Re-organising existing data from various scientific surveys on foraminifera into machine readable data format, and integrating the data on accessible information platform are helpful to know the current condition of marine ecosystems and to provide base-line data for predicting effects of climate change on the ecosystems in the future.

Most information systems on biodiversity including OBIS adopts DarwinCore (DwC, https://dwc.tdwg.org/) format as a data standard. DwC provide rules on describing location information (latitude, longitude, footprint WKT or geodetic datum), time (year, day, time or time zone), and methodology of the observation. Using standardized data format of DwC makes it easier to merge and analyse with other data source. In addition, there are many analysis tools or libraries specialized for DwC data, which is one of the large merits of using DwC. In this presentation, we will present a newly generated dataset on large benthic foraminifera occurrence pattern around Southern Japanese in DwC format, and also present our information system, BISMaL (a data portal of OBIS Japan node, https://www.godac.jamstec.go.jp/bismal/e/) that was originally developed to estimate environment conditions for past observations specialized for the north-western Pacific region.

We extracted and generated DwC data on foraminifera belonging to Amphistegina (Amphisteginidae); Baculogypsina, Calcarina, Neorotalia (Calcarinidae); Heterostegina (Nummulitidae); Peneroplis (Peneroplidae); Amphinorsus, Marginopora, Sorites and Soritidae (Soritidae) from 47 papers published in 1925-2011. As latitude and longitude are a required term in DwC, we carefully detected location information in the publications. When maps or location names were only available, the coordinate (latitude and longitude) was estimated from GoogleMaps and the uncertainty of the coordinates was set. A total of over 1500 valid occurrence records were generated in a DwC format, and annual fluctuation of the water temperature for about 900 locations where the foraminifera species were recorded were estimated quantitively as past habitat condition. It is quite usual that data structures or formats differ among scientific surveys with different purposes. However, by re-organising these data into DwC format, it can be merged into a single dataset. In addition, water temperature that was not observed during the survey can be estimated by registering them with BISMaL in DwC format. BISMaL can provide a useful information platform for integrating and analysing foraminifera occurrences from the past (but limited to “recent” past) to the present.

A high-resolution morphological record of planktonic foraminifera across the K-Pg boundary

HSIANG Allison Yi1*

1Department of Geological Sciences, Stockholm University, Svante Arrhenius väg 6A, Stockholm, SE; allison.hsiang@geo.su.se
*Corresponding author

Morphology is one of our primary sources of data for understanding biological evolution in deep time. Here, I present a high-resolution morphological record of planktonic foraminifera across the K-Pg boundary generated using high-throughput image processing and deep learning methods. This record spans a time period of ≈2.5 MY; from 0.5 MY (66.507 MYA; late Maastrichtian) before the boundary to 2 MY (63.998 MYA; early Danian) after. The purpose of generating this record is to investigate morphological evolution on a community level through a catastrophic extinction event and determine the correlations between planktonic foraminifer community structure and morphospace occupation and environmental/climatic patterns and parameters, including the collapse and recovery of the biological pump. The samples used here originate from the Walvis Ridge (Ocean Drilling Program [ODP] Leg 208, Site 1262, South Atlantic, 27°11.15’S, 1°34.62’E). The covered time period is split into 200 time slices with an average time interval of 12.610 kyr between each slice. Segmentation and
measurement of 2D and semi-3D morphological information is achieved using the open-source software AutoMorph and mask R-CNNs (region-based convolutional neural networks) implemented using the Detectron2 library in the PyTorch open-source machine learning framework. The methods developed and discussed here will allow for the rapid generation of large morphological datasets of foraminifera and other microfossils for understanding community evolution and interactions between the biosphere and the environment in deep time.

Albian–Cenomanian planktonic foraminifera and the warm to hot Cretaceous greenhouse climate transition at southern high latitudes: Results from IODP Sites U1513, U1514, and U1516 (SE Indian Ocean)

HUBER Brian T., MACLEOD Kenneth G., PETRIZZO Maria Rose and WATKINS David H.

1National Museum of Natural History, Smithsonian Institution, MRC-121, Washington, DC 20013, USA; huberb@si.edu
2Department of Geological Sciences, University of Missouri-Columbia, Columbia, MO 65211, USA; MacLeodK@mizzou.edu
3Department of Geosciences, University of Nebraska, Lincoln, NE 68588, USA; dwatkins1@unl.edu
*Corresponding author

Albian–Cenomanian sediments from IODP Expedition 369 Sites U1513, U1514, and U1516 on the Mentelle Basin (MB) in the SE Indian Ocean (60°S paleolatitude) yield extraordinarily well-preserved foraminiferal assemblages that provide new insight to biotic, palaeoceanographic, and palaeoclimatic changes at southern high latitudes (SHL). The planktonic foraminiferal assemblages are very low in species diversity and age-diagnostic taxa are very rare and sporadic in their occurrence. Fortunately, generally good age control is provided by calcareous nannofossils, and their distribution are the primary observations used to construct age models at each of the sites.

In addition to the overall low diversity of the planktonic foraminiferal assemblages, each site contains one or more carbonate-poor intervals up to 37 m thick that have few or no calcareous microfossils. Where they occur, the planktonic foraminiferal assemblages are consistently dominated by abundant and well-preserved, small-sized, long-ranging species of *Microhedbergella* that co-occur with varying abundances of radiolarians and calcispheres. The carbonates-poor intervals yield common to abundant radiolarians and clinoptilolite, a diagenetic zeolite. Morphology of the clinoptilolite suggest it may have replaced tests of calcareous plankton and/or radiolarians. The carbonate-poor intervals correlate among all three MB and extend from 96.5–100.5 Ma. The most extensive carbonate-poor intervals occur at Site U1516, with carbonate-poor intervals spanning from 96.5–104 Ma and >106.5 Ma. Occurrence of clinoptilolite in carbonate sequences is considered as a proxy for enhanced biogenic silica productivity. Thus, the primary control on the presence of biogenic carbonate or dominance of authigenic clinoptilolite probably depended on the amount of primary biogenic silica in the sediments that was available to react with interstitial clay minerals.

Oxygen isotope records were generated for the Albian-Cenomanian intervals that yielded well-preserved specimen foraminifera. Compiled results show a parallel trend in planktonic and benthic results suggesting gradual warming from the early Albian through late Cenomanian. Early Albian benthic and planktonic d18O values average -0.3‰ and -1.3‰, respectively at ~111 Ma and average -0.9‰ and -1.7‰, respectively, at 95 Ma, indicating a 2–3°C warming of bottom and surface waters. Previously published foraminiferal oxygen isotope analyses demonstrate a relatively rapid warming of surface and bottom waters across the Cenomanian-boundary by an average of 2.0 to 2.5°C, with some benthic specimens recording d18O values as low as -2.6‰ and planktonic specimens as low as -3.8‰. Transition from the warm greenhouse of the Albian–Cenomanian to the hot greenhouse of the latest Cenomanian–Coniacian may explain why planktonic foraminiferal diversity increased and of age diagnostic planktonic foraminiferal became more common in the SHL Indian Ocean starting in the Turonian.

A benthic foraminiferal stable isotope record of changes in overturning circulation of the Red Sea during the Marine Isotope Stage 3

HUBERT-HUARD Raphaël1*, SCHMIEDL Gerhard1 and ANDERSEN Nils2

1Institute of Geology, Universität Hamburg, Bundesstraße 55, 20146 Hamburg, Hamburg Germany; rhubertuard@gmail.com; gerhard.schmiedl@uni-hamburg.de
2Leibniz Laboratory for Radiometric Dating and Isotope Research, CAU, Kiel University, Max-Eyth Str. 11-13, 24118 Kiel, Germany; nandersen@leibniz.uni-kiel.de
*Corresponding author

The oceanography of the landlocked basin of the Red Sea is controlled by a restricted exchange of water masses with the Indian Ocean through the narrow and shallow strait of Bab al-Mandab and by high evaporation rates due to the arid-semiarid climate of the surrounding land areas. At intermediate water depths, the overturning circulation in the northern Red Sea, associated with the replenishment of oxygen-rich deep waters and the local oxygen consumption due to the remineralization of organic matter, drives the strength of the oxygen minimum zone. Here, we present stable isotope data of benthic
foraminifera from core KL11 core (central Red Sea) for the quantification of orbital and millennial-scale changes in the bottom water during Marine Isotope Stage 3. Three shallow infaunal species have been chosen to create a composite record: *Cibicides mabahethi*, *Discorbina bella berthelotii* s.l. and *Hanzawaia boueana* s.l. Our results indicate that changes in the overturning circulation of the Red Sea are a result of the influence of (i) the high-latitude millennial-scale climate variability and, (ii) the African-Arabian monsoon system. Specifically, the comparison of δ18O signals from KL11 and NGRIP shows the influence of Heinrich Stadials and Dansgaard-Oeschger events on the deep-water formation in the northern Red Sea. The δ13C signal exhibits orbital variations, which are in phase with northern hemisphere summer insolation. This suggests an additional influence of the African-Arabian monsoon system and related surface-water productivity in the central Red Sea.

Geochemical differences between alive, uncrusted and dead, crusted shells of the planktic foraminifera

*Negloboquadrina pachyderma*: Implications for paleoreconstruction

HUPP Brittany1,2,3* and FERENBACHER Jennifer2

1NOAA Climate and Global Change Postdoctoral Fellowship Program, CPAESS, UCAR, P.O. Box 3000, Boulder, CO 80307 USA; bhupp@gmu.edu
2Department of Earth, Ocean, and Atmospheric Sciences, Oregon State University, Ocean Administrative Building 104, 101 SW 26th St, Corvallis, OR 97331 USA; bhupp@gmu.edu; jennifer.fehrenbacher@oregonstate.edu
3Department of Atmospheric, Oceanic and Earth Sciences, George Mason University, 4400 University Drive, MS2B3, Fairfax, VA 22030 USA; bhupp@gmu.edu
*Corresponding author

Planktic foraminiferal-based trace element-calcium ratios (TE/Ca) are a cornerstone in paleoceanographic reconstructions. While TE-environment calibrations are often established through culturing experiments, shell growth in culture is not always consistent with growth in a natural setting. For example, many species of planktic foraminifera thicken their shell at the end of their life cycling, producing a distinct ‘gametogenic’ crust. Crust is common in fossil foraminifers, however, shells grown in culture do not often develop a thick crust. Here we investigate potential vital effects associated with the crust formation by comparing the trace element (Mg/Ca, Na/Ca, Ba/Ca, Sr/Ca, Mn/Ca, Zn/Ca) and stable isotope (δ13C, δ18O) composition of alive, fully mature, uncrusted shells to recently deceased, crusted shells of *Neogloboquadrina pachyderma* collected from the same plankton tows off the Oregon coast. We find that uncrusted (N = 55) shells yield significantly higher Ba/Ca, Na/Ca, Mn/Ca, and Sr/Ca than crusted (N = 66) shells, and crust calcite records significantly lower TE/Ca values for all elements examined. Isotopic mixing models suggest that the crust calcite accounts for ~40 to 70% of the shell volume. Comparison of foraminiferal and seawater isotopes indicate that *N. pachyderma* lives in the upper 90 m of the water column, and that crust formation occurs slightly deeper than their average living depth habitat. Results highlight the necessity to establish calibrations from crusted shells, as application of calibrations from TE-enriched uncrusted shells may yield attenuated or misleading paleoceanographic reconstructions.

‘Unmixing’ Deep-Sea Sedimentary Records of Planktic Foraminifer Community Turnover during the PETM through Isotopic Filtering

HUPP Brittany1,2* and KELLY D. Clay2

1Department of Atmospheric, Oceanic and Earth Sciences, George Mason University, 4400 University Drive, MS2B3, Fairfax, VA 22030 USA; bhupp@gmu.edu
2Department of Geoscience, University of Wisconsin-Madison, 1215 W. Dayton St., Madison, WI 53706 USA; ckelly@geology.wisc.edu
*Corresponding author

Microfossil records provide a wealth of information about the biotic consequences of abrupt climate change. Yet their diminutive sizes make microfossils susceptible to sediment reworking, which can mask primary ecological signals in the sedimentary record. Here we present a method for deconvolving the effects of sediment mixing on foraminifer assemblages associated with periods of abrupt biogeochemical change called “isotopic filtering”. Isotopic filtering was employed to assess the planktic foraminifer response to the Paleocene-Eocene thermal maximum (PETM) at Ocean Drilling Program (ODP) Site 865 in the equatorial Pacific Ocean and ODP Site 1135 in the southern Indian Ocean. The PETM was an ancient global warming event associated with a rapid perturbation of the global carbon cycle that is delimited by a δ13C excursions (CIE) in the global rock record. The abrupt decrease in the δ13C of dissolved inorganic carbon at the onset of the PETM imparted markedly lower δ13C signatures to foraminifer shells calcified during the event compared to shells calcified prior to the PETM. Abundant isotope analyses (~500 per site) of individual foraminifer shells representing the major taxa from within the CIE interval were used to estimate the proportions of reworked, non-CIE shells within the CIE interval. Frequency distributions of individual-shell δ13C values from within the CIE intervals of the Site 865 and Site 1135 PETM records are distinctly bimodal where approximately 49% and 39% of shells were found to be reworked contaminants, respectively. To obtain a clearer picture of the planktic foraminifer
Under the south-eastern deep Mediterranean Sea: Benthic foraminifera serve as sentinels for various microhabitats definition

HYAMS-KAPHZAN Orit1†, ALMOGI-LABIN Ahuva1, ZOLOTARVESKY Sophia1, KITIN Michael1 KATZ Oded1
TÖRSTEIN Adi2,3 and LANGER R. Martin4

1Geological Survey of Israel, 32 Yesha’ayahu Leibowitz, Jerusalem, 9692100, Israel; orithy@gsi.gov.il; almogilab@gsi.gov.il; sofiazolot@gmail.com;
misha.kit@gsi.gov.il; odedk@gsi.gov.il
2Fredy and Nadine Herrmann Institute of Earth Sciences, Hebrew University of Jerusalem, Israel; adi.torf@mail.huji.ac.il
3Interuniversity Institute for Marine Sciences, Eilat; adi.torf@mail.huji.ac.il
4Institut für Geowissenschaften, Paläontologie, Nussallee 8, 53115 Bonn, Germany; martin.langer@uni-bonn.de
*Corresponding author

Benthic foraminifera constitute an important part of the deep-water (> 200 m) meiofauna, including in the Mediterranean Sea, where their spatial distribution and assemblage composition are influenced by food quantity and quality, sediment characteristics, topographic features and bottom-water dissolved oxygen concentration. The southeastern part of the deep Levantine basin (LB), the most oligotrophic part of the Mediterranean, was the least studied region, despite the urgent need for delineating a firm baseline for future studies of sea-floor changes due to increasing activity of gas/oil companies in Israel exclusive economic zone (EEZ) and in the surrounding region (Turkey, Greece, Cyprus and Egypt). Hence, in August 2013 a multi-survey study was conducted in 50 sites, including qualitatively characterization of the live and dead benthic foraminiferal macrofauna (> 250 µm) of the deep south-eastern LB and their relationships to environmental conditions. In addition, water depth, particle size distribution, CaCO₃ (wt.%), clay fraction (wt.%), TOC (wt.%) and continental slope processes were correlated with foraminiferal composition. Overall, we identified 100 species of living foraminifera and 197 species of dead foraminifera, many of them, for the first time in this region. Surprisingly, the living foraminifera revealed heterogeneous seafloor consisting six different biotopes, including unique slope habitats as the cold-seeps in Palmachim and Dor disturbance areas and the lower continental slope and the bathyal (> 800 m water depth) that were enriched with arenogenic pteropods-associated agglutinated foraminifera, therefore showing an increase in carbonate content. We concluded that the “pteropods habitat” in the bathyal is unique to the eastern Mediterranean, with epibenthic foraminifera using pteropod shells as a hard substrate, which enriches the deep LB in meiofauna.

During the years 2017-19, we conducted complementary surveys at 16 stations along two transects, Haifa and Tel-Aviv, between 45-1900 m. In these surveys we sampled three Perspex-cores in each site, and examined the living BF (in size fraction > 125 µm) in each cm along the top 10 cm. The northern part of the Israeli EEZ (Haifa section) contains higher species richness and living foraminifera down to 10 cm, and show heterogenic upper slope assemblages similar to the observations made in the 2013 survey. Its inhabiting infaunal species are mainly opportunistic such as Globobulimina, Bolivina and Chilostomella dominating water depths > 120 m where TOC is increased. However, the bathyal region of Tel-Aviv section (central Israeli EEZ) contains the highest agglutinated foraminiferal species richness associated with pteropod shells.

Besides the heterogeneity in the lower continental slope in Haifa section, we also observed shallow foraminiferal shells (e.g. Ammonia tepida and Sorites orbiculus) that were transported to the bathyal region in the northern part of the Israeli territorial water and EEZ, indicating a recent marine landslide only where the shelf is narrow. Similarly, shelf transported foraminifera were also detected in the submarine blind Canyon off Nahariya (northern Israel), which was studied during 2018. Utilizing Lead-210 and Cs-137, we dated sediments from the upper 30 cm of the Canyon to the last 150 years. In these sediments down to 915 m water depth in the outlet of this blind Canyon, we observed live and recently dead benthic foraminiferal species that originated from the shelf, which implies intense turbidites along that period.

Taken together, we demonstrate that benthic foraminifera serve as perfect sentinels defining biohabitats as a function of environmental parameters as well as environmental disturbance (as marine landslides and turbidites).
**Time-course analyses on foraminiferal strain Ammonia veneta reveal unique adverse physiological effects and metabolic changes when exposed to nanoplastics**

ISHITANI Yoshiyuki1,*, CIACCI Caterina2, UJIÉ Yurika1, NOMAKI Hidetaka1 and FRONTALINI Fabrizio4

1Institute for Extra-Cutting-Edge Science and Technology Avant-garde Research (X-star), Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Natatsushima-cho 2-15, Yokosuka, Kanagawa, Japan; ishitaniy@jamstec.go.jp; nomakiho@jamstec.go.jp
2Department of Biomolecular Science, Università degli Studi di Urbino, Via Aurelio Saffi 2, Urbino, Italy; caterina.ciacci@uniurb.it
3Center for Advanced Marine Core Research, Kochi University, Monobe-Otsu 200, Namagoku, Kochi, Japan; yujiei@kochi-u.ac.jp
4Department of Pure and Applied Science, Università degli Studi di Urbino, Via Aurelio Saffi 2, Urbino, Italy; fabrizio.frontalini@uniurb.it

*Corresponding author

Plastic pollution is one of the most urgent issues in marine environments. Recent scientific studies have revealed that persistent plastic debris drifts through ocean gyre, then break into micro-to-nano size pieces. Because of their physical and chemical properties, nanoplastics have considerably more toxic effects due to their higher surface area to volume area that increase the capability of adsorbing or leaching toxic substances. Two kinds of functionalized nanoplastics, namely carboxylated-(PS-COOH) and cationic amine- (PS-NH$_2$) terminated polystyrene are known to induce adverse effects on marine organisms. Although nanoplastics are recognized to lead to harmful effects spanning from physiological to cellular alterations such as enhanced productions of reactive oxygen species (ROS) and lipidic polarity changes, the underlying mechanisms and metabolic pathways remain largely unknown.

Here, we tackle these gaps through a time-course (1, 6 and 24-hours) experiment of two characteristic (PS-COOH and PS-NH$_2$) nanoplastics based on confocal laser scanning microscopic (CLSM) observations with three specific probes (CellROX®Green for ROS, Acridine Orange for normal and acid endosome, and Nile Red for polar and neutral lipid) and transcriptome analyses on the benthic foraminiferal strain, *Ammonia veneta*. The PS-NH$_2$ is commonly more harmful than PS-COOH in several marine organisms, however foraminifers exhibit an opposite trend. The CLSM observations on foraminifera show that ROS production continuously increases through 24 h and neutral lipids and acidic endosomes increase in 6 h in PS-COOH. On the other hand, PS-NH$_2$ treated specimens reveal an enhanced ROS production, polar lipids, and acidic endosomes only at 1 h, and normal conditions are substantially re-established within 6 h. The transcriptome analyses document that both nanoplastics are taken into the cell via endocytosis. The comprehensive results of both transcriptome analyses and CLSM observations indicate that ROS are mainly produced under endoplasmic reticulum (ER) stress and porphyrin metabolism in mitochondria. Such ROS are then quenched by sulfide oxidase, glutathione peroxide, and neutral lipids (i.e., unsaturated fatty acids). Cytotoxicity of PS-NH$_2$ is suggested to be related to the positive charge of its surface in acidic endosome. Indeed, PS-NH$_2$ treated foraminifers exhibit a decrease of ROS production with respect to decreasing of acidic endosome after 1 h. Moreover, NAD(P)H quinone dehydrogenase (NQO1) is significantly expressed at 6 h. This enzyme not only disrupts ROS production in mitochondria but also slows down ATP synthesis, which accelerates endosome acidity. These metabolic patterns enable to dismiss ROS production in PS-NH$_2$ treated foraminifers, but not in PS-COOH ones. Finally, both foraminifers treated with PS-COOH and PS-NH$_2$ show a significant increase of ceramide biosynthesis. This indicates that foraminifers are capable of excreting nanoplastics using ceramide envelopes. As foraminifers expel these ceramide envelopes via exocytosis, coat foreign nanomaterials could isolate such toxicants from foraminifers and float out from the environment.

**Quantifying oceanic regime shifts south of Iceland across glacial/interglacial transitions and millennial scale oscillations using the planktonic foraminifera record**

JACKSON Rebecca1,2, ANDREASEN Nanna1, RIBEIRO Sofia2, KNUTZ Paul2, GUDMUNSDÔTTIR Esther Ruth1, KJER Kurt1 and RICHARDSON Katherine1

1Globe Institute, University of Copenhagen, Øster Voldgade 5 – 7, Copenhagen 1350, Denmark; rebecca.jackson@sund.ku.dk; kurtk@sund.ku.dk; kari@sund.ku.dk
2Geological Survey of Denmark and Greenland (GEUS), Øster Voldgade 10, Copenhagen 1350, Denmark; rebecca.jackson@sund.ku.dk; nan@geus.dk; sri@geus.dk; pkn@geus.dk
3University of Iceland, Sturlugata 7, 101 Reykjavik, Iceland; estherrg@hi.is

*Corresponding author

Iceland’s oceanic regime and the marine ecosystem it supports are modulated by the Atlantic Meridional Overturning Circulation and associated changes in surface water mass properties of the northern North Atlantic and Nordic seas. Recent warming has led to a decline in cold-adapted, commercially important marine fish species in southern Iceland. During previous warm periods such as the Eemian interglacial (ca. 150 – 130 ka BP), oceanic conditions were mediated by rapid migrations of the subpolar front. To chart the evolution of past regional (sub-) sea surface conditions in response to global climatic variation, we use a selection of marine cores from the Iceland and Irminger Basins, located both along the transect of the northward ocean heat advection and below known subpolar frontal positions. Using the fossil planktonic foraminifera record, we combine stable isotope analysis and Mg/Ca paleothermometry on *Neogloboquadrina pachyderma* (sin.) to
reconstruct (sub-) sea surface temperatures and salinities across these two basins. A combination of absolute dating methods (radiocarbon dating, tephrachronology and paleomagnetic dating) indicates that these marine records extend back to between 30 and 60 ka BP, thus capturing glacial/interglacial transitions and several series of the millennial-scale Dansgaard-Oeschger cycles. We assess how these differing climate states and millennial scale oscillations propagated into, and influenced, Iceland’s oceanic and ecosystem regimes, both in terms of their magnitude and timing.

Submicron Computed Tomography to analyse and quantify microstructures in *Uvigerina* spp.

JAQUES Victory A.J.1,*, VAŇATKOVÁ Kateřina2, KERKHOFF Marta1, HOLCOVÁ Katarína1, ŠALPLACHTA Jakub1, ZIKMUND Tomáš1 and KAISER Jozef1

1CEITEC - Central European Institute of Technology, Brno University of Technology, Purkynova 656/123, 612 00 Brno, Czech Republic; victory.jaques@ceitec.vutbr.cz; jakub.salplachta@ceitec.vutbr.cz; tomas.zikmund@ceitec.vutbr.cz; josef.kaiser@ceitec.vutbr.cz
2Department of Anthropology, Faculty of Science, Masaryk University, Kotlářská 267/2, 601 37 Brno, Czech Republic; katerina.vanatkova@muni.cz
3Institute of Geology and Palaeontology, Faculty of Science, Charles University in Prague, Albertov 6, 12843 Praha 2, Czech Republic; hereniom@natur.cuni.cz; katarina.holcova@natur.cuni.cz;
*Corresponding author

Visual study of foraminiferal test is commonly done using light or scanning electron microscopy, both of which are non-destructive 2D surface analyses. To study the tiny structures inside the foraminiferal wall (pores, microborings), it was necessary to use destructive methods. In our work, we want to show the possibilities of submicron Tomography for the visualisation and morphometry of these structures.

Our study focuses on pores (1-2 μm), which size and density yield important palaeoceanographic information (e.g. oxygen levels, pyhotdetritus input), and bioerosion traces (1-10 μm), another significant aspect of foraminifera caused by microboring organisms like fungi and cyanobacteria. Bioerosion traces are also important features, even though often overlooked. Observation and quantification of bioerosion traces can provide valuable insights into the environmental conditions of early burial of foraminiferal tests.

Three *Uvigerina* sp. were scanned by Computed Tomography (CT). The bioerosion traces and the pores were segmented (specific post-processing and segmentation protocol) from the test material. Their shape, orientation, volume, distribution, location in the test were analysed.

CT allows the observation of the surface and internal structures of a foraminifera test in 2D and 3D, providing more detailed information about the microstructures’ shape, distribution, orientation, but also quantification information. CT can achieve high resolution (submicron) and contrast, enabling the observation of small characteristics (nm-μm) related to the morphology of foraminifera non-destructively.

CT uses x-ray projections of an object at different angles to reconstruct a fully three-dimensional distribution of x-ray attenuation. Moreover, CT can be used to analyse specimens that are too delicate or rare to be examined using traditional “preparation” techniques, such as broken specimens or resin-casting, and observation techniques, such as stereo and scanning electron microscopy. These analytical methods are limited to surface or cross-section views (2D).

Our study demonstrates that CT is a powerful tool for the analysis of foraminifera, providing detailed information about their morphology and internal minute structures. Because this technique is non-destructive, specimens can be scanned and analysed without being damaged or altered. This allows the preservation of specimens for further analyses or storage in museums, which can be used by future generations of researchers to study these important microfossils.

Classification challenges from overlapping distributions of final whorl chamber numbers

JONES Chloe Louise1,*, BROMBACHER Anieke1 and EZARD Thomas1

1Department of Ocean and Earth Sciences, University of Southampton, National Oceanography Centre, European Way, SO14 3ZH; C.L.C.Jones@soton.ac.uk; Anieke.Brombacher@soton.ac.uk; T.Ezard@soton.ac.uk
*Corresponding author

Morphological-based taxonomy underpins how we identify species, but current definitions for many Neogene and Quaternary planktic foraminifera species are not up to date, making species identification difficult and biased by individuals. For example, current definitions for *Menardella limbata* and *Menardella multicamerata*, are based on the classical taxonomy and do not separate the species distinctly enough. The two species share many characteristics, including a low trochospiral test with lobulate periphery and pronounced keel; chambers increasing slowly in size; sutures curving backwards into keel on the sutural side and almost radial on the umbilical side; a smooth and densely perforate surface; with a low aperture bordered by a lip. *M. multicamerata* is only distinguished from *M. limbata* by the circular outline of the test, a deep and circular umbilicus, and an increased number of chambers (8-10) in the final whorl. However, *M. limbata* is defined as having 6-8 chambers in the final whorl, creating an overlap in definitions, and the other diagnostics are not always obvious. Other
species within the menardii lineage also overlap in chamber number in the final, adding to the confusion: *M. menardii* has 5-6, *M. pertenuis* has 6-8, and *M. exilis* and *G. miocenica* have 6-7.

Therefore, I aim to provide more succinct definitions of problematic species using updated morphological parameters. In *M. limbata* and *M. multicameralata*, initial morphological clustering analysis, using the size and shape of 500+ specimens of each species from 2D imaging, has shown a distinct difference between the species when applying the newly proposed definitions. These patterns cannot be detected when using traditional classification, which is based largely on chamber numbers, and therefore supports the need to update the current definitions. This study will be completed with further morphometrics analysis, using 2D light-microscope imaging and 3D Computer Tomography (CT) imaging, for both *Menardella* species and analysis via Gaussian Additive Mixture Modelling, which aggregates similar individuals into clusters that vary in size, shape, and orientation without *a priori* classification. The species refinement will be incorporated into the Neogene and Quaternary Planktic Foraminiferal Atlas.

### Using spatial patterns in planktonic foraminifera biodiversity to assess climate models

**JONKERS Lukas**¹, **LAEPPELE Thomas**¹⁻²⁻³, **RILLO Marina C.**¹⁻⁴, **SHI Xiaoxu**⁴, **DOLMAN Andrew M.**², **LOHMANN Gerrit**¹, **PAUL André**¹, **MIX Alan**⁵ and **KUCERA Michal**¹⁻³

¹MARUM Center for Marine Environmental Sciences, University of Bremen, Leobener Strasse 8, 28359, Bremen, Germany; ljonkers@marum.de; tlaepple@awi.de; marina.rillo@evobio.eu; apaul@marum.de; mkucera@marum.de
²Alfred-Wegener-Institut Helmholtz-Zentrum für Polar-und Meeresforschung, Telegrafenberg A5, 14473 Potsdam, Germany; tlaepple@awi.de; andrew.dolman@awi.de
³Department of Geosciences, University of Bremen, Klagenfurter Strasse 1, 28359 Bremen, Germany; tlaepple@awi.de
⁴Institute for Chemistry and Biology of Marine Environments, Carl-von-Ossietzky University Oldenburg, Schleusenstrasse 1, 26382 Wilhelmshaven, Germany; marina.rillo@evobio.eu
⁵Alfred-Wegener-Institut Helmholtz-Zentrum für Polar-und Meeresforschung, Klussmannstr. 3, 27570 Bremerhaven, Germany; xiaoxu.shi@awi.de; Gerrit.Lohmann@awi.de
⁶College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, Corvallis, 2651 SW Orchard Avenue, OR 97331-5503, USA; mix@coas.oregonstate.edu
*Corresponding author

The Last Glacial Maximum (LGM) remains a prime target to evaluate climate models outside modern boundary conditions. However, climate reconstructions are indirect and associated with marked uncertainty, complicating model-data comparison. Here we take a different approach and use macro-ecological patterns in fossil marine zooplankton to evaluate simulations of LGM near-surface ocean temperature.

We use the distance-decay pattern in planktonic foraminifera assemblage similarity to evaluate modelled thermal gradients. Distance decay emerges because of species-specific habitat preferences, which causes species assemblages to increasingly differ from each other with increasing environmental distance between them. Temperature has consistently been shown to be the most important environmental variable for planktonic foraminifera species assembly. Indeed, their assemblages preserved in surface sediments show decreasing similarity with increasing thermal distance between them. Because the ecological niches of planktonic foraminifera have remained stable over time scales much longer than studied here, the distance-decay relationship based on simulated LGM temperatures and LGM assemblages should in principle be identical to the modern pattern. Thus we can use fossil planktonic foraminifera assemblages to evaluate climate model simulations based on ecological principles, without the intermediate step of transforming assemblage composition into temperature estimates.

Our analysis is based on an extended LGM planktonic foraminifera database (2,085 assemblages from 647 unique sites; 50% larger than a previous synthesis) and a suite of 10 simulations from state-of-the-art climate models (PMIP3 and 4). We find that the distance-decay pattern that emerges when the LGM assemblages are combined with simulated ocean temperatures is different from the modern pattern. All simulations show large thermal gradients between regions where the planktonic foraminifera indicate no, or only weak, compositional gradients. This difference arises from a shift to polar species assemblages in the North Atlantic, where the simulations predict only moderate cooling. Importantly, simulations with a reduced AMOC due to coastal freshwater forcing and hence lower North Atlantic temperatures, yield a distance-decay pattern that is much more similar to the modern pattern, suggesting that simulations using the PMIP protocol for the LGM lack important ice-ocean feedbacks.

By combining insights from different disciplines we have demonstrated the power of using ecological principles to evaluate simulations of past climate. Because distance decay arises from the presence of thermal niches among planktonic foraminifera, our novel method can be applied to any time period, potentially even using assemblages containing extinct species as long as marked niche adaptation can be ruled out.
Towards FAIRer micropalaeontological data

JONKERS Lukas1, STRACK Anne1, HUBER Robert2 and KUCERA Michal1

1MARUM Center for Marine Environmental Sciences, University of Bremen, Leobener Strasse 8, 28359, Bremen, Germany; jonkers@marum.de; astrack@marum.de; mkucer@marum.de
2PANGAEA, Leobener Strasse 8, 28359, Bremen, Germany; rhuber@uni-bremen.de
*Corresponding author

Microfossil assemblage data are invaluable for palaeoclimatology, palaeoecology and biomonitoring. Meta-analysis of such data allows answering different questions than can be addressed using individual studies and can hence yield marked progress in these fields. However, such meta-analyses are difficult because microfossil assemblage data rarely comply with the FAIR (findable, accessible, interoperable and reusable) data principles.

Raw assemblage data is often not publicly available or only findable by searching for derived data. This not only hinders findability, but lack of access to raw data renders quantitative ecological research irreproducible. Interoperability, in turn, is often hindered by inconsistent formatting. Formally, reusability issues arguably present the largest challenge to meeting FAIR standards. They primarily stem from the complexity of taxonomic data and insufficient metadata.

Standardisation of this type of data is challenging because of evolving taxonomic insights that are difficult to apply to legacy data sets. Many taxonomic issues arise from the use of synonyms. Together with the tendency to report relative, rather than absolute, abundances and the habit to include counts of individual and lumped species in the same data set, this has led to an embarrassingly high proportion of archived data sets to contain obvious errors.

Clearly, these issues need to be addressed in order to increase the value of microfossil assemblage data. Here we propose a set of measures that will help to harmonise legacy taxonomic data and summarise these in a form of recommendations for reporting standards that includes metadata requirements. These proposals are meant as a starting point for a discussion and we explicitly solicit feedback from the entire community on how to increase the FAIRness of micropalaeontological data.

Plastic particles can be mistaken as a food source and incorporated into benthic foraminifera tests

JOPPIEN Marlena1,2,3,4, WESTPHAL Hildegard1,2,3, CHANDRA Viswasanthi2, DOO Steve S.1,2 and STUHR Marleen1*

1Geoecology and Carbonate Sedimentology Group, Leibniz Centre for Tropical Marine Research (ZMT), Fahrenheitstr. 6, 28359 Bremen, Germany; marlena002@e.ntu.edu.sg; hildegard.westphal@kaust.edu.sa; Steve.Doo@leibniz-zmt.de; Marleen.Stuhr@leibniz-zmt.de
2Physical Science and Engineering Division, King Abdullah University of Science and Technology (KAUST), Engineering Science Hall (Building 9), Level 4, 4700 KAUST, Thuwal 23955-6900, Kingdom of Saudi Arabia; marlena002@e.ntu.edu.sg; hildegard.westphal@kaust.edu.sa; viswasanthi.chandra@kaust.edu.sa; Steve.Doo@leibniz-zmt.de
3Department of Geosciences, University of Bremen, Klagenfurter Str. 2-4, 28359 Bremen, Germany; marlena002@e.ntu.edu.sg; hildegard.westphal@kaust.edu.sa
4Asian School of Environment, Nanyang Technological University (NTU), 21 Lower Kent Ridge Road, Singapore 119077, Singapore; marlena002@e.ntu.edu.sg
*Corresponding author

Large benthic foraminifera (LBF) are essential components of tropical coral reef communities and key carbonate-producing organisms. Among other applications, LBF can be utilised as indicators of pollution and environmental change. Marine litter, particularly plastic debris, presents a novel, yet largely unquantified, stress on foraminifera. While the effects of plastic pollution are increasingly being documented, most studies have focused on physiological responses of few organism groups (e.g., fishes, corals). Many previous studies showed negative effects of microplastics and nanoplastics on organisms' physiology and ecosystem functioning, but potential responses of foraminifera remain widely unknown.

We here present some of the first feeding choice experiments on LBF, comparing plastics with common food choices. Initially, we document the impact of microplastics (150-300 µm) on the heterotrophic feeding behaviour of Amphistegina gibbosa incubated with Artemia sp. nauplii only, with pristine microplastic particles only, or with a choice of nauplii and pristine microplastic. In a duplicate experiment, we compared the effect of pristine microplastic vs. microplastic that was pre-conditioned in artificial seawater. Feeding responses in both cases were evaluated a day later. Our results indicate a strong feeding selection against pristine microplastic, suggesting a selective ability of the foraminifera to discern between potential food sources. However, the presence of pre-conditioned microplastic caused similar feeding interaction rates as with the natural food source Artemia. This suggests that feeding behaviour (and subsequently energy resources) of LBF may be more severely impacted by microplastics with longer residence times in marine environments.

In a subsequent long-term study, we exposed A. lobifera and A. gibbosa to nanoplastic particles (~1 µm) and sterilised Nanochloropsis algae cells as a natural food source within the same size range. Here, we did not only observe the uptake of polymer nanoparticles deep into the foraminiferal test, but also the incorporation of plastic particles into the outer calcite walls of the tests. Despite the high degree of specialisation regarding the skeletal formation of LBF, abundant cases of nanoplastic encrustation in the calcite tests were observed. Nanoplastic incorporation into the test was associated with LBF growth by formation of new chambers, in conjunction with continuous nanoplastic ingestion and subsequent incomplete
Foraminiferal communities of intertidal estuarine mudflats – The MII and EFDI indices, a first step towards solving the estuarine quality paradox

JORISSEN Frans1, FOUET, Marie1, SINGER, David1 and HOWA Hélène1

1Angers University, Nantes Université, Le Mans Université, CNRS, UMR 6112 LPG, 49000 Angers, France; frans.jorissen@univ-angers.fr; marie.fouet@gmail.com; david.singer.bio@outlook.com; helene.howa@univ-angers.fr
*Corresponding author

Today, there is still a lack of reliable indices of environmental quality for estuaries. Because of the harsh environmental conditions, leading to low diversity communities, most biotic indices systematically indicate poor environmental quality, the so-called estuarine paradox. In this context, a thorough understanding of the relationships between environmental parameters and assemblage composition is crucial. It will only be possible to recognise an anomalous assemblage composition due anthropogenic pollution once the response to natural parameters is fully understood and correctly described. There is a wide consensus that salinity is the main controlling parameter in estuaries. However, due to the huge small-scale temporal and spatial variability of intertidal estuarine mudflats, it is almost impossible to obtain salinity measurements that are relevant for the biota. To overcome these problems, we developed two new indices:

1) the MII (Marine Influence Index) describes the extent of “marine influence”, a composite factor including salinity, nutrients, marine biota, hydrodynamics, etc., for any point in the estuary.

2) the EFDI (Estuarine Foraminiferal Diversity Index) is based on the diversity of each of four species groups with different tolerance of lowered salinity and associated estuarine constraints.

The good correlation between these two indices suggests that they adequately describe the relationship between natural controlling parameters and assemblage composition in natural intertidal estuarine mudflats. As such, they are the first step to the development of a foraminiferal index of environmental quality.

Foraminifera as indicators of late Holocene sediment contamination in the Bay of Sept-Iles

JOSHI Neha1,2*, SAULNIER TALBOT Émilie1,2,3 and MONTERO-SERRANO Jean-Carlos1,4

1Département de géographie et Institut de biologie intégrative et de systèmes, Université Laval, 2325 Rue de l'Université, Québec, QC G1V 0A6, Canada; neha.joshi.1@ulaval.ca; emilie.saulnier-talbot@bio.ulaval.ca
2Département de biologie, Université Laval, 2325 Rue de l'Université, Québec, QC G1V 0A6, Canada; neha.joshi.1@ulaval.ca; emilie.saulnier-talbot@bio.ulaval.ca; jeancarlos_monteroserrano@uqar.ca
3Département de biologie, Université Laval, 300 Allée des Ursulines, Rimouski QC G5L 3A1, Canada; emilie.saulnier-talbot@bio.ulaval.ca
4Département de biologie, Université Laval, 300 Allée des Ursulines, Rimouski QC G5L 3A1, Canada; emilie.saulnier-talbot@bio.ulaval.ca; helene.howa@univ-angers.fr
*Corresponding author

In recent decades, coastal environments all over the world have been experiencing rapid change due to increasing anthropogenic impacts. Coastal sediments act as a repository for contaminants entering the coastal marine systems and can preserve a reliable record of their sources. This contamination is not always directly evident but can make the sediments toxic for benthic and epibenthic organisms, which spend a large part of their life cycle in or on the sediment. Foraminifera (or forams) is one such single-celled organisms that are sensitive to their environment and form tests which are preserved in the sediment record, making them useful environmental and paleoenvironmental indicators. The Bay of Sept-Iles (BSI) is a high-use, deep-water mineral port, located in eastern Quebec (Canada) where recent anthropogenic activities may show a marked effect on surface sediments and the benthic and pelagic communities that inhabit them. In this context, 50 surface sediment samples and 2 sediment cores were collected to investigate the presence of potential sources of contamination and to assess their effects on foraminiferal assemblages. Foraminifera analysis of the surface sediments revealed an abundance of agglutinated species. Lepidodenteramina ochrcea, Crypostomoidus sp, Ammonia cassis and Eggerella advena were the major agglutinated species identified, whereas the calcareous Haynesina sp., Elphidium spp., Buccella, Calida, Cornuspira planorbis, and Buccella frigida were identified. E. advena was vastly dominant at some of the sites that had higher metal...
content in the sediments. Morphological deformities, such as crooked tails of *E. advena*, bulged shell in *Elphidium adventum*, and Siamese twinning indicate the presence of a stressful environment in this region.

For a better correlation of these anomalies with the deposition environment, bulk mineral and elemental composition for surface sediment samples were studied using quantitative X-ray diffraction (qXRD) and X-ray fluorescence (XRF), respectively. The qXRD and XRF data suggests that the abnormal morphology of the forams from sites located near a large aluminum smelter could be due to the presence of high Fe-oxides (mainly, hematite) and metal contents (Fe, V, Al). Thus, further foram analysis on these archives will help us develop a better spatio-temporal picture of the effects of anthropogenic activities on benthic communities in the Bay of Sept-Îles in the past half millennium.

**Turnover in agglutinated foraminifera across the Cretaceous/Paleogene boundary at Contessa, Umbria-Marche Basin, Italy: assessing the Signor-Lipps Effect**

KAMINSKI Michael A.¹, HIKMAHTIAR Syouma¹ and CETEAN Claudia G.²*

¹Geoscience Department, College of Petroleum Engineering and Geoscience, King Fahd University of Petroleum & Minerals, PO Box 5070, Dhahran, 31261 Saudi Arabia; kaminski@kfupm.edu.sa; syoumahikmahtiar@yahoo.co.id

²CGG Services SAS, P.O. Box 27246, Al Otaiba Building 801, Abu Dhabi, UAE; claudia.ctean@cgg.com;

*Corresponding author

The record of deep-water agglutinated benthic foraminifera (DWAF) from the Cretaceous–Paleogene boundary (K/PgB) section in the Scaglia Rossa Formation of the Umbria-Marche Basin has been studied in the Contessa Highway Section. The section was sampled bed-by-bed in the lowermost 50 cm of the Paleocene, and every 10 cm thereafter. The DWAF obtained from hydrochloric acid residues were compared with the record of the Maastrichtian DWAF. The purpose of this study is to assess the degree of faunal turnover among the DWAF at the K/PgB.

Three groups of DWAF are distinguished, namely: survivor species (including Lazarus taxa), extinction species, and incoming species. The total foraminiferal record consists of 86 species and is dominated by the epifaunal morphogroup (*Rhizammina, Caudammina, Ammodiscus* and *Glomospira*). Our record shows an abrupt decrease in the number of species across the K/Pg boundary. The lowermost Paleocene is characterised by the loss around 38% of the species (including *Caudammina gigantea, C. ovuloides, Recurvoides retroseptus, Gerochammina* spp., and *Bicazammina* spp.). A comparison with the uppermost Maastrichtian DWAF assemblages results in a combined total of 94 DWAF species over the K/PgB interval at Contessa Highway. Of these, 49 species are listed as extinction taxa, nine are survivor taxa, 19 are Lazarus taxa, and 8 taxa display first occurrences in the lowermost 50 cm of the Paleocene. Blooms of opportunists are observed in the lowermost Paleocene. Some species reappeared gradually in the lowermost Paleocene and may be considered Lazarus taxa. Based on our samples, we report around 9% incoming species (including *Ammonmarginulina aubertae, Spiroplectammina spectabilis*) in the basal Paleocene, some of which are described as new species. The common occurrence of some infaunal forms such as *Reophax/Nodulina* spp. and *Spiroplectinella* is regarded as opportunistic behaviour because they were rare in the Maastrichtian, survived the K/PgB, and then bloomed in the Early Paleocene.

For the purpose of estimating the apparent extinction rate of the DWAF, we considered nine stratigraphic intervals: the first interval above the K/PgB with five samples and successive intervals adding multiples of five samples. This approach to calculating the extinction rate therefore takes into account the Signor-Lipps Effect, and provides an estimate of the number of samples required in order to account for the presence of Lazarus taxa. Our results show that apparent species extinction rate varies from 84% if only the lowermost five samples of Danian are considered, but decreases to 53% when all 44 Paleocene samples are taken into account. We estimate that at least 30 samples are needed in order to calculate an accurate extinction rate across the K/PgB.

The Lazarus taxa are lowering the apparent extinction rate, and create a linear model to represent its additive decrease as additional samples are added to the calculation: simply stated, the calculated extinction rate across the boundary is a function of height of the stratigraphic interval studied and the number of samples collected from the interval overlying the boundary clay. A quantitative comparison between the Maastrichtian and Paleocene DWAF assemblages in Contessa yields new insight into the nature of the extinction rates and changes in the trophic structure across the K/PgB in the western Tethys. The K/PgB interval records a major shift in the proportions of DWAF morphgroups, from a suspension-feeding community in the Maastrichtian to one dominated by epifaunal detritivores in the lower Paleocene, reflecting a fundamental change in trophic structure following the bolide impact, while total marine primary productivity undergo relatively small changes. Our ultimate goal is to produce an unbiased record in order to quantify extinction and origination rates. These data, together with details of recognition of foraminiferal assemblages, taxonomic studies, and paleoenvironmental analysis can address the complex paleoecological problems associated with the K/PgB.
Analysing source and transport of submarine mass wasting along the continental margins of southeastern Mediterranean Sea using assemblages and taphonomy of benthic foraminifera

KATZ Oded1, ABRAMOVICH Sigal2, ASHKENAZI Leeron1,2, TORFSTEIN Adi3,4, MOSHE Naomi1,3, LESHNO-AFRIAT Yael1 and HYAMS-KAPHZAN Orit1*

1Geological Survey of Israel, 32 Yeshayahu Leibowitz St., Jerusalem 9692100, Israel; odedk@gsi.gov.il; leeron92@gmail.com; naomimish4@gmail.com; yaeshno@gmail.com; orithy@gsi.gov.il
2Fredy and Nadine Herrmann Institute of Earth Sciences, Hebrew University of Jerusalem, Jerusalem, 9190401, Israel
3Interuniversity Institute for Marine Sciences, Eilat 88103, Israel; adi.torf@mail.huji.ac.il
4*Corresponding author

Cross-shelf sediment transport is responsible for conveying sediment towards the upper-slope of the southeastern Mediterranean continental margins, yet it has been relatively understudied compared to the longshore transport of Nile-derived sediments. In order to evaluate the cross-shelf vs. longshore component of sediment transport for better understanding mass wasting processes along the slope, we analysed benthic foraminiferal assemblages and their shell taphonomy along cores sampled in the upper and lower scars of three submarine landslides along the Israeli slope: Goliath, Apollonia and Owl landslides located at the southern, middle and middle-north parts of the slope respectively, as well as in the Nahariya blind canyon located north of those landslides.

At each site we first identified the autochthonous (auto) benthic foraminiferal species (which naturally inhabit the continental slope area) vs. the allochthonous (allo) species (transported from the continental shelf) and then we calculated the allo/auto ratio. Where the ratio is larger than zero a contribution of transported shelf sediment to the slope is indicated. Moreover, where the ratio is higher than 1 a major contribution of shelf material exists. We also qualitatively analysed the taphonomy of the benthic foraminiferal shells and considered high fragmentation as an indication for long transport distance. Planktonic indicative foraminiferal species were used as an age constraint.

Glacial deposits (hosting Globorotalia scitula, indicative of glacial period) were sampled only in the lower parts of the cores sampled in the toe of Goliath and Apollonia landslides at water depth of ~900 m, with allo benthic foraminifera found only in Apollonia. Glacial sediment is overlain in both sites by Holocene hemipelagic sediment (including Globigerinoides ruber pink, indicative of the Holocene), where allo foraminifera are rare. Likewise, Holocene sediment from the upper scars of Goliath and Apollonia landslides at water depth of ~500 m shows rare allo foraminifera. The top ~1 m of this Holocene sediment in Apollonia is finely laminated with a high percentage of poorly preserved allo foraminifera dated to the last millennia and interpreted as shelf-origin turbidites. Similarly, the sediment of the last 600 years from the Owl landslide upper scar at 280 m water depth consists of two alternating distinct sedimentary facies: laminated intervals showing a high allo/auto ratio of benthic foraminiferal species and a high percentage of fragmented shells, indicating contribution of transported sediments originating from the shelf. These laminated intervals are interpreted as turbidites; Non-laminated intervals showing a low allo/auto ratio and low percentages of fragmented shells, indicating mostly hemipelagic deposition.

For the landslides, we conclude that the observed transported benthic foraminifera only in glacial but not Holocene deposits, suggests that cross-shelf sediment transport decreased following the post-LGM transgression and widening of the shelf, no longer reaching beyond the upper slope. Yet, the cross-shelf sediment transport renewed in the last millennia resulting intensified turbidite activity.

Two cores sampled in the middle and the outlet of the Nahariya submarine Canyon revealed glacial period with mostly-homogeneous sediment, which is uncomfortably capped by fine laminated sediment dated to the last 200 years. The recent sequence consists of fining upwards cyclic layers, interpreted as turbidites. Fragmented shells of shallow shelf foraminiferal species were found abundantly throughout both cores, indicating that shelf sediments are prevalent along glacial and recent sediments. Living allo foraminiferal species that were found in surface sediments indicate that sediment transport processes along this canyon exist to this day. The reported studies demonstrate that foraminifera are a valuable tool to identify and analyse sediment transport and submarine mass wasting events.

Recovery of planktic ecosystems following the end-Cretaceous mass extinction at El Kef, Tunisia

KEARNS Lorna E.1*, SÁNCHEZ-MONTES Maria Luisa2, JONES Heather3, SEPÚLVEDA Julio2 and LOWERY Christopher M.1

1Institute for Geophysics, Jackson School of Geosciences, University of Texas at Austin, 10601 Exploration Way, Austin, TX, 78758, USA; lorna.kearns@austin.utexas.edu; cmlowery@utexas.edu
2Department of Geological Sciences and Institute of Arctic and Alpine Research, University of Colorado Boulder, 2200 Colorado Ave, Boulder, CO, 80309, USA; mariuluisa.sanchezmontes@colorado.edu; jsepulveda@colorado.edu
3MARUM–Center for Marine Environmental Sciences, University of Bremen, Leobener Str. 8, 28359 Bremen, Germany; heatherjones394@gmail.com
4*Corresponding author
Anthropogenic warming is altering our oceans, impacting complex systems such as primary productivity and the global carbon cycle. Ongoing ecological changes include poleward shifts of plankton such as planktic foraminifera and diatoms. However, our understanding of how planktic ecosystems will respond to ongoing global change is limited. The geological record contains climate analogues to present and future ocean-climate states that can be investigated to gain a better understanding of ecosystem responses to climate perturbations. Planktic foraminifera, calcareous nannofossils, and organic biomarkers for non-fossilizing plankton can be recovered to investigate the ecological changes in planktic ecosystems during the aftermath of the Cretaceous mass extinction 66 million years ago.

Using sedimentary rocks recovered from the El Kef Coring Project, near the Cretaceous-Paleogene Global Stratotype Section and Point at El Kef (Tunisia), we generated a record of planktic foraminifera diversity at ~20cm resolution from the latest Maastrichtian Plummerita hantkeninoides Zone to the early Danian Zone P2. We then combined this record with nannofossil and organic biomarker records to provide a holistic view of ecosystem responses. We show that planktic foraminifera assemblages in the immediate aftermath of the K/Pg are dominated by the survivor species Guembelitria cretacea. The domination of Guembelitria then gradually reduces concurrently with increased genera abundance at the top of Pz. This change in diversity is accompanied by a significant increase in mean test size. Nannofossil assemblages show a quick transition from disaster taxa, such as Cerviisella, to acme events of upcoming Paleocene taxa such as Neobisbucer spp., transitioning to a more even, diverse assemblages in P1b. Furthermore, we show through organic biomarkers that non-fossilizing plankton were undergoing rapid turnover through Pz into P1b signifying ongoing ecological changes. Organic biomarkers show a shift from brown algae and pelagophytes in the immediate aftermath of the K/Pg followed by blooms of dinoflagellates, diatoms and prymnesiophytes which are gradually replaced by red algae. Looking at any of these planktic ecosystems in isolation would lead to conflicting interpretations ecosystem recovery and stability following the end-Cretaceous mass extinction. Instead, by using an interdisciplinary approach we show that turnovers in phytoplankton may have increased niche stability for zooplankton enabling non-synchronous diversity increases and an overall relatively quick recovery for parts of the planktic communities.

Elevated productivity during Oceanic Anoxic Event 2 in the Mentelle Basin, Western Australia (IODP Expedition 369), indicated by benthic foraminifera and geochemical proxies

Kender Sev1,2, Walker-Trivett Chloe1,2, Edvardsen Trine1, Bogus Kara1, Littler Kate1, Lacey Jack2 and Leng Melanie2

1Department of Earth and Environmental Sciences, University of Exeter, Penryn Campus, Penryn, TR10 9FE, United Kingdom; s.kender@exeter.ac.uk; cw725@exeter.ac.uk; edvardsentrine@gmail.com; k.bogus2@exeter.ac.uk; k.littler@exeter.ac.uk
2British Geological Survey, Nicker Hill, Keyworth, Nottingham, NG12 6GJ, United Kingdom; s.kender@exeter.ac.uk; cw725@exeter.ac.uk; jackl@bgs.ac.uk; mj@bgs.ac.uk

*Corresponding author

Oceanic Anoxic Event 2 (OAE2) was a period of geologically abrupt greenhouse gas release ~94 Ma, associated with Large Igneous Province (LIP) volcanism and severe ocean anoxia. However, relatively little is known of palaeoceanographic changes in the Southern Hemisphere. We refined the stratigraphy of International Ocean Discovery Program (IODP) Site U1516 by measuring high resolution carbon and oxygen stable isotopes from bulk rock carbonate (δ13C_{CARB}, δ18O_{CARB}) and total organic carbon (δ13C_{TOC}), and benthic foraminiferal isotopes. Published records of bulk rock δ13C_{CARB} show a clear positive excursion, which is traditionally used to correlate OAE2 globally, but biostratigraphic age control at Sites U1513 and U1516 suggests that OAE2 was stratigraphically more extensive than δ13C_{CARB} suggests. We resolve this discrepancy by compiling a composite benthic foraminiferal stable isotope record (δ13C_{FORAM}, δ18O_{FORAM}) from several species at Site U1516, after defining species-specific isotope offsets. Our composite δ13C_{FORAM} record agrees with biostratigraphic age control that OAE2 in the Mentelle Basin was stratigraphically more extensive than suggested by bulk δ13C_{CARB} alone.

We reconstruct palaeoceanographic change through OAE2 in the Mentelle Basin by comparing published records of biogenic silica and Nd isotopes with our new records of benthic foraminiferal assemblages and stable isotopes for Site U1516. Benthic foraminifera are moderately well preserved in most samples – outside of a prominent carbonate dissolution horizon – with 69 taxa identified, an average diversity of 14 taxa per sample, and species indicative of outer neritic to upper bathyal environments. Correspondence analysis indicates two clear assemblages in the record, with the assemblage change occurring over the dissolution horizon during the main phase of OAE2. Species characterised as high organic carbon flux/lower oxygen indicators proportionally increase within OAE2, indicating a likely change to elevated primary productivity. Productivity appears to have increased substantially during the dissolution horizon in the early main phase of OAE2, occurring with increased biogenic silica, occasional pulses of high TOC, and more negative εNd values, indicative of enhanced terrigenous runoff and eutrophication. Within the later part of the main phase of OAE2, terrigenous runoff and productivity fell, carbonate reappeared, but benthic foraminifera indicate productivity was likely higher than before OAE2, and δ18O_{FORAM} indicates warmer bottom waters, indicative of possible upwelling from less thermal stratification.
Tropical calcifiers are key organisms for understanding marine ecosystem responses to global changes. Expressly, holobiont organisms such as corals and Large Benthic Foraminifera (LBF) represent a more complex biological system for coping with the expected environmental changes. One of the most known and well-studied marine endosymbiosis is between the dinoflagellate algae of the genus *Symbiodinium* and reef-building corals. This symbiosis is the key to reef-building corals’ success, allowing them to form massive structures that support many marine organisms. This interaction determines the holobionts' functionality and their resilience to environmental stressors. Many studies have shown an influence on this symbiosis upon exposure to various stressors such as light, high salinity, and warming that caused photoinhibition and downregulation of photosynthates. One of the most noticeable signs of such stress is a phenomenon known as bleaching, which could result from a loss of symbiont cells and/or the loss of photosynthetic pigments, eventually leading to death. For the last decades, massive global coral reef mortality has been promoted by coral bleaching, and it is predicted to increase due to ongoing global climate change and warming. Previous studies have shown that the heterogeneous thermal sensitivity among *Symbiodinium* symbionts in corals could be manifested by 1. Changing in situ *Symbiodinium* populations from heat-sensitive to heat-resistant ecotypes or by 2. Ecophenotypic thermal acclimation mechanisms that develop high-temperature tolerance. Here we use the common cosmopolitan LBF species, *Sortites orbitus*, and its dinoflagellate symbionts for tackling the mechanisms of thermal tolerance of *Symbiodinium* symbiosis in foraminiferal using temperature-manipulated physiological experiments that were done separately on summer and fall populations in July 2021, and November 2022. Three weeks of culturing were done on each population under four temperatures 15, 25, 30, and 35°C. Calcification of the *S. orbiculus* holobiont was evaluated by measuring alkalinity loss in the culturing seawater as an indication of carbonate ion uptake. The symbiont's photosynthetic performance was determined by measuring dissolved oxygen in the same seawater. At the beginning of the experiment and the end of each week, a sub-set of specimens were frozen for molecular analysis of the algal symbionts. Both experiments show that the *S. orbiculus* exhibits optimal calcification performance at 25°C and 30°C, and its growth is significantly reduced upon exposure to the two extreme temperatures. *Symbiodinium* symbiosis recorded the highest oxygen levels at 25°C and 30°C in the summer experiment and only at 25°C in the fall experiment. In both experiments, net oxygen values at 15 °C were significantly lower than those at 25°C, yet positive, indicating sub-optimal conditions for photosynthesis. The most intriguing observation was the drop below zero of oxygen values, at 35°C in week 1, and the consequent increase in weeks 2 and 3 to the levels of the 30°C and 15°C treatments. A similar increase in oxygen production was observed in the 25°C and 30°C. This distinct recovery in time could be explained by either shuffling of different algal types or by acclimation. The mechanism of this recovery will be unraveled by the metagenomic analysis of the symbionts that will be obtained soon.

The effect of the end-Cretaceous ocean acidification on the community structure of planktic foraminifera

KENIGSBERG Chen1*, PINKO Doron1 LEVIN Sivan2 ABDU Uri3 and ABRAMOVICH Sigal1

1Department of Department of Earth and Environmental Sciences, Ben-Gurion University of the Negev, P.O.B. 653, Beer-Sheva, Israel; chenk@post.bgu.ac.il, doronpi@post.bgu.ac.il, sigalabri@bgu.ac.il
2Jusidman Science Center for Youth, Ben-Gurion University of the Negev, P.O.B. 653, Beer-Sheva, Israel; sivan.levin@gmail.com
3Department of Life Sciences, Ben-Gurion University of the Negev, P.O.B. 653, Beer-Sheva, Israel; abdu@bgu.ac.il
*Corresponding author

The Cretaceous – Palaeogene (K-Pg) boundary mass extinction is marked by the disappearance of more than 70% of planktic foraminifera. About 25% of the Cretaceous species were short-term survivors into the Palaeogene. *Guembelitria cretacea* is a disaster opportunist species that is the only known long-term survivor of this event. Severe biotic stress preceding the K-Pg boundary is observed in individual planktic species as dwarfing, deformation and decreased calcification. On a community level, stress is identified in the extinction of specialized K-strategists, higher abundance of generalist species and acme of opportunistic species. The proposed stress mechanisms include climate shifts, oceanographic changes and trophic system collapse and ocean acidification. This study presents new evidence for restructuring of planktic communities due to surface ocean acidification based on species-specific test carbonate budgets.

The test weights and/or volumes of three Cretaceous morphgroups (globotruncanids, rugoglobigerinids and planoheterohelicids) from four size-fractions (<63-120µm, 120-150µm, 150-250µm and >250µm) were measured. Results show that an average globotruncanid, a rugoglobigerinid and a planoheterohelicid is equivalent to ~5-188X, ~6-44X and ~4-21X tests of *Guembelitria cretacea*. The outcome from this study is important in understanding the link between carbonate crisis and demand related to ocean acidification in context of survivorship of these morphgroups during the Late
Epiphytic Foraminifera in *Posidonia oceanica* Meadows as a Tool for Monitoring Heavy-Metal Pollution in the Balearic Islands (Spain)

**KHOKHOLOVA Anna¹, GUDNITZ Maria N.², FERRIOL Pere³, TEJADA Silvia³, SUREDA Antonio³, PINYA Samuel¹, MATEU-VICENS Guillem¹,³**

¹Catedra Guillem Colom, University of the Balearic Islands, Ctra. Valldemossa km 7.5, E-07122 Palma de Mallorca, Spain; khokhlovaanna@gmail.com; guillem.mateu@uib.es

²Florida International University, Department of Earth and Environment, 33199 Miami, Florida, USA; mariagudnitz@gmail.com

³Interdisciplinary Ecology Group, University of the Balearic Islands, Ctra. Valldemossa km 7.5, E-07122 Palma de Mallorca, Spain; pere.ferriol@uib.cat; silvia.tejada@uib.es; antoni.sureda@uib.es; s.pinya@uib.es; guillem.mateu@uib.es

*Corresponding author

Because of their toxicity, persistence and difficult biodegradability heavy metals are one of the most significant pollutants in marine environments, including seagrass meadows. Epiphytic foraminifers are conspicuous in the *Posidonia oceanica* meadows and can be utilized as cost-effective bioindicators. To evaluate the ecological conditions of *P. oceanica* meadows around the Balearic Islands four indices based on benthic foraminiferal assemblages, such as, the modified FORAM Index (FI’), the “Long vs Short life span” index (ILS), the Foram Stress Index (FSI), and Shannon-Weaver index (H’), were calculated. High index values for all sampling sites with different anthropogenic activities indicated a good ecological status of the seagrass. In contrast, the proportion of abnormal foraminiferal tests (FAI), based on morphological analysis, was variable among the study sites and reach very high abundances in areas with a priori low anthropogenic impact. Although there is not a univocal cause-effect pattern between the occurrence of deformed individuals and heavy metal pollution (such as Cu, Zn, Cd, Pb, Co, Ni, As and Sn), abnormal growth forms were significantly more abundant in sites where the tests contained higher concentrations of trace elements, and certain deformities (occurrence of protuberances and supernumerary chambers) seemed to be associated with specific pollutants (Zn, Ni and As). The disparity between the foraminiferal biotic indices and the percentage of aberrant forms associated with the heavy metal uptake can be explained by differences in the type of environmental impact and the mineral composition of the foraminiferal tests. Thus, the use of foraminifera as bioindicators, combining different approaches such as ecological indices, quantification of abnormal growth patterns and geochemical analysis of their tests, are very helpful in determining the health of seagrass meadows ecosystems. The indices are proxies to show dominant conditions over a large area, whereas the morphological and geochemical analysis of the foraminiferal tests shows very localized but long-lasting impacts with sublethal effects.

**Coiling direction and biostratigraphic utility of mid Miocene paragloborotaliids and globorotaliids (planktonic foraminifera)**

**KING David J.¹, WADE Bridget S.¹ and MILLER C. Giles²**

¹Department of Earth Sciences, University College London, Gower Street, London, UK; david.j.king@ucl.ac.uk; b.wade@ucl.ac.uk

²Department of Earth Sciences, Natural History Museum, Cromwell Road, London, UK; g.miller@nhm.ac.uk

*Corresponding author

Trochospiral planktonic foraminifera will exhibit either a sinistral (left-handed) or dextral (right-handed) coiling direction. This morphological trait is unambiguous and so can be readily recorded and tracked through a stratigraphic interval within a given species. The ratio of sinistral to dextral forms can change through time, leading to a dominance in coiling direction. Coiling prevalence holds biostratigraphic value with a number of bioevents being recognised in Recent to late Miocene (~0-7 Ma) biochronology within the tropical-subtropical realm. Although a change in preferential coiling direction is known to occur within several species through older time intervals, no such events have been applied beyond the late Miocene (~15 Ma).

We investigated *Paragloborotalia siakensis* from multiple sites in the equatorial Pacific Ocean (IODP Sites U1337 and U1338, ODP Site 871), equatorial and mid latitude Atlantic Ocean (ODP Site 925 and JOIDES-3 respectively) and the Caribbean (Trinidad, Jamaica and Barbados). We also studied material from the high latitude Southern Ocean (ODP Site 747) to assess the global the global synchronicity of the coiling change. However due to the scarcity of *P. siakensis* at Site 747, we instead recorded coiling in the more prevalent paragloborotaliids, as well as the genus *Globorotalia* due to their dominance in the mid to late Miocene at this site.

Our high-resolution record from Site U1337 indicate a change from a random to sinistral coiling preference at 15.37 Ma within planktonic foraminifera Zone M5, and shows excellent correlation with our lower resolution records from Site
U1338, JOIDES-3 and Trinidad. The sinistral coiling preference in *P. siakensis* is maintained up until the extinction of the species in the late Miocene (~10.50 Ma; Site 925). In the high latitudes (Site 747), the absence of *Paragloborotalia* through a portion of the mid Miocene precludes accurate dating of the coiling change. However random coiling trends are found in the older paragloborotaliids between ~19.8-17.3 Ma (*P. semivera* and *P. incognita*) compared to the sinistral coiling adopted by *Paragloborotalia continuosa* in the younger part of the record (~13.5-9.0 Ma). *Globorotalia* at Site 747 show two changes in coiling direction namely one from random to sinistral at 15.14 Ma, within a *G. praescitula* and *G. zealandica* dominated assemblage, and at 10.02 Ma within *G. scitula*.

We propose the recognition of the coiling change in *Paragloborotalia siakensis* as a secondary bioevent in the mid Miocene at ~15.37 Ma, and a useful biostratigraphic means of recognising the base of the Langhian in the tropical-subtropical realm. The bioevent will be of particular use in regions where the historic base Langhian planktonic foraminifera event, namely the *Praeorbulina-Orbulina* lineage, are rare or poorly represented. Our preliminary investigation of coiling changes within *Globorotalia* suggest coiling is biostratigraphically useful in the high latitudes, particularly as foraminiferal assemblages are typically lower in diversity compared to tropics.

The influence of the Caribbean in Oligo-Miocene planktonic foraminifera taxonomy and biostratigraphy

KING David J.1*, WADE Bridget S.1 and MILLER C. Giles2

1Department of Earth Sciences, University College London, Gower Street, London, UK; david.j.king@ucl.ac.uk; b.wade@ucl.ac.uk
2Department of Earth Sciences, Natural History Museum, Cromwell Road, London, UK; g.miller@nhm.ac.uk
*Corresponding author

The Caribbean region represents one of the most historically important regions in planktonic foraminiferal research, accounting for the description of over 100 species with a full or partial range in the Oligocene and/or Miocene between 1839-1980. The vast majority of these species are still valid with 14 species being erected as the type taxa for the relevant genus either at the time of description or in subsequent studies.

The region was also the birthplace of planktonic foraminiferal biostratigraphy in the mid part of the 20th century. In 1945 Joseph Cushman and Robert Stainforth produced the initial biozonations for the Oligo-Miocene sediments exposed at the Cipero Beach section in Southern Trinidad. Subsequent work within Trinidad, spearheaded by Hans Bolli, allowed for a near complete planktonic foraminifera zonation from the late Cretaceous to late Miocene with much of this being detailed in the seminal United States Museum Bulletin 215 “Studies in Foraminifera”. Subsequent studies in the 1960s focused on filling in the late Miocene to Recent interval with eastern Venezuela and Jamaica being of particular importance. Although the advent of ocean research drilling in the late 1960s allowed for more complete and higher-resolution records, the impact of the Caribbean provided the backbone for subsequent zonations.

Here we present a review and reassessment of Caribbean region to bring the original findings in line with our modern day understanding of Cenozoic planktonic foraminifera taxonomy and biostratigraphy. Unfortunately, many of the original localities applied in the aforementioned studies are no longer accessible. Thankfully, the original authors had the foresight to distribute material, including type slides and residues, to museums and academic institutions worldwide. A number of these classic sections have been re-examined as part of this study, with a particular focus on Trinidad. In terms of biostratigraphy, there is remarkable consistency in the bioevents applied within the tropical-subtropical realm, with some (e.g. Top *Globorotalia liguensis* and Top *Catapsydrax dissimilis*) being applied consistently in biozonations since their initial recognition. Regarding taxonomy, we have focused on species where the original description was based only on the holotype (e.g. *Globorotalia liguensis* and *Globorotalia archecampani*) with no other associated type specimens (e.g. paratypes). Analysis of topotypic material, such as the original residue and subsequent specimen slides, allowed us to ascertain the abundance of the relevant species and the morphological variability exhibited, as well as illustrating additional specimens to aid our taxonomic concepts.

When stress creates high diversity: the case of Thermaikos Gulf (NW Aegean Sea)

KOUKOUSIOURA Olga1*, GEORGIOU Sofia1, DIMIZA D. Margarita2, TRIANTAPHYLLOU V. Maria2 and LANGER R. Martin3

1School of Geology, Aristotle University of Thessaloniki, 54124, Thessaloniki, Greece; okoukous@geo.auth.gr; sgeorghiou89@hotmail.com
2Faculty of Geology and Geoenvironment, National and Kapodistrian University of Athens, 15784, Athens, Greece; mdimiza@geoil.uoa.gr, mtriant@geoil.uoa.gr
3Institute for Geosciences, University of Bonn, D-53115, Bonn, Germany; martin.langer@uni-bonn.de
*Corresponding author

Living and dead benthic foraminiferal assemblages were analysed to determine their seasonal variation and evaluate the effects of environmental factors on their abundance, species composition and distribution, in the semi-enclosed Thermaikos Gulf, in the NW part of the Aegean Sea. Three major rivers, two minor ones and several ephemeral streams flow into the
shallow Thermaikos basin. During the high precipitation period (January-May) the fresh water intrusion extends to the major part of the gulf (surface salinities <25). The high river water supply to the gulf enriched in nutrients and terrigenous matter, causes great amounts of dissolved solids in the water column, enrichment of heavy metal content and eutrophication. Therefore, the gulf is considered as one of the most anthropogenically impacted coastal regions of Greece.

A twelve-month monitoring was carried out in order to investigate the foraminiferal abundance and distribution, in relation to a multi-parameter environmental dataset (temperature, salinity, pH, total dissolved solids and nutrients), metal content and organic carbon. One station (S1) was sampled on a monthly basis (January-December), whereas five stations (S1-S5) during winter (January), spring (April), summer (July) and autumn (October), located in the inner part of Thermaikos Gulf.

A total of 82 living benthic foraminiferal species were identified out of stained specimens, while 150 species have been defined in the total assemblage. In combination with the high species richness and diversity indices the inner Thermaikos Gulf is indicated as a high diversity environment. Interestingly, the muddy substrates in the eastern and central parts of the gulf are dominated mainly by stress-tolerant taxa, whereas samples from the sandy western part are characterized by a more diversified assemblage including also sensitive foraminiferal species such as miliolids and a variety of small epiphytic rotaliid species.

Hence, the exceptional environmental conditions that prevail in the environments of the inner Thermaikos Gulf, although deriving from a combination of stress parameters, create a high diversity foraminiferal fauna in a natural but physiochemically complex environment.

**Paleoenvironmental changes in the Gulf of Corinth (eastern Mediterranean) during MIS 5 from benthic foraminifera and geochemical proxies**

**KOUKOUSIOURA Olga**1,2*, **PUENTES-JORGE Xabier**2, **PANAGIOTOPoulos Konstantinos**2, **DIZ Paula**3 and **GRUNERT Patrick**1

1 Institute of Geology and Mineralogy, University of Cologne, Zülpicher Strasse 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, Spain; xabier.puentes-jorge@uni-graz.at, pauladiz@uvigo.es
*Corresponding author

The Gulf of Corinth is a relatively young (<5 Ma) and active continental rift zone in the eastern Mediterranean Sea, which is currently connected to the Ionian Sea through a shallow sill (60 m of depth) and to the Aegean Sea via the Corinth canal. The closed drainage system and the high sedimentation rates (approx 0.5-3 mm/yr) make the study area a natural laboratory for the investigation of the complex interaction between sedimentary input, tectonics and climate through its evolution. In this study, we investigate the paleoenvironmental changes in the IODP Expedition 381 core M0080A during MIS 5 (21-36.5 mbsf), using a multiproxy approach including a combined benthic foraminiferal (assemblages and abundances), sedimentological (grain size) and geochemical (inorganic carbon content, benthic foraminifera oxygen and carbon isotopes) dataset.

The benthic foraminiferal record is highly variable, with two intervals (22.8-25.5 mbsf and 30-35.8 mbsf) characterized by high abundances of *Hyalinea balthica, Bolivina spathulata, Melonis affinis, Bulimina aculeata, Bulimina marginata* and *Cassidulina carinata* indicative of mesotrophic to eutrophic marine conditions, likely occurring during high sea-levels. These intervals are separated by periods when benthic foraminifers were very low in numbers or even absent, suggesting a sea-level drop below sill level and the subsequent (semi-) isolation of the basin. The inorganic carbon content varied following the interpreted sea-level fluctuations, with higher values occurring during low sea level intervals. Furthermore, several aragonite layers were found during the transition from high to low sea level (marine to isolated intervals), whereas the predominant grain size is very fine silt and clay.

The benthic foraminifera oxygen isotope record is discontinuous and conditioned to the presence of well-preserved benthic foraminifers. The species *Melonis affinis* and *Bulimina aculeata* were used to construct a benthic foraminiferal composite record corresponding to MIS 5a, early MIS 5c and MIS 5d-e periods, where the sea level was inferred to be above the sill level.

Ongoing high-resolution studies and a new age model will improve our understanding of paleoenvironmental changes in the Gulf of Corinth during glacial and interglacial stages and allow us to define the factors driving changes in this unique active rift of the eastern Mediterranean.

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).
New approach to calculating dissolved marine oxygen values with the Enhanced Benthic Foraminifera Oxygen Index

KRANNER Matthias1*, HARZHAUSER Mathias1, BEER Christoph2, AUER Gerald1 and PILLER Werner E.3

1Geological-Palaeontological Department, Natural History Museum Vienna, Burgring 7, 1010 Vienna, Austria; matthias.kranner@nhm-wien.ac.at, mathias.harzhauser@nhm-wien.ac.at
2PwC Austria, Donau-City-Straße 7, 122 Vienna, Austria; christoph.beer@hotmail.de
3Institute of Earth Sciences (Geology and Palaeontology), NAWI Graz Geocenter, University of Graz, Heinrichstr. 26, 8010 Graz, Austria; gerald.auer@uni-graz.at, werner.piller@uni-graz.at
*Corresponding author

Changing climates and anthropogenic influences disrupt the oceanic metabolic cycle leading to major changes in biodiversity. Tracking oxygen minimum zones (OMZs) gained much interest due to their effect of trapping greenhouse gases and the reduction of livable habitat. This makes changes in dissolved oxygen (DO) a driving factor of changing biodiversity. A frequently used tool to reconstruct DO values is the Benthic Foraminifers Oxygen Index (BFOI). We realized major differences using the original BFOI calculation and quantitative analyses. Therefore, we revised and enhanced this method by using all available data, including oxic, suboxic, and dysoxic indicators. Our enhanced BFOI (EBFOI) thus considers calcareous and agglutinated foraminifers and infaunal and epifaunal taxa for calculating the livable habitat of benthic foraminifers, including bottom water oxygenation and pore water oxygenation.

Additionally, we introduce a transfer function to directly convert the EBFOI into DO values in ml/l for the first time (DO[ml/l]=5.28475*e^{-3.78475}).

Our new approach significantly improves the definition and reconstruction of marine oxygen levels and eutrophication. All formulas are calibrated on modern samples, showing an accuracy increase of up to ~38% near OMZs compared to the BFOI. The EBFOI was subsequently also applied to three Cenozoic fossil datasets. Thus, our new formulas provide a major improvement in reconstructing oxygen levels and the reliability of benthic foraminifers as an oxygen proxy in general. This allows a better understanding of past changes and tracking and predicting future expanding OMZs.

 Assessing Heavy Metal Contamination Along the Mediterranean Coast of Israel Using Foraminiferal Shell Geochemistry

KREKOVA Vasilisa1*, ABRAMOVICH Sigal1, HERUT Barak 2 and TORFSTEIN Adi 3,4

1Department of Earth and Environmental Sciences, Ben Gurion University of the Negev, Beer Sheva 8410501, Israel; vasilisa@post.bgu.ac.il; sigalabr@bgu.ac.il
2Israel Oceanographic and Limnological Research, Haifa 3108000, Israel; barak@ocean.org.il
3The Fredy and Nadine Herrmann Institute of Earth Sciences, The Hebrew University of Jerusalem, Jerusalem 9190401, Israel; adi.torf@mail.huji.ac.il
4Interuniversity Institute for Marine Sciences in Eilat, Eilat 8810302, Israel; adi.torf@mail.huji.ac.il
*Corresponding author

Heavy metals (HM) pollution can have a critical impact on the sustainability of the marine environment, with potential effects on marine ecosystems, human health, and economical activity. Direct monitoring of water chemistry islogistically difficult and analytically expensive, particularly in coastal areas. Here, we present a systematic study of the HM pollution of the Israeli Mediterranean coast using the compositions of benthic foraminifera shells, which act as "living data loggers" of pollution levels. Our research question was: "What is the spatial and temporal variability of HM pollution along the Israeli Mediterranean coast, as recorded by benthic foraminifera shells?"

The study was carried out in eight stations spread over 150 km, between Achziv in the north and Palmahim in the south. Some stations are located in pristine environments (e.g., nature reserves), while others, such as Haifa Bay and Jaffa Coast, are proximal to industrial or urban areas and are suspected to be polluted. Samples were collected from each station and three species were selected to demonstrate variability among foraminiferal calcifications: Lachlanella sp., Amphistegina lobifera, and Pararotalia calciforma. Samples were collected seasonally between November 2022 and September 2023 to evaluate temporal variability. The samples were stained with Rose-Bengal solution to mark living specimens at the time of sampling. Live specimens were picked and rigorously cleaned in an ultraclean lab to remove organic matter and other external contaminants. The samples were subsequently digested, and the HM content of group of specimens of each species was measured using ICP-MS.

Our study found that the HM content was higher near Haifa Bay and the coast of Jaffa, but no clear geographic trend was observed in other areas. As expected, the HM content of the miliolid species Lachlanella sp. was higher than those of A. lobifera. These results provide the first documentation of the distribution of HM pollution along the Mediterranean coast of Israel and illustrate the benefits of using benthic foraminifera as environmental monitors. The significance of these findings lies in their potential implications for environmental policy, public health, and future research directions.

During this study, we made another discovery regarding the staining of samples in Rose Bengal solution. This method was chosen due to the need to process a large number of samples. Upon comparing the dyed samples with those that were
not, we observed an unexpected pattern of lower values of in the dyed specimens relative to the stained ones. We interpret this observation as an indication that the Rose Bengal staining process causes specific elemental impurities to detach from the foraminifera shells, leading to a counter-intuitive decrease in some of the HM contents. This phenomenon was observed across all three species we examined.

**When rose Bengal fails to detect living foraminifers by simple observation through the tests – methodological approaches in the Santos Basin, Brazil (Southwestern Atlantic)**

KROPWIEC Isabela S.†1 and DISARÓ Sibelle T.†

1Laboratório Foraminíferos e Micropaleontologia Ambiental, Federal University of Paraná, Av. Cel Francisco Heráclito dos Santos 100, Curitiba, Brazil; isabelaskoki@gmail.com; stdisaro@ufpr.br

*Corresponding author

The samples of this study were provided within the “Santos Project - Santos Basin Environmental Characterization” – coordinated by Petrobras/CENPES. The samples were collected in triplicates at eight sampling stations located 150 m deep; they were fixed with 4% buffered formaldehyde and stained with rose Bengal (2 g.L⁻¹). The wet volume was standardized to 20 mL at the laboratory, and the samples were washed on a 63 μm mesh sieve with water. Further, they were dry and separated by density with trichloroethylene PA. All supernatant material was thoroughly analysed; the residue was split, and a 5 mL subsample had all non-transparent agglutinated specimens selected for counting and identification.

The rose Bengal is a dye widely used to identify living foraminifers, and for most of the specimens, the stained protoplasm is visible by the transparency of the tests. A total of 45,916 living benthic foraminifers from the continental shelf of Santos Basin were studied; the classical staining technique worked for most individuals, and the protoplasm's colour was adequately seen through the tests. However, in some non-transparent agglutinated foraminifers, it was impossible to detect the stained protoplasm through the test, even when the specimens were immersed entirely under water or glycerine, observed under transmitted and incident light. For those specimens, no pattern allowed a confident decision to distinguish living from non-living individuals. Thus, to correctly estimate the contribution of these organisms to the density at the Santos Basin's outer shelf, the tests of non-transparent agglutinated foraminifers had to be broken to inspect their contents, and the percentage of living individuals registered for each species was confidently quantified.

Two of the three collected replicates had the non-transparent agglutinated foraminifera broken and inspected for stained protoplasm. The percentage of living foraminifers of each species was applied to extrapolate the amount of the living foraminifers from the unbroken replicate. Of 20,457 tests, 5,075 were broken, and 322 were considered alive, representing 1.6% of the non-transparent agglutinated tests. Considering other living foraminifers groups, 6,874 individuals were registered at the outer shelf and the density of living non-transparent agglutinated corresponded to 4.5% of the total. In the Northern portion, non-transparent foraminifers represent up to 18% of the total density.

A non-metric Multidimensional Scaling analysis (nMDS) was performed with the non-transparent living foraminifers; four groups were detected (two from the northern area, one transitional, and one from the southern area). Canonical correspondence analysis (CCA) showed that non-transparent agglutinated foraminifers were related to declivity, distance from the coast, phaeopigments, and sedimentary properties (size and grain selectivity); three groups (north, south and transitional) were identified. The Correlation Analysis with 5 mL and 10 mL aliquots showed that the abundance of the sub-samples was positively correlated with the whole sample.

We are applying living foraminiferal assemblages to characterize the Santos Basin; if they are not adequately quantified, some regions will not be adequately distinguished from others. Therefore, incorporating qualified data is vital; if these foraminifers were not considered, density would have been underestimated. These non-transparent individuals are essential components of the benthic foraminiferal assemblages. They differentiate some portions of the continental shelf, and in the case of Santos Basin, they are significant components of the northern outer shelf.

**The Albești nummulitic limestones: biostratigraphic, paleoenvironmental and paleogeographic remarks**

KÖVECȘI Szabolcs-Attila†1, LESS Győrgy2, PLEȘ George1, BINDIU-HAITONIC Raluca1 and SILYE Lóránd1

1Babeș-Bolyai University, Department of Geology, Kogălniceanu, 1, 400084 Cluj-Napoca Romania; szabolcs.kovecsi@ubbcluj.ro; george.ples@ubbcluj.ro; raluca.haitonic@ubbcluj.ro; lorand.silye@ubbcluj.ro

2University of Miskolc, Institute of Exploration Geosciences, H-3515 Miskolc-Egyetemváros, Hungary; gyorgy.less@uni-miskolc.hu

*Corresponding author

Within the territory of Romania, the Albești nummulitic limestone is considered one of the classical Eocene successions, which consists of abundant larger benthic foraminiferal (LBF) tests. The Albești type limestone has been exploited and used as building stone over the centuries. Despite its economic interest and paleontological importance just few papers discuss its paleontological and sedimentological aspects. Even the LBF assemblages and age of the Albești limestone have been
discussed in some papers in the second half of the twentieth century, questions, as its exact age, depositional environment and paleogeographic affinity still remain open.

To answer these questions, we performed a high resolution taxonomical and microfacies analysis based on 40 samples collected along seven exposures located in and near Albești locality (Arges county, southern foot of the S Carpathians, northern part of the Getic Basin).

Based on the sedimentological features and paleontological content of the investigated thin-sections, four main microfacies types were established (in stratigraphic order): 1. densely packed bioclastic grainstone-rudstone; 2. fine-grained packstone; 3. glauconitic grainstone; and 4. bioclastic packstone and floatstone.


Based on the identified main microfacies-types and the abundance of the LBF a high energy depositional environment, situated in the middle parts of a carbonate ramp has been inferred for the studied carbonatic succession. The recovered LBF assemblages are typical for the SBZ10/11 (LBF in general) and OZ 6/7 (orthophragminid) biozones and confer a late Ypresian (early-middle Cuisian) age to the studied sedimentary record.

The exclusive presence of taxa belonging to the non-granular Nummulites shows affinity to the northern nummulitic bioprovince (Dobrogea: SE Romania and NE Bulgaria, Crimea, Mangyshlak and the vicinity of Lake Aral) and suggests that the northern part of the Getic Basin was in a direct connection with the Peri-Tethyan realm during the Eocene. No provinciality could be detected, however, in the case of orthophragmines, similar lower-middle Cuisian assemblages have been reported from SW France, the Crimea and from N and Central Turkey.

An in-depth study of macroperforate and microperforate Neogene planktonic foraminifera speciation events

LAMYMAN Grace† and AZE Tracy†

†School of Earth and Environment, University of Leeds, Woodhouse, Leeds, LS2 9JT, UK; eegsl@leeds.ac.uk; T.Aze@leeds.ac.uk

*Corresponding author

Planktonic foraminifera are marine microorganisms with one of the most complete fossil records of the Cenozoic era. Due to this fact they are often utilised as a tool to investigate micro- and macroevolutionary questions. In this study a high-resolution direct sampling approach was taken to analyse multiple speciation and extinction events across both macroperforate and macroperforate lineages within the Neogene. The speciation of Globigerinella siphonifera, Globigerinella calida, Globigerinella adamsi and Beella megastoma and the extinction of Globigerinella praesiphonifera were studied in detail with paired single specimen morphometric and geochemical data allowing the investigation of relationships between macroperforate planktonic foraminifera test morphology and ocean depth habitat through time. A further analysis of speciation events was carried out on the microperforate genera Polyperibola and Globigerinatella. This work allowed the in-depth study of Globigerinatella sp., Polyperibola christiani and the identification of a new species within the Polyperibola genus.

Phylogeny of the Cenozoic planktonic foraminifera

LAMYMAN Grace1, FORDHAM Barry2, PEARSON Paul3, WADE Bridget4, WOODHOUSE Adam5, YOUNG Jeremy4 and AZE Tracy1*

1School of Earth and Environment, Faculty of Environment, University of Leeds, Leeds, LS2 9JT, UK; T.Aze@leeds.ac.uk; eegsl@leeds.ac.uk
2Research School of Earth Sciences, Australian National University, Canberra, ACT, Australia; barry.fordham@anu.edu.au
3School of Earth & Ocean Sciences, Cardiff University, Cardiff, CF10 3AT, United Kingdom; PearsonP@cardiff.ac.uk
4Department of Earth Sciences, University College London, London UK; b.wade@ucl.ac.uk; jeremy.young@ucl.ac.uk
5University of Texas Institute for Geophysics, University of Texas at Austin, Austin, TX, USA; adam.woodhouse@austin.utexas.edu

*Corresponding author

Here we present an updated phylogeny and relational database of the Cenozoic planktonic foraminifera. The phylogeny is graphically integrated to display morphospecies contained within lineages as stratigraphic ranges calibrated to GTS2020 and linked to datums, with additional pop-up and digital information on species ecologies, biogeographies, and key
morphological traits, providing an unparalleled resource for empirical analyses aimed at investigating macroevolutionary processes and responses of biodiversity to climate change.

New developments include the ejection of new species from new core material from previously understudied regions of our global oceans, developments in molecular analysis, and the revision of taxonomic concepts as part of the efforts of the Paleogene Planktonic Foraminifera Working Group. The most recent synthetic phylogeny produced in 2011 was restricted to the Cenozoic Globigerinoides, as this group was considered to be the most well studied and with the richest fossil record. This new phylogeny expands its scope and incorporates the Superfamilies Globigerinoidoidea, Guembelitrioidea and Bollivinoidea.

The recent formation of the Neogene and Quaternary Planktonic Foraminifera Working Group (NQPFWG) will revisit the most comprehensive synthetic taxonomic revision of the Neogene planktonic foraminifera that was completed in the 1980’s and the construction of this phylogeny will provide a phylogenetic framework against which the NQPFWG can test existing evolutionary hypotheses.

Planktonic foraminifera microbial associations in the subtropical Pacific

LANE M. Kelsey1*, FEHRENBACHER Jennifer1, BIRD Clare2, BRANSON Oscar1, LEKIEFFRE Charlotte3, REN Abby4 and CRUMP Byron1

1College of Earth, Ocean and Atmospheric Sciences, Oregon State University, 101 SW 26th St, Corvallis, OR, 97331, USA; lanemary@oregonstate.edu; jennifer.febrnenacher@oregonstate.edu; byron.crump@oregonstate.edu
2Department of Biological and Environmental Sciences, University of Stirling, Stirling, FK9 4LA, UK; clare.bird2@stir.ac.uk
3Department of Earth Sciences, University of Cambridge, Downing St., Cambridge CB2 3EQ, UK; ob266@cam.ac.uk
4University Grenoble Alpes, CNRS, CEa, INRAe, IRIG-LPCV, 621 Av. Centrale, 38400 Saint-Martin-d’Hères, Grenoble, France; charlotte.lekiefre@gmail.com
5Department of Geosciences, National Taiwan University, No. 1, Section 4, Roosevelt Rd, Da’an District, Taipei City, Taiwan 10617; abbyren@ntu.edu.tw
*Corresponding author

Molecular techniques reveal the microbial associations within planktonic foraminifera, with implications for shell geochemistry. Many planktonic foraminifera species contain photosymbionts, and some species could contain bacterial symbionts. For example, previous research has found that Globigerina bulloides, a species commonly used in paleopore reconstructions, contains the cyanobacterial photosynthetic endobiont Synechococcus. The photosynthesis and cellular respiration of these endobionts could explain the elevated isotope signature of G. bulloides compared to other spinose foraminifera species. It is not yet known if planktonic foraminifera have a specific microbiome associated with their life cycle, whether as symbionts or preferential prey, or if their microbiome reflects the water mass they live in. In this study, the prokaryotic community associated with subtropical western Pacific planktonic foraminifera were identified using next-generation sequencing. Six planktonic foraminifera species – Candeina nitida, Globigerinoides glutinata, Globorotalia menardii, Neogloboquadrina dutertrei, Hastigerina pelagica and Pusteniella obliquiloculata - were collected in May 2019 nearshore to Green Island, Taiwan, located in the Kuroshio Current. Water samples were collected to provide information on the background bacterial community. To identify the bacterial community, all foraminifera and water samples were sequenced using 16S Microbiome Primers metabarcoding. Preliminary results suggest foraminifera have a distinct microbiome, separate from the water column, although the bacterial community is not always consistent by foraminiferal species. We examine whether these differences can be explained by genotypic variability or environmental factors. Understanding the ecology and symbiotic relationships of more foraminiferal species’ various genotypes can explain variability in shell geochemistry, which has been a limitation in paleoclimate research.

Genotypic & geochemical variability of a planktonic spinose foraminifera species, G. bulloides, across the Northeast Pacific

LANE M. Kelsey1*, FEHRENBACHER Jennifer1, HÖNISCH Bärbel2, HAYNES Laura3, IZAGUIRRE Ingrid2 and CRUMP Byron1

1College of Earth, Ocean and Atmospheric Sciences, Oregon State University, 101 SW 26th St, Corvallis, OR, USA; lanemary@oregonstate.edu; jennifer.febrnenacher@oregonstate.edu; byron.crump@oregonstate.edu
2Lamont-Doherty Earth Observatory and Department of Earth and Environmental Sciences of Columbia University in the City of New York, 61 Route 9W, Palisades, NY, USA; boenisch@ldeo.columbia.edu
3Department of Earth Science and Geography, Vassar College, 124 Raymond Avenue, Poughkeepsie, NY 12601, USA; lhaynes@vassar.edu
*Corresponding author

The discovery of genetic diversity within morphologically identical foraminifera species has complicated the well-established use of foraminiferal fossils as geochemical proxies as many genotypes cannot typically be identified under the microscope. Foraminifera of different genotypes are thought to have habitat preferences that could explain variability in shell geochemistry within populations. However, identifying the genotype and distinguishing shell variability definitively has
been challenging as many DNA extraction techniques destroy the foraminiferal shell. Some DNA extraction methods do not destroy the shell and thus offer promising potential to pair molecular and geochemical techniques to resolve population variability with the same shells. In this research, we paired molecular and geochemical techniques with Northeast Pacific *Globigerina bulloides*, a species associated with the thermocline and upwelling regimes that has known genotypic and geochemical variability. The *G. bulloides* morphospecies is genetically diverse; with seven genotypes recognized so far. Three genotypes have been identified in the North Pacific: types Ila, IId, and Ile. Type IId might be endemic to the region. Type Ila is thought to calcify with a thicker, more encrusted shell than type IId, but genotyping and geochemical analysis have never been conducted on the same shell. We collected samples from the Channel Islands, in California and from opportunistically targeted research cruises in the North Pacific (Oregon Coast and Subtropical Gyre). Genotype and shell geochemistry were analysed on the same individual foraminifera shells, with the aim of identifying if consistent morphological or geochemical signatures of specific genotypes exist and further, testing whether DNA extraction alters trace metal geochemistry. We compare the morphology, using microCT scans, and trace metal geochemistry, using laser-ablation-ICP-MS, of air-dried and extracted samples. We will also genotype specimens to see if there is genotypic variability in the collected samples. This research will help elucidate how genotypic population variability is reflected in a common geochemical proxy species and may inform paleo reconstructions for this genetically diverse species.

Biogeography of modern larger symbiont-bearing foraminifera: A fully revised update

**LANGER R. Martin**, **FÖRDERER E. Meena** and **RÖDDER Dennis**

1. Institute for Geosciences, University of Bonn, Nussallee 8, D-53115, Bonn, Germany; martin.langer@uni-bonn.de; meena.foerderer@gmail.com
2. Zoological Research Museum Alexander Koenig, Adenauerallee 160, Bonn, Germany; D.Roedder@leibniz-lib.de

Modern larger symbiont-bearing foraminifera (LBF) are prominent carbonate producers and perform vital roles in tropical and subtropical reef and shelf environments. In this presentation, a fully revised update on the world-wide biogeographic distribution of LBF is presented. The analysis constitutes the most comprehensive data compilation available to date and includes a total of 105 LBF species and almost 4800 occurrence records covering a latitudinal range between 45°N and 33°S. The spatial patterns that emerge from this study were employed to (1) visualize species-specific distribution patterns, (2) to identify latitudinal and longitudinal species richness gradients and hotspots of diversity, and (3) highlight some of the major variables exerting control over the modern biogeographic distribution of larger foraminifera.

Species distribution modeling using Maxent was then applied on the fully updated dataset to assess future species richness patterns on a global scale for the time periods 2040–2050 and 2090–2100 with a focus on Representative Concentration Pathway 6.0 (RCP) from the Intergovernmental Panel on Climate Change. The RCP 6.0 scenario projects mean surface temperature changes of +2.2°C by the year 2100. Our results project substantial range extensions, an increasing widening bimodal latitudinal pattern of species diversity, a temperature-driven decline in low-latitude species richness, and support hypothesis that biogeographic patterns of LBF will fundamentally change under future climate conditions.

**Benthic foraminifera mediate oxygen penetration and prokaryotic diversity in intertidal sediment**

**LANGLET Dewi**1**,2**, **MERMILLOD-BLONDIN Florian**3, **DELDICQ Noemie**4, **BAUVILLE Arthur**4,5, **DUONG Gwendoline**4, **KONECNY Lara**3, **HUGONI Mylene**6,7, **DENIS Lionel**1 and **BOUCHET M.P. Vincent**1

1. Univ. Lille, CNRS, IRD, Univ. Littoral Côte d’Opale, UMR 8187, LOG, Laboratoire d’Océanologie et de Géosciences, Station Marine de Wimereux, F-59000, Lille, France; dewi.langlet@oist.jp; noemie.deldicq@outlook.fr; gwendoline.duong@univ-lille.fr; lionel.denis@univ-lille.fr; vincent.bouchet@univ-lille.fr
2. Evolution, Cell Biology and Symbiosis Unit, Okinawa Institute of Science and Technology, Okinawa 904-0495, Japan; dewi.langlet@oist.jp
3. Univ. Lyon, Université Claude Bernard Lyon 1, CNRS, ENTPE, UMR 5023 LEHNA, Laboratoire d’Ecologie des Hydrosystèmes Naturels et Anthropisés, F-69622, Villeurbanne, France; florian.mermilod-blondin@univ-lyon1.fr; lara.konecny@univ-lyon1.fr
4. Center for Mathematical Science and Advanced Technology, Japan Agency for Marine-Earth Science and Technology, 236-0001, Yokohama, Japan; a.bauville@gmail.com
5. Now at: Axelspace corporation, 103-0023, Tokyo, Japan; a.bauville@gmail.com
6. Univ. Lyon, Université Claude Bernard Lyon 1, CNRS, INSA de Lyon, UMR 5240 MAP, Microbiologie, Adaptation et Pathogénie, F-69622, Villeurbanne, France; mylene.hugoni@univ-lyon1.fr
7. Institut Universitaire de France (IUF), 75005 Paris, France; mylene.hugoni@univ-lyon1.fr

Bioturbation processes influence particulate (sediment reworking) and dissolved (bioirrigation) fluxes at the sediment-water interface. Recent works showed that benthic foraminifera largely contribute to sediment reworking in intertidal mudflats; yet their role in bioirrigation processes remains unknown. In a laboratory experiment, we showed that foraminifera
motion-behavior increased the oxygen penetration depth and decreased the total organic content. Their activity in the top 5 mm of the sediment also affected prokaryotic community structure. Indeed, in bioturbated sediment, bacterial richness was reduced and sulfate reducing taxa abundance in deeper layers was also reduced, probably inhibited by the larger oxygen penetration depth. Since foraminifera can modify both particulate and dissolved fluxes, their role as bioturbators can no longer be neglected. They are further able to mediate the prokaryotic community, suggesting that they play a major role in the benthic ecosystem functioning and may be the first described single-celled eukaryotic ecosystem engineers.

**Eukaryotic symbioses of large benthic foraminifera**

LANGLET Dewi*, RUPPLI Rahel1,2, SUZUKI H. Nicole1, PHUA Yong-Heng1, FUJITA Kazuhiko3 and HUSNIK Filip1

1Evolution, Cell Biology and Symbiosis Unit, Okinawa Institute of Science and Technology, Okinawa 904-0495, Japan; dewi.langlet@oist.jp; rahel.rupalli@oist.jp; suzuki.ni@northeastern.edu; yong.phua@oist.jp; filip.husnik@oist.jp
2Integrative Community Ecology Unit, Okinawa Institute of Science and Technology, Okinawa 904-0495, Japan; rahel.rupalli@oist.jp
3Department of Physics and Earth Sciences, University of the Ryukyus, Okinawa 903-0213, Japan; fujitaka@sci.u-ryukyu.ac.jp
*Corresponding author

Eukaryote-eukaryote endosymbioses are less common than eukaryote-bacteria endosymbioses. However, they can be surprisingly abundant in a few understudied groups of microbial eukaryotes. One of such groups are large benthic foraminifera (LBFs) which host a wide range of eukaryotic photosymbionts including diatoms, dinoflagellates, red algae, and green algae. LBFs are single-celled eukaryotes mostly thriving in coral reef flats and creating cm-long calcium carbonate shells (i.e., they are among the largest single-celled organisms). Here, we used multiple methods such as fluorescent microscopy, electron microscopy, and single-cell metagenomics to understand the evolution and cell biology of the foraminifer-algal symbioses. We show that LBF symbioses are host-specific with different foraminiferal lineages hosting distinct clades of symbionts. Phylogenetic analyses showed unexpected results. In green-algae hosting *Parasoritites* sp., we identified that the symbiont does not belong to the *Chlamydomonas* genus but likely to a new undescribed genus. Similarly, the diatoms symbionts of *Amphistegina lobifera*, *Calcarina gaudichaudii* and *Baculogypsina sphaerulata* also belong to undescribed *Serratifera* and *Nitzschia* species. Surprisingly, we also revealed that the dinoflagellate symbionts are the most dynamic and that some dinoflagellates can co-exist with other symbionts in diatom- and red algae-housing foraminifera. Assembled plastid genomes of the algal photosymbionts then uncovered potential differences in their photosynthetic abilities. Foraminifera-algal symbioses are thus emerging as a useful comparative model of eukaryote-eukaryote endosymbioses.

**A new species of pink pigmented *Globigerinoides* (planktonic foraminifera) from the Pleistocene**

LATAS Marcin1, PEARSON Paul N.1, POOLE Christopher1, FABBRINI Alessio1 and WADE Bridget3

1Department of Earth Sciences, University College London, Gower St, London, United Kingdom; marcin.latas@ucl.ac.uk; p.pearson@ucl.ac.uk; poolechr@s-live.co.uk; a.fabbrini@ucl.ac.uk; b.wade@ucl.ac.uk
*Corresponding author

Shipboard scientists on International Ocean Discovery Program (IODP) Expedition 363 reported the presence of unusual pink coloured planktonic foraminifera at two sites in the tropical Indian Ocean off northwest Australia (IODP Sites 1482 and 1483). These exhibit “mosaic morphology”, combining morphological characteristics typical for *Globigerinoides conglobatus* and *Globigerinoides ruber*, suggesting potential evolutionary relationship with either. They were provisionally referred to as ‘*Globigerinoides* sp. cf. *conglobatus* (pink)’.

Here we present morphometric image analysis data acquired from a series of 860 specimens from IODP Site U1483, documenting morphological variability of these new foraminifers and both similar species of *Globigerinoides*, all of which co-occur within the Pleistocene sedimentary sequence. We find that the newly discovered foraminifer occurs as two colour variants, a pigmented (pink) form and a non-pigmented (white) form. Non-pigmented forms are on average ~50% larger than their pink counterparts. As genetic information is not available for fossil species and both colour variants share many morphological characteristics, we regard the pink and white forms as variants of a single morphospecies. The new foraminifer is morphologically distinct from both potential sister taxa, indicating that it should be regarded as a separate species with biostratigraphic potential. It most likely evolved from *G. conglobatus*, although that has yet to be demonstrated, and became extinct about 0.8 Ma.

We also report its presence in the tropical Pacific, at IODP Site U1486 north of Papua New Guinea, expanding its known geographic range. In fact it is likely that the species has occasionally been described in the past from Pacific sediments under the name *Globigerinoides gomitulus*, a form originally described from the Pliocene of Italy, but we argue from comparative morphology that the identification as *G. gomitulus* is incorrect and it is appropriate to erect a new species. This is so far only
the third instance of planktonic foraminifera known to exhibit pink pigmented shells, after commonly recognised Globoturborotalita rubescens and Globigerinoides ruber.

A Neritic Record of Oceanic Anoxic Event 2 from Coastal Utah: New Insights into U.S. Western Interior Seaway Paleogeography and Foraminiferal Paleocology

LECKIE R. Mark1*, PARKER Amanda1, DAMERON Serena N.1 and BRYANT Raquel2

1Department of Earth, Geographic, and Climate Sciences, University of Massachusetts, 627 N. Pleasant St., Amherst, MA 01003, USA; leckie@umass.edu; a.l.parker121@gmail.com; sn.dameron@gmail.com
2Department of Earth and Environmental Sciences, Wesleyan University, Middletown CT 06459, USA; rbryant@wesleyan.edu
*Corresponding author

The Upper Cretaceous Tropic Shale of southern Utah captures oceanographic changes that occurred along the western margin of the U.S. Western Interior Seaway (WIS) during Oceanic Anoxic Event 2 (OAE2). This study focuses on the

Foraminifera as indicators of trophic state in tropical lagoons: Rio de Janeiro, Brazil

LAUT LAZARO1*, BELART Pierre1 and BONETTI Carla2

1Laboratory of Micropaleontology, Universidade Federal do Estado do Rio de Janeiro - UNIRIO, Av. Pasture, 458, IBIO/CCET, Urca, CEP 22.240-490 - Rio de Janeiro, RJ – Brazil; lazarolaut@gmail.com; pbelart@gmail.com
2Laboratory of Coastal Oceanography, Universidade Federal de Santa Catarina – UFSC, Campus Universitário, SN, CEP. 88040-900, Trindade, Florianopolis, SC - Brazil; carla.bonetti@ufsc.br
*Corresponding author

Rio de Janeiro Coast presents a unique series of lagoon systems formed during the regression that followed the last Holocene maximum, circa 5,000 years ago, that is confined within a narrow coastal plain, approximately 120 km long and 10 km wide. The essential differences among then are related to the region's climate, which varies from humid tropical to semi-arid, and the intensity of anthropic impacts on its catchments. The impacts of human activities have transformed most of these lagoons in environments with strong eutrophication processes, due to the launch of organic sewage, PAHs, and trace elements. In the last 10 years, studies on environmental characterization of the trophic state in these lagoons (Itaipu, Maricá, Saquarema, Vermelha, and Arraúma) and their effects on foraminiferal fauna have been developed with the purpose of identifying species or groups of species that can be used in the biomonitoring of these ecosystems. In this context, the present study aimed to apply different statistical approaches to understand the relationship between the 87 species of foraminifera identified in the lagoons and organic matter compounds (organic matter -OM; total organic carbon – TOC; total sulphur – TS; total biopolymers – BPC; carbohydrates -CHO; protein -PTN; and lipids -LIP). The statistically significant differences in the behaviour of these variables among the lagoons were verified using the non-parametric Kruskal–Wallis test (KW). The samples (n=90) were classified into four classes of trophic conditions using K-means and the Euclidean distances between them were represented by the first two dimensions of a non-metric multidimensional scaling (NMDS).

The KW results showed that all lagoons differed from each other by at least two variables indicating trophic state. The K-means grouped all samples from Vermelha Lagoon in a single group (TROF-PTN) characterized by the highest PTN. This lagoon is reported as the most hypersaline lagoon in Brazil where the formation of recent stromatolites is verified. The other groups were: TROF-1 grouped the samples located near the tidal channels with the lowest TOC and TS contents; TROF-2 grouped samples from Maricá and Itaipu lagoons that present the highest values of LIP indicating regions of greater anthropic impact; and TROF-3 grouped most of samples from Saquarema, characterized by the highest values of TOC, TS, CHO, and BPC indicating high organic concentration, but still in the moderate trophic state because they are regions that present balance between the concentrations of biopolymers. A discriminant analysis was applied to evaluate if the foraminifera species (with abundance > 1%) allow discriminating the groups previously defined by geochemical variables. The linear discriminant model correctly classified 77.8% of samples in their respective trophic states. The best result was obtained for the TROF-PTN group where 35 of 36 samples were correctly identified, being Quinqueloculina seminulum and Milolimella subrotunda the most important species for the regions under high PTN concentrations. The worst performance was observed for the TROF-1 group, with 43% misclassification. This was the smallest sample group (n=14) and was most strongly associated with Ammonia rolshauseni and Quinqueloculina milletti, which would be the indicators for regions with good trophic conditions. The TROF-2 grouped samples with species characteristic of both TROF-1 and TROF-3 presenting its centroid in the transition between both groups. In the TROF-3 group the importance of Ammonia tepida, Ammonia parkinsoniana, Cribroelphidium gunteri and Elphidium excavatum increases, and 68.8% of the samples were classified correctly. This assemblage is commonly found in several coastal ecosystems of Brazil with high concentrations of organic matter. The results show the potential use of foraminifera in the predictive modelling of trophic conditions in lagoons under different stages of eutrophication.
response of planktic and benthic foraminifera in a shallow (<80-100 m) marine environment as informed by high-resolution (1.5 - 5.0 ka) population counts and isotope measurements of specimens from a 40-m composite outcrop and core section of the lower Tropic Shale. The OAE 2 interval is identified by a distinctive δ¹³Corg signature, and by correlation of bentonites and carbonate-rich units across the seaway.

Prior to the onset of OAE2 at Big Water UT, the foraminiferal assemblages are dominated by rare agglutinated taxa. The onset of OAE2 coincided with a very rapid transgression; surface waters were initially dominated by the tiny triserial planktic Guembelitria cenomana, with minor abundances of trochosphiral Muricohedbergella delrioensis. The benthic assemblage was initially dominated by the infaunal species Neobulimina albertensis, suggesting low oxygen conditions in these coastal waters at the onset of OAE2. Other rare species of calcareous benthics just above Bentonite A, including Hoeglundina charlottae, demonstrate that this interval is correlative with the "Benthonic Zone" elsewhere in the WIS. A recent study shows that the development of the "Benthonic Zone" is diachronous across the WIS.

Epifaunal Gavelinella dakotaensis briefly proliferated as OAE2 intensified in the interval below Bentonite B during the latest Cenomanian. The "Gavelinella acme" coincides closely with the widespread "Heterohelix shift" and marks the plateau phase of OAE2. Biomarker data suggest that the "Heterohelix shift" was triggered by photic zone euxinia, and that P. globulosa dominated the planktic foraminiferal assemblages when productivity was high. By contrast, Gavelinella dakotaensis likely records higher seafloor oxygen levels, proposed to be a function of caballing along a Boreal-Tethyan oceanographic front, alternating with euxinic conditions dominated by Planoheterohelix.

The peak of OAE2 in Utah is marked by an abrupt shift back to Neobulimina dominance in benthic assemblages of the uppermost Cenomanian. We suspect incursion of oxygen-poor Tethyan waters with approach of peak transgression during the early Turonian, coupled with water column stratification and seasonally high productivity. Eutrophic nannofossil Biscutum constans sharply increased in abundance near the Cenomanian/Turonian boundary signaling cooler, highly productive surface waters along the western margin of the WIS following OAE2.

The idea of caballing (the mixing of two water masses to create a third denser water mass) in the WIS has been around since the early 1990s, and one study documented the presence of an oceanographic front in the Black Hills region of Wyoming and Montana, separating Tethyan and Boreal waters along which the process of caballing may have occurred. A later study proposed that such a water mass front extended southwestward into the Colorado Plateau region. The "Gavelinella acme" was a longer-lived bioevent along the western margin of the WIS and shorter-lived to the east in New Mexico and central Colorado, where it occurred just below Bentonite B. At an outcrop in Billings Montana, the "Gavelinella acme" occurs above Bentonite B, and the change to Neobulimina dominance does not occur until the Cenomanian/Turonian boundary suggesting that these bioevents, driven by the position of the ocean front and then stratification of Tethyan and Boreal waters, were diachronous from southwest to northeast in the U.S. Western Interior Seaway.

Recent benthic foraminifera from Marian Cove, King George Island, Antarctica

LEE SOMIN1, FRONTALINI FABRIZIO2 and LEE WONCHOEL1*

1Department of Life Science, College of Natural Sciences, Hanyang University, Seoul 04763, South Korea; smkhlee@gmail.com; wlee@hanyang.ac.kr
2Department of Pure and Applied Sciences, Urbino University, 61029 Urbino, Italy; fabrizio.frontalini@uniurb.it
*Corresponding author

West Antarctica has experienced rapid environmental changes since the middle of the 20th century. Accordingly, the need for endemic biodiversity research and environmental monitoring in the region, and paleoenvironmental research to respond to the climate change is increasing. Particularly, in Marian Cove, a small fjord located in King George Island (West Antarctica), significant environmental changes including the retreat of glaciers by 1.7 km have occurred since the 1950s. However, few researches on the diversity and distribution of foraminifera, common bioindicator for environmental monitoring and paleoclimate reconstruction, has been conducted in the region since the 1990s. During the austral summer of 2021/2022, we collected surface sediment samples from five sites in Marian Cove, at water depths of up to 111 m. Total of 2,890 benthic foraminiferal individuals belonging 45 genera, 29 families, seven orders and four classes were recognised. Thirty genera were identified at each of the two sites closest to the Cove entrance, which is the highest number among the sampling sites. Eleven genera were recognized in the innermost part of the Cove, which is the lowest number among the study sites. The most common genera in the study site were Adercotryma, Cassidulinoides, Globocassidulina, Portatrochammina, Psammosphaera, Reophax and Spiroplectammina, which were consistent to previous studies on King George Island. The data resulted from this study will be used as a basis for further molecular biodiversity, environmental monitoring studies using foraminifera as proxies of climate changes also by covering a wider area within Maxwell Bay in the King George Island.
The application of biostratigraphic studies in the energy and subsurface-storage industries. An example from the Ainsa Basin, Spain

LEON-RODRIGUEZ Lizette1*, JONK Rene2, KNABE Keith3, KEVIN BOHACS Kevin4 and DAVIS J. Steve5

1Ellington Geological Services; 1414 Lumpkin Rd. Houston, TX 77043; geo.llr@gmail.com
2APA Corporation, USA; sjonk1977@gmail.com
3retired – ExxonMobil; humble997@yahoo.com
4KMBohacs GEOconsulting LLC, USA; bohacs@k@gmail.com
5Stanford Center for Carbon Storage, Stanford University, USA; lunaripple1@gmail.com
*Corresponding author

Biostratigraphic studies are commonly used in the oil industry for age calibration and facies characterization. Particularly in fine-grained sedimentary successions, integration of biostratigraphic data with sequence-stratigraphic interpretations and rock-property measurements are useful to understand and predict retention of fluids in the subsurface. This has application to petroleum exploration, as well as hydrogen and CO2 storage. Outcrop studies serve as powerful analogs to make subsurface predictions for such applications. Here, we present an integrated study of Eocene strata of the Ainsa Basin in Spain which is a great outcrop analog for many subsurface settings and issues. This tectonically-influenced siliciclastic deepwater to fluvial succession has been heavily researched for understanding reservoir architecture and seal properties, initially for oil and gas exploration, and more recently as an analog for CO2 storage. Our studies reveal the distribution and sealing potential of overall low Net-to-Gross successions (mudstones and siltstones) as well as their spatial and temporal relation to associated coarser-grained strata. We integrated biostratigraphy (foraminifera, nannoplankton, palynomorphs), pore typing (MICP), geochemistry, sedimentology, to build a predictive model for facies distribution and architecture in the subsurface.

We studied two stratigraphic sections: an older Upper Ypresian unit and a younger Upper Lutetian unit. The older unit (150m thick) is dominated by deepwater sediment-gravity-flow deposits interbedded with transitional to hemipelagic deposits with relatively abundant nannoplankton and planktonic foraminifera. Mudstones contain variable amounts of calcareous and agglutinated benthic foraminifera, with some clay-mineral-rich horizons exclusively containing agglutinated microfauna. These facies are interpreted as overbank deposits (levees) of channel complexes as well as distal fringes of lobe complexes. Paleoenvironmental conditions near the seafloor were at times stressful and sometimes dysoxic. Paleobathymetric estimations indicate upper to middle bathyal depths (200 - 500m). The younger section (170 m thick), in contrast, displays a progressive decrease of planktonic foraminifera and calcareous nannoplankton and a notable increase of diversity and abundance of calcareous benthic foraminifera and reworking of larger benthic foraminifera (mostly Nummulites). This pattern records an overall shallowing of water depth from upper bathyal (500m) to neritic water depths of no more than several meters. MICP data suggests the most favorable sealing facies correspond to mudstones with significant volumes of detrital clay minerals and variable amounts of biogenic carbonate. Mudstones with high biogenic carbonate content have poor capillary sealing capacity and also tend to have abundant natural fractures, which may adversely affect mechanical sealing capacity. The poor sealing capacity of biogenic-rich mudstones is due both to primary porosity associated with microfossils, as well as secondary dissolution porosity. Using biostratigraphic observations, we hypothesize that mudstone facies from hemipelagic settings with abundant nannoplankton and planktonic foraminifera, and slope facies with abundant calcareous benthic foraminifera would have lower quality seals. Mudstones deposited from muddy turbidites (overbank facies or distal fringe facies with abundant clay mineral aggregates) and moderate to abundant agglutinated foraminifera would make good quality seals.

This model is a useful analog to subsurface case studies of petroleum exploration and fluid storage projects, where the evaluation of capillary seal quality and fracture potential is a key uncertainty.

The distribution of some numerical parameters of Nummulites perforatus (Montfort) A-forms from the Bartonian of Transylvania (W Romania): evidence for trimorphic life cycle in fossil foraminifera?

LESS György1*, KÖVECSI Szabolcs Attila2 and SILYE Lóránd2

1University of Miskolc, Institute of Exploration Geosciences, H-3515 Miskolc-Egyetemváros, Hungary; gyorgy.less@uni-miskolc.hu
2Bátyi-Bolyai University, Department of Geology, Kogálineczanu 1, 400084 Cluj-Napoca, Romania; szabolcs.kovecsi@ubbcluj.ro; lorand.silve@ubbcluj.ro
*Corresponding author

The general use of arithmetic mean in the biometric characterization of measured or counted numerical parameters of many fossils presumes that their distribution is normal in the given population, although this assumption has never been seriously tested. However, if the distribution were lognormal, we would have to calculate the geometric mean. Available fossil populations (with less than 100 specimens) are too small to decide this dilemma. To perform a reliable analysis on the distribution of crucial numerical parameters we need at least 1000 isolated, easily identifiable specimens of the same taxon
from a max. 10–15 cm thick stratigraphical interval of a section and excellent preservation for unequivocal and rapid measuring.

Non-cemented, Bartonian monospecific nummulitic accumulation made up by well-preserved specimens of both A- and B-forms of Nummulites perforatus (Montfort) with empty chambers in rock-forming quantity recovered from two outcrops (Văleni and Leghia) located in NW Transylvania (Romania), entirely fulfill the above conditions. We measured two external parameters on 1000 specimens of A-forms from both sites, the diameter (D) and the thickness (T) of the tests, from which their shape (D/T) could be calculated. Internally, in the equatorial section opened by splitting, we measured the inner cross-diameter of the proloculus (P, representing the same ontogenetic stage for each specimen) also on 1000 specimens.

The input data of the four parameters were used in their raw form and also in logarithmically transformed one, in order to test both (normal and lognormal) distributions. As a result, four types of normality tests on the eight datasets were proceeded using PAST. The null hypothesis in all tests applied was that the sample was taken from a population with normal (or lognormal) distribution. If the obtained probability is less than 5%, normal (or lognormal) distribution could be rejected.

Normal distribution of all external parameters in both samples could be definitely excluded. Their lognormal distribution is permitted in most cases by the normality tests, exclusions may be explained by sampling uncertainties. Thus, the lognormal distribution of external parameters is highly probable.

Both tested distributions of the internal parameter P are rejected in both samples by the normality tests. However, more detailed analysis shows that in both samples the strong deviation from the lognormal distribution may be caused by a few extra specimens with very small proloculus (25–30 in Văleni and 10–15 in Leghia out of 1000!), which are otherwise cannot be distinguished from other specimens with normal-sized proloculus. Indeed, mixture analysis (proceeded by PAST) suggests the presence of two size-groups for Văleni, while this is not confirmed for Leghia with very few specimens bearing small proloculus.

The size-overlap of the two groups hampers their separation in both assemblages, therefore specimens with very small-sized proloculus were picked out arbitrarily. Three different selections were tested for both samples: with 23–31 specimens with very small proloculus from Văleni, and with 10–16 such specimens from Leghia. The distribution of these groups can be both normal and lognormal due to the very small number of specimens. However, the distribution of the remaining specimens in the assemblages (all bearing normal-sized proloculus) turned out to be most probably lognormal while their normal distribution is definitely rejected in both cases.

Paleobiologically, the presence of two different A-forms can be explained most plausibly by trimorphism, well-known among recent foraminifera, but it is evidenced now for the first time on fossil assemblages. In addition to the B-forms with large-sized test (agamonts), we interpret the specimens with small-sized test bearing very small proloculus as A₁-forms (schizonts) whereas those with normal-sized proloculus can belong to the A₂-forms (gamonts).

Theoretically, the verification of lognormal distribution of numerical parameters in foraminiferal populations would imply the substitution of arithmetic means by geometric means. However, since in most cases the arithmetic mean in many larger foraminiferal populations exceeds the geometric mean only with 0.5–2.5%, and this corresponds only to 0.2–0.6% of the standard error of the arithmetic mean, there is no practical need for the change-over. However, the recognition of fossil trimorphism may imply more serious consequences, which are beyond the scope of this study.

Seasonal variation of Planktonic Foraminifera in the South China Sea and its paleoceanographic implication

LI Baohua1*, YU Zhoufei1, WANG Xiaoyan1, CHEN Jianfang2 and JIAN Zhimin3

1State Key Laboratory of Palaeobiology and Stratigraphy, Nanjing Institute of Geology and Palaeontology and Centre for Excellence in Life and Paleoenvironment, Chinese Academy of Sciences, 39 East Beijing Road, Nanjing 210008, China; bh-li@nigpas.ac.cn; zfyu@nigpas.ac.cn; xywang@nigpas.ac.cn
2Key Laboratory of Marine Ecosystem Dynamics, Ministry of Natural Resources, 36 North Baoku Road, Hangzhou 310012, China; fjchen@sio.org.cn;
3State Key Laboratory of Marine Geology, Tongji University, 1239 Siping Road, Shanghai, 200092, China; jian@tongji.edu.cn
*Corresponding author

The Asian monsoon has played an important role on the heat and moisture distribution in the west Pacific Ocean and neighbouring continents. A stronger East Asian summer monsoon will lead to the northern movement of the raining belt in China, resulting in the floods of the middle and lower reaches of the Yangtze River, or even in the Yellow River region. Monsoon variations also influence the oceanographic and climatic conditions, such as the sea surface temperature, mixed-layer depth, upper water column structure and productivity.

In this study, planktonic foraminifers were investigated on the samples from two sediment traps deployed in the southwestern and northern South China Sea, to monitor their relationship with the monsoon variation. A stronger monsoon wind corresponds to the higher chlorophyll a concentration, higher content of Neogloboquadrina dutertrei, and higher Globigerinoides ruber/Globigerinoides sacculifer ratio. It indicates that N. dutertrei content, instead of the Globigerina bulloides as an upwelling indicator in the Arabian Sea, showing highly significant correlation with the strength of the upwelling/monsoon in the South China Sea, which suggests it might be a valuable upwelling/monsoon index in this region.

The speculation was applied on the down-core variation of the planktonic foraminifers in Core MD05-2901 from the southwestern South China Sea. The N. dutertrei indexed upwelling/monsoon variations is consistent with other
paleoceanographic reconstructions, such as the Mg/Ca sea surface temperature, organic carbon based primary productivity and faunal composition during the last 400 kys.

This research was supported by the National Natural Science Foundation of China (41776073) and Strategic Priority Research Program of Chinese Academy of Sciences (XDB26000000).

Individual foraminifera analyses: comparison of morphometric and isotopic methods and application for the penultimate deglaciation

LICHTERFELD Yohan1*, DE GARIDEL-THORON Thibault1, LEDUC Guillaume1, DEWILDE Fabien2, VIDAL Laurence3 and LUCIANI Elise1

1Aix-Marseille Université, CNRS, IRD, INRAE, Collège de France, CEREGE UM34, 13545 Aix en Provence, France; lichterfeld@cerege.fr; garidel@cerege.fr; leduc@cerege.fr; vidal@cerege.fr; luciani@cerege.fr
2Univ Brest, CNRS UMS3113, Plouzané, 29280, France; fabien.dewilde@univ-brest.fr
*Corresponding author

Records of geochemical composition based on individual foraminifera analyses (IFA) have been used to reconstruct past interannual climate variability such as the El Niño-Southern Oscillation (ENSO). Due to sedimentary bioturbation and low accumulation rates, downcore sedimentary analysis can usually not record past climate variability at seasonal and/or interannual timescales. However, IFA can theoretically estimate the variance of a population of foraminifera that experienced hydrological variability changes at sub-centennial timescales. Previous studies suggested that IFA on thermocline-dwelling planktonic foraminifera captured changes associated with ENSO in sediments retrieved in the eastern equatorial Pacific. To test whether such changes have their counterparts in the western equatorial Pacific, or whether these changes reproduced over each glacial-interglacial transition during the late Pleistocene would provide some reliability to this approach. Here, we focus on a marine sediment core (MD05-2920) retrieved from the western Pacific warm pool, North off Papua New Guinea. This area is characterized by a weak seasonal variability of sea surface temperature (exceeding 28°C on annual mean). On the interannual timescale, the stratification of the water and the thermocline’s depth is influenced by ENSO events with drier (wetter) conditions and a shallower (deeper) thermocline during El Niño (La Niña) years. We use a combination of two methods (i) an automated imaging and sorting system (MiSo) to pick the Neogloboquadrina dutertrei specimens and to count planktonic foraminifera assemblage using a convolutional neural network method. We focus on N. dutertrei, which maximum abundance is found within the thermocline and could be used as a proxy for interannual climate variability; (ii) IFA δ18O analyses on N. dutertrei over the penultimate deglaciation (100 kyr BP-160 kyr BP). 5 samples of 50 individual specimens were selected for 5 different depths in the core to extract the thermocline variability, which is hypothesized to be directly related to ENSO activity. By this approach we will be able to characterize the frequency and the intensity of ENSO events over the studied period and compare it to results from MiSo that provides information on the total assemblages. Preliminary results suggest a higher value of the standard deviation of N. dutertrei δ18O for the MIS5, characterizing an increased thermocline variability compared to MIS6.

Symbiont-bearing foraminifera Heterostegina depressa affected by sunscreens

LINTNER Michael1, SCHAGERL Michael2, LINTNER Bianca1, NAGY Matthias1 and HEINZ Petra1*

1Department of Paleontology, University of Vienna, Josef-Holaubek-Platz 2, 1090 Vienna, Austria; michael.lintner@univie.ac.at; a1201280@unet.univie.ac.at; matthias.nagy@univie.ac.at; petra.heinz@univie.ac.at
2Department of Functional and Evolutionary Ecology, University of Vienna, Djerassiplatz 1, 1030 Vienna, Austria; michael.schagerl@univie.ac.at
*Corresponding author

Heterostegina depressa is an extant representative of the family Nummulitidae and reported worldwide from tropical to warm-temperate, shallow-marine environments. It harbours obligatorily endosymbiotic diatoms, which provide essential photosynthetic products for the foraminiferal host. The photosynthetic performance of the photobionts is largely influenced by physical and chemical parameters.

We studied potential impacts of four sunscreen products, which might be found at higher concentrations especially along beach areas and river deltas. Two of them are sold as “conventional” and two more are offered as “ecofriendly”. Further, the impact of pure Ensulizole (phenylbenzimidazole sulfonic acid) was tested, which is commonly added to sunscreens as UVB blocker. Foraminifera were incubated at varying concentrations (10, 50 and 200 mg L−1) of the different sunscreens and the pure Ensulizole for 7 days. The non-invasive technique of pulse-amplitude modulated (PAM) fluorescence microscopy was used for analysing the effects. The photosynthetic performance was measured after 1, 3, and 7 days.

Pure Ensulizole showed a strong negative impact on the photobionts, which was reflected by a significant reduction of the areal fluorescence signal. Additionally, “ecofriendly” sunscreens affected the health of foraminifera more severely
compared to “conventional” ones. We assume that metal nanoparticles like titanium dioxide or zinc oxide of “eco-friendly” sunscreens are causing this impact, because these substances were already classified as toxic for several microorganisms.

The use of VIS spectroscopy to detect kleptoplasts and food particles in foraminifera

LINTNER Michael1*, WILDNER Manfred2, LINTNER Bianca1, WANEK Wolfgang3 and HEINZ Petra1

1University of Vienna, Department of Palaeontology, Josef-Holaubek-Platz 2 (UZA II), 1090 Vienna, Austria; michael.lintner@univie.ac.at; a120128@unet.univie.ac.at; petra.heinz@univie.ac.at
2University of Vienna, Department of Mineralogy and Crystallography, Josef-Holaubek-Platz 2 (UZA II), 1090 Vienna, Austria; manfred.wildner@univie.ac.at
3University of Vienna, Center of Microbiology and Environmental Systems Science, Department of Microbiology and Ecosystem Science, Division of Terrestrial Ecosystem Research, Djerassiplatz 1 (UBB), 1030 Vienna, Austria; wolfgang.wanek@univie.ac.at
*Corresponding author

A large number of foraminifera feed on algae. Furthermore, some species are able to use kleptoplastidly, which allows them to incorporate functioning chloroplasts from their algal food source into their own cell body. Sincechlorophyll (a and c) can be detected in the intact cells using spectroscopic methods in the visible spectral range, this method allows indirect investigation of the presence of sequestered chloroplasts and food particles. Starving experiments of Elphidium williamsoni in the light (24 h continuous) showed that the greatest decrease in chlorophyll content was recorded within the first 20-30 days. From day 60 on, chlorophyll was hardly detectable. Through subsequent feeding on a renewed algal food source a significant increase in the chlorophyll content of E. williamsoni was noticed. The degradation of chlorophyll in the dark (24 h continuous darkness) during the starving period was much more complex. Chlorophyll was still detected in the cells after 113 days of starving time. Therefore, we hypothesised that the effect of photoinhibition applies to chloroplasts (kleptoplasts) in foraminifera under continuous illumination. The method used in our study also allows a precise search for food particles in each individual chamber of the foraminifera. In all specimens it was possible to record the food particles in the first chambers. However, the food particles were no longer detected in older chambers. This indicates that the digestion of the food particles takes place in the first 3-5 chambers of the foraminifera.

Late Pliocene-Early Pleistocene surface ocean conditions at the SW Iberian margin

LOPES Ana1,2*, SALGUEIRO Emília2,3, RODRIGUES Teresa2,3, PADILHA Mária4, ABRANTES Fátima2,3 and ALONSO-GARCÍA Montserrat1

1Department of Geology, Salamanca University, Plaza de los Caidos, s/n, Salamanca, Spain; alopes@usal.es; montseag@usal.es
2Marine Geology and Georesources Division, Portuguese Institute for the Sea and Atmosphere, Avenida Doutor Alfredo Magalhães Ramalho, 6, Algés, Portugal; alopes@usal.es; emilia.salgueiro@ipma.pt; teresa.rodrigues@ipma.pt; fatima.abrantes@ipma.pt
3Center of Marine Sciences, Algarve University, Campus Gambelas, Faro, Portugal; emilia.salgueiro@ipma.pt; teresa.rodrigues@ipma.pt; fatima.abrantes@ipma.pt
4Former fellow at Marine Geology and Georesources Division, Portuguese Institute for the Sea and Atmosphere, Avenida Doutor Alfredo Magalhães Ramalho, 6, Algés, Portugal; mlpadilha@gmail.com
*Corresponding author

The Late Pliocene-Early Pleistocene marks a transition from a globally warmer climate with high CO₂ concentrations to a colder climate with the development of northern hemisphere glaciations. The West Iberian margin is a key region to study past climatic changes as it can document both high (Greenland) and low (tropical-subtropical) latitude climate variability during the Pleistocene. In addition, the high sedimentation rates make it an ideal location for high-resolution paleoceanographic and paleoclimatic studies. However, few marine climate records exist in the Iberian margin before 1 Ma due to the absence of long sediment cores.

In this study, we examined sediment samples from IODP Site U1391 (37°21.5′N; 9°24.6′W, 1085 m water depth), recovered at the Southwest Iberian margin during Expedition 339. This site provided an almost continuous marine record of the SW Iberian margin dating back to the Pliocene. To get a comprehensive understanding of changes in sea surface temperature, productivity, seasonality, and ecological diversity across Marine Isotope Stages (MIS) KM2 to 96 (3.11 to 2.44 Ma), planktonic foraminifer assemblages were compared to the alkenone-derived sea-surface temperature (SST), and the total alkenone concentration records of Site U1391.

From ~3.0 Ma to ~2.5 Ma, alkenone-derived SST shows temperatures typically between 22-26°C, except during glacial periods MIS G6-4, 100, and 98 when SST reached ~17-18 °C. The warm water taxa follow the changes observed in alkenone-derived temperature but also show a reduction at MIS G6-4, indicating warmer and more oligotrophic conditions prior to MIS G6-4. On the other hand, the cold-water taxa such as Neogloboquadrina pachyderma and Turborotalita quinqueloba increased after the glacial period MIS G6-4. Globigerina bulloides and Neogloboquadrina incompta represent the most abundant species linked to higher productivity conditions nowadays. N. incompta shows in general high abundance
during glacial periods with maximum abundances during MIS G16. *G. bulloides* abundances are lower from ~3.0 to ~2.76 Ma and tend to increase after that, suggesting that along with the onset of the Northern Hemisphere glaciations the seasonal upwelling that generates primary productivity in the Iberian margin increased.

**Integration of Multiple Data Types to Reconstruct the Whole Plankton Ecosystem After the K/Pg Mass Extinction**

**LOWERY Christopher M.**, **KEARNS Lorna E.**, **SÁNCHEZ-MONTES Maria Luisa**, **JONES Heather** and **SEPULVEDA Julio**

1 Institute for Geophysics, University of Texas at Austin, 10100 Burnet Road, Austin, TX, 78758; cmlowery@utexas.edu; lorna.kearns@austin.utexas.edu
2 Department of Geological Sciences and Institute of Arctic and Alpine Research, University of Colorado Boulder, UCB 399 Boulder, CO 80309; MariaLuisa-SanchezMontes@colorado.edu
3 MARUM–Center for Marine Environmental Sciences, University of Bremen, Leobener Str. 8, 28359 Bremen, Germany; hjones@marum.de

**Microfossils, especially foraminifera and calcareous nanoplanckton, have played a central role in our understanding of change in the oceans for over a hundred years, and the tireless work of micropaleontologists over that time has produced records of environmental and evolutionary change that are unmatched in geographic, temporal, and taxonomic resolution compared to other fossil groups. However, in the modern ocean, plankton with extensive fossil records represent just a fraction of the total plankton biomass (a small fraction at that, if you remove diatoms, which are only preserved under ideal conditions). There are thus large parts of the plankton ecosystem for which we have practically no record. This represents a problem for understanding past changes in ocean ecosystems as well as predicting future ones. For example, many non-fossilizing groups of phytoplankton are much smaller than calcareous nanoplanckton or diatoms, which means that they can support a smaller overall biomass and lower export production compared to their larger cousins. By the end of the 21st century, anthropogenic warming and increased stratification are projected to favor smaller phytoplankton and cause a 5-10% decline in global primary productivity. We can use similar changes in the geologic past to contextualize what these changes might mean for marine ecosystems as a whole, but to do that we first need more complete records of all the plankton groups, not just the ones that fossilize.**

The Cretaceous–Paleogene (K/Pg) mass extinction is an ideal interval to address this question because it represents a major and rapid perturbation of the entire marine ecosystem. ~90% of planktic foraminifera and calcareous nanoplanckton went extinct as a result of the disruptions following the Chicxulub impact. Calcareous nanoplanckton were important primary producers in the Cretaceous ocean, and their decline left a gap that was, presumably, filled by smaller, non-fossilizing phytoplankton like cyanobacteria and various algae. This change would have had a profound effect on ocean nutrient cycling and export production, and would have had consequences up the food chain, limiting the potential size of fossilizing phytoplankton like cyanobacteria and various algae. This change would have had a profound effect on ocean nutrient cycling and export production, and would have had consequences up the food chain, limiting the potential size of the fossilizing groups of phytoplankton are much smaller than calcareous nanoplanckton or diatoms, which means that they can support a smaller overall biomass and lower export production compared to their larger cousins. By the end of the 21st century, anthropogenic warming and increased stratification are projected to favor smaller phytoplankton and cause a 5-10% decline in global primary productivity. We can use similar changes in the geologic past to contextualize what these changes might mean for marine ecosystems as a whole, but to do that we first need more complete records of all the plankton groups, not just the ones that fossilize.

**Eocene Evolution of Surface Circulation and Export Production in the Western South Atlantic**

**LOWERY Christopher M.***, **STANDRING Patricia**1, **BORRELLI Chiara**2, **ROUTLEDGE Claire**3, **VILLA Alexandra**4, **M McIntYRE Andrew** and **THE SOUTH ATLANTIC TRANSECT IODP EXPEDITION 390 & 393 SCIENTISTS**

1University of Texas Institute for Geophysics, University of Texas at Austin, 10100 Burnet Rd., Austin, Texas 78758; cmlowery@utexas.edu; patty.standring@utexas.edu
2Department of Earth and Environmental Sciences, University of Rochester, 227 Hutchinson Hall, Rochester, New York 14627; cborrelli@ur.rochester.edu
3Institute of Geosciences, Christian-Albrechts-University of Kiel, Olshausenstr. 40 D-24118 Kiel, Germany; Claire.Routledge@ifg.uni-kiel.de
4Institute for Geophysics, University of Wisconsin-Madison, 1215 West Dayton Street, Madison, Wisconsin 53706; avilla2@wisc.edu
5School of Geology, Geography, and the Environment, University of Leicester, University Road, Leicester, LE1 7RH, United Kingdom; am1442z@leicester.ac.uk
The Eocene-Oligocene Transition (EOT) represents the first major glaciation of Antarctica and a significant reorganization of global ocean circulation. Prior to this abrupt event, the Eocene records the gradual cooling from the peak warmth of the Early Eocene Climate Optimum and the progressive openings of the Drake Passage and then the Tasman Gateway. These long-term changes gradually set the boundary conditions in which the EOT was able to occur, but are more poorly understood than the EOT itself. Here, we utilize new cores from International Ocean Discovery Program Sites U1557 and U1558, collected in the western South Atlantic by the South Atlantic Transect Expeditions 390C, 390, and 393. Located within the South Atlantic Gyre, these sites are well positioned to reconstruct the evolution of Eocene ocean circulation and accompanying shifts in primary and export production, both of which may be linked to Eocene cooling. We utilize shipboard data as well as foraminifera accumulation rates, X-ray fluorescence core scanning data, and preliminary planktic foraminifera assemblage counts to document shifts in surface ocean circulation and export production throughout the Eocene. Following a short-lived peak in mass accumulation rate and export production in the late Paleocene, we find changing conditions throughout the Eocene with a shift in the middle/late Eocene at approximately 40 Ma (6 Myr prior to the EOT) toward gradually increasing export production. This shift is associated with an increase in mass accumulation rate and associated increases in foraminifer accumulation rate, organic carbon accumulation rate, and carbonate accumulation rate. These increases, prior to the opening/deepening) of the Tasman Gateway, the development of the Antarctic Circumpolar Current, and the glaciation of Antarctica, track a late Eocene increase in export production in the South Atlantic Gyre that we hypothesize is related to gradual changes in surface ocean circulation preceding the major shifts of the EOT.

Pattern of foraminiferal diversity change across the Eocene-Oligocene transition

LU Zhengbo1 and FAN Junxuan1,2

1School of Earth Sciences and Engineering and Frontiers Science Center for Critical Earth Material Cycling, Nanjing University, Xianlin Street 163, Qixia District, Nanjing, China; 544902679@qq.com; jxfan@nju.edu.cn
2State Key Laboratory for Mineral Deposit Research, Nanjing University, Xianlin Street 163, Qixia District, Nanjing, China; jxfan@nju.edu.cn
*Corresponding author

The Eocene-Oligocene transition (EOT) - 33.9 million years ago (Ma) - is regarded as a turning point in Earth’s history, when the Earth’s climate shifted from a “warmhouse” to an “icehouse” state. Significant biotic responses, especially from foraminifera, have often been discussed for this period. However, due to the lack of high-resolution diversity data, the detailed evolutionary history of different types of foraminifera during this period is still unclear. Here, we use a quantitative method, CONOP, to reconstruct a species diversity history of foraminifera during the EOT with an average temporal resolution of ~26,000 years. We find a significant decline in diversity from the middle Eocene to the Oligocene, eliminating 74% of foraminifer species. This pattern of foraminiferal diversity change can be separated into four major factors by using Q-mode factor analysis, i.e. foraminiferal fauna, which are dominant in the early Eocene, middle Eocene, late Eocene-early Oligocene and late Oligocene, respectively. In addition, foraminifera are usually divided into three groups that are generally distinct in their life-history strategy, morphology, and ecology, including planktonic foraminifera, larger benthic foraminifera, and smaller benthic foraminifera. Among these three major foraminiferal groups, larger benthic and planktonic foraminifera show similar trends in diversity change during this period, since the correlation coefficient ρ of them is considerably high (0.89). In contrast, the smaller benthic foraminifera suffered a longer decline in diversity (~7.53 Myr) throughout the Eocene and Oligocene.

Early Cretaceous (Aptian–Albian) depositional environments of Sergipe-Alagoas Basin (northeastern of Brazil): microbiofacies and foraminiferal assemblages

LUFT-SOUZA Fernanda1*, TERRA Gerson José Salamani2, PATARROYO German David1 and FAUTH Gerson1

1Itt Oceaneon, Instituto Tecnológico de Paleoenanografia e Mudanças Climáticas, Unisinos University, Av. Unisinos, 950, Cristo Rei, São Leopoldo, 93022-750, Rio Grande do Sul, Brazil; felufts@gmail.com; germanp@edu.unisinos.br; gersonj@unisinos.br
2Terra Carbonates, Tauphick Saadi Street, Bela Vista, 231, Porto Alegre, 90470-040, RS, Brazil; gersonjterra@gmail.com
*Corresponding author

During the Early Cretaceous, several extensive carbonate shelves were deposited in the sedimentary basins located on the Central Segment of the South Atlantic Ocean. These marine successions were characterized by mixed calcareous and siliciclastic sediments with a diverse fossil content. For the Aptian–Albian interval, one of the most complete marine stratigraphic records among all the basins of the Brazilian and African continental margins is found in the onshore portion of
the Sergipe-Alagoas Basin, Brazilian continental margin. Although many basins of the Brazilian and African continental margins have a relatively continuous onshore and offshore record from the Early Cretaceous, the Sergipe-Alagoas Basin stands out for its fossil-rich units and sedimentary sequences that represent all the phases that comprise the fragmentation of Gondwana and the opening of the South Atlantic Ocean.

The Aptian–Albian studied deposits correspond to the Riachuelo Formation, which are characterized by a mixed shelf system (carbonatic-siliciclastic), composed of sandstones/packstones with quartz, deposited in a transitional system partially protected by carbonate banks (packstones, grainstones, and rudstones), representing as bars and shelf-edge, grading to more stable and deeper outer shelf environments, characterized by mudstones/wackestones. In this work, we studied the microbiofacies content of two continuous cores (SER-01 and SER-03), each approximately 200 m deep, drilled on the onshore portion of the Sergipe Sub-basin. Core SER-01 consists of mudstones, wackestones, packstones, grainstones, rudstones, marls, claystone, shales, and sandstones, while the sediments from Core SER-03 are essentially constituted by fine-grained lithologies such as mudstones, wackestones, claystone, and shales.

Six sedimentary microfacies were recognized. They indicate deposition in a high energy shallow marine environment with a bar system, which later evolved into a low energy deep marine environment (outer shelf). The microfossil content includes planktonic and benthonic foraminifera, which are dominant in both cores, as well as macrofossils such as echinoderms and mollusks. The microfossil content is impoverished with low-diversity. Planktonic foraminiferal assemblages are composed of globular chambered specimens with trochoidal, planispiral and, very rarely, biserial tests (favuselids, hedbergellids, globigerinelloidids and heterohelicids). Favusella washtensis is the dominant taxon in both wells. The benthonic microfauna is characterized by agglutinated lituolids, textulariids, as well as rare nodosarids (Dentalina sp.) and vaginulinds (Lenticulina sp.). Most planktonic and benthonic specimens (textulariids and nodosarids) show pyrite-filled molds. Such feature is probably due to post-mortem under reducing conditions, shortly after burial or during the early stages of diagenesis of the more susceptible (thinner and porous) calcareous tests.

Extremely rapid evolution of earliest Danian planktonic foraminifera? Evidence from the Brazos River Cretaceous–Paleogene boundary sequence

Macleod Kenneth G.¹ and Huber Brian T.²*¹

¹Department of Geological Sciences, University of Missouri-Columbia, Columbia, MO 65211, USA; MacLeodK@missouri.edu
²National Museum of Natural History, Smithsonian Institution, MRC-121, Washington, DC 20013, USA; huberb@si.edu

The Cretaceous/Paleogene (K/Pg) ‘River Bank South’ boundary section, which crops out along the Brazos River in Falls County, Texas (USA), provides an extraordinary record of foraminiferal morphologic and sedimentary geochemical changes following the terminal Cretaceous asteroid impact. Foraminiferal specimens with excellent test preservation are consistently present in the section, and the basal Paleogene P0 Planktonic Foraminiferal Zone is quite thick at this locality (2.9 m). The K/Pg boundary is placed at the contact between the scoured upper surface of the Corsicana Fm and overlying beds rich in impact debris. The top of the P0 Zone is placed at lowest occurrences of Parvularugoglobigerina eugubina and Globoconusa daubjergensis, 2.9 m above the boundary.

A number of events and excursions that document changes within the first millennia of the Paleogene are present within the 2.9 m thick P0 Zone. The lowest 75 cm of the Paleogene are represented by high energy storm and/or tsunami deposits. Projecting in from nearby sections, organic carbon paleothermometry provides evidence for an impact winter with coldest temperatures at ~100 to 140 cm above the boundary; the level of a diffuse Ir anomaly projects to ~120 to 150 cm above the boundary. The relative abundance of Guembelitriina cretacea starts to increase at 150 cm and peaks at 230 cm above the boundary whereas blooms of calcareous nannoplankton ‘disaster taxa’ project to levels starting at ~180 cm above the boundary.

An interval of dramatic warming starting at 170 cm above the boundary is suggested by an ~1‰ decrease in d18O values (~5°C warming) in visually screened fragments of individual crushed specimens of the benthic foraminifer Lenticulina. The lowest occurrence (LO) of the first new Paleogene foraminiferal species (Woodringina claytonensis and Parvularugoglobigerina extensa) also occur at the 170 cm level, and the LO of Parvularugoglobigerina alabamensis is documented at 190 cm. Finally, the LO of Parasubbotina aff. pseudobulloides and Eoglobigerina eobulloides occur in a sample from 310 cm above the boundary (20 cm above the base of the Pu Zone), and the LO of Chiloguembelina moresi occurs at 330 cm.

A 290 cm thick P0 Zone already requires high average sedimentation rates, but, if the ~5°C warming pulse was the direct consequence of CO2 released by post-impact wildfires, which should incur within decades of the impact, sedimentation rates would need to be extremely high over the first 1.5 to 2.0 m of the Paleogene (10-20 cm/yr). Biotaxonomic and sedimentological observations allow the possibility of such high sedimentation rates, but they lack the resolution to rigorously demonstrate them. If model predictions for impact-induced warming are correct, though, the evolution of the Woodringina–Parvularugoglobigerina lineages must have occurred within decades of the impact rather than the previously assumed 1000’s of years afterwards. By extension, if the decadal timescale is correct, the profound changes in wall structure,
chamber coiling and apertural position that characterize the evolution from the trans-K/Pg ancestor Guembelitria cretacea to the descendent lineages of Woodringina and the first species of Parvulorugoglobigerina would need to have occurred within only a few hundred planktonic foraminiferal generations.

**Depth-influenced variation of symbiont relationship between large benthic foraminifera and Symbiodiniaceae**

MAEDA Ayumi, HAMAMOTO Kohei, NISHIJIMA Miyuki, IGUCHI Akira and SUZUKI Atsushi

1Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology, 1-1-1 Higashi, Tsukuba, Ibaraki 305-8567 Japan; ay-maeda@aist.go.jp, hamamoto.kohei@aist.go.jp, nishijima.miyuki@aist.go.jp, iguchi.a@aist.go.jp, a.suzuki@aist.go.jp
*Corresponding author

The symbiont relationship between dinoflagellates in the family Symbiodiniaceae and marine organisms supports the coral reef ecosystems. Although foraminifera in the family Soritidae hosting Symbiodiniaceae forms unique symbiont relationships, environmental influences on the diversity of Symbiodiniaceae in soritid individuals have not been understood.

We investigated variations of Symbiodiniaceae community in Amphisorus kudakajimensis at individual level collected in nine depths at three sites in Akajima island, Okinawa, Japan. Next-generation sequencing and the Symportal pipeline specific to analyses of Symbiodiniaceae resulted in the 39 lineages in 137 specimens using internal transcribed spacer region 2 of nuclear ribosomal RNA gene (ITS2). The dominant lineages are clade C, F, and H, and multiple lineages constitute a Symbiodiniaceae assemblage in a single specimen. Clade H is dominant in the assemblages at the deep population (> 9 m), while clade H was not detected in the shallow population (< 2 m). The diversity of Symbiodiniaceae community is higher in the deep population dwelled on narrow points than in the shallow population distributed around the reef flat zone. The specific combination of clade C and F in A. kudakajimensis under large environmental fluctuations in the shallow reef suggests that symbiont communities converge a low diverse combination to adapt to a severe environment. In this presentation, we discuss the full range of depth adaptations associated with the genotypic composition of shallow-water foraminifera zooxanthellae.

**Benthic foraminiferal communities (stained) in sub-Antarctic fjords of South Georgia**

MAJEWSKI Wojciech, SZCZUCIŃSKI Witold and GOODAY J. Andrew

1Institute of Paleobiology, Polish Academy of Sciences, Twarda 51/55, 00-818 Warszawa, Poland; wmaj@twarda.pan.pl
2Geohazards Research Unit, Institute of Geology, Adam Mickiewicz University, Poznań, Bogumila Krygowskiego 12, 61-680 Poznań, Poland; witold.sczucinski@amu.edu.pl
3Ocean BioGeosciences, National Oceanography Centre, European Way, Southampton SO14 3ZH, UK; ang@noc.ac.uk
4Life Sciences Department, Natural History Museum, Cromwell Road, London SW7 5BD, UK; ang@noc.ac.uk
*Corresponding author

Sub-Antarctic fjords are among the environments most affected by the recent climate warming. These vulnerable spaces are strongly understudied, but as they may serve as sentinels for the climate change, they do deserve more scientific attention. Here, we present a baseline study of rose-bengal-stained benthic foraminifera from fjords of South Georgia, including fjords with and without tidewater glaciers. Their distribution is analysed in the light of oceanographic and sedimentological data.

Four assemblages are recognized. Miliammina earlandi, dominating in the near-shore and glacier-proximal habitats, can tolerate strong glacial influence, including high sedimentation and sediment anoxia. This versatile species can thrive on different types of food. A smooth-walled variant of Cassidulinoides aff. parkerianus, dominating in mid-fjord areas, seems endemic to South Georgia. It is the calcareous rotaliid best adapted to inner-fjord conditions characterized by moderate glacial influence and sedimentation rates and showing no preference for particular sedimentary redox conditions. The outer parts of fjords with clear, well-oxygenated bottom water are inhabited by Globocassidulina aff. rossensis. Ammobaculites rostratus, Reophax subfusciformis, and Astronion echolsi dominate in the deepest-water settings in the outer parts of the fjords, with water salinities ~33.9 PSU and temperatures 0.2–1.4 °C, characteristic of winter water and Upper Circumpolar Deep Water. The inner- and mid-fjord foraminiferal assemblages seem specific to South Georgia, although with continued warming and deglaciation, they may become more widespread in the Southern Ocean.

The study was funded by the Polish National Science Centre grant No. 2018/31/B/ST10/02886.
Impact of the invasive foraminifer *Amphistegina lobifera* Larsen on infralittoral benthic foraminiferal assemblages in the Sicily Channel (Central Mediterranean)

MANCIN Nicoletta1*, EVANS Julian2*, GUASTELLA Roberta1, CARUSO Antonio3 and MARCHINI Agnese1

1Dipartimento di Scienze della Terra e dell’Ambiente, Università di Pavia, Via Ferrata 1, 27100, Pavia, ITALY; nicoletta.mancin@unipv.it
roberta.guastella@universitadipavia.it; agnese.marchini@unipv.it
2Department of Biology, University of Malta, Msida, MSD2080, MALTA; julian.evans@um.edu.mt
3Dipartimento di Scienze e Tecnologie Biologiche Chimiche e Farmaceutiche, Università di Palermo, Via Archirafi 18, 90123, Palermo, ITALY; antonio.caruso@unipa.it
*Corresponding author

Among the emerging threats that are currently affecting marine ecosystems, the invasion by alien species is one of the most impacting, because alien species have the potential to cause decline or even extinctions of native species, with effects ranging from the individual to the entire ecosystem level. The Mediterranean Sea is one of the marine ecosystems most affected by invasion of alien species. In recent decades, several studies have reported the ecological effects of invasion by marine alien macrobiota, such as macroalgae, crustaceans, bivalves and fishes, but very little is known about the effects of small-sized alien taxa, such as unicellular foraminifera. These ‘hidden invaders’ are able to colonize wide marine areas without being noticed due to their small size (< 2 mm). In some severe cases, alien foraminifera have been recorded only after having already caused significant changes (often irreversibly damaging) to native communities and, consequently, to local ecosystems.

In the Mediterranean Sea, the most successful and widespread benthic foraminiferal invader is *Amphistegina lobifera* Larsen 1976, a non-indigenous species coming from the Red Sea through the Suez Canal. Although *A. lobifera* has been considered as one of the benthic foraminiferal alien species with the highest potential impact, the effects of its invasion on native assemblages are poorly known, especially in the Central Mediterranean, where the species was only recently recorded. This research documents, through a quantitative approach, the negative effect of the highly invasive species *A. lobifera* on native benthic foraminiferal assemblages of coastal areas in the Sicily Channel (Central Mediterranean). To this purpose, a nested sampling design was applied through the comparison of benthic foraminiferal community structure across three areas that are known to be at different stages of invasion (i.e. Maltese islands - advanced, southern Sicily – medium, and eastern Sicily - early). Additionally, given that sediment grain-size can influence the distribution and abundance of benthic species, including foraminifera, because it is related to the extent of hydrodynamism, the grain-size of soft-bottom sediments was also taken into account in the applied design.

Results suggested that both diversity and richness of benthic foraminiferal community from the Maltese islands were strongly modified by increased abundances of *A. lobifera*. In contrast, this phenomenon is less impacting in southern and eastern Sicily, where the invader displayed lower abundances and the community structure was more diversified. The invasion success of *A. lobifera* is promoted, and probably also accelerated, by climate change, which is causing a rapid increase of Mediterranean Sea surface temperature; thus the negative effects recorded in the present work can be expected to extend over larger areas of the Mediterranean basin in the future.

Hotspot pattern of benthic foraminifera in highly productive environments of the Levant

MANDA Sneha1*, ASHCKENAZI-POIVODA Sarit2, HERUT Barak3, RILOV Gil3, KUCERA Michal4 and ABRAMOVICH Sigal1

1Department of Earth and Environmental Sciences, Ben Gurion University of the Negev, POB. 653, Be’er Sheva, Israel 84105; manda@post.bgu.ac.il; sigalabr@bgu.ac.il
2Dead Sea and Arava Science Centre, Masada National Park, Mount Masada, Dead-Sea mobile phone 86910, Israel; sarit@adscc.org
3National Institute of Oceanography, Israel Oceanographic and Limnological Research, POB 9735, Haifa, Israel 3109701; barak@ocean.org.il; rilov@ocean.org.il
4MARUM Centre for Marine Environmental Sciences, University of Bremen, POB 330440, Germany 28334; mkucera@marum.de
*Corresponding author

Given the role of foraminifera as ecosystem engineers, it is very important to characterize the foraminiferal hotspots around the world. It is well-known that benthic foraminifera are ubiquitous in lagoonal and reefal habitats where they are often referred to as living sands. Vermitid reefs are an underrated coastal habitat with a great potential as substrates for foraminifera that is yet to be completely understood. The intertidal carbonate platforms of the Levant basin are the longest known vermitid reefs at the forefront of Lessepsian invasion and rapid ecological community shifts. However, with increasing anthropogenic pressures and ongoing climate change, these habitats face the greatest risk, making this ecosystem a top priority for marine biomonitoring studies. This study deals with efforts undertaken to characterise the presence of benthic foraminifera in this complex ecosystem. Four microhabitats were seasonally sampled along the 150 km Israeli coastline to obtain standing crop and numerical abundances of benthic foraminifera species on suitable substrates.

We found the densities of foraminiferal communities on the vermitid reefs to be very high along the coast with an average of 14,785 specimens per m². We identified two specific hotspots in Shikmona and Nahsholim where the densities of
Symbiont-Bearing Foraminifera and their Potential as Major Carbonate Producers in Coastal Environments Undergoing Global Warming

MANDA Sneha1, ASHCKENAZI-POLIVODA Sarit2, HERUT Barak3, RIOLOV Gil4, KUCERA Michal4 and ABRAMOVICH Sigal1

1Department of Earth and Environmental Sciences, Ben Gurion University of the Negev, POB. 653, Be’er Sheva, Israel 84105; manda@post.bgu.ac.il; sigalabr@bgu.ac.il
2Dead Sea and Arava Science Centre, Masada National Park, Mount Masada, Dead-Sea mobile post 86910, Israel; sarit@adsc.org
3National Institute of Oceanography, Israel Oceanographic and Limnological Research, POB 9735, Haifa, Israel 3109701; barak@ocean.org.il, rilovg@ocean.org.il
4MARUM Center for Marine Environmental Sciences, University of Bremen, Leobener Strasse 8, 28359, Bremen, Germany; mkucera@marum.de

*Corresponding author

First-order estimates suggest that benthic foraminifera are essential players in the global carbon cycle contributing to 4% of the total carbonate production in the modern oceans. Specifically, Large Benthic Foraminifera (LBFs) are the major contributors to carbonate production in tropical reefal habitats. Even though the major presence of foraminifera in the Eastern Mediterranean (EaM) is widely accepted in the scientific community, robust baseline research quantifying the contribution of benthic foraminifera in carbonate production potential in the EaM is notably lacking.

This study aims to provide some of the data required to allow an estimation of foraminiferal carbonate production in highly productive environments of the shallow Eastern Mediterranean shelf, which is at the forefront of ocean warming.

Four microhabitats hosting vermitid reefs were seasonally sampled along the 150 km Israeli coastline for a period of one year to analyse the distributional characteristics of key-habitat forming foraminiferal species, their carbonate producing capabilities, and assess their role as ecosystem engineers.

We calculated the gross foraminiferal carbonate standing stock on vermitid reefs to be 20,000 mg of CaCO$_3$ m$^{-2}$. Empirically calculated mass-diameter relationships were combined with the seasonal population dynamics for three invasive LBFs, Amphistegina lobifera, Sorites orbiculus, and Peneroplis, to compute their calcium carbonate standing stock for each season. We found that three LBFs contribute to 83% of the gross foraminiferal carbonate standing stock. A. lobifera appears to have the most significant contribution, despite its small or comparable diameter relative to S. orbiculus and to Peneroplis. The experimentally derived thermal resilience of these invasive LBFs indicates they will continue to proliferate and enrich the calcium carbonate production in these environments. Carbonate production estimation combined with data on the foraminiferal substrate preferences, holobiont thermal thresholds, and their response to environmental changes should be used to gain insight into the future of the dominant players of the community and their role in carbonate production in these coastal environments threatened by rising ocean temperatures.

Modern agglutinated foraminifera in the surface sediments of NE Mediterranean environments

MARKOGLOU Eleni Anastasia1,2, TSOUROU Theodora1, PARINOS Constantine3, GOGOU Aleka1, DIMIZA Margarita1, DANELIAN Tania1 and TRIANTAPHYLLOU Maria1

1Department of Historical Geology and Palaeontology, Faculty of Geology and Geoenvironment, National and Kapodistrian University of Athens, Panepistimioupolis 15784, Athens Greece; markoglou@geo.auth.gr; ttsourou@geol.uoa.gr; mdimiza@geol.uoa.gr; mtriant@geol.uoa.gr
2Department of Geology and Palaeontology, Faculty of Geology, University of Thessaloniki, Panepistimioupolis 54124, Thessaloniki Greece; markoglou@geo.auth.gr
Aim of this study is to record and present the agglutinated foraminiferal assemblages retrieved from eight surface sediment samples, collected from relatively shallow (3 samples: 335 m – 485 m) to bathyal (5 samples: 1150 m- 2150 m) environments of the central and southern Aegean Sea and the Levantine Sea in the NE Mediterranean. The study material was recovered with a box corer during R/V Aegaeo MSFD cruise in March 2019 and stored in an ethanol-Rose Bengal mixture. In the laboratory the samples were carefully wet sieved through 63 μm and 125 μm sieves, oven dried, and the sediment fraction >125 μm was examined for the micropaleontological content. The faunal analysis revealed rich assemblages consisting of pteropods, planktonic and benthic foraminifera, ostracods as well as otoliths.

Benthic foraminifera represented the most diverse group of benthic organisms in the samples and their assemblages were composed of calcareous (hyaline) and agglutinated taxa. The latter were particularly dominant in the deep basins of the Cretan Sea and off Rhodes Island (up to about 76% of the total foraminiferal content).

The agglutinated foraminifera group in the studied material was composed of arborescent, tubular, and globular taxa and a total of 13 genera and 15 species have been so far identified. *Saccorhiza ramosa* (Brady, 1879) is the most abundant taxon (11-84% of the agglutinated fauna), constantly present in all the samples. Its wall is made of mineral grains and sponge spicules and in certain samples radiolarians and pteropods are also incorporated in the test structure. Other common taxa are *Rhabdamminella cylindrica* (Brady, 1882) (present in six samples; 0.2-12.5%); *Rhizammina algaeformis*, Brady, 1879 (present in five samples; 1-26%), being coarsely agglutinated, beside inorganic grains, with planktonic foraminifera, radiolaria and pteropods; *Glamospira* spp. (present in four samples; 1-57%) and *Psammosiphonella* spp. (present in four samples; 7.85-63%). Other taxa with scarce presence in the studied samples are *Psammosphaera fusca* Schulze, 1875 and species of *Bathysiphon*, *Marsipella*, *Hyperammina*, *Reophax*, *Cribrostomoides*, *Ammoscalaria* and *Anmodiscus*.

Reconstructing Eocene mid-latitudinal environmental changes through *Nummulites* geochemistry

MARTENS Lise¹, STASSEN Peter¹², STEURBAUT Etienne¹² and SPEIJER Robert P.*¹

¹Department of Earth and Environmental Sciences, KU Leuven, Celestijnenlaan 200E, Leuven, Belgium; lise.martens@kuleuven.be; peter.stassen@kuleuven.be; etienne.steurbaut@naturalsciences.be; robert.speijer@kuleuven.be

²OD Earth and History of Life, Royal Belgian Institute of Natural Sciences, Vautierstraat 29, Brussels, Belgium; peter.stassen@kuleuven.be; etienne.steurbaut@naturalsciences.be

*Corresponding author

The early Eocene is characterized by warming trend towards the Early Eocene Climatic Optimum (EECO), which is followed by a general cooling trend towards the Oligocene. Both trends are interrupted by brief episodes of global warming. The Eocene warm phases resulted in (sub)tropical conditions in the southern North Sea Basin enabling the proliferation of *Nummulites* at relatively high northern latitudes ~45°N. The geochemical signal (Mg/Ca) of their calcareous tests can be used as a paleotemperature proxy for nearshore conditions, enabling a reconstruction of this mid-latitude environment, and the parameter that constrain their distribution. We present our results for the early (Ypresian) and middle Eocene (Lutetian), using our developed preparation methodology, taking post-depositional alterations into account, accompanied with δ¹⁸O data. Specimens are derived from outcrop and core material from Belgium and northern France: Ypresian, pre-EECO: Aizy-Jouy site; EECO: Ampe site; Lutetian: Zemst, Balegem and Mont-de-Récollets sites.

The Mg/Ca data display a pre-EECO averaged temperature rise of ± 6°C (from 20 to 26°C) and a further warming pulse during the EECO to ± 30°C. Stable isotope data do not indicate any significant temperature or salinity changes linked to layers containing Nummulites, but do record regional long-term paleoceanographic changes in the southern North Sea Basin. Early Eocene Nummulites are mainly found in sandy deposits and are absent in clay-silt rich intervals, indicating that the driver for their occurrence relates to water depth and/or clarity. The warmest conditions were optimal, as the largest tests reflect the highest annual temperature estimates. Preservation of early Lutetian Nummulites from Belgium is poor, but published data from the Cuisié-la-Motte outcrop indicate the continuation of (sub)tropical temperatures (30-34°C). Smaller Nummulites species reappear in middle Lutetian deposits in Belgium, recording maximal annual temperatures of 20-25°C. Our temperature record thus documents the rise and fall of large nummulites in the North Sea Basin, related to the range of (sub)tropical conditions in this region. Late Eocene Nummulites from Belgium are too poorly preserved to provide useful information, but specimens from the Hampshire Basin provide a reliable paleotemperature record for the late Eocene, reflecting their final presence in the region.
Paleoclimatic and paleoceanographic changes and their impact on planktic foraminifera in the Tyrrenhian Sea during the last 32 ka

MARTINELLI Pierluigi1*, GENNARI Rocco1, LIRER Fabrizio2 and CASCELLA Antonio3

1Dipartimento di Scienze della Terra, Università di Torino, Via Valperga Caluso 35, 10125, Italy; pierluigi.martelli@unito.it; rocco.gennari@unito.it.
2Dipartimento di Scienze della Terra, Sapienza Università di Roma, P. Aldo Moro 5, 00185 Roma, Italy, fabrizio.lirer@uniroma1.it.
3Istituto Nazionale di Geofisica e Vulcanologia, Via della Faggiola 32, 52126 Pisa, Italy, antonio.cascella@ingv.it.
*Corresponding author

The marine sediment core NDT_22_2016 was recovered offshore of La Spezia Gulf at 436 m depth in 2016 during an oceanographic survey by the National Research Council (CNR), as part of the NextData project. Within the 320 cm-long core, only one stratigraphic level (at 150 cm) was dated at 15.912 ±111 cal kyr BP by means of AMS14C on planktic foraminifera Globigerina bulloides. So, considering a constant sedimentation rate, we can estimate a possible age of ca. 32 kyr BP for the bottom of the core.

The main aim of this research is to investigate the paleoenvironmental and paleoceanographic changes that took place in the northern sector of the Tyrrenhian Sea over the past 32,000 years, as revealed by planktic foraminifera (PF). This area received little attention in the past decades studies from this point of view, despite it has the potential to record both high and low latitude climatic forcings in response to the variation of the characteristics of the Modify Atlantic Water (MAW), which forms the upper water, and the Levante Intermediate Water (LIW), which forms the intermediate water.

The preliminary quantitative analyses, performed on >125 µm size fraction, identify that in the first 80 cm (cambt), the thanatocoenosis is composed of a rather wide PF biodiversity, mainly composed of Globigerinoides elongatus, G. ruber, Globoconella inflata, Globorotalia truncatulinoides, Globigerina bulloides, G. falconensis and Neogloboquadrina incompta. Below 80 cm, the planktonic foraminiferal assemblage exhibits a drastic reduction in biodiversity, as the 70% of the association is commonly composed by cold species such as G. bulloides, Turborotalita quinqueloba, and Globorotalia scutula, while Neogloboquadrina pachyderma is absent. Since this variation occurs in a stratigraphic level younger than 15.912 ±111 cal kyr BP, we believe that this faunal change reflects the transition from warmer conditions, occurring during the Holocene, to colder conditions which were established during the Younger Dryas event. Work is in progress to increase the sample resolution to achieve a century-scale resolution and identify paleoceanographic oscillations both during the warm (interglacial) and cold (glacial) configurations.

This research has been financially supported by ERC-Consolidator TIMED project (REP-683237).

Comparative analysis of potential toxic element extractions in environmental micropaleontology: “Bioavailability” anyone?

MARTÍNEZ-COLON Michael1*, ROSS Benjamin1, MARTINS Maria V.A.2, OWENS Jeremy3, FAJEMILA Olugbenga T. 4 and BOUCHET Vincent M.P.5

1School of the Environment, Florida A&M University, 1515 South MLK, Tallahassee, FL, USA; michael.martinez@famu.edu; benjamin.ross@famu.edu
2Faculdade de Geologia, Universidade Do Estado Do Rio Janeiro, UERJ, Av. São Francisco Xavier, 24, sala 2020A, Maracanã, Rio de Janeiro, RJ 20550-013, BRAZIL; virginia.martins@ua.pt
3Department of Earth, Ocean and Atmospheric Science, Florida State University, 1011 Academic Way, Tallahassee, FL, USA; jdowens@fsu.edu
4Department of Geological Sciences, Osun State University, 230261, Osogbo, Nigeria; olugbenga.fajemila@uniosun.edu.ng
5Univ. Lille, CNRS, Univ. Littoral Côte d’Opale, IRD, UMR8187, LOG, Laboratoire d’Océanologie et de Géosciences, Station Marine de Wimereux, Lille, FRANCE; vincent.bouchet@univ-lille.fr
*Corresponding author

Potential toxic element (PTE) concentrations are generally measured in sediments following “total” chemical extraction. This is an incorrect approach because total concentrations do not reflect PTE physiochemical behavior related to their bioavailability. The working statement is that PTEs found in both the “exchangeable” (adsorbed) and “oxidizable” (complexed to organic matter) fractions are bioavailable to benthic foraminifera. We compared two different sequential extraction methods (Method A: Tessier’s five-step; and Method B: BCR’s three-step) to elucidate which provided the most realistic results.

(1) “Exchangeable” fraction: Principal component analysis (PCA) showed how different the methods are in terms of the distribution of the PTE concentrations in the samples. As expected, Method B extracted PTEs from the carbonate fraction as well, which showed higher concentrations that are not truly bioavailable and led to an overestimation of the effects in this fraction. This overestimation becomes evident when looking at the results of the canonical correspondence analysis (CCA), which clearly shows that the relative abundance of Ammonia beccarii was influenced differently by the PTEs extracted from Method A (negatively by Pb-Se-Co) and B (negatively by Cu-Pb and positively by Co-Cr). Similar observations were recorded for the relative abundance of Quinqueloculina rhodensi.
(2) “Oxidizable” fraction: The PCA showed “similarities” between methods and how the sample distribution was influenced by the concentrations, although Method A produced higher PTE concentrations. The dissimilarities observed in how the PTEs influenced foraminifera (CCA) were evident and unexpected. This is attributed to the differences in the leachant molar concentrations between methods. The data produced by Method A show that the relative abundance of \textit{A. beccarii} was positively and negatively influenced by As-Cr-Ni and Cu-V-Zn respectively. However, this species was influenced positively (Method B) by Cr-As-Co-Ni-Pb and negatively by Zn-Cu.

The widely used Method B overestimated the influence of the “exchangeable” PTEs on the foraminifera. Thus, the extraction step from Method A is recommended as more realistic in leaching out PTEs that were not co-precipitated with carbonate minerals. The results are more complicated for the “oxidizable” fraction and making a proper recommendation without further research and reassessment is more challenging. Both methods “target” PTEs associated with organic matter and sulfide ligands. Method A’s use of leachants with higher molar concentrations explains the higher PTE concentrations. It could be argued that this could lead to an overestimation of the influence of this fraction on foraminiferal ecology. However, PTEs-bound to organic matter must be considered labile and bioavailable as these could be leached out of food particles due to enzymatic degradation while feeding, which suggests that Method A may be more accurately reflecting PTE availability than Method B.

**Historical foraminiferal and microbial environmental health assessment of Guánica Bay (Puerto Rico)**

\textbf{Martínez-Colón Michael}¹,  \textbf{Ross Benjamin}¹,  \textbf{Shrey Benjamin}¹,  \textbf{Chauhan Ashvini}¹,  \textbf{Pathak Ahish}¹,  \textbf{Owens Jeremy}² and \textbf{Bouchet Vincent M.P.}³

¹School of the Environment, Florida A&M University, 1515 South MLK Blvd, Tallahassee, FL, USA; michael.martinez@famu.edu; benjamin.ross@famu.edu; benjamin1.shrey@famu.edu; ashvini.chauhan@famu.edu; ahish1.pathak@famu.edu

²Department of Earth, Ocean and Atmospheric Science, Florida State University, 1011 Academic Way, Tallahassee, FL, USA; jdowens@fsu.edu

³Univ. Lille, CNRS, Univ. Littoral Côte d’Opale, IRD, UMR8187, LOG, Laboratoire d’Océanologie et de Géosciences, Station Marine de Wimereux, Lille, FRANCE; vincent.bouchet@univ-lille.fr

*Corresponding author

In 2022, the United States Environmental Protection Agency added the Ochoa Fertilizer Co. site adjacent to Guánica Bay to the National Priorities List of hazardous waste sites as a Superfund site. Pollutants such as nickel and chromium have been found in the bay’s waters, surface sediments, fish tissue, and human blood (Polychlorinated biphenyls). To assess the historical changes in environmental health, a 52 cm sediment core collected in 2021 was analyzed for trace metals. The water column at the time of collection was stratified with anoxic conditions at depths >2.2 m. This is critical because redox conditions play an integral role in the fate and transport of microbially-mediated pollutants. A noticeable change in sedimentation was observed at a core depth of 36 cm (pending \textsuperscript{14}C dating) where total organic carbon, carbon-to-nitrogen molar ratios, and mud-sized sediments began to decline towards the core top. Trace metals like Cu-Zn-Pb and Co-Ni decreased and increased in concentrations respectively at the same core depth. Relatively high bulk concentrations of U (9–11 mg/kg) and Hg (0.06–0.2 mg/kg) showed an up-core increase, and it is unclear if the source is allochthonous or autochthonous. All trace metals exceeded the Effect Range Median values stipulated by EPA, strongly suggesting that the benthic communities have been impacted. More interestingly, the historical sediment deposition occurred during anoxic (borderline euxinic) conditions based on Mo/U plots.

The three most abundant foraminiferal species were \textit{Ammonia beccarii} (total: 4,495), \textit{Quinqueloculina seminula} (total: 1,217), and \textit{Quinqueloculina rhodiensis} (total: 350). The temporal variability of their relative abundances (RA) (\textit{A. beccarii} > \textit{Q. seminula} > \textit{Q. rhodiensis}) showed a decreasing trend between 52–40 cm, with the \textit{A. beccarii} (RA range: 67–42%) increasing between 40–1 cm reaching a maximum 92% RA at 3 cm. The \textit{Q. seminula} and \textit{Q. rhodiensis} combined RA mirrored that of \textit{A. beccarii}, reaching a maximum value of 48% at 40 cm and a minimum of 4% at 8 cm. The ecological indices show similar trends. For example, species richness varied from 7–13 between core bottom and 18 cm followed by an overall decreasing trend reaching the lowest value of 5 at 7 cm. Similarly, the Shannon Diversity Index showed an increasing trend starting at the core bottom and ending with a maximum value of 1.4 at 14 cm. The diversity then decreased towards the core top reaching a minimum value of 0.4 at 3 cm.

The environmental health of this estuary is considered severely compromised based on bacterial eDNA and benthic foraminifera. The bacterial community-based microgAMBI index is showing that although the site is regarded to have an average of “poor” condition (average = 3.9), opposing up-core trends were observed. A “bad” to “moderate” stepwise trend between 47–22 cm was followed by a deteriorating “moderate” to “poor” trend between 20–2 cm. Likewise, the Foraminiferal Stress Index mostly evaluated the site as “heavily polluted” with two trends also recorded. A relative slight improvement was observed between 52–12 cm almost reaching “moderately polluted” conditions followed by a deteriorating trend towards core top.
A matter of choice: The interactions between foraminifera and their seagrass host as a model ecosystem for biomonitoring environmental and anthropogenic stressors

MASAWA Jenipher1,2, WINTERS Gidon1,2, KAMINER Moran1, SZITENBERG Amir1, GRUNTMAN Michal2 and ASHCKENAZI-POLYODA Sarit1,3*

1Dead Sea and Arava Science Centre, Masada National Park, Mount Masada, Dead-Sea mobile post 86910, Israel; jennmasawa@gmail.com; wintersg@adssc.org; moran@adssc.org; amir.szitenberg@weizmann.ac.il; sarit@adssc.org
2School of Plant Sciences and Food Security, Porter School of the Environment and Earth Sciences, Tel Aviv University, P.O.Box 39040, Tel Aviv 6997801, Israel; jennmasawa@gmail.com; mgruntman@tauex.tau.ac.il
3Eilat Campus, Ben-Gurion University of the Negev, 162 ha-Temarim Avenue, Eilat, Israel; wintersg@adssc.org; sarit@adssc.org
*Corresponding author

Seagrasses and foraminifera are both widely used as bioindicators to monitor and predict changes in marine ecosystems. Seagrass meadows are recognized as one of the most important ecosystems of coastal environments due to their role as ecosystem engineers and their ability to sequester and bury blue carbon. In sub/tropical water, benthic foraminifera are among the most abundant epiphytic organisms inhabiting seagrass meadows. Although both are extensively studied, little is known about their ecological interactions with each other. With the growing anthropogenic pressure on coastal regions, providing predictions on the interactions between these two model organisms could benefit conservation and management efforts in coastal areas.

This study explored the nature of the association between foraminifera and the tropical seagrass species Halophila stipulacea, aiming to determine whether these interactions are facilitative or random. A “cafeteria” experiment was conducted, in which foraminifera were given a choice to settle on H. stipulacea or alternative plastic plants in both roots and shoot compartments. Halophila stipulacea and sediments were collected from the Gulf of Aqaba-Eilat and planted in a dedicated seagrass mesocosm, fully controlled for salinity (40 ppm), light (100 µmol photons m⁻² s⁻¹), and temperature (25°C). In five aquariums, four H. stipulacea plants (thoroughly cleaned from foraminifera and microbiome) and four plastic plants were planted. On days 10, 20, and 30, one H. stipulacea and one plastic plant were pulled out for foraminiferal analysis. At the end of the experiment, a microbiome analysis was performed to identify possible variances in the microbial community and diversity of the substrates.

Results showed that the foraminiferal numerical abundances and species diversity were significantly higher in H. stipulacea plants than in the plastic plants (1-5 and 5-20 specimens per cm², d=1-3 and 4-14, respectively). While foraminiferal abundance increased with time on all plants, this increase was more pronounced in H. stipulacea compared to the plastic plants, particularly in H. stipulacea’s roots. Foraminiferal abundances also increased with shoot age (~1 and up to 16 specimens per cm² in younger and older shoots, respectively). Microbiome analysis showed that epiphytic microbial community abundance and species diversity were higher in H. stipulacea compared to the plastic plants. Moreover, the oldest shoot had a higher microbial community than the younger ones, which correlated with the leaf-age changes in foraminiferal abundance. This correlation suggests that the older seagrass leaves offer the foraminifera substrate richer in biofilm.

This study reveals that seagrass meadows are important hosts of the foraminifera community and suggest the potential facilitative effect of H. stipulacea on epiphytic foraminifera, which might be attributed to a greater diversity of the microbial community inhabiting H. stipulacea. Our results demonstrate the importance of understanding the relationship between foraminifera and their plant hosts, especially in light of impending population decreases due to global changes. This study emphasizes the urgent need to protect seagrass meadows, which can equally preserve and facilitate the abundance and diversity of foraminifera and other organisms.

Late Silurian (Ludlow, Pridoli) and Earliest Devonian (Lochkovian) Foraminifers of South-Central Oklahoma, USA

McCAULEY Chris1*, NESTELL Galina1, NESTELL Merlynd1 and BARRICK James2

1Department of Earth and Environmental Sciences, University of Texas at Arlington, 500 Yates Street, Arlington, TX 76019, USA; christopher.mccauley@mavs.uta.edu; gnestell@uta.edu; nestell@uta.edu
2School of Geosciences, Texas Tech University, Lubbock, TX 79409, USA; jim.barrick@ttu.edu
*Corresponding author

In south-central Oklahoma, Late Silurian and Early Devonian strata are represented by the Henryhouse and Haragan Formations of the Hunton Group and are exposed in the Arbuckle Mountains and Lawrence Uplift. The formations consist mainly of argillaceous wackestone and mudstone with some beds of skeletal wackestone and packstone. In samples from seven outcrop localities, agglutinated foraminifers are common and occur with stratigraphically important conodonts. To date, foraminifers of the Henryhouse and Haragan Formations have never been systematically described, with only three species previously reported from the Henryhouse, and six from the Haragan. A well exposed and most complete section is present in the Highway 77 road cut, in which the age of the Henryhouse Formation extends from the Gorstian (Kockelella...
Benthic foraminifera are known to follow a complex reproduction strategy involving various types of sexual and asexual reproductive modes. In contrast, planktonic foraminifera were long thought to be obligate sexual outbreeders. In a study on the polar species *Neogloboquadrina pachyderma*, we recently showed that this assumption, counter-intuitive for the maintenance of reproductive success at low population densities, is an observational artifact. The frequency of asexual reproduction in *N. pachyderma* is low (~3%), partly explaining why it had only been observed twice and serendipitously in the past. The survival of the asexually produced offspring is high and results in ~75% of the population renewal, suggesting that the vast majority of specimens deposited on the seafloor result from this reproductive mode. This discovery not only sheds light on planktonic foraminifera population ecology but also opens the possibility to maintain these organisms continually in culture and grow them entirely in controlled conditions.

In autumn 2022 we selected specimens of *N. pachyderma* from the Baffin Bay by traits, that I previously observed in specimens that reproduced asexually. We placed them in a culture setting designed to facilitate and track their reproduction. This increased the probability to obtain asexually produced offspring in the laboratory from 3% to 58.7%. Moreover, we showed that it was possible to raise the offspring to up to 400 µm in diameter, which constitute ideal material for shell element-to-calcium ratio and/or stable isotopes. In the six months since the collection of the specimens we obtained three generations of *N. pachyderma* in the laboratory. This provides unequivocal evidence that like their benthic ancestors, planktonic foraminifera possess the ability to reproduce asexually across several generations.

Because *N. pachyderma* lives almost exclusively in polar environments and therefore might behave differently than tropical or subtropical species, we applied our sampling and culture methodology to the species *Globigerinita glutinata* from the Gulf of Aqaba in March 2023 and also observed events of asexual reproduction. The high number of asexual reproductive events we recorded, 37 in total, allowed the imaging of specimens before and during the events themselves, documenting the first steps of life and calcification of the offspring.
Planktonic foraminifera from cold and warm water environments are capable of reproducing asexually in vivo and vitro. This offers the tantalizing prospect of studying their geochemistry under controlled environmental conditions for their entire life cycle and will give new insights into their ecology. In a first of many applications, it will allow to quantify the so-called “vital effect” of planktonic foraminifera by comparing the geochemistry of clones raised in the exact same condition.

The significance of foraminifera in Southern Ocean: examples from the west-central Ross Sea

MELIS Romana1*, COLIZZA Ester1, DEL CARLO Paola2, DI ROBERTO Alessio3, TORRICELLA Fiorenza1,3 and CAPOTONDI Lucilla1

1 Dipartimento di Matematica e Geoscienze, Università di Trieste, Via E. Weiss, 2, 34128 Trieste, Italy; melis@units.it; colizzae@units.it; ftorricella@ogs.it
2 Istituto Nazionale di Geofisica e Vulcanologia (INGV), sezione di Pisa, Via C. Battisti 53, 56125 Pisa, Italy; paola.delcarlo@ingv.it; alessio.diroberto@ingv.it
3 Istituto Nazionale di Oceanografia e Geofisica applicata, OGS Trieste, Borgo Grotta Gigante 42/C, 34010 - Sgonico (TS); ftorricella@ogs.it
4 Consiglio Nazionale delle Ricerche - Istituto di Scienze Marine (CNR-ISMAR), Via Gobetti 101, 40129 Bologna; lucilla.capotondi@cnr.it
*Corresponding author

The importance of planktic and benthic foraminifera in the study of current and past marine environments is well established. These microfossil groups are well-known as helpful proxies for decipher and time constrain environmental changes in polar areas documented in sedimentary facies ranging from sub-glacial to open marine conditions. Nevertheless, their presence, conservation and diversity in the polar region is limited by a number of several factors. One of the major problems is the calcite compensation depth (CCD) which fluctuates through time. On the Antarctic shelves, the CCD is usually forced to be between 350 and 1000 m due to low temperatures and extremely corrosive water masses. Additionally, the production and accumulation of biogenic carbonate are restricted by significant quantities of siliciclastic sediments associated with glacial activities. Consequently, biogenic carbonate accumulations on the Antarctic shelves are very limited in time and in space and the presence of calcareous foraminifera is regarded as a chance.

Furthermore, as demonstrated by researches conducted in the Ross Sea, the availability of well-preserved calcareous material offers an excellent possibility to build a more accurate age model respect the use of acid-insoluble organic matter (AIOM). Several investigations report that the ages determined by AIOM are frequently anomalously old, with an overestimated age of glacial retreat.

Insufficient data exist on the ecological requirements of foraminifera and their present-day distribution. Studies performed on core-top samples from different oceanographic areas of the Ross Sea document that diversity and abundances of the taxa are strongly influenced by the regional differences in water mass properties. The exclusively occurrence of agglutinants observed in sediments from the Drygalski and Lewis Basins may be attributed to cold, saline, CO2-rich bottom waters and to the presence of a shallow CCD, conditions unfavourable to carbonate precipitation and preservation. Instead, samples from the JOIDES Basin and from the Pennell Trough are characterised by a higher species richness and by the presence of calcareous as a result of the intrusion of the relatively warm, salty and rich in nutrients Modified Circumpolar Deep Waters.

The recovery of foraminifera in the late Quaternary sediments in various sectors of the west-central Ross Sea allow to interpret the climatic phases that determined the advances and retreats of the Ross Sea Ice Shelf. The dynamics of the RIS, the largest in Antarctica, has been investigated by several researchers, however, the timing of its retreat from the Last Glacial Maximum (LGM) is still under debate, mainly due to a lack of robust marine chronostratigraphy. From inner continental shelf to the shelf break, the Drygalski and JOIDES Basins together with the Pennell Trough and Central Basin were investigated. In the inner continental shelf, the strong glacial influence together with the occasionally occurrence of tephra and cryptotephra limit the diversity of the foraminifer associations.

In contrast, towards the outer part of the continental shelf, the particular oceanographic conditions favour a greater availability of carbonate and thus a greater richness of foraminifera.

In the outer basins, of particular importance is the presence of Neogloboquadrina pachyderma, the only calcareous planktic foraminifer able to live in polar areas, surviving in brine channels within sea-ice under hyper-saline and low temperature conditions. We document intervals with an abundant occurrence of well-preserved N. pachyderma (juveniles and adult forms) from deglacial sedimentary sequences of northern Drygalski Basin and Hallett Ridge (Western Ross Sea), reflecting situations of open water conditions and/or variation in the length and intensity of seasonal sea ice.
Living Benthic foraminifera as ecological and biomonitoring tools in the Marano and Grado Lagoon (northern Adriatic Sea, Italy)

MELIS Romana1, FIGUS Billy1, FLOREANI Federico2, PETRANICH Elisa1 and TERRANOVA Kevin Gabriele1

1Dipartimento di Matematica e Geoscienze, Università di Trieste, via E. Weiss, 2, Trieste, Italy; melis@units.it; BILLY.FIGUS@units.it; FEDERICO.FLOREANI@phd.units.it; etpetranich@units.it; KEVINGABRIELE.TERRANOVA@studenti.units.it
*Corresponding author

Lagoons are distinctive naturalistic ecosystems with a delicate biological balance hosting a wide range of organisms. They represent the traditional paralic environment (sensu Guelorget & Perthuisot), along with fjords, deltas, and estuaries, where variations in salinity, oxygenation, nutrients, and other factors produce a complex degree of confinement that symbolizes the amount of time required for the renewal of marine waters. Lagoons and other coastal marine ecosystems have experienced heavy human-related use in recent decades, with negative effects on the aquatic ecosystem. Through the study of these biological consequences, which affect both animal and plant species, we can discover biological indicators (also known as bio-indicators) that can detect changes due to human activity.

The Marano and Grado Lagoon is a 160 km² coastal shallow coastal water system located along the northern Adriatic Sea (Italy), between the Tagliamento and Isonzo River deltas. This lagoon is typically regarded as a well-preserved place where natural environment conservation must coexist with a variety of human activities such as fishing, clam harvesting, shipping, and industry.

The Marano and Grado Lagoon, especially in the eastern Grado sector, is well known for being contaminated by mercury (Hg) released from the Idrija Hg mine (Slovenia) and transported by the Isonzo River and secondarily from the decommissioned chlor-alkali plant of Torviscosa (Italy). Inside the lagoon, Val Noghera is one of the greatest and most productive fish farms, where a semi-intensive farming approach is employed to mitigate the high Hg concentrations. It covers a surface of 220 ha and, in addition to a regulated water exchange through sluice gates and rainwaters, the fish farm receives limited freshwater inputs from several artesian wells (with temperatures up to 33°C).

This study presents the living foraminifera from several sites located in the Grado sector of the lagoon and in the Val Noghera. This survey represents one of the first study on the foraminiferal fauna in biocoenosis, since the data collected to date for the Marano and Grado Lagoon only consider the distribution of foraminifera in tanatocoenosis.

The main aims of this study are the following: i) to provide information on the distribution of the main foraminiferal species in lagoon areas with different degrees of confinement to understand how variations in environmental conditions, total organic carbon (TOC) and Hg concentrations might control the distribution, abundance of species, and the possible occurrence of deformations in foraminiferal tests; ii) provide a judgement of the ecological quality status (EcoQS) of the various environments examined based on the biotic indices inferred from the foraminifera in biocoenosis.

Predicting deep-sea living (stained) benthic foraminifera from the continental slope and São Paulo Plateau, Santos Basin (SW Atlantic): Differences between genus and species data using machine learning

MENDES Rafaela1, YAMASHITA Cintia1, VICENTE Thaisa1, SANTA ROSA Ana1, FONSECA Gustavo2, VIEIRA Danilo2, MARTINS Maria Virginia1,4 and SOUSA Silvia Helena1

1Departamento de Oceanografia Fisica, Quimica e Geologica, Instituto oceanografico, Universidade de Sao Paulo, Praça do Oceanográfico, 191, Cidade Universitaria, Sao Paulo, SP, BR; rafaela.mendes@usp.br; cintia.yamashita@usp.br; thaisamvy@gmail.com; anasantarosa@gmail.com; smsousa@usp.br
2Instituto do Mar. Universidade Federal de Sao Paulo – Campus Baixada Santista, Brazil; gfonseca@unifesp.br; viieradc@yahoo.com.br
3Universidade do Estado do Rio de Janeiro, Faculdade de Geologia, Departamento de Estratigrafia e Paleontologia, Av. São Francisco Xavier, 524, sala 2020A, Maracanã, 20550-013 Rio de Janeiro, RJ, Brazil; virginia.martins@ua.pt
4Universidade de Aveiro, GeoBioTec, Departamento de Geociências, Campus de Santiago, 3810-193 Aveiro, Portugal; virginia.martins@ua.pt
*Corresponding author

The objectives of this work are to compare the use of genera and species data in environmental assessment and to predict the distribution of foraminifera, using abiotic data, in the sediments from the continental slope and São Paulo Plateau in the Santos Basin (SW Atlantic Ocean).

Four hundred and eleven sediment samples, including replicates, were collected (box corer) in 48 stations located on the continental slope and São Paulo Plateau, between 400 and 2,400 m of water depth, in the summer of 2019 and winter of 2021, from the Santos Project - Santos Basin Environmental Characterization, PETROBRAS. The upper 0-2 cm of each core was sliced for living foraminifera. The samples were stored in a solution of rose Bengal and 10% formaldehyde buffered with borax. The sedimentological parameters (gravel, sand, mud, and calcium carbonate- CaCO₃) and geochemical data (Cu/Zn, V/(V/Cr), organic phosphorus, total organic carbon, δ¹³C, δ¹⁵N, chlorophyll a, phaeopigments, lipids, carbohydrates, and biopolymers) were obtained in the Santos project. Machine learning analysis was performed by the iMesc application, and hierarchical clustering, and self-organizing maps (SOM) were used to separate the foraminifera genera and species into groups. The Random Forest (RF) was performed using the abiotic data as predictor of the foraminifera groups.
The cluster analysis on the SOM (Bray Curtis index) applied on the genera data recognized 4 different groups which followed the bathymetric gradient: upper slope stations (400 m depth -Group I), upper-middle slope stations (400 to 1,300 m -Group II), upper-middle slope stations (400 to 1,300 m -Group III), and lower slope and São Paulo Plateau stations (1,900-2,400 m -Group IV). The abiotic data that best predicted the 4 groups with 65% of accuracy were Cu/Zn, phaeopigment (phaeo), total organic matter (TOC), V/(V/Cr), and organic phosphorus (Porg). The most representative genera of each association were: *Globocassidulina, Reophax, Bolivina, Lagenammina*, and *Thurammina*. Applying the same analysis in a species matrix, the groups also showed a bathymetric arrangement. However, an additional group of the middle slope (1000 m and 1,300 m depth) was identified. The abiotic data that best predicted the 4 groups with 59% of accuracy were Cu/Zn, V/(V/Cr), phaeo, carbonate concentration (CaCO₃), lipids, and carbohydrate concentration. The most representative species were: *Globocassidulina subglobosa, Reophax sp. 1, Bolivina albatrossi, Triarifina bradyi, Epistominella exigua* and *Siphonina bradyana*. The model was based on 80% of foraminifera data that was used to predict the other 20% foraminifera distribution.

The comparison between the results obtained from analyses applied on both genera and species revealed that the foraminifera distribution in the Santos basin is mainly controlled by the availability/quality of food and oxygen. We also concluded that the genus data, which analysis is less time-consuming, can be applied in the environmental assessment of the basin. However, we cannot discard species data’s contribution to understanding the oceanographic processes in the study area.

Recent foraminiferal assemblages in terrestrial salt ponds and meadows in Central Germany

**MILKER Yvonne**1*, SCHÖNFELD Joachim2 and SCHMIEDEL Gerhard1

1Institute for Geology, Center for Earth System Research and Sustainability, Universität Hamburg, Bundesstrasse 55, Germany; yvonne.milker@uni-hamburg.de
2GEOMAR Helmholtz Centre for Ocean Research Kiel, Wischhofstraße 1-3, 24148 Kiel; jschoenfeld@geomar.de

*Corresponding author

Benthic foraminifera are common and highly diverse in marine ecosystems. They have also been observed at low abundances and species numbers in terrestrial brackish lakes and salt ponds. First observations of benthic foraminifera in central Germany date back to 1939 and 1958 where single species of intertidal foraminifera have been reported from saline ponds and meadows in the states of Sachsen-Anhalt and Thüringen. The saline waters derive from late Paleozoic and early Mesozoic salt deposits under ground. In 2022, we took surface sediment samples along transects of vegetation zones from known and previously unexplored saline ponds and meadows at different locations in Sachsen-Anhalt and Thüringen to examine whether foraminifera are still living in these habitats. We found live (Rose Bengal stained) and dead foraminifera at all locations, partly with a higher species richness than in marginal marine ecosystems at the German North Sea coast. The modern, terrestrial assemblages are composed of typical salt-marsh foraminifera (*Entzia macrescens, Trochammina inflata, Trochamninita irregularis, Miliammina fusca, Halophragmoides manilaensis, and Halophragmoides wilberti*). We also found species that have not yet been reported from temperate salt marshes in northern Germany (*Trochamninita salsa and Gordiospira arctica*), and a species (*Entzia sp.*) which probably developed as an endemic species in the saline ponds and meadows in Central Germany. We assume that the foraminifera were transported to Central Germany via migrating birds. 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 salt-marsh foraminifera developed endemically and further field campaigns will provide insights into the population dynamics at various terrestrial saline ecosystems in Germany.

Reconstruction of calcification depths of Quaternary planktic foraminifera from the Espirito Santo Basin (southwestern Atlantic) using stable isotopes

**MILLO Christian**1*, STASEVSKAS KUJAWSKI Rita1 and BADARACO COSTA Karen1

1Instituto Oceanográfico, Universidade de Sao Paulo, Praça do Oceanográfico 191, Sao Paulo, Brazil; millo@usp.br; ritaskuja@hotmail.com;
karen.costa@usp.br

*Corresponding author

The oxygen isotope composition of foraminiferal tests is a well-established proxy to reconstruct seawater salinity, temperature and water masses distribution in the geological past. For example, the oxygen isotope analysis of planktic foraminifera calcifying at different depths can reveal changes in the structure of the thermocline. These reconstructions rely on the precise knowledge of the calcification depth of each species, which poses challenges, especially when dealing with fossil records. In this study we reconstruct the calcification depths of *Globigerinoides ruber* (white and pink), *Globigerinoides sacculifer*, *Globorotalia truncatulinoides*, and *Globorotalia menardii* by means of oxygen isotope analysis.
of core top samples (size fraction > 150 µm) collected in the Espirito Santo Basin (southwestern Atlantic). The measured δ¹⁸O values (vs. V-PDB) are as follows, *G. ruber* (white): –0.92 per mil, *G. ruber* (pink): –0.99 per mil, *G. sacculifer*: –0.61 per mil, *G. truncatuloides*: +0.69 per mil, *G. menardii*: +0.43 per mil. Based on the present-day vertical salinity profile and on the linear relationship between salinity and seawater δ¹⁸O value, we obtained a vertical profile of δ¹⁸O values for foraminiferal calcite, under the assumption of isotopic equilibrium. Plotting the measured δ¹⁸O values on top of the theoretical δ¹⁸O profile yielded the following calcification depths, *G. ruber* pink: 85 m, *G. ruber* white: 95 m, *G. sacculifer*: 115 m, *G. menardii*: 190 m, *G. truncatuloides*: 225 m. Since the δ¹⁸O values of the tests reflect the long-term calcification period, our estimates represent average calcification depths, integrating the potential effect of vertical migration in the water column.

Vertical distribution of planktonic foraminifera and its controlling environmental factors in the eastern South Pacific

MIYAMOTO Yusei¹* and TAKAGI Haruka¹

¹Department of Earth Sciences, Faculty of Science, Chiba University, 1-33 Yayoicho, Inage, Chiba-shi, Chiba 263-8522, Japan; 19s5034u@student.gs.chiba-u.jp; htakagi@chiba-u.jp

*Corresponding author

Planktonic foraminifera play an essential role in the marine food web and biogeochemical cycles in pelagic ecosystems, so it is necessary to gain knowledge of their characteristics as living organisms. However, studies on modern planktonic foraminifera are still not enough to understand their ecology, distribution, and its limiting factors. For example, planktonic foraminiferal habitat depth has been studied and conceptualised mainly using stable oxygen isotope ratios preserved in their tests. Such generalized concepts of their living depth are useful when foraminifera are utilized as proxy careers. However, it is not necessarily the case that is observed in the real oceanic environment. It is also pointed out that planktonic foraminifera responds to various environmental factors irrespective of depth, which means that understanding their distribution in multivariate space is necessary. Here, as a case study, we aimed to investigate the relationship between marine environmental parameters and habitat depth of planktonic foraminifera in the eastern South Pacific. Such coupling of knowledge of modern planktonic foraminifera distribution and corresponding ocean environments can also contribute to understanding a more detailed picture of paleoenvironments reconstructed using planktonic foraminifera. Planktonic foraminifera samples used in this study were collected during R/V Hakuhomaru Southern Pacific Cruise KH-19-6. Stations were located off the coast of Peru in the eastern South Pacific Ocean, St1 (10°S, 100°W), St3 (20°S, 90°W), and St5 (30°S, 90°W). Samples were collected from 7 intervals (0-20 m, 20-50 m, 50-100 m, 150-200 m, 200-500 m, and 500-1000 m) using a Vertical Multiple Plankton Sampler. We picked up all planktonic foraminifera tests under a stereo microscope and recorded the number of individuals of each species in each interval. Then, we considered the number of individuals by species per 1 cubic meter as one community. For the vertical environmental parameters, we used five physicochemical data from CTD observations at the same station: water temperature, salinity, dissolved oxygen concentration, chlorophyll concentration, and density. We conducted a multivariate statistical analysis (dB RDA) to determine the correlation between the environmental parameters and the foraminiferal communities.

11,931 planktonic foraminifera individuals were picked up and classified into 39 species in 19 genera. The community data were analyzed by hierarchical cluster analysis using Chao index as the distance, and each community was divided into four groups, reflected the location and depth. The dB RDA analysis revealed that all five parameters significantly affected the vertical distribution of the community, particularly seawater density, temperature, and salinity. Besides, differences between stations were related to dissolved oxygen concentrations. Since the eastern South Pacific Ocean has some water mass structures characterised mainly by water temperature, salinity, and dissolved oxygen concentration. It indicates that the characteristics of each water mass structure may be reflected in the community composition. Even though these physicochemical parameters could explain the compositional differences to some extent, the dB RDA analysis also highlighted that these five parameters alone could not sufficiently describe the differences. We presume that parameters related to biological factors, such as nutrient concentrations, and the density of other plankton that may interact with planktonic foraminifera, affect the foraminifera community composition. If these parameters can be obtained and considered in the analysis, it would allow us to better understand the role of planktonic foraminifera within marine ecosystems and interactions with other organisms that could not be observed directly.

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

MOJTAHIRD Meryemi¹*, DEPUYDT Pauline¹, MOURET Aurélie¹, LE HOUEDEC Sandrine¹,², FIORINI Sarah¹, CHOLLET Simon³, MASSOL Florent¹, DOHOU Francis³, FILIPSSON Helena L.⁴, BOER Wim⁵, REICHART Gert-Jan ⁵,⁶ and BARRAS Christine¹
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 explored the use of strontium/calcium ratio (Sr/Ca) of the calcite shells of benthic foraminifera as a potential seawater C-system proxy through a controlled growth experiment with two deep-sea species (*Bulimina marginata* and *Cassidulina laevigata*) and one intertidal species (*Ammonia T6*). 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 ppm, 410 ppm, 1000 ppm, 1500 ppm). Our results demonstrated that pH did not influence the survival and growth of the three species. However, low DIC conditions (879 µmol kg$^{-1}$) negatively affected *B. marginata* and *C. laevigata* through reduced growth, whereas no effect was observed for *Ammonia T6*. Our results also showed that Sr/Ca was positively correlated with total Alkalinity (TA), DIC and bicarbonate ion concentration ([HCO$_3^-$]) for *Ammonia T6* and *B. marginata*; i.e., DIC and/or [HCO$_3^-$] were the main controlling factors. For these two species, the regression models were coherent with published data (existing so far only for *Ammonia T6*) and showed overall similar slopes but different intercepts, implying species-specific effects. Furthermore, the Sr/Ca - C-system relationship was not impacted by ontogenetic trends between chamber stages, which is a considerable advantage for paleo-applications. This applied particularly to *Ammonia T6* that calcified many chambers compared to the two other species. However, no correlation with any of the C-system parameters was observed for Sr/Ca in *C. laevigata*. This might imply either a strong species-specific effect and/or a low tolerance to laboratory conditions leading to a physiological stress, thereby impacting the Sr incorporation into the calcite lattice of *C. laevigata*.

**Benthic foraminifera as tools to reconstruct past tidewater glacier dynamics: A case study from Kongsfjorden (Svalbard)**

MOJTAHID Meryem$^1$, FOSSILE Eleonora$^1$, SANTONI Serena$^2$, HUSUM Katrine$^2$, STREUFF Katharina$^2$, FORWICK Matthias$^2$, HOWA Hélène$^1$ and NARDELLI Maria Pia$^{1*}$

$^1$University of Angers, Nantes University, Le Mans University, CNRS, Laboratoire de Planétologie et Géosciences LPG UMR 6112, 49000 Angers, France; meryem.mojtahid@univ-angers.fr; eleonora.fossile@gmail.com; volpesantoni@gmail.com; helene.howa@univ-angers.fr; mariapia.nardelli@univ-angers.fr

$^2$Norwegian Polar Institute, Fram Centre, N-9296 Tromsø, Norway; Katrine.Husum@npolar.no

$^3$MARUM, University of Bremen, Klagenfurterstr. 4, 28359 Bremen, Germany; kstreuff@marum.de

$^4$Department of Geosciences, UiT The Arctic University of Norway, NO-9037 Tromsø, Norway; matthias.forwick@uit.no

*Corresponding author

Located at the interface between terrestrial and marine systems, high latitude glaciated fjords are sensitive spots to current and past climate change. Kongsfjorden is located on the western part of the Svalbard archipelago and is characterized by steep environmental gradients, due to the dynamics of the tidewater glaciers, and the inflow of warm Atlantic Water (AW). Here we analyze fossil benthic foraminiferal assemblages in two main sediment cores in order to reconstruct past environmental changes in link with these environmental gradients. Sediment core 10JM-GLACIBAR-GC01, located in front of a surge-type tidewater glacier (Kronenbreen complex) in the inner Kongsfjorden, represents a historical record spanning the period from 1950 to 2010 AD. In this record, we tested relationships between taxonomic and functional diversity metrics and the reconstructed distance from the glacier front. We observed a general increase in foraminiferal fluxes and diversity with the progressive glacier retreat, confirming a positive benthic response to reduced glacier-induced disturbance through time. This historical record confirms therefore the successful use of diversity metrics as proxies for tidewater glacier retreat. A study of a second sediment core, NP07-13/58-GC, spanning the last 3000 years and located in the central Kongsfjorden, was initiated to reconstruct the two end-members relationship between AW inflow and glacier retreat using benthic foraminiferal assemblages and diversity metrics applied in the historical record. The preliminary results show that until 1.6 cal ka BP and between 800 and 500 yrs cal BP, a low diversity and high relative abundances of glacier proximal species characterized the assemblages. According to the developed diversity metrics models, this suggests that the glacier grounding line/ice sheet was advanced by about 10 km compared to its position during the mid 20$^{th}$ century. From 1.6 to 0.8 cal ka BP and between 500 and 200 yr cal BP, taxonomic diversity increased, suggesting decreased glacial influence at the core site (in the central Kongsfjorden). Additionally, the most recent part of the record (500 - 200 yr cal BP) recorded increased relative
abundance of the AW indicator *Adercotryma glomeratum*, suggesting increased influence of the AW carried by the West Spitsbergen Current in the central Kongsfjorden. These ecological observations need further investigations and comparison with published studies from Kongsfjorden and other Svalbard fjords. Investigations with multivariate analyses and Generalised Additive Models could help better interpret the patterns observed in term of species composition and general diversity.

From “source to sink” - a new perspective on the past dynamics of the Murray Canyon Group from benthic foraminiferal communities

MOJTAHID Meryem1,2*, MICHEL Elisabeth1 and DE DECKER Patrick3

1Université d’Angers, Nantes Université, Le Mans Université, CNRS, Laboratoire de Planétologie et Géosciences, LPG UMR 6112, 49000 Angers, France; meryem.mojtahid@univ-angers.fr
2Laboratoire des Sciences du Climat et de l’Environnement, LSCE/IPSL, CEA-CNRS-UVSQ, Université Paris-Saclay, l’Orme des merisiers, F-91191 Gif-sur-Yvette, France; Elisabeth.Michel@lsce.ipsl.fr
3Research School of Earth Sciences, The Australian National University, Canberra, ACT 2600, Australia; meryem.mojtahid@univ-angers.fr;
*Corresponding author

We present fossil benthic foraminiferal assemblage data from marine sediment core SS02/06-GC2 located in the abyssal plain of the Murray Canyon Group (offshore South Australia). The sedimentological characteristics indicate the presence of turbidite deposits showing classical Bouma-like sequences, dated between ~40 and 12 cal ka BP. These results confirm the previous interpretation of the observed large deep-water holes in the abyssal area where the core was sampled as being gouged by surges of high-energy turbidity currents. The presence of good indicator taxa and unique assemblages occupying specific bathymetric depths allows the determination of the source origin of the sediments making the turbidites. Three distinct faunal groups are found: 1) mostly shelf species, 2) mostly bathyal species and 3) mostly abyssal species. In the sediment core, these groups present a quasi-systematic succession, with nearly all Bouma-like sequences starting with the dominance of bathyal species in the coarse-grained base, followed by the dominance of shallow species in the silty part, and finally with abyssal species in the clays. To explain such phenomena, turbidites triggered by mixed hyperpycnal/hypopycnal flow processes and turbidity currents during periods of river floods are considered for the first time within the Murray Canyon Group. They are mostly related to periods of increased fluvial discharges during wet phases in the Murray-Darling Basin.

Paleoproductivity fluctuations at the seafloor in the Gulf of Cadiz during MIS 25-MIS 19: evidence from benthic foraminifera assemblages

MOLINA Giulia1,2*, MEGA Aline1,2, SCHMIEDL Gehard3, RODRIGUES Teresa1,2 and VOELKER Antje1,2

1Centre of Marine Sciences (CMAR), University of Algarve, Campus Gamelas, Faro 8005-139, Portugal; giulia.molina@ipma.pt; alinemega20@gmail.com; teresa.rodrigues@ipma.pt; antje.voelker@ipma.pt
2Marine Geology and Georesources Division, Portuguese Institute for the Sea and Atmosphere (IPMA), Avenida Brasilia 6, Lisbon 1449-006, Portugal; giulia.molina@ipma.pt; alinemega20@gmail.com; teresa.rodrigues@ipma.pt; antje.voelker@ipma.pt
3Center for Earth System Research and Sustainability, Institute for Geology, University of Hamburg, Bundesstraße 55, Hamburg 20146, Germany; gerhard.schmiedl@uni-hamburg.de
*Corresponding author

Benthic foraminifera assemblages can be used to trace trophic conditions and oxygen levels at the seafloor during the Early-Middle Pleistocene Transition (EMPT, 700-1250 kyr). The EMPT was an event that marked a change in how Earth's climate system responded to orbital forcing. Throughout the EMPT, the frequency of glacial-interglacial cycles shifted from ~ 41 kyr to ~100 kyr, which resulted in more intense and longer-lasting interglacial periods. While the EMPT has been studied worldwide, the impacts of those changes in the Gulf of Cadiz, a transition zone between the Mediterranean Sea and the Atlantic Ocean, are still mostly unknown. Reconstructing and understanding changes in environmental conditions under varying climatic conditions is fundamental to predict how ecosystems might react to the ongoing and future climate change. The present study aims to reconstruct productivity and oxygen levels based on benthic foraminifera across the EMPT interval from Marine Isotope Stage (MIS) 26 to MIS 19 (970–761 kyr). Our data come from sediment samples of IODP Site U1387 (36.8°N, 7.7°W; 559 m water depth), drilled into the Faro Drift and under the influence of the Mediterranean Outflow Water (MOW). Variations in MOW properties can affect the productivity, oxygen level, and bottom current velocity along the western Iberian margin and thus the benthic ecosystem. For the environmental interpretation, I am combining my faunal data with various other parameters, such as total organic carbon and total alkenone contents and planktonic foraminifera and diatom abundances. Organic matter availability and oxygen concentration are major factors controlling benthic foraminifera distribution, abundance, and diversity. The first analyses focus on the glacial/interglacial cycle of MIS 20 to MIS 19, and
interglacial MIS 25 as both experienced considerably different conditions in abiotic (e.g., insolation; sea-surface temperature) and biotic (e.g., productivity) factors. MIS 25 experienced warmer temperatures, a bloom in diatoms and a poorly ventilated water mass at the seafloor. The abundances of benthic foraminifera species *Bulimina aculeata* and *Sphaeroidina bulloides* reached more than 30% during the early MIS 25 period associated with seasonal upwelling as indicated by *Chaetoceros* spores. During interglacial MIS 19c, on the other hand, an increased flux of fresh phytoplankton food, as indicated by high concentrations of alkenones, possibly caused the increase in the *Hyalinea baltica* abundance. Relative high abundances of *Cassidulina laevigata* and *Globocassidulina subglobosa* throughout glacial MIS 20 point to changes in the quality of food. Finally, during the MIS 20/MIS 19 glacial-interglacial transition, we observe a rise in sub-oxic species abundances that might be linked to degraded organic matter, potentially exported from the Mediterranean Sea during sapropel formation. Those results highlight varying conditions, and we need to expand the analyses to include MIS 24 to MIS 21 and perform Principal Component Analysis to clarify the mechanisms driving the ecological preferences of the species under glacial and interglacial conditions.

The global genetic diversity of planktonic foraminifera

Morard Raphaël1,*, Darling Kate F.2,3, Cordier Tristan4, Henry Nicolas5,6, HassnerNück Christiane7, Vanni Chiara1, Greco Mattia8, Weiner Agnes K. M.4, Vollmar Nele M.1,4, Milivojevic Tamara1,2, Rahmann Shirin N.1, Siccha Michael1, Meillard Julie1, Jonkers Lukas1, Quillevère Frédéric1, Escarguel Gilles1, Douady Christophe J.1,11, Garidel-Thorin Thibault11, De Vargas Colomban14 and Kucera Michal1

1MARUM Center for Marine Environmental Sciences, University of Bremen, Leobener Strasse, 28359 Bremen, Germany; morard@marum.de; cvamm@marum.de; nevo@nорceresearch.no; tamara.milivojevic@gmail.com; msichica@maun.de; jmeillard@marum.de; mkucera@marum.de
2School of GeoCommunity Sciences, University of Edinburgh, Edinburgh EH9 3JW, UK; Kate.Darling@ed.ac.uk
3Biological and Environmental Sciences, University of Stirling, Stirling FK9 4LA, UK; Kate.Darling@ed.ac.uk
4NORCE Climate & Environment, NORCE Norwegian Research Centre AS, Bjerkes Centre for Climate Research, Jaenabekken 5, 5007 Bergen, Norway; teco@nорceresearch.no; agwe@nорceresearch.no; nevo@nорceresearch.no
5CNRS, Sorbonne Université, FR2424, ABiMS, Station Biologique de Roscoff, 29680 Roscoff, France; nicolas.henry@sb-roscoff.fr; vargas@sb-roscoff.fr
6Research Federation for the study of Global Ocean Systems Ecology and Evolution, FR2022/Tara Oceans GOSEE, 3 rue Michel-Ange, 75016 Paris, France; nicolas.henry@sb-roscoff.fr
7Biological Oceanography, Leibniz Institute for Baltic Sea Research Warnemünde (IOW), Seestrasse 15, 18119 Rostock-Warnemünde, Germany; christiane.hassnerueck@io-warnemunde.de
8Institute of Oceanology, Polish Academy of Sciences, 81-712 Sopot, Poland; mgreco@icm.csic.es
9Max Planck Institute for Marine Microbiology, 28359 Bremen, Germany; tamara.milivojevic@gmail.com
10CNRS UMR 5276, Laboratoire de Géologie de Lyon: Terre, Planètes, Environnement, Université Lyon 1, 69622 Villeurbanne, France; frederic.quillever@gmail.univ-lyon1.fr
11Université de Lyon ; UMR5023 Ecologie des Hydrostèmes Naturels et Anthropisés ; Université Lyon 1 ; ENTEPE ; CNRS ; 6 rue Raphaël Dubois, 69622 Villeurbanne, France; gilles.escarguel@univ-lyon1.fr; christophe.douady@univ-lyon1.fr
12Institut Universitaire de France, Paris, France; christophe.douady@univ-lyon1.fr
13Centre Européen de Recherche et d’Enseignement de Géosciences de l’Environnement, Centre National de la Recherche Scientifique, et Aix-Marseille Université, 13100 Aix-en-Provence, France; garidel@cerege.fr
14Sorbonne Université, CNRS, Station Biologique de Roscoff, AD2M, UMR7144, Place Georges Teissier, 29680 Roscoff, France; vargas@sb-roscoff.fr
*Corresponding author

The sequencing of the ribosomal RNA gene of planktonic foraminifera has challenged the morphological species concept since the 1990s when specimens of a single morphospecies showed large divergences among their sequences, indicating the presence of several biological but morphologically cryptic species. Almost three decades of single-cell sequencing carried out by multiple research teams resulted in the publication of ~40 papers and the generation of thousands of single-cell rRNA gene sequences. In addition, the onset of global metabarcoding surveys in the mid-2010s generated a profusion of genetic data that are challenging to align with the first generation data derived of single-cell sequencing. This ultimately renders the biodiversity assessment of planktonic foraminifera difficult. Here we developed an approach to bring the single-cell and metabarcoding data under the same taxonomic umbrella to assess the worldwide diversity of planktonic foraminifera. We assembled an observational dataset of ~10,000 single-cell foraminifera genetically characterized and queried a global metabarcoding dataset of ~2,000 samples and 2.42 billion reads to retrieve planktonic foraminifera environmental sequences, resulting in ~1100 oceanic stations distributed worldwide. Globally, we identified 94 “biological” species, which nearly doubles the diversity assessment based on exclusively morphological traits. However, our analysis revealed that only 16 morphotypes carry more than one genotype. This means that the majority of the ~50 morphologically defined species of planktonic foraminifera do not have cryptic diversity. Morphotypes inhabiting mid to high-latitude environments have the highest degree of cryptic diversity while low-latitude taxa are moderately affected pointing to a non-random distribution of the phenomenon. Overall, our analysis shows that despite a profusion of genetic data, planktonic foraminifera diversity is modest and finite in contrast to other planktonic protists.
Renewal of planktonic foraminifera diversity after the Cretaceous Paleogene mass extinction by benthic colonizers

MORARD Raphael1,2, HASSENRÜCK Christiane1,2, GRECO Mattia1, FERNANDEZ-GUERRA Antonio2, RIGAUD Sylvain3, DOUADY Christophe J.4,5 and KUCERA Michal1

1MARUM Center for Marine Environmental Sciences, University of Bremen, Leobener Strasse, 28359 Bremen, Germany; rmorard@marum.de; christiane.hassenruetch@io-warnemuende.de; mkucera@marum.de
2Biological Oceanography, Leibniz Institute for Baltic Sea Research Warnemünde (IOW), Seestrasse 15, 18119 Rostock-Warnemünde, Germany; christiane.hassenruetch@io-warnemuende.de
3Institute of Oceanology, Polish Academy of Sciences, 81-712 Sopot, Poland; mgreco@icm.csic.es
4Centre for GeoGenetics, Natural History Museum of Denmark, University of Copenhagen, Øster Voldgade 5-7, Copenhagen 1350K, Denmark; antonio.fernandez-guerra@sund.ku.dk
552 chemin de Clarét, F-05700 Serres, France; sylvain.rigaud@hotmail.fr
6Université de Lyon ; UMR5023 Ecologie des Hydrostéomes Naturels et Anthropisés ; Université Lyon 1 ; ENTPE ; CNRS ; 6 rue Raphaël Dubois, 69622 Villeurbanne, France; christophe.douady@univ-lyon1.fr
7Institut Universitaire de France, Paris, France; christophe.douady@univ-lyon1.fr
*Corresponding author

The biotic crisis following the end-Cretaceous asteroid impact resulted in a dramatic renewal of pelagic biodiversity. Considering the severe and immediate effect of the asteroid impact on the pelagic environment, it is remarkable that some of the most affected pelagic groups, like the planktonic foraminifera, survived at all. Here we queried a surface ocean metabarcoding dataset to show that calcareous benthic foraminifera of the clade Globotomalae are able to disperse actively in the plankton, and we show using molecular clock phylogeny that the modern planktonic clades originated from different benthic ancestors that colonized the plankton after the end-Cretaceous crisis. We conclude that the diversity of planktonic foraminifera has been the result of a constant leakage of benthic foraminifera diversity into the plankton, continuously refueling the plankton niche, and challenge the classical interpretation of the fossil record that suggests that Mesozoic planktonic foraminifera gave rise to the modern communities.

Response of Ammonia conferritesta (T6) to Triple Stressors: Ocean Acidification, Warming, and Deoxygenation

MULLER Elsa1*, CHOQUEL Constance1, DUPONT Sam2, GESLIN Emmanuelle2 and FILIPSSON Helena L.1

1Department of Geology, Sölvegatan 12, SE 22362 Lund, Lund University, Sweden; Elsa.muller36@orange.fr; constance.choquel@geol.lu.se; helena.filipsson@geol.lu.se
2Department of Biological and Environmental Sciences, The Kristineberg Centre for Marine Research and Innovation, University of Gothenburg, Fiskebäckskil, Sweden; Sam.dupont@bioenv.gu.se
3Université d’Angers, Nantes Université, Le Mans Université, CNRS, UMR 6112, LPG, F-49000 Angers, France; emmanuelle.geslin@univ-angers.fr
*Corresponding authors

Global changes lead to ocean acidification, warmer temperatures, and the expansion of hypoxic zones in coastal areas. These three stressors can have complex and poorly understood combined effects on calcifying marine microorganisms. In this study, we aimed to better understand the consequences of these threats on the survival and shell calcification of one of the most important marine calcium carbonate-secreting microorganisms - foraminifera. Our experiment was designed to culture benthic foraminifera under two temperatures, two different oxygen concentrations (oxic versus hypoxic), and three different pH (high and two low pH conditions based on the IPCC scenarios by 2100, -0.4 and -0.6 pH units). The experiment was performed at Kristineberg Centre for Marine Research and Innovation (Sweden).

In September 2022, benthic foraminifera were collected from the Gullmar Fjord (50 m station) and Fiskebäckskil’s mudflat. Several species were identified, including Nonionella sp. T1, Nonionellina labradorica, Bulimina marginata, and the intertidal species Ammonia conferritesta (T6), and Quinquemoculina sp. Specimens were calcine-labeled before the experiment, to differentiate between pre-existing and newly formed chambers. After the experiment, the specimens were then CellTracker Blue-labeled to determine live individuals. Specimens were cultured for 48 days in Petri dishes maintained in aquaria and fed weekly with a mixture of freeze-dried algae. Ten different environmental conditions were tested. Two thermoregulated rooms were set at 9°C (in situ) and 13°C, respectively. In each room, we had controls (normal pH 8.0, oxic), pH 7.6 (medium pH, oxic), pH 7.4 (low pH, oxic), hypoxic high pH (pH 8.0, [O2]< 63 µmol L⁻¹), and hypoxic low pH (pH 7.4, [O2]< 63 µmol L⁻¹). Aquaria were duplicated for the controls and the two lower pH conditions run at both temperatures. We monitored the temperature, salinity, alkalinity, pH, and [O2] in hypoxic aquaria weekly to ensure stable water conditions. Survival and growth were estimated, and newly formed chambers were analyzed by laser ablation.

Here, we focus on Ammonia conferritesta (T6) which calcified more chambers than other species. Our preliminary results showed no statistical difference between replicated aquaria for the seawater chemistry. However, we observed that the survival rate varied by up to a factor of two between replicates for all conditions, suggesting that survival is not only dependent on environmental conditions but also on internal or confounding factors (e.g., physiological stress). A total of 60 newly formed chambers were analyzed coming from the different experimental conditions, however, no calcification occurred for the most severe combination of stressors (i.e., warm + hypoxic + low pH). Furthermore, the ratios of Mg/Ca,
Mn/Ca, Ba/Ca, and Sr/Ca were not impacted by ontogenetic trends between chamber stages, making it advantageous for environmental reconstructions. Although few chambers were analyzed by laser ablation, a larger variability in the TE/Ca values is observed at the low pH. Because laser ablation is a destructive method, new geochemical analyses will be performed on specimens after μCT reconstructions.

The “glacial” sapropel S6 (172 ka; MIS 6): a multiproxy approach to solve a Mediterranean “cold case”

MYERS Savannah1*, AUJDI Laura1, CARIDI Francesca1, DONDES Timme2, GRANT Katharine1, DE GROOT Michelle2, MORIGI Caterina1, ROHLING Eelco1, SABBATINI Anna1, SANGIORGI Francesca3 and NEGRI Alessandra1

1Dipartimento di Scienze della Vita e dell’Ambiente, Università Politecnica delle Marche, Via Brecce Bianche, Ancona, Italy; s.myers@pm.univpm.it; laura.aujdi93@libero.it; f.caridi@staff.univpm.it; a.sabbatini@staff.univpm.it; a.negri@staff.univpm.it
2Department of Physical Geography, Utrecht University, Heidelberglaan 8, Utrecht, The Netherlands; t.h.donders@uu.nl; mrdgroot@hotmail.com; f.sangiorgi@uu.nl
3Research School of Earth Science, Australian National University, 142 Mills Rd, Canberra, Australia; katharine.grant@anu.edu.au; eelco.rohling@anu.edu.au
4Dipartimento di Scienze della Terra, Università di Pisa, Via Santa Maria 53, Pisa, Italy; caterina.morigi@unipj.it
*Corresponding author

Sequences of dark colored, organic-rich sediment layers, called sapropels have been observed throughout the geological archive of the Mediterranean Sea, but the mechanisms behind their cyclical deposition are not yet fully understood by the scientific community. They are representative of large-scale bottom water deoxygenation and have been found to correspond with times of high-amplitude precession minima and insolation maxima. As a result of this specific orbital configuration the NH monsoon systems are intensified, heavily increasing precipitation over North Africa causing significant changes in the freshwater and heat budgets of the Mediterranean basin, limiting bottom water ventilation and leading to basin-wide bottom water anoxia. For these reasons, most sapropels are deposited during warm interglacial periods, as glacial conditions are theoretically less suitable for sapropel events. However, glacial sapropels have been recorded, such as sapropel S6, which was deposited during the penultimate glaciation of Marine Isotopic Stage 6 (MIS 6; 191 – 130 ka) responsible for the largest Quaternary Eurasian ice sheet to exist. With the use of high-resolution foraminiferal isotope, speleothem, and pollen records, previous literature pertaining to MIS 6 has evidenced the presence of millennial scale climate variability (sequences of interstadial-stadial episodes) controlled by the interactions between ocean-atmosphere-ice sheets impacting the North Atlantic and the Mediterranean Sea. Therefore, in addition to the monsoon sourced freshwater input being added to the Mediterranean at the time of S6, the interstadial warming events within this abrupt climate variability result in the melting of the surrounding ice sheets, acting as a second source of freshwater input. It is therefore argued that this combination of freshwater input is the mechanism behind the decreased rates of eastern Mediterranean (EMED) deep water formation causing bottom water anoxia, and, ultimately, the deposition of sapropel S6.

Here, we present a multiproxy paleoecological and geochemical study of the sapropel S6 sedimentation layer found in piston core M25/4-12 retrieved from the Ionian Sea of the EMED basin. Results from the analyses of planktonic foraminifers, calcareous nannofossils, pollen, dinocysts, and foraminiferal δ13C and δ18O were compiled, and compared to the findings of the previously mentioned published literature on MIS 6 and sapropel S6. Because of our high-resolution sampling effort, we were able to recognize within our multiproxy results the proposed millennial scale climate variability that impacted sapropel S6. This paleoecological evidence, therefore, offers a new level of confirmation regarding the mechanisms behind the deposition of S6. Additionally, in agreement with the consensus of sapropel S6, our results also suggest that this period within MIS 6 experienced more mild/temperate and humid conditions than expected for a glacial period.

Ultrasound structure observation and pH imaging of site of calcification in Sorites orbiculus

NAGAI Yukiko1*, TSUBAKI Remi2, FUJITA Kazuhiro3 and TOYOFUKU Takashi4

1X-star, JAMSTEC, Natsushima-cho 2-15, Yokosuka city, Kanagawa, Japan; nagai.y@jamstec.go.jp; toyofuku@jamstec.go.jp;
2Eusapia Co., Ltd. 1-5-6, Kudan-minami, Chiyoda-ku, Tokyo, Japan; tsubaki@eusapia.jp;
3University of the Ryukyus, Senbaru 1, Nakagami-Gun Nishihara-Cho, Okinawa, Japan; fujita@sci.u-ryukyu.ac.jp;
4TUMSAT, 4-5-7, Konan, Minato-ku, Tokyo, Japan; toyof00@kaiyodai.ac.jp
*Corresponding author

Foraminifera are unicellular organisms with calcareous shells. As the elemental composition of foraminiferal shells reflects the paleoenvironmental conditions, it can be used as a paleoceanographic proxy. However, our knowledge of the biological processes of elemental uptake associated with calcification is still limited. In particular, the full details of the role of pseudopodia and organic sheet structures of the shell during calcification remain unclear. In order to reveal the process of shell formation in hyaline-shelled rotallids (Ammonia confertetista), one of the two types of calcareous foraminifera, we performed ultrasound structural observations of individuals during shell formation. From these observations, we have shown
that calcification site is separated from an outer environment by an organic sheet structure where calcium carbonate is deposited. We also studied using intracellular and extracellular pH observations on living individuals in the process of chamber formation. These observations revealed that a high pH microenvironment was created at the site of calcification, where calcium carbonate is easily deposited. Conversely, a low pH microenvironment was created at the outside of the test, which facilitates the uptake of carbonate/bicarbonate ions as a carbon dioxide.

On the other hand, the formation process of porcelain-shelled miliolids, another type of calcareous foraminifera, have not been well studied since Hemleben’s previous study revealed the formation of needle-like calcite crystals in the intracellular vesicles. Parker’s study focused on the shell structure of diverse miliolid species, but there is still limited knowledge on how their shells are organised with long, elongated calcium carbonate crystals. If the long, thin crystals are secreted from the vesicles and intertwined each other, it is necessary to observe how they are arranged into the test wall. To clarify the detailed process of chamber formation in the porcelain-shelled miliolid foraminifera, we observed the ultrafine structure of the calcification site and pH imaging during calcification of *Sorites orbiculus*.

A focused ion beam scanning electron microscope (FIB-SEM) was used to make smooth transverse sections of the chamber wall during the process of calcification. The FIB-SEM images showed that a highly porous cotton candy-like structure was formed in the calcification site, structure was highly branched and fibrous. On the other hand, the shell structure of the penultimate chamber was packed with crystals and denser than the newly calcifying chamber. In addition, no crystal-like morphology has so far been observed in the intracellular vesicles.

The series of intracellular pH observation showed an increase in pH at the place of a newly forming chamber (i.e. 0) in *S. orbiculus*. However, in *S. orbiculus*, the increase in pH is also observed in the penultimate chamber (i.e. -1) and the chamber before the penultimate chamber (i.e. -2).

These results suggest that calcification of *Sorites orbiculus* does not occur in the manner proposed by Hemleben’s previous study, in which the intracellular vesicles form needle-like crystals to construct the shell wall. This observation may reveal a novel and unknown mode of biomineralization in foraminifera and also be a key to understanding elemental partitioning and isotopic fractionation in foraminiferal shells.

**Documentation of the native shallow water benthic foraminiferal assemblage in a sediment core from the coastal region of Northern Israel**

NAGY Matthias¹, ENGE Annekatrin J.,¹ HEINZ Petra¹ and ALBANO Paolo G.¹²

¹University of Vienna, Department of Palaeontology, Josef-Holaubek-Platz 2, UZA II Geozentrum, 1090 Vienna, Austria; matthias.nagy@univie.ac.at; annekatrin.enge@univie.ac.at; petra.heinz@univie.ac.at;
²Stazione Zoologica Anton Dohrn, Department of Animal Conservation and Public Engagement, Villa Comunale, 80121 Naples, Italy; paolo.albano@univie.ac.at;
*Corresponding author

The opening of the Suez Canal in 1869 created a renewed direct connection between the Red Sea and the Mediterranean Sea. This enabled hundreds of species (Lessepsian invaders) to overcome a long-standing biogeographical barrier between these two seas that had previously existed since the Miocene. There has been an increasing number of publications that reported the presence of invasive and non-native species in the Mediterranean Sea among which foraminifera can be found. The focus of these studies lies on the most recent part of the invasion process, the establishment success and possible harm to the ecosystem by invasive species. However, the sensitivity to microhabitats and spatial microdistribution of foraminiferal community structures in the Eastern Mediterranean Sea makes it important to understand the local native communities and their natural changes through time first, so later studies can assess the impact of non-native foraminifera species better.

To address this research need, a sediment core of ~80 cm length and 7 cm in diameter was taken in 40 m water depth on the coast of Israel, near Atlit. The total assemblage of foraminifera (>63 µm) was determined for every 5 cm and their biodiversity indices were calculated (Shannon-Wiener index, Dominance, Evenness, Fisher’s alpha index).

The majority of it provides an archive of native foraminiferal communities that predates the opening of the Suez Canal. The most recent part of the core shows the progression of the migration process. The sediment composition was characterized by a change to coarser sediment in the top 10 cm.

We found 244 species in total and calculating biodiversity indices showed a high biodiversity (e.g. maximum Shannon-Wiener index of 3.95 at 65 cm, extrapolated age of ~7050 years), which is typical for the Eastern Mediterranean Sea. Calcareous (49.6%) and porcellaneous (44%) species showed a high species richness throughout the core while there were only a few agglutinated species present (5.7%). Regarding the number of individuals, *Asterigerinata mamilla* (13.35% of all individuals) was the most dominant species, followed by *Textularia bocki* (4.75% of all individuals) and *Tretomphalus sp.* (4.0% of all individuals). Graphical analysing methods (Detrended Correspondence Analysis and Non Metric Multidimensional Scaling Analysis) showed a dissimilarity between the older part of the core (70 – 8 cm) and the recent part of the core (7 – 1 cm).

The top 7 cm of the core showed an altered community structure, higher total abundances and the presence of most non-native species (11 species in total). The most abundant non-native foraminifera species was *Heterostegina depressa*. Correlating the grain sizes with the number of species and number of individuals showed a positive and significant
relationship between grain sizes and foraminifera. Analysing lifestyle proportions showed that throughout the core epifaunal living foraminifera species dominated over infaunal living species.

The introduction of Lessepsian species and the changes in substrate drove an overall shift of the foraminiferal assemblage.

Automation adventures: First steps in the automatic identification of benthic foraminifera from high resolution 3D images of sediment cores

Nardelli Maria Pia¹, Vanderesse Nicolas², Moller Maryline¹, Zhao Yaqian¹, Guilhermic Corentin¹, Lenta Laurent¹ and Mouret Aurélia¹

¹University of Angers, Nantes University, Le Mans University, CNRS, Laboratoire de Planétologie et Géosciences LPG UMR 6112, 49000 Angers, France; mariapia.nardelli@univ-angers.fr; marilyne.moller@etu.univ-amu.fr; yaqian.zhao.polly@gmail.com; corentin.guilhermic@univ-angers.fr; aurelia.mouret@univ-angers.fr
²University of Bordeaux, CNRS, PACEA UMR 5199, France; nicolas.vanderesse@a-bordeaux.fr
³Nantes University, Angers University, Le Mans University, CNRS, Laboratoire de Planétologie et Géosciences LPG UMR 6112, 44000 Nantes, France; laurent.lenta@univ-nantes.fr
*Corresponding author

X-ray CT scanning, or microtomography, is a non-destructive analysing technique that allows the visualization of the inner structure of materials. It is based on the differential attenuation of an x-ray beam transmitted through a sample. Depending on the local density and the atomic number of the material, the x-rays are more or less absorbed, producing a radiographic projection very similar to medical radiography. Provided that the sample under investigation is imaged from different angles, the radiographic projections can be combined to produce a 3D image in which the intensity values carried by the unit cells (voxels) correspond to the local density of the material.

In our study, we used this technique to investigate the 3D distribution of benthic foraminiferal individuals in a sediment core, previously embedded with resin following the FLEC (Fluorescently Labeled Embedded Core) protocol. Due to their dense shell, the foraminifera appeared slightly brighter than most of the surrounding sediment, with the notable exception of scattered dense grains and other shell fragments.

After image acquisition, we manually pointed the benthic foraminifera present in the core and obtained the 3D coordinates of their exact position in the sediment with a resolution of 13 µm respectively in the x, y and z axes. A correction was applied to these coordinates to account for the inclined sediment surface. This allowed us to count and spatially locate benthic foraminifera within their actual life position. The results allowed us to observe a general preference for sub-superficial (100-300 µm depth) microhabitats for species generally considered as “epifaunal”.

In parallel, at a first attempt to automatically identify foraminifera in the matrix, we applied a successive series of filters on the original images to minimize noise and then let the software count the foraminifera with the ImageJ program. However, comparison between manually pointed specimens and automatically identified specimens revealed a high proportion of false positives for the latter, i.e., a bias towards selection of non-significant fragments, sediment grains, etc.

Ongoing investigations are therefore oriented towards the application of Convolutional Neural Networks to CT scan images. Preliminary results are highly encouraging, with a high accuracy in the identification of benthic foraminifera in their natural position within a sedimentary matrix.

Future work will improve the model on other independent samples and enlarge the spectrum of species, with different test composition and preferential microhabitats, that can be analysed and recognised using this technique. Distinction between living and dead specimens will be an additional challenge. The optimisation of this kind of technique will finally allow to study benthic foraminifera directly in their natural microhabitat and at high spatial resolution, which could be particularly useful to investigate fine scale processes inducing for example patchiness or migrations.

Roadian foraminifers of the Williams Ranch Member of the Cutoff Formation (Guadalupian, Middle Permian), Delaware Basin, West Texas (USA)

Nestell Galina¹ and Nestell Merlynd¹

¹Department of Earth and Environmental Sciences, University of Texas at Arlington, Arlington, TX, 76019, USA; gnestell@uta.edu; nestell@uta.edu
*Corresponding author

In West Texas, Middle Permian rocks of the Delaware Basin outcrop in the Guadalupe and Apache Mountains. The World stratotype area for the Middle Permian, Guadalupian Series and the GSSP's for the Roadian, Wordian and Capitanian stages are located within Guadalupe Mountains National Park. The Guadalupe Mountains area contains a unique Middle Permian Reef Complex with strata of various paleoenvironments ranging from back reef, reef, fore reef to basinal. Guadalupian strata in the Delaware Basin are divided (in ascending order) into the Cutoff, Brushy Canyon, Cherry Canyon,
and Bell Canyon Formations. In the Guadalupe Mountains each formation is divided into several members characterized by distinctive lithofacies. The Roadian part of the Cutoff Formation is subdivided into four members (in ascending order): El Centro, Butterfield, Rest Area, and Williams Ranch. The first appearance of the conodont species Jinogondolella nankingensis marks the lower boundary of the Roadian stage, which is placed in the middle part of the El Centro Member of the Cutoff Formation.

In the Guadalupe Mountains area, the Guadalupian small foraminifers have not been extensively studied and are known mostly from the Capitanian strata. Roadian small foraminifers have not been monographically studied at all, their presence in this interval only mentioned in one abstract. A diverse assemblage of Roadian foraminifers is present in strata of the Williams Ranch Member in the Quarry section that outcrops along U.S. Highway 62/180 in the Guadalupe Mountains area. The strata of the Quarry section are represented in the lower part by thin-bedded black carbonate mudstone with small black pebbles of packstone. In this part of the section can be seen soft sediment deformation. Above this unit is a zone of debris associated with thin- to medium-bedded black carbonate mudstone with lenses of mollusc-bearing packstone. Some beds of the carbonate mudstone are laminated and contain a rich assemblage of radiolarians. The packstone lenses contain a very diverse fauna consisting of ammonoids, a fish assemblage of micromains of chondrichthyan and actinopterygians, some radiolarians, ostracodes, scolecodonts, holothurian sclerites, conodonts, and a rich assemblage of mostly small foraminifers and some fusulinids.

Conodonts are represented by the species Jinogondolella nankingensis with three subspecies (J. nankingensis nankingensis, J. nankingensis temuis, and J. nankingensis behnken), elements of Sweetina, and elements of the apparatus of Hindeodus wordensis.

Small foraminifers are abundant and represented by agglutinated and calcareous genera. Among the agglutinated forms, species are of the genera Ammobaculites and rare biserial “Textularia”. Calcareous forms are abundant and are represented by genera such as Pseudoammodiscus, Multidiscus, Hemigordius, Nodosaria, rare Tristis, Lingulodonosaria, Ichthyolalaria, rare Howchinella, Geinitzina, Neoendoothyranella, Globivalvulina, Tetrataxis, and attached forms of the genera Calcitornella and Calciverterella. Some species such as Ichthyolalaria longissima, Tristis tcherdynzevi, and Geinitzina spandeli are known from Kazanian strata of the Volga River area in the East-European Platform.

Fusulinaceans are represented by rare broken tests of the genus Parafusulinia and abundant smaller forms of an ozawainellid type reported mostly from China and Japan and called Chenella.

**Amphistegina lobifera as a sink for H$_2$O$_2$ in coral reef sediments of the Gulf of Aqaba**

**NEUMÜLLER Katharina$^{1,2,3,4,}$, BASU Subhajit$^{4,5,}$, SCHMIDT Christiane$^{6,}$, STUHR Marleen$^{6,}$, DE BEER Dirk$^{6,}$, WESTPHAL Hildegard$^{6,7,}$ and KLATT Judith$^{1,2,3,4,}$**

1Microcosm Earth Center, University of Marburg and Max Planck Institute for Terrestrial Microbiology, Hans-Meerwein-Straße 4, Marburg, Germany; kati.neumueller@hotmail.de; judith.klatt@uni-marburg.de
2Biogeochemistry Group, Department of Chemistry, University of Marburg, Hans-Meerwein-Straße 4, Marburg, Germany; kati.neumueller@hotmail.de; judith.klatt@uni-marburg.de
3Center for Synthetic Microbiology (SYNMIKRO), Karl-von-Frisch-Straße 10, Marburg, Germany; kati.neumueller@hotmail.de; judith.klatt@uni-marburg.de
4Max Planck Institute for Marine Microbiology, Celsiusstraße 1, Bremen, Germany; kati.neumueller@hotmail.de; subhajit.basu@ddn.upes.ac.in; dbeer@mpi-bremen.de; judith.klatt@uni-marburg.de
5School of Health Science & Technology, University of Petroleum and Energy Studies (UPES), Dehradun, India; subhajit.basu@ddn.upes.ac.in
6Leibniz Center for Tropical Marine Research (ZMT), Fahrenheitstraße 6, Bremen, Germany; christiane.schmidt@leibniz-zmt.de; marleen.stuhr@leibniz-zmt.de; hildegard.westphal@leibniz-zmt.de
7King Abdullah University of Science and Technology, Thuwal, Saudi Arabia; hildegard.westphal@leibniz-zmt.de

$^{*}$Corresponding author

Large benthic foraminifera (LBF) have been recognized as prolific ecosystem engineers due to their contribution to sediment production and reef framework stabilization. A largely unexplored way in which LBF might further shape their surroundings is through influencing reactive oxygen species (ROS) concentrations. Various marine organisms were found to impact concentrations of ROS such as hydrogen peroxide (H$_2$O$_2$) in their environment, potentially resulting in wide-reaching effects on redox states, bioavailability of trace metals and biogeochemical cycles linked to ROS.

In order to better understand the functional role of LBF in the microenvironment of marine sediments and their benthic habitats at large, we therefore assessed if the common diatom-bearing LBF *Amphistegina lobifera* impacts H$_2$O$_2$ concentrations in coral reef sediments from the Gulf of Aqaba (GoA). We hypothesized a) high H$_2$O$_2$ concentrations in the iron-rich GoA sediment, since reactions involving iron can generate various ROS, and b) that LBF can protect themselves against high environmental H$_2$O$_2$ levels by lowering H$_2$O$_2$ concentrations in their microenvironment, for example through enzymatic scavenging.

Combining H$_2$O$_2$ and O$_2$ microsensors in a laboratory set-up, we recorded H$_2$O$_2$ and O$_2$ depth profiles across the sediment-water interface and in the upper millimetres of GoA sediment samples with and without *A. lobifera*. We found that H$_2$O$_2$ concentrations in LBF-free sediment samples with minimal biotic activity reached up to 13 µM in the deeper anoxic layers, from which H$_2$O$_2$ seeped into the water column. Addition of *A. lobifera*, which was the dominant LBF species in the
Foraminifera diversity from the ocean surface to the surface layer of sediments in Nordic Sea

NGUYEN Ngoc-Loi1*, PAWŁOWSKA Joanna1 and PAWŁOWSKI Jan1

1Institute of Oceanology, Polish Academy of Science, Sopot 81-712, Poland; loinguyen@iopan.pl; pawlowska@iopan.pl; janpawlowski@iopan.pl

*Corresponding author

Foraminifera are single-celled organisms that play a significant role in the marine ecosystem and are important for reconstructing past environmental conditions due to their sensitivity to environmental changes. 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. 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. The use of metabarcoding has become increasingly popular in recent years, particularly in the study of microbial ecology and biodiversity. Here, we present results from a study that examines the diversity of foraminifera, from the ocean surface to the surface layer of sediments in the Nordic Seas by metabarcoding approach. In brief, seawater and sediment samples from twenty-five stations were collected from the water column (5 m, 100 m and bottom) and the seafloor (surface sediment) and analysed using molecular techniques. The study revealed a diverse assemblage of foraminifera species, with variations in community structure and abundance between different water depths and sediment layers. The results also suggest that environmental factors, such as water temperature and salinity, play a crucial role in shaping foraminifera communities. This study provides new insights into the distribution and diversity of foraminifera in the Nordic Sea and their potential use as indicators of environmental changes in the region. The findings have implications for understanding past and present marine ecosystems and their responses to climate change.

The research was financially supported by the Norwegian Financial Mechanism for 2014-2021, project no 2019/34/H/ST10/00682.

Bio-erosional traces on the foraminiferal test

NIELSEN Kurt Søren Svenson1*

1Odsherred gymnasium, Lyshøj Alle 15,3 Valby 2500 Denmark.; Knieslen@yahoo.dk

*Corresponding author

Previous studies have shown that bio-erosional traces on the Benthic foraminiferal test are quite common in many modern and fossil environments. A few of the trace makers are known, but most traces are made by unknown organisms. Likewise, it is also unknown why such organisms make these traces. Some species of foraminifera are known to excavate pits or borings in different substrates such as the tests of dead as well as living organisms or limestone rock. Some of these traces have been attributed to predatory or parasitic behavior in both modern and fossil environments. Several species of benthic foraminifera have been observed to demonstrate what seems to be a parasitic or predatory mode of life. However, many more species are believed to have a similar behavior due to their ability to bore into different substrates and tests of calcareous organisms, including other foraminifera. In this study I will show that the morphological variety of the traces found in foraminiferal test is in general caused by unknown organisms.
The High-Low: combined analytical approaches yield both high and low past ocean temperatures from the equatorial Indian Ocean across the Cenozoic

NILSSON-KERR Katrina1,2, MECKLER Anna Nele1,2, PEDERSEN Leif-Erik1, ANAND Pallavi1 and GARRIDO Sebastián4

1Department of Earth Sciences, The University of Bergen, Allégaten 41, N-5007, Bergen, Norway; katrina.nilsson-kerr@uib.no; nele.meckler@uib.no; leif-erik.pedersen@uib.no
2The Bjerknes Centre for Climate Research, Jahnubakken 5, N-5007, Bergen, Norway; katrina.nilsson-kerr@uib.no; nele.meckler@uib.no
3School of Environment, Earth and Ecosystem Sciences, The Open University, Walton Hall, MK7 6AA, Milton Keynes, United Kingdom; pallavi.anand@open.ac.uk
4The Lyell Centre, Heriot-Watt University Research Avenue, Currie, EH14 4BA, Edinburgh, United Kingdom; sag15@hw.ac.uk
*Corresponding author

Our ability to accurately reconstruct ocean temperatures in the geological past has inherent weaknesses with traditionally applied proxies for temperature reconstruction (e.g., Mg/Ca) having both biological and geochemical caveats. The recent decade has seen the increased development and application of clumped isotope thermometry (Δ47) as a viable approach for temperature reconstruction from foraminifera. The clumped isotope (Δ47) approach is thought to be out with biological vital effects and the requisite assumptions regarding past seawater chemistry due to the clumping of 13C-18O bonds being dictated, in isolation of seawater chemistry, by thermodynamics.

We present paired Mg/Ca-temperatures and Δ47-temperatures from inferred mixed-layer dwelling planktic foraminifera spanning the Cenozoic (0-58 Ma) from IODP Site U1443 in the southern Bay of Bengal. There is good agreement between the two analytical approaches across the Pliocene-Pleistocene. However, this relationship breaks down with a divergence between Mg/Ca-temperatures with Δ47-temperatures in the late Miocene, with the latter recording cooler than expected temperatures. The cooler than expected temperatures recorded by the Δ47 suggests a sensitivity to post-depositional diagenetic effects greater than that of the Mg/Ca-temperatures. In order to help constrain the degree of diagenetic overprinting we present Δ47-bottom water temperatures reconstructed from benthic foraminifera to assess the differences in carbonate precipitation settings, between the upper mixed layer with bottom waters, at the site across the studied interval.

Abundant chitinous structures in cytoplasm of Chilostomella and their potential functions

NOMAKI Hidetaka1*, CHEN Chong1, ODA Kaya1, TSUCHIYA Masashi1, TAMEakihiro2, UEMATSU Katusyu2, SALONEN Iines3 and ISOBE Noriyuki2

1Japan Agency for Marine-Earth Science and Technology (JAMSTEC), 2-15 Natsushima-cho, Yokosuka, Kanagawa, 237-0061, Japan; nomakih@jamstec.go.jp; cchen@jamstec.go.jp; odakaya@jamstec.go.jp; tsuchiyama@jamstec.go.jp; isalonen@jamstec.go.jp; isoben@jamstec.go.jp
2Marine Works Japan, 3-54-1 Oppama-Higashi-cho, Yokosuka, Kanagawa, 237-0063, Japan; akihiro@jamstec.go.jp; uematsu@jamstec.go.jp
3School of Environment, Earth and Ecosystem Sciences, The Open University, Walton Hall, MK7 6AA, Milton Keynes, United Kingdom; tsuchiyam@jamstec.go.jp
*Corresponding author

Benthic foraminifers inhabit a broad range of marine environments and are particularly common in hypoxic sediments. The biology of benthic foraminifera is a key to understanding benthic ecosystems and relevant biogeochemical cycles. *Chilostomella* is a foraminiferal genus commonly found in hypoxic deep-sea sediments and has poorly understood ecological and biogeochemical characteristics. The carbon isotope compositions of their lipids and calcite test are substantially different from other co-occurring genera, probably reflecting unique features of its metabolism. Here, we investigated the cytoplasmic and ultrastructural features of *Chilostomella ovoidea* from bathyal sediments of Sagami Bay, Japan based on serial semi-thin sections examined using an optical microscope followed by a three-dimensional reconstruction, combined with TEM observations of ultra-thin sections. Observations by TEM revealed abundant electron-dense structures dividing the cytoplasm. Based on histochemical staining, these structures are shown to be composed of chitin. Our 3D reconstruction revealed chitinous structures in all chambers and particularly abundant in last few chambers. These had a plate-like form in the final chambers but became rolled up in earlier chambers (towards the proloculus). These chitin-plate structures may function to partition the cytoplasm in a chamber to increase the surface/volume ratio, and/or act as a reactive site for some metabolic functions. They co-occur with putative chloroplasts, suggesting these two unique features likely play significant roles on *Chilostomella*'s metabolic adaptations to the hypoxic environments and distinct isotopic compositions.

Assessing the environmental quality of a historically-polluted fjord: a comparison of benthic foraminiferal eDNA and morphospecies proxy approaches

O’BRIEN Phoebe A.J.1*, BARRENCEHA ANGELES Inês2, Pávelowski Jan3, NORDBERG Kjell1, ALVE Elisabeth4 and POLOVODOVA ASTEMAN Irina3

198
Patterns of foraminiferal diversity and species composition from a three-year time series in the Southeastern Clarion-Clipperon Zone, an area designated for deep sea mining

O’MALLEY Bryan1*, SCHWING Patrick1, LAM Tristan1, LARSON Rebekka1, BROOKS Gregg1 and GOODAY Andrew2

1Department of Marine Science, Eckerd College, 4200 54th Ave S., St. Petersburg, Florida, USA; bjomal@eckerd.edu; schwintp@eckerd.edu; tsalam@eckerd.edu; larsonra@eckerd.edu; broksgr@eckerd.edu
2National Oceanography Centre, European Way, Southampton SO14 3ZH, United Kingdom; ang@noc.ac.uk
*Corresponding author

The Clarion-Clipperon Zone (CCZ) in the eastern equatorial Pacific is a target of commercial deep-sea mining (DSM) due to its extensive deposits of high-grade polymetallic nodules. Benthic foraminifera play a crucial role in the ecological balance of oligotrophic abyssal plain communities, where they are the dominant eukaryotes across all size classes (meio-, macro-, mega-) and contribute significantly to the deep-sea food web. Effects of DSM include the generation of sediment plumes, the redeposition of sediment and organic matter, sediment compaction, as well as the loss of hard substrate as habitat heterogeneity in an otherwise homogeneous environment. In order to establish a baseline prior to test mining, this study investigated patterns of foraminiferal diversity, species composition, and density (>63 μm; stained and total) from the top 5 centimetres of 80 multicores across three timestamps (Oct 2020, May 2021, Aug 2022) from the NORI-D exploration lease area. All samples were stained with rose bengal, sieved to 63-μm, wet-picked, and identified to the lowest possible taxon. Nearly 60% of morphospecies found were undescribed. Morphospecies that could not be identified as a described species were preserved, photographed, and given a unique identifier using the lowest identified taxonomic level and a serialized voucher code. All voucher specimens were preserved and will be sequenced for future species description. As the largest quantitative foraminiferal study from the CCZ with over 700 distinct morphospecies found and over 100,000 individuals identified (stained and unstained), this research reinforced the previously documented high species richness and diversity found in polymetallic nodule fields as well as the dominance of monothalamous foraminifera. Additionally, this analysis unveiled a connection between nodule presence/size and its effect on foraminiferal species composition.

The effect of [Mg\(^{2+}\)], [SO\(_4\)^{2-}\], and temperature on Mg incorporation in cultured benthic foraminifera

PACHO Laura1*, DE NOOIJER Lennart1, NAGAI Yukiko2, TOYOFUKU Takashi2 and REICHART Gert-Jan1,3

1NIOZ - Royal Netherlands Institute for Sea Research, Landsdiep 4 1797 SZ \’t Horntje (Texel) The Netherlands; laura.pacho.sampedro@nioz.nl; lennart.de.nooijer@nioz.nl; gert-jan.reichart@nioz.nl
2Japan Agency for Marine-Earth Science and Technology, 2-15, Natsushima-cho, Yokosuka-city, Kanagawa, 237-0061, Japan; nagai.y@jamstec.go.jp; toyofuku@jamstec.go.jp
3Department of Geosciences, Utrecht University, Postbus 80125, 3508 TC Utrecht Bestuursgebouw, Heidelberglaan 8, 3584 CS Utrecht, The Netherlands; gert-jan.reichart@nioz.nl

199
Element incorporation into foraminifera has proven essential to many paleoceanographic and environmental reconstruction studies. One of the most applied proxies to reconstruct past temperature is the Mg/Ca ratio. As happens with most of the proxies, Mg/Ca doesn’t work perfectly and the accuracy, precision, and sensitivity of the reconstructions are affected by the influence of other environmental parameters. Besides temperature, seawater [Mg$^{2+}$], the marine inorganic carbon system, and salinity also affect foraminiferal Mg/Ca. Moreover, different species can have vastly different Mg/Ca even when grown under identical conditions.

To understand how Mg incorporation is affected by these conditions, we applied a systematic approach by testing the effect of [Mg$^{2+}$]$_{ioo}$, [SO$_4^{2-}$]$_{ioo}$, and temperature on species of foraminifera with different biomineralization mechanisms (i.e. species with contrasting calcite chemistries and shells that have different microstructures). Results will allow us to 1) apply Mg/Ca as a paleothermometer with greater accuracy, 2) investigate the use of Mg/Ca and how it could be influenced by other environmental parameters, and 3) investigate phylogenetic relation in Mg incorporation.

**Laboratory feeding experiments - investigating respiration rates of the benthic foraminifer Nonionella sp. T1**

PALME Tina1*, HEINZ Petra1, WUKOVITS Julia1, MAIER Andreas2, POLOVODOVA ASTEMAN Irina3, NAGY Matthias1 and GLATZEL Stephan2

1Department of Paleontology, University of Vienna, Josef-Holaubek-Platz 2, 1090 Vienna, Austria; tina.palme@univie.ac.at, petra.heinz@univie.ac.at; julia.wukovits@univie.ac.at, matthias.nagy@univie.ac.at
2Department of Geography and Regional Research, University of Vienna, Josef-Holaubek-Platz 2, 1090 Vienna, Austria; andreas.maier@univie.ac.at; stephan.glatzel@univie.ac.at
3Department of Marine Sciences, University of Gothenburg, Carl skottsbergs gata 22 b, 41319 Gothenburg, Sweden; irina.polovodova@marine.gu.se

Benthic foraminifera are important components of marine ecosystems, contributing to biogeochemical cycling and serving as indicators of environmental change. Their behaviour under different environmental conditions is of importance for the study of paleoclimate due to their extensive use as paleoproxies. Gaining knowledge of their role in energy and nutrient flows leads to a better understanding of ecosystem functioning. In this study we investigated respiration rates of the potentially invasive benthic foraminifer Nonionella sp. T1 originating from sediments within the Gullmar Fjord and cultivated in artificial sea water (ASW) in the laboratory at the University of Vienna. In order to assess the flux of organic carbon within an organism both oxygen respiration and carbon assimilation need to be considered. A non-invasive method was used to analyze oxygen respiration rates. The method involved placing an Oxygen Sensor Spot in a small, 2.5 ml airtight glass vial alongside the foraminifera. Oxygen concentrations under dark and light conditions were documented using an Oxygen Microsensor. We used a large number (n = 100 per sample, triplicates measured) of cleaned, living specimen. Respiration rates are given in nl O$_2$/h calculated for biovolume (µm$^3$) which was assessed for each individual using photo microscopy. For the purpose of quantifying CO$_2$ production from foraminiferal respiration samples were additionally analysed via Cavity Ring-Down Spectroscopy (CRDS) which detects trace metals and measures isotopic ratios from a gas phase. In order to more clearly trace the carbon signal from the foraminifera within this experimental setup they were fed with freeze-dried $^{13}$C-labelled diatoms (Phaeodactylum tricornutum) prior to the CO$_2$ measurements. Our results from the Oxygen Microsensor show a consistent respiratory activity for Nonionella sp. T1 by a significant ($r^2$ ≥ 0.98) linear decrease in oxygen content over time (~ 7 h). The oxygen respiration rates measured at 7.37 x 10$^{-6}$ to 3.32 x 10$^{-6}$ nl O$_2$/µm$^3$/h under dark conditions fall within the upper range of previously observed foraminiferal respiration rates. With most other studies using much less specimen for measurements due to their focus on the relation between respiration rates and individual biovolume a direct comparison is difficult. Further, first results from CRDS analysis show detectable amounts of CO$_2$ release from foraminiferal respiration and more results are needed. Combining these findings our research contributes to a better understanding of the metabolic processes and the ecological role of the potentially invasive foraminifer Nonionella sp. T1. Quantifying respiration rates using significant sample sizes supports the continuous evaluation of the contribution of benthic foraminifera to O$_2$ consumption and CO$_2$ production within benthic communities.

**Composition of Foraminifera test bound organic matter and proxy potential**

PAOLONI Tommaso1*, HOOGAKKER Babette1, NAVARRO RODRIGUEZ Alba1, PEREIRA Ryan1, MCCLYMONT Erin2, JOVANE Luigi3 and MAGILL Clayton1

1The Lyell Centre, Heriot-Watt University, Currie EH14 4BA, Edinburgh, UK; tp47@hw.ac.uk; b.hoogakker@hw.ac.uk; a.navarro_rodriguez@hw.ac.uk; r.pereira@hw.ac.uk; c.magill@hw.ac.uk
2Department of Geography, Durham University, Lower Mountjoy, South Rd, Durham DL1 3LE, UK; erin.mcclymont@durham.ac.uk
3Oceanographic Centre for Stratigraphic Records of the São Paulo Oceanographic Institute (IOUSP), Praça Oceanográfico, 191 - Vila Universitaria, SP, 05508-120, São Paulo-SP, Brazil; jovane@usp.br
Foraminiferal shells are extensively used to reconstruct the marine environment in the geological past. The foraminifera test-bound organic material (FBOM) has been used as a proxy for past atmospheric CO$_2$ concentrations, past nitrogen cycling and has the potential to provide information on water mass circulation and carbon cycling. Additionally, unlike particulate organic matter, FBOM has the advantage of being sheltered by the foraminifera test from diagenetic alteration and potential contamination. However, to fully exploit the proxy potential of FBOM, its molecular composition must be clearly assessed. Recent work suggests that FBOM may be characterized by a substantial lipid content and that this would justify depleted FBOM $\delta^{13}$C values. To assess this hypothesis and provide further information on the FBOM chemical composition, we carried out analyses using gas chromatography-mass spectrometry and flame ionization detection (GC-MS/FID) together with liquid chromatography organic carbon and nitrogen detection (LC-OCD/OND). Our results show no evidence of a sizeable lipid component. Instead, they indicate that polysaccharides and proteins dominate the FBOM, as proposed by earlier studies. Furthermore, our study explored for the first time the potential of LC-OCD/OND analyses on FBOM and the impact on this proxy of the methodology used.

Larger foraminiferal biodiversity from Paleocene to Miocene: possible relationships with climate changes

PAPAZZONI Cesare Andrea1* and BENEDETTI Andrea1

1Dipartimento di Scienze Chimiche e Geologiche, Università degli Studi di Modena e Reggio Emilia, Via Campi 103, I-41125 Modena, Italy; papazzoni@unimore.it; andrea.benedetti@liceodestetivoli.net

*Corresponding author

A list of over 1,300 species belonging to 215 genera spanning Danian to Langhian, and including 26 Shallow Benthic Zones (SBZ) was used to obtain a biodiversity analysis based on a comprehensive and critical review of the scientific literature on larger foraminifera (LF) and other accompanying shallow-water foraminifera of the Mediterranean Neotethys. This large dataset allows us to recognize a quick evolutionary radiation shortly after the abrupt extinction of LF occurred at the end of the Cretaceous period: high origination rates are recorded at both genus and species level in the early Danian, followed by a rather constant biodiversity throughout the rest of the Paleocene. A tipping point is represented by the Paleocene-Eocene Thermal Maximum (PETM), which is followed by a startling radiation of K-strategists species, giving rise to an exceptionally high number of species belonging to the genera *Alveolina*, *Nummulites*, *Assilina*, *Discocyclina*, and *Orbitoclypeus*. Similarly, even if to a lesser extent, a second minor turnover occurred in SBZ12, right after the Early Eocene Climatic Optimum (EECO).

Lutetian and Bartonian times were subjected to a general cooling trend, shortly interrupted by the Middle Eocene Climatic Optimum (MECO), which however seems having no significant influence on the general demise of several Eocene LF groups such as nummulitids. The Eocene/Oligocene transition (EOT), known as contemporary with a major cooling event, also coincide with the extinction of major groups of LF such as the orthophragmines (= discocyclinids + orbitoclypeids). During the Oligocene, lepidocyclinids and miogypsinids flourished in the Neotethys but already in the Late Oligocene, at the end of the SBZ23, which roughly coincides with the end of the Late Oligocene Warming Event (LOWE), the biodiversity dropped to low values. Unfortunately, during the Miocene the diversity became so low that it’s very hard to precisely detect the influence of the Middle Miocene Climatic Optimum (MMCO) on the LF communities. This study has been funded by the Italian Ministry of University and Research (MUR), funds PRIN 2017: project “Biota resilience to global change: biomineralization of planktic and benthic calcifiers in the past, present and future” (prot. 2017RX9XXY).

A new proposal for biozonation of the Paleocene: Shallow Benthic Zones (SBP) calibrated with calcareous nanofossils

PAPAZZONI Cesare Andrea1*, FORNACIARI Beatrice1, GIUSBERTI Luca2, SIMONATO Michela2 and FORNACIARI Eliana2

1Dipartimento di Scienze Chimiche e Geologiche, Università degli Studi di Modena e Reggio Emilia, Via Campi 103, I-41125 Modena, Italy; papazzoni@unimore.it; beatrice.fornaciari89@gmail.com

2Dipartimento di Geoscienze, Università degli Studi di Padova, Via Gradenigo 6, 35131 Padova, Italy; luca.giusberti@unipd.it; michela.simonato.1@phd.unipd.it; eliana.fornaciari@unipd.it

*Corresponding author
The Danian-Thanetian interval has been investigated in three sites from northern Italy, i.e., Tabiago and Monte Giglio in Lombardy and Ardo in Veneto. All these are deep-sea sections with abundant content in calcareous nannofossils, but they contain intercalations as well of calciturbiditic, larger foraminifera-bearing beds derived from shallow-water environments, making them suitable for a direct correlation of different biozonation tools. The analysis of both larger foraminifera and calcareous nannofossils allowed us to reconstruct with sufficient detail the Southern Alps record, which could be considered as a starting point to obtain a new biozonation integrated scale. The shallow benthic (SB) zones, calibrated with the calcareous nannofossils (CN) zones, provided new data about the biozonation of the Paleocene. Accordingly, we propose to introduce four new SBP (Shallow Benthic Paleocene) Zones (SBP1-4), partly coincident with the former SB Zones of the standard biozonation but defined following an innovative biostratigraphic approach for larger foraminiferal, which is based on biohorizons instead of marker species as in the traditional approach used since the introduction of the SB Zones. One of our main results is that the SBP1/SBP2 boundary, coincident with the recovery of the complexity among foraminifera, turns out to occur only 2 Ma after the K/Pg crisis, faster than previously retained.

**Unexpected high records of non-indigenous foraminiferal species in the eastern English Channel**

PAVARD Jean-Charles1*, RICHTIR Julien2, BOUCHET Vincent M.P.3, HOLZMANN Maria4, MCGANN Mary4, ARMYNOT DU CHATELET Eric3, PEZY Jean-Philippe5, DAUVIN Jean-Claude4 and SEURONT Laurent1,7,8

1Univ.Lille, CNRS, ULCO, UMR8187, LOG, Laboratoire d’Océanologie et de Géosciences, Station Marine de Wimereux, F-59000 Lille, France; 28 avenue Foch, 62930 Wimereux, France; jcharles.pavard@gmail.com; vincent.bouchet@univ-lille.fr; laurent.seuront@seuront.com
2Institute for Extra-cutting-edge Science and Technology Avant-garde Research (X-star), Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Yokosuka, Japan; 2-15, Natsushima-cho, Yokosuka-city, Kanagawa, 237-0061, Japan; richtir.julien@jamstec.go.jp
3Department of Genetics and Evolution, University of Geneva, 30 Quai Ernest Ansermet, CH-1211 Geneva 4, Switzerland; maria.holzmann@unige.ch
4U.S. Geological Survey, 345 Middlefield Road, Menlo Park, CA 94025, USA; mmcgann@usgs.gov
5Univ.Lille, CNRS, ULCO, UMR8187; LOG, Laboratoire d’Océanologie et de Géosciences, F-59000 Lille, France; Université de Lille Faculté des sciences et technologies, Département Sciences de la Terre, Avenue Paul Langevin - Cité scientifique, Bâtiment SN5, 59655 Villeneuve d’Ascq CEDEX, France; eric.armynot@univ-lille.fr
6Normandie Univ, UNICAEN, UNIROUEN, Laboratoire Morphodynamique Continentale et Côtière, CNRS UMR 6143 M2C, 24 rue des Tilleuls, 14000 Caen, France; jean-philippe.pezzy@unicaen.fr; jean-claude.dauvin@unicaen.fr
7Department of Marine Energy and Resource, Tokyo University of Marine Science and Technology, 4-5-7 Konan, Minato-ku, Tokyo, 108-8477, Japan; laurent.seuront@seuront.com
8Department of Zoology and Entomology, Rhodes University, Grahamstown, 6140, South Africa; laurent.seuront@seuront.com
*Corresponding author

The English Channel is known as a hotspot of Non-Indigenous Species (NIS). Besides aquaculture, their other main entry is commercial harbours due to globalised shipping through ballast waters and fouling. Recently, we witnessed the emergence of foraminiferal species originating from Asia yet unrecorded in the English Channel i.e. *Trocchammina hadai*, *Virgulinella fragilis*, *Spirobolivina* sp. and to a lesser extent *Ammonia confertitesta*. After presenting some general statements on these newcomers in the English Channel, and potential impacts of these species on their new ecosystems, we will illustrate the arrival of NIS species based on the *Ammonia tepida* morphogroup that includes the three pseudo-cryptic species, *A. aberdoveyensis*, *A. confertitesta* and *A. veneta*. The morphological discrimination of the latter three species has been recently established, but information on their ecology and habitats is still relatively scarce. This study aims to define distribution patterns of these species at eight sites scattered along the French coasts of the English Channel, covering a total of 39 stations. These sites were classified into two contrasted habitats based on the intensity of anthropogenic influence, either harbours (heavily modified habitat) or less impacted (moderately influenced habitat). The use of stations. These sites were classified into two contrasted habitats based on the intensity of anthropogenic influence, either harbours (heavily modified habitat) or less impacted (moderately influenced habitat). The use of stations. These sites were classified into two contrasted habitats based on the intensity of anthropogenic influence, either harbours (heavily modified habitat) or less impacted (moderately influenced habitat). The use of stations. These sites were classified into two contrasted habitats based on the intensity of anthropogenic influence, either harbours (heavily modified habitat) or less impacted (moderately influenced habitat). The use of stations. These sites were classified into two contrasted habitats based on the intensity of anthropogenic influence, either harbours (heavily modified habitat) or less impacted (moderately influenced habitat). The use of stations. These sites were classified into two contrasted habitats based on the intensity of anthropogenic influence, either harbours (heavily modified habitat) or less impacted (moderately influenced habitat). The use of stations. These sites were classified into two contrasted habitats based on the intensity of anthropogenic influence, either harbours (heavily modified habitat) or less impacted (moderately influenced habitat). The use of stations. These sites were classified into two contrasted habitats based on the intensity of anthropogenic influence, either harbours (heavily modified habitat) or less impacted (moderately influenced habitat). The use of

**Foraminiferal diversity uncovered by sedaDNA metabarcoding**

PAWLOWSKA Joanna1*, NGUYEN Ngoe-Loi2 and PAWLOWSKI Jan1

1Department of Paloeceanography, Institute of Oceanology of the Polish Academy of Sciences, Powstańców Warszawy 55, 81-712, Sopot, Poland; pawlowska@iopan.pl; loinguyen@iopan.pl; janpawlowski@iopan.pl
*Corresponding author

The Arctic marine biodiversity undergoes rapid changes due to global warming. These changes have been demonstrated in the case of macroorganisms, but little is known about their impact on the biodiversity of small, single-celled organisms,
such as foraminifera. Furthermore, our knowledge of the impact of climate changes on marine biodiversity across geological times is limited to a few taxa that leave fossilized remains. Recent advances in environmental genomics can change this situation radically. In particular, environmental DNA analysis is an effective method for tracking the evolution of biodiversity over time and space in a holistic manner. Evidence that DNA can be preserved in marine sediments at geological time scales has opened up new avenues for the use of sedimentary ancient DNA (sedDNA) in paleoenvironmental research.

Our research indicates the existence of foraminiferal sedDNA in the Late Quaternary sediments in the Nordic Seas and revealed foraminiferal assemblages much more diverse than those inferred from the fossil records. In particular, sedDNA studies have revealed a vast diversity of non-fossilizing monothalamous foraminifera, including several new potential indicator species. Although microfossil and sedDNA records complement each other rather than overlap, combined together they reveal more detailed information than may be derived from each approach individually. Furthermore, our results show that a finer molecular analysis can provide valuable information about the occurrence of different foraminiferal genetic variants over time. These changes at the genotype level are associated with environmental conditions, indicating that genotypes have different ecological preferences and can be used as alternative paleoceanographic proxies in the future.

Despite the limitations of the sedDNA approach, resulting from the degraded nature of sedDNA or potential technical biases, it may provide a powerful mean to reconstruct paleoenvironments more comprehensively and to better understand what drives past Arctic environmental changes. However, to fully exploit the potential of sedDNA as a proxy, it is essential to increase our knowledge about the molecular ecology of modern foraminifera. As the present is the key to the past, metabarcoding data on living-species distributions and their population structures are indispensable to the accurate interpretation of paleometabarcoding data and the use of foraminiferal genomic variants as indicators of changing environmental conditions.

The study was funded by the National Science Center grants no. 2015/19/D/ST10/00244 and 2018/31/B/ST10/01616.

**Monothalamous foraminifera: mapping the unknown diversity revealed by environmental genomics**

Pawłowski Jan1*, Barrenechea Angeles Inès2, Nguyen Ngoc-Loi3, Holzmann Maria4 and Gooday Andrew4,5

1Institute of Oceanology, Polish Academy of Sciences, 81-712 Sopot, Poland; janpawlowski@iopan.pl; loinguyen@iopan.pl
2Department of Geosciences, UIT, N-9037, Tromsø, Norway; ines.a.angeles@uit.no
3Department of Genetics and Evolution, University of Geneva, 1205 Geneva, Switzerland; Maria.Holzmann@unige.ch
4National Oceanography Centre, European Way, Southampton SO14 3ZH, UK; ang@noc.ac.uk
5Life Sciences Department, Natural History Museum, Cromwell Road, London SW7 5BD, UK; ang@noc.ac.uk

*Corresponding author

The diversity of forams is usually associated with the morphological complexity of their external skeletons. However, with the advances of molecular research it became clear that there is a parallel world of non-skeletonized monothalamous foraminifera that might be as diverse, or even more diverse, than their multichambered calcareous or agglutinated cousins. These monothalamids dominate in practically all metabarcoding studies. Some of them could be assigned to a few described species or genera, but the majority remain unidentified. Great efforts have been made in recent years to describe morphologically and genetically at least some of the most common monothalamids. Yet, given the continuous flood of new sequences being produced by metabarcoding studies, these newly described species are like a drop of water in an ocean of unseen biodiversity. Here, we report the first attempts to classify these unknown monothalamids based on their molecular signatures. Numerous novel lineages have been revealed, and their distributions have been tentatively assessed. Further efforts are needed to characterize these new lineages morphologically. Nevertheless, the lack of morphological taxonomy should not be viewed as an impediment to the future development of foraminiferal metabarcoding. Our work is the first step towards making ecological sense of the huge unknown diversity of monothalamids and testing their potential use as bioindicators of environmental impacts.

**Morphological variations in Pseudohastigerina micra from the upper Eocene flysch sediments of the island of Hvar, Croatia**

Pejnović Igor1* and Cosović Vlasta1

1Department of Geology, University of Zagreb, Horvatovac 102b, Zagreb, Croatia; igor.pejnovic@geol.pmf.hr; vlasta.cosovic@geol.pmf.hr

*Corresponding author

Upper Eocene flysch sediments are an important unit of Dinaric foreland basin deposits. At the island of Hvar, Croatia, two outcrops where these sediments are well exposed were selected and sampled for micropaleontological studies. These are Zarače and Podstine coves sections.

Taxonomic identification of foraminifera revealed that the flysch sediments at both sections contain an abundance of planktonic foraminifera, with P/B ratio being rather uniform across both sections, ranging from 0.83 to 0.93. Planktonic
foraminifera assemblage is very similar at both sections. It is dominated by small (Globoturborotalita) and large (Subbotina, Dentoglobigerina) representatives of fam. Globigerinidae. Members of smooth-walled Turborotalia ceroazulensis lineage are also present and were used to correlate the samples to planktonic zonal schemes in the absence of index taxa. The samples collected at the Zaraće section correspond to planktonic foraminiferal zone E15, while Podstine section ranges across the E15 and E16 zones, placing both within the upper Eocene age of deposition. There is a notable abundance of small-size, ‘opportunist’ species belonging to genera Tenuiella, Strepitrichus and Pseudohastigerina. The latter, largely represented by its species Pseudohastigerina micra, is consistently present throughout both sections. This research aims to determine whether any biometric changes can be detected in tests of P. micra specimens.

P. micra is considered to have been a surface dweller lacking algal symbionts, the latter being a common trait among small-sized species. It was common in low to high latitudes and tolerant of eutrophic environments. In samples from both studied sections P. micra was mostly limited to the 63-125 μm size fraction and in seven samples (five from Zaraće section and two from Podstine section) it was both sufficiently abundant and well-preserved to allow accurate biometric measuring of their tests. For each sample 50 P. micra tests from the 63-500 μm size fraction were randomly picked, observed under a stereoscopic microscope and photographed in side and aperture views. The measured parameters were the maximum test diameter, the dimensions of the ultimate chamber and the number of chambers in the final whorl. Aperture type of each specimen was identified to determine the frequency of bipartite aperture configuration among the specimens.

Across both sections, the average test size of P. micra ranges from 140.3 to 159.9 μm, placing the specimens in the lower size range for this species during the Eocene. The lowest average test size was recorded within the lower part of zone E15 in a sample taken at Zaraće section. This sample also stands out by having the largest abundance of small species as well as the record abundance of P. micra where it makes up for 11.3% of the entire foraminiferal assemblage. The size and shape of the final chamber is highly varied even among individual samples, with no discernible rules or patterns to their variations. Lastly, the frequency of bipartite aperture is very low in the studied specimens, with only up to 4% of tests exhibiting this aperture configuration in any given sample.

This research indicates that in subtropical to temperate latitudes during upper Eocene, P. micra could exhibit particularly small test sizes. This is notable, as the disappearance of large-sized P. micra specimens is in some cases used to distinguish the Eocene/Oligocene boundary when warm-water index taxa are absent. Further investigation is required to compare these measurements with specimens from other nearby Eocene and Oligocene sites.

First record of deep-sea benthic foraminiferal response to the Late Lutetian Thermal Maximum in the Tasman Sea (IODP Site U1508, Southwest Pacific)

PEÑALVER-CLAVE Irene1*, AGNINI Claudia2, BHATTACHARYA Joyeeta3, DALLANAVE Edoardo4, WESTERHOLD Thomas5, DICKENS Gerald6, SUTHERLAND Rupert7 and ALEGRET Laia1

1Departamento de Ciencias de la Tierra, & IUCA, University of Zaragoza, Calle Pedro Curbena 12, 50009, Zaragoza, Spain; irenepec@unizar.es; laia@unizar.es
2Dipartimento di Geoscienze, Università degli Studi di Padova, Via Giovanni Gradenigo 6, 35131, Padova, Italy; claudia.agnini@unipd.it
3Picarro Inc. Headquarters, 3105 Patrick Henry Dr, Santa Clara, CA 95054, U.S.A; joyeetabhattacharya91@gmail.com
4Faculty of Geosciences, University of Bremen, Bibliothekstrasse 1, 28359, Bremen, Germany; edoardo@uni-bremen.de
5MARUM, University of Bremen, Leobener Str. 8 D-28359, Bremen, Germany; twesterhold@marum.de
6School of Natural Sciences, Museum Building, Trinity College Dublin, Dublin 2, Ireland; dickensg@tcd.ie
7School of Geography, Environment and Earth Sciences, Victoria University of Wellington, PO Box 600, Wellington 6140, New Zealand; rupert.sutherland@vuw.ac.nz
*Corresponding author

Transient global warming events, called hyperthermals, occasionally interrupted the gradual cooling trend of the middle Eocene. Like early Eocene warming events, they are characterised by increased pCO2 levels, a paired negative excursion in carbon and oxygen stable isotopes (measured on bulk sediment and benthic foraminifera) and marine carbonate dissolution. Understanding how these events affected deep-sea ecosystems in the past is essential to unravel disruption of climate system dynamics during periods of increased pCO2 levels. Here we analyse the effects of the Late Lutetian Thermal Maximum (LLTM, also known as the C19r event), in the Reinga Basin of the Tasman Sea (Southwest Pacific). The short duration of the LLTM, ~ 30 kyr in the Atlantic Ocean records, poses a challenge to identify this event in deep-sea sediments, and so far only three studies have dealt with its paleoecological consequences in the deep sea, all of them in the Atlantic Ocean.

This study is the first record of the deep-sea benthic foraminiferal response to the LLTM in the Tasman Sea. The magneto- and biostratigraphic shipboard age model was refined in order to locate the event in the International Ocean Discovery Program Hole U1508C. Assuming linear sedimentation rates between tie points, using GPTS2012, the age of 41.38 Ma for the studied event identifies it as the LLTM.

No evidence for carbonate dissolution was observed across the study interval. Quantitative analyses of benthic foraminifera show changes in the relative abundance of species across the LLTM, but no extinctions. The dominance of dysoxic taxa (such as Lenticulina sp. or Uvigerina peregrina) and species of the Superfamily Buliminacea (e.g. Bulimina...
**Benthic foraminiferal response to the Middle Eocene Climate Optimum in the Tasman Sea (IODP Site U1511, Southwest Pacific)**

PEÑALVER-CLAVER Irene¹, DALLANAVE Edoardo², WESTERHOLD Thomas³, DICKENS Gerald R.⁴, SUTHERLAND Rupert² and ALEGRET Laia¹

¹Departamento de Ciencias de la Tierra, & IUCA, University of Zaragoza, Calle Pedro Cerbuna 12, 50009, Zaragoza, Spain; irenepc@unizar.es; laia@unizar.es.
²Faculty of Geosciences, University of Bremen, Bibliothekstraße 1, 28359, Bremen, Germany; edoardo@uni-bremen.de.
³MARUM, University of Bremen, Leobener Str. 8 D-28359, Bremen, Germany; twesterhold@marum.de.
⁴School of Natural Sciences, Trinity College Dublin, Dublin 2, Ireland; DICKENSG@tcd.ie.
²School of Geography, Environment and Earth Sciences, Victoria University of Wellington, PO Box 600, Wellington 6140, New Zealand; rupert.sutherland@vuw.ac.nz.

*Corresponding author

The gradual cooling trend of the Eocene was interrupted at ~40 Ma by a global warming event, the Middle Eocene Climatic Optimum (MECO). This long duration event (~500 ka) is marked by a negative δ¹⁸O excursion associated with a 3–6 °C global warming, an increase in atmospheric pCO₂ and shallowing of the carbonate compensation depth (CCD). Furthermore, using mineralogical and chemical analyses, significant changes in atmospheric and oceanic circulation dynamics are identified during the event.

Although the MECO is sometimes referred to as a hyperthermal event, it is an enigmatic case due to its differences with other Eocene hyperthermals, which normally display a rapid onset followed by a gradual return to roughly pre-event temperatures. In contrast, the onset of the MECO was gradual and it was followed by a rapid return to pre-event conditions. In addition, the onset of the MECO does not coincide with a global negative carbon isotope excursion in marine carbonates, and carbonate dissolution in the deep sea was greater than expected, raising questions about the carbon cycle dynamics during this warming event. Despite being key to unravel the relative role of changes in carbon flux vs. warming on the ocean floor, there are only a few studies focused on the MECO effects.

The MECO was recovered at Site U1511 during International Ocean Discovery Program Expedition 371 in the Tasman Sea. The site lies in the Tasman abyssal plain (at 4,858 m water depth), and Eocene sediments were deposited below the CCD. Calcareous microfossils are absent, but agglutinated benthic foraminifera are well preserved and the study of their assemblages allows us to investigate for the first time the assemblage turnover and paleoenvironmental changes across the MECO at abyssal depths.

Diversity of the assemblages is low throughout the study interval (<20 species identified), and the opportunistic species *Spiroplectammina spectabilis* peaked during the MECO. This species is interpreted as indicative of an elevated organic flux to the seafloor and/or high siliciclastic flux. The proliferation of this opportunistic species indicates environmental instability at the seafloor during the MECO. The combination of our results with published litho- and magnetostratigraphic studies and multi-elemental XRF data analyses will contribute to understand the effects of the MECO at abyssal depths. Furthermore, the comparison of our results with those observed across other events characterized by high temperatures and elevated pCO₂ levels will help understand how global changes affect the deep ocean and ecosystems.

**Response of foraminifera to anthropic changes in tidal channels from a tropical lagoonal system: Maricá-Guarapina Lagoonal System, Brazil**

PEREIRA Kettollen¹*, CAMARA Gabriel¹, DIAS Andriu¹, CARELLI Thiago¹ and LAUT Lazaro¹

¹Department of Natural Sciences, Universidade Federal do Estado do Rio de Janeiro - UNIRIO, Av. Pasteur, 458, Urca, Rio de Janeiro, Brazil; kettollen@gmail.com; gabriel.kauaicamara@gmail.com; andriu.dias@edu.unirio.br; tgcarelli@gmail.com; lazarolaut@gmail.com

*Corresponding author

Coastal lagoons show a high vulnerability to the effects of climate change and most of them are under accelerated process of environmental degradation promoted by several human activities. In order to mitigate these impacts, public agencies have implemented the dredging and opening of channels to increase the circulation of marine waters in the environment aiming to improve the system health. In southeastern Brazil, the Maricá-Guarapina Lagoonal System (MGLS) constituted by four interconnected lagoons (Maricá, Barra, Padre, and Guarapina) provides essential ecosystem services but it’s under accelerated process of pollution and silting. Benthic foraminifera have shown great potential for biomonitoring.
Barium incorporation of benthic foraminifera – high resolution proxy calibration from the natural laboratory of the Northern Aegean Sea

Petersen Jassin1, Bouhdayat Fatima1, Grunert Patrick1, Schleinkofer Nicolai2,3, Radatz Jacek2,3, Bahr Andre4, Mojtahid Meryem1, Pross Joerg1, Jorissen Frans1, and Schmiedl Gerhard6

1Institute of Geology and Mineralogy, Working Group on Micropalaeontology and Palaeoecology, University of Cologne, Otto-Fischer-Str. 14, 50674 Cologne, Germany; jassin.petersen@uni-koeln.de; bouhdayat.fatima@uni-koeln.de; pgrunert@uni-koeln.de
2Institute of Geosciences, Goethe University Frankfurt, Altenhöferallee 1, 60438 Frankfurt am Main, Germany; Nicolai.Schleinkofer@gmx.de; radatz@em.uni-frankfurt.de
3Frankfurt Isotope and Element Research Center (FIERCE), Goethe University Frankfurt, Germany; Nicolai.Schleinkofer@gmx.de; radatz@em.uni-frankfurt.de
4Institute of Earth Sciences, Heidelberg University, Im Neuenheimer Feld 234, 69120 Heidelberg, Germany; andree.bahr@geow.uni-heidelberg.de; joerg.pross@geow.uni-heidelberg.de
5LPG UMR CNRS 6112, University of Angers, UFR Sciences, 2 Boulevard Lavoisier, 49045 Angers Cedex 01, France; meryem.mojtahid@univ-angers.fr; frans.jorissen@univ-angers.fr
6Institute for Geology, Center for Earth System Research and Sustainability, Universitat Hamburg, Bundesstrasse 55, 20146 Hamburg Germany; gerhard.schmiedl@uni-hamburg.de
7Corresponding author

The barium cycle of the ocean is thought to be coupled to the marine carbon cycle; therefore, allowing the reconstruction of export productivity through the assessment of the Ba content in the geological record. In the upper water column of marginal marine settings, riverine input provides a source of Ba for the uptake in organic matter and the subsequent downward flux of particulate Ba, in addition to upwelled Ba. Thus, not only export productivity, but also riverine input can potentially be reconstructed from Ba in the (shallow) benthic realm. In this context, we want to address the specific question how the barium/calcium signal of a benthic foraminiferal test (Ba/Ca,raw) is formed. Benthic foraminifera colonize the sediment surface and precipitate their shell with an elemental and isotopic composition (e.g., δ13C) reflecting the surrounding bottom and pore water composition. We analysed, at high vertical resolution, the Ba/Ca ratios of live and dead specimens of Uvigerina mediterranea and Melonis affinis of seven core tops from several basins (water depths of 600-1500 m) within the Northern Aegean Sea (NAS). The transect spanning the different basins of the NAS shows a south to north gradient of increasing surface productivity and riverine input, setting the frame for the proxy calibration approach. In the Sporades Basin, the water column shows a vertically increasing gradient of dissolved Ba, which allows for the comparison to models.
and data of the Ba cycle from other regions with similar trends. Our strategy is to investigate external (sediment geochemistry, early diagenesis) and internal (ecology, biomineralization) aspects leading to the formation of $\text{Ba}/\text{Ca}_{\text{form}}$ in the complex present day situation of the NAS. We intend to refine and strengthen calibrations needed for the application of this proxy in the sedimentary record to reconstruct paleoenvironmental changes, and specifically export productivity, in this region. Novel high resolution Laser Ablation ICP-MS results show that besides biological factors (vital effects assessed from chamber-to-chamber variability), combined ecological-geochemical factors (the specific microhabitat depth of different foraminiferal species in relation to pore water redox zones assessed from inter-species comparison) can significantly influence the $\text{Ba}/\text{Ca}_{\text{form}}$ signal. This calls for species-specific calibrations, for which we show an example, and downcore applications.

**Planktonic foraminifera and paleoceanographic changes across the middle Cenomanian carbon-isotope excursion (MCE 1) in south-east England, UK**

PETRIZZO Maria Rose$^{1*}$ and GALE Andy S.$^{1,2}$

1Dipartimento di Scienze della Terra “A. Desio”, Università degli Studi di Milano, via Mangiagalli 34, 20133 Milano, Italy; mrose.petrizzo@unimi.it
2Department of Earth and Atmospheric Sciences, University of Nebraska, 126 Bessey Hall, Lincoln, NE 68588, USA; dwatkins1@unl.edu

Planktonic foraminifera were studied across the Mid-Cenomanian Event 1 (MCE 1, identified by a positive $\delta^{13}C$ excursion) at Lydden Spout, near Folkestone (Kent, south-east England, UK), the reference section of the middle Cenomanian Event 1 (MCE 1) characterized by a prominent double-peak $\delta^{13}C$ excursion of 1‰ identified in different ocean basins and considered a global event. Biostratigraphic and quantitative analysis of planktonic foraminifera are correlated to the carbon cycle perturbation that identifies the MCE 1, to the positive $\delta^{18}O$ shifts identified within the MCE 1, and to the occurrence of Boreal macrofossils (*Chlamys arleisienis*, *Oxytoma seminudum*, and *Præctinocamax primus*).

Planktonic foraminifera show moderate preservation, are common throughout the section and comprise 40-50% of total foraminiferal abundance, although the population is mainly composed by small-sized specimens (< 250 mm). Large-sized specimens become more common and show a continuous occurrence up-section after the termination of MCE 1. The stratigraphic interval studied is assigned to the *Thalmanninella greenhornensis* and *Rotalipora cushmani* Zones. Variations in abundance and species richness of the planktonic foraminifera are correlated with the inferred palaeoecological preferences of taxa and permit the identification of distinct palaeoenvironmental settings across the MCE 1.

The stratigraphic interval corresponding to the MCE 1 is characterized by the absence of single keeled oligotrophic rotaliporids, by the evolutionary appearance of double keeled meso-eutrophic dicarinellids, and by the appearance of *Muricohedbergella portsdownensis*, a species interpreted as a cold-water taxon that first appears at the same level of Boreal macrofossils, and a positive $\delta^{18}O$ excursion of bulk carbonate within the lower part of MCE 1. These observations point to a paleoceanographic scenario characterized by reduced stratification of surface waters and absence/disruption of the thermocline in a dominantly eutrophic regime during MCE 1.

Evidence provided by planktonic foraminifera, Boreal macrofossils and oxygen isotope records documented for the late Cenomanian Plenus Cold Event (PCE) at Eastbourne (UK) reveal similarities that confirm the periodic inflow of cold Boreal seawater originating in the Norwegian Sea as previously postulated to explain the occurrence of Boreal fauna in the Anglo-Cenomanian Plenus Cold Event (PCE) at Eastbourne (UK) reveal similarities that confirm the periodic inflow of cold Boreal seawater originating in the Norwegian Sea as previously postulated to explain the occurrence of Boreal macrofossils. The stratigraphic interval studied is assigned to the Cenomanian Plenus Cold Event 1 (MCE 1) in south-east England, UK.

**Turonian - Santonian paleoceanographic changes registered by planktonic foraminifera and stable isotopes at southern high latitudes**

PETRIZZO Maria Rose$^{1*}$, MACLEOD Kenneth G.$^{2}$, WATKINS David K.$^{3}$, WOLFGRING Erik$^{1,4}$ and HUBER Brian T.$^{3}$

1Dipartimento di Scienze della Terra “A. Desio”, Università degli Studi di Milano, via Mangiagalli 34, 20133 Milano, Italy; mrose.petrizzo@unimi.it; erik.wolfgring@univie.ac.at
2Department of Geological Sciences, University of Missouri-Columbia, 203 Geological Science Building, Columbia, MO 65211, USA; MacLeodK@missouri.edu
3Department of Earth and Atmospheric Sciences, University of Nebraska, 126 Bessey Hall, Lincoln, NE 68588, USA; dwatkins1@unl.edu
4Department of Palaeontology, University of Vienna, Josef Holaubek Platz 2, 1090 Vienna, Austria; erik.wolfgring@univie.ac.at
5National Museum of Natural History, Smithsonian Institution, MRC-121, Washington, DC, USA; huberb@si.edu

*Corresponding author

The Turonian to Santonian sedimentary record recovered at IODP Expedition 369 Site U1513 in the Mentelle Basin (eastern flank of the Naturaliste Plateau, SE Indian Ocean, paleolatitude 60°S at 85 Ma) is studied to interpret the
paleoceanographic evolution in the Southern Hemisphere. The changes in planktonic foraminiferal assemblage considering depth ecology preferences of different species and surface and seafloor temperatures inferred from the stable isotopic values measured on foraminiferal tests provide a valuable perspective on Late Cretaceous climate.

The hothouse climate during the Turonian - Santonian, characterized by weak latitudinal temperature gradients and high atmospheric CO₂ concentrations, is followed by a progressive cooling during the Campanian. At Site U1513 the beginning of this climatic transition is nicely recorded within the Santonian, as indicated by an ~1% increase in δ¹⁸O values of planktonic foraminifera suggesting a significant decline in surface water paleotemperatures of 4°C. The onset of cooling also recorded changes in the planktonic foraminiferal assemblages including extinctions among surface (Marginotruncana) and deep (Planoheterohelix papula) dwellers, appearances (Archaeglobigerina cretacea) and diversification of newly evolving taxa (Globoitruncana), and changes from predominantly epifaunal oxic to infaunal dysoxic/suboxic taxa among co-occurring benthic foraminifera.

Overall, the data presented here document an interval in the Santonian during which the rate of southern high latitude cooling increased. Both surface and bottom waters were affected, although the cooling signal is more evident in the data for surface waters. This pattern of cooling is in agreement with model simulations and paleotemperature reconstructions and ascribes the deterioration of the Late Cretaceous climate to decreased CO₂ in the atmosphere and changes in the oceanic circulation correlated with enhanced meridional circulation.

The Middle Miocene benthic foraminiferal assemblages from Krndija Mt. (Našice quarry, Croatia)

PEZELJ Đurdica¹, SABOL Jurica², KOVAČIĆ Marijan¹ and MARKOVIĆ Fran¹

¹Department of Geology, Faculty of Science, University of Zagreb, Horvatovac 102b, 10 000 Zagreb, Croatia; djurdjica.pezelj@geol.pmf.hr; markovic@geol.pmf.hr
²Museums of the Croatian Zagorje, Gornja Stubica, Samci 64, 49 245 Gornja Stubica, Croatia; jurica.sabol@mhz.hr
*Corresponding author

On the northern slopes of the Krndija Mt., near the Našice town, there is a large active quarry where the Middle and the Upper Miocene deposits are intensively excavated for cement production. During the Middle Miocene, this area of the North Croatian Basin was located on the southwestern margin of the Central Paratethys Sea and was part of the Pannonian Basin System. In the southern part of the quarry, the 100 m thick BG section consists of four lithofacies: algal limestones, bioclastic limestones, marls and pyroclastics. Due to the exploitation in the quarry, the new upper floors were opened, and the BGM5 section cropped out. In 58 m thick section, marls alternate with tufts and bioclastic limestones, with rare interlayers of clay. The marls are laminated and form beds ranging in thickness from a few cm up to 7 m. Alternation of dark beds with great amount of organic matter and light beds rich in carbonates can be observed at BGM5 section. Marl samples were processed by the standard wet sieving method, and micropaleontological analysis was made on standardized samples (of about 300 foraminiferal specimens). The analysis included study of taphonomic conditions of foraminiferal tests, quantification of planktonic vs benthic foraminifera (P/B ratio) and detailed analysis of small benthic foraminiferal assemblages.

Study of benthic foraminifera revealed continuity of sedimentation from the Badenian to the Sarmatian at BG section. The Late Badenian age of middle part of the section has been proven with index species Pappina neudorfiensis (TOULA), Uvigerina brunnensis KARRER and Bulimina insignis LUCZKOWSKA that are characteristic for the Bulimina-Bolivina zone. This part of section shows middle to outer shelf depositional settings with Valvulineria-Bolivina and Cassidulinina-Bolivina assemblages. The P/B ratio range is 41-81%, BFOI values vary between medium and low oxic conditions and benthic foraminifera assemblages reflect changes in nutrient input that triggers the fluctuation of oxygen content at the sea bottom. The upper part of succession, points to a shallowing upwards trend and sea-level fall at the end of the Late Badenian.

According to benthic foraminiferal assemblages the marls from top of the BG section and lower part of BGM5 section are attributed to the Anomalalinoides dividens zone/ecozone of the Lower Sarmatian. The age determination is based on the findings of the species Anomalalinoides dividens (LUCZKOWSKA), Elphidium hauverinum (d’ORBIGNY) and Bolivina sarmatica (DIDKOVSKY). The low values of P/B ratio (5-12%) indicate a shallow-water, inner shelf depositional setting, whereas greater values of the ratio (up to 49 %), found in some parts of the BGM5 section, suggest deepening of the Sarmatian paleoenvironment. Elphidium assemblage, typical for light marls, is dominated by epifaunal forms and herbivores. That benthic foraminiferal assemblage inhabited a normal marine highly oxic environment with lush vegetation on the sea floor. Bolivina assemblage is characteristic of dark marly beds and indicates a change in environmental conditions. Infaunal forms and detritivores dominate this assemblage being adapted to an environment with a lower oxygen content at the seafloor (moderate to low condition). Such alternation of benthic foraminiferal assemblages may indicate local sea level oscillations and/or changes in terrigeneous input caused by different rate of weathering.
Trimorphism in *Orbitolites complanata* Lamarck, 1801 from the Lutetian of the Paris Basin (France)

PIGNATTI Johannes¹*, MARIANELLI Diego² and OLIVERIO Dalila¹

¹Department of Earth Sciences, La Sapienza University, Piazzale Aldo Moro 5, Roma, Italy; johannes.pignatti@uniroma1.it; diego.marianelli@uniroma1.it; oliverio.1939817@studenti.uniroma1.it
²Corresponding author

Despite being one of the earliest described Eocene larger foraminifera, *Orbitolites* is a little investigated genus. Herein, we provide new evidence from three classical outcrops of the Paris Basin (Grignon, Chaussy and Villiers) where the preservation of matrix-free specimens is exceptional. First, a comment is needed on why we do not refer to this species as *O. complanatus*, as in current practice. In 1801, Lamarck unambiguously considered as feminine the gender of the genus of *Orbitolites*, describing both *O. complanata* and *O. concava*. Thus, *Orbitolites complanata* is not a typographical error, it is the correct form according to the current Code of Zoological Nomenclature (Art. 30.1.4.4). For over two decades, this is a serious avoidance issue in foraminiferal nomenclature: a feminine gender is correct for about 12% of the foraminiferal genus-group names ending in -*ites*, and about 18% of those ending in -*oides*.

In our material, we did not find any microspheric (B) forms. In contrast, the large number of sectioned megalospheric (A) forms from the three localities shows two groups of embryos, small-sized (mostly < 200 µm) and large-sized (> 300 µm). Normality tests confirm two A generations. Among the large-sized forms, both dumbbell-shaped and subspherical protoconchs occur, followed by an annular deuteroconch and auxiliary camberlets. Our data indicate unambiguously that in *O. complanata* from the Paris Basin two megalospheric generations are present. This trimorphism is interpreted as a simplesiomorphy of the Soritidae.

Insights into the benthic foraminiferal response to precessional forcing and environmental changes across the Messinian Salinity Crisis onset in the Sorbas Basin (SE Spain)

PILADE Francesco¹*, MANCINI Alan¹, PELLEGRINO Luca¹, LOZAR Francesca¹, SCHMIEDL Gerhard² and GENNARI Rocco¹

¹Dipartimento di Scienze Della Terra, Università degli Studi di Torino, Via Valperga di Caluso 35bis, I-10125 Torino, Italy; francesco.pilade@unito.it; alan.mancini@unito.it; lu.pellegrino@unito.it; francesca.lozar@unito.it; rocco.gennari@unito.it
²Institut für Geologie, Centrum für Erdsystemforschung und Nachhaltigkeit, Universität Hamburg, D- 20146 Hamburg, Germany; gerhard.schmiedl@uni-hamburg.de
*Corresponding author

The Messinian Salinity Crisis (MSC) is a geological event that occurred at the end of the Miocene epoch, resulting in the deposition of large volumes of evaporite sediments after 5.97 Ma in the Mediterranean region. Before the onset of the MSC, long-term tectonic processes and orbital variations triggered the step-wise restriction, finally resulting in extreme paleoenvironmental conditions with periodic changes in the marine realm.

The Perales section in the Sorbas Basin (SE Spain), provides an astronomically tuned sedimentary record that precisely documents these changes up to the onset of the MSC. This record displays alternating layers of sapropels, deposited during insolation maxima, and (brown) marls deposited during insolation minima, sometimes intercalated by diatom rich deposits. The uppermost 23 lithological cycles prior to the MSC onset (6.22 – 5.97 Ma) were investigated.

We conducted a detailed quantitative analysis of the benthic foraminifera (BF) combined with morphometric measurements of *Bolivina* specimens. Quantitative data were used to calculate the BF Oxygen Index (EBFOI), which estimates the dissolved bottom water oxygen content. These proxies were compared to previously published calcareous nanofossil and planktic foraminifer data to study the paleoenvironmental evolution at the sea floor and the planktic-benthic coupling.

High export productivity is linked to organic matter preservation and abundance of the *Rectuvigerina* spp. gr. during insolation minima in the lowermost cycles. The same mechanism is thought to trigger the deposition of sapropels, which is then maintained by water column stratification. The *Rectuvigerina* gr. becomes very rare after 6.145 Ma following a long-term decline, and finally disappears at 6.033 Ma, which reflects a significant reduction in oxygen content (EBFOI). Following the *Rectuvigerina* disappearance, buliminds and bolvinids alternate within the cycles. The latter taxa show statistically significant cyclical size variations in phase with oxygen changes, which should reflect also NO₃⁻ and food availability in the infaunal niches, all related to export productivity and water column stratification.

The MSC onset is preceded by a prolonged organic matter accumulation and sea-floor oxygen depletion, in an anomalous sedimentary cycle deposited during a phase of low eccentricity and reduced oscillation of the insolation index. The deposition of this anomalous cycle is triggered by a strong restriction of the Sorbas Basin, which received a large amount of nutrients from terrestrial runoff strongly impact the marine biota.
**Shared ancestry of algal symbiosis and chloroplast sequestration in foraminifera**

PINKO Doron1*, ABRAMOVICH Sigal1, RAHAV Eyal2, BELKIN Natasha2, RUBIN BLUM Maxim2, KUCERA Michal1, MORARD Raphael1, HOLZMANN Maria3 and ABDU Uri3

1Department of Earth and Environmental Science, Ben-Gurion University of the Negev, David Ben Gurion Blvd 1, Beer Sheva, Israel; doronpi@post.bgu.ac.il; sigalabr@bgu.ac.il.
2National Institute of Oceanography, Israel Oceanographic and Limnological Research, Tel Shikmona, 3108000, Haifa, Israel; eyalrahav@gmail.com; tashabelkin@gmail.com; mrubin@ocean.org.il.
3MARUM-Center for Marine Environmental Sciences, University of Bremen, Leobener Str. 8, 28359, Bremen, Germany; mkucera@marum.de; rmorard@marum.de.
4Department of Genetics and Evolution, University of Geneva, Quai Ernest Ansermet 30, 1211 Geneva 4, Switzerland; maria.holzmann@unige.ch.
5Department of Life Science, Ben-Gurion University of the Negev, David Ben Gurion Blvd 1, Beer Sheva, Israel; abdu@bgu.ac.il.

*Corresponding author

The mixotrophic benthic foraminifera have repeatedly established symbioses with various groups of algae and can engage in the sequestration of chloroplasts, known as kleptoplasty. So far, kleptoplasty has been documented exclusively in rotaliid foraminifera. Here, we report the discovery of kleptoplasty in the species *Hauerina diversa*, which belongs to milolid foraminifera. The discovery of kleptoplasty in the two main clades of foraminifera suggests that this phenomenon is more widespread than previously documented. We observed intact chloroplasts in clustered structures within the foraminiferal cytoplasm and estimated the phototrophic activity using an isotopically labeled carbon source that confirmed the photosynthetic activity of the 'stolen' chloroplasts inside the host cell. Phylogenetic analysis of 18S rRNA gene sequences showed that *H. diversa* branches as sister to symbiont bearing Alveolinidae. This is the first time a close relationship between kleptoplastic and symbiotic species has been documented. Analysis of ribosomal SSU rDNA and metagenomics revealed that alveolinid symbionts and kleptoplasts both belong to the same clade within Coscinodiscophyceae, a group of centric diatoms. This evolutionary linkage suggests a common ancestry of kleptoplasts and algal symbionts in foraminifera.

**Identification of environmentally relevant benthic foraminifera from the Skagerrak fjords by deep learning image modelling**

PLAVETIĆ Marko1*, JOSEFSON Mats2, HULTHE Gustaf2, HSANG Allison Yi3 and ASTEMAN POLOVODOVA Irina4

1Department of Biological and Environmental Sciences, University of Gothenburg, Carl Skottsbergs gata 22B, Gothenburg, Sweden; gusplavma@student.gu.se
2Oral Product Development, Pharmaceutical Technology & Development, Operations, AstraZeneca, Pepparedsleden 1, Gothenburg, Sweden;
3Department of Geological Sciences, Stockholm University, Svante Arrhenius väg 8, Stockholm, Sweden; allison.hsang@geo.su.se
4Department of Marine Sciences, University of Gothenburg, Carl Skottsbergs gata 22B, Gothenburg, Sweden; irina.polovodova@marine.gu.se

*Corresponding author

Over the several past decades there has been increasing interest in using foraminifera as environmental indicators for coastal marine environments. As compared to macrofauna, which are currently used in environmental studies, foraminifera offer several distinct advantages as bioindicators, including short generation times, high number of individuals per small sample volume, hard and durable tests with high preservation potential, and low cost of sample extraction. One of the main problems with foraminifera identification is reliance on manual identification and expert judgement, which is a tedious and slow process prone to errors and subjectivity. Deep learning, a subfield of machine learning, has emerged as a promising solution to this challenge, since a neural network can learn to recognize subtle differences in shell morphology that may be difficult for the human eye to distinguish. Benthic foraminifera mounted on microslides from several Skagerrak fjords including Gullmar Fjord, Hakefjord and Iddefjord were imaged using a Nikon SMZ-10 stereomicroscope and DeltaPix DP450 microscope camera. Images were then processed in Roboflow API, where individual foraminifera were labelled and classified. This resulted in 3003 images and 22,138 labelled individuals. Using the labeled images, a dataset was created to be used for deep learning training. We used the YOLO (You Only Look Once) v7 model implemented in the PyTorch framework, which has demonstrated state-of-the-art speed and performance for object detection as of the time of writing. Models were trained using a Nvidia RTX A4000 GPU (graphical processing unit). Preliminary results show a 90.3% mAP (mean average precision) and 78.8% mAP on the best and the worst performing models, respectively. Even though the imaging and labelling was done in a short amount of time, the results look promising and show that even a relatively small dataset can be used for training a reliable deep learning species identification model.
Assessing the impact of diagenetic bias on sea-level reconstructions spanning the last full glacial cycle based on deep-sea benthic foraminiferal stable isotope records

POIRIER Robert K.,1, BORRELLI Chiara2,3, FUNG Megan3, SCHALLER Morgan F.4 and KOZDON Reinhard5

1Florence Bascom Geoscience Center, U.S. Geological Survey, 12201 Sunrise Valley Drive, Reston, USA; rpoirier@usgs.gov
2Department of Earth and Environmental Sciences, University of Rochester, 120 Trustee Road, Rochester, USA; cborrelli@ur.rochester.edu
3Department of Earth and Environmental Sciences, California Lutheran University, 60 West Olsen Road #3700, Thousand Oaks, USA; mknflng@callutheran.edu
4Department of Earth and Environmental Sciences, Rensselaer Polytechnic Institute, 110 Eight Street, Troy, USA; schall@rpi.edu
5Lamont–Doherty Earth Observatory of Columbia University, 61 Route 9W, Palisades, USA; rkozdon@ldeo.columbia.edu
*Corresponding author

One of the emerging debates regarding past sea-level variability and its relevance to future change involves discrepancies between reconstructions based on deep-sea proxies and those based on modeling simulations and geologic data from land-based deposits during the last full glacial cycle (i.e., Marine Isotope Stage [MIS] 6-1, ~150-11 ka). For example, sea-level estimates derived from deep-sea benthic foraminiferal stable isotope records indicate a range of sea level between approximately 60 m and 90 m below present during MIS 3. In contrast, glacio-isostatic modeling and ice sheet reconstructions based on land-based geochronology range from ~30 m to 50 m below present. Similar offsets between proxy-based reconstructions and models exist throughout the record, with specific interest in MIS 5a, 5c, and 5e. We focus on the extent to which diagenetic alteration may have biased deep-sea benthic foraminiferal stable isotope records. Specifically, we generated new single-test stable isotope records on specimens of the genus Cibicidoides from Ocean Drilling Program Sites 846 (deep equatorial Pacific) and 929 (deep equatorial North Atlantic) spanning the last full glacial cycle. We measured the stable oxygen and carbon isotope ratios of ideally-preserved specimens (i.e., glassy), in addition to those being moderately- (i.e., pseudo-glassy) and poorly-preserved (i.e., frosty) to determine the extent to which inclusion of diagenetically altered specimens in pooled-test records may affect sea-level estimates. Using the results from only ideally-preserved specimens, as well as paired LA-ICPMS Mg/Ca measurements, we apply an ocean basin water mass-balance to calculate new sea-level estimates and compare them to land-based records.

Spreading of an alien benthic foraminifer in the North Sea: a reason to be worried?

POLOVODOVA ASTEMAN Irina1,2*, ALVE Elisabeth3, DOLVEN Jane K.2, ELIASSEN Nicole1, FERRARO Mattia1, HESS Silvia2, MORIN Filip1, PANOVA Marina1, RUMPFUHBER Nina1, SCHWEIZER Magali4, WIECHMANN Marlene R.1, MACHIUTE Adele1, CHOQUEL Constance1, FILIPSSON Helena L.5, SUNDBERG Per1, BERGSTROM Per1, RISEDROBAKKEN Bjørg6 and AASGAARD Sigrid2

1Department of Marine Sciences, University of Gothenburg, Sweden; irina.polovodova@marine.gu.se; marina.panova@marine.gu.se
2Department of Geosciences, University of Oslo, Norway; elisabeth.alve@geo.uio.no; silvia.heiss@geo.uio.no
3Geophysical Institute, University of Bergen, Bjerknes Centre for Climate Research, Norway; mattia.ferraro@uib.no
4Laboratory of Planetology and Geosciences (LPG) UMR6112, University of Angers; Nantes University, Le Mans University, CNRS, France; magali.schweizer@uni-angers.fr
5Department of Geology, Lund University, Sweden; constance.choqueil@geol.lu.se; Helena.filipsson@geol.lu.se
6NORCE Climate & Environment, Bjerknes Centre for Climate Research, Norway; bjri@norceresearch.no
*Corresponding author

In the Skagerrak-Kattegat (eastern North Sea), the alien benthic foraminifer Nonionella sp. T1 (previously referred to as “Nonionella stella”) was reported for the first time in 2011 and 2012 in the Swedish and southern Norwegian fjords, respectively. Based on dated sediment cores its first occurrence can be traced back to the 1980s in the Gullmar Fjord, to the 2000s in the Øresund and to 2010 in the Oslofjord. Since then, Nonionella sp T1 has spread all over the Kattegat and coastal Skagerrak, according to sampling campaigns performed between 2016 and 2022.

The species is now highly abundant in the entire Kattegat, including the Øresund, as well as in fjord mouths of the seasonally hypoxic Gullmar Fjord, the oxic Hakefjord and the long-term polluted Idefjord as demonstrated by molecular and morphospecies data. At the same time, Nonionella sp T1 is rare to absent in the Baltic Sea, Skagerrak deep basin and in deep fjords of western and northern Norway. This study shows some preliminary results on the species’ present distribution in the study area and raises questions about the driving factors and potential effects on the local biodiversity.
Distribution of the putative invasive species *Nonionella* sp. T1 in the Gullmar Fjord – What is its potential contribution to biogeochemical cycles?

POLOVODOVA ASTEMAN Irina¹*, CHOQUEL Constance²,³, MOURET Aurélie¹, SCHWEIZER Magali², L. FILIPSSON L. Helena², SCOZZINA Eva¹, METZGER Edouard¹ and GESLIN Emmanuelle³

¹Department of Marine Sciences, University of Gothenburg, Carl skottsbergs gatea 22 b, 41319 Göteborg, Sweden; irina.polovodova@marine.gu.se
²Department of Geology, Sövegatan 12, SE 22362 Lund, Lund University, Sweden; constance.choquel@geo.lu.se; helena.filipsson@geo.lu.se
³LPG UMR 6112, Université d’Angers, Nantes Université, Le Mans Université, CNRS, Laboratoire de Planétologie et Géosciences, 40000 Angers, France

*Corresponding author

Benthic foraminifera, both fossil and living, have been extensively studied in the seasonally hypoxic Gullmar Fjord (Sweden) for decades to decipher hydrographic changes and ecological status. In 2011, a non-indigenous species named *Nonionella* sp. T1 was discovered in the fjord for the first time. Here, we aim at evaluating its putative invasive behavior and life strategies by combining assemblage analyses of living foraminifera along a fjord transect of surface sediment (0-3 cm) together with four longer sediment cores (0.5-5 cm) from two stations at 51 m and 117 m water depth.

Our results showed that *Nonionella* sp. T1 collected in the surface sediment in September 2021 and 2022, was present in almost all the transect samples. This species dominated the living foraminiferal assemblages with an abundance between 15 and 72 %, at seven of the eight sites visited. The highest relative and absolute abundances were noted between 39 and 78 m water depth, proximal to the fjord mouth, with a reduced presence towards the deepest station and the fjord head. However, *Nonionella* sp. T1 was completely absent in the sandy sediments at the shallowest station (1 m water depth).

Sediment cores collected in November 2017 and May 2022 revealed that *Nonionella* sp. T1 exhibited higher abundance at 51 m water depth compared to 117 m. In a previous study, higher densities were observed at the station 51 m below the oxygenated sediment zone (< 2 mm depth), where high nitrate concentrations in pore waters were measured (2017 data). The authors demonstrated that *Nonionella* sp. T1 respirates nitrate and the pool of specimens denitrifies up to 50 % -- 100 % of the nitrate in sediment porewaters, revealing its non-negligible contribution to benthic denitrification. The 10-fold higher abundance of *Nonionella* sp. T1 recorded in 2022 (compared to 2017) supports previous hypotheses about their invasive character and alerts about their important role in the nitrogen cycle of the Gullmar Fjord. The results of this study highlight the need for continued monitoring of this invasive species, its spreading dynamics and ecological/biogeochemical impacts.

### Exploring the Larger Benthic Foraminifera Diversity and Deformities in the Hypersaline Arabian Gulf: An Update on the Ecological Aspects

PRAYUDI Sinatrya D.¹*, AMAO Abduljamiu O.², KORIN Asmaa¹,³ and KAMINSKI Michael A.¹

¹Geoscience Department, College of Petroleum Engineering and Geoscience, King Fahd University of Petroleum and Minerals, Academic Belt Road (Building 76), Dhahran, Saudi Arabia; g202114310@kfupm.edu.sa; g202212160@kfupm.edu.sa; kaminski@kfupm.edu.sa
²Center for Integrative Petroleum Research, College of Petroleum Engineering and Geoscience, King Fahd University of Petroleum and Minerals, Academic Belt Road (Building 78), Dhahran, Saudi Arabia; amao@kfupm.edu.sa
³Geology Department, Faculty of Science, Port Said University, 23rd December Street, Port Said City, Egypt; asmaa.elsayed@sci.psu.edu.eg

*Corresponding author

In the 1960s and 1970s, Professor John Murray conducted several studies on foraminifera in the hypersaline coastal and shallow marine environment of the Arabian Gulf. Murray focused mainly on the United Arab Emirates region, examining the variety of benthic foraminifera in the area and laying the foundation for the ecological studies of benthic foraminifera in hypersaline environments in and outside the Gulf. Murray’s six major publications revealed that the foraminiferal families Soritidae, Peneropilidae, and Nummulitidae were the main constituents of Larger Benthic Foraminifera (LBF) assemblage in the area, with the genus *Peneroplis* being the most prominent.

Since Murray’s work, the Arabian Gulf has seen an increase in the discovery of new LBF families. Our study aims to update his findings by visiting several interrelated studies after Murray’s studies and supported further by conducting field sampling in Saudi Arabia and Bahrain, with a focus on areas with different salinity levels. We also considered the abnormal morphologies frequently found in the Gulf. Our literature survey of 34 published and unpublished study about LBF (excluding Murray’s papers) in the entire Arabian Gulf reveals several key findings. The first findings are two additional families, Alveolinidae and Amphistegiidae, bringing the total number of LBF families to five compared with earlier reports. Secondly, the Peneropilidae, particularly the species *P. pertusus* and *P. planatus*, was found to be the most prevalent and widespread in the Arabian Gulf, followed by one member of genus *Coscinopora* (*C. hemprichii*). The third aspect of our reveals that only 7 out of 34 publication report deformities among LBF. In addition to fill the gap of some unexplored area, our field samples data of LBF from three localities (East Bahrain, Half Moon Bay, and Al-Uqayr) reveal that more than 40% of specimens are deformed, and moreover the proportion of deformities increases at higher salinity sites. In general, the adult or more developed younger stage displays more deformities than the juvenile or undeveloped later stage specimens (but these still exhibit deformities). We also discover that, according to the different salinity data, the number of genus *Peneroplis*...
is larger at higher salinities (over 50 PSU) in a 5:1 ratio than the number of genus Coscinospira, while the ratio for salinities between 40 and 50 PSU is equal to or higher.

These findings and our new discoveries have raised intriguing questions for future studies in the Gulf: how diverse the LBF are; what is the cause of morphological deformities in a hypersaline environment; and the resilience of foraminifera within the system, despite its initial characterization as being less diverse.

Can benthic foraminiferal morphological deformities be considered lethal in a natural hypersaline environment?

**Case studies at several localities of the western Arabian Gulf**

PRAYUDI Sinatrya D.1,2, AMAO Abduljamiu O.2, TAWABINI Bassam S.1, KORIN Asmaa1,3 and KAMINSKI Michael A.1

1Geoscience Department, College of Petroleum Engineering and Geoscience, King Fahd University of Petroleum and Minerals, Academic Belt Road (Building 76), Dhahran, Saudi Arabia; g202114310@kfupm.edu.sa; bassamsat@kfupm.edu.sa; g202212160@kfupm.edu.sa; kaminski@kfupm.edu.sa
2Center for Integrative Petroleum Research, College of Petroleum Engineering and Geoscience, King Fahd University of Petroleum and Minerals, Academic Belt Road (Building 78), Dhahran, Saudi Arabia; amao@kfupm.edu.sa
3Geology Department, Faculty of Science, Port Said University, 23rd December Street, Port Said City, Egypt; asmaa.elsayed@sci.psu.edu.eg

*Corresponding author

The occurrence of morphological deformities in benthic foraminifera is a well-known phenomenon across the world. Deformities can be caused by anthropogenic factors (i.e., heavy metals and nutrients), natural ecological factors (such as salinity, pH, and oxygen levels), and mechanical factors. While in general, their deformities for some species are not linked to the actual death of the organism based on culture experiments and field findings; only deformities attributed to decreasing pH as well as salinity, and heavy metals pollution are considered as main culprit. Only a small number of studies outline the impact of a high salinity environment, especially in a natural hypersaline environment such as the Arabian Gulf.

To address that point, we conducted our morphological abnormalities in foraminifera study in the western side of the Arabian Gulf, consisting of six representative localities with varying salinity. A standard procedure was used to identify living and dead specimens, including Rose Bengal staining, unbiased splitting, and dry sampling with approximately 300 specimens. We used several techniques to confirm the physio-chemical proxies from sea water and bottom sediments, both in the field (on-site parameter measurements) and in the laboratory. Substrate (sediments) underwent geochemical analysis for identifying heavy metals and total organic carbon (TOC) constituents, along with field physio-chemical data acquisition for the water such as salinity, temperature, and pH of the water. Our physio-chemical data results show the abnormal constraints within our study area mostly concerned from the above normal sea water salinity (hypersaline/>40 PSU), while the other parameters such as heavy metals and TOC are below the hazardous limit or even below detection limit. Analysis of the foraminifera assemblages results reveal that larger benthic foraminifera (LBF) such as the genera Peneroplis, Monasidium and Coscinospira have a very large proportion of morphological deformities (above 50% from the entire assemblages for each locality) and predominantly consist of dead specimens, while smaller benthic foraminifera (SBF) such as Quinqueloculina, Elphidium and Ammonia have fewer deformities, and some were pink-stained, and therefore alive at the time of collection.

Our initial findings suggest that foraminiferal assemblages that exhibit morphological deformities with different lethal effects are potentially triggered by elevated salinity. Our current conclusions can be employed as a future baseline for other localities that may be confronted by rising salinity in the future, even though more supportive investigations, such as culture-based experiments, are required to support the field observations.

Development of the Late Karpatian to Early Badenian benthic foraminifera assemblages in the Sava Sub-basin (Croatia), SW Central Paratethys

PREMEC FUČEK Vlasta1,2, HERNITZ KUČENJAK Morana2, GALOVIĆ Ines3, MATOŠEVIĆ Mario2, MIKŠA Goran2, HAJEK-TADESSE Valentina1, KRIZMANIĆ Krešimir2, BELAK Mirko1 and FUČEK Ladislav3

1Krvarić 36/1, 10000 Zagreb, Croatia; vlasta.pfuelcek@gmail.com
2E&P Laboratory, INA-Industrija Nafta, d.d., Lovinčićeva 4, 10000 Zagreb, Croatia; morana.hernitz-kucenjak@ina.hr; mario.matosevic@ina.hr; goran.miksa@ina.hr; kreznor.krizmanic@ina.hr
3Croatian Geological Survey, Sachsova 2, 10000 Zagreb, Croatia; ingalovic@hgi-cgs.hr; tadesse@hgi-cgs.hr; mbelak@hgi-cgs.hr; lfucek@hgi-cgs.hr

*Corresponding author

The Miocene sediments of the North Croatian Basin belong to the south-western margin of the Central Paratethys. In this study, we described the benthic foraminiferal assemblages that inhabited the new marine environments in the Sava sub-basin during the Late Karpatian and Early Badenian in two localities: 1) Cučerje (Plaz) locality on the NW margin of the Sava sub-basin, and 125 km away 2) Tisovac locality, situated on the SE margin, respectively. The age of the marine sediments was determined according to the calcareous nannoplankton, which belongs to NN4 and NN5 Zones; i.e. regional MNN4c and MNN5a Zones.
During the Late Karpatian, in the Čučerje, marls were generally deposited on a mid-outter shelf, in a sedimentary basin that had a restricted connection with the Mediterranean during the M2 climatic event. The benthic foraminiferal assemblage is characterized by low biodiversity and the dominance of Bulimina subalata and Cibicidoides pseudooungerianus, while the species Favulina hexagona, Pappina primiformis, Melonis pompiiloides, Spiroloculina canaliculate and Bolivina hebes are represented with a smaller number of specimens. The Early Badenian assemblage of moderate diversity is characterized by the first appearance of the warm-water taxa Glabratella sp. and Pararotalia sp., and higher percentage of planktonic foraminifera (up to 50%), indicating a warmer climate and open connection with the Mediterranean Sea. With the progress of transgression and the creation of the new environments, the community becomes richer both in the number of species and the number of individuals. Dominant species are Uvigerina macrocarinata and Spirorutilis carinatus, while Schlumbergerina, Heterolepa, Cibicidoides, and Siphonina occur frequently. The species such as Lobatula lobatula, Quinqueloculina mammilla, Elphidium rugosum, and Pararotalia aculeata are present in smaller numbers. The upper part of the Lower Badenian, consisting of silty and sandy sediments, present a shallowing-upwards cycle. In these sediments, the predominantly infaunal benthic assemblage has been replaced by a shallow, warm-water community with Elphidium spp., Ammonia viennisens, Porosononion granosum, Pararotalia aculeata, and Amphistegina mammila.

In the southeastern part of the Sava sub-basin, in the Tisovac locality, the beginning of the marine transgression in the Late Karpatian is marked by a small and poor community with only a few specimens of Bulimina subalata, Bolivina sp., and Nonion sp. Already in the next sample, this community increases and is characterized by the dominance of the species C. pseudooungerianus and Ammonia viennisens, and by the presence of the genera: Cibicidoides, Lenticulina, Heterolepa, Sigmoilinita, Valvulinera and Guttulina. With the maximum marine transgression in the Lower Badenian, the community reaches an abundance of about 32 species. The most important genera are Schlumbergerina, Lobatula, Cibicidoides, Elphidium, Neocorbina, and Heterolepa. In the upper part of the Lower Badenian, Schlumbergerina, Cibicidoides, Bulimina, and Sigmoilinita are still frequent, but the share of agglutinated species such as Haplophragmoides, Cyclamina and Textularia, significantly increase, making up to 20% of the community.

During the Late Karpatian and Early Badenian infaunal benthic foraminifera, together with Cibicidoides spp. were pioneers in the settlement of the new marine environments on the southwestern margin of the Central Paratethys.

Using electron backscatter diffraction to investigate shell microstructure and preservation impacts on planktonic foraminiferal calcite

PROCTER Frances1, PIAZOLO Sandra1, JOHN Eleanor2, WALSHAW Richard1 and AZE Tracy1

1School of Earth and Environment, University of Leeds, LS2 9JT, UK; gy14fap@leeds.ac.uk; S.Piazolo@leeds.ac.uk; R.D.Walshaw@leeds.ac.uk; T.Aze@leeds.ac.uk
2School of Earth and Environmental Sciences, Cardiff University, Main Building, Park Place, Cardiff, CF10 3AT, UK; JohnE11@cardiff.ac.uk

*Corresponding author

A growing body of research is focussed on understanding the mechanistic processes of biomineralisation, and many of the processes involved in biomineralisation are currently poorly constrained. In this work we present novel data visualizing the internal microstructure and preservation quality of planktonic foraminiferal calcite, using electron backscatter diffraction analysis (EBSD). EBSD is an SEM-based microscopy technique that enables microstructural crystallographic characterization at high resolution, where intra-test crystal structure can be visualized and geometrically quantified. Here we present microstructural EBSD data, paired with chemical electron microprobe analysis (Mg/Ca) for both well preserved and diagnostically altered specimens of the Neogene species Globigerinoides ruber (cancellate wall texture) and the Paleogene species Morozovella crater (muriicate wall texture). Well preserved specimens are assumed to be representative of the original calcite microstructure for each species and accordingly shed light on biomineralisation processes. EBSD crystal maps and associated pole plots show the shell is composed of mesocrystals (0.4 - 110 μm), and the preferred crystallographic orientation of calcite growth is shown to be perpendicular to the growth surface. By contrast specimens that have been diagnostically altered have strikingly different EBSD maps and whilst preferred crystal orientation is preserved, much of the original biogenic calcite structure is lost via replacement with inorganic crystal precipitation. We link our EBSD observations to quantitative electron microprobe analysis Mg/Ca distribution datasets, and find that the Mg/Ca banding that is typical of primary biogenic calcite is intact in our well preserved specimens, but is largely absent in our poorly preserved specimens. Our results shed light on the biomineralisation processes of two species with distinct wall textures, but also highlight the extent to which microstructural reorganization due to diagenesis can impact geochemical signals.

Menthol-induced bleaching of Amphistegina lobifera and investigation on diatom photosymbiont flexibility

PUERTO Diana1*, STUHR Marleen2 and SCHMIDT Christiane2

1Department of Marine Biology, University Bremen, Bibliothekstr. 1, Bremen, Germany; dipuerto@uni-bremen.de
Large benthic foraminifera (LBF) are unicellular eukaryotes that occur in oligotrophic (sub-)tropical shallow-water environments, such as coral reefs. Because LBF host endosymbiotic algae that are sensitive to temperature and other environmental changes, as corals, they are vulnerable to bleaching (loss of photosymbiotic algae and pigments associated). However, the uptake of new symbiont strains after bleaching events and the symbiont flexibility of LBF remains widely unresolved. To better understand bleaching and symbiont flexibility, the bleaching agent menthol combined with the photosynthetic inhibitor DCMU has been used on several coral reef organisms hosting dinoflagellates. More recently, menthol-induced bleaching has been tested for the first time on the diatom-bearing LBF Amphistegina lobifera and the dinoflagellate-bearing Sorites orbiculus. Bleaching was achieved in ~97% of organisms over a six-week experiment, which showed that menthol bleaching is an effective method to rear foraminifera aposymbiotic. However, re-inoculating new symbiont strains on LBF after menthol-bleaching treatment has not yet been tested.

This project, therefore, aims to investigate whether there is a significant difference in the rate and effectiveness of bleaching between two size classes of A. lobifera (0.5-1 mm and 1-2 mm) collected from the Red Sea, Israel, to assess if choosing smaller species for aposymbiosis investigations has an advantage on bleaching success and survivorship. Furthermore, the aim is to assess the capacity of aposymbiotic LBF to take up diatom strains and re-establish symbiosis. Bleaching and re-inoculation will be measured through the reduction of symbiont and uptake of new strains in menthol-bleached hosts using symbiont density analysis of images taken via confocal laser-scanning microscopy (CLSM) weekly. Furthermore, Pulse-Amplitude Modulated (PAM) fluorometry measurements will be used to assess photosynthetic efficiency during menthol-bleaching and after the uptake of newly re-inoculated symbiont strains to confirm the re-establishment of symbiosis.

The results showed a ~85-93% reduction of diatom density compared to initial levels in A. lobifera in the 1-2 mm size class and ~73-92% bleaching in the 0.5-1 mm size class. The results showed that bleaching is successful, with slightly higher success rates in the larger specimens, and that most likely a six-week phase would allow rearing the LBF fully aposymbiotic.

For the following re-inoculation experiment, the aposymbiotic foraminifera will be incubated with diatoms that have previously been found to be hosted in A. lobifera from the northern Red Sea, such as Minutocellus spp., Nitzschia spp., and Fragilaria spp. To our knowledge, this is the first study to experimentally determine symbiont flexibility in LBF using the menthol-bleaching approach. The findings of our study will have implications for understanding the ecological role of thermally tolerant symbionts and their preferential incorporation in the host within coral reef ecosystems. Successful re-inoculation can provide a first understanding of symbiont flexibility as an adaptive trait of LBF.

Benthic Foraminifera of the Albain-Cenomanian (Cretaceous) Washita Group in North-Central Texas, USA

RASHALL Jenny¹, NESTELL Galina² and NESTELL Merlynd²

¹Department of Chemistry and Biochemistry, University of Texas at Tyler, 3900 University Boulevard, Tyler, TX 75799, USA; jrashall@uttyler.edu
²Department of Earth and Environmental Sciences, University of Texas at Arlington, 500 Yates Street, Arlington, TX 76019, USA; gnestell@uta.edu
*Corresponding author

The upper Albian-lower Cenomanian (mid-Cretaceous) Washita Group of North-Central Texas consists of nine formations (in ascending order): Kiamichi, Duck Creek, Fort Worth, Denton, Weno, Paw Paw, Main Street, Grayson, and Buda formations. Apart from the Kiamichi Formation, which is a shaley claystone, the Washita Group comprises alternating marl and limestone beds deposited in the shallow, epeiric seaway that flooded the region during the late Albian and early Cenomanian. The diverse and well-preserved benthic foraminiferal assemblages of the Washita Group of North-Central Texas were well documented throughout the early to mid-twentieth century by several foraminiferal workers, including H. Tappan, A. Loeblich, and F. Lozo, among others. Nearly two hundred species of mid-Cretaceous benthic foraminifers were identified from the area within two decades. However, few recent studies have sought to review these species since their initial descriptions for instances of synonymy or misidentification, or to investigate the full stratigraphic range of species beyond the formation from which they were initially described. The purpose of this study is to re-evaluate the taxonomy of the Washita Group foraminiferal assemblages and provide insight on the overall distribution of foraminiferal species.

One hundred and thirty-one samples from 21 localities of the Washita Group of North-Central Texas were included in this study. Materials from all formations of the Washita Group were studied, except for the Buda Formation that rarely outcrops in North-Central Texas. Samples include collections of the present authors for the purpose of this study, as well as samples collected by F. Lozo, A. Loeblich, and H. Tappan, which were loaned to the authors by the Department of Paleobiology at the Smithsonian National Museum of Natural History (NMNH). Type material of species originally described from North-Central Texas deposited in the NMNH Cushman Collection was used to aid in species determination.

From the studied material, 84 species of benthic foraminifers have been identified, 25 of which are agglutinated. Of the species identified, six are new and yet to be described. The species considered new by the authors were previously included...
Middle Pennsylvanian-Cisuralian (Early Permian) fusulinids from the Cache Creek Complex near Meadow Lake, southern British Columbia, Canada: An exotic fauna with Paleo-Tethyan affinities

Michael T. Read and Merlynd K. Nestell

Upper Moscovian (Middle Pennsylvanian) to Artinskian (mid-Cisuralian) isolated limestone exposures of the Cache Creek Complex northwest of Meadow Lake, British Columbia, yield rich and diverse fusulinid assemblages with distinct paleobiogeographic affinities to Eurasian Paleo-Tethyan faunal realms. The Cache Creek Complex, or the Cache Creek terrane, comprises a narrow, elongate band of amalgamated tectonic blocks of considerable lithologic variability (e.g., limestone, chert, argillite, volcanic units, intrusive bodies, ultramafic units) extending from southern Yukon to southern British Columbia. Collectively, the Mississippian to Jurassic rock bodies of the Cache Creek Complex are interpreted to be the obducted remains of various bathymetric high features that developed in the Panthalassic Ocean, with the upper Paleozoic units likely originating as oceanic plateaus or seamounts in the far westmost portion of Panthalassa, adjacent to the eastern Paleo-Tethys Ocean. The Cache Creek terrane was subsequently accreted during the Late Jurassic to the North American Plate as part of composite blocks associated with the surrounding Quesnel and Stikine terranes.

Although fusulinid taxa of known Paleo-Tethyan affinity have been recognized in the allochthonous, unstratified limestone bodies of the Cache Creek Complex since the late 1870s, only a few studies have been conducted on the Pennsylvanian and Cisuralian fusulinids of the accretionary complex. This paucity of research is a consequence of the rather limited areal extent, protracted temporal range, and lithologic heterogeneity of the Cache Creek Complex. The few other investigations of Pennsylvanian and Cisuralian fusulinid faunas of the Cache Creek Complex have been mostly concerned with sections of the so-called Pope succession near the town of Fort St. James, British Columbia, located approximately 380 kilometers to the north-northwest of Meadow Lake. To date, the Late Moscovian to Artinskian fusulinids of the Meadow Lake area have only received the preliminary treatment of a 1970 abstract by M.K. Nestell and the late W.R. Danner. The present study is a taxonomic re-evaluation and augmentation of the initial report by these authors.

In total, 21 fusulinid species of 17 genera have been identified from 12 sampling locations in the study area. Although the Meadow Lake exposures preserve a disordered and stratigraphically discontinuous record, the recovered fusulinid collections provide a number of significant findings that are of interest. First, the recovered fusulinid collections have been identified with the following age constraints for the 12 sampling locations: upper Moscovian (one site), lower Kasimovian (one site), middle Kasimovian (one site), upper Kasimovian (one site), middle Gzhelian (two sites), lower Asselian (five sites), and Artinskian (one site). No Sakmarian fusulinids were collected from the study area. The assemblages include both taxa that were previously unreported from the Cache Creek Complex and forms already known to occur in the east-equivalent Pope succession. Fusulinid genera collected for the first time from the Cache Creek Complex include Cervoschwagerina, Eoparafusulina, Pseudochusenella, Raurerites, Schellwienia, and Sphaeroschwagerina. Previously reported genera included Carbonoschwagerina, Cuniculinella (reported as “Chalaroschwagerina”), Fusulinella, Nankinella, Obsoletes (reported as “Protriticites”), Pseudoschwagerina, Quasifusulina, Quasifusulinoides (reported as “Quasifusulina”), Schubertella, Schwagerina, and Tristix. Many of the fusulinid species found in the Cache Creek Complex are not known to occur elsewhere in North America, but the presence of critical Paleo-Tethyan marker taxa in the assemblages permits zonal correlations to be made with a number of thoroughly studied Eurasian localities, including (but not limited to) the Carnic Alps (Central Europe), the Donets Basin (eastern Ukraine), the Russian Platform, the Darvaz (Central Asia), western Guizhou (South China), and the Akiyoshi, Chichibu, and Mino terranes (southern Japan).
Evaluation of the effects and emerging perspectives of electric current stimulation on larger benthic foraminifera: a case study on the genus *Amphistegina*

REBECCHI Federica1*, LATTANZI Davide2, ABRAMOVICH Sigal3, AMBROGINI Patrizia2, CIACCI Caterina2, BETTI Michele2, SCHMIDT Christiane1 and FRONTALINI Fabrizio1

1Department of Pure and Applied Sciences, Urbino University, Via Ca’ le Suore 2, Urbino, ITA; frebecchi@campus.uniurb.it; fabrizio.frontalini@uniurb.it
2Department of Biomolecular Science, Urbino University, Via Ca’ le Suore 2, Urbino, ITA; davide.lattanzi@uniurb.it; patricia.ambrogini@uniurb.it; caterina.ciacci@uniurb.it; michele.betti@uniurb.it
3Department of Earth and Environmental Sciences, Ben Gurion University of the Negev, P.O.B 653, Beer Sheva, ISR; sigalabr@bgu.ac.il

Many marine animals are electrorreceptive species being capable of detecting natural electric fields in their environment and utilize them in important life processes such as movement, orientation, and foraging. However, our understanding of how animals, particularly benthic organisms, interact with anthropogenic sources of electric fields remains quite limited. Among benthic organisms, foraminifera are commonly used as bioindicators in marine environments, but studies on the effects induced by electrical stimulation are not documented. Here we provide an overview of the effects of different electrical stimulation on a larger benthic foraminiferal species. Specifically, we document the effects of short-term exposure (72 h) to different electric current densities on the viability of benthic foraminiferal species *Amphistegina lessonii* by checking the pseudopodal activity and defining the tolerance to different electrical densities (range 0.29 to 20 µA/cm²). After 3 days of treatment, *A. lessonii* stimulated with constant direct current showed pseudopodal activity at lower electric current densities (0.29, 0.86 µA/cm²) up to 24 h. With increasing stimulation time, the percentages of pseudopodal activity decreased and pseudopodal activity was basically absent at high current densities (5.71 and 8.57 µA/cm²). The viability of *A. lessonii* exposed to pulsed direct current is higher at low and middle electric current densities (from 0.29 to 5.71 µA/cm²) than at high electric current density (from 11.43 to 20 µA/cm²). Based on these results, the selected benthic foraminiferal species seems to better stand pulsed direct currents than constant ones, which will also be used in subsequent experiments.

Furthermore, electrical stimulation could be responsible for oxidative stress as revealed by several biomarkers (i.e., proteins and enzymes). We also document the effect of different low pulsed direct electric current densities on the photosynthetic activity (Pulse Amplitude Modulated Fluorometry, PAM) of *Amphistegina* diatom endosymbionts to determine their photosynthetic performance. Finally, we evaluate whether the electrochemical technique used in this study could promote the precipitation of dissolved ions in seawater and its consequent effect on the growth rate of *Amphistegina*. With this experimental work, we hope to increase the knowledge of electrostimulation on the important protist *Amphistegina* and evaluate at which current densities the stimulation can have a positive effect.

ExploRarE: Exploring the potential of REEs as productivity indicators in planktonic foraminifera along western Iberian Margin

REBOTIM Andreia1,2*, SALGUEIRO Emilia1,2, MATOS Lélia1,2, LOPES Cristina1,2, VOELKER Antje H.L. 1,2, BRITO Pedro A.1 and ABRANTES Fátima1,2

1Instituto Português do Mar e da Atmosfera, I.P. (IPMA, IP), Av. Alfredo Magalhães Ramalho 6, 1495-165 Algés, Portugal; andreia.rebotim@ipma.pt; emilia.salgueiro@ipma.pt; lelia.matos@ipma.pt; cristina.lopes@ipma.pt; antje.voelker@ipma.pt; pbrito@ipma.pt; fatima.abrantes@ipma.pt
2Centro de Ciências do Mar do Algarve (CCMAR), Universidade do Algarve, Campus de Gambelas, 8005-139 Faro, Portugal; andreia.rebotim@ipma.pt; emilia.salgueiro@ipma.pt; lelia.matos@ipma.pt; cristina.lopes@ipma.pt; antje.voelker@ipma.pt; fatima.abrantes@ipma.pt

*Corresponding author

The carbon dioxide (CO₂) emitted to the atmosphere since the Industrial Revolution led to a global, unprecedented increase of its concentration from 280 ppm to over 400 ppm. The ocean has been absorbing around 30%, partly compensating the excess of atmospheric CO₂ with drastic impacts on the Marine environment, including changes in productivity. The Eastern Boundary Upwelling Systems (EBUS) are among the world’s most productive ocean ecosystems, playing also an important role in the atmospheric CO₂ sequestration. Three out of the four global EBUS are already suffering the effects of climate changes with winds intensification whereas for the Canary/Iberian EBUS the impacts remain uncertain. The Iberian EBUS supports large communities that are socio-economically dependent on this system. Thus, it is critical to understand how it is responding to climate-driven changes and how it will evolve in the future. One way of addressing this question is by establishing the differences between anthropogenic and natural climate variability, by using productivity tracers. Though over the last 50 years, several methods have been applied to reconstruct productivity, each of them holds specific limitations. Hence, the search for more robust, high-fidelity productivity proxies is still necessary. For a long time, rare earth elements (REEs) were recognized as having potential to reconstruct past ocean conditions. Since then, several methodologies have been tested and applied, yet, there is no clear agreement on which cleaning methodology is more efficient to use for REEs measurements. To address this subject, one of the objectives of the ExploRarE project is to evaluate four cleaning procedures: 1) oxidation; 2) oxidation and reduction using hydrazine; 3) oxidation and reduction with sodium.
the Mg/Ca proxy in these regions. In these parts of the ocean. Because of this, data from surface sediments in the eastern Mediterranean Sea and Red Sea have
regions of high salinity, high-Mg overgrowths can impact foraminifera in the sediment, leading to anomalously high Mg/Ca
the magnesium concentration, salinity, and pH of the water in which the test grew, along with species-specific effects. In
reconstruct past climate. In addition to temperature, incorporation of magnesium into planktic foraminiferal tests is related to

(Meta)Barcoding all forams - An invitation to contribute to the Foraminifera Reference Database ForamBase

RENEMA Willem1,2*, GIRARD Elsa B.1,2 and MACHER Jan-Niklas1

Consistent taxonomic assignments are essential for cross comparison of results between regions and studies. Reference
databases are critical resources for molecular analysis and taxonomy, but only have value when entries are properly
illustrated and placed in a solid taxonomical framework. Despite the high diversity and ecological importance of
Foraminifera in many marine ecosystems, there is currently no integrative database containing nuclear and mitochondrial
sequences, photos and metadata for Foraminifera. We propose to build such a centralised database for Foraminifera based on
existing resources and available databases, providing an invaluable tool for understanding foram ecology, taxonomy, and
global scale geographical and ecological patterns.

To achieve this, we invite you to share Foraminifera samples suitable for molecular work and collaborate across
institutions to build this resource for the foram community. We are building a reference database containing at least nuclear
(18S) and mitochondrial (COI) markers, which will be complemented with photos, CT-scans, and additional molecular
sequences. Our ultimate goal is to publish a comprehensive foraminifera reference database with a group author. All
contributors to the database will be acknowledged by co-authorships.

Participating in the effort to build the ForamBase will be straightforward - share your foram samples or sequences with us, and your name and affiliation will automatically be added to the group author ForamBase_Contributors of the database manuscript. We envision the ForamBase becoming the new baseline resource for molecular foram taxonomy, enhancing our understanding of foraminifera diversity, their ecological role and evolutionary significance.

Thank you for considering our invitation. We look forward to collaborating with you to enhance the scientific community's understanding of foraminifera.

Assessing seasonal, size, and depth-related influences on planktic foraminiferal Mg/Ca ratios in the eastern
Mediterranean Sea through comparison of sediment trap and surface sediment samples

RICE Addison1, MELIS BESTARD Neus1, FRAUENSCHUH Saskia1, ZIEGLER Martin1, REICHART Gert-Jan1,2*, DE NOOIJER
Lennart1, LOURENS Lucas1, DE LANGE Gert1, PETERSE Francien1 and SLUIS Appy1

Paleoceanographic studies often use the temperature dependence of the Mg/Ca ratio in foraminiferal calcite to
reconstruct past climate. In addition to temperature, incorporation of magnesium into planktic foraminiferal tests is related to
the magnesium concentration, salinity, and pH of the water in which the test grew, along with species-specific effects. In
regions of high salinity, high-Mg overgrowths can impact foraminifera in the sediment, leading to anomalously high Mg/Ca
in these parts of the ocean. Because of this, data from surface sediments in the eastern Mediterranean Sea and Red Sea have
been removed from calibration sets even in the absence of such overgrowths, leading to greater uncertainty when applying
the Mg/Ca proxy in these regions.

We assess samples from a sediment trap series in the oligotrophic Ionian Sea. The traps collected material at
assessed for species assemblage and the size of individuals. Specimens of *Globigerinoides ruber* (white) dominate the assemblage year-round, but the largest sizes and greatest numbers occur during late summer. However, specimens in the studied trap samples are thus far smaller than the size fraction typically targeted in sediments (>250 μm). Based on notes taken during sample retrieval and splitting, large planktic foraminifers were not captured in this sediment trap series, which was collecting over the course of 20 years (1991-1994, 1999-2006, 2008-2011), raising questions on the circumstances which would lead to the growth of larger *G. ruber* (white) in this region. Species and size assemblage will be determined in a nearby surface sediment sample for comparison.

Mg/Ca in *G. ruber* (white) specimens from six summer samples in 1999 and 2000 (32 specimens) and one winter sample in 2001 (7 specimens) were measured using LA-ICP-MS. Between one and five spots located on the final three chambers were measured on each specimen. Results from the two seasons are not statistically distinct. Final chamber Mg/Ca is somewhat higher on average in the winter sample (3.0 mmol/mol; stdev = 1.2; n = 15 shots) than in the summer samples (2.6 mmol/mol; stdev = 0.8; n = 58 shots). Similarly, Mg/Ca ratios in the previous two chambers are higher in the winter sample (4.4 mmol/mol; stdev = 1.1; n = 13 shots) than in the summer samples (3.9 mmol/mol; stdev = 0.8; n = 59 shots). Final chamber Mg/Ca values are lower than in previous chambers, consistent with previous literature. These results suggest that the foraminifera dwell below the surface mixed layer in summer, where water temperatures are similar to winter mixed layer temperatures.

These results confirm the summer seasonal bias of foraminifera-based proxies in this region, but pose questions to the origin of larger (>250 μm) specimens and the validity of using foraminifera growing at depth as an indicator of summer sea surface temperatures. Implications for proxy reconstructions and plans to expand the dataset will be discussed.

Assessing the use of carbon isotope between epifaunal and shallow infaunal as a proxy for paleo-productivity in the Southeast Pacific

REYES-MACAYA Dharmar,1,2,3, GARRIDO Sebastian,1,2, HEBBELN Dierk, 2, GLOCK Nicolaas,4, HERNANDEZ Ivan,5, TAPIA Raul,6, MICHEL Elisabeth,7, CORDOVA Kathy,8, FLORES Edgar,9, BARRAGAN-MONTILLA Sofia,10, VILLALOBOS Katherine,10, MENA Valentina,11, CARDICH Jorge,12, ROMERO Dennis,13, SAVICKAITE Kotryna,13, KUHNERT Henning,14, BARANOWSKI Ulrike,15, MOHTADI Mahyar,2, LENG Melanie,13, GAYO Eugenia,1 CASTILLO Alexis,1, DIZ-FERREIRO Paula10 SCHMIEDEL Gerhard,15, SOTO-SARAVIA Ricardo1, HOOGAKKER Babette1

1Lyell Centre, Heriot-Watt University, Research Avenue South, Riccarton, EH14 4BA, Edinburgh, UK; d.reyes_macaya@hw.ac.uk; sag15@hw.ac.uk; b.hoogakker@hotmail.com 2MARUM - Center for Marine Environmental Sciences, Leobener Str. 8, 28359, University of Bremen, Bremen, Germany; d.reyes_macaya@hw.ac.uk; dhebbeln@marum.de; sobarraganmo@gmail.com; kkuhnert@marum.de; mmnohtadi@marum.de 3ANID-Millennium Science Initiative Program, Núcleo Milenio UPWEML, Raul Bitran 1305, 1720256, La Serena, Chile; d.reyes_macaya@hw.ac.uk; sag15@hw.ac.uk; kenagayah@gmail.com; acastillo@ucm.cl 4Centre for Earth System Research and Sustainability, Institute of Geology, University of Hamburg, 20146, Hamburg, Germany; nicolaas.glock@uni-hamburg.de; gerhard.schmiedl@uni-hamburg.de 5Department of Earth Sciences, ETH, Zürich, Sonneggstrasse 5, 8092, Zürich, Switzerland; ivan.hernandez@erdw.ethz.ch 6Institute of Oceanography, National Taiwan University, No. 1, Sec. 4, 106319, Taipei, Taiwan; raultapia@ntu.edu.tw 7Laboratoire 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, Gilil sur Yvette Cedex, France; elisabeth.michel@lsce.ipsl.fr 8University Permana Cayetano Heredia, Lima, Avenida Honorio Delgado 430, San Martin de Porres 15102, Lima, Peru; lisyric25@gmail.com; jorge.carich.s@upch.pe 9Facultad de Ciencias Naturales y Oceanograficas, Universidad de Concepcion, Barrio Universitario, Casilla 160-C, Concepcion, Chile; edgar.flores@imo-chile.cl; vmena2019@udec.cl; risoto@udec.cl 10Chemical Oceanography Laboratory, Facultad de Ciencias del Mar, Universidad Catolica del Norte, Larrondo 1281, 1781421, Coquimbo, Chile; kvillalobosmartinez@gmail.com; praxedes@ucn.cl 11Instituto del Mar del Perú, Esquina Gamarra y General Valle S/N Chucuito, Callao, Lima, Peru; dromero@imarpe.gob.pe 12NERC National Environmental Isotope Facility NEIF, British Geological Survey, Nicker Hill, Keyworth, Nottingham, NG12 5GG, England, UK; ksvav@bgs.ac.uk; mjl@bgs.ac.uk 13Wolfson Stable Isotope Mass Spectrometer Lab, School of Geosciences, King’s Buildings, James Hutton Road, University of Edinburgh, EH9 3FE, Edinburgh, UK; ulrike.baranowski@ed.ac.uk 14Departament de Marine Geosciences, Universida de Vigo, Circunvalación ao Campus Universitario, 36310 Vigo, Pontevedra, Spain; pauladiz@uvigo.es 15*Corresponding author

The difference in carbon isotope between epifaunal and shallow infaunal benthic foraminifera species (δ13C_epi) seems to be proportional to the organic matter carbon flux to the seafloor. Therefore, it has been proposed that the carbon isotope difference between epifaunal and shallow infaunal benthic foraminifera could be used as a paleo-productivity proxy. The Southeast Pacific margin is an ideal natural laboratory to evaluate the potential of this proxy due to the contrasting gradients in productivity and organic matter type.

In this work, we test the applicability of the δ13C_epi to reconstruct paleo-productivity in this region based on surface sediment samples retrieved along the Peruvian and Chilean continental margins between 24 and 4,000 m water depth. We analysed stained and unstained specimens of the shallow infaunal genera *Uvigerina* (*U. peregrina, U. auberiana*), *Bolivina* (*B. interjuncta, B. plicata, B. spissa*) and epifaunal genera *Cibicidoides* (*C. wuellerstorfi, C. mundulus, C. lobatus*),
Cibicides (C. aknerianus) and Planulina (P. limbata, and P. ariminensis). We compared our δ13C_{epi-sii} with satellite surface chlorophyll and derived surface water primary productivity (seasonal, yearly, interannual and decadal), bottom water oxygen and nutrients concentrations; and bulk sediment productivity proxies and organic matter quality indicators as total organic carbon, total nitrogen, C:N ratio, biogenic opal, calcium carbonate, δ18O_{org} and δ15N_{org}. Preliminary results show that δ13C_{epi-sii} computed between Cibicoides/Planulina and Uvigerina species has a negative relationship with chlorophyll/primary productivity/TOC/C:N/δ15N_{org} and a positive relationship with oxygen. An unclear relationship is reported of δ13C_{epi-sii} for these pair’s species with biogenic opal, calcium carbonate and δ18O_{org}. For the δ13C_{epi-sii} calculated between Cibicoides/Planulina and Bolivina species, an unclear relationship is observed with any of the environmental variables.

**Stable isotopes of oxygen and carbon in benthic foraminifera: Proxy validation in the Southeast Pacific, an international collaborative endeavour**

REYES-MACAYA Dharma1,2,3, HOOGAKKER Babette1, MARTINEZ FONTAINE Consuelo1, GLOCK Nicolaas5, TAPIA Raúl1, DE POL HOLZ Ricardo1, MARTINEZ – MÉNDEZ Gema1, ERDEM Zeynep1, GARRIDO Sebastian1,5, MICHEL Elisabeth2, MCCORKLE Daniel5, YOKOYA Yasuko11, MOHTADI Mahyar11, TAVERA Laura21, MARCHANT Margarita12, CARDICH Jorge11, FLORES Edgart2, INGLE James14, CORDOVA Kathy13, KUHNERT Henning15, KRAUSE Stefan16, GAYO Eugenia1, CASTILLO Alexis2, HROMÍC Tatiana16, LÜCKGE Andreas13, SANTAMARIA Pablo13, TRONCOSO-OJEDA Rodrigo17, AGUILERA Víctor18, DAVIS Catherine13, VARGAS Cristian22 and HEBBELN Dierk2

1Lyell Centre, Heriot-Watt University, Research Avenue South, Riccarton, EH14 4BA, Edinburgh, UK; d.reyes_macaya@hw.ac.uk; b.hoogakker@hw.ac.uk; sag15@hw.ac.uk
2MARP – Center for Marine Environmental Sciences, Leobener Str. 8, 28359, University of Bremen, Bremen, Germany; d.reyes_macaya@hw.ac.uk; d.hubbeln@marum.de; mmohktadi@marum.de; k.hurnert@marum.de
3ANID-Millennium Science Initiative Program, Nucleo Milenio UPWELL, Raul Bitran 1305, 1720256, La Serena, Chile; d.reyes_macaya@hw.ac.uk; sag15@hw.ac.uk; kenagayoh@gmail.com; acastillo@uem.cl
4Geochronology laboratory, GAIA Antarctica, Domo Antártico, Avenida Bulnes 01855, 6210427, Universidad de Magallanes, Punta Arenas; consulola.mn@email.com; ricardo.depol@umag.cl
5Centre for Earth System Research and Sustainability, Institute of Geology, University of Hamburg, 20146, Hamburg, Germany; nicolaas.glock@uni-hamburg.de
6Institute of Oceanography, National Taiwan University, No. 1, Sec. 4, 106319, Taipei, Taiwan; raultapia@ntu.edu.tw
7Helmholtz Institute for Functional Marine Biodiversity at the University of Oldenburg (HIFMB), Ammerländer Heerstrasse 231, D-26129 Oldenburg and Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung, Bremerhaven, Germany; gema.martinezmendez@hifmb.de
8NIOZ Royal Netherlands Institute for Sea Research, PO Box 59, 1790 AB Den Burg, Texel, The Netherlands; zeynep.erdem@nioz.nl
9Laboratoire 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, GIF sur Yvette Cedex, France; elisabeth.michel@lisse.ipsl.fr
10 Woods Hole Oceanographic Institution, 86 Water St, Falmouth, MA 02543, Massachusetts, USA; d.mccorkle@whoi.org
11Atmosphere and Ocean Research Institute, The University of Tokyo, 5-1-5, Kashiwanoha, Kashiwa-shi, 277-8564, Chiba, Japan; yokoyama@aori.u-tokyo.ac.jp
12Facultad de Ciencias Naturales y Oceanográficas, Universidad de Concepción, Barrio Universitario, Casilla 160-C, Concepción, Chile; itavera@udec.cl; mmarcan@udec.cl; edgart.flores@imo-chile.cl
13Universidad Peruana Cayetano Heredia, Avenida Honorio Delgado 430, San Martin de Porres 15102, Lima, Peru; jorge.cardich@upch.pe; liyexia25@gmail.com
14Department of Geophysics, Stanford University, Mitchell Building, 397 Panama Mall, CA 94305, Stanford, California, USA; send11@stanford.edu
15Landesamt für Umwelt des Landes Schleswig-Holstein (LÜ), Hamburger Chaussee, 25 24220, Flintbek, Germany; stefan.krause@llur.landsh.de
16Laboratorio de Micropalentología, Avenida Bulnes 01855, 6210427, Universidad de Magallanes, Punta Arenas, Chile; tatiana.hromic@umag.cl
17Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Stillwege 2, 30655, Hannover, Germany; andreas.lueckgo@bgr.de
18Data Management Department, INNOVEX Technologies, Fahrenheit Street 1, 28359, Bremen; pablo@santamaria.de
19Universidad de Vigo, Circunvalación ao Campus Universitario, 36310 Vigo, Pontevedra, Spain; rodrigo.alfredo.troncoso.ojeda@gmail.com
20CEAZA – Center for Advanced Studies in Arid Zones, Qassim University, Riyadh 822, 91618, Saudi Arabia; victor.aguilera@ceaza.cl
21Department of Marine, Earth, and Atmospheric Sciences, North Carolina State University, Jordan Hall, 2800 Faucette Dr, Raleigh, 27607, North Carolina, United States; catherine.davis@nwsu.edu
22Faculty of Environmental Sciences, & Instituto Milenio de Oceanografia, Universidad de Concepción, Barrio Universitario, Casilla 160-C, Concepción, Chile; cvargas@udec.cl
23*Corresponding author

The oxygen (δ18O_{org}) and carbon (δ13C_{inf}) isotope signals of benthic foraminifera (BF) are widely used for reconstructing bottom water temperature, salinity, density, oxygen and nutrient content. However, the accuracy of these reconstructions can be biased by vital (kinetic and metabolic) and environmental effects (microhabitat, phytodetritus, carbonate ion saturation) as they influence δ18O_{org} and δ13C_{inf}, causing offsets or isotope disequilibria between the stable isotope signature of the BF and the ambient bottom water. The Southeast Pacific (SEP) is an important region due to its role in heat transfer, productivity, and carbon-oxygen-nutrient cycling. Over the past two decades, paleo reconstructions in this region have relied on δ18O_{org} and δ13C_{inf} for understanding past environmental changes. Nevertheless, no proxy validation for stable isotopes in BF has ever been done. We conducted the first-ever assessment of the stable isotope disequilibria in common epifaunal and infaunal BF species in the SEP, and evaluated its implications for paleoceanography. We utilized a large sample set of modern and/or fossil (Rose Bengal-Stained) BF collected along the Peruvian and Chilean continental margins, alongside sedimentological
and geochemical (water and sediment) characteristics. Through this extensive dataset, we analyzed the effects of 1) organic matter respiration (i.e., Mackensen effect), 2) microhabitats, and, 3) carbonate chemistry on δ18Owater and δ13Cwater. Epifaunal BF δ18O values reveal a 1:1 relationship with ambient bottom waters across the entire water column. Infaunal BF show positive offsets to the bottom waters. Epifaunal BF δ13C generally follows a 1:1 relationship with bottom waters between 4000 and 800 m. While infaunal BF δ13C data become progressively depleted compared with ambient bottom waters, with deeper infaunal habitats. However, above 800 m this relationship with the bottom waters breaks down, and epibenthic BF δ13C values show a positive offset in the order of 0.7‰. A similar trend towards more positive values in the upper 800 m is also seen for the infaunal species. Regression analyses of the isotopic disequilibria with ambient bottom water data and bulk sediments characteristics suggest that the combination of low oxygen concentrations, poorly remineralized organic matter and low carbonate ion concentrations affect the δ13C signatures of infaunal and epifaunal BF within the upper 800 meters in the SEP, where the epifaunal BF actually show a quite uncommon positive disequilibrium.

**Spatio-temporal distribution patterns of benthic foraminifera in the northern Barents Sea**

RICARDO DE FREITAS Thaise1*, HESS Silvia1, RENAUD Paul E.2,3 and ALVE Elisabeth1

1Department of Geosciences, University of Oslo, Sem Sælends 1, Oslo, Norway; t.r.de.freitas@geo.uio.no; silvia.hess@geo.uio.no; elisabeth.alve@geo.uio.no
2Akvaplan-niva, Fram Centre for Climate and the Environment, Hjalmar Johansens gate 14, Tromso, Norway; per@akvaplan.niva.no
3University Centre on Svalbard, Longyearybyen 917, Svalbard, Norway; per@akvaplan.niva.no
*Corresponding author

The most pronounced declines in the extent and thickness of the Arctic sea-ice are occurring in the Barents Sea. In this region, the irregular topography and seasonal sea ice dynamics associated with the Atlantic Water inflow and mixing increase the spatial variability in biogeochemical processes. In this study, we aim to extend the knowledge of how distinct depositional environments associated with seasonal food availability and temperature conditions affect the Arctic benthic foraminiferal community structure. Living (rB stained) benthic foraminifera were collected from the Barents Sea shelf, slope and Arctic Basin. The community was analysed from surface sediment samples (0 - 1, 1 - 2 cm) collected at eight stations during August and December 2019, and March and May 2021. The size fractions 63, 125 and 500 µm were analysed separately. Foraminiferal diversity and faunal composition patterns were observed in association with sedimentary parameters, such as elemental carbon and nitrogen content, stable isotopic composition and grain size. We observed that agglutinated species were dominant (> 50 %), particularly at shallow, southern sites with high sand content. The agglutinated species, *Lagenammina diffugiformis* and *Adercotryma glomeratum*, are common throughout the study area. *Portatrochammina bipolaris* and *Textularia torquata* are abundant in shelf sites associated with Atlantic Water inflow. Their abundance is highest mainly during winter when the inflow is intensified. In the shelf sites, allogromiids were abundant, reaching > 40% of the assemblage. High percentages of calcareous species were observed at slope stations, where the presence of cold deep-water species such as *Melonis affinis* and *Pullenia bulloides* are characteristic. A substantial proportion of calcareous species were decalcified (> 25 %), mostly in southern shelf sites and subsurface samples. *Elphidium excavatum var. clavatum* and *Robertina sp.* show the most severe degree of dissolution, while *Melonis affinis* displays mild degrees of dissolution. Areas with frequent dissolved individuals had a low inorganic carbon content in the sediments, where the low calcite content does not reach a saturation state. The highly abundant calcareous species *Epistominella arctica* and *Stetsonia horvathi* were frequent found in slope and basin sites, associated with deep water depth and high clay content. These species showed peaks in abundance during winter and lowest values during summer. Overall, there was more spatial than temporal variability in abundance and faunal composition in the study area. Shallow bank areas had the lowest richness and abundance whereas deeper shelf, slope and basin areas had high numbers of taxa and abundance. Although there were no intra-annual differences in the analysed sedimentary parameters, the species composition observed showed an abundance increase during winter periods (December 2019, March 2021) particularly in the smallest size fraction (63-125 µm). The abundant small size individuals are possibly an effect of reproduction based on the previous year's productivity. This suggests that smaller individuals and species are responding to interannual productivity pulses associated with different sea ice cover and Atlantic Water inflow. Continued biodiversity assessments within the Barents Sea are necessary to improve our understanding of seasonality in the benthic realm providing insights into the past and future of the Arctic ecosystem functioning.

**Vacuoles size and abundance in Foraminifera: new insight about their metabolic adaptation to low oxygen environments**

RICHI RENAUD Julien1*, MATSUZAKI Takuya2, ISHITANI Yoshiyuki1, TAME Akihiro1, ODA Kaya1 and NOMAKI Hidetaka1

1Institute for Extra-cutting-edge Science and Technology Avant-garde Research (X-star), Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Yokosuka, Japan; richirren@jamstec.go.jp; ishitaniy@jamstec.go.jp; odakaya@jamstec.go.jp; nomakih@jamstec.go.jp
2Center for Advanced Marine Core Research, Kochi University, 200 Monobe Otsu, Nankoku, Kochi 783-8502, Japan; jm-takuya@kochi-u.ac.jp
Several benthic foraminiferal species of the order Rotaliida were shown to be facultative anaerobes and able to perform denitrification, entering the very restricted group of eukaryotes exhibiting this metabolic pathway. In certain environments such as fjords or oxygen minimum zones, they might be responsible for up to 50-100% of the total benthic denitrification. These observations support that benthic foraminifers could play a key role, so far overlooked, in the nitrogen cycle. However, the exact way they are performing denitrification is still hypothetical. In species dwelling in deep sea sediments, the concurrent observation of (1) higher concentrations of nitrate in their cell relatively to the ambient sea water (>1000 times), (2) the presence of numerous and large vacuoles in their cytoplasm and (3) the preferential clustering of mitochondria around vacuoles, led to the idea that vacuoles could be the place for nitrate storage to sustain denitrification. While an extended surface of contact is necessary to optimise exchanges between vacuolic content and the cytosol to support metabolic activity, an efficient storage capacity requires high volume. Following this reasoning, and because volume increases quicker than surface (cubic vs. square, respectively), there should be a trade-off between storage volume and surface of exchange for different oxygen and nitrate concentrations in the foraminiferal environment.

Here, we present preliminary data for the species Bolivina spissa sampled at ~1400 m depth in the central part of the Sagami Bay (Japan). Specimens were collected from different sediment depth (every 1 cm down to 5 cm depth) to characterise their vacuole pattern regarding the oxygen (hypoxic or anoxic) and nitrate concentrations (40µM to absence) profiles in pore waters. Sediment samples where fixed with glutaraldehyde on board directly after sampling. Specimens were then isolated, decalcified, stained with osmium, embedded into resin and imaged using a micro-CT (Computed Tomography) scan. Volume, surface area, and position of vacuoles in the cell were determined using the software Amira and followed by 3D reconstruction of the whole individual associated with their vacuole pattern. Further TEM (Transmission Electron Microscopy) images on the same specimens will help us to establish other organelle distributions regarding the vacuoles considered such as mitochondria.

Our results did not show a clear and systematic difference in the vacuoles pattern of specimens sampled from different sediment depths (i.e. different oxygen and nitrate conditions). Conversely, the distribution of vacuoles was different regarding the chamber, showing an increase in number and a decrease in size from the older toward the youngest chambers. The differences observed regarding individual chamber might indicate that each chamber could perform different activities hence vacuoles in different chambers have different roles. We will further discuss the relationships between these patterns and their environment linked to their living depth in sediments, i.e. different oxygen and nitrate concentrations.

**Correlative analyses of cellular structures and elemental distribution of soluble compounds: Cryo-SEM imaging coupled to EDS elemental mapping in the denitrifying species Bolivina spissa**

RICHIRT Julien1*, OKADA Satoshi1, GLOCK Nicolaas2, ISHITANI Yoshiyuki1 and NOMAKI Hidetaka1

1Institute for Extra-cutting-edge Science and Technology Avant-garde Research (X-star), Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Yokosuka, Japan; richirt.julien@jamstec.go.jp; okadasa@jamstec.go.jp; ishitaniy@jamstec.go.jp; nomaki@jamstec.go.jp
2Institute for Geology, University of Hamburg, Bundestrasse 55, 20146 Hamburg, Germany; nicolaas.glock@uni-hamburg.de
*Corresponding author

Benthic foraminifers perform a wide variety of metabolisms to cope with adverse conditions of their surrounding environment. Among these metabolic adaptations, numerous species were shown to be facultative (an-)aerobes able to perform denitrification. In some environments, they are responsible for 50-100% of the total benthic denitrification, making them major protagonists in this process and ultimately emphasising their potential key role in the nitrogen cycle. Concurrently, while they significantly contribute to nitrogen cycle, little is known about the mechanisms involved regarding this metabolic pathway. Several denitrifying species belonging to the rotalids are known to store nitrate in their cell with concentrations >1000 times higher than in their surrounding environment. In some species, parallel observations of a remarkably developed vacuolic system surrounded by mitochondria clusters led to the hypothesis that vacuoles are likely to be the place where nitrate is stored in the cell. However, vacuole content is difficult to assess, mostly because ultrastructure observation generally requires cell fixation and subsequent preparations for sectioning that includes a dehydration step, causing the loss of dissolved elements such as nitrate. One way to preserve the liquid phase is the cryo-fixation of specimen prior observation, but this technique is challenging to implement.

Here, we present data about cellular structures using cryo-SEM (Scanning Electron Microscope) imaging combined with the distribution of elements using EDS (Energy Dispersive X-ray Spectroscopy) mapping on cryo-fixed specimens of the denitrifying species Bolivina spissa. Individuals were sampled in October 2022 at the central part of the Sagami Bay (Japan) at ~1400 m depth. Specimens from the topmost centimetre were isolated, directly embedded in a sucrose-based aqueous glue and cryofixed (liquid nitrogen-cooled isopentane) onboard while others were cryofixed only after exposition to different conditions of oxygen and nitrate concentration (presence/absence) for two days. After cryo-fixation, specimens were cracked open using a diamond knife aiming for a clean cut limiting topographic variations of the sample surface. After sublimation and chromium coating steps, the same sample regions were SEM imaged and elemental composition was mapped by EDS.
Transmission Electron Microscopy (TEM). Limited studies have been conducted on hydrocarbon-seep foraminiferal evolution. While the cellular adaptations of calcareous foraminifera in certain extreme environments (e.g., anoxic, euxinic, methane-enriched sediments) include peroxisome proliferation, symbiosis, kleptoplasty, and mitochondria-test pore associations, there is still much to be learned about the mechanisms allowing thecate (i.e., organic-walled) and agglutinated monothalamid foraminifera to occupy these seemingly extreme environmental conditions. As monothalamid foraminifera are considered by most to be early-evolving forms, it is important to define their cytology. This work presents the preliminary results of a study that aims to integrate the recent benthic foraminifera assemblages (total fauna, > 63 µm) and sedimentological data along depth gradients in the Espirito Santo Continental Shelf (ESCS, southeastern Brazilian Continental Margin, 18° 20' and 21° 20' S). The ESCS varies in width and shelf-break depth, currently presenting a morphology that was shaped by several changes in relative sea level during the Quaternary. The ESCS sedimentation is essentially mixed (coeval carbonate/terragenous deposition), with rhodolith beds on the entire outer shelf. The Doce River is the main source of terrigenous sediment to the shelf. Northward of the river, the South Abrolhos Shelf keeps the most important coral reef system of the South Atlantic. Surface sediment samples (0-2 cm) were collected in 2013 comprising six transects evenly distributed in the ESCS (B-F) and North Campos Basin (A) at depths of 25, 40, 50, and 150 m. Density, diversity, life strategy, test composition, and assemblage composition change with depth and according to the influence of the Doce River. The microfauna is dominated by hyaline taxa, mainly represented by species of the genus Globocassidulina. However, a high abundance of porcelaneous taxa (e.g., Archaias angulatus, Articulina pacifica, Miliochinella subrotunda, Peneroplis planatus, Quinqueloculina spp.), combined with sandy sediments and low organic matter content, was observed along the transect C and in the two transects located in the South Abrolhos shelf. To the north of the Doce River, the relative abundance of Hanzawaia bowenae increased in the sandy carbonate-poor sediment. The low CaCO₃ content in this sector of the ESCS indicates a strong influence from the Doce River sediment plume. To the south of the Doce River, species from the genus Cibicides and Cibicidoides were more frequent and abundant, mostly along the transect of the North Campos Basin. The microfaunal and sedimentological data observed in the 150 m isobath indicate a clear beginning of the transition from the shelf to the slope, with an increase in the P/B ratio and higher hyaline abundances, when compared to shelf samples.

Inhabitation of bathyal hydrocarbon seeps by basal benthic foraminifera evidenced by ultrastructural observations

Rohret Shari1,2* and Bernhard Joan M.1

1Department of Earth, Atmosphere, and Planetary Science, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA 02139, USA; srohret@mit.edu
2Department of Geology and Geophysics, Woods Hole Oceanographic Institution, 266 Woods Hole Rd, Woods Hole, MA 02543, USA; srohret@whoi.edu
*Corresponding author

While the cellular adaptations of calcareous foraminifera in certain extreme environments (e.g., anoxic, euxinic, methane-enriched sediments) include peroxisome proliferation, symbiosis, kleptoplasty, and mitochondria-test pore associations, there is still much to be learned about the mechanisms allowing thecate (i.e., organic-walled) and agglutinated monothalamid (single chambered) foraminifera to occupy these seemingly extreme environmental conditions. As monothalamid foraminifera are considered by most to be early-evolving forms, it is important to define their cytology. This is especially true for populations inhabiting environments representing habitats of the Proterozoic Oceans, where life may have first evolved. A first step to establish how foraminifera can live in extreme environments is by analyzing their cellular ultrastructure via Transmission Electron Microscopy (TEM). Limited studies have been conducted on hydrocarbon-seep foraminifer
Assessing biodiversity of benthic foraminifera in an anoxic-hypoxic karst subterranean estuary of the Yucatan Peninsula, Mexico

ROHRET Shari1,2*, BORDA Elizabeth1 and BERNHARD Joan M.1

1Department of Geology and Geophysics, Woods Hole Oceanographic Institution, 266 Woods Hole Rd, Woods Hole, MA 02543, USA; srohret@whoi.edu; jbernhard@whoi.edu
2Department of Earth, Atmospheric, and Planetary Science, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA 02139, USA; srohret@mit.edu

Assessing biodiversity of benthic foraminifera in an anoxic-hypoxic karst subterranean estuary of the Yucatan Peninsula, Mexico

Karst subterranean estuaries (KSEs) form in coastal carbonate aquifers where precipitation, saline groundwater, and oceanic water interact. These environments are biogeochemical hotspots that provide a unique opportunity to study the ecology and diversity of organisms inhabiting a range of physico-chemical gradients. To date, most studies of KSEs in the Yucatan Peninsula and Cozumel Island, Mexico have focused on the water-column community, composed primarily of endemic crustaceans. These organisms have drawn interest from many, but we are just beginning to describe the diversity and ecosystem functioning within these complex systems. Despite considerable efforts into describing ecosystem functioning within the KSE water column, very little is known about the role of the benthos. Better understanding of the diversity and community composition of benthic meiofauna (small eukaryotic organisms, including foraminifera) in these systems is a crucial first step toward understanding their role in KSEs. In particular, benthic foraminifera are well-known environmental indicators that can inhabit a range of extreme habitats, including anoxic and sulfidic conditions, yet little is known about their diversity in KSEs. Sediment samples collected from Cenote Crustacea, a hypoxic to anoxic coastal cave in the Yucatan Peninsula, were analyzed to establish a baseline for benthic foraminiferal diversity in this system.

Agglutinated foraminifera as early indicators of microplastic pollution in two Mediterranean marine caves

ROMANO Elena1, BERGAMIN Luisa1, DI BELLA Letizia2*, D’AMBROSI Andrea3, DI FAZIO Melania2, MEDEGHI Laura2, PIERDOMENICO Martina3, PROVENZANI Claudio1, RAMPAZZO Romano2, RINALDI Sheila1 and SPAGNOLI Federico1

1ISPRRA, Institute for environmental protection and research, Via Vitaliano Brancati 60, Rome, Italy; elena.romano@isprambiente.it; luisa.bergamin@isprambiente.it
2Earth Science Department, Sapienza University of Rome, P.le Aldo Moro 1, Rome, Italy; letizia.dibella@uniroma1.it; melania.difazio@uniroma1.it; laura.medeghini@uniroma1.it
3BigBlueXplorers ASD, Via di San Fabiano 20, Rome, Italy; andrea.dambrosi@outlook.it; claudio@gue.com
Benthic foraminifera as bioindicators of reef health in Jobos Bay, Puerto Rico

ROSA MARÍN Angelique¹ and MARTINEZ-COLÓN Michael²

¹College of Marine Science, University of South Florida, 140 7th Ave S, Saint Petersburg, USA; arasamarin@usf.edu;
²School of the Environment, Florida Agricultural and Mechanical University, 1601 S Martin Luther King Jr Blvd, Tallahassee, USA;
michael.martinez@famu.edu
*Corresponding author

Monitoring tools are needed to support effective management actions to protect the coral reefs in Jobos Bay National Estuaries Research Reserve (JBNERR) at Salinas, Puerto Rico. These reefs occur along a strong environmental gradient between an historically impacted terrestrial environment (i.e., by agriculture and waste disposal) with a currently increasing human population, and the clear, oligotrophic waters of the Caribbean just offshore. Here we show the feasibility of benthic-foraminiferal assemblages as bioindicators to understand the role of environmental parameters on these reefs. Water-quality, nutrients, sediment parameters, and foraminiferal assemblages were assessed in samples from the fore-reef and back-reef of Cayo Morillo, Cayo Pájaros, and Cayo Caribe. Temperature and salinity reflected seasonal variations; nitrates and ammonium concentrations indicated terrestrial runoff; and sediment parameters such as predominant grain-size and proportions of organic carbon and carbonate calcium indicated wave energy and wind influence. Foraminiferal assemblages

Marine caves are considered extreme environments for aquatic life because, due to their enclosed setting, they are affected by extreme conditions for scarcity or absence of light, limited nutrient availability, the difficulty of larval dispersal, and possible hypoxic conditions. Moreover, caves connected with karst systems receive terrestrial contributions (water, sediments, and organic matter) that, interacting with the marine ones, determine wide spatial and temporal environmental variability. Combining all these variables determines a strong environmental gradient from the outer to the inner parts of caves that is reflected in the biota’s zonation; despite these unfavorable conditions, marine caves are biodiversity reservoirs. However, they are extremely fragile environments because they are affected by natural environmental stress and potentially exposed to contamination from both the land and the sea; for this reason, they are included in the European Habitats Directive for protection and conservation. Recently, microplastic pollution was recorded for the first time in the water and sediments of a Mediterranean marine cave. Benthic foraminifera were recognized as reliable environmental indicators in these environments, where they develop more and more different assemblages from those of the surrounding marine area with the increasing distance from the cave entrance. In particular, the agglutinated taxa, not abundant in the shallow water Mediterranean environment, are relatively numerous in cave assemblages.

This work considered two Italian marine caves with different characteristics: the huge Bue Marino cave (Sardinia), which receives terrestrial contributions through the vast karst system of the Gulf of Orosei during rainy periods, and the small Argentarola cave (Tuscany archipelago), which is permanently characterized by fully marine conditions. Sediment samples from the two caves were analyzed for grain size, organic carbon (C\text{org}), microplastic and benthic foraminifera. In the Bue Marino cave, sediment ranged from sandy silt to sand, it was rich in C\text{org} (up to 8.07%), and microplastics were 10-27 items kg\textsuperscript{-1}. The agglutinated, infaunal, and opportunistic Egggerelloides advena was the dominant species, with Ammonia tepida and Ammonia inflata. In the Argentarola cave, sediment was silty clay or clayey silt, poor in C\text{org} (at most 0.13%), and microplastics were 70-300 items kg\textsuperscript{-1}. The most abundant foraminiferal taxa were the epifaunal calcareous Spirillina vivipara and Patelliina corrugata, and the infaunal agglutinated Lagenammina diffugiformis, while Glomospira charoides was common.

Microplastics were searched in the tests of the three agglutinated species through Micro Fourier Infrared Spectroscopy (µFTIR) because it was supposed that these items could be incorporated by specimens collecting grains during the building of new chambers; moreover, it is easier to recognize the signal associated with the presence of MPs in the agglutinated than in the calcareous tests. FTIR spectra revealed the presence of plastic components in E. advena (Bue Marino) and L. diffugiformis but not in G. charoides (Argentarola). The different responses among species may be attributed to their different ability to select the grains from the sediment for building new chambers.

This result is particularly alarming from an environmental point of view because it testifies that microplastics enter a biological matrix, being included in the trophic chain, without the need to be ingested and metabolized. On the other hand, this study demonstrated that some species of agglutinated foraminifera are powerful proxies of microplastic pollution in sediments. Moreover, because the peculiar conditions of marine caves favor the presence of agglutinated species, agglutinated foraminifera may be successfully applied as early indicators of this pollution in these environments.
in the fore reef were dominated by *Amphistegina* (algal-symbiont-bearing) indicating suitable water-quality, while the back-reef stations were dominated by heterotrophic species such *Discorbis* and *Quinqueloculina*, reflecting their dominance in finer sediments with higher organic content. Low densities associated with water depth and wave energy limited further interpretation of foraminiferal assemblages. The dominance of symbiont-bearing taxa in fore-reef sites suggest suitable water quality for reef development. This pilot project provides the first description of foraminiferal assemblages in JBNERR reefs, providing baseline data on their ecological preferences.

A well oxygenated eastern tropical Pacific during the warm Miocene

**ROSENTHAL Yair**1,2*, **HESS Anya V.**1, **AUDERSET Alexandra**1,2,5, **MILLER Kenneth G.**1, **ZHOU Xiaoli**4, **SIGMAN Daniel M.**4 and **MARTÍNEZ-GARCÍA Alfredo**7

1Department of Marine and Coastal Sciences, Rutgers the State University of New Jersey; 71 Dudley Rd. New Brunswick 08901, New Brunswick, NJ, USA; rosenthal@marine.rutgers.edu; anya.heuss@rutgers.edu
2Department of Earth and Planetary Sciences, Rutgers the State University of New Jersey, NJ, USA, 610 Taylor Rd., Piscataway, NJ 08854-8066; rosenthal@marine.rutgers.edu
3Department of Geosciences, Princeton University; Princeton, NJ, USA, Guyot Hall, Princeton, NJ 08544, USA; a.auderset@mpic.de
4Department of Earth and Planetary Sciences, Rutgers the State University of New Jersey, NJ, USA, 610 Taylor Rd., Piscataway, NJ 08854-8066; kgm@eps.rutgers.edu
5State Key Laboratory of Marine Geology, Tongji University; 1238 Gonghexin Rd, Shanghai, 200070, China; a.auderset@mpic.de; xlzhou@tongji.edu.cn
6Department of Geosciences, Princeton University; Princeton, NJ, USA, Guyot Hall, Princeton, NJ 08544, USA; sigman@princeton.edu
7Climate Geochemistry Department, Max Planck Institute for Chemistry; Hahn-Meitner-Weg 1, 55128 Mainz, Germany; a.martinez-garcia@mpic.de

*Corresponding author

The oxygen content of the oceans is susceptible to abrupt climate change, and has declined in recent decades, with the largest effect in oxygen deficient zones—mid-depth regions with oxygen concentrations <5 µmol/kg. Here, we investigate changes in ocean oxygenation during the warmer-than-present Miocene Climatic Optimum (17.0–14.8 Ma), a possible analog for future climate. We use two foraminiferal proxies of ocean deoxygenation namely the iodine to calcium ratio and foraminiferal bound nitrogen isotopes. To that end we develop a new method that allows us to measure I/Ca and other elemental ratios in the same foraminifera sample solution. Planktic foraminifera I/Ca and δ18O show that dissolved oxygen concentrations in the eastern tropical Pacific, home to the largest modern oxygen-deficient zone, exceeded 100 µmol/kg during the Miocene Climatic Optimum. Paired Mg/Ca-derived temperature data suggest that an oxygen-deficient zone developed in response to an increased west-to-east temperature gradient and shoaling of the eastern tropical Pacific thermocline. The new records align with model simulations that suggest weaker equatorial Pacific trade winds during warm periods may lead to decreased equatorial upwelling, causing equatorial productivity to be less concentrated in the east. These findings shed light on how warm climate states like during the Miocene Climate Optimum may affect ocean oxygenation, supporting models suggesting that the recent deoxygenation trend and expansion of the eastern tropical Pacific oxygen deficient zone may eventually reverse.

Species distribution and biostratigraphic evaluation of fossil foraminifera from Miocene to late Pleistocene sediments obtained from deep wells offshore Brunei Darussalam

**ROSILM Amajida**1*, **ALFAN Amirah**1, **BRIGUIGLIO Antonino**2, **GOETING Sulia**3 and **KOCIS László**3

1Geology Group, Faculty of Science, Universiti Brunei Darussalam, Jalan Tunghu Link Gadong, BE1410, Brunei Darussalam; amajida.rosilim@uobd.edu.bn; nuralamajidarosilim@gmail.com
2DI.T.S.A.V. – Dipartimento di Scienze della Terra, dell’Ambiente e della Vita, Università degli Studi di Genova, Corso Europa 26, 1 - 16132 Genova, Italy; antoninobriguglio@unige.it
3The Stable Isotope Laboratory (ISOLAB), Institute of Earth Surface dynamics (IDYST), Faculty of Geosciences and Environment (FGSE), University of Lausanne, Switzerland; sbhms@live.com; Laszlo.Kocis@unil.ch

*Corresponding author

Fossil foraminifera are indicators of past environmental conditions and are also useful for marine biostratigraphy. In this study, the foraminiferal fauna from drill cuttings of two deep wells; Well A with 5 intervals (labelled C1, C2, C3, C4, C5) reaching to 2210 meters deep and Well B with 8 intervals (labelled D1, D2, D3, D4, D5, D6, D7, D8) extending to 3431 meters depth from offshore Brunei was investigated. The results are used to interpret the palaeoenvironment and to update the biostratigraphic record of the Miocene sediments in Brunei. The obtained samples were dried, weighed, and washed over three sieve sizes (250, 125 and 63 µm). All samples were standardized to 100 grams. The sieved fractions were examined through a stereomicroscope and documented through Scanning Electron Microscope (SEM).

A total of 247 species of foraminifera has been retrieved from both wells; Well A revealed 140 species comprising of 36 planktonic and 104 benthic foraminifera, while in Well B, 107 species of foraminifera consisting of 32 planktonic and 75 benthic foraminifera have been retrieved. Highest number of foraminifera species was seen in Well A, interval C2 (830 to
Paleoenvironmental evolution of Abrolhos Depression (Brazil - SW Atlantic) based on the distribution of benthic foraminiferal assemblages

RUSCHI Anita G.¹, RODRIGUES André R.º, CETTO Paulo H.¹ and BASTOS Alex C.¹

¹Laboratory of Marine Geosciences (LaboGeo), Postgraduate Program in Environmental Oceanography, Department of Oceanography and Ecology, Universidade Federal do Espírito Santo, Av. Fernando Ferrari, 514, Goiabeiras, CEP 29075-910, Vitoria, ES, Brazil; anitaruschi@hotmail.com; andre.rosch.rodrigues@gmail.com; paulocetto@gmail.com; alexcardosobastos@gmail.com

This study will provide more information on the past marine-coastal environment occurred in the Miocene. Moreover, data will be used to contribute towards upgrading the biostratigraphic record of much older sediments which are rarely published in Brunei and its nearby region. At a later phase of the project, stable isotope analyses on the planktonic foraminifera Orbulina universa, Globigerinoides ruber, Uliviina obliquiloculata, Globorotalia limbata, Trilobatus trilobus and common occurring benthic foraminifera shells of Cibicides kullenbergi, Lenticulina calcar, Pseudorotalia yabei will be conducted to provide further palaeoclimatic information.

The paleoenvironmental evolution of Abrolhos Depression was marked by secular climate fluctuation events that directly influenced paleoenvironmental evolution on global continental shelves. During the transgression, cooling events such as the Younger Dryas (YD) and rapid melting events such as the Meltwater Pulse (MWP), among others, played an important role in varying the rates of relative sea level rise, as well as in the formation of coastal environments. The focus of this study is the south shelf of Abrolhos, which is marked by a feature known as the Abrolhos Depression (AD), having previously been described as a paleolagoon. The objective of this study is to investigate the formation of this paleolagoon and the paleoenvironmental variations to which it was subjected during the marine transgression in the last 18 thousand years. The study was conducted using a core located in the center of the DA, collected at a depth of 63 m. The main focus of the paleoenvironmental analysis was the identification of benthic foraminifera and carbon 14 data, in addition to the use of stable isotope analyses on the planktonic foraminifera Orbulina universa, Globigerinoides ruber, Uliviina obliquiloculata, Globorotalia limbata, Trilobatus trilobus and common occurring benthic foraminifera shells of Cibicides kullenbergi, Lenticulina calcar, Pseudorotalia yabei will be conducted to provide further palaeoclimatic information.
Toxicological effects of CBs and nicotine as emerging pollutant for benthic foraminifera

SABBATINI Anna1, CARIDI Francesca1, COSTANZI Elisa1,2, BIRARDA Giovanni1, MEDAS Daniela4, BUOSI Carla4, AMICI Adolfo3 and MOBBILI Giovanna1

1Marche Polytechnic University, Department of Life and Environmental Sciences (DiSV A), Via Brecce Bianche 12, 60131 Ancona, Italy; a.sabbatini@staff.univpm.it; f.caridi@staff.univpm.it; elisa.costanzi@iusspavia.it; g.mobbili@staff.univpm.it
2Department elettra - Sincrotrone Trieste S.C.p.A. S.S. 14 km 163, 5 in Area Science Park, 34149, Basovizza, Trieste, Italy; giovanni.birarda@elettra.eu
3Department of Medical and Geological Sciences, Università degli Studi di Cagliari, Cittadella Universitaria di Monserrato - Blocco A, S.S. 554 bivio per Sestu, 09042, Monserrato (CA), Italy; dmedas@unica.it; cbuosi@unic.it
4Department of Clinical Sciences (DISCO), section of Biochemistry, Marche Polytechnic University, Via Tronto 10/A, 60020 Torrette di Ancona, Italy; a.amici@staff.univpm.it

*Corresponding author

Marine debris is a global environmental issue. The chemistry of water and sediments, thus environmental quality and eventually the trophic chain, are affected by the dispersal of chemicals. Various studies have provided evidence that smoked cigarette butts (CBs) represent an important part of marine litter from the Mediterranean coasts to South America and Australia. CBs are the predominant human coastal litter item that can be bioaccumulated in marine organisms. CBs present a vector for transporting and introducing toxicants, including nicotine, harmful metals, total particulate matter and known carcinogens to aquatic habitats.

The health risks associated with smoking cigarettes have been addressed for decades while the fate of CBs after the disposal has only more recently received some attention. In particular, the European regulation classified CBs as hazardous waste for their acute toxicity (H6) mainly due to the nicotine content. It is a matter of fact that distribution and diffusion of CBs and their associated toxicants in the aquatic environment can be a threat to various prokaryotic and eukaryotic species inhabiting these aquatic habitats, including foraminifers.

In this study, the viability and ultrastructural analysis involved three foraminifer species from three different biomineralization pathways: the calcareous perforate Rosalina globularis, the calcareous perforate Quinqueloculina spp. and the agglutinated Textularia agglutinans. The toxicological effects of CBs and synthetic nicotine were evaluated in terms of survival rate, cellular stress, and decalcification. FTIR (Fourier-transform infrared) spectroscopy analysis allowed us to investigate the response of key macromolecules and calcium carbonate to this pollutant. To further enrich our knowledge on bioavailability of nicotine in the medium culture, High Performance Liquid Chromatography analysis (HPLC) was carried out.

Different acute tests were conducted at different times; all confirmed that CBs and synthetic nicotine are acutely toxic at lethal and sublethal concentrations for all three cultured foraminiferal taxa. Each species showed a species-specific response related to the type of shell biomineralization. FTIR analyses showed that synthetic nicotine promotes shell decalcification and also alters the composition of cytoplasmic macromolecules, such as lipids and proteins. At lethal concentration the lipid content increased maybe due to vesicles formation. Proteins signal evidenced overall cellular dyshomeostasis associated to beta sheets and aggregate structures. Finally, the HPLC analyses confirmed that foraminifera can absorb until the 85% of the synthetic nicotine to which they have been exposed.

It is clear that CBs and nicotine contained in them affects the viability, the shell-building mechanism, and the macromolecular composition of the foraminifera themselves. The integration among acute toxicity assay, synchrotron and chemical HPLC analyses provided a valuable approach for the assessment of nicotine as biomarker of exposure to the toxicants associated with smoking and the impact of this emerging and hazardous material on calcifying marine species.

AI for unknown marine Foraminifera

SABBATINI Anna1, CARIDI Francesca1*, LUCARELLI Anastasia1 and NEGRI Alessandra1

1Marche Polytechnic University, Department of Life and Environmental Sciences (DiSV A), Via Brecce Bianche 12, 60131 Ancona, Italy; a.sabbatini@staff.univpm.it; f.caridi@staff.univpm.it; stesy_92@hotmail.it; a.negri@staff.univpm.it

*Corresponding author

Life characterizes the Earth, and the most extraordinary feature of life is diversity. Despite 2 million species of identified eukaryotes, the most recent biodiversity estimates suggest that more than 80% of species remain unknown to science, among them foraminiferan Monothalamea. We want to focus on these tiny single-celled creatures forming an organic “soft” test, recently approached by taxonomic studies, counting relatively few known species vs a huge number of undescribed morphotypes spread across the marine realm. Few researchers deal with their taxonomy because of the difficulties in the morphological identification and their time-consuming task. In addition, due to the fact “soft” monothalamids are not fossilizing, they are generally overlooked by micropaleontologists. However, they are abundant and represent an important foraminiferal component living in the marine ecosystem whose further knowledge might fill some empty, but potentially important, knowledge areas to responsibly manage and conserve the planet’s resources. In fact, lack of biodiversity data...
impairs our ability to deeply understand the issues affecting our oceans. The fact that “soft-shelled” monothalamous foraminifera often represent a largely undocumented component of foraminiferal diversity in coastal sediments makes them worthy of attention. Moreover, the missing taxonomic information on monothalamids, might be responsible for the biodiversity underestimate and compromise the biodiversity loss evaluation in case of environmental deteriorations.

In this view, the last decades, molecular systematics partially solved problems related to their taxonomic identification. However, sometimes molecular phylogeny identifies clades represented by undescribed or undetermined morphotypes from the morphological point of view. Based on this, we tried to develop an AI based approach to overcome the listed issues. Our AI approach concerns the use of machine learning techniques in order to support experts in the identification of 1) new morphologically-based species and 2) morphotypes in order to decrease their redundancy due to difficulties in classification. A total of 1000 images have been selected from scientific literatures and specific morphological targets have been chosen to capture taxonomic features of specimens per images (i.e., chamber shape, shell type and composition, type of aperture, type of cytoplasm, presence of stercomata or other inclusions). The dataset obtained from this step has been processed by clustering algorithms (i.e., K-Means and DBSCAN), resulting in different levels of clusters.

Preliminary results evidence that when the algorithm considers elements like basic chamber shape, the nature of shell and the shell type, all the morphotypes as well as the species of monothalamid group in 12 clusters where the chamber form is the major morphological element segregating each cluster. Moreover, in each cluster the taxonomic ranking of some monothalamous morphotypes (sp., family level) might be improved until generic level. Therefore, this compiles the recent taxonomic revision present in WoRMS based on molecular SSU rDNA phylogeny completed with the description of major morphological trends in the evolution of this group. Authors conclude that basic chamber shape is one of the major taxonomic features separating orders or families among foraminifera as confirmed by the machine learning technique.

Our preliminary results therefore suggest that the taxonomic community might directly benefit from the AI system to fill the biodiversity gap on this key group at the base of the trophic chain among bacteria and pluricellular organisms.

Oceanographic condition on the southwestern Portuguese Margin during the Marine Isotope Stage 35: an atypical interglacial

SALGUEIRO Emília1,2*, VOELKER Antje H.L.1,2, SIERRO Francisco J.1,2, HODELL David4, RODRIGUES Teresa1,2, REBOTIM Andreia1,2 and ABRANTES Fátima1,2

1Marine Geology and Georesources Division, Portuguese Institute for the Sea and Atmosphere, Avenida Doutor Alfredo Magalhães Ramalho, 6, Algés, Portugal; emilia.salgueiro@ipma.pt; antje.voeller@ipma.pt; teresa.rodrigues@ipma.pt; andreia.rebotim@ipma.pt; fatima.abrantes@ipma.pt
2Center of Marine Sciences, Algarve University, Campus Gambelas, Faro, Portugal; emilia.salgueiro@ipma.pt; antje.voeller@ipma.pt; teresa.rodrigues@ipma.pt; andreia.rebotim@ipma.pt; fatima.abrantes@ipma.pt
3Department of Geology, Salamanca University, Plaza de los Caídos, s/n, Salamanca, Spain; sierro@usal.es
4Godwin Laboratory for Palaeoclimate Research, Department of Earth Sciences, University of Cambridge, Downing Street, Cambridge, CB2 3EQ, UK; dah73@cam.ac.uk
*Corresponding author

The Mid-Pleistocene Transition (MPT) was the most prominent global climate event of the Quaternary period. It was characterized by a global gradual cooling with an increase in ice sheet sizes and severity of glaciations, in parallel with the transition of 41 to 100 ky climatic cycles starting around 1250 ka, and the full establishment of maximum glaciations and 100 ky cycles around 700 ka. However, the exact timing and mechanisms behind this transition are still a matter of debate, with the number of high-resolution North Atlantic records that extend into the early Pleistocene, prior to the Mid-Pleistocene Transition, still being limited. Millennial-scale climatic variability is observed also in the early Pleistocene, including Marine Isotope Stage (MIS) 35, which, lasting from 1190 to 1148 ka, stands out as the longest interglacial period within the last 1.5 Ma.

To better understand this atypical interglacial, we produced high-resolution sea surface temperature (SST) and export productivity (Pexp) records determined from planktonic foraminifera assemblages, between MIS 36 and MIS 34 (1220–1140ka) in IODP Site U1385 located off the SW Portuguese margin. The Portuguese margin is considered a key paleoceanographic region since it records the climatic conditions at the high latitudes of both hemispheres (Greenland and Antarctica). For a broader perspective, these data are combined with benthic and planktonic foraminifera stable isotope records, XRF-derived element ratios, and total organic carbon data from this and nearby sites.

The results show relatively cold and productive conditions (11ºC and 82 gC/m²/y) during the MIS 36/35 transition. Temperature proxies during MIS 35 follow the insolation trend, with stable temperatures around 16ºC (4ºC colder than the present interglacial) between 1190 and 1162 ka, maxima of tropical-subtropical and transitional assemblages coincide with a maximum insolation period suggesting an intensification/ persistence of warm subtropical waters. The maximum in productivity (Neogloboquadrina incompta, Pexp) during MIS 35 is recorded at the beginning of the interglacial, followed by relatively high and stable (as well as warmer) conditions between 1190 and 1162 ka. However, low Globigerina bulloides but high N. incompta abundances suggest diminished coastal upwelling conditions but a stronger influence of a North Atlantic Drift branch (paleo-Portugal Current).
During the cold event that marks the inception of glacial MIS 34 (1152 ka) SST drops to 6°C and Pexp to 63gC/m²/y, only to rise again to 22°C SST and 50gC/m²/y Pexp at 1147 ka, i.e., during the subsequent warmer period. These fluctuations in SST and Pexp likely reflect fluctuations of hydrographic front(s).

The ecology and evolution of the deep-sea foraminifer *Chilostomella ovoidea* and its enigmatic plastid

SALONEN Ilves\(^1\), HUSNIK Filip\(^2\), NAUMOVA Mariia\(^3\), ISHITANI Yoshiyuki\(^1\), RICHIRT Julien\(^1\) and NOMAKI Hidetaka\(^1\)

\(^1\)SUGAR, X-star, Japan Agency for Marine-Earth Science and Technology (JAMSTEC), 2-15 Natshushima-cho, Yokosuka, Kanagawa, 237-0061, Japan; salonen@jamstec.go.jp; ishitaniy@jamstec.go.jp; richirt.julien@jamstec.go.jp; nomakihi@jamstec.go.jp
\(^2\)Okinawa Institute of Science and Technology (OIST), 1919-1 Tancha, Onna, Kunigami, Okinawa 904-0412, Japan; filip.husnik@oist.jp; maria27nm@gmail.com
\(^*\)Corresponding author

Foraminifera represent some of the most abundant microeukaryotes in many marine benthic environments. Contributing to their ecological success is their ability to thrive in the most challenging environments, such as the hypoxic sediments in the deep sea. To cope with such extreme conditions, different foraminiferal species have developed a variety of ecological strategies, such as nitrate respiration in the absence of oxygen or harboring diverse ecto- or endosymbionts. Yet, despite the potential ecological complexity, the deep-sea foraminiferal symbioses remain poorly understood.

*Chilostomella ovoidea* is a common and abundant species in bathyal deep-sea sediments. Previous research has indicated that *C. ovoidea* has several unique traits that include, for example, abundant chitinous structures in its cytoplasm and a distinct low-diversity intracellular microbiome. Surprisingly, *C. ovoidea* also harbors an intracellular plastid, of which the closest known relative is the plastid of the xanthophycean alga *Vaucheria litorea*. Retaining chloroplasts is common for kleptoplastic foraminifera living in the photic zone, but the function and origin of intracellular plastids in dark habitats like the deep-sea sediment is yet to be resolved.

In this study, we collected living *C. ovoidea* specimens from Sagami Bay, Japan, and used single-cell genomics and transcriptomics to gain molecular insights into the ecology and evolution of *C. ovoidea* and its potential symbionts. Gene expression analyses were used to identify the metabolic capabilities of the *Chilostomella* host. The single-cell metagenome was utilized to analyze the identity and function of the intracellular plastid. Our preliminary results indicate that the plastid genome is highly reduced and lacks several key features, such as the ability to photosynthesize. These findings suggest a potentially unique evolution of *Chilostomella* in conjunction with the plastid, where kleptoplasty has likely developed into a more permanent endosymbiosis. Such unique symbiosis may contribute to *C. ovoidea*’s ability to thrive in hypoxic and anoxic environments.

Revitalizing historic and iconic Trinidad type sections through archival research within Hans G. Kugler’s Legacy in Basel, Switzerland

SAMSOONDAR Sadie\(^1\) and KNAPPERTSBUSCH Michael\(^1\)

\(^1\)Department of Geology, Natural History Museum Basel, Augustinergasse 2, 4051 Basel, Switzerland; sadie.samsoondar@bs.ch; michael.knappertsbusch@bs.ch
\(^*\)Corresponding author

Cenozoic planktonic foraminiferal biozonations originated largely in Trinidad, SE Caribbean. Renowned micropalaeontologists like A Senn, HH Renz, J Cushman, PW Jarvis, RM Stainforth, P Brönnimann, B Carr-Brown, HM Bolli, and JB Saunders erected historic type sections there. Their efforts were economically driven within companies like Trinidad Leasetholds Ltd. Less known to the micropalaeontological community was that these pioneering works were orchestrated by Chief Petroleum Geologist Dr. Hans G. Kugler (1893-1986). He prioritized the use of microfossils while drilling for oil in Venezuela and Trinidad. Kugler, Father of Trinidad Geology, built the foundation of Trinidad’s geology where microfossils played an essential role.

Kugler’s Legacy is unique and highly treasured for Caribbean micropalaeontology. It is home to the world’s largest Trinidad collection, stored at Natural History Museum Basel (NMB), Switzerland. The Legacy comprises an 85 box archive, field books, maps, photo collection, rock and microfossil collections, raw sediment samples, and a very special hand library. Kugler and collaborators, in the 1930s-1970s, established iconic type sections in Trinidad. From these type sections, replicate samples were distributed around the world (e.g. Natural History Museum London and The Smithsonian Institute, USA), though the majority is stored at the NMB. Among others, these Trinidad type sections became international standards for biostratigraphy.

For this project, all archival documents were read, contextualized, catalogued, and where possible, reconnected to original objects at the NMB. Very important documents were digitized. This project is the first deep investigation into Kugler’s archive. We found that Kugler meticulously preserved practically all relevant information, including that of his
collaborators. The Legacy was originally systemically built with numbered documents and books. However, order was lost when shipping the Legacy from Trinidad to Basel in batches and bits. Our current research has shown that the original numbering system is extremely useful in finding virtually any relevant information. Kugler’s archive also details advances in field mapping, aerial photography, oil well drilling, and electrical logging.

Unique to Basel, Kugler’s Legacy is the only means to restore scientific context (age, location, date, author, etc) to Trinidad type material stored at the NMB and around the world. From our research, original type samples can be restored to their original geographic position using literature, photos and maps within the archive. Interestingly, many Trinidad type samples are encrypted with a peculiar biostratigraphic code, rendering them unsuitable for new scientific investigations. We have, however, uncovered ciphers within the samples that decode the samples, something largely unknown for over 25 years.

Our new research will allow the construction of age-depth models and subsequently contribute to quantitative refinement and help decipher age information of historical reference samples around the world, that otherwise would be lost to science forever. Our effort may thus inspire similar studies on other Trinidad classical type localities using archival materials and collections held at other museums around the world. We also call to draw much more attention to linking micropaleontological archives with their collections – such as those maintained at NMB and others around the world – which reflect much of the historical rise of the petroleum industry, its influence on micropaleontology, climate research, and man’s attempt to tackle current global climate deteriorations.

Biogeography of benthic foraminifera in contourite drift systems

SAUPE Anna¹, PETERSEN Jassin¹, SCHMIDT Johanna¹, BAHR André² and GRUNERT Patrick²*

¹Institute of Geology and Mineralogy, University of Cologne, Otto-Fischer-Straße 14, 50674 Cologne, Germany; anna.saupe@uni-koeln.de; jassin.petersen@uni-koeln.de; johanna.schmidt@uni-koeln.de; pgrunert@uni-koeln.de
²Institute of Geosciences, Heidelberg University, Im Neuenheimer Feld 234, 69120 Heidelberg, Germany; andre.bahr@geow.uni-heidelberg.de
*Corresponding author

Contourite Depositional Systems (CDSs) are areas along continental margins where thick sedimentary deposits accumulate due to the persistent action of intensified bottom currents. The hydrodynamic conditions in CDSs pose unique challenges for the benthic meiofauna with respect to substrate (in)stability, winnowing and potential displacement. At the same time, CDSs provide ideal habitats for suspension feeders. Faunal studies on benthic foraminifera from the SW Iberian Margin have demonstrated that intensified bottom currents linked to Mediterranean Outflow Water (MOW) favour a distinct group of suspension-feeding foraminifera. Through occupation of elevated substrates these foraminifera optimize the acquisition of food particles carried by the bottom current, giving them a competitive advantage over other epibenthic organisms. Abundances of this elevated epifauna (EEF) follow gradients of bottom current velocity, making them a potentially powerful proxy of hydrodynamic properties of ocean currents in the past. However, quantitative information on the distribution of benthic foraminifera in CDSs beyond the Iberian Margin is sparse. This lack of biogeographic knowledge inhibits the development and application of assemblage-based proxy methods to successfully unlock paleoceanographic and paleoclimatic archives of CDSs linked to intermediate and deep waters of the thermohaline circulation in the Atlantic Ocean. Here we present new benthic foraminiferal data from surface samples in CDSs of the northern North Atlantic (Björn, Gardar and Eirik drifts, 55-62°N) and along the Brazilian Margin (11-22°S) and integrate them with available foraminiferal data sets from the Iberian Margin.

Multivariate statistical analyses reveal that the quantity and quality of organic matter flux, hydrodynamic conditions at the sediment-water interface and substrate properties act as major controls on foraminiferal distribution in and between CDSs. A distinct biogeographic divide can be recognized, reflected in the distribution of different types of suspension feeding foraminifera. High abundances of attached EEF species such as Cibicides lobatus, C. refugens, C. pachyderma or Planulina ariminensis are sustained at strongly increased current velocities > 20 cm/sec along the European, Greenland and Brazilian continental margins at intermediate water depths. Assemblages along the pathway of MOW show a particularly high diversity of EEF species, probably the result of the Mediterranean heritage of this fauna. In contrast, cold, deep and comparatively less saline water masses with lower bottom current velocity (< 15 cm/sec) linked to the Atlantic Meridional Overturning Circulation are dominated by more delicate agglutinated tubular suspension feeders such as Saccorhiza ramosa, Rhizammina algaeformis and Rhabdammina abyssorum. EEF taxa are comparably rare or even absent as their competitive advantage is reduced at low current speeds.

The integrated CDS data sets suggest that assemblage-based proxy methods for the assessment of hydrodynamic properties cannot be generalized. For successful development and application, the regional effects of hydrodynamic conditions and ecological heritage on the distribution of suspension feeding (morpho)types have to be considered for a given study area.

This study was funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) through project GR52851/1-1.
Paleoclimate and paleoenvironment reconstructions from middle Eocene successions at Beni-Suef, Egypt: foraminiferal assemblages and geochemical approaches

SAVED Mostafa M.1,2,3, HEINZ Petra2, ABD EL-GAIED Ibrahim M.3 and WAGREICH Michael1

1Department of Geology, Faculty of Earth Sciences, Geography and Astronomy, University of Vienna, Althanstrasse 14, 1090 Vienna, Austria; mostafam92@univie.ac.at; michael.wagreich@univie.ac.at
2Department of Palaeontology, Faculty of Earth Sciences, Geography and Astronomy, University of Vienna, Althanstrasse 14, 1090 Vienna, Austria; petra.heinz@univie.ac.at
3Geology Department, Faculty of Science, Beni-Suef University, Salah Salem street, Beni Suef, Egypt; himmamicro2004@yahoo.com

The studied outcrops in north Egypt were lithologically subdivided into two middle Eocene rock units, the Qarara Formation (Lutetian) at the base and the overlying El Fashn Formation (Bartonian). The investigation of forty-three rock samples yielded 160 species of benthic foraminifera and subspecies which belonging to 4 suborders, 19 superfamilies, 34 families and 59 genera. Four local benthic foraminiferal zones were identified and named as follow: (1) Bolivina carinata Lowest Occurrence Zone (Lutetian), (2) Bulimina jacksomensis Concurrent-Range Zone, (3) Nonion scaphum Lowest Occurrence Zone and (4) Brizalina cooki / Nonionella insecta Concurrent-Range Zone (Bartonian). The depositional environments and prevailing climatic conditions were estimated depending mainly on the geochemical results coupled with the statistical analysis of the benthic foraminiferal fauna and their bio-ecological preferences, the lithologic features and the associated macrofossils and large benthic foraminifera. The lower part of the Qarara Formation was deposited in middle to outer shelf settings with low to moderate oxygen levels, humid and wet climatic conditions. The upper part of the Qarara Formation and the exposed part of the El Fashn Formation at Gebel Qarara were accumulated in shallow water-depth, well oxygenated environments, hot and arid climatic conditions. El Fashn Formation at El Heiba area was deposited in deeper settings compared to the same rock unit at Gebel Qarara, this change in the depositional environments may be related to changes in the paleotopography of the depositional basin or could be attributed to local tectonics. The strong similarity of the identified foraminiferal assemblages with Libya (southern Tethys) indicates migration through the Trans-Sahara Seaway, while minor similarities with the northwestern Tethys province and the North Atlantic could be correlated to their benthic nature which limit their distribution distance the cooler climatic conditions further to the north.

Apparent Megadiversity of Tibetan Orbitolininae: Revision Overdue

SCHLAGINTWEIT Felix1*, XU Yiwei2 and LI Xiangu1

1Lerchenauerstr. 167, Munich, Germany; felix.schlagintweit@gmx.de
2Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, East Beijing Rd. 39, Nanjing, China; kongjuzixing@126.com
3School of Earth Sciences and Engineering, Nanjing University, Xianlinladao 163, Nanjing, China; seanlee@nju.edu.cn

The published literature concerning Lower to mid-Cretaceous (late Barremian–Albian, ?early Cenomanian) Tibetan Orbitolinidae suggests a megadiversity with almost exclusive reference to taxa with a complex embryo (subfamily Orbitolininae). In fact, 40 new species of the Orbitolininae were described from Tibet, alongside several well-established species and their synonyms. A critical revision (excluding study of type-material) concludes that among these supposedly new species just three appear to represent valid taxa: Palorbitolinoides hedini Cherchi & Schroeder, P. pileus (Fossaman) comb. nov. (junior synonym P. orbiculatus Zhang), and Mesorbitolinia tibetica (Zhang) comb. nov. The genera Columnorbitolina Zhang and Tibetella Zhang are herein considered as junior synonyms of Mesorbitolina Schroeder. As a consequence, the mid-Cretaceous Orbitolininae assemblage of Tibet appears to be not substantially more diversified than in other regions of central and western Neotethys.

In contrast to the Orbitolininae, Dictyoconininae are clearly underrepresented in the Tibetan region. The first record of Palaeodictyoconus actinostoma Arnaud-Vanneau & Schroeder, a species previously known from eastern Spain, southeastern France and Central Iran is worth mentioning. Many other dictyoconids known from the western and central parts of the Neotethys are seemingly absent.

The stratigraphic record of the Tibetan Orbitolinidae still needs further data as well as knowledge concerning the apparently poorly diversified associated assemblages of other benthic foraminifera and dasycladalean algae. Finally, controversial recently published data on the biostratigraphy of orbitolinids from Tibet, such as the occurrences of Palorbitolina lenticularis (Blumenbach) in the late Aptian, or Praeorbitolina cf. wienandsi in the late Albian need to be reconsidered as they contradict widely accepted range charts.
Local biodiversity of recent foraminifera in three coral reefs in the extremely warm Persian/Arabian Gulf

SCHMIDT Christiane1,2*, MORARD Raphael1, RAPP Sophia K.3, AMAO Abduljamiu O.3, RAHMAN Shirin Nurshan2, VAUGHAN Grace1, FARRELL Oliver M.3 and BURT John A.5

1ZMT, Leibniz Centre for Tropical Marine Research, Fahrenheithstraβe 6, 28359 Bremen, Germany; christiane.schmidt@leibniz-zmt.de
2MARUM, Center for Marine Environmental Sciences, Leobenerstraβe, 28359 Bremen, University of Bremen, Bremen, Germany; christiane.schmidt@leibniz-zmt.de; morard@marum.de; rapp@uni-bremen.de; shirin.nurshan.rahman@uni-oldenburg.de
3Center for Integrative Petroleum Research, College of Petroleum Engineering and Geosciences, King Fahd University of Petroleum and Minerals, 31261 Dhahran, Saudi Arabia; amao@kfupm.edu.sa
4Center for Genomics and Systems Biology (CGSB), New York University Abu Dhabi, PO Box 129188, Abu Dhabi, United Arab Emirates; grace.vaughan@nyu.edu
5Arabian Center for Climate and Environmental Sciences (ACCESS) and Water Research Center (WRC), New York University Abu Dhabi, PO Box 129188, Abu Dhabi, United Arab Emirates; oliver.farrell@nyu.edu; john.burt@nyu.edu
*Corresponding author

Extremely warm seas are characterized by hostile conditions due to temperatures that threaten sensitive symbiotic relationships or require specific adaptation strategies within local organisms. These environments can help to shed light on conditions in other areas of the world where climate change is causing increasingly extreme temperatures. The Persian/Arabian Gulf (PAG) is such a sea, hosting coral reefs adapted to extremely warm temperatures (up to 36°C in the summer) which is exceeding the thermal maxima of nearly all tropical reef fauna by more than 2°C, as well as having extreme salinities (>42 ppm). Due to these extremes there is a limited coral biodiversity, whereas foraminiferan biodiversity is comparable to other water bodies in the world, with ~750 benthic foraminiferal species identified to date. Benthic foraminifera are excellent indicators of coral reef health and are often used in biomonitoring studies as pollution indicators.

In order to improve foraminifera biodiversity assessment in the local scale, three reefs of the Southern Gulf, off the coast of Abu Dhabi, were screened for biodiversity with replicated sampling along several 10 m transects (Ras Ghanada, Saadiyat and Dhabiya, n=12). Sediment samples were stained immediately in rose bengal to distinguish live from dead foraminifera. Living foraminifera community was analysed using three biodiversity indices (Shannon diversity, Margalef’s richness and Dominance) and principal component analysis. It was shown that 33 species were present. Tretomphalus sp. being the most abundant, which is remarkable. The fauna of Ras Ghanada was strongly dominated by the species Tretomphalus sp. (59 to 88 %), which was also observed to a lesser extent in Saadiyat (maximum of 67%). This species had a patchy distribution, as it occurred as a colonizing form mainly attached on dead coral fragments but also loose. The second most abundant species was the symbiont-bearing species, Peneroplis planatus, hosting red algae symbionts. The biodiversity indices showed that the fauna of Ras Ghanada had lower diversity and higher dominance of individual species compared to Dhabiya and Saadiyat. There are also differences among replicates within the reefs, showing that the benthic foraminifera assemblage in this coral reef habitat can vary substantially on small scales, and confirming that replicated sampling is essential. Furthermore, the reefs therefore differ in the proportion of test wall material. Within the Dhabiya reef, the highest proportion of agglutinated and porcelaneous-agglutinated tests was found. Dhabiya and Saadiyat are characterized by a high proportion of porcelaneous tests, whereas Ras Ghanada is dominated by hyaline species. The results of this project contribute to biodiversity assessments of extreme habitats, and can help to interpolate how this population is different from other locations. The PAG is an important study region for understanding local adaptations of species to extreme warm and saline conditions.

Menthol-induced bleaching as an effective method to rear foraminifera aposymbiotic

SCHMIDT Christiane1*, PUERTO RUEDA Diana1,2, STUHR Marleen1, RAPOSO Debora3, POCHON Xavier4 and DAVY Simon4

1ZMT, Leibniz Centre for Tropical Marine Research, Fahrenheithstraβe 6, 28359 Bremen, Germany; christiane.schmidt@leibniz-zmt.de; marleen.stuhr@leibniz-zmt.de
2Department of Marine Biology, University Bremen, Postfach 330 440, 28334 Bremen, Germany; dipuerto@uni-bremen.de
3MARUM, Center for Marine Environmental Sciences, Leobenerstraβe, 28359 Bremen, University of Bremen, Bremen, Germany; draposo@marum.de
4Cawthron Institute, 98 Halifax Street, The Wood, Nelson 7010, New Zealand; xavier.pochon@cawthron.org.nz
5School of Biological Sciences, Victoria University of Wellington, TTR 406, Te Toki A Rata, Gate 7, Kelburn Parade, Wellington 6012, New Zealand; simon.davy@vuw.ac.nz
*Corresponding author

Symbiotic relationships with microalgae and thermal adaptations of host and symbiont are shaping the stress tolerance of LBF (larger benthic foraminifera) to climate change. The aim to better understand bleaching has led to search for novel ways to gain aposymbiotic hosts. Menthol-bleaching is an innovative methodological approach which has been recently applied in Aiptasia pallida, a sea anemone, to rear aposymbiotic individuals for symbiosis investigations. Repeated menthol applications cause a cold-sensation in the host organism, which subsequently expels its microalgal symbionts. To test if this method can be used to rear LBF aposymbiotic was tested in a bleaching experiment for 6 weeks. We applied the treatment to the diatom containing Amphistegina lobifera and dinoflagellate containing Sorites orbiculus.
Life in a dark environment –physiological response of benthic foraminifera to the environmental changes of the Paleogene

SCHMIDT Daniela N.1*, ADEBOWALE Monsuru1, FLOWER Amy1, THOMAS Ellen2, RIDGWELL Andy3,4, COTTON Laura J.3,5 and WITTs James1

1School of Earth Sciences, University of Bristol, Wills Memorial Building, Bristol BS8 1RJ, UK; d.schmidt@bristol.ac.uk; monsooradebowale@gmail.com; amy.flower.2021@bristol.ac.uk; james.witts@bristol.ac.uk
2Department of Earth and Planetary Sciences, Yale University, 210 Whitney Avenue, New Haven, CT 06511, USA; ellen.thomas@yale.edu
3School of Geographical Science, University of Bristol, University Road, Bristol BS8 1SS, UK; andy@seao2.org
4Department of Earth and Planetary Sciences, Geology Building, University of California, Riverside, 900 University Avenue, Riverside, CA 92521, USA; andy@seao2.org
5Present address: Natural History Museum Denmark, Øster Voldgade 5 - 7, 1350 København K, Denmark; laura.cotton@snm.ku.dk
*Corresponding author

The Paleogene is a dynamic interval of Earth’s climatic history, beginning with the trauma of the K/Pg, followed by a series of hyperthermal events, including the PETM and ETM2. These events represent severe disturbances/perturbations of global carbon cycling and the wider Earth system. Extinctions, migrations and evolutionary turnover are associated with all events, and their patterns give insight into physiological stress affecting marine biota.

We investigate morphological response (surface area, test volume, calcite volume, chamber number) in benthic foraminiferal species (Nuttallides truempyi, epifaunal; Oridorsalis umbonatus, shallow infaunal) at central Pacific Site 1210 (Paleo Depth 2100 m), Southern Ocean Maud Rise Site 690 (PD 1900 m), Walvis Ridge Site 1262/1263 (PD = 3500/1500 m), and Kerguelen Plateau Site 1135 (PD ~800 m) using computed tomography (CT).

Despite the lack of extinction of benthic foraminifera during the environmental crisis at the K/Pg boundary, taxa from the Southern Ocean display shifts in species abundance, richness, size, growth rate, and surface area:volume in the aftermath of the Chicxulub impact event, revealing the potential role of morphological plasticity for promoting resilience and survival in benthic calcifiers. In contrast, data from the central Pacific reveal very few changes, also suggesting that trait changes across the K/Pg occurred at different times in different environmental settings and groups, supporting the hypothesis that environmental heterogeneity is important in modulating resilience.

During the PETM and ETM2, the relative warming was similar at all study sites, thus differences in biotic effects between locations are probably not related to differential warming. During the PETM, environmental changes led to reduction of test volume of both species, negatively impacting their potential ability to generate gametes. Similar reductions are found for N. truempyi during the ETM2 except for the deepest site in the Atlantic. During the PETM, N. truempyi increased its surface area relative to volume in the Southern Ocean, potentially increasing its ability to forage and take up oxygen. In contrast, there is no clear pattern of change in shallow infaunal O. umbonatus which, given sufficient food, can thrive at lower oxygen conditions. Calcite volume/test volume decreased in both species during the PETM in the Southern Ocean during the PETM; the lack of response in the Pacific was possibly driven by persistent severe oligotrophy. For the ETM, no change in calcification was detected. Food availability at the Southern Ocean sites may have supported growth (indicated by test volumes), but did not supply enough energy for calcification to mitigate against acidification during peak PETM conditions.

Faunal composition and isotopic fingerprinting of benthic foraminifera to distinguish contourites from turbidites

SCHMIDT Johanna1, HERWARTZ Daniel1, DE CASTRO Sandra2, HERNÁNDEZ-MOLINA Javier3, PETERSEN Jassim1, SAUPE Anna1, Bahr André4 and GRUNERT Patrick15

1Institute of Geology and Mineralogy, University of Cologne, Otto-Fischer-Straße 14, 50674 Cologne, Germany; johanna.schmidt@uni-koeln.de; d.herwartz@uni-koeln.de; jassin.petersen@uni-koeln.de; anna.saupe@uni-koeln.de; pgrunert@uni-koeln.de
2Arquimea Research Center, Camino Las Mantecas, 38320 San Cristobal De La Laguna, Santa Cruz de Tenerife, Spain; scastro@arquimea.com
3Department of Earth Sciences, Royal Holloway University London, Egham, Surrey TW20 0EX, United Kingdom; javier.hernandez-molina@rhul.ac.uk
4Institute of Geosciences, Heidelberg University, Im Neuenheimer Feld 234, 69120 Heidelberg, Germany; andre.bahr@geow.uni-heidelberg.de

In order to induce bleaching, the foraminifera were exposed to repeated seawater changes containing menthol at non-lethal concentrations in the presence of the photosynthetic inhibitor DCMU (3-(3,4-dichlorophenyl)-1,1-dimethylurea) diluted in seawater for a 6-week bleaching experiment. Survival rate of foraminifera was high, as pseudopodal movement was visible under the inverse microscope. The foraminifera in this bleached state were able to move and extend their pseudopodial network for feeding and locomotion. After the 6 weeks experiment, foraminifera were >95% symbiont-free, visible through images in the inverted epifluorescence microscope and chlα measurements. This method is hence effective and will serve in subsequent experiments to test symbiont-uptake post-bleaching, for which selected diatom species will be re-inoculated in the aposymbiotic hosts. With this approach we hope to shed light on symbiont flexibility in LBF and to test the capacity to elevate their thermal tolerance by selecting thermally tolerant symbiont strains before re-inoculation.
Benthic foraminifera in Contourite Depositional Systems (CDSs) potentially provide key information for the reconstruction of oceanic bottom currents. In the CDS of the SW Iberian Margin, abundances of a distinct group of benthic foraminifera are controlled by the velocity and nutrient load of bottom currents. This so-called “elevated epifauna” (EEF) comprises highly specialized suspension feeding benthic foraminifera attached to elevated substrates as an adaptation to strong bottom currents. A direct relation between EEF abundances and Mediterranean Outflow Water (MOW) velocity has been demonstrated in modern surface samples, highlighting their potential as a bottom current proxy. In the sedimentary record, however, contourite deposits are often intercalated with gravitational deposits that may compromise paleoceanographic interpretations. The reliable distinction of the contourites, turbidites and turbidites reworked by bottom currents and their respective content of foraminiferal shells is thus essential to ensure the reliability of the EEF proxy method. Here we present a unique, highly resolved set of faunal and isotopic ($\delta^{18}O$, $\delta^{13}C$) data from benthic foraminiferal shells > 250 µm in Pleistocene contourite and turbidite sequences at IODP Site U1389 in the Gulf of Cadiz. The data allow us to characterize and compare assemblage composition, abundances of EEF species and provenance of shells of EEF taxa.

Two-website statistical analyses reveal foraminiferal assemblages distinctive for contourites and turbidites, respectively. EEF data along the bi-gradational contourite sequence indicate that their abundances may serve as a reliable indicator of bottom current strength even at strongly increased bottom current velocity beyond the limits of some established sedimentological proxy methods. When combined, sedimentological and micropaleontological proxy data thus allow for a more complete and robust characterization of the processes underlying contourite deposition.

Non-reworked and reworked turbidite deposits show significant amounts of taxa with a bathymetric distribution limited to the shelf as well as EEF taxa. In the non-reworked turbidite, their abundances decrease along the normally graded sequence. Isotopic data of several hundred EEF shells suggest that at least 50% of C. lobatulus were re-deposited from the shelf, while the vast majority of C. pseudolobatulus, P. arminensis and Discanomalina spp. originate from the continental slope. The combination of high abundances of C. lobatulus and shelf taxa may thus serve as a good indicator of bias by turbiditic transport, in particular when turbiditic deposits have been reworked by bottom currents and are barely distinguishable from contourites. While used in the present study to characterize the differential origin of EEF shells within a turbidite, isotopic fingerprinting potentially allows the characterization of gravitational mass wasting events in general by pinpointing its origin and allowing for assumptions regarding its pathway and transport distance.

This study was funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) through project GR52651/1-1.

Benthic foraminiferal record of deep-sea biodiversity changes during the late Quaternary

SCHMIDL Gerhard1*, MILKER Yvonne1 and MACKENSEN Andreas2

1Institute for Geology, Center for Earth System Research and Sustainability, Universität Hamburg, Bundesstrasse 55, 20146 Hamburg, Germany; gerhard.schmiedl@uni-hamburg.de; yvonne.milker@uni-hamburg.de
2Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Am Alten Hafen 26, 27568, Bremerhaven, Germany; amackens@posteo.de
*Corresponding author

The biodiversity of deep-sea ecosystems is closely linked to climate variability as documented by the diversity and species composition of benthic foraminifera in late Quaternary sediments. The benthic foraminiferal diversity changes are primarily controlled by variations in food fluxes and bottom-water oxygenation with distinct regional differences. The observed regional diversity patterns and temporal trends suggest that highly diverse deep-sea ecosystems are more resilient to drops in oxygen than low-diverse ecosystems, supporting the diversity-stability hypothesis. Seasonally enhanced food fluxes in oligotrophic and well-ventilated deep-sea ecosystems, such as the Nordic Seas, commonly lead to a dominance of opportunistic taxa and thus do not necessarily result in a diversity increase. Absolute diversity contrasts between glacial and interglacial periods increase with increasing water depth, with relatively lower glacial diversity in the deep parts of the open oceans (Nordic Seas, Atlantic Ocean, Southern Ocean, Indian Ocean) but higher glacial diversity in the marginal seas (Mediterranean Sea, Red Sea). This difference can be attributed to the different regional response of thermohaline processes to climate changes. Specifically, benthic ecosystems of deep open-ocean basins profit from enhanced ventilation during interglacial conditions, while in marginal basins of the Mediterranean and Red seas, warm and humid conditions during insolation maxima repeatedly result in a temporal shut-down of deep-water formation with transient collapses of deep-sea ecosystems.
Foraminifera and Other Organisms: Determination of Interactions and Ecology (project FOODIE) in two contrasting environments

SCHWEIZER Magali1,2, GESLIN Emmanuella1, BIRD Clare2, FILIPSSON Helena L.2,2, JAUFFRAIS Thierry4, LEKIEFFRE Charlotte1, MANERO Florence2, METZGER Edouard1, MOURET Aurélia1 and QUINCHARD Sophie1

1Université d’Angers, Nantes Université, Le Mans Université, CNRS, Laboratoire de Planétologie et Géosciences, LPG UMR 6112, 2 bd de Lavoisier, 49000 Angers, France; magali.schweizer@univ-angers.fr; emmanuella.geslin@univ-angers.fr; edouard.metzger@univ-angers.fr; aurelia.mouret@univ-angers.fr; sophie.quinchard@univ-angers.fr
2Department of Biological and Environmental Sciences, University of Stirling, Stirling FK9 4LA, UK;clare.bird2@stir.ac.uk
3Department of Geology, Lund University, Sölvegatan 12, Lund, Sweden; helena.filipsson@geo.lu.se
4UMR 9220 ENTROPiE, Ifremer, IRD, Univ Nouvelle Calédonie, Univ La Réunion, CNRS, Campus IRD - 101 Promenade Roger Laroque - BP 32078 - 98897 Nouméa Cedex, New Caledonia; thierry.jauffrais@ifremer.fr
5Univ. Grenoble Alpes, CNRS, CEA, INRAe; IRIG-LPCV, 17 avenue des Martyrs, 38 054 Grenoble cedex 9, France; charlotte.lekiefre@gmail.com
6SCIAM, University of Angers, 4 rue Larrey, 49933 Angers, France; florence.manero@univ-angers.fr
*Corresponding author

Foraminifera represent a critical part of the meiofauna and are present in all marine benthic environments from salt marshes to abyssal trenches, they have also colonised the planktonic realm. Denitrification and kleptoplasty demonstrate that foraminifera have diverse life strategies and are part of a complex association network that remains poorly defined. Their life strategies could be influenced by the geochemical conditions of the living environment (microhabitat). An adequate description of these conditions with high-spatial resolution measurements is thus essential.

Our study combines high-throughput sequencing of the microbiome (prokaryote and eukaryote) with morphological and TEM (transmission electron microscopy) analyses of foraminifera sampled at the same time in the same location. In parallel, geochemical data were collected to characterise the microhabitats from which these foraminifera originated. Additionally, sediment samples were sequenced for environmental DNA (eDNA) to compare the foraminiferal microbiome with in situ micro-organism communities. Two contrasting sites were chosen: Bourgneuf Bay, a mudflat located on the French Atlantic coast, and the Gullmar Fjord, located on the Swedish Skagerrak coast. At both sites the biodiversity are well known and at Bourgneuf Bay foraminiferal population dynamics combined to sediment geochemistry are well understood through a long term survey (Mudsurv). Therefore, these sites are ideal to study the interactions of foraminifera with other organisms.

The main objective of this study is to document the trophic strategies of foraminifera and their interactions with the ecosystem of the sites studied. For Bourgneuf Bay, foraminifera belonging to five taxa have been sequenced for their microbiome in three different sediment depths. The three taxa with a hyaline test have also been examined with TEM. For the Gullmar Fjord, 29 species sampled in three different sites could be sequenced for their microbiome. Among these species, six hyaline ones were fixed for TEM analyses. The microbiome profiling shows that kleptoplastic species contain diatom sequences (16S and 18S rDNA) in higher abundances and more systematically than more omnivorous or less specialised species. The diversity of the internal microbiome of foraminifera, the similarity of the microbiome in the same species between different locations and the ecological interactions between foraminifera and their microbiome will also be discussed. With TEM, kleptoplastic species show well preserved chloroplasts in higher numbers than non-kleptoplastic species, whereas denitrifying species have higher numbers of large vacuoles. Combining the microbiome and TEM results with geochemical characterisation and live foraminiferal distribution in the sediment will also help answering how the foraminiferal microbiome compare to the microhabitat, how environmental differences influence foraminifera and other micro-organisms and what are the most influential associations in the habitats examined.

Harmful Algal Bloom (Red Tide) Monitoring Utilizing Benthic Foraminifera on the West Florida Shelf (USA)

SCHWING Patrick1,2, SCHWING Garrett Matthew2, HUBBARD Katherine2, LAM Tristan1, MOPPS Gabe1, DAZUARDIS Geo1, INGA Bailey1, CORY Ariana1, O’MALLEY Bryan1, LARSON Rebekka1 and BROOKS Gregg2

1Department of Marine Sciences, Eckerd College, 4200 54th Ave. S., Saint Petersburg, FL, 33711, USA; schwimgt@eckerd.edu, glmopps@eckerd.edu; gedaazuardis@eckerd.edu; bringag@eckerd.edu; abcor@eckerd.edu; bjormalle@eckerd.edu; larsonra@eckerd.edu;
2Fish and Wildlife Research Institute, Florida Fish and Wildlife Conservation Commission, 100 8th Ave. SE, Saint Petersburg, FL 33701, USA; Matthew.Garrett@myfwc.com; Katherine.Hubbard@myfwc.com
*Corresponding author

*Karenia brevis* is the primary species of dinoflagellate that causes “red tide” in Southwest Florida, a harmful algal bloom associated with brevetoxins. Blooms of *K. brevis* can result in reduced water quality including anoxia, fish and wildlife mortalities, and human health concerns on the West Florida Shelf. The majority of observations for *K. brevis* and related impacts are focused in the nearshore neritic zone, since blooms occur there throughout the water column. Far less sampling in the benthic zone has been conducted, thus whether there’s a role of the benthos in bloom initiation and other key dynamics remains unknown. Recent evidence that similar species, including *Karenia mikimotoi*, produce resting stages has led to an increased interest in understanding the life cycle of *K. brevis* and thus the role that the benthic environment plays on
initiation and termination of bloom events. This collaborative effort involves working with the Florida Fish and Wildlife Conservation Commission-Fish and Wildlife Research Institute’s Harmful Algal Bloom (FWRI-HAB) group to investigate K. brevis benthic coupling with the goals of 1) providing environmental context of the benthos; 2) establishing baselines of K. brevis bloom impacts/conditions in benthic environments utilizing multiple benthic foraminifera metrics including density, diversity indices, and marine biotic indices coupled with, and calibrated to, K. brevis abundance and 3) evaluating the historical record of the magnitude and frequency of red tide blooms constrained by short-lived radioisotope dating, coupled with seafloor ecological quality status based on benthic foraminiferal biotic indices.

To address these goals, surface sediment samples have been collected on a monthly basis since January 2021 at five sites along a westerly transect (70 km offshore, 5-40 m water depth) from Tampa Bay, Florida. Multicores have been collected at sites specifically identified as depocenters to produce continuous historical records and avoid sediment reworking as much as possible. Both stained (rose Bengal, for monitoring purposes) and total (for historical purposes) benthic foraminifera assemblages have been characterized to produce density, diversity indices (e.g. Shannon, Fisher’s Alpha, Evenness), and marine biotic indices (f-AMBI). These benthic foraminifera metrics have been paired with sedimentology (texture and composition) and short-lived radioisotope dating for historical record constraint. Future work will pair the benthic foraminifera records of seafloor health with and calibrate the f-AMBI to indicators for K. brevis, and complements ongoing work using neritic cell concentrations of this HAB.

This study will present more than two years of monitoring data along with historical (last 100 years) profiles, linking benthic foraminifera indicators of seafloor health with potential red tide indicators. Preliminary evidence suggests that the f-AMBI recorded a decrease in seafloor ecological quality status in response to high concentrations of K. brevis during a bloom in late 2021. Ongoing and future work will include refining historical records, developing new tools for historical red tide tracers, and refining the calibration of benthic foraminifera-based marine biotic indices to various red tide indicators. These collective goals are critical for laying the groundwork for a benthic monitoring program to aid in forecasting bloom dynamics (initiation and termination) as well as the seasonal and interannual effects of red tide on the seafloor.

Trace elements through life and time of planktic foraminifera

SEARLE-BARNES Alex1*; MILTON J. Andy1; STANDISH Christopher1; FOSTER Gavin1 and EZARD Thomas1

1Ocean and Earth Science, University of Southampton, European Way, Southampton, SO14 3ZH, UK; c.j.a.searle-barnes@soton.ac.uk; james.a.milton@noc.soton.ac.uk; c.d.standish@soton.ac.uk; g.l.foster@soton.ac.uk; t.ezard@soton.ac.uk
*Corresponding author

Trace elements incorporated within a foraminifera test along with stable isotope ratios can reveal the chemical and environmental conditions at the time of their growth. We investigate how chamber specific trace element ratios correlate with individual-level stable isotope ratios and which parts of the life cycle imprint the largest geochemical signal for the whole individual. We ask if these correlations vary over geological time, by species or individual growth stage. As the sensitivity of geochemical analysis improves, it is now feasible to build sufficiently powerful datasets to investigate palaeoecological variation at the level of individual chambers within individual foraminifera, rather than averaging analyses that obscures systemic sources of variation.

We present the largest trace element, mass and stable isotope ratio data set of four Menardella from Plio-Pleistocene sediments at ODP Site 925 in the western equatorial Atlantic Ocean. We measured trace elements in six chambers within the final whorl, whole test mass and stable isotope ratios for ~2,000 individuals over the Menardella menardii, M. limbata, M. exilis and M. pertenuis evolutionary lineage. Deploying improved protocols for laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS), we quantify the elemental composition of fossilised foraminifera tests while controlling for individual ID, age and species.

We show how Mg/Ca ratios change through ontogeny, suggesting a change in how organisms use their environment during life by inhabiting different water depths and if symbionts were hosted. The ancestral species demonstrate a marked increase in Mg/Ca ratios during life, whereas descendent species show no detectable changes, suggesting the ancestral species alter their depth habitats during life, unlike their descendent species.

In earlier chambers, where the calcite wall is thickest, Mg/Ca ratios are 3-4 times stronger in correlation to whole test δ18O values than later chambers, implying that the environment that determines the individual level δ18O value is that experienced earlier in life.

The correlations between chamber-specific trace element ratios and individual-level δ18O values reinforces the repeatability of these high-resolution analyses and the capacity of planktonic foraminifera to record the chemical and environmental conditions at a fine, mid-life resolution.
Warm Water Incursions and Water Mass Changes on the Ross Sea Shelf (Antarctica) During the Plio-Pleistocene 
Based on Foraminifera from IODP Exp 374

SEIDENSTEIN, Julia L.1,2, LECKIE, R. Mark1*, HARRYWOOD, David3 and IODP Exp. 374 Shipboard Scientists

1Department of Earth, Geographic, and Climate Sciences, University of Massachusetts, 227 N. Pleasant St., Amherst, MA 01003, USA; julia.l.seidenstein@gmail.com; leckie@umass.edu
2U.S. Geological Survey, Florence Bascom Geoscience Center, 12201 Sunrise Valley Dr MS926A, Reston, VA 20192, USA; julia.l.seidenstein@gmail.com
3University of Nebraska-Lincoln, Department of Earth and Atmospheric Sciences, Lincoln NE, USA; dharrywood@unl.edu
*Corresponding author

International Ocean Discovery Program (IODP) Expedition 374 sailed to the Ross Sea in 2018 to reconstruct paleoenvironments and assess model simulations that show warming waters in the Southern Ocean led to the loss of Antarctic ice in the past. Site U1523 (water depth 828 m) is located at the continental shelf break and is sensitive to both warm water incursions from the Ross Sea Gyre and modified Circumpolar Deep Water (mCDW) coming onto the Ross Sea shelf when the Antarctic Slope Current weakens with a warming climate. Shelf sites U1521 (562 m) and U1522 (558 m) provide data for the environment closer to the Ross Ice Shelf. Multiple incursions of subpolar or temperate planktic foraminifera taxa occurred prior to ~1.8 Ma and after 4 Ma. Based on an updated age model at Site U1523 (2022), these warm water taxa incursions could represent Gi3 or Gi5, G15 or G17, Marine Isotope Stage (MIS) 91 or 89, and MIS 73-67 indicating warmer than present conditions and less ice cover in the Ross Sea. High abundances of foraminifera in the mid-to-late Pleistocene associated with MIS 31-37 and MIS 5e might also indicate a reduced ice shelf and relatively warmer conditions. The interval of abundant foraminifera around MIS 31 suggests multiple warmer interglacials during the Mid-Pleistocene Transition (MPT; ~800 ka). A change in benthic foraminiferal assemblages and a large increase in foraminiferal fragments after the MPT indicate stronger currents at the seafloor, and perhaps corrosive waters, suggesting a major change in water masses entering (mCDW) and exiting (High Salinity Shelf Water; HSSW) the Ross Sea since the MPT.

Carboniferous-earliest Permian foraminifera radiation certificated by a high-resolution biodiversity analysis

Shi Yukun*1

1School of Earth Sciences and Engineering and Frontiers Science Center for Critical Earth Material Cycling, Nanjing University, No. 163 Xianlin Avenue, Nanjing, China; ykshi@nju.edu.cn
*Corresponding author

A general foraminiferal biodiversification trend from the Carboniferous to the Early Permian has long been recognized by many researchers because of the sudden increase in fossil records. Several integrated quantitative analyses have been confirmed this trend, but only with limited data. A high-resolution biodiversity analysis based on 551 geological sections distributed over all the major Chinese tectonic plates was performed using a parallel computing version of the algorithm called CONOP.SAGA and the Chinese supercomputer “Tianhe II”. As a result, the temporal resolution reached 36 kyr and 21 kyr for the Carboniferous and Permian, respectively. The precise details of the biodiversification process were revealed, including the high-resolution changes in species and genus richness, and the rates of origination and extinction. The biodiversification lasted 41.2 Myr from the middle Visean of the Carboniferous to the late Asselian of the Permian. The oldest type of larger benthic foraminifera, fusulinids, underwent an adaptive radiation event during this process and made a dominant contribution to the diversification. Fusulinid species richness increased nearly 40-fold during the radiation and developed two pulses in the late Bashkirian-Moscovian (Carboniferous) and Gzhelian (Carboniferous)-Asselian respectively, with peaks at the late Moscovian and late Asselian. During the same period, a diversification trend was also observed in the benthic brachiopod fauna. With a 246% increase in the total number of marine species, this event was named as the Carboniferous-earliest Permian Biodiversification Event (CPBE) to indicate the flourishing of the marine fauna. With the help of the high-resolution biodiversity analysis, more patterns and details would be revealed in the evolution of foraminifera.

Analysis of planktonic foraminifera abundance in ceramic samples from Pian della Tirena (Calabria, southern Italy): Application of JMicroVision software

SICILIANO Julie1*, RUSSO Bianca2, BARATTOLO Filippo3 and DE BONIS Alberto2

1Department of Earth Sciences “Ardito Desio”, University of Milan, Via Mangiagalli 24, 20133 Milan, Italy; julie.siciliano@studenti.unimi.it
2Department of Earth Sciences, Environment and Resources, University of Naples Federico II, Via Cinthia 21, 80126 Naples, Italy; brusso@unina.it; filippo.baratolo@unina.it; alberto.debonis@unina.it
*Corresponding author
In the geological sciences, as in other scientific disciplines, the use of image analysis is becoming increasingly important for the analysis of remote sensing data and images, seismic images, thematic maps, and maps, but also for the study of thin-section samples photographed with a microscope-mounted camera.

For this thesis, an innovative study was carried out with the image analysis software JM MicroVision version 1.3.4 to assess the abundance of planktonic foraminifera in photos of thin sections of ceramic and clay samples taken from the area of the archaeological site of Pian della Tirena (Calabria, southern Italy). The results obtained were compared with those obtained by traditional abundance analysis. This work encompassed all the steps for a quantitative analysis of the material, from obtaining the photos to collecting and processing the data, having as its ultimate goal to verify whether the measurement of the surface area occupied by planktonic foraminifera, calculated by the software, can represent a suitable and faster method than the traditional counting for the evaluation of planktonic foraminifera abundance.

The results obtained from both analyses are not directly comparable, so they were compared after their transformation into dimensionless numbers. Comparison of the data obtained with JM MicroVision version 1.3.4 with those from the abundance calculation shows differences that are probably due to the limited size of the survey field used (8.6 x 6.4 mm) and the number of points classified (300). Therefore, further study is needed to identify the minimum area of the survey field and the minimum number of points to be classified so that the variability in the size of planktonic foraminifera is not a limiting factor.

Mg/Ca surface-water paleotemperatures at the Early Eocene Climatic Optimum from the Pacific Ocean: repercussions on planktonic foraminiferal assemblages

Sigsimondi Silvia*, Filippi Giulia1, D’Onofrio Roberta1, Tiepolo Massimo2, Cannao Enrico2, Dickens Gerald R.3, Wade Bridget S.2, Westerhold Thomas4 and Luciani Valeria1

1 Dipartimento di Fisica e Scienze della Terra, University of Ferrara, Via Giuseppe Saragat 1, 44122, Ferrara, Italy; silvia.sigsimondi@unife.it; giulia.filippi@unife.it; roberta.donofrio@unife.it; valeria.luciani@unife.it; enrico.cannao@unimi.it
2 Dipartimento di Scienze della Terra “A. Desio”, University of Milan, Via Sandro Botticelli, 23, 20133 Milano, Italy; massimo.tiepolo@unimi.it; enrico.cannao@unimi.it
3 Department of Geology, Museum Building, Trinity College Dublin, College Green, Museum Building, 1 Park Ln E, Dublin, Ireland; DICKENSG@tcd.ie
4 Department of Earth Sciences, University College of London, Prince Consort Road, South Kensington, London SW7 2BP, United Kingdom; br.wade@ucl.ac.uk
5 MARUM – Center for Marine Environmental Sciences, University of Bremen, Leobener Street 8, 28359 Bremen, Germany; twesterhold@marum.de

*Corresponding author

The Early Eocene Climatic Optimum (EECO; ~53-49 Ma), that records the peak of Cenozoic warmth and CO2, induced climatic and paleoceanographic changes that significantly affected planktic foraminiferal assemblages. The main change is the permanent marked decline in abundance and diversity of the mixed-layer symbiotic bearing genus Morozovella, coupled with the increase of Acarinina starting from the basal EECO at the tropical Pacific Ocean (sites 1209-1210), similarly to the previously documented record from the Atlantic Ocean. A second significant variations is the change in coiling direction of morozovellids that moved from dominantly dextral to sinistral close to the K/X event, which differs from Acarinina which does not display any preferential coiling direction throughout. Even though a link between the aforementioned modifications and the EECO perturbation appears evident, the driving causes of the recorded modifications are still unknown.

With the aim to evaluate whether potential temperature increase may have impacted the observed planktic foraminiferal changes, we performed Mg/Ca derived paleotemperatures from tropical Pacific sites 1209-1210 through Laser Ablation (LA)-ICP-MS. Our results on B/Ca and Sr/Ca content in all the examined species and the low planktic foraminiferal test-reduction, we performed Mg/Ca derived paleotemperatures from tropical Pacific sites 1209-1210 through Laser Ablation (LA)-ICP-MS. Our results on B/Ca and Sr/Ca content in all the examined species and the low planktic foraminiferal test-fragmentation allow us to exclude significant influence on derived temperatures of pH variations and contamination. Our results reveal major temperature increase at the EECO as recorded by all the species and the minimum planktic foraminiferal temperature increase, with respect to dextral forms.

The Early Eocene Climatic Optimum (EECO; ~53-49 Ma), that records the peak of Cenozoic warmth and CO2, induced climatic and paleoceanographic changes that significantly affected planktic foraminiferal assemblages. The main change is the permanent marked decline in abundance and diversity of the mixed-layer symbiotic bearing genus Morozovella, coupled with the increase of Acarinina starting from the basal EECO at the tropical Pacific Ocean (sites 1209-1210), similarly to the previously documented record from the Atlantic Ocean. A second significant variations is the change in coiling direction of morozovellids that moved from dominantly dextral to sinistral close to the K/X event, which differs from Acarinina which does not display any preferential coiling direction throughout. Even though a link between the aforementioned modifications and the EECO perturbation appears evident, the driving causes of the recorded modifications are still unknown.

With the aim to evaluate whether potential temperature increase may have impacted the observed planktic foraminiferal changes, we performed Mg/Ca derived paleotemperatures from tropical Pacific sites 1209-1210 through Laser Ablation (LA)-ICP-MS. Our results on B/Ca and Sr/Ca content in all the examined species and the low planktic foraminiferal test-fragmentation allow us to exclude significant influence on derived temperatures of pH variations and contamination. Our results reveal major temperature increase at the EECO as recorded by all the species and the low planktic foraminiferal temperature increase, with respect to dextral forms.

We hypothesize that the rise in temperature recorded by morozovellids may have contributed to a reduction in their symbiotic relationship that, in turn, caused their decline in abundance, as symbiosis is known to advantage life in oligotrophic mixed-layer habitat and helping test-growth. This hypothesis is also supported by the lower 813C signatures of the survivor sinistral morozovellids with respect to dextral morphotypes, and suggests less dependence on their photosymbiotic partnerships. It is thus possible that this character may have enabled sinistral morozovellids to be resilient, though in low abundance, to the EECO perturbation with respect to dextral forms. Although the exact causes of photosymbiotic degradation can be manifold, increased temperature is considered a primary factor of degradation in present tropical larger benthic foraminifera. Even though it cannot be demonstrated whether sinistral and dextral morphotypes were cryptic species, the differences in their stable-isotope derived paleobiology could encourage this hypothesis.

The minor temperature increase recorded by acarininids may have been not sufficient to generate crisis in their symbiosis relationship. The acarininids 813C signatures do not display appreciable variations before and within the EECO thus to support this hypothesis. In addition, we record a thermocline temperature increase up to ~2°C through the analysis on...
subbotinid specimens that may justify their drop in abundance and the chiloguembelinids virtual disappearance as being cold-water indices.

Impact of the Middle Eocene Climatic Optimum (MECO) on Atlantic planktic foraminiferal assemblages

SIGMONDI SilVia1,2*, LUCIANI Valeria1 and ALEGRET Laia2

1Dipartimento di Fisica e Scienze della Terra, University of Ferrara, Via Giuseppe Saragat 1, 44122, Ferrara, Italy; silvia.sigmondi@unife.it; valeria.luciani@unife.it
2Deparmento de Ciencias de la Tierra & Instituto Universitario de Ciencias Ambientales, Universidad de Zaragoza, Pedro Cerbuna 12, 50009 Zaragoza, Spain; laia@unizar.es
*Corresponding author

The Middle Eocene Climatic Optimum (MECO), centered at ~40 Ma, is characterized by marine bulk and benthic carbonate δ18O values steadily declining by roughly 1‰ in over ~400 kyr, usually interpreted as a 3–6 °C increase in global temperature followed by a rapid return to pre-event conditions. This event is increasingly attracting the scientific attention as it records temperatures and pCO₂ that Earth will reach whether anthropogenic emissions will not stop (RCP8.5). Despite that, the biotic impact of the MECO are still poorly constrained. With the aim to contributing in filling this gap, we focus on planktic foraminifera, which, being extremely sensitive to the physical and chemical state of the oceans, can offer valuable insights on the impact of this global warming event on marine ecosystems. In addition, the δ13C signal across the MECO event such as the paleoceanographic repercussions show great geographic heterogeneity. These features and the absence of a clear triggering mechanism make the MECO one of the most enigmatic events in the Cenozoic also known as middle Eocene “carbon cycle conundrum”. We selected the Ocean Drilling Program sites, 1051, 1263 and 702 that cover tropical northern to farther southern high-latitude settings and provide established stratigraphic and stable isotope constrains.

The most pronounced change in planktic foraminifer assemblages is recorded at Site 1051 (Blake Nose) as the ‘large acarininids’ (>150 µm) markedly and permanently reduce their abundance at the MECO top, as also recorded from Tethyan successions. It is well known that photosymbiosis is functional for growth in oligotrophic habitats so the loss of symbiosis may have represented a possible cause to explain the observed abundance reduction.

In the post-MECO interval planktic foraminiferal assemblages at Site 1051 do not recover the pre-event genera abundances. The planktic foraminiferal community shifted to a new permanent and different state thus we deduce that this group was not resilient to the MECO perturbation at this site.

In addition, our data suggest a southern migration of ‘large acarininids’ as, at Site 1263 (Walvis Ridge), the abundance drop of this group is much less marked. The southern migration of the ‘large acarininids’ is much more evident at Site 702 (Islas Orcadas Rise) where ‘large acarininids’ markedly increase at the MECO interval favoured by the temperature increase. The post-MECO assemblages here show a recovery of the pre-event abundances, with the exception of the genus Chiloguembelina, which shows a striking increase in abundance thus suggesting an intensification of the Oxygen Deficient Zone.

The recorded changes further document the complexity and the geographic variability of the MECO repercussions on marine ecosystem.

A critical review of Larger Benthic Foraminifera of the Cenomanian; planispiral (or near-planispiral) forms

SIMMONS Mike1,2* and BIDGOOD Mike3

1Halliburton, 97 Milton Park, Abingdon, OX14 4RW, UK; mike.simmons@halliburton.com
2The Natural History Museum, Cromwell Road, London, SW7 5BD, UK
3GSS (Geoscience) Ltd, 2 Meadows Drive, Oldmeldrum, AB51 0GA, UK; mike@gssgeoscience.co.uk
*Corresponding author

A key task for biostratigraphers is provide a biozonal/bioevent framework for geological correlation. This can be challenging because of lack of agreement on stratigraphic ranges and calibration between fossil groups and to the standard geological timescale. Larger Benthic Foraminifera (LBF) are a case in point. LBF are important biostratigraphic markers in depositional environments where classical biostratigraphic fossils such as planktonic micro- and macrofossils are rare or absent – for example, in tropical-subtropical shallow water platform and ramp carbonates. However, a seeming lack of taxonomic rigour in identifying species, together with a general lack of good age-calibration of their occurrences, has given rise to artificially extended biostratigraphic and paleogeographic ranges for many taxa, thus diluting their usefulness. In this study the occurrences of Cenomanian LBF belonging to a morphological subgroup consisting of essentially planispiral coiled and uncoiled forms, both agglutinated and calcareous (the “planispiral morphogroup”) have been critically evaluated to determine (i) identity; (ii) stratigraphic range; and (iii) palaeogeographic distribution.
The last major review of mid-Cretaceous LBF took place in 1985, and even then, did not include all the planispiral taxa known at that time. Since then, a voluminous literature has appeared reporting occurrences and adding new taxa. An extensive literature review of some 600-700 published items on Cenomanian “planispiral” LBF – mostly published after 1985 – and a critical review of the confidence in species identification and age-calibrations therein, has led us to identify 39 taxa (including three in “open” status) which appear to be separable. These taxa belong to the Lituolida, Loftusiida, Miliolida and Soritida. The vast majority of these records are from Neotethys although some also occur in (or are endemic to) the Caribbean/West Atlantic and the Eastern Pacific. Much of the quality of the published taxonomic data is variable and many published records can be discounted or termed “unconfirmed” as to correct identity. In parallel, many records (confirmed or otherwise) are poorly age-calibrated due to a lack of corroborating biostratigraphy or (e.g.) chemo-stratigraphy or by using circular reasoning.

Although not a monographic treatment, we summarise and illustrate the main defining characteristics of each taxon and their possible “confusion” species and include new taxa described since the mid-1980s. We publish new, more confident, age-ranges for these taxa – confirmed by identity and/or age-calibration – and identify where (published) range data may be less reliable or completely unreliable. Paleogeographic distribution maps for each taxon are also provided. Particular stratigraphic issues around the Cenomanian-Turonian boundary are observed due to the difficulty of identifying that boundary in the field, especially in the central - eastern Neotethys region.

Although most Cenomanian “planispiral” LBF are generally long-ranging, an increase in diversity throughout the middle and late Cenomanian has shown potential for biostratigraphic resolution to at least substage level with this group. It is hoped that similar future treatment afforded to other LBF morphogroups (integrated with the “planispirals”) will yield even higher biostratigraphic resolution of Cenomanian LBF and provide a sound basis for biozonation (both local and global), correlation, and age calibration.

Geochemical and Mineralogical investigation of “foraminifera barren layer” in Maastrichtian carbonate ooze of Walvis ridge

SINGH Brijesh1*, SRIWASTAVA Piyush1 and PUNEKAR Jahnavi1

1Department of Earth Sciences, Indian Institute of Technology Bombay, Powai, Mumbai 400076, India; brijeshs@iitb.ac.in; Piyush.ks@iitb.ac.in; jpunekar@iitb.ac.in
*Corresponding author

The paleoclimate reconstructions for Maastrichtian are extensively based on test carbonate δ18O of foraminifera from DSDP Site 525A (South Atlantic, Walvis Ridge). However, the fidelity of such datasets is contingent upon the taphonomic state of individual tests as well as assemblages. Two conspicuous foraminifera-barren levels stand out at 511 mbsf in contrast to the generally planktic foraminifera rich oozes. The stratigraphically adjacent levels of these barren layers yield assemblages of comparable taphonomy and species composition, indicating an apparent continuum of paleoenvironmental conditions. This warrants an investigation of the foraminifera-barren layer to ascertain whether it is of palaeoenvironmental or epigenetic hydrothermal origin.

Results show that the planktic foraminifera assemblages in the immediately underlying and overlying stratigraphic levels of the barren layers are fragile and are dominated by robust globotruncanids (~50%), while the other groups such as rugoglobigerinids, heterohelicids and globotruncanellids are lower in abundance. The relative abundance of Heterohelix rajagopalanii, a robust thick-walled deep-dwelling biserial, is also high. Other stratigraphic levels away from the barren layer record typical Maastrichtian assemblages with abundant rugoglobigerinids, heterohelicids and globotruncanellids, and a lower representation of globotruncanids. Together these indicate the possibility of taphonomic inflation of robust species in the levels adjacent to the barren layers. X-ray diffraction study of the barren layers reveals jarosite, orthoclase and gypsum. This mineral assemblage suggests an interaction of oxygenated fluid with the host carbonate ooze. Mass balance calculations suggest that the ozone is a potential source of calcium for the formation of gypsum. It may be speculated that the sulphur supply for jarosite, natrojarosite and gypsum could have come from hydrothermal vents related to Walvis ridge activity. It can be concluded that the barren layers are of an epigenetic (hydrothermal) rather than palaeoenvironmental origin.

Migration of the Subtropical Front over the Indian Ocean and its Impact on the Agulhas Current during Quaternary: Planktonic Foraminiferal Evidences

SINGH Vikram Pratap1*, PATHAK Shivani1 and DWIVEDI Rahul1

1Department of Geology, Indira Gandhi National Tribal University, Podki, Lalpur, Amarkantak, Madhya Pradesh, India- 484887; vikram.singh@ignatu.ac.in; shivani.jpathak@gmail.com; drahul718@gmail.com
*Corresponding author
Agulhas Current (AC) is the largest western boundary current transporting ~70 Sv water. It feeds the returning arm of the Atlantic Meridional Overturning Circulation (AMOC). The Indo-Atlantic exchange of waters occurs through the Agulhas Leakage (AL) transports heat and salt to the Atlantic Ocean in form of rings and eddies. AL is regulated by the latitudinal position of the Sub-Tropical Convergence (STC), which has been defined as the boundary between warm saline subtropical surface waters and cooler fresher Subantarctic waters, with its normal latitudinal position at 40° S. The onset of glacial climates causes the northward shift of the STC, which in turn not only reduces the AC flow, but also the AL.

We analysed 136 samples from IODP Hole U-1474A for the planktonic foraminiferal census data and δ18O of Globigerinoides ruber to study the variation of AC during the last ~1 million year. The age model was developed using the stable oxygen isotope data.

We selected the key planktonic foraminiferal species on the basis of the relative abundance and watermass preference. The key species considered for the study are Globigerinoides ruber (warm tropical to subtropical watermass), Globorotalia inflata and Globorotalia truncatulinoides (subtropical to transitional water mass), Neogloboquadrina pachyderma (subpolar watermass, indicative of cold polar water intrusion at the lower latitudes), Globigerinina glutinata and Neogloboquadrina dutertrei (productivity indicators at tropical to subtropical latitudes) and Globigerina bulloides (subpolar watermass, indicative of seasonally enhanced productivity at mid and high latitudes). The Sub-Tropical Convergence (STC) index was calculated as: [Globorotalia truncatulinoides/(Globorotalia truncatulinoides + Neogloboquadrina pachyderma + Globorotalia inflata)].

The comparison of relative abundances of these species with the δ18O and the STC index for the last 1 My points out towards 7 events of northward migration of the STC encountered at 940-870 ky, 760-640 ky, 520-450 ky, 400-350 ky, 320-270 ky, 210-150 ky, and 80-30 ky. These events are marked by high relative abundance of Globorotalia inflata, low abundance of Globigerinoides ruber, rise in the abundance of Globigerina bulloides along with positive excursion of δ18O of Globigerinoides ruber and lower values of STC index. The higher abundance of Globorotalia inflata indicates cooler conditions, which are well corroborated by the lower abundance of warm water species, Globigerinoides ruber. The higher abundance of Globigerina bulloides marks increased productivity during the cold conditions due to upwelling. The cold conditions are also by the positive excursion in δ18O values during these intervals. The lower values of STC index indicate the northward position of STC. These evidences are considered to represent a reduced AC flow. The events at 520-450 ky and 400-350 ky show abrupt rise in the abundance of Neogloboquadrina pachyderma, which otherwise was quite low. These are indicative of an extremely reduced AC and almost complete cessation of AL.

The events are indicative of glacial climate, leading to the waxing of the Antarctic Ice Sheet, thereby pushing the STC northward. The glacial climate would have reduced the AC flow, while the northward shift of STC would have caused the cessation of AL.

Quaternary Episodes of Variation in the Western Pacific Warm Pool: Planktic foraminiferal evidences from the Sulu Sea (ODP Hole 769B)

SINGH Vikram Pratap1*, SINGH Ashutosh K.2 and SINHA Devesh K.2

1Department of Geology, Indira Gandhi National Tribal University, Podki, Lalpur, Amarkantak, Madhya Pradesh, India– 484887; vikram.singh@ignatu.ac.in
2Department of Geology, Chhatra Marg, University of Delhi, Delhi, India-110007; 2007ashu@gmail.com; deveshksinha@yahoo.com
*Corresponding author

The Sulu Sea is an important pericratonic basin in the proximity of South China Sea and western Pacific Ocean. It is connected via several shallow straits, which act as conduits for interocean exchange. The Western Pacific Warm Pool (WPWP) exerts a major impact on the Sulu Sea waters, due to its direct connection. There have been several changes in the WPWP during the Quaternary Period (last 2.6 My) due to development of glacial conditions and El Niño. These variations are well preserved in the pelagic sediments from Sulu Sea.

The P. obliquiloculata Minimum Events (PMEs), defined as the abrupt decline in the abundance of Pu. obliquiloculata due to changing water conditions, reflect the reduction in the Western Pacific Warm Pool and strength of the Kuroshio Current. We analysed 403 samples from the ODP Hole 769B to study the census data and oxygen isotope records of planktic foraminifera.

We discovered seven PMEs during the Quaternary Period which are proxies for the reduction in the WPWP. The age of the events are: PME7 (0.04-0.02 Ma), PME6 (0.16-0.13 Ma), PME5 (0.48-0.44 Ma), PME4 (0.79-0.65 Ma), PME3 (0.90-0.87 Ma), PME2 (1.8-1.36 Ma) and PME1 (2.21-2.08 Ma). The PMEs are accompanied with high abundance of eutrophic species, associated with enhanced fertility related either to upwelling or nutrient entrainment in the Sulu Sea. We have also found the occurrence of temperate fauna during PME7, PME6, PME5 and PME4, which indicates the influx of cold temperate and subpolar water mass in the Sulu Sea. The most plausible mechanism for this event could be the southward enhancement of Oyashio Current. The cool nutrient rich waters of the Oyashio Current caused a decline in the SST of the Sulu Sea and increased the fertility.
The PME3, PME2 and PME1 do not show presence of temperate fauna. The very high relative abundance of *Neogloboquadrina dutertrei* indicates the influx of nutrient rich waters from the Western Pacific Ocean via Luzon strait. These events suggest the development of El Niño like conditions.

The WPWP has reduced seven times during the last 2.6 My, where the pre-Mid Brunhes Event (MBE) reduction was the result of dominant El Niño like conditions, while the post-MBE reduction events were the result of enhanced Oyashio Current, which led to development of glacial conditions.

**Automated image/video classification and object detection of foraminifera**

SØRENSEN Steffen Aagaard*, MYRVOLL-NILSEN Eirik², GALATA Stamatiá, JOHANNES Thomas Haugland³, MARTINSEN Iver², HALD Morten¹ and GODTLEBSEN Fred²

¹Department of Geosciences, The Arctic University of Norway, Postboks 6050 Langnes, 9037 Tromso, Norway; steffen.sorensen@uit.no; morten.hald@uit.no
²Department of Mathematics and Statistics, The Arctic University of Norway, Postboks 6050 Langnes, 9037 Tromsø, Norway; eirik.myrvoll-nilisen@uit.no; iver.martinsen@uit.no; fred.godtliebsen@uit.no
³School of Biological and Environmental Sciences, Liverpool John Moores University, Tithebarn St., Liverpool L2 2QH, England; s.galata@2019.ljmu.ac.uk
⁴NORCE Norwegian Research Centre, Siva Innovasjonscenter, Sykehusveien 25, 9294 Tromso, Norway; thjo@norceresearch.no

The project “Transforming ocean surveying by the power of DL and statistical methods” investigates objects/structures at and in the seabed reaching from micro to macro scale by utilizing a range of data capture methods, including digital photo/video, acoustics and electromagnetics, for identification/classification. Achieved data are further supported by auxiliary data (Water salinity, temperature, depth, current strength, etc.).

Here we present the usage of YOLO (You Only Look Once) networks to automatically detect/classify foraminifera (and micro plastics) in digital images and video sequences captured though the microscope. Initial work has shown promise to classify overall groupings of foraminifera (planktic, calcareous benthic, agglutinated benthic) within the sediment matrix at the 100 µm - 1 mm fraction. Training is conducted on pre-identified mono specific samples of the above mentioned foraminiferal groupings as well as on a separate sediment grouping. Further work relates to detection/classification of specific species within the benthic foraminiferal groups, detection of live rose-bengal stained specimens in addition classification of micro plastic groupings (fragments, fibers, film and pellets) in sediment samples.

The project entails an international collaboration between private sector partners and universities. The overarching goal of the project is to utilize synergies of statistics and deep learning to improve several aspects of classification and pave the way for a) groundbreaking new DL-methodology and b) establishment of workflow procedures for use in object classification relating to application in ocean surveying and geoscience.

**Geochemistry of *Textularia agglutinans*: environmental and paleoclimatic importance**

SOSNITSKY Tamara¹*, ASHKENAZI-POLIVODA Sarit² and ABRAMOVICH Sigal¹

¹Department of Earth and Environmental Sciences, Ben-Gurion University of the Negev, Beer Sheva 8410501, Israel; sosnitta@post.bgu.ac.il; sigalabri@bgu.ac.il
²Dead Sea and Arava Science Center, Masada National Park, Mount Masada, 86910, Israel; sarit@adsce.org

Calcite precipitating foraminifera are widely used as geochemical recorders of paleoceanographic and environmental research. These foraminifera mainly belong to calcareous orders Rotaliida and Miliolida. Agglutinated species are generally overlooked in geochemical studies because their shells are mostly composed of collected particles from the surrounding environment that are either glued by an organic matrix or cemented by calcitic micrite. The benthic agglutinated species *Textularia agglutinans* d’Orbigny is exceptional. Its test 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, making him one of the most cosmopolitan foraminifera. In many environments, it consists a large percentage of the benthic foraminiferal assemblages. The evolutionary record of this species is exceptionally long, possibly spanning back to the Late Cretaceous. These qualities make *T. agglutinans* potentially important for paleoenvironmental research. To date, most of the research on *T. agglutinans* was primarily ecological and molecular. The few geochemical studies that were done on this species focused on the mineralogical characterization of its agglutinated shell.

The present study aims to characterize the geochemical composition of the calcitic layer of *T. agglutinans* in order to establish its future use as an accessible tool for the environmental reconstruction of paleotemperatures and heavy metal concentrations. The study is based on specimens collected from Israel’s Mediterranean coast, where this species has become extremely abundant over the past years.
The collected specimens are cultured in the laboratory under a range of temperatures (17°, 20°, 24°C) representing the regional and seasonal range of the coastal seawater. Single-chamber analyses of the newly grown chambers will be done by using LA-ICPMS on specimens collected from the field and cultured in the lab. The Mg/Ca records will be used to establish the temperature calibration of this species and compare it to established curves of rotallids and miliolid species. This study also aims to determine the heavy metals (HM) composition of *T. agglutinans* and to explore its ability to record anthropogenic enrichment in seawater, as shown by rotallids and miliolid species. This will be done by exposing specimens to different HMs in variable concentrations and exposure times. Then, it will be clear whether *T. agglutinans* can serve as a recorder for long-term and short-term pollution, making monitoring the conditions in its many habitats possible. This research will provide chemical and biological information about a widespread species and ultimately will reveal the geochemical relevancy of agglutinated species with internal calcitic shells and external matrix.

**Environmental compartmentation of the Santos estuary complex (SW Atlantic, Brazil): Response of biotic indices and pollutants**

**Sousa Silvia Helena Mello**, **Damasio Bruno**, **Santos Felipe Rodrigues**, **Bonetti Carla**, **Siegle Eduardo**, **Martins Maria Virginia** Alves and **Bicego Marcia Caruso**

1 Oceanographic Institute, São Paulo University, Praça do Oceanográfico, 191. 05508-120, São Paulo, Brazil; smsousa@usp.br; bvdamasio@gamil.com; feliperod@usp.br; esiegle@usp.br; cintinea@gmail.com; marciabicego@usp.br

2 Federal University of Santa Catarina, Center for Physical and Mathematical Sciences, Department of Oceanography. Campus Universitário Trindade 88040-900 – Florianópolis, SC – Brazil; carla.bonetti@ufsc.br

3 State University of Rio de Janeiro, Faculty of Geology, Department of Stratigraphy and Paleontology, Av. São Francisco Xavier, 524, sala 2020A, Maracanã, 20550-013 Rio de Janeiro, RJ, Brazil; virginia.martins@ua.pt

4 University of Aveiro, GeoBioTech, Department of Geosciences, Campus de Santiago, 3810-193 Aveiro, Portugal; virginia.martins@ua.pt

*Corresponding author*

The Santos estuary complex (SEC), located on the Brazilian southern coast (23°51' S and 23°58' S; 46°08' W and 46°19' W), comprises the Santos, São Vicente and Bertioga estuaries. It is considered an important petrochemical complex and hosts the largest port in Latin America. The region was urbanized and industrialized from the 1950s onwards in an uncontrolled manner and the activity of the petrochemical and fertilizer industries, among others, with a high polluting potential, made the SEC a large receiver of toxic waste and contaminated liquid effluents.

The main objective of the work is to comprehend the environmental compartmentation of the SEC based on benthic foraminifera indices and organic pollutants. Twenty-one stations were sampled in triplicates, during the austral winter and spring of 2019, using a manual sampling core and a multiple corer for benthic foraminifera analysis and a stainless steel van Veen bottom grab for the organic compounds. Sediment samples were kept in a solution of ethanol buffered with rose Bengal stain (2 g of rose Bengal to 1000 ml of ethanol 90%) to identify living (stained) foraminifera at the time of sampling. The samples remained stored in a refrigerator for at least 14 days to assure a good staining of the cytoplasm of living organisms. The sediments for organic compounds analysis were kept frozen. A volume of 50 cm³ of wet sediment per sample was washed in a 63 μm mesh sieve, and then oven dried at 40 °C for benthic foraminifera analysis. Analyzes were performed on the >63 μm fraction, and at least 100 foraminifera tests were screened per sample.

Density (FD, number of individuals/50 cm³ of sediment), Richness (S, number of different species in the sample), Shannon-Wiener Diversity (H’), Ecological Quality Status (EcoQS), Foram Stress Index (FSI) and Tolerant Species Index (TSstd) were calculated. Total organic carbon (TOC), aliphatic hydrocarbons (AHs), linear alkylbenzenes (LABs) polycyclic aromatic hydrocarbons (PAHs), and fecal sterols (the last two being chemical indicators of contamination by domestic effluents) were measured.

The most abundant species (relative abundance >1%) were *Ammonia parkinsoniana, Ammonia tepida, Ammonia spp., Cribroelphidium excavatum, Cribroelphidium spp., Hapluragmoides sp., Paratrochammina sp., Pseudotriloculina sp., Quinqueloculina* spp. and *Trocchammina* sp. Cluster analysis was applied on the mean relative abundance values of the representative species present in replicates with Bray Curtis similarity index greater than 0.7. This analysis allowed us to identify six environmental compartments in the SEC: Santos Bay, inner and outer Bertioga estuary, São Vicente estuary, inner and outer Santos estuary. A principal components analysis applied on organic pollutants dataset revealed a stress gradient along the SEC, showing that Santos Bay and the outer Santos estuary are the environments with the lowest anthropic impact. Most of the São Vicente estuary and towards the upper estuary of Santos are characterized by a moderate anthropic impact, and Bertioga and the upper Santos estuaries are the most polluted in the SEC. A discriminant analysis applied to evaluate the predictive capacity of the biotic indices in the recognition of three classes of environmental impact (low, moderate, high) correctly classified 76.2% of the sites. Estuarine hydrodynamics plays the main role in this compartmentation.
Reconstructing past changes in cloud cover from foraminifera population geochemistry – A testable hypothesis

SPERO Howard1*

1Department of Earth and Planetary Sciences, University of California, Davis, 1 Mrak Rd, Davis, California USA; hjspero@ucdavis.edu
*Corresponding author

One of the most important paleoclimate model parameters remaining to be quantified by sedimentary proxies is cloud cover in Earth’s past. Because elevated regional cloudiness decreases surface irradiance levels, geochemical proxies sensitive to water column light levels should be sensitive to cloud cover change. Laboratory experiments have demonstrated that the carbon isotope (δ13C) composition of the symbiont-bearing species, Orbiluna universa, varies with irradiance such that ambient light levels above symbiont Pmax yields shells that are considerably enriched in 13C relative to individuals growing at reduced, sub Pmax levels. In oligotrophic regions of the ocean, Pmax light levels are found shallower than ~30 m. The O. universa δ13C range observed in laboratory experiments, ~2-2.5‰, agrees well with the δ13C range recorded among O. universa individuals in fossil populations. Because O. universa inhabits the full photic zone in the ocean, the distribution of δ13C values among individuals should reflect the habitat depth distribution of the population. Furthermore, the % of individuals living at shallow depths with irradiance >Pmax levels will yield the highest grouping of δ13C values. As cloudiness increases, the Pmax irradiance depth will shoal such that fewer individuals will record high 13C values. This change in δ13C distribution is quantifiable and can be modelled. I will discuss how to test this hypothesis and present population geochemical data from fossil assemblages that suggests glacial equatorial Indian Ocean cloud cover during MIS 6 was significantly higher than later interglacial and glacial periods.

Understanding coral thermal bleaching thresholds during past interglacial extremes: Insight into thermal stresses dynamics on tropical coral reef ecosystems (RESILIENCE)

SPEZZAFERRI SilVia1*, SAMANKASSOU Elias2, BASSO Daniela1, PISAPIA Chiara4, KROON Dick4, DE LEAU Erica5, MARTINEZ-COLON Michael4 and STAINBANK Stephanie7

1Department of Geosciences, University of Fribourg, Chemin Du Musée 6, 1700, Fribourg, Switzerland; silvia.spezzaferr@unifr.ch
2Department of Earth Sciences, University of Geneva, Rue des Maréchaux 13, 1205 Geneva, Switzerland; elias.samankassou@unige.ch
3Department of Earth and Environmental Sciences, University of Milano-Bicocca; CoNISMa, ULR of Milano-Bicocca, Piazza della Scienza 4, 20126, Milan, Italy; daniela.basso@unimib.it
4King Abdullah University of Science and Technology, Jeddah, Saudi Arabia; chiara.pisapia.1@gmail.com
5School 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
6Florida A&M University FSH Science Research Center, RM306B 1515 South MLK Blvd, Tallahassee, FL, 32307, USA; michael.martinez@famu.edu
7Kudala Environmental Ecology Lab (KEEL), Priscilla Vale Estates 17426, R603, Eston 3740, Durban, South Africa; stephaniehayman.23@gmail.com
*Corresponding author

Tropical and subtropical coral reefs are biodiversity hotspots distributed around the world and are currently under unprecedented stress. One of the main visual signs of thermal stress is bleaching, a predominant stressor on reefs, and one of the main drivers of coral-bleaching is drastic temperature changes (thermal stress), which is associated with photo-inhibition. The best approach to gain insights to how global climate change will impact reef ecosystems is to learn from the past. However, in the fossil record, bleaching cannot be observed! The Earth’s paleoclimatic record, found in deep sea sediments geochemical data from fossil assemblages that suggests glacial equatorial Indian Ocean cloud cover during MIS 6 was significantly higher than later interglacial and glacial periods.

Here we show how the δ18O of single specimens (Individual Foraminiferal Analyses – IFA) coupled with Mg/Ca of the planktonic foraminifer Globigerinoides ruber (white) can be used to extract the relative frequency and magnitude of temperature extreme events from past interglacials, which exceeded the modern-day coral bleaching thresholds, in order to better understand possible warmer-world scenarios. As an example, we propose the Maldivian archipelago where Expedition 359 drilled and cored extended sedimentary drift deposits in the Inner Sea.

A preliminary investigation on Marine Isotope Stage 11 (MIS11) revealed that this interglacial was 0.30-0.41°C warmer than modern time and that sea-surface temperatures exceeded the coral bleaching threshold during this time interval. Additional MIS are being investigated in the present research.

The modern habitat is used as a baseline for past assessment of potential modern stresses (temperature and nutrients) and for defining temperature thresholds for coral bleaching. Further research will focus on the Great Barrier Reef (ODP Leg 133) and its shallow water equivalent (e.g., the coral reefs in Lizard Island) and the Great Bahamas Bank (ODP Leg 166) and its equivalent in the Florida Keys.

This research is performed within the framework of the Swiss National Science Foundation (SNSF) Project RESILIENCE 200020_201106.
Palaeoceanographic Changes and Ecological Impacts on Foraminifera during Eocene-Oligocene Transition in the Gulf of Mexico

STANDRING Patricia1,2, LOWERY Christopher1, KEARNS Lorna1* and MARTINDALE Rowan2

1Institute for Geophysics, Jackson School of Geosciences, University of Texas at Austin, 10601 Exploration Way, Austin, TX, 78758, USA; patty.standring@utexas.edu; emlowery@utexas.edu; lorna.kearns@austin.utexas.edu
2Department of Geological Sciences, Jackson School of Geosciences, University of Texas at Austin, 2275 Speedway Stop C9000 Austin, TX, 78712-1722, USA; martindale@utexas.edu
*Corresponding author

Within the overall Cenozoic cooling trend, the Eocene-Oligocene Transition separates warmhouse and coolhouse climate regimes. This time period consists of a rapid drawdown in atmospheric carbon dioxide, the permanent glaciation of Antarctica, and a reorganization of deep-sea circulation. At the Eocene/Oligocene Boundary, both planktic and benthic foraminifera experienced extinctions as they adjusted to changing climate and ocean circulation. Benthic foraminifera diversity decreased in some ocean basins but not all, suggesting deep-sea circulation changes likely contributed to this decline. Research indicates that Northern Component Water formed and circulated through the Atlantic and into the Southern Ocean in the late Eocene and early Oligocene; however, there is no data on its circulation into nearby ocean basins, like the Gulf of Mexico. In particular, the impact this change in ocean circulation had on benthic foraminifera in the Gulf of Mexico remains understudied. Here we present benthic foraminiferal assemblage, stable isotope, X-ray fluorescence, grain size, and seismic data from the southern Gulf of Mexico Deep Sea Drilling Project Sites 95 and 540. Preliminary results indicate that local volcanic activity and diagenesis likely overprint any temperature changes driven by global climate and, despite global cooling, the southern Gulf of Mexico deep water records exhibit a negative carbon isotope excursion at the Eocene/Oligocene Boundary. Grain size analysis of sortable silt, combined with XRF proxies (e.g., Zr/Al) indicate an increase in bottom water current velocity in the early Oligocene, congruent with global trends. We explore how these local and global changes impacted benthic foraminiferal communities of the southeastern Gulf of Mexico.

Differential gene expression over the life cycle of Allogromia laticollaris CSH to understand complex nuclear dynamics

STERNER Elinor G.1*, LELEU Marie1 and KATZ Laura A.1,2

1Department Biological Sciences, Smith College, Northampton, Massachusetts, 01063, USA; estern@smith.edu; mleleu@smith.edu; lkatz@smith.edu
2Program in Organismic and Evolutionary Biology, University of Massachusetts Amherst, Amherst, Massachusetts, 01003, USA; lkatz@smith.edu
*Corresponding author

We combine fluorescence microscopy and single cell transcriptomics to elucidate underlying genome mechanisms that drive the highly complex life cycle of Allogromia laticollaris. The life cycle of this species includes an alternation of generations, extreme ploidy fluctuations, and a process of nuclear cleansing called Zerfall, but the genomic mechanisms underlying these processes are unknown. The Allogromia laticollaris CSH cell line was isolated at Cold Spring Harbor (NY, USA) laboratories and studied by Arnold in 1955 and McEnery and Lee in 1976. We are using this species to explore differential gene expression in different life cycle stages. We are working to analyse 48 transcriptomes spanning the life cycle of this lineage, a subset of which have associated Hoechst-stained images taken prior to sequencing. For each cell, we will compare nuclear number and sizes with presence and absence of certain gene families using PhyloToL, our in-house phylogenomics pipeline. The search for candidate genes will enable us to assess differential mRNA patterns associated with varying genomic organisation processes, which will provide insights into the molecular basis of extreme changes in genome content in A. laticollaris. Despite recent advances in genomics, these techniques are rarely applied to diverse eukaryotic clades such as foraminifera. Instead, our understanding of genome evolution is largely limited to a small group of model systems, which excludes a large diversity of complex and dynamic genomes present among microeukaryotes. Through studying the genomic mechanisms of this species with two powerful tools – fluorescence microscopy and molecular biology –, we are working towards a stronger understanding of the ‘rules of life’ that govern the evolution of genomes.

Early Cretaceous marine incursions in the Proto-South Atlantic Ocean: foraminiferal record from Brazilian basins

STROHSCHOEN Oscar Jr1, LUFT-SOUZA Fernanda1*, KRAHL Guilherme1, BRUNO Mauro Daniel Rodrigues1, BAECKER-FAUTH Simone1 and FAUTH Gerson1

1itt Oceanoeon, Instituto Tecnológico de Paleoceanografia e Mudanças Climáticas, Unisinos University, São Leopoldo, RS, Brazil; gersonf@unisinos.br; oscarjgeoa@gmail.com; felufts@gmail.com; geounikrah@gmail.com; dbruno@unisinos.br; sbfauth@unisinos.br
*Corresponding author
The timing of the first marine connections of the South Atlantic Ocean in the Brazilian interior and marginal basins, during the Early Cretaceous, has long been subject of debate. Those basins show stratigraphic sequences that often contain marine abundant fossils, which represents the initial incursions related to opening South Atlantic. For decades, biozonation schemes applied to these mostly non-marine intervals were restricted to ostracods and palynomorphs local biozones. The scarcity of age diagnostic marine microfossils in the Early Cretaceous stratigraphic sequences from Brazilian basins resulted in a series of tentative chronocorrelations (still under debate) of local biozonations with the standard international biostratigraphic schemes.

Even the occurrence of those early marine incursions, due to the poor and sparse paleontological evidence, is still object of debate. Many studies registered the occurrence of foraminifers in these Brazilian basins (Campos, Recôncavo, and Sergipe-Alagoas). Since 1990, occurrences of benthic foraminifera (Ammodiscidae, Lituloidae, Glomospirella arctica, and Paratrochamminoides kaminskii), as well as foraminiferal linings recovered in palynological studies, were registered for Recôncavo and Campos basins, related to late Barremian–early Aptian. For Sergipe-Alagoas Basin, Aptian foraminifera (Globigerinelloides aptensis, G. barri, G. blowi, G. ferroelensis, G. maridalensis, Hedbergella labocaensis, H. maslakovae, H. semielongata, and H. similis) were found associated to coeval ammonites.

Foraminifers were also recovered in Brazilian interior basins, as Araripe and San Franciscana. For the Araripe Basin, foraminifers were registered in the Early Cretaceous sedimentary sequence, represented by Barbalha, Crato, Ipubi, and Romualdo formations. The Barbalha Formation is the basal unit and is considered mostly non-marine. However, we recovered foraminifers from two boreholes (1-PS-06-CE and 1-PS-10-CE). The lower part of Barbalha Formation (Batateiras Beds) displays abundant benthonic foraminifera (Bathyssiphon sp.), and in the upper part of this unit, Leupoldina sp., Globigerinelloides cf. barri, and Globigerinelloides cf. ferroelensis were found, correlated to early/early late Aptian biozones L. cabri/G. algerianus. In addition, those boreholes planktonic foraminifers (ticinellids and hedbergellids) were found in thin sections associated with abundant radiolarians in the Crato Formation strata.

For the upper units of Araripe Basin (Ipubi and Romualdo formations), several studies recovered foraminifers. In the Ipubi Formation Hedbergella sp., Hedbegegella aff. taitanae, and Hedbergella infracretacea were described, and for Romualdo Formation sections recent studies (from 2020) reveal early/late Aptian planktonic (Microhedbergella miniglobularis, Hedbergella praellippe, Hedbergella apitiana, and Hedbergella sigali) and benthonic (Rhizammina sp., Bathyssiphon sp., Ammobaculites sp., Quinqueloculina sp., Sigmollinita sp., Patellina sp., Spirillina sp., Pseudonodosaria sp., and Astacolus sp.) foraminifers.

At the Sanfranciscana Basin (interior Brazilian basin) reports of radiolarian and foraminifera found in chert beds has been subject of debate about their origin. Those strata apparently are in a continental sequence, contrasting thus with the micropaleontological evidence. After a refined sampling we identified Leupoldina sp., Globigerinelloides sp., and Hedbergella sp. that corresponds to the early Aptian, L. cabri biozone. The occurrence of Leupoldina genus in Araripe and Sanfranciscana basins here reported indicates possibly the older marine immigrations correlated in the Brazilian interior basins until this moment, even if any correlation between those basins and the possible seaways that led those marine associations into those basins is still under heavy debate.

Foraminifera of the remote Chagos Archipelago – Community responses to local and global drivers and their effects on coral reef sediment production

STUHR Marleen1*, GEA NEUHAUS Aitana1,2, FUCHS Lea T.A.1,3, PERRY Chris T.4 and LANGE Ines D.4

1Biogeochemistry and Geology, Leibniz Centre for Tropical Marine Research (ZMT), Fahrenheistr. 6, 28359 Bremen, Germany; Marleen.Stuhr@leibniz-zmt.de; Aitana.Gea.Neuhaus@uni-oldenburg.de; Fuchs_Lea@gmx.de
2School of Mathematics and Science, Carl von Ossietzky University, Ammerländer Heerstr. 114-118, 26129 Oldenburg, Germany; Aitana.Gea.Neuhaus@uni-oldenburg.de
3Department of Geosciences, University of Bremen, Klagenfurter Str. 2-4, 28359 Bremen, Germany; Fuchs_Lea@gmx.de
4 Geography, University of Exeter, Amory Building, Rennes Drive, Exeter, EX4 4RJ, UK; C.Perry@exeter.ac.uk; I.Lange@exeter.ac.uk

*Corresponding author

The production of carbonate sediments by coral reef organisms is an essential driver of tropical beach and island formation. Especially low-lying islands rely heavily on biological sand supply, but the ongoing degradation of coral reef ecosystems may diminish this important geo-ecological function. Benthic foraminiferal tests are abundant components of many reef sediments and locally contribute significantly to carbonate sediment production. Alterations in foraminiferal assemblages serve as sensitive bioindicators that allow us to reconstruct past and recent environmental conditions, assess ecosystem ‘health’ status or recovery potential. This is especially useful in regions that are difficult to access and often lack continuous monitoring.

To assess climate impacts on foraminiferal assemblages, we analysed changes in community composition in the remote Chagos Archipelago over the last 40 years. This group of atolls in the central Indian Ocean is hardly affected by local anthropogenic impacts, but is nonetheless exposed to global ocean warming. Assemblages in recently collected surface sediment samples on seaward and lagoonal reefs in Peros Banhos atoll were compared to data derived in 1979, pre-dating the severe global coral bleaching events in 1997/98 and 2015/16. Recent foraminiferal communities showed spatial
Although the sea surface productivity pattern documented by is different between cores, both record a high carbonate productivity and high calcium carbonate dissolution during MIS 5 to low productivity and high dissolution in MIS 4. Conversely, core GL-852 records a decoupling between sea surface and seafloor conditions during 4, going from high times. Core SIS-249 shows an increase from low to high productivity and carbonate dissolution from MIS 5 to 4. The cores span the marine isotope stages (MIS) 5–4 and are bathed by the North Atlantic Deep Water in present carbonate dissolution (calcium carbonate content, benthic/planktic ratio and planktonic foraminifera fragmentation index) compare proxies for sea surface productivity (relative abundances of planktonic foraminifera species”)

While the FoRAM Index suggests favourable conditions for high post-disturbance reef recovery potential due to the absence of local pollution, further climate change-related reef degradation may progress shifts in foraminiferal assemblages and related changes in sediment production around coral reefs, with important implications for sand supply to connected ecosystems and the islands.

Decoupling of productivity and carbonate dissolution in the western South Atlantic during MIS 5–4

SUÁREZ-IBARRA Jaime Y.1,2, FREIRE Tiago M.1, BATTAGLIN Beatriz B.F.4, DIAS Bruna B.2,5, BALLALAI João6,7, CHALK Thomas2, CHAABANE Sonia3, COSTA Karen3, TOLEDO Felipe1, SCHEINER Filip2, HOLCOVA Katarina2, DE GARIDEL-THORON Thibault2 and PIVEL Maria A.G.8

1Ústav geologie a paleontologie, Univerzita Karlova v Praze, Albertov 6 148 00, Prague, Czech Republic; jysuarezibarra@gmail.com; filip.scheiner@natur.cuni.cz; katarina.holcova@natur.cuni.cz
2CEREGE, Aix-Marseille Université, CNRS, Collège de France, IRD, Technopôle de l’Arbres-Méditerranée, BP80, 13545 Aix-en-Provence, France; jysuarezibarra@gmail.com; chalk@cerege.fr; chaabane@cerege.fr; garidel@cerege.fr
3Institut für Geologie & Mineralogie, Universität zu Köln, 50674 Cologne, Germany; tiagomfreire@gmail.com
4Instituto de Geociências, Universidade Federal do Rio Grande do Sul, Av. Bento Gonçalves, 9500 - Agronomia, Porto Alegre - RS, 90650-001, Brazil; maria.pivel@ufgrs.br
*Corresponding author

with ongoing anthropogenic perturbations in the Earth’s climate system, it is important to understand the role of feedback mechanisms in regulating climate, and their sensitivity to rapid change. In the past, mechanisms modulating greenhouse gases (e.g., the biological pump) have been invoked to trigger the changes in atmospheric CO₂ between glacial and interglacial states, amplifying the relatively subtle orbital forcing on global temperature. Recent studies from the western South Atlantic (southernmost Brazilian continental margin), have suggested that an enhanced glacial biological pump was the main driver of calcium carbonate dissolution above the lysocline: when organic matter (OM) is remineralised, it releases CO₂ and lowers the pH of the water. This impacts the CaCO₂ preservation and recycles previously removed (in)organic carbon back into the ocean, decreasing the effectiveness of CO₂ export via the biological pump. Nevertheless, this hypothesis has not been shown elsewhere, for example, where high productive periods occurred at different times. In this study, we compare proxies for sea surface productivity (relative abundances of planktonic foraminifera species Globigerina bulloides, Globigerinoids ruber and Globigerinita glutinata), organic matter flux (benthic foraminiferal accumulation rates) and carbonate dissolution (calcium carbonate content, benthic/planktic ratio and planktonic foraminifera fragmentation index) from two cores recovered from the western South Atlantic (SIS-249, Pelotas Basin, 2091 mbsl, and GL-852, Santos Basin, 1938 mbsl). The cores span the marine isotope stages (MIS) 5–4 and are bathed by the North Atlantic Deep Water in present times. Core SIS-249 shows an increase from low to high productivity and carbonate dissolution from MIS 5 to 4. Conversely, core GL-852 records a decoupling between sea surface and seafloor conditions during 4, going from high productivity and high calcium carbonate dissolution during MIS 5 to low productivity and high dissolution in MIS 4. Although the sea surface productivity pattern documented by is different between cores, both record a high carbonate
dissolution event during MIS 4. Although benthic δ\(^{13}\)C records from both cores suggest a larger influence of the more corrosive southern-component water (SCW) during MIS 4, the δ\(^{13}\)C solely is not sufficient to prove changes in the geometry of bottom water masses, since carbon stable isotopes can also be affected by the other biogeochemical processes invoked here. Nevertheless, we suggest that the reconfiguration of the water masses geometry also drives carbonate dissolution during MIS 4.

**Exploring the link between Pore Morphology in Benthic Foraminifera (Ammonia) and Dissolved Oxygen: Insights from Chilika Lagoon (INDIA)**

SUBBA Rohan\(^{1*}\) and GHOSH Anupam\(^1\)

\(^1\)Department of Geological Sciences, Jadavpur University, Raja S.C. Mallick Road 188, Kolkata, INDIA; rohans.geology.rs@jadavpuruniversity.in; anupam.ghosh@jadavpuruniversity.in

*Corresponding author

The depletion of dissolved oxygen in marine ecosystems is a major concern, with substantial environmental and socio-economic implications. Here, we present a study of benthic foraminifera, the most reliable indicator used in paleoclimatic and paleoenvironmental studies. *Ammonia*, a dominant benthic foraminifera, is distributed throughout the shallow marine areas of the tropical and warm temperate zones. They are highly sensitive to changes in environmental conditions, which are recorded and preserved in their tests. Therefore, the characterization of pore morphology in foraminifera is useful for understanding changes in local oxygen levels. In this study, Atomic Force Microscopy (AFM) was used to observe the pore structure through three-dimensional mapping and quantification.

The use of AFM has enhanced the characterization potential of the surface morphology, thereby providing a much closer perspective on pore studies. The *Ammonia* specimens were analyzed from the core-top samples collected from the Chilika Lagoon. A standard measurement frame was considered for the analysis of the penultimate chamber (n-1) on the spiral side. Based on the three-dimensional analysis, topographical mapping, pore depth and surface roughness were measured along with two-dimensional features, porosity, pore density and diameter.

Morphometric analysis was conducted for two different species: *Ammonia* cf. *beccarii* and *Ammonia parkinsoniana*. The results showed distinct and characteristic pore properties. Topographical mapping revealed contrasting pore patterns between the two species. The pore density of *Ammonia* cf. *beccarii* (0.155/µm\(^2\)) was higher than that of *Ammonia parkinsoniana* (0.035/µm\(^2\)). Moreover, it was found that the value of the pore depth bears a specific value in each species. *Ammonia parkinsoniana* showed a pore depth value approximately two–three times higher than that of *Ammonia* cf. *beccarii*. However, we are yet to understand the relationship between pore properties and dissolved oxygen. At present, we are working on exploratory data analysis to establish a correlation between pore data and dissolved oxygen in the lagoon.

This research study will develop a comprehensive knowledge of the pore morphology in *Ammonia* and its use as a proxy for dissolved oxygen in the lagoon. Subsequently, it will be applied to the core samples to deduce oxygenation trends of the distant past.

**Neritic Benthic Foraminifers as Indicators of Ocean Deoxygenation in the Salisbury Embayment (U.S. Atlantic Coastal Plain) during the Mid-Miocene Climatic Optimum**

SUTTON Seth Reid\(^1\) and KELLY Daniel Clay\(^{1*}\)

\(^1\)Department of Geoscience, University of Wisconsin-Madison, Madison, WI 53706 USA; srsutton@wisc.edu; ckelly@geology.wisc.edu

*Corresponding author

The Middle Miocene Climatic Optimum (MCO, ca. 17-14.8 Ma) is typified by atmospheric paleo-pCO\(_2\) levels (~500 ppm) comparable to those projected for the year 2050, global temperatures ~5°C warmer than present (pre-industrial), and global mean sea level ~50 meters higher than today. Thus, the MCO represents an informative ancient analogue to anthropogenic climate change. Here we use complementary micropaleontological (neritic benthic foraminifer communities) and geochemical (benthic foraminifer δ\(^{18}\)O, alkenone unsaturation index U\(_{37}^k\)) records constructed for a sediment core drilled in the U.S. Atlantic Coastal Plain (Haynesville, Virginia) to assess the effects of ocean warming and fluctuating sea level on coastal ecosystems during the MCO. The paleogeographic setting places the Haynesville study site in inner to middle shelf waters within a broad, shallow embayment of the Atlantic Ocean along the eastern margin of the North America called the Salisbury Embayment. Alkenone thermometry (U\(_{37}^k\)) is at its upper limit of temperature detection (28-29°C) over much of the Haynesville MCO record, suggesting exceptionally warm sea-surface temperatures. A major compositional change among benthic foraminifer assemblages coincides with an episode of increased organic carbon burial signalled by a modest but sustained ~1% increase in foraminifer δ\(^{18}\)O values marking the onset of the Monterey Carbon Isotope Excursion (MCIE) and elevated primary productivity as inferred from increased alkenone abundances. On the basis of an “enhanced benthic foraminifer oxygen index”, the faunal shift entailed a transient change from aerobic assemblages composed largely of genera
(Valvuliniera, Cibicidites) reflecting oxic (>3 ml/l O₂) bottom waters to assemblages dominated by buliminids and bolivinids indicating suboxic (0.3-1.5 ml/l O₂) bottom waters and increased primary productivity. Benthic foraminifer communities show a marked decrease in species richness, diversity, and evenness across the suboxic interval. Moreover, foraminifer abundances increase dramatically from background levels (~100 specimens per gram) to an overall high (~7,000 specimens per gram) directly below the stratigraphic level of the MCIE onset in the Haynesville MCO record. This brief peak in foraminifer abundances likely reflects a stratigraphic “condensation” horizon associated with a marine flooding surface that, in turn, is overlain by a highstand systems tract characterized by the dysaerobic (suboxic) faunas. We therefore attribute the change in local redox conditions to ocean deoxygenation stemming from some combination of temperature-gas solubility effects, increased levels of primary productivity and microbial respiration, and a rapid rise in sea level that caused an onshore shift of deeper waters with lower dissolved oxygen concentrations over our study site. Benthic foraminifer communities subsequently revert back to more aerobic faunas as their abundances decline (0-100 specimens per gram) over the remaining upper half of the study section, suggesting a shallowing upwards sequence. The collective evidence is consistent with the view that a sharp rise in sea level increased shelf accommodation space for carbon burial during the MCO, which helped curtail the overall increase in atmospheric CO₂ levels being fuelled by tectonic outgassing at that time.

Reconstruction of the Oligocene paleoenvironment in the Central Paratethys, North Hungarian Paleogene Basin

SZÉKELY Adrienn¹ and GÖRÖG Ágnes²

¹Department of Geology, Eötvös Loránd University, H-1117 Budapest, Pázmány Péter sétány 1/C, Hungary; a.szekely@zohomail.eu
²Hantken Foundation, H-1022 Budapest, Detrekő utca 1/b, Hungary; ag.gorog@gmail.com

*Corresponding author

The geological research of the North Hungarian Paleogene Basin (NHPB) dates back more than 150 years, just like the study of the petrological, sedimentological, and tectonic features as well as the fossil content of the Paleogene formations (Buda Marl and Kiscell Clay). However, the geological structure of the basin is still not completely clear in certain areas, such as in the studied Szentendre region, north of Budapest. The taxonomic and stratigraphic results of foraminifera in the Paleogene formations were first published by Miksa Hantken. Although there have been several studies on the investigation of the Oligocene Kiscell Clay since then, a detailed study containing quantitative data on foraminifera from the Szentendre area has not been conducted yet. Our study aimed to give a detailed taxonomic description and quantitative analysis of the foraminiferal fauna of the borehole Szentendre II., to interpret the biostratigraphic and palaeoecological conditions. The previous paleontological results of the examined borehole, based on molluscs, nannoplankton, palynomorphs, and ostracods, have also been reinterpreted.

The fully cored Oligocene succession of the borehole Szentendre II. represents a whole Oligocene series on the western margin of the NHPB. The core samples contained well-preserved foraminiferal assemblages comprising 112 taxa of 82 genera. Two new species of benthic foraminifera are named and described from the marl layers of the Kiscell Clay. Apart from the typical highly diverse “Kiscellian fauna” the same fauna appeared but with low diversity. Its agglutinated fauna is dominated by specimens of the order Lituolida and Textulariida. Porcelaneous forms are mostly represented by the genera Quinqueloculina. Most hyaline taxa belong to the suborder Lagenina and Rotaliina. In general, the taxa have long ranges, only the appearance of Epistomaroides cryptomphalus is limited to the Oligocene. Further subdivision of the section was possible by defining five foraminiferal horizons, which correlated well with previously determined zones around the Paleogene Basin. According to the foraminiferal fauna, the section of the borehole should be divided into the Rupelian and Chattian.

To decipher the paleoenvironmental changes, we used planktonic/benthic ratio, diversity indices, principal component analysis, detrended correspondence analysis, and BFOI. Altogether 7 agglutinated and 9 calcareous morphgroups were established. Based on their ratio and considering the estimated paleodepth, the calculated benthic foraminiferal oxygen index and the occurrence of other fossils 7 ecozones were defined. In the lower part of the Rupelian of the Szentendre II. borehole section fluctuating BFO indices present changes in bottom water oxygenation. Presumably, the sediments deposited in lower oxygen conditions represent the upper part of the NP23 Zone. In the upper part of the Rupelian of the Szentendre II. borehole section the high diversity of foraminifera in the Kiscell Clay indicated that the sedimentation took place in bathyal depth and normal salinity seawater. The Chattian age of the uppermost layers cannot be confirmed. Considering its shallow-water fauna, which is very similar to the upper Oligocene fauna of other Paratethyan areas, it probably belongs to the Chattian Törökbálint Sandstone.

Based on our detailed biostratigraphical and palaeoecological evaluation, the paleoenvironmental changes of Paratethys throughout the Oligocene could be traced. Although neither the fauna nor the lithological appearance of the studied sequence exhibits typical, well-known features, our horizons are arranged in the same succession as in other areas of the HPB. Therefore, these changes are not only local but also regional. It seems that the entire HPB was uniformly affected by environmental changes.
Climate change induced decrease in foraminifera abundance in an Arctic fjord (Hornsund, Svalbard). Implications for carbon burial

SZYMANSKA Natalia1*, LACKA Magdalena1 and ZAJACZKOWSKI Marek1

1Department of Paleooceanography, Institute of Oceanology, PAN, ul. Powstańców Warszawy 55, Sopot, Poland; natalia@iopan.pl; mlacka@iopan.pl; trapper@iopan.pl
*Corresponding author

Atlantification and glacier retreat, two processes linked to the modern climate change, can negatively impact foraminiferal assemblages. Although the impact of modern climate change on foraminiferal assemblages is relatively known, the changes in foraminiferal carbon contribution to the sediments remains understudied. The effects of climate change are prevalent in high-latitude North Atlantic fjords, where foraminifera are an important part of the benthic community. We picked Hornsund fjord as a study site because its oceanographic conditions are highly affected by Atlantification and loss of glacier volume. In the last two decades, Hornsund waters became warmer and more saline. The calving speed and meltwater volume of local glaciers rapidly increased. This induced changes in oceanographic conditions of fjordic waters that affected local foraminifera assemblages. Our study aimed to quantify changes in foraminiferal carbon contribution to the sediments in an environment highly affected by the modern climate change. Foraminifera are potentially the most important calcifiers in glaciomarine sediments of the Arctic, as they constitute up to ~40% of inorganic carbon in the sediments of Adventfjorden, and up to 68% in Norwegian fjords. Changes in abundance and species composition of foraminifera assemblages can provide strong feedback to the carbon cycle.

We examined two foraminifera datasets from the same site—one from 2002 and one from 2019—in comparative perspective to assess the changes that have occurred in oceanographic conditions in an Arctic fjord over the last two decades. Additionally, we calculated how these changes affected the amount of carbon supplied to the sediments in the form of foraminifera tests. Our study revealed that the Hornsund foraminifera assemblages underwent a set of changes indirectly influenced by global warming. The 2002 assemblage represented conditions where Arctic Waters dominated. The 2019 assemblage represented conditions of increased Atlantic Water presence and loss of glacier coverage in the fjord’s catchment area.

A fourfold decline in the contribution of foraminiferal carbon to the 2019 sediments compared to those in 2002 was found. In 2002 the foraminiferal assemblage was characterized by high species diversity and low abundance of agglutinated species. One of the most abundant species was Nonionellina labradorica. A species characterized by large size and high carbon content per test. The 2019 assemblage was defined by low abundance of foraminifera, as well as higher amount of agglutinated and small, opportunistic species. The most abundant species were Cassidulina renifrome and Elphidium clavatum. Both were characterized by low carbon content in their tests. The results highlight the negative impact of modern climate change-driven changes on the assemblage and the subsequent decrease in inorganic carbon buried in the sediments. These data allow for a better interpretation of palaeoceanographic sedimentary records and future predictions regarding the inorganic carbon cycle.

The research was financially supported by the Norwegian Financial Mechanism for 2014–2021 [project no 2019/34/H/ST10/00682] and by the National Science Centre in Poland [project no. 2019/33/B/ST10/00297].

Photosymbiotic partnerships and evolution in planktonic foraminifera revealed by single-cell metabarcoding

TAKAGI Haruka1*, NAKAMURA Yasuhide2, SCHMIDT Christiane3, KUCERA Michal4, MORIYA Kazuyoshi5 and SAITO Hiroaki6

1Department of Earth Sciences, Chiba University, 1-33 Yayoi-cho, Inage, Chiba, Japan; htakagi@chiba-u.jp
2Estuary Research Center, Shimane University, 1060 Nishikawatsu-cho, Matsue, Shimane, Japan; jasnakamura@gmail.com
3Leibniz Centre for Tropical Marine Research (ZMT) GmbH, Fahrenheitstr 6, Bremen, Germany; christiane.schmidt@leibniz-zmt.de
4MARUM – Center for Marine Environmental Sciences, University of Bremen, Leobener Str. 8, Bremen, Germany; mkucera@marum.de
5Department of Earth Sciences, Waseda University, 1-6-1 Nishiwaseda, Shinjuku, Tokyo, Japan; kmoriya@waseda.jp
6Atmosphere and Ocean Research Institute, The University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa, Chiba, Japan; hsaito@aori.u-tokyo.ac.jp
*Corresponding author

Photosymbiosis, a mode of endosymbiosis with phototrophic algae, is generally thought to be an innovative adaptation to oligotrophic oceans. Among modern planktonic foraminifera, photosymbiosis has been discovered in nearly half of the species, most of which are found in the oligotrophic regions. Thus, photosymbiosis should be a key factor in understanding their evolution, diversity, and ecological adaptation in warm pelagic surface waters. Recent studies have identified photosymbiosis in modern species by detecting the photosynthetic signal from planktonic foraminiferals and obtaining evidence of living algae in the cell. It has successfully revealed the existence of previously unrecognized symbiosis in planktonic foraminifera. However, even though symbiosis is determined, the type of algae has yet to be investigated for many host species. To better understand the evolutionary role of photosymbiosis, investigating host-symbiont partnership, its specificity/flexibility, and the persistency through the host phylogeny are to be resolved.
Responses to DCMU, high light, and high temperature in *Trilobatus sacculifer* photosymbiosis

TAKAGI Haruka¹ and SAITO Hiroaki²

¹Department of Earth Sciences, Chiba University, 1-33 Yayoi-cho, Inage, Chiba, Japan; htakagi@chiba-u.jp
²Atmosphere and Ocean Research Institute, The University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa, Chiba, Japan; hsaito@aori.u-tokyo.ac.jp
*Corresponding author

*Trilobatus sacculifer*, a photosymbiotic planktonic foraminifera living in warm surface waters, has dinoflagellate symbiont *Pelagodinium béei*. Their relationship is generally thought to be mutualistic, in which symbiont photosynthesizes are transferred to the host, and the symbionts utilize the host derived inorganic nutrients. Previous studies revealed that the symbionts can proliferate in the host; hence the number of symbionts increases through the host ontogeny until the time of the host’s gametogenesis. As such, this symbiotic relationship is quite intimate and indispensable with each other. Recently, corruptions of photosymbiosis, or “bleaching”, due to environmental stress (especially extreme heat) were often reported in corals. Whether this kind of symbiont loss (and/or pigment loss) can occur in planktonic foraminifera has not been experimentally examined so far, but needs to be tested to understand the biological responses of photosymbiosis to global environmental stressors that can induce bleaching. Here, we conducted three series of culture experiments in each of which a single variable changed; (1) photoinhibition experiments, (2) light experiments, and (3) temperature experiments.

In this study, the series of culturing experiments were conducted for 7–10 days using *T. sacculifer* alone, except for the DCMU experiments using free-living *P. béei* culture as well. Foraminiferal samples were collected during tropical Pacific cruises by Hakuho-maru KH-16-7 for the DCMU experiments, KH-17-4 and KH-19-6 for the light experiments, and at Sagami Bay for temperature experiments. *P. béei* culture was originally isolated from *T. sacculifer* and has been maintained at the lab. The photoinhibition experiments were conducted using seawater which DCMU concentration of 0 μmol L⁻¹ (control group), 1 μmol L⁻¹ (L-DCMU group), and 10 μmol L⁻¹ (H-DCMU group). The light experiments were conducted under three irradiance levels; 10–20 μmol m⁻² s⁻¹ (LL group), 70–100 μmol m⁻² s⁻¹ (control group), and 200–250 μmol m⁻² s⁻¹ (HL group). Finally, the temperature experiments were conducted under three temperature levels; 19.5°C (LT group), 24.5°C (control group), and 32°C (HT group). The photosystem II (PSII) parameters representing the physiological state of photosynthesis (*Fₘ, Fₘ/Fₘ, 0, 0, 0A*) were measured daily by fast repetition rate fluorometry for each individual.

Based on the results of DCMU experiments, we could obtain the response profiles when photosynthesis is inhibited. Surprisingly, even though the chlorophyll content of individual foraminifera (estimated from *Fₘ* value) became nearly zero...
Biotic response of deep-sea benthic foraminifera at ODP Site 744 (Kerguelen Plateau) in the Southern Ocean during the early Oligocene

TAKATA Hiroyuki1*, SAKAI Saburo2, NOMURA Ritsuo3, TSUJIMOTO Akira3, NISHI Hiroshi3, SOO LIM Hyoun4 and KHIM Boo-Keun5

1BK21 School of Earth and Environmental Systems, Pusan National University, 2 Busandaehak-ro 63 beon-gil, Busan, Korea; yuu@pusan.ac.kr
2Biogeochemistry Research Center, Japan Agency for Marine-Earth Science and Technology, 2-15 Natsushima, Yokosuka, Japan; saburo@jamstec.go.jp
3Faculty of Education, Shimane University, 1060 Nishikawatsu, Matsue, Japan; nomura@edu.shimane-u.jp; tsujimoto@edu.shimane-u.jp
4Institute of Dinosaur Research, Fukui Prefectural University, 4-1-1 Kenjojima, Fukui, Japan; hiroshi.nishi.b3@tohoku.ac.jp
5Department of Geology, Pusan National University, 2 Busandaehak-ro 63 beon-gil, Busan, Korea; tracker@pusan.ac.kr

The early Oligocene is an epoch that the marked Antarctic glaciation happened, and the latitudinal gradient of surface oceanography such as episodic food supply became more significant between low- and high-latitude areas. Deep-sea benthic foraminifera responded to such oceanographic changes across the Eocene–Oligocene transition (EOT).

We investigated the Oligocene deep-sea benthic foraminiferal fauna at IODP Site U1334 (eastern Equatorial Pacific; EEP) and noted transiently common Astrononion echolsi (33.3–33.0 Ma and 32.9–32.8 Ma). Because this species seems to be related to the Southern Component Water (SCW), the possible influence of the SCW to the EEP was expected during the earliest Oligocene. Here we report the faunal transition of benthic foraminifera (>105 µm fraction) at ODP Site 744 (Kerguelen Plateau, 2307 m water depth; ~1800 m paleodepth) during 34.8–30.4 Ma, in order to reveal how benthic foraminifera responded to the paleoceanographic changes across the EOT in the Southern Ocean.

At ODP Site 744, Nuttallides umbonifer, Oridorsalis umbonatus, Epistominella exigua, and A. echolsi are common constituents during the late Eocene to early Oligocene. Across the EOT, Turrillina brevispira were temporally dominant with E. exigua at 33.5 Ma. Then, A. echolsi was common during the early Oligocene. The timings at the pulses of A. echolsi (33.8–33.0 Ma and 32.4–30.7 Ma) were generally similar to those of Astrononion spp. in the abyssal depths of the Atlantic Ocean. In contrast, the first common occurrence of A. echolsi at ODP Site 744 in 33.7–33.2 Ma may correlate to that of IODP Site U1334 just during ~33.3–33.0 Ma. Thus, the first common occurrence of this species was likely traced among the Southern Ocean, the Atlantic Ocean and EEP.

Additionally, this first common occurrence of A. echolsi at ODP Site 744 consists of the two small maxima at ~33.6 Ma and ~33.4 Ma that are similar to those of published benthic δ18O and opal mass accumulation rate (MAR) at the same site, suggesting the close relation to the Antarctic Oi-1 glaciation. Especially, high opal MAR implies the rapid increase of siliceous plankton and the change in mode of food supply from the surface ocean to the seafloor, especially on ballasting effect of particulate organic matter. Benthic foraminiferal fauna likely responded to such surface oceanographic changes in Kerguelen Plateau (Indian Sector of the Southern Ocean).

Faunal transition of benthic foraminifera across the Eocene–Oligocene transition at ODP Site 744 (Kerguelen Plateau) in the Southern Ocean

TAKATA Hiroyuki1*, SAKAI Saburo2, NOMURA Ritsuo3, TSUJIMOTO Akira3, NISHI Hiroshi3, SOO LIM Hyoun4 and KHIM Boo-Keun5

1BK21 School of Earth and Environmental Systems, Pusan National University, 2 Busandaehak-ro 63 beon-gil, Busan, Korea; yuu@pusan.ac.kr
2Biogeochemistry Research Center, Japan Agency for Marine-Earth Science and Technology, 2-15 Natsushima, Yokosuka, Japan; saburo@jamstec.go.jp
3Faculty of Education, Shimane University, 1060 Nishikawatsu, Matsue, Japan; nomura@edu.shimane-u.jp; tsujimoto@edu.shimane-u.jp
4Institute of Dinosaur Research, Fukui Prefectural University, 4-1-1 Kenjojima, Fukui, Japan; hiroshi.nishi.b3@tohoku.ac.jp
5Department of Geology, Pusan National University, 2 Busandaehak-ro 63 beon-gil, Busan, Korea; tracker@pusan.ac.kr
The Eocene-Oligocene transition (EOT) is known as the onset of icehouse world. A two-step transition is common in deep-sea records, such as more positive shifts of stable oxygen isotope data of benthic foraminifera. It is generally agreed that the first step of the $\delta^{18}O$ change of benthic foraminifera (EOT-1) primarily due to decreasing temperature, whereas the second step largely resulted from development of the Antarctic ice sheet (Oi-1).

Deep-sea benthic foraminifera responded to such oceanographic changes across the Eocene–Oligocene transition (EOT). Here we report the faunal transition of benthic foraminifera (>105 µm fraction) at ODP Site 744 (Kerguelen Plateau, 2307 m water depth) during 34.8–30.4 Ma and compare the faunal transitions of benthic foraminifera across the EOT between the Southern Ocean and the eastern Equatorial Pacific Ocean. Paleo-depth of ODP Site 744 was inferred as ~1800 m that seems to locate above the calcium carbonate compensation depth in general.

At ODP Site 744, *Nuttallides umbonifer*, *Oridorsalis unbonatus*, *Epistominella exigua*, and *Asterionella echolsi* are common constituents during the late Eocene to early Oligocene. Such faunal association is generally similar to that of ODP Site 689 (Maud Rise, Southern Ocean). *Turritillina brevispira* were temporarily dominant (maximum ~54%) at 33.5 Ma with *E. exigua* (~19%). The timing seems to correspond to the EOT-1. Then, *A. echolsi* was generally common during the early Oligocene. This common occurrence is similar to those of benthic $\delta^{18}O$, suggesting the close relation to the Antarctic Oi-1 glaciation. Thus, the faunal transition of benthic foraminifera across the OET consists of the two-step transition, like that of stable oxygen isotope record of benthic foraminifera. Finally, *N. umbonifer* was common during the early Oligocene, occasionally reaching ~60% at ~31.4 Ma.

The distribution of planktonic foraminifera from Central Luconia province, southern South China Sea

**TANG Hung Yung**, **MINHAT Fatin Izzati**$^{1,2,3}$, **MOHAMMAD Muhammad Hanif Haziq**$^1$, **ABDULLAH Amira Afrina**$^{1}$ and **ROSMAN Nur Iman Iwana**$^{1}$

$^1$Faculty of Science and Marine Environment, Universiti Malaysia Terengganu, 21300 Kuala Nerus, Terengganu, Malaysia; tanghungyung@gmail.com; fatinminhat@umt.edu.my; hanifhaziq@gmail.com; s54718@ocean.umt.edu.my

$^2$Paleoceanography Research Interest Group (PoRIG), Universiti Malaysia Terengganu, 21300 Kuala Nerus, Terengganu, Malaysia; fatinminhat@umt.edu.my

$^3$Institute of Oceanography and Environment (INOIS), Universiti Malaysia Terengganu, 21300 Kuala Nerus, Terengganu, Malaysia; fatinminhat@umt.edu.my

$^*$Corresponding author

A total of 45 core top samples (10 cm) from the Sarawak margin were used for foraminiferal analysis. The Sarawak deepwater area, also known as the Northwest Borneo margin, is considered part of the Sunda Shelf, with water depths ranging from 200 m to 2000 m. The study area belongs to the North Luconia province, bounded to the west by the Bunguran Trough, to the south by the Central Luconia province and to the northeast by the Dangerous Ground in the southern South China Sea (SCS). These samples were collected using piston cores at water depths ranging from 269 to 1,774 meters by Furgo for PETRONAS in 2019. Twenty species of planktonic foraminifera were identified. However, the most common species with an average relative abundance of >5% are *Globorotalia menardii*, *Globigerinoides trilobus*, *Neogloboquadrina dutertrei*, *Globigerinoides ruber*, *Orbulina universa* and *Pullemnina obliquiloculata*. Among these species, *Globorotalia menardii*, has been identified as the most dominant species, with an average relative abundance of 52%. It occurred at all 45 stations, followed by *Globigerinoides trilobus* and *Neogloboquadrina dutertrei* comprised 9% and 7%, respectively. *Globigerinoides ruber* and *Orbulina universa* hold 6%, and *Pullemnina obliquiloculata* is of 5% average relative abundance. We noticed some stations are barren or near-barren of foraminifera; this would have been related to the hydrothermal activities (a record of the average heat flow of 60 mW/m² at the North Luconia). In addition, the preliminary carbon-14 Accelerator Mass Spectrometry dates of foraminiferal *Globorotalia menardii* ranged from 510 – 690 ± 30 cal BP. Therefore, we assumed the foraminifer test preserved is equivalent to the modern living foraminifera.

The assemblage of planktonic foraminifera from the Sarawak margin (located at southern SCS) shared eight common species with the deepwater sediment trap records at the South East Asia Time-series Study (SEATS) site in the northern SCS. Among them, *Neogloboquadrina dutertrei*, *Pullemnina obliquiloculata* and *Orbulina universa*, recorded a similar value of average relative abundance in both regions. On the contrary, the average relative abundance for *Globorotalia menardii*, *Globigerinoides ruber*, *Globigerinoides sacculifer*, *Globigerinoides trilobus* and *Globigerinoides siphonifera* in the two regions are having significant differences. For example, *Globorotalia menardii* recorded a 52% average relative abundance at the Sarawak margin but only recorded 1% at the SEATS site, and *Globigerinoides sacculifer* is the most abundant species (34% average relative abundance) at the northern SCS but having just ~5% in the southern SCS. Noticeably, species with similar average relative abundance in the northern and southern SCS regions are mostly thermocline dwellers. However, the surface mixed layer dwellers are the foraminifer species with significant average relative abundance differences.
A mid-Holocene cold spell in the Nordic Seas and its links to a global cooling event

TELESIŃSKI Maciej1* and ZAJĄCZKOWSKI Marek1

1Department of Paleoceanography, Institute of Oceanology Polish Academy of Sciences, Powstańców Warszawy 55, 81-712 Sopot, Poland; mtelesinski@iopan.pl; trapper@iopan.pl
*Corresponding author

Apart from long-term changes, the climate of the Earth has been punctuated by numerous short-lived events that had a tremendous influence on terrestrial and marine ecosystems. The present interglacial period is relatively warm and stable, especially compared to the preceding glacial time. However, several prominent cooling events have been identified within the Holocene, some of them of overregional importance. Based on previously published marine records from the Nordic Seas, we describe for the first time an event centred around 6.7 ka BP. Planktic foraminiferal records along the North Atlantic Drift reveal distinct subsurface water cooling. It was preceded by a stepwise increase in sea-ice cover in the eastern Fram Strait, as indicated by a biomarker record. The results suggest that the onset of deep convection in the Greenland Sea and the westward shift of the main flow of Atlantic Water allowed sea-ice advection from the Barents Sea into the Fram Strait. The increase in sea-ice cover weakened the advection of Atlantic Water advection. The perturbation of the overturning circulation in the eastern Nordic Seas had far-reaching consequences, including changes in deep-water circulation in the North Atlantic, cooling over vast areas of both hemispheres, and weakening of the East Asian monsoon. The described events show that during a relatively warm and stable interval, fairly local cooling can occur and the resulting sequence of environmental changes can spread globally. Understanding the mechanisms behind events that occur within generally stable intervals is invaluable for future climate predictions.

This study was supported by grant no. 2020/39/B/ST10/01698 funded by the National Science Centre, Poland.

The life cycle of Allogromia laticollaris has brief haploid and diploid phases followed by a 12,000 fold amplification of genome content and then Zerfall

TIMMONS Caitlin1, LE Kristine1, RAPPAPORT Hannah1, STERNER Elinor G. 1, MAURER-ALCALÁ Xyrus X.2 and KATZ Laura A.1,3*

1Smith College, Department of Biological Sciences, 44 College Lane, Northampton, MA, 01063, USA; caitlintimmons811@gmail.com; kle@smith.edu; hbrappaport@gmail.com; esterner@smith.edu
2American Museum of Natural History, Department of Invertebrate Zoology, 200 Central Park West, New York, NY, 10024, USA; maurerax@gmail.com
3University of Massachusetts Amherst, Program in Organismic & Evolutionary Biology, 230 Stockbridge Road, Amherst, MA, 01003, USA; lkatz@smith.edu
*Corresponding author

In contrast to the canonical view of genomes that fluctuate only between haploid-diploid cycles, many eukaryotes have dynamic genomes that change content throughout an individual’s life cycle. However, our understanding of eukaryotic genome dynamics is incomplete, as most studies have focused on ‘model’ lineages of animals, plants, and fungi. Here, we expand knowledge on eukaryotic features through analyses of the foraminifera Allogromia laticollaris strain CSH. Foraminifera (Rhizaria) are an ancient and ecologically important clade with complex life cycles that include dramatic changes in ploidy. Here, we apply fluorescence microscopy and image analysis techniques to over 2,800 nuclei in 110 cells to characterize the life cycle of A. laticollaris. We show that haploidy and diploidy are relatively brief life stages, and that A. laticollaris nuclei experience substantial endoreplication to generate up to 12,000 times the haploid genome content in uninnucleate adults. Further, we find that A. laticollaris reorganizes a highly endoreplicated nucleus into thousands of haploid genomes through a non-canonical mechanism called Zerfall. First, and perhaps best, described by Føyn in 1936, we demonstrate that the nuclear envelope breaks down during Zerfall, extruding chromatin into the cytoplasm; this chromatin is then reorganized into thousands of haploid genome complements through an intermediate thread-like phase. Based on these findings plus preliminary staining of RNA expression and insights from the literature, we believe that A. laticollaris uses spatio-temporal mechanisms to delineate germline and somatic DNA within a single nucleus. These analyses expand on our understanding of germline/soma distinctions in eukaryotes, and extend our understanding of genome dynamics across the eukaryotic tree of life.

Objective identification of Lepidocyclina (Foraminifera) species from the Eocene of Cuba based on growth-invariant morphometric characters

TORRES-SILVA Ana I.1* and HOHENEGGER Johann1
The Lepidocyclinidae are one group of Cenozoic three-layered larger foraminifer that came to dominate the Paleogene neritic biota around the American-Caribbean faunal province, optimally documenting the maturity and evolution of benthic communities. The high evolutionary rates exhibited by members of this family have been routinely used in biostratigraphy to improve the correlation of shallow water deposits across America. Their extreme morphologic complexity is represented by an initial embryonal part consisting of a deuteroconch and protoconch, followed by an equatorial layer of numerous, radially to concentrically arranged chamberlets and two variably developed layers of lateral chamberlets. Taxonomic classification was basically defined by the embryonic apparatus as the only reliable tool for species identification, however, further growth expressed by the sequence of equatorial or neanic chamberlets have received less taxonomic and morphometric attention. Megalospheric specimens of Lepidocyclina from seven localities in Western and Central Cuba were morphometrically investigated using 11 growth-independent characters for equatorial sections of nepions and 19 growth–independent and – invariant characters describing equatorial sections of neanic chamberlets. This provides a complete geometric reconstruction of the equatorial morphology for lepidocyclins. Specimens were objectively classified by clustering and ordination methods resulting in four morphologically homogenous groups. These unprejudiced groups are then subjectively identified as Lepidocyclina macdonaldi, L. pustulosa, L. ariana and L. ocalana following the taxonomic rules and checked for significant differences. The D/P(deuteroconch/protoconch)-ratio separates L. ocalana (D/P > 1) from L. pustulosa (D/P = 1), L. macdonaldi and L. ariana (D/P < 1). The form of neanic chamberlets differentiates both L. macdonaldi and L. pustulosa possessing arcuate chamberlets from L. ariana and L. ocalana with spatulate chamberlets. The smaller size characters isolate L. pustulosa from the other species. Lepidocyclina macdonaldi has the longest stratigraphic range occurring from ABZ 9 to ABZ 16 (American Larger Benthic Foraminifera Zonation). Lepidocyclina ariana is restricted to ABZ 12, while L. pustulosa and L. ocalana range from ABZ 13 to ABZ 16 and ABZ 15 to ABZ 16, respectively. An evolutionary trend could be detected in nepions of L. macdonaldi starting from slightly smaller nepions at the first appearance to significantly larger nepions at the end of the Priabonian. Additionally, the arcuate chamberlets arranged in rows transform from not-connected to connected. Differences within L. ocalana can be explained by environmental influences due to the paleo-geographical position of samples. Subgroups within L. macdonaldi on the one side and L. ocalana on the other describing nepiont and neanic chamberlets explain the influence of environmental factors, therefore reaffirming an ecological species concept.
calcium ions, and it is clear that they obtain carbonate ions from calcium ions and CO2 or bicarbonate ions in seawater and produce calcium carbonate by reacting both in specific locations. The manipulation of such microenvironments had limitations when observed using glass electrodes in the past. The development of visualization techniques using microscopy has deepened our understanding by making environmental changes visible as images.

Future research could potentially elucidate the mechanisms governing overall shape and the locations of chamber additions. As massive sequencers are developed and applied to foraminifer research, molecular biology approaches may provide clues to solving these cellular biological functions. To interpret this, we would like to estimate the biochemical reactions occurring by conducting live imaging of shell formation through time-lapse imaging, chemical environment imaging of calcium and pH, and imaging of intracellular organelles. Furthermore, by applying the results of RNA expression analysis, techniques such as FISH can be employed, potentially identifying specific gene expression sites in the future.

Paleoenvironmental changes during the late Paleogene – Early Neogene in the SW Caribbean Region (ANH-San Jacinto-1 well): inferences from benthic foraminifera.

TREJOS-TAMAYO Raúl1,2*, GARZÓN Darwin3, FLORES José-Abel1, PARDO Andrés2, VALLEJO-HINCAPIÉ Felipe1,2 and DUQUE-CASTAÑO Mónica2,3,4

1Departamento de Geología, Universidad de Salamanca, Plaza de los Caídos s/n, 37008 Salamanca-Spain; raulandres_tt@usal.es; raulandres_tt@usal.es; diego.vallejo@ucaldas.edu.co
2Instituto de Investigaciones en Estratigrafía (IIES), Universidad de Caldas and Departamento de Ciencias Geológicas, Universidad de Caldas, Calle 65 #26-10, Manizales, Colombia; raulandres_tt@usal.es; raulandres_tt@usal.es; andres.pardo@ucaldas.edu.co; diego.vallejo@ucaldas.edu.co; monica.duque@ucaldas.edu.co
3Centro de Ciências do Mar – CCMAR, Universidade do Algarve, Campus de Gambelas, 8000-139 Faro, Portugal; monica.duque@ucaldas.edu.co
4División de Geología e Geo Recursos Marinos, Instituto Portugués do Mar e da Atmosfera, Rua Alfredo Magalhães Ramalho, 6, Lisboa, Portugal; monica.duque@ucaldas.edu.co
*Corresponding author

Changing tectonic dynamics from oblique to orthogonal subduction played an important role in developing marine environments controlling bathymetry, subsidence, and accommodation space in the southwestern Caribbean region during the Late Cenozoic. Foraminifera and palynology have been used in the region to understand the temporal context and the most general elements of geological evolution. However, detailed micropaleontological studies are becoming relevant recently to understanding the magnitude of the regional signal in the Caribbean and the influence of the global climate on sedimentary systems.

The onshore ANH-San Jacinto-1 well in the central Sinu-San Jacinto Basin (NW South America) records a complete marine sequence from the late Paleogene to the Early Neogene marine deposits. Here we present the micropaleontology (planktonic foraminifera and calcareous nanofossils) age model and paleoenvironmental reconstruction based on the benthic foraminifera record along the core.

Our results show an age model from the late Eocene (Priabonian) to the Early Miocene (Burdigalian) between the planktonic foraminifera biozones E15-E16 to M2 and calcareous nanoplankton biozones NP19-20 to NN2. In addition, we identified 140 genera and 288 species of benthic foraminifera. Seven main assemblages are distributed stratigraphically along the core, showing variations in wall type, biodiversity, and microhabitats.

The late Eocene assemblages indicate shifts from shallow marine turbiditic environments, in the continental shelf (neritic zone), to deeper conditions in the slope (upper to middle bathyal zone). The transition between the Eocene and Oligocene shows low diversities, epifaunal and agglutinated benthic foraminifera dominance, and neritic depths, suggesting the influence of the global climatic transition due to the onset of the icehouse stage. With a rhythmic trend, the early Oligocene to the Early Miocene assemblages comprises infaunal and calcareous-walled foraminifera, higher diversities, and environments between the outer shelf and the upper slope. During this time, the basin behaved almost stable due to the significant influence on the environments caused by orthogonal subduction as the gradual increase of subsidence. The rhythmicity shown by the benthic foraminifera seems to respond to the global climatic trend during the Oligocene.

Our results show that although the solid regional signal plays an essential role in the behavior of micropaleontological communities, the global climatic signal exerts a strong control at low latitudes.

Early evolution of trochosaminoids (trochosporial organic-cemented agglutinated foraminifera)

TREMBLIN Clément M.1* and HAIG David W.1

1Oceans Institute, The University of Western Australia, 35 Stirling Highway, Perth, WA 6009, Australia; 23126169@student.uwa.edu.au; david.haig@uwa.edu.au
*Corresponding author
Trochamminids are the oldest known trochospiral group of foraminifera. Exceptionally well-preserved tests of four species of trochamminids and one that seems closely related and of trochamminoid affinity have been found in the Lower Permian (upper Sakmarian, 290–293 Ma) Holmwood Shale in the Irwin Basin of Western Australia. These represent the oldest known well-preserved representatives of the superfamily. Previously known Carboniferous trochamminids are very poorly preserved and diagnostic characters such as apertural position and three-dimensional chamber shape are obscured.

The studied assemblage consists of four trochamminid species *Trochammina geoffplayfordi*, *Trochammina gloveri*, *Trochamminopsis teichertii*, and *Tritaxis crespinae*. *Verispira holmesi* has an *Ataxophragmium*-like coiling but seems related to the broader Trochamminoidea. All the species have agglutinated angular, sometimes rounded, quartz grains set in a finer quartz matrix. An inner organic lining is present in the inner whorls of all species. The apertural position is characteristic for each genus, and all have a distinct lip developed on the upper margin of the aperture.

This study shows that by 290–293 Ma species of *Trochammina*, *Trochamminopsis* and *Tritaxis*, remarkably like modern species, had developed in a shallow-water interior sea with muddy substrate. Species of *Trochammina* and *Trochamminopsis* may have lived in the flocculent surface layer of the mud as do some modern analogues. Species of *Tritaxis* and *Verispira* may have lived as epiphytes on the monostromatic alga *Litostroma* or as epibionts on skeletal debris present on the seafloor. A broad stratigraphic review for possible ancestors and later evolutionary diversification shows that (1) no potential trochosorial ancestor is known among the Late Paleozoic calcareous Tetrataxoidea and broader Endothyrida; (2) Triassic *Duostomina* seems to be the oldest calcareous taxa with simple trochosorial coiling (also having an inner organic lining); (3) following the Late Paleozoic diversification of trochosaminoids (evidenced among the studied material) major diversifications took place during the Late Jurassic–Early Cretaceous involving different chamber shapes and during the Cenozoic involving apertural modifications. Molecular analyses of few modern species suggest that the morphological group like modern *Trochammina hadai* (including Permian *T. geoffplayfordi*) lies at some genetic distance from *Trochammina inflata* (type species of the genus).

**Invasive *Trochammina* in a south-west Australian estuary**

TREMBLIN Clément M.1*, HOLZMANN Maria2, PARKER Justin H.1, SADEKOV Aleksey4 and HAIG David W.1

1Oceans Institute, The University of Western Australia, 35 Stirling Highway, Perth, WA 6009, Australia; 23126169@student.uwa.edu.au; david.haig@uwa.edu.au
2Department of Genetics and Evolution, The University of Geneva, 30 Quai Ernest Ansermet, CH-1211 Geneva, Switzerland; maria.holzmann@unige.ch
3Independent researcher, Perth, Australia; winderabandi@gmail.com
4Centre for Microscopy, Characterisation and Analysis, The University of Western Australia, 35 Stirling Highway, Perth, WA 6009, Australia; aleksey.sadekov@uwa.edu.au

*Corresponding author

An invasive foraminiferan has been recorded for the first time in an Australian estuary. *Trochammina hadai*, originally described as endemic from Japan and subsequently found to be alien in coastal waters of California and Brazil, has been identified in estuarine sediment in the vicinity of Bunbury Port in Western Australia. Species determination is based on morphological, molecular and ecological similarities to the Japanese type. The species has not been recorded in other estuaries in Australia. The very close molecular similarity to living specimens from Japan and North America indicates rapid invasive dispersal of *T. hadai*, rather than slower natural dispersion with greater genetic drift.

Bunbury Port, in south-west Australia, is a major exporter of woodchip to Japan and the introduction of *T. hadai* may have come from ballast water out of shallow-draught woodchip vessels. Small sediment samples of estuarine mud obtained at water depths of <5 m contain abundant *T. hadai* (on average 0.4 mm in adult diameter) that are easily recognised in microscopic view of the sediment surface by their bright reddish-brown colour. The species lives in the top 1 cm layer of flocculent mud on the estuarine floor. This study demonstrates that foraminiferal species can be included among the invasive marine taxa in Australian estuaries. *Trochammina hadai* may also provide an indicator, identified by simple microscopic examination, for the detection of other more elusive exotic species, particularly from the vicinity of ports elsewhere.

**Benthic foraminifera from shallow-water of Line Islands**

TRUBIN Yaroslav S.1,2* and LANGER Martin R.1

1Institut für Geowissenschaften, Paläontologie, Universität Bonn, Nussallee 8, 53115 Bonn, Germany; yir-2009@mail.ru; martin.langer@uni-bonn.de
2Laboratory of Sedimentology and Paleobiosphere Evolution, University of Tyumen, Volodarskogo 6, Tyumen, Russia; yir-2009@mail.ru

*Corresponding author

The Line Islands rank among the most isolated in the tropical Pacific Ocean, form a chain of 11 atolls, and hold a biogeographic key position for the translocation of taxa across the Pacific. Because of their isolated location, the islands constitute the ultimate steppingstone for the dispersal of species from east to west and vice versa. Since benthic foraminifera
The Foraminifera of the Western Siberian Seas – with what sorts of treasures they filled their homes after life?

TRUBIN Yaroslav S.1,2,*, MARINOV Vladimir A.2,3, RUDMIN Maxim A.2,4, SMIRNOV Pavel V.2,5, WINKLER Alina1, BRIT Vyacheslav A.6, NOVOSELOV Andrey A.3,7 and LANGER Martin R.1

1Institute of Geosciences, Paleontology, University of Bonn, Nussallee 8, Bonn, Germany; trubinjs@gmail.com, martin.langer@uni-bonn.de
2Laboratory of Sedimentology and Paleobiosphere Evolution, University of Tyumen, Volodarskogo 6, Tyumen, Russia; iyr-2009@mail.ru; marinova@mail.ru; rudiminma@tpu.ru; geolog.08@mail.ru; mr.andreygeo@mail.ru
3Tyumen Petroleum Research Center, Maksima Gor’kogo 42, Tyumen, Russia; marinova@mail.ru
4Division for Geology, Department of Machine building, National Research Tomsk Polytechnic University, Lenin Avenue 30, Tomsk, Russia; rudiminma@tpu.ru
5Clausthal University of Technology, Adolph-Roemer-Strasse 38, Clausthal-Zellerfeld, Germany; geolog.08@mail.ru
6Siberian Federal University, Svobodny Avenue 79, Krasnoyarsk, Russia; amazzanit@mail.ru
7Earth Cryosphere Institute, Tyumen Scientific Centre SB RAS, Malygina 86, Tyumen, Russia; mr.andreygeo@mail.ru
*Corresponding author

Western Siberia is widely covered by marine sedimentary deposits comprising clastic Middle Triassic through Middle Paleogene rock units. To shed new light on depositional and post-depositional processes, we have conducted a comprehensive analysis on Late Mesozoic-Early Cenozoic materials from the West Siberian epicontinental basin. The foraminiferal tests, that are widely distributed in the Western Siberian basin, contain various authigenic mineral associations. These provide additional information about the post-depositional processes of the sedimentary units. The authigenic mineral infills recovered from the foraminiferal tests comprise calcite cement, glauconite, baryte, wurtzite, pyrite, and marcasite. Here we have studied authigenic mineral associations within foraminiferal chambers to provide a better understanding of the diagenetic history of the marine sediments of the West Siberian.

The material includes a total of 82 sedimentary rock samples of which 5 samples are from the Sokolovskii section in the southernmost part of Western Siberia, 65 core drilling samples from the Kyshtyrla Quarry located in the south western corner of Western Siberia, and 12 core drilling samples are from Kharasavey oil and gas field on the Yamal Peninsula. The samples analysed were taken from three prominent formations: Tibeisale (Lower Paleocene), Sokolovsk (Upper Paleocene) and Tava Formation (Upper Eocene). All samples were sieved over 63-µm mesh sieves and inspected for foraminifera by using a stereomicroscope. A total of 3570 foraminifera were recovered from all samples and 48 tests were dissected and polished to analyse the inner structure and chamber infillings of authigenic mineral associations. Chamber infillings were then examined by SEM and EDS-SEM.

The foraminiferal chambers examined were found to act as storage devices for iron sulfides such as pyrite, authigenic calcite, and gypsum. The pyrite mineral deposits are mainly small frambooids (5–10 µm) and fine-grained globular and octahedral forms of pyrite (30–40 µm). Pyrite mineral infillings were predominantly associated with Upper Eocene deposits and rarely occurred in Paleocene sediments. The authigenic calcite often covered the internal surfaces of the foraminiferal tests and comprises mainly microsparite (<1 µm) and occasionally sparite (~10–20 µm). The external test layer was frequently coated by a thin layer of microsparite. Authigenic calcite was found to occur within tests from all formations. Gypsum infillings typically occurred as elongated crystals (up to 80–100 µm), partially filled the chambers and often surrounded the small pyrite frambooids or other non-authigenic particles in chambers. Gypsum infillings were recorded only in the Upper Eocene units.

The formation of mineral infillings appears to follow a chronology of phases that can be inferred from crystal form and crystal boundaries, and the transitions between them. The first phase commonly includes the formation of pyrite frambooids, that are later surrounded by calcite and gypsum (second phase). The formation of pyrite frambooids is generally related to the
degradation of organic matter within the test chambers, the removal of dissolved oxygen by aerobic bacteria and the reduction of sulphate to hydrogen sulphide, and iron ion reactions. The second mineral phase includes the formation of authigenic calcite filling the chamber interior and covering of external surfaces. The formation of authigenic calcite is considered to be the result of redissolution and recrystallization of the primary total carbonate present in the sediment and in biogenic materials. The appearance of gypsum crystals appears to be linked to the pyrite aggregates is probably related to the oxidation of the sulfidic sediments.

**Phylogenetic patterns of Foraminifer Organic Linings**

**TYSZKA Jarosław**, **GODOS Karolina**, **GOLEN Jan** and **RADMACHER Wiesława**

1ING PAN – Institute of Geological Sciences, Polish Academy of Sciences, Research Centre in Cracow,Senacka 1, 31-002 Kraków, Poland; ndtyszka@cyf-kr.edu.pl; ngodos@cyf-kr.edu.pl; ndgolen@cyf-kr.edu.pl; ndkrol@cyf-kr.edu.pl

*Corresponding author

Foraminifera leave three types fossil records that include: composite mineral-organic tests (shells); foraminiferal organic linings (FOLs); and ancient foraminiferal DNA. All these record types differ in sample preparation techniques and methods of taxonomic identification. While our knowledge of the mineral record is impressive, our understanding of organic remains is still highly limited. In particular, the fossil archive of acid resistant linings is highly fragmentary, and in consequence, the overall foraminiferal record is strongly biased towards mineral tests. Despite these limitations, we explore the potential of the FOLs record for understanding the evolution of Foraminifera. We are especially interested in learning evolutionary trends of morphogenetic and biomineralisation principles emerged from the record of extremely diverse foraminiferal tests. Therefore, we have analysed the overall published Phanerozoic record of FOLs that integrates over 600 images (see ForamL, doi: 10.17632/xw7w5ns649.2). Exploration of the phylogenetic trends within the dataset is the first goals of our project. This was a non-trivial task, as most of the FOLs in the database have never been taxonomically identified. Despite

**Planktonic foraminiferal quantitative record of the Burdigalian to Langhian interval at Site 1264 (Walvis Ridge, south-eastern Atlantic Ocean)**

**TURCO Elena**¹, **DI RENZO Rosalia**¹ and **LOURENS Lucas**²

¹Department of Chemistry, Life Sciences and Environmental Sustainability, Parma University, Parco Area delle Scienze 157/A, Parma, Italy; elena.turco@unipr.it; rosaliadirenzo@gmail.com

²Department of Earth Sciences, Faculty of Geosciences, Utrecht University, Princetonlaan 8a, Utrecht, The Netherlands; L.J.Loureens@uu.nl

*Corresponding author

During the late Burdigalian to Langhian interval (Early to Middle Miocene) the Earth’s climate was characterized by a global warming period (Miocene Climatic Optimum) from 17 to 14.7 Ma, which was followed by a gradual decline in temperature (Middle Miocene Climate Transition) culminating in the marked M3b cooling event at about 13.8 Ma. This evolution of the ocean-climate system favoured the development of marked meridional and vertical thermal gradients, the increase of zonality and the contraction of tropical and subtropical bioprovinces to lower latitudes. Planktonic foraminiferal assemblages were also affected by these climatic changes and their differentiation between low- and mid-latitude regions increased leading to the ejection of different biozonal schemes.

High-resolution quantitative studies of planktonic foraminiferal assemblages and a good age control (e.g., by the integration with magnetostratigraphy and/or cyclostratigraphy) are fundamental to improve the understanding of spatial and temporal distribution of planktonic foraminiferal species. Moreover, this integrated approach enhances biostratigraphic resolution, the accuracy of age calibration of bioevents and the evaluation of their synchronism at a global scale.

Here, we present the results of high-resolution quantitative analysis of the planktonic foraminiferal assemblages, focussing on biostratigraphic markers, from the astronomically tuned Site 1264 (ODP Leg 208), located in the south-eastern Atlantic Ocean at a latitude of ~28°S. The investigated stratigraphic interval, spanning from ~17.5 to ~13.5 Ma, consists of foraminifer-bearing nannofossil oozes containing well preserved planktonic foraminiferal assemblages. The quantitative biostratigraphic analysis, performed with a time resolution of ~20 kyr, allowed us to obtain detailed distribution patterns of the marker species and to refine the stratigraphic position and the age calibration of the bioevents. The presence of taxa used as zonal markers in the (sub)tropical standard zonation (e.g., *Catapsydrax dissimilis*, the evolutionary stages of *Trilobatus-Praeorbulina-Orbulina* lineage) and taxa typical of temperate assemblages (e.g., *Globorotalia miozea* and *Globorotalia zeelandica*) and the absence of *Globigerinatella insueta* s.s., typical of the tropical assemblages, indicate that planktonic foraminiferal assemblages at Site 1264 differ from those of the low-latitude regions since the late Burdigalian. Moreover, a comparison of the biostratigraphic record of Site 1264 with the low-latitude distribution range of marker species and biochronology (literature data) highlighted diachronism of some main events, such as the first occurrences of *Praeorbulina* and *Orbulina* species, and differences in the distribution patterns of marker species (e.g., *Paragloborotalia siakensis*).
this limitation our meta-analysis demonstrates that nearly all foraminiferal organic linings show globular chambers with minimized distances between successive foramina. It means that multilocular foraminifera with tubular chambers are almost missing from the record. If we separate unilocular linings of monothalamean foraminifera from the dataset, it appears that most of the multilocular organic linings should be classified to the class Globothalamea. We hardly recognize linings attributed the class Tubothalamea. The Devonian *Tolympammina tantula* Bell assigned to Ammodiscina is nearly the only exception identified so far within Tubothalamea. However, its long uncoiled tubular test may suggest association with monothalamean astrorhizids, therefore, its tubothalamean assignment is still very uncertain. Our analysis does not allow identification of orders that represent globothalamean agglutinated and calcareous tests. We can just assume that some of multilocular linings with globular chambers could be classified to the order Textulariida. Foraminifera from this group tend to preserve linings that are similar to the linings of calcareous tests. Another intriguing observation is that planktic foraminifera belonging to the class Globothalamea do not preserve organic linings in the fossil record. Earlier dissolution experiments proved the lack of acid resistant organic linings after dissolution of planktic foraminiferal tests. We observe a limited number of lagenid linings, however, they are relatively rare, even in the Jurassic records where Lagenina dominate within mid to shallow marine sediments. All these phylogenetic patterns of irregular appearance of linings provoke main research questions. Why there is nearly no record of fossil linings that belong to Tubothalamea. Do all foraminifera truly produce fossilizable organic linings? Are these linings compositionally and structurally similar? What is their taphonomic potential? Foraminiferal organic linings as “residual organic remnants of foraminifera left after chemical dissolution of their mineral tests” represent residues of extracellular organic matrix incorporated and/or coating foraminiferal tests. The most prominent is the inner organic lining that seems to be directly associated with biomineralization, protection, physiology, combined functions in Foraminifera. These functions might follow phylogenetic trends and different evolutionary adaptations. All these problems encourage our interdisciplinary investigations.

Our research is supported by the Polish National Science Center (Grant 2020/37/B/ST10/01953).

**Foraminiferal succession across the Permian–Triassic boundary in Northern Thailand**

UENO Katsumi¹, CHAROENTITIRAT Thasinee² and KAMATA Yoshihito³

¹Department of Earth System Sciences, Fukuoka University, Fukuoka 814-0180, Japan; katsumi@fukuoka-u.ac.jp
²M.Sc. Program in Petroleum Geoscience, Faculty of Science, Chulalongkorn University, 254 Phayathai, Bangkok 10330, Thailand; thasineec@gmail.com
³Graduate School of Life and Environmental Sciences, University of Tsukuba, Ibaraki 305-8571, Japan; yoshi_kamata@geol.tsukuba.ac.jp
*Corresponding author

In Southeast Asia, Late Permian and Early Triassic foraminifera are rarely known so far, and therefore the foraminiferal faunal succession across the Permian–Triassic boundary has not yet been documented in detail. We investigated latest Permian to Middle Triassic strata distributed in the Lampang area of Northern Thailand to understand foraminiferal faunal features and transition across this systematic boundary. The Late Permian in this area is attributed to the Huai Thak Formation in the Ngao Group and previously, the Changhsingian *Palaeofusulina-Gallowayinella-Colaniella* foraminiferal fauna was described from it. The Triassic is called the Lampang Group and consists of the Phra That, Pha Kan, Hong Hoi, Doi Long, and Pha Daeng formations in ascending order. Of these, the Phra That Formation in the lowest is conventionally assigned to the Early Triassic, and is overlain conformably by the carbonate Pha Kan Formation of early Middle Triassic (Anisian) age. Although the Phra That Formation in its type area has been described as consisting mostly of siliciclastics, we newly found an entirely carbonate succession that is equivalent chronologically to the Pha That Formation, in other area of Lampang. Consequently, almost continuous carbonate stratigraphy ranging from the latest Permian to the early Middle Triassic can be established in the investigated section.

The studied carbonate strata are about 1300 m thick, with several unexposed intervals. The basal part, corresponding to the uppermost part of the Huai Thak Formation, consists of bioclastic limestone (wackestone/packstone) and contains variable foraminifers, such as *Palaeofusulina sinensis*, *Reichelina changhsingensis*, *Colaniella cylindrica*, *Rectostipulina quadrata*, *Dagmarita*, *Paraglomospirella*, and *Retroseptellina*. This foraminiferal fauna indicates a late Changhsingian age. Then, this latest Permian interval is succeeded continuously by approximately 800 m-thick dolomite and dolomitic limestone. Its lower portion is characterized by dolomite and laminated lime-/dolo-mudstone with diagnostic laminated microbialites in some levels, and contains *Postcladella kalhori* sporadically. The middle–upper portion is dominated by cross-laminated oolitic and pisolithic dolomitic limestone and dolomite, and rarely yielded a monotonous and restricted foraminiferal assemblage composed of *Postcladella*? or primitve *Arenovidalina*? and “Glomospirella discoidalis”. These foraminifers suggest that the dolomite and dolomitic limestone succession is correlated broadly to the Lower Triassic. This further implies that the present dolomitic interval represents a contemporaneous heterotopic facies of the clastic-dominant Phra That Formation. The overlying, approximately 500 m-thick part consists mainly of dark-colored micritic limestone. Based on the lithological features, this part is considered as the Pha Kan Formation, which is known to be characterized by the Anisian *Citarella dinarica* foraminiferal fauna.

In view of foraminferal succession and lithological features, the Permian–Triassic boundary is placed in the very base of the section, at the base of the dolomite-dominant interval, which directly overlies bioclastic limestone containing the late
Changhsingian *Palaeofusulina sinensis-Reichelina changhsingensis* fauna. The overlying, approximately 800 m-thick, dolomite-dominant succession is considered to be Early Triassic and is characterized by unusual foraminiferal features and carbonate lithology, such as restricted faunal diversity, laminated microbialites, and pisoid-rich dolomitic limestone. This is the first documentation of Early Triassic carbonates and foraminifers in Southeast Asia. The present Early Triassic section would have good potential for elucidating paleoenvironments of the eastern Paleotethys during the relevant time interval.

Transcriptome analyses unveil the molecular framework of calcification in Rotaliida, benthic and planktic foraminifers: What are the differences among species?

UIJIÉ Yurika1*, ISHITANI Yoshiyuki2, ULANOVA Dana3, INAGAKI Yuuka4, IKUMA Issui1, YOSHIMURA Yoshihiro4 and ENDO Hirotoshi5

1Marine Core Research Institute, Kochi University, Monobe-Otsu 200, Nankoku, Kochi, Japan; yujiie@kochi-u.ac.jp; b193s005@s.kochi-u.ac.jp; b193s002@s.kochi-u.ac.jp
2Institute for Extra-Cutting-Edge Science and Technology Avant-garde Research (X-star), Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Natsushima-cho 2-15, Yokosuka, Kanagawa, Japan; ishitaniy@jamstec.go.jp
3Faculty of Agriculture and Marine Science, Kochi University, Monobe-Otsu 200, Nankoku, Kochi, Japan; ulanova@kochi-u.ac.jp
4Research Institute for Marine Resources Utilization, Biogeochemistry Research Center, Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Natsushima-cho 2-15, Yokosuka, Kanagawa, Japan; yoshimurar@jamstec.go.jp
5Department of Creative Engineering, National Institute of Technology, Tsuuraoka College, 104 Sawada, Inooka, Tsuruoka, Yamagata, Japan; hiro_endo@tsuruoka-nct.ac.jp
*Corresponding author

Rotaliida foraminifers have contributed to more than 20% of calcium carbonate (CaCO₃) production over the world ocean, owing to their abundance in both seafloor and pelagic oceans. Their CaCO₃ tests have been widely used in geochemical analyses to reconstruct paleoenvironments because their chemical and isotopic composition are interacted with physicochemical conditions of ambient seawater. Despite of such utilities, we need to examine the non-equilibrium state of chemical compounds between foraminiferal tests and the external environment. One of the biggest problems is how foraminifers biologically control the uptake of Ca²⁺ and inorganic carbon in biomineralization. Although the molecular mechanism of foraminiferal calcification had been completely masked, our recent study successfully estimated the metabolic pathway driving calcification in a benthic foraminifer based on comparative transcriptomic analyses. Foraminifers actively take up Ca²⁺ to boost mitochondrial ATP synthesis during calcification but pump excess intracellular Ca²⁺ to the calcification site to avoid cell death. The enzyme α-carbonic anhydrase (CA) induces the generation of HCO₃⁻ and H⁺ from multiple CO₂ sources. The evolution of Ca²⁺-related and CA genes is likely a key for calcification in Rotaliida. However, calcification mechanisms have been also thought to show species specificity among diversity in Rotaliida. In particular, the presence of microalgal symbionts may be involved in planktic foraminifer calcification. Here, we conducted the transcriptome analyses of two planktic foraminifera species and examined the common and different points for calcification among benthic and planktic species.

In the present study, we cultured *Trilobatus sacculifer* (with microalgal symbionts) and *Globorotalia inflata* at three different temperatures to observe their chamber formation processes. These two species formed a new chamber via the arrangement of reticulopodia as same as the process of a benthic foraminifer *Ammonia beccarii*. Based on these observations, we extracted mRNA from single cells during calcification and non-calcification stages and conducted single-cell RNAseq analysis. Using comparative transcriptomics, we predicted the candidate genes, which were highly or only expressed during calcification in each species. Most genes, in particular Ca²⁺-related and CA genes, were commonly used among three species. Interestingly, qPCR analysis showed expression levels of the Ca²⁺-related gene are different among species and temperatures. These differences could be reflected in chemical composition of the foraminiferal tests.

**Biological adaptation of Foraminifera to low oxygen conditions**

VAN DIJK Inge1*, BARRAS Christine1, ORON Shai2,3, MOURET Aurelia1 and GESLIN Emmanuelle1

1UnivAngers, Nantes Université, Le Mans Univ, CNRS, Laboratoire de Planétologie et Géosciences, LPG UMR 6112, 2 Boulevard de Lavoisier, 49000 Angers, France; Inge.vandijk@univ-angers.fr; Christine.Barras@univ-angers.fr; Aurelia.Mouret@univ-angers.fr; Emmanuelle.Geslin@univ-angers.fr
2Department of Marine Geosciences, Charney School of Marine Sciences, University of Haifa, 199 Aba Khoushy Ave. Mount Carmel Haifa, Israel; shaioron80@gmail.com
3The Interuniversity Institute for Marine Sciences, Coral Beach, P.O.B 469 8810302 Eilat, Israel; shaioron80@gmail.com
*Corresponding author

Marine low-oxygen areas have been increasing since the 1960s due to ongoing climate change and eutrophication, and has led to dramatic ecological and economic consequences that will most likely be amplified in the near future. Deoxygenation will affect the stability of marine ecosystems, of which unicellular protists called Foraminifera are a major
component. This key group of ecological indicators contributes significantly to both the nitrogen and carbon cycling in benthic ecosystems, but are also sensitive to changes in the environmental parameters like temperature, salinity and oxygen. Many foraminifera make a calcite test riddled with pores, which are hypothesised to be used for gas exchanges. The characteristics of these pores are observed to change according to oxygenation conditions and/or nitrate concentrations. However, so far, this has not been tested nor calibrated in controlled laboratory conditions. This study aims to better understand the adaptation capability of foraminifera to predicted hypoxic and anoxic conditions, in order to determine their fate in future oceans and evaluate their potential as proxy.

We investigated the response of two different species of foraminifera to different oxygen concentrations, the symbiont-barren species *Ammonia tepida* T6 and the tropical symbiont-bearing species *Amphistegina* sp. We analysed shell porosity as well as a range of different biological parameters, i.e. survival and shell growth rate. For both species, the number of newly formed chambers decreased with decreasing oxygen concentration, while survival rates were not affected. These results suggest that foraminifera can survive short periods of lower oxygen conditions, but will perform less well (create less new chambers). In both species, porosity increased with decreasing oxygen content. However, for *Ammonia tepida* T6, the porosity gradually increased with decreasing oxygen concentration, while for symbiont-bearing *Amphistegina* sp., shell porosity only increased at the lowermost oxygen conditions tested, suggesting symbionts might support the foraminifer until a certain hypoxia threshold. The results might indicate that species of foraminifera with symbionts might be more resilient to low oxygen conditions, but also that the shell porosity of symbiont-barren species could be used as a proxy for past oxygen conditions.

**Cogwheel structures in foraminiferal shells**

**VAN DIJK Inge**, CISNEROS-LAZARO Deyanira, RAITZSCH Markus, BRUMMER Geert-Jan, MOORE Jo, MEIBOM Anders and BJMA Jelle

1Alfred-Wegener-Institut, Helmholtz-Zentrum für Polar- und Meeresforschung, Division Marine BioGeoScience, Am Handelshafen 12, 27570 Bremerhaven, Germany; Inge.vandijk@uni-vangern.fr; Markus.Raitzsch@awi.de; Jelle.Bijma@awi.de
deyanira.cisneroslazaro@epfl.ch; anders.meibom@epfl.ch

2Laboratory for Biological Geochemistry, École Polytechnique Fédérale de Lausanne, Rte Cantonale, 1015 Lausanne, Switzerland;
deyanira.cisneroslazaro@epfl.ch; anders.meibom@epfl.ch

3NIOZ-Royal Netherlands Institute for Sea Research and Utrecht University, Department of Ocean Systems, PO Box 59 1790 AB Den Burg, The Netherlands; geert-jan.brummer@nioz.nl

4Institute of Earth Sciences, University of Lausanne, CH-1015 Lausanne, Switzerland; josephine.moore@unil.ch; anders.meibom@epfl.ch

*Corresponding author

Most studies designed to better understand biomineralization by foraminifera focus mainly on their shell chemistry in order to retrace processes responsible for element uptake and shell formation. Shell formation is a combination of not only chemical and biological processes but also structural limitations. Since the processes involved in the formation of the foraminiferal shell remains elusive, new focus has been put on potential structural constraints during shell formation. Revealing structural details of shells of foraminifera might increase our mechanistic understanding of foraminiferal calcification, and even explain species-specific differences in element incorporation.

Recently, shell structures have been studied in increasingly higher resolution and detail. This project aims to provide new insights on the structural features on foraminiferal shells, so-called cogwheels, which can be observed in the shell wall and at its surface after mild etching. Electron Backscatter Diffraction (EBSD) analysis of embedded foraminifera shows that individual cogwheels have their own crystallographic orientation perpendicular to the primary organic sheet, which suggests that these microunits are independent and likely separately formed during the calcification process. Finally, we present a novel method to image and quantify these cogwheel structures based on the freeware ImageJ, using field specimens from different environments and ecological groups, including benthic and planktonic species. Application of this method allows for comparing shell structures at specimen and species level, to unravel potential drivers of shell formation.

**Response of benthic foraminifera biomass on the slope and plateau of Santos Basin (South Atlantic, Brazil) to different carbon flux models**

VILAR Amanda¹, VICENTE Thaisa¹, OMACHI Claudia¹, DE SANTIS Wlademir¹, SAMBUGARO Julia¹, NOGUEIRA Rafaela¹ and SOUSA Silvia Helena¹

¹Instituto Oceanográfico, Universidade de São Paulo, Praça do Oceanográfico, 191, Cidade Universitária, São Paulo 05508-120, SP, Brazil; amandavilar@usp.br; thaisamv@gmail.com; comachi@gmail.com; wsantisj@gmail.com; sambugari@usp.br; rafanmm@gmail.com; smsousa@usp.br

*Corresponding author

The biomass of benthic meiofauna is very representative in the oceans, with benthic foraminifera representing 50% or more of the eukaryotic biomass in deep-sea environments. The ecological indices of benthic foraminifera are influenced by different factors, and biomass is related mainly to the quality and quantity of organic matter (OM), which is a limiting factor
in these environments. A way of providing OM to the ocean floor organisms is the vertical carbon flux, which will indicate the export of OM from the euphotic layer to deep regions of the ocean through the water column. However, there is no consensus between the decantation velocity and model of carbon flux that can be applied in the understanding of benthic organisms distribution in deep-sea, which makes it difficult to compare the response of benthic foraminifera biomass to OM input to the bottom sediment. This study aims to understand the influence of carbon flux on the biomass in foraminifera in Santos Basin (South Atlantic, Brazil) and propose a model that is most suitable for deep-sea oligotrophic regions. Sediment samples (0-2 cm) were collected from 29 stations in 5 transects along the slope and plateau of Santos Basin, between depths of 400 m and 2400 m, during the winter of 2019 within the Santos Project –The Santos Basin Regional Environmental Characterization (PCR-BS) – coordinated by energy company PETROBRAS. The sediment was stored in a solution of Rose Bengal (2g/L) and 10% formalin buffer with borax, and the living benthic foraminifera were picked out, identified, and photographed for biomass. The biomass was calculated by biovolume methodology, comparing the individuals to geometric figures, and considered the cytoplasmic occupation of 35% of the test. Five models of flux carbon were compared with an estimate of benthic foraminifera with different export efficiency equations (e-ratio) considering two decantation velocities (100 and 200 m.day⁻¹). The models of carbon flux data were based on remote sensing MODIS aqua and processed by SeaDAS 7.5.3 (average between 21 and 35 days before the benthic sampling). The Eppley-VGPM model, which considers the temperature effect over physiology/photoacclimation, was used to estimate the primary productivity and the hydrodynamic 3-D modelling was realized with HYCOM to estimate the origin of the photosynthized particle. Five hundred and seventeen living species of benthic foraminifera were identified, and the biomass values demonstrated a latitudinal gradient, occurring with the lowest values in the south and the highest values in the north of the basin. The biomass values also evidenced a bathymetric gradient, occurring with the lowest values in the station at 2400 m water depth (plateau). The carbon flux values were higher considering the decantation velocity of 200 m.day⁻¹. The three carbon flux models that considered temperature and primary production (D05a, L113 and CF165) in the e-ratio equation demonstrated higher values compared to the others. The Kruskal-Wallis test demonstrated a significant difference both between the methods and between the decantation speeds. In addition, all methodologies indicated gradient of latitude and depth, such as the estimate of biomass of benthic foraminifera. Spearman's correlation analysis did not indicate significant correlations between total estimate of biomass and carbon flux results, but part of the species demonstrated significant weak to strong correlation coefficients. The highest number of significant correlations was found between the decantation speed of 200 m.day⁻¹ and two carbon flux models (D05a and L113). Thus, the biomass of benthic foraminifera demonstrated satisfactory responses to the carbon flux models analysed, mainly considering the decantation velocity of 200 m.day⁻¹ and the flux models, occurring the highest correlation values between the species and the models D05a and L113, demonstrating that these models can be used for oligotrophic deep-sea regions.

**Benthic foraminifera biomass on the continental slope and São Paulo plateau of Santos basin (South Atlantic, Brazil): Comparison between different cytoplasmic occupation in the test**

**VILAR Amanda**, **VICENTE Thaisa**, **SAMBUGARO Julia**, **Nogueira Rafaela** and **Sousa Silvia Helena**

---

1Instituto Oceanográfico, Universidade de São Paulo, Praça do Oceanográfico, 191, Cidade Universitária, São Paulo 05508-120, SP, Brazil; amandavilar@usp.br; thaisamv@gmail.com; sambugar@usp.br; rafammm@gmail.com; smsousa@usp.br

*Corresponding author*
Assessing the environmental drivers of seasonal-to-decadal shifts in planktonic foraminiferal assemblages in the Gulf of Mexico

Maoli N.1,2*, Pincelli H.1, REYNOLDS Caitlin2 and RICHEY Julie2

1Department of Earth and Planetary Sciences, Yale University, 210 Whitney Ave, New Haven, CT, 06511, USA; maoli.vizcaino@yale.edu; pincelli.hull@yale.edu
2U.S. Geological Survey, St. Petersburg Coastal and Marine Science Center, 600 4th St S, St. Petersburg, FL, 33701, USA; creynolds@usgs.gov; jrichey@usgs.gov
*Corresponding author

Marine ecosystems experience fluctuations in environmental conditions (e.g., temperature, salinity, nutrients, light availability, stratification, etc.) on daily up to millennial timescales and beyond, with magnitudes often exceeding those caused by anthropogenic forcing. There are few ecological datasets temporally resolved enough to disentangle the effects of natural environmental variability from those due to modern anthropogenic change. Here we use an exceptionally long running and resolved USGS sediment trap from the Gulf of Mexico (GoM; 27.5°N, 90.3°W) to investigate whether there are emergent signals of anthropogenic change in the assemblage composition of planktic foraminifera from January 2008–January 2020. This study focuses on the GoM, a semi enclosed basin in the northwest subtropical Atlantic Ocean affected by a variety of factors including loop current dynamics, Mississippi River discharge, and the frequency and intensity of storms and tropical cyclones. The Gulf’s relatively large seasonal temperature range (~10 °C) and dynamic setting on a continental margin makes it an ideal location to explore the interacting effects of multiple environmental factors on the planktonic foraminiferal community.

We use Bray-Curtis dissimilarity to quantify differences in community composition from month to month and explore the dominant modes of variability using a principal component analysis. Temporal trends in β diversity (as compared to the initial month in the time series) and the principal component analysis show a strong two-phase (winter/summer) variability in community composition, unlike the seasonal patterns of winter/spring/summer/fall in the northern GoM. The first two principal components account for nearly 60% of the variance, with a secular trend in PC1 and β diversity from 2008 to 2020 towards more dissimilar populations, even in the same months and in the winter/summer population framework. We explore the environmental and anthropogenic drivers of these trends using regression and factor analysis against a suite of environmental parameters from in situ, remote sensing, and gridded data.

Nature of cooling events on the southern Iberian margin point to extreme contraction of the North Atlantic’s subtropical gyre during the early Pleistocene

Antje H.L.1,2*, MEGA Aline2, DUQUE CASTAÑO Monica1,2, SALGUEIRO Emilia1,2 and RODRIGUES Teresa1,2

1Instituto Português do Mar e da Atmosfera, Divisão de Geologia e Georecursos Marinhos, Av. Doutor Alfredo Magalhães Ramalho 6, 1495-165 Alges, Portugal; antje.voelker@ipma.pt; monica.castano@ipma.pt; emilia.salgueiro@ipma.pt; teresa.rodrigues@ipma.pt
2Centro de Ciências do Mar do Algarve (CCMAR), Universidade do Algarve, Campus de Gambelas, Edif. 7, 8005-139 Faro, Portugal; antje.voelker@ipma.pt; alinemega26@gmail.com; monica.castano@ipma.pt; emilia.salgueiro@ipma.pt; teresa.rodrigues@ipma.pt
*Corresponding author

The Gulf of Cadiz on the western side of the Strait of Gibraltar marks the transitional zone between the North Atlantic and the Mediterranean Sea and is nowadays influenced by North Atlantic subtropical gyre waters. Studies on deep-sea cores from that region have shown that during the Heinrich events of the last glacial cycle colder surface waters penetrated into...
those southern mid-latitudes, but with reduced intensity. Making use of the centennial-scale paleoclimate records from IODP Site U1387 (36°48’N 7°43’W; 559 m water depth), which cover the early to middle Pleistocene interval of Marine Isotope Stage (MIS) 16 to MIS 52 (0.65 – 1.51 Ma), we are exploring the nature of cooling events during the Early to Middle Pleistocene transition (EMPT) and the early Pleistocene using the planktonic foraminifera fauna and transfer function and alkeneone derived sea-surface temperature reconstructions.

Terminal stadial events during abrupt glacial/interglacial transitions, for example MIS 20/19, MIS 22/21, MIS 26/25, MIS 48/47 and MIS 50/49, recorded periods of extreme surface water cooling with annual sea-surface temperatures dropping below 15°C and planktonic foraminifera faunal based reconstructions for winter below 10°C. The abundance of polar planktonic foraminifera species *Neogloboquadrina pachyderma* exceeded 40% during those events, indicating the influx of subpolar surface waters into the southern mid-latitudes of the Northeast Atlantic. The terminal stadial events are related to disintegration of circum-North Atlantic continental ice sheets and their impact on the Atlantic Meridional Overturning Circulation (AMOC), similar to the late Pleistocene Heinrich events.

Additional stadial events with comparable characteristics are observed during early MIS 22, MIS 32 and MIS 38. The cooling on the Algarve margin during all those early Pleistocene events was more intense than during Heinrich events 1 to 6 pointing to an extreme contraction of the North Atlantic’s subtropical gyre, at least along the eastern margin. Duration of the cooling events varied between 1000 and 3000 years with a cumulation within MIS 22 with its two extended phases of extreme cooling. Prevalence of subtropical surface waters after the cooling event occurred generally within 1500 years, independent of the duration of the preceding cooling event, pointing to common processes leading to reestablishment of a strong AMOC. The IODP Site U1387 data reveals cooling events were a regular feature, but were, unexpectedly, more intense during the early than the late Pleistocene.

**Biostratigraphic and marine palaeoenvironmental change associated with the Plio-Pleistocene transition along the western continental shelf of southern Africa**

WALSH Jared1*, FIETZ Susanne1 and BERGH Eugene2

1Department of Earth Sciences, Stellenbosch University, Private Bag X1, 7602 Matieland, South Africa; 21997764@sun.ac.za; sfietz@sun.ac.za
2Unit for Environmental Sciences and Management, Geology, North-West University, Potchefstroom, 2531, South Africa, 2520; eugene.bergh@nwu.ac.za
*Corresponding author

The oceanography and sedimentation of the western margin of southern Africa (Orange Shelf) have been influenced by the highly productive Benguela Upwelling System (BUS) since the late Miocene (> 5.3 million years ago) which later intensified in the Pleistocene. The Plio-Pleistocene environmental transition on the western margin of southern Africa has largely been understudied in a foraminiferal context. Previous work from the Namibian margin indicates a drastic change in palaeoenvironments during the Pliocene, notably a period of cooling and CO2 levels that are similar to today. In an attempt to further refine the Neogene to Quaternary stratigraphy along the South African margin, and to determine how past environments changed during the Plio-Pleistocene, three vibracores from offshore western South Africa (260 – 403 mbsl) were analysed using a combination of faunal analyses, foraminiferal biostratigraphy, and strontium isotope stratigraphy. Collectively 600 benthic and planktonic foraminifera specimens from each sample were counted where 27 benthic species were identified from 36 genera and all 14 species were identified from the 14 planktic genera. Biostratigraphy showed evidence of the Plio-Pleistocene transition by the appearance of *Globorotalia truncatulinoides*, marking the start of the Pleistocene and the synchronous proliferation of *Globoconella inflata* abundances, while the rapidly diminishing *Siphonodasoria lepidula* abundances marked the end of the Pliocene. Cores from the outer shelf indicate a lapse in abundance for the region’s primary productivity indicator, *Globigerina bulloides*, during the Plio-Pleistocene transition. *G. bulloides* saw resurgence following a strengthening of the Benguela Upwelling System with the development of Southern Hemisphere glaciation in the Pleistocene. Occasional samples showed periods of low abundance for *G. bulloides* and may be indicative of a shift in the frontal zone along the shelf generally associated with the large amplitude glacial-interglacial cycles for this time. The ongoing Sr radiometric age analysis on these samples will confirm whether such relationship exists. In the Pliocene samples, *Orbulina universa* remained dominant and was indicative of warmer waters in comparison to the colder Pleistocene. Occasional warmer periods were observed in the Pleistocene through *O. universa*, suggesting either a lapse of glaciation or an external influence such as warm water leakage from the Agulhas Current. For the benthic environments, *Uvigerina* spp. saw high and stable abundances across the Plio-Pleistocene and were consistent indicators of eutrophic environments under high organic carbon fluxes, contrasting the benthic conditions in the Miocene but still typical of strong upwelling regions such as the BUS. This remained true for the Pleistocene, where an intensification of upwelling supported and sustained infaunal taxa such as *Uvigerina* spp. in the benthic sediment. This study aims to further its palaeoenvironmental assessment by utilising a comparative core on the inner shelf of western southern Africa, which will aid in the development of a shelf profile in relation to paleoceanographic change. The results from this study contributed to a better understanding of the stratigraphy of the region and the development of the Benguela Upwelling System in a foraminiferal context.
Historic sediment samples as early-Lessepsian baselines for the biogeography and diversity of benthic foraminifera in the Mediterranean Sea

WEINMANN Anna E. 1*, HASSENRÜCK Christiane2, RAPOSO Débora1,4, GOLDSTEIN Susan T.3, LANGER Martin R.5, LI Qingxia1, TRIANTAPHYLLOU Maria V.6, and MORARD Raphaël7

1Department of Geology & Paleontology, Natural History Museum Vienna, Burggring 7, Vienna, Austria; anna.weinmann@nhm-wien.ac.at
*Corresponding author

One of the most important effects of ongoing climate change on benthic foraminifera are changes in their distribution ranges. This has been shown especially for the Mediterranean Sea, where warm-adapted species are expanding their distribution ranges mostly from the eastern to the western basin. This is further facilitated by the Lessepsian migration from the Red Sea into the Mediterranean since the opening of the Suez Canal in 1869. Among the foraminiferal “invaders” are the symbiont-bearing Amphistegina lobifera and other tropical taxa, which are not only continuing their expansion towards the west but also appear to have lasting effects on local communities and diversity structures. Over the last years, it was possible to monitor the expansion of A. lobifera and other species by tracking new occurrence records and applying habitat models to predict their future distribution ranges in the Mediterranean.

However, in order to evaluate the degree and implications of shifting species’ distribution ranges, it is also important to know about the situation in the past, e.g. before the onset of the Lessepsian migration. While we can monitor recent distribution changes over the last several decades and with the help of future studies, it is much harder to evaluate the biogeographic situation of the 19th century – especially in the early days of the industrialization and the Suez Canal. While older foraminiferal assemblages can be studied from sediment cores, there always remains an uncertainty concerning exact dating of the studied sediment layers and possible mixing with younger faunal elements even before the coring process.

Here, historic sediment samples can be a valuable asset to get a glimpse into the actual species distribution and assemblage composition at a specific time in the past. The Department of Geology and Paleontology at the Natural History Museum in Vienna houses a collection of sediment samples that have been donated by various internal and external scientists and/or collectors during the 19th century and have never been studied until now. The collection includes recent sediment samples from near-shore locations in Malta and Sicily – two islands that are the focus of several recent biogeographic studies on benthic foraminifera in the central Mediterranean. One set of samples from Sicily and Malta was collected between 1871 and 1874 by Theodor Fuchs (1842–1925), assistant at the then k.k. Hofmineraliencabinet. Another set from Sicily was donated to the Museum in 1889 by Tommaso di Maria Allery Marchese di Monterosato (1841–1927), a Sicilian malacologist. While the latter samples are not dated, his biography suggests that they were collected during the 1870s or early 1880s. As such, the samples provide a unique window into the times of early industrialization and shortly after the opening of the Suez Canal. The samples cover different locations and depth ranges and their preservation status is very good. Foraminifera were picked from a total of 30 samples.

The present study aims at providing a comprehensive inventory and catalogue of the benthic foraminiferal assemblages from central Mediterranean locations in the 1870s. This will be coupled with an up-to-date revision of existing reference literature and catalogues. These will provide an important baseline in terms of industrialization effects – especially climate change and pollution – and Lessepsian migration. The study will be further expanded by including evaluations of biodiversity and environmental indices. A comparison with modern material is also envisioned.

Tracking community turnover through time: A combined approach of propagule culture experiments and eDNA metabarcoding

WEINMANN Anna E. 1*, HASSENRÜCK Christiane2, RAPOSO Débora1,4, GOLDSTEIN Susan T.3, LANGER Martin R.5, LI Qingxia1, TRIANTAPHYLLOU Maria V.6 and MORARD Raphaël7

1Department of Geology & Paleontology, Natural History Museum Vienna, Burggring 7, Vienna, Austria; anna.weinmann@nhm-wien.ac.at
2Department of Biological Oceanography, Leibniz Institute for Baltic Sea Research Warnemünde (IOW), Seestraße 15, Rostock-Warnemünde, Germany; christiane.hasenrucek@io-warnemuende.de
3Department of Geology, University of Georgia, 210 Field Street, Athens, GA, USA; sgoldst@uga.edu
4MARUM - Center for Marine Environmental Sciences, University of Bremen, Leobener Str. 8, Bremen, Germany; draposo@gfbio.org; rmarard@marum.de
5Department of Geoscience, Section Paleontology, University of Bonn, Nussallee 8, Bonn, Germany; martin.langer@uni-bonn.de
6Faculty of Geology and Geoenvironment, National and Kapodistrian University of Athens, Panepistimioupolis, Athens, Greece; mtriant@geol.uoa.gr
7Laboratory of Marine Organism Taxonomy and Phylogeny, Institute of Oceanology, Chinese Academy of Sciences, Nanhai Road 7, Qingdao, China; 945063523@qq.com
*Corresponding author

Shallow-water environments harbour diverse and variable communities of benthic foraminifera. Such environments are characterised by annual, seasonal, and diurnal changes in ecological variables such as temperature, salinity, and nutrient
supply. Benthic foraminiferal assemblages are known to respond quickly to such changes, leading to continuous faunal turnovers and highly dynamic community structures.

For several years now, culture experiments with foraminiferal propagules (juveniles <63 µm) have been established as a useful tool to analyse and evaluate assemblage reactions to changing variables (e.g., temperature, salinity, pH, and others). The propagules are separated from the coarser fraction (>63 µm) and cultivated under different conditions, before analysing the grown experimental assemblages. The resulting differences show that assemblages can respond in the course of few weeks, supporting the assumption of the highly dynamic structures. However, such experiments were mostly single-time events and continuous faunal turnovers have not been analysed in detail before. Furthermore, there has never been quantitative information about the fine fraction itself.

In the present study, we combined for the first time the propagule cultivations and their subsequent census counts with simultaneous environmental(e)DNA metabarcoding. With this combined approach we aim to (i) assess the community turnover through time by sub-sampling the material in defined time intervals, (ii) evaluate if the observed dynamics apply for the coarse, as well as the fine fraction and (iii) support the recognition that morphological and molecular approaches complement each other profitably in environmental monitoring.

Sediment samples were collected in May and October 2019 from a shallow lagoon on Corfu Island (Greece) and sieved over 63 µm to separate the propagules from the coarser fraction. The in-situ material of the sampling site was taken as baseline for the following experiments (T0). The finer fraction (<63 µm) was set up in 2 replicate tanks for 15 weeks under stable conditions (22°C, 38 psu, constant aeration). The cultures were repeatedly harvested for grown foraminifera (>63 µm) after 5, 10, and 15 weeks (T1, T2, T3). At the same intervals, additional samples were taken and re-sieved for eDNA metabarcoding of both size fractions (<63 µm and >63 µm).

In our morphological dataset, we retained 117 species. Among those species, some were present in all samples and others were exclusive to the experimental assemblages (T1–T3). Certain species were also exclusive to samples originally collected in May and October, respectively, suggesting a seasonal effect, which continues within the experiments. These observations were mirrored by the OTUs retained from the metabarcoding dataset.

Our two resulting datasets both showed an assemblage turnover through time with regard to alpha and beta diversity. The most significant difference was between T0 (in-situ) and the experiments (T1–T3), but also all harvesting intervals showed significant changes in composition. The morphological count data also revealed strong variations in foraminiferal density as well as shell accumulation over time (especially between T2 and T3), which suggests one or more reproduction cycles during the experiment. The metabarcoding data revealed that both the coarser and the finer fraction experienced assemblage turnover through time.

The outcomes of our study are useful to better understand and quantify the mechanisms behind quick assemblage responses and community dynamics. They can also serve as a model study for combining morphological and molecular approaches in environmental monitoring to get deeper insights into the complex assemblage structures in shallow-water environments.

---

**Upper Oligocene to Holocene planktonic foraminifera from DSDP Site 407, Reykjanes Ridge: towards a revised taxonomy of Neogene high-latitudes species**

**WEITKAMP Tirza M.1,2*, PEARSON Paul N.3 and COXALL Helen K.1,2**

1Department of Geological Sciences, Stockholm University, Svante Arrenius väg 8, 114 18 Stockholm, Sweden; tirza.weitkamp@geo.su.se; helen.coxall@geo.su.se
2Bolin Centre for Climate Research, Stockholm University, SE-106 91 Stockholm, Sweden; tirza.weitkamp@geo.su.se; helen.coxall@geo.su.se
3Department of Earth Sciences, University College London, Gower Street, London WC1E 6BT, UK; PearsonP@cardiff.ac.uk
*Corresponding author

Deep Sea Drilling Program (DSDP) Site 407, on the Reykjanes Ridge (Irminger Sea, Southwest Iceland), is one of the few sites from the high latitude North Atlantic with a record of Neogene planktonic foraminifera evolution. An early study of Site 407 shows good planktonic foraminifera preservation and progressive diversity loss over the past 23 myrs as climate cooled. However, the species names and higher taxonomy used in the early study (1979) are difficult to align with modern taxonomic concepts. This study reports a taxonomic and biostratigraphic reanalysis of the upper Oligocene to Holocene from Site 407. A key aim is to integrate recent understanding of *Neogloboquadrina* morphology and systematics, including the genetically-defined, dominantly sinistral-coiling concept of *N. pachyderma*, the dominantly dextral coiling concept of *N. incompta*, as well as the ‘5-sub-morphotypes’ concept of *N. pachyderma* (defined in the Central Arctic Ocean).

Test fragmentation has concentrated dissolution resistant species to some extent. Nevertheless, the Site 407 record provides important information on northern high latitude assemblages. A hiatus spanning Zones M6-M12 (at least 5 myrs) occurs between 158.56 –160.06 mbsf based on (i) the sudden appearance of *N. atlantica, N. incompta* and *N. pachyderma* (all have their lowest occurrences [LOs] within Zone M13 Site 407 at 158.56 mbsf) and (ii) the presence of *Paragloborotalia acrostoma, Globorotalia archeomenardii, G. praemenardii, G. praescitula* and *G. zealandica* (Zone M5) at 160.06 mbsf. Diversity decreased from 28 species in the upper Oligocene to 10 species in the upper Quaternary. Upper Oligocene species include *Catapsydrax* spp., *Globoturborotalita ouachitaensis, Globorotaloides suteri, G. stainforthii,*
South Georgia palaeo-productivity and glacial evolution over the past 15 ka

WILKIN Jack1,2*, KENDER Sey1, DEJARDIN Rowan4, ALLEN Claire2, PECK Victoria2, SWANN George2, MCCLYMONT Erin6, SCOURSE James1, LITTLET Kate1,7 and LENG Melanie1,2,8

1Department of Earth and Environmental Sciences, University of Exeter, Penryn, TR10 9EZ, UK; jw923@exeter.ac.uk; S.Kender@exeter.ac.uk; j.scourse@exeter.ac.uk; k.littler@exeter.ac.uk
2British Antarctic Survey, Cambridge, CB3 0ET, UK; jw923@exeter.ac.uk; csall@bas.ac.uk; vl@bas.ac.uk
3British Geological Survey, Nottingham, NG12 5GG, UK; S.Kender@exeter.ac.uk; mjl@bgs.ac.uk
4School of Geographical Sciences, University of Bristol, Bristol, BS8 1SS, UK; rowan.dejardin@bristol.ac.uk
5School of Geography, University of Nottingham, University Park, Nottingham, NG7 2RD, UK; george.swann@nottingham.ac.uk
6Department of Geography, Durham University, Durham, DH1 3LE, UK; erin.mcclymont@durham.ac.uk
7Environment and Sustainability Institute, University of Exeter, Penryn, TR10 9EZ, UK; k.littler@exeter.ac.uk
8School of Biosciences, University of Nottingham, Loughborough, NG12 5RD, UK; melanie.leng@nottingham.ac.uk
*Corresponding author

The island of South Georgia is a biodiversity hotspot, and is particularly sensitive to climate change due to its position close to the Polar Front in the Southern Ocean. However, due to a low number of well-dated subtropical palaeoclimate archives, there is still uncertainty about how the climate of South Georgia changed in the recent geological past. Here, we reconstruct primary productivity changes and infer Holocene glacial evolution by analysing two marine gravity cores (GC666: 15.1 to 0.3 cal. kyr BP; GC673: 9.3 to 0.3 cal. kyr BP) on the inner South Georgia shelf. The study cores come from the northern ends of cross-shelf troughs that propagate from Royal Bay (GC666) and Cumberland Bay (GC673), on the northern part of the South Georgia Shelf. GC666 is more distal being ca. 21 km from the modern shore and GC673 is in the mouth of Cumberland Bay. We analysed benthic foraminiferal assemblages, stable isotopes, sedimentary total organic carbon and biogenic silica to reconstruct primary productivity changes and infer Holocene glacial evolution in both cores. Using Detrended Correspondence Analysis, we identified three different assemblages of benthic foraminifera: *Miliammina earlandi*, *Furseenkoina fusiformis*, and *Cassiduloides parkeri*as. The assemblage of particular interest in reconstructing glacial changes is the *F. fusiformis* assemblage, which represents high productivity in both cores and may be associated with glacial runoff. Our multiproxy analysis from both cores provides evidence that the latest Pleistocene (15.1 to 12.3 cal. kyr BP) and early Holocene (12.3 to 7.5 cal. kyr BP) were periods of high productivity associated with increased glacial meltwater discharge. The middle Holocene (7.5 to 2.9 cal. kyr BP) is associated with a fall in sedimentation rates and lower productivity associated with a reduction in the size of South Georgia’s glaciers, but with several short-lived episodes of glacial advance. The late Holocene (2.9 to 0.3 cal. kyr BP) saw an increase in productivity and glacial advancement associated with cooling temperatures (based on ice core data from James Ross Island) and increased precipitation. We propose that shifts in the South Westerly Winds drive the glacier dynamics reconstructed from cores GC666 and GC673. The relative abundance of *F. fusiformis*, interpreted here as a proxy for increased terrestrial runoff associated with the spring-summer melting of glaciers, is closely aligned with glacial trends previously constrained with plant macrofossil and pollen evidence from peat bogs and dating of glacial moraines. Thus, we conclude that palaeo-productivity can be used as an indirect proxy for glacier readvancements on the South Georgia shelf.

FORAMS 2023, June 26th–30th, 2023, Perugia, Italy – Abstract Book

269
Research Avenue South, Edinburgh, EH14 4AP Planktic foraminifera iodine/calcium ratios and relationship to seawater oxygen content

WINKELBAUER Helge1, HOOGAKKER Babette1†, ANDERSON Robert2, MELANIE Leng1, HAMILTON Elliot1 and CHENERY Simon1

1The Lyell Centre, Heriot-Watt University, Research Avenue South, EH14 4AP Edinburgh, UK; hav2@hw.ac.uk; b.hoogakker@hw.ac.uk
2Lamont Doherty Earth Observatory, Columbia University, 61 Route 9W, New York, USA; bobia@ldeo.columbia.edu
3The British Geological Survey, Nicker Hill, NG12 5GG Keyworth, UK; mi@bgs.ac.uk; ellha@bgs.ac.uk; srch@bgs.ac.uk
*Corresponding author

Iodine to calcium ratios in foraminifera calcite have emerged as an exciting proxy method to assess oxygen concentrations in past seawater. Planktic foraminifera I/Ca have been proposed as a proxy to assess changes in subsurface water oxygen concentrations, whereas benthic foraminifera I/Ca have been proposed as a proxy to reconstruct bottom water oxygen concentrations. In this study we focus on planktic foraminifera I/Ca. Recent core top studies show that in locations that are characterized by oxygen depletion in the subsurface waters, planktic foraminifera I/Ca values are relatively low compared with locations lacking oxygen depletion in their subsurface waters. Here we expand on this calibration using sample material from the Lamont Doherty core repository and IODP. We also compare the complete core-top calibration set with results obtained from planktic foraminifera captured by plankton-tows.

We use radiocarbon dating and benthic foraminifera stable isotope stratigraphy to ensure our core samples are Holocene/interglacial in age. I/Ca ratios were measured for a total of ~22 locations from the Indian and Pacific Ocean using twelve different planktic foraminifera species. Sample are from water depths between 200 and 4000 meters, and from poorly oxygenated (<10 µmol/kg) to well oxygenated (> 180 µmol/kg) settings. Our new core top I/Ca ratios show similar trends as previous studies, with generally lower values when ‘minimum’ oxygen concentrations are below 80 µmol/kg.

Compared to results recently obtained from plankton tows these values are an order of magnitude higher in well oxygenated areas. We will discuss situations under which planktic foraminifera I/Ca from sediment cores may gain additional iodine.

Integrated biostratigraphy of the Albian of the Southern High Latitudes

WOLFRING Erik†, PETRIZZO Maria Rose3 and WATKINS David3

1Department of Palaeontology, University of Vienna, Josef Holaubek Platz 2, 1090 Vienna, Austria; erik.wolfring@univie.ac.at
2Dipartimento di Scienze della Terra “A. Desio”, Università degli Studi di Milano, Via Mangiagalli 34, 20133 Milano, Italy; mrose.petrizzo@unimi.it
3Department of Earth and Atmospheric Sciences, University of Nebraska, Lincoln, NE 68588, USA; dwatkins1@unl.edu
*Corresponding author

We present an integrated micro- and nanofossil biostratigraphic evaluation of Albian strata documented at the Mentelle Basin (eastern flank of the Naturaliste Plateau, Indian Ocean, SW Australia) during Integrated Ocean Discovery Program (IODP) Expedition 369 (Sites U1513 and U1516, paleolatitude of between 57°S to 62°S during the mid-Cretaceous).

Characterized by deep-water benthic taxa, the Albian benthic foraminiferal record is dominated by cosmopolitan opportunist taxa, i.e., Gyroidinoides, Saracenaria/Lenticulina, Pleurostomella, Dentalina and agglutinated, monothalam forms like Glomospira and Ammodiscus. Besides opportunist taxa, the benthic foraminiferal assemblages documented at the Mentelle basin yield the contemporaneously globally documented Gavelinella intermedia, G. uturenensis, G. schloenbachii, as well as markers for the southern high latitudes documented in the Albian of South America, South Africa, and the Great Australian Basin, e.g., Lingulogavelinella albiana, Scutoloris sp. The potential for possible correlations of the benthic foraminiferal assemblages to other Lower- to mid-Cretaceous established calcareous markers can be considered.

Upper Albian microfossil assemblages demonstrate the decreasing abundance of benthic foraminifera and the decline of calcareous-, and an increase in the relative abundance of agglutinated taxa illustrated particularly in the extraordinary increment in the percentage of Ammodiscus cretaceus, A. pervianus, Glomospira charoides and Glomospira sp.

The planktonic foraminiferal assemblage is dominated by the small-sized Microhedbergella praeplanispira, followed by common biserial and planispiral taxa. The large-sized fractions contain Muricohedbergella simplex, Ticinella primula and Lavesiella bentomensis allowing identification of the upper Albian, although no marker taxa have been observed hampering the application of the tropical-subtropical biozonation.

Calcareous nanofossils of the Naturaliste Plateau/Mentelle basin are characterized by relatively diverse but distinctly high-latitude assemblages providing biostratigraphic control for the non-barren intervals of the Albian record. Sequential first occurrences of Eiffellithus moneciiae and Eiffellithus turrisseiffeli indicate Upper Albian subzones CC8d and CC9a-b, respectively.

With the exception of shifts in the abundance of respective microfossil groups, preliminary abundance data, particularly of benthic foraminiferal assemblages, suggest, despite documenting a distinctly depauperate record in the upper Albian of
the Austral Realm, considerable environmental stability. In bottom waters, no major benthic foraminiferal bioevents be
identified.

**The influence of post-mortem alterations in calcareous microfossils on their proxy values - exemplified by Neogloboquadrina pachyderma in sediment cores of the Arctic Ocean**

**WOLLENBURG Jutta E.¹**, **MATTHIESSEN Jens¹**, **VOGT Christoph²**, **GROTHEER Hendrik¹,²**, **WILHELM-DICK Dorothee¹**, **GEIBERT Walter¹** and **MOLLENHAUER Gesine¹,²**

¹Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Am Handelshafen 12, 27570 Bremerhaven, Germany; Jutta.wollenburg@awi.de; jens.matthiessen@awi.de; hendrik.grotheer@awi.de; wilhelms-dick.dorothee@awi.de; geibert.walter@awi.de; gesine.mollenhauer@awi.de
²Geosciences and MARUM, University of Bremen, Klagenfurter Strasse 4, 28359 Bremen, Germany; cvogt@uni-bremen.de; hendrik.grotheer@awi.de; gesine.mollenhauer@awi.de
*Corresponding author

It has been accepted for a long time, that ordinary inspection of microfossil shells under the stereomicroscope allows to identify diagenetic overprint and moreover, that minor overprint may not impact isotope-, trace metal-Ca ratios or radiocarbon ages. This talk reports the impact of diagenetic alterations on calcareous foraminifera and shell-derived paleo-proxies. It summarizes results of many years work including thousands of comparative stereomicroscope- and scanning electron microscope pictures, EDS (Energy-dispersive X-ray spectroscopy), stable carbon and oxygen isotope, and radiocarbon measurements. Partial dissolution mainly impacts the shell by exposing an increased microfossil-surface to the surrounding pore-bottom water with which it reacts. However, even more dramatic impacts on proxy records are observed when authigenic calcite is deposited on foraminiferal shells. Exemplified by Neogloboquadrina pachyderma shells from Arctic Ocean sediments, we show that a large proportion of modern to Holocene, and the majority of last glacial shells are altered by authigenic calcite overgrowth. We show that this diagenetic alteration has the potential to affect all shell-based proxies, first of all the radiocarbon age. Our investigations show that due to massive diagenetic overprinting of pre-Holocene foraminifera, ¹⁴C ages increase rapidly downcore, and diminishing MIS2 sediments are inferred. As significantly less than 1% of preserved shells show no to little overgrowth, several tens of thousands to several hundreds of thousands of shells must be screened to pick 20-60 specimens that can be regarded suitable for radiocarbon measurements. The ¹⁴C age-offset between pristine, translucent -white, overgrowth free shells compared to altered translucent-white shells with overgrowth in the same sediment horizon can be up to 20 ka in older sediments. As the majority of age-models for the last 45 ka rely on radiocarbon measurements of biogenic calcite, the reliability of published arctic paleoceanographic events assigned to late MIS3-2 age, is at stake!

**Late Cenozoic cooling restructured global marine planktonic foraminiferal communities**

WOODHOUSE Adam¹, SWAIN Anshuman²,³,⁴,⁵ FAGAN William F.⁵ FRAASS Andrew J.⁶ and LOWERY Christopher M.¹

¹University of Texas Institute for Geophysics, J.J. Pickle Research Campus, Bldg. 196, Austin, TX 78758, U.S.A.; adam.woodhouse@austin.utexas.edu; chris.lowery@austin.utexas.edu
²Department of Organismic and Evolutionary Biology, Harvard University, 26 Oxford Street, Cambridge, MA 02138, U.S.A; anshuman2111@gmail.com
³Museum of Comparative Zoology, Harvard University, 26 Oxford Street, Cambridge, MA 02138, U.S.A; anshuman2111@gmail.com
⁴Department of Paleobiology, National Museum of Natural History, 10th St. & Constitution Ave. NW, Washington, DC 20560, U.S.A.; anshuman2111@gmail.com
⁵Department of Biology, University of Maryland, 1210 Biology-Psychology Building, 4094 Campus Dr, College Park, MD 20742, U.S.A.; anshuman2111@gmail.com; bfagan@umd.edu
⁶School of Earth and Ocean Sciences, University of Victoria, 3800 Finnerty Road, Bob Wright Centre A405, Victoria, BC V8P 5C2, Canada; andyfraass@uvic.ca
*Corresponding author

The geographic ranges of marine organisms, including planktonic foraminifera, diatoms, dinoflagellates, copepods and fish, are shifting polewards owing to anthropogenic climate change. However, the extent to which species will move and whether these poleward range shifts represent precursor signals that lead to extinction is unclear.

Understanding the development of marine biodiversity patterns over geological time and the factors that influence them are key to contextualizing these current trends. The fossil record of the macroperforate planktonic foraminifera provides a rich and phylogenetically resolved dataset that provides unique opportunities for understanding marine biogeography dynamics and how species distributions have responded to ancient climate changes.

Here we apply a bipartite network approach to quantify group diversity, latitudinal specialization and latitudinal equitability for planktonic foraminifera over the past eight million years using Triton, a recently developed high-resolution global dataset of planktonic foraminiferal occurrences. The results depict a global, clade-wide shift towards the Equator in
ecological and morphological community equitability over the past eight million years in response to temperature changes during the late Cenozoic bipolar ice sheet formation.

Collectively, the Triton data indicate the presence of a latitudinal equitability gradient among planktonic foraminifer functional groups which is coupled to the latitudinal biodiversity gradient only through the geologically recent past (the past two million years). Before this time, latitudinal equitability gradients indicate that higher latitudes promoted community equitability across ecological and morphological groups. Observed range shifts among marine planktonic microorganisms in the recent and geological past suggest substantial poleward expansion of marine communities even under the most conservative future global warming scenarios.

Multi-million-year lags between planktonic foraminifer functional richness and community responses to Cenozoic climate perturbations

WOODHOUSE Adam1*, SWAIN Anshuman2,3,4,5, FAGAN William F.5, FRAASS Andrew J.6 and LOWERY Christopher M.1

1University of Texas Institute for Geophysics, J.J. Pickle Research Campus, Bldg. 196, Austin, TX 78758, U.S.A.; adam.woodhouse@austin.utexas.edu; chris.lowery@austin.utexas.edu
2Department of Organismic and Evolutionary Biology, Harvard University, 26 Oxford Street, Cambridge, MA 02138, U.S.A; anshuman2111@gmail.com
3Museum of Comparative Zoology, Harvard University, 26 Oxford Street, Cambridge, MA 02138, U.S.A; anshuman2111@gmail.com
4Department of Paleobiology, National Museum of Natural History, 10th St. & Constitution Ave. NW, Washington, DC 20560, U.S.A; anshuman2111@gmail.com
5Department of Biology, University of Maryland, 1210 Biology-Psychology Building, 4094 Campus Dr, College Park, MD 20742, U.S.A; anshuman2111@gmail.com; bfagan@umd.edu
6School of Earth and Ocean Sciences, University of Victoria, 3800 Finnerty Road, Bob Wright Centre A405, Victoria, BC V8P 5C2, Canada; andyfraass@uvic.ca
*Corresponding author

The origin and maintenance of the latitudinal biodiversity gradient (LBG), a key feature of global biodiversity, remains relatively obscure, especially with respect to past and future climates. LBG studies typically adopt a species-based-perspective, rather than a functional or trait-based one, especially in paleontological studies. Unlike species, which are evolutionarily ephemeral, functional groups can be consistent across an entire clade’s history, providing broader perspectives.

Using Triton, a global dataset of Cenozoic macroperforate planktonic foraminifer occurrences and network analyses, we contextualize changes in functional diversity, palaeolatitudinal specialization, and community equitability across the Cenozoic, identifying: 1. specialized morphological communities in the aftermath of the Cretaceous-Paleogene extinction, 2. ecological specialization of communities during the Early Eocene Climatic Optimum globally, except in southern mid-high latitudes, 3. an increase in specialized morphological communities in response to Antarctic glaciation preceding the loss of morphological diversity by millions of years, 4. a synchronous change in morphological specialization and richness ~19 Ma, coeval with pelagic shark extinctions, and 5. a significant delay between niche exploitation and diversification as bipolar ice sheet expansion triggered global paleoceanographic change, providing key context for late Cenozoic marine biodiversity patterns.

We find that functional responses of communities to large-scale Cenozoic climate events are separated from richness and reveal novel structural changes necessary for understanding how marine ecosystems respond to global change.

A review and new observations on Tholosina vesicularis Brady (1879), an extraordinary monothalamous foraminifera

WUKOVITS Julia1*, WOLLENBURG Jutta2, GLOCK Nicolaas3, HEINZ Petra1 and ROY Alexandra-Sophie1

1Department of Palaeontology, University of Vienna, Josef-Holaubek-Platz 2 (UZA II), 1090, Vienna, Austria; julia.wukovits@univie.ac.at; petra.heinz@univie.ac.at
2Alfred Wegener Institute for Polar and Marine Research, Handelsblauen 12, 27570, Bremerhaven, Germany; jutta.wollenburg@awi.de; gernot.nehrke@awi.de
3University of Hamburg, Bundesstraße 55, 20146 Hamburg, Germany; nicolaas.glock@uni-hamburg.de
4German Marine Research Consortium, Ludewig-Meyn-Str. 10, 24118 Kiel, Germany; roy@deutsche-meeresforschung.de
*Corresponding author

Tholosina vesicularis is a large, monothalamous, agglutinated foraminifer that can be found in a wide range of habitats, from temperate to polar regions, with an epilithic, epiphytic or epizoic lifestyle. Despite its global distribution and locally very high abundances, little is known about its ecological significance or nutrient demand. As it usually colonizes rocks and gravel, the species is often overlooked in ecological studies, confined to the < 2 mm size fraction.

The current study was conducted on a push-core (10 cm diameter) sample from the Swedish Gullmar Fjord taken at 7 m depth at the fjord mouth. The first five centimetres of the coarse sediment were cut in layers (0-1 cm, 1-2 cm, 2-3 cm, 3-5
cm) and stained with Rose Bengal. Subsequently, the samples were sieved to obtain the > 1 mm and 125-1000 µm fractions to determine the most abundant species of both fractions. The cell volume of the two most abundant species (T. vesicularis and Ammonia sp.) was compared to estimate their ecological impact due to their space occupation within the microhabitat. Qualitative stereo and scanning electron microscopy (SEM) were carried out to investigate the morphology and the protoplasmic content of T. vesicularis specimens in the < 1 mm fraction. Quantitative stereo microscopy was applied to map the distribution of the epilithic T. vesicularis populations.

The top layer contained a brick fragment (~17 cm² surface area) that was densely populated by T. vesicularis individuals (13 ind. cm⁻²). Another rather large stone fragment (Quartzite, ~21 cm² surface area) in the same layer was also populated by T. vesicularis, however in a lower abundances (3 ind. cm⁻²). The brick seemed to be a more attractive habitat for this species rather than the Quartzite, possibly due to its more heterogeneous surface presenting several gaps and slots. These might provide shelter to T. vesicularis from currents or potential predators. Furthermore, the diatom biofilm on the brick was more pronounced than on the Quartzite, potentially providing food for the foraminifer.

The spatial distribution of the T. vesicularis population inhabiting the brick fragment showed a clumped distribution pattern (Clark Evans distribution; R = 0.30, z = -11.78). This is the most frequent distribution pattern found for heterotrophs in nature, mostly due to a patchy distribution of resources in their habitat.

Tholosina vesicularis (median test diameter 450 µm, n = 74) was the most abundant species in the >1 mm fraction (87%, 199 ind. 10 cm⁻³) of the topmost layer. Ammonia sp. (median test diameter 221 µm, n = 110) was the most abundant species in the 125-1000 µm fraction (67%, 337 ind. 10 cm⁻³) in the topmost layer. Total cell volumes of the two species showed a far higher space occupation of T. vesicularis (median 50 mm³ 10 cm⁻³) than Ammonia sp. (median 10 mm³ 10 cm⁻³). There was a drastic decrease of T. vesicularis abundances down core (e.g. 4 ind. 10 cm⁻³ within the 3-5 cm layer), whereas Ammonia sp. was still highly abundant (e.g. 148 ind. 10 cm⁻³ within the 3-5 cm layer). Stereo microscopy and SEM of T. vesicularis individuals revealed that the foraminifer ingests copious amounts of diatoms. Thus, we stipulate that this species depends on freshly accumulated diatom-phytodetritus that diminishes downcore.

In conclusion, this study sheds light on T. vesicularis ecological significance such as its high space occupation and its dependence on freshly accumulated diatom-phytodetritus. The clumped population distribution pattern observed in this study may reflect the patchy distribution of resources in the foraminifer’s habitat, indicating its adaptation to local conditions. Additionally, this study emphasizes the importance of considering larger size fractions in ecological studies to fully understand the distribution and ecological impact of epilithic species like T. vesicularis.

Adaptive thermal niche of planktic foraminifera and the emergence of mechanistic model

YING Rui*, MONTEIRO Fanny M.2 and SCHMIDT Daniela N.1

1School of Earth Sciences, University of Bristol, Queens Road, Bristol, UK; rui.ying@bristol.ac.uk; D.Schmidt@bristol.ac.uk
2School of Geographical Sciences, University of Bristol, University Road, Bristol, UK; f.monteiro@bristol.ac.uk
*Corresponding author

Global oceans are warming at unprecedented rate and imposing selective pressure to marine plankton. However, we lack the quantification of the adaptive capacity of marine plankton to the ongoing warming environment. While some groups are well studied, information on planktic foraminifers is missing. Furthermore, the stability of foraminifera niche determines the precision of many paleoeceanography proxies constraining past events of environmental change. Existing studies propose a static thermal niche based on the measurement of niche overlap at different time intervals in earth history. This approach might overlook though a shift of their optimal temperature versus the theoretical niche. Here we reconstruct the foraminifera thermal fitness curve of 12 species using abundance and sea surface temperature (SST) data from the Last Glacial Maximum (LGM) and late Holocene from the literature. We find that the selected species have a significantly increased thermal maximum, minimum and optimum by on average 3.1, 2.9, and 3.7°C. Our finding suggests adaptation during the last deglacial warming and contradict niche conservation assumed in paleoeceanography proxies like abundance-based transfer function. Niche-based models do not represent such adaptive response resulting in uncertainty and making a mechanistic foraminifera model necessary.

Therefore, we introduce our trait-based solution (ForamEcoGENIE) simulating foraminifera diversity and biogeography based on dynamic physiological processes such as predation and mortality rather than the empirically determined niche. ForamEcoGENIE is based on the intermediate-complexity Earth system model cGENIE and is well suited to paleoeceanographic study as it is based on functional trait (calcification, symbiosis, spines) instead of individual species. Focusing on four main functional groups instead of taxa allows to overcome the taxonomy differences throughout the geological record. The model is calibrated with core-top foraminiferal abundance data. Estimates of biomass and carbon export agree with literature data and under the glacial boundary condition the model agrees with data in biogeographical and niche shifts.

Using ForamEcoGENIE to project future foraminiferal growth, niche distribution, and biogeography in 2100 under emission pathways causing +1 to +4 °C warming relative to pre-industrial, we find a biomass loss of 5-17.5% which is mainly caused by a reduction of primary productivity. The North Atlantic is projected to have the highest biomass loss and
compositional shift, followed by the Southern Ocean. Thereby we conclude that the loss of high food availability will further impact the adaptive thermal niche. This trait-based mechanistic model ForamEcoGENIE is a unique tool to explore the biogeography and niche variability across different geological times.

Integrated stratigraphy of the last glacial-interglacial transition in the Sergipe-Alagoas basin, South Atlantic Ocean

ZARDIN Tamires N.1,2*, KOCHHANN Karlos 1,2, KRAHL Guilherme1,2, MARTINS Alisson2, ROLOFF Greice2, FAUTH Gerson1,2 and CHIESSI Cristiano4

1Geology Graduate Program, UNISINOS University, Av. Unisinos 950, São Leopoldo, Brazil; tamireszardin@gmail.com; kkochhann@unisinos.br; gkrahl@unisinos.br; georoloff@gmail.com; gersonf@unisinos.br
2Technological Institute for Palaeoceanography and Climate Change, It Oceaneon, Av. Unisinos 950, São Leopoldo, Brazil; tamireszardin@gmail.com; kkochhann@unisinos.br; gersonf@unisinos.br
3Graduate Program in Geosciences, Federal University of Rio Grande do Sul, Av. Bento Gonçalves, 9500, Porto Alegre, Brazil; alissonkmartins@gmail.com
4School of Arts, Sciences and Humanities, University of São Paulo, Rua Arlindo Bettio, 1000, São Paulo, Brazil; chiessi@usp.br

*Corresponding author

The last glacial-interglacial transition is characterized by major climate changes that affected the geographic distribution of planktonic foraminiferal species and changed sedimentary dynamics in shelf and slope settings. We present an integrated stratigraphic approach (chemo- and biostratigraphy) to characterize the last glacial-interglacial transition in the Sergipe-Alagoas Basin, in the western South Atlantic Ocean. We performed faunal and stable isotopic analyses of planktonic foraminifera, as well as major and minor elemental ratios of bulk sediment from two sediment cores collected from the Brazilian continental slope (Core SEAL-20230001, 2650 m water depth, and Core SEAL-20230070, 1300 m water depth). We identified planktonic foraminiferal biozones Y2 to Z at both cores, and the ages of the biozone boundaries were determined with planktonic foraminiferal accelerator mass spectrometry radiocarbon ages and benthic foraminifera stable oxygen isotope stratigraphy. We identified 30 planktonic foraminiferal species at core SEAL-20230070 and 27 at core SEAL-20230001. At both cores, Globorotalia truncatulinoides and Globococcolina inflata present highest abundances within the Last Glacial Maximum (LGM) and are practically absent during Heinrich Stadial 1 (HS1) and the Younger Dryas (YD). In core SEAL-20230070, the tropical Menardiform complex is absent in the LGM and HS1, but is abundant in the YD. These observations suggest that marked environmental changes occurred in the pelagic ecosystem during HS1 and the YD in the western South Atlantic Ocean. These events were also characterized by increased continental runoff, as suggested by sedimentary elemental ratios, which may have affected nutrients supply and/or water column stratification in the region.

The evolution of the barrier layer in the centre of the western Pacific warm pool during the last deglacial based on planktonic foraminifera surface species

ZHANG Shuai1*, YU Zhoufeng2, CHANG Fengming3 and LI Tiegang4

1College of Oceanography, Hohai University, Xikang Road 1, Nanjing, China; zhangshuai5@126.com
2State Key Laboratory of Palaeobiology and Stratigraphy, Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, East Beijing Road 39, Nanjing, China; zfya@nigpas.ac.cn;
3Key Laboratory of Marine Geology and Environment, Institute of Oceanology, Chinese Academy of Sciences, Nanhai Road 7, Qingdao, China; chfms@dio.ac.cn;
4Key Laboratory of Marine Sedimentology and Environmental Geology, First Institute of Oceanography, MNR, Xianxialing Road 6, Qingdao, China; tgli@fio.org.cn;
*Corresponding author

The role of the tropical Pacific El Niño-Southern Oscillation (ENSO) in modulating global climatic changes is critical, particularly the role of the barrier layer (BL, a salinity stratification above the thermocline) in forming it, which could reduce subsurface entrainment cooling into the mixed layer and impede the energy transmission downward. Yet, prior BL changes are weakly restricted by marine archives. We analyzed the Ontong-Java Plateau sediment core KX97322-4 (00°01.73’S, 159°14.66’E, water depth 2362 m) to reconstruct previous changes in the BL. Based on the minor difference in calcification depth between two surface species of planktonic foraminifera (Globigerinoides ruber and Trilobatus sacculifer), we used stable isotopes of oxygen and Mg/Ca ratio analyses to document temperature and salinity variation (considering the linear correlation between the sea water δ18O and salinity, it is represented by δ34Sw) of surface water in the centre of western Pacific warm pool over the last 30 ky. The comparison of vertical temperature and salinity change amplitudes suggests that the BL was strengthened during the last deglacial. This is compatible with the maritime continent’s increasing precipitation. Increased rainfall in the warm pool during the deglaciation period may have produced in higher vertical salt stratification in the surface water, resulting in BL thickening. It might provide positive feedbacks to the La Niña-like condition that existed during the deglaciation period. Earlier in the Holocene, the BL is thinner and associated with an El Niño-like condition. Moreover, 169 δ34Sw measurements gathered throughout the whole western Pacific suggest that rainfall in the western
section of the warm pool rose while rainfall in the eastern part of the warm pool declined. This rain band’s westward migration may have contributed to the BL’s thinning. Our data give fresh light on the dynamics of ENSO-like events during the latest deglaciation.

Pliensbachian–Aalenian (Jurassic) palaeobiogeographical patterns of the Neotethyan benthic foraminifera

ZSIBORÁS Gábor1* and GÖRÖG Ágnes1

1Hantken Foundation, H-1022 Budapest, Detrekő utca 1/b, Hungary; zsgbedavies@gmail.com; ag.gorog@gmail.com

*Corresponding author

In the last more than 160 years, many taxonomic works have been published on benthic foraminiferal assemblages of the late Pliensbachian–Bajocian interval in Western European carbonate–siliciclastic ramps and the deposits of the former carbonate platforms. In the last 25 years, the Hungarian assemblages of the same age, but with different facies, representing the former pelagic regions, have also been studied. Thus, we had the opportunity to evaluate the paleobiogeography of benthic foraminifera.

In the Early–Middle Jurassic of the Neotethyan Realm, we designated two foraminiferal bioprovinces, the Tethyan Carbonate Platform Province and the Boreal-Atlantic-Caucasian Province, whose composition differs from each other at the genus level, so they have no common species. Agglutinated larger benthic foraminifera are characteristic of the former, while benthic smaller benthic foraminifera with mostly calcareous skeletons are characteristic of the latter.

According to the low ratio of endemism based on the Provinciality Index of Johnson, Jaccard and Simpson similarity coefficients, and taxa–area relationship, no further biogeographical subdivisions (biochores) can be separated within the territory of the provinces. Within the Boreal-Atlantic-Caucasian Province, the generic and species composition of the assemblage is similar in different environments, but the individual groups occur in different proportions.

Based on these, it can be divided into different biomes. Biomes are different communities of living areas in contiguous areas, but endemism is not assumed. The shallower assemblages of the siliciclastic-carbonate ramp of the Neotethys, closer to the coast (e.g., Lusitanian basin) were classified into the Boreal-Atlantic Biome, and the pelagic assemblages of its predominantly carbonate, condensed formations (e.g., Apennines, Transdanubian Central Mountains – Hungary) were classified into the Mediterranean Biome. In the Pliensbachian–Bajocian, the Neotethys was connected to the Arctic Ocean in the northwest, from where many species crossed into the Boreal-Atlantic Biome. The Mediterranean Biome was presumably populated from the Boreal-Atlantic Biome, since the foraminiferal assemblages are less diverse and there are very few endemic species (e.g., Nodosaria szentgali), most species are found in both biomes.

The Pliensbachian in the Boreal-Atlantic Biome is characterized by the high frequency and variety of shallow-deep endobenthic lenticulinids, smooth-walled and ornamented specimens lenticular in shape occurred in a similar proportion to elongated forms. In the early Toarcian, the proportion of the endobenthic Eoguttulina, the ribbed Paralingulina and the smooth Prodentalina increased, and then the Lenticulina became the majority again until the late Aalenian–early Bajocian, when the Spirillina became common (e.g., Lusitanian Basin, Iberian-Cordillera).

During the late Pliensbachian, the Mediterranean Biome was characterized by assemblages dominated by the epibenthic Glomospira–Ammodiscus, in addition to the similarly common shallow endobenthic, ornamented Ichthyolaria, Paralingulina, and the smooth-walled Lenticulina (e.g., Umbria-Marche-Apennines, Transdanubian Central Mountains). These were replaced by less diverse assemblages with a majority of Eoguttulina–Spirillina from the early Toarcian, and then from the middle–late Toarcian to the Bajocian, the Spirillina mostly dominated alone, and the diversity continues to decrease (e.g., Transdanubian Central Mountains).
## List of participants

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rachel Alcorn</td>
<td>NC State University</td>
</tr>
<tr>
<td>Laia Alegret</td>
<td>University of Zaragoza</td>
</tr>
<tr>
<td>Elisabeth Alve</td>
<td>Oslo University</td>
</tr>
<tr>
<td>Maria Virginia Alves Martins</td>
<td>University of Rio de Janeiro</td>
</tr>
<tr>
<td>Giulia Amaglio</td>
<td>University of Milan</td>
</tr>
<tr>
<td>Timea Aranyi</td>
<td>Eötvös Loránd University</td>
</tr>
<tr>
<td>Anthea Arns</td>
<td>Max Planck Institute for Chemistry</td>
</tr>
<tr>
<td>Sarit Ashkenazi-Polivoda</td>
<td>Dead Sea and Arava Science Center</td>
</tr>
<tr>
<td>Alessandra Asioli</td>
<td>Italian National Research Council</td>
</tr>
<tr>
<td>Tracy Aze</td>
<td>University of Leeds</td>
</tr>
<tr>
<td>Sofia Barragán Montilla</td>
<td>MARUM - University of Bremen</td>
</tr>
<tr>
<td>Christine Barras</td>
<td>University of Angers</td>
</tr>
<tr>
<td>Ines Barrenechea Angeles</td>
<td>Université de Genève</td>
</tr>
<tr>
<td>Annachiara Bartolini</td>
<td>National Museum of Natural History - Paris</td>
</tr>
<tr>
<td>Davide Bassi</td>
<td>University of Ferrara</td>
</tr>
<tr>
<td>Claudia Baumgartner</td>
<td>University of Lausanne</td>
</tr>
<tr>
<td>Peter Baumgartner</td>
<td>University of Lausanne</td>
</tr>
<tr>
<td>Eugene Bergh</td>
<td>North West University</td>
</tr>
<tr>
<td>Joan Bernhard</td>
<td>Woods Hole Oceanographic Institution</td>
</tr>
<tr>
<td>Erica Bicchi</td>
<td>ESAIP Engineer School</td>
</tr>
<tr>
<td>Mike Bidgood</td>
<td>GSS Geoscience Ltd.</td>
</tr>
<tr>
<td>Aaron Linard Bieler</td>
<td>Max Planck Institute for Chemistry</td>
</tr>
<tr>
<td>Clare Bird</td>
<td>University of Stirling</td>
</tr>
<tr>
<td>Gregg H. Blake</td>
<td>Blake Geological Services LLC</td>
</tr>
<tr>
<td>Samantha Bombard</td>
<td>University of Massachusetts Amherst</td>
</tr>
<tr>
<td>Gabriella Boretto</td>
<td>CNR - ISP</td>
</tr>
<tr>
<td>Chiara Borrelli</td>
<td>University of Rochester</td>
</tr>
<tr>
<td>Flavia Boscolo Galazzo</td>
<td>MARUM</td>
</tr>
<tr>
<td>Vincent Bouchet</td>
<td>University of Lille</td>
</tr>
<tr>
<td>Fatima Bouhdayad</td>
<td>University of Cologne</td>
</tr>
<tr>
<td>Edward Bower Booth</td>
<td>University of Stirling</td>
</tr>
<tr>
<td>Samuel S. Bowser</td>
<td>School of Public Health, University of Albany,</td>
</tr>
<tr>
<td>Oscar Branson</td>
<td>University of Cambridge</td>
</tr>
<tr>
<td>Antonino Briguglio</td>
<td>University of Genova</td>
</tr>
<tr>
<td>Inda Brinkmann</td>
<td>Dept. of Glaciology and Climate, Geol. Survey of Denmark and Greenland</td>
</tr>
<tr>
<td>Anieke Brombacher</td>
<td>University of Southampton</td>
</tr>
<tr>
<td>Raquel Bryant</td>
<td>Wesleyan University</td>
</tr>
<tr>
<td>Ashley Burkett</td>
<td>Boone Pickens School of Geology</td>
</tr>
<tr>
<td>Marina Čančar</td>
<td>University of Zagreb</td>
</tr>
<tr>
<td>Torin Cannings</td>
<td>University of Edinburgh</td>
</tr>
<tr>
<td>Lucilla Capotondi</td>
<td>ISMAR - CNR</td>
</tr>
<tr>
<td>Martina Caratelli</td>
<td>Universidad Nacional de Rio Negro</td>
</tr>
<tr>
<td>Thiago Carelli</td>
<td>University of Rio de Janeiro</td>
</tr>
<tr>
<td>Francesca Cardi</td>
<td>Università Politecnica delle Marche</td>
</tr>
<tr>
<td>Claudia Cetean</td>
<td>CGG Services - Abu Dhabi</td>
</tr>
<tr>
<td>Sonia Chaabane</td>
<td>Biodiversity Research Foundation</td>
</tr>
<tr>
<td>Thasinee Charoentitirat</td>
<td>Chulalongkorn University, Bangkok</td>
</tr>
</tbody>
</table>
Laurie M. Charrieau  |  Alfred Wegener Institute  
Constance Choquel  |  Lund University  
Rodolfo Coccioni  |  University of Urbino  
Clementine Colpaert  |  Nanjing Institute of Geology Palaeontology and Stratigraphy  
Lorenzo Consorti  |  ISMAR-CNR  
María Fernanda Copete Hernández  |  Universidad de Vigo  
Vlasta Cosovic  |  University of Zagreb  
Elisa Costanzi  |  IUSS Pavia  
Laura Cotton  |  Natural History Museum of Denmark  
Julia Courtial  |  University of Angers  
Helen Coxall  |  Stockholm University  
Sooraj CP  |  Indian Company  
Simone Crobu  |  University of Genova  
Martin Crundwell  |  Surface Geosciences Department, GNS Science, New Zealand  
Blanka Cvetko Tešović  |  University of Zagreb  
Fabricio Leandro Damasceno Ferreira  |  State University of Rio de Janeiro  
Serena Dameron  |  University of Massachusetts Amherst  
Kate Darling  |  University of Edinburgh  
Maxime Daviray  |  University of Angers  
Catherine Davis  |  North Carolina State University  
Fabiana Karla de Almeida  |  Federal University of Espirito Santo  
Thaise Ricardo de Freitas  |  University of Oslo  
Thibault de Garidel-Thoron  |  CEREGE-CNRS  
Renata De Mello  |  PETROBRAS  
Lennart de Nooijer  |  Royal Netherlands Institute for Sea Research  
Jeanette deCuba  |  Florida International University  
Arianna Valentina Del Gaudio  |  University of Graz  
Dhanushka Devendra  |  Polish Academy of Sciences  
Letizia Di Bella  |  Sapienza University of Rome  
Thomas Dignes  |  Micropaleontology Press  
Grigoria Vasiliki Dimou  |  University of Thessaloniki  
Sibelle Trevisan Disaro  |  Federal University of Paraná  
Joicce Dissenha Gonçalves  |  University of Vale do Itajai  
Paula Diz Ferreiro  |  University of Vigo  
Shannon Doherty  |  NC State University  
Monika Doubrava  |  KU Leuven University  
Mônica Liliana Duque Castaño  |  The Portuguese Institute for Sea and Atmosphere  
Pezelj Durdica  |  University of Zagreb  
Daniela Eichner  |  University of Hamburg  
Jonathan Erez  |  The Fredy & Nadine Herrmann Institute of Earth Sciences  
Alessio Fabrini  |  University College London  
Kamila Faizieva  |  University of Vienna  
Francesca Falzoni  |  Italian National Research Council  
Wei-ning Fang  |  University of Cambridge  
Shirin Fassihi  |  University of Vienna  
Katherine Faulkner  |  The University of Texas at Austin  
Jennifer Fehrenbacher  |  Oregon State University  
Robin Fentimen  |  University of Angers
Andriu Ferreira de Aquino Dias, University of Rio de Janeiro
Giulia Filippi, University of Ferrara
Helena Filipsson, Lund University
Alexa Fischer, Heidelberg University
Trenity Ford, Oklahoma State University
Barry Fordham, Australian National University
Luca Maria Foresi, University of Siena
Fabio Francescangeli, University of Fribourg
Daniel Francois do Nascimento Silva, Royal Netherlands Institute for Sea Research
Oliver Friedrich, Heidelberg University
Fabrizio Frontalini, University of Urbino
Kazuhiro Fujita, University of the Ryukyus
Megan Fung, California Lutheran University
Luka Gale, University of Ljubljana
Stephen Gallagher, University of Melbourne
Antonella Gandolfi, University of Genova
Isabel Garcia, University of Rio de Janeiro
Jon Gardoki, University of the Basque Country
Sebastian Garrido-Medina, Heriot-Watt University
Maria Elena Gastaldello, University of Padova
Holger Gebhardt, Geological Survey of Austria
Rocco Gennari, University of Torino
Emmanuelle Geslin, University of Angers
Christian Gfatter, Florida State University
Masoumeh Gheiasvand, National Museum of Natural History - Paris
Anupam Ghosh, Jadavpur University
Vicente Gilabert Pérez, University of Zaragoza
Francesca Giovenzana, King Abdullah University of Science and Technology (Saudi Arabia)
Victor Manuel Giraldo Gomez, University of Genova
Elsa Girard, Naturalis Biodiversity Center of Leiden
Nicolaas Glock, University of Hamburg
Maria Angelica Godoi Millan, Universidad de Magallanes
Elly Goetz, Yale University
Susan Goldstein, University of Georgia
Jan Golen, Research Centre in Kraków
Elena Golikova, Saint Petersburg State University
Andrew Gooday, National Oceanography Centre
Charles Guy Goodwin, Texas A&M University Galveston Campus
Ágnes Görög, Eötvös Loránd University
Anjaly Govindankutty Menon, University of Hamburg
Jeroen Groeneveld, National Taiwan University
Adrianna Grow, Smith College
Patrick Grunert, University of Cologne
Maria N. Gudnitz, Florida International University
Corentin Guilhermic, University of Angers
Nicté Andrea Gutiérrez Puente, National Autonoma University of Mexico
David W. Haig, University of Western Australia
Hagar Hauzer, Israel Oceanographic and Limnological Research
Emily Havard  
NC State University

Laura Haynes  
Vassar College

Bruce W. Hayward  
Geomarine Research, New Zealand

Lena Heins  
Max Planck Institute for Chemistry

Petra Heinz  
University of Vienna

Morana Hermiz Kučenjak  
INA - Industrija naftne

Silvia Hess  
Oslo University

Johann Hohenegger  
University of Vienna

Daniel Holguin Caldera  
Wesleyan University

Maria Holzman  
University of Geneva

Lin Hooper  
Ben-Gurion University of the Negev

Babette Hoogakker  
Heriot-Watt University

Takashi Hosono  
Japan Agency for Marine-Earth Science and Technology

Allison Hsiang  
Stockholm University

Brian Huber  
Smithsonian National Museum of Natural History

Raphaël Hubert-Huard  
University of Hamburg

Brittany Hupp  
George Mason University

Orit Hyams-Kaphzan  
Geological Survey of Israel

Yoshiyuki Ishitani  
Japan Agency for Marine-Earth Science and Technology

Rebecca Jackson  
University of Copenhagen

Victory A. J. Jaques  
CEITEC

Chloe Jones  
University of Southampton

Lukas Jonkers  
University of Bremen

Frans J. Jorissen  
University of Angers

Neha Joshi  
Laval University

Michael Kaminski  
King Fahd University of Petroleum and Minerals

Laura A. Katz  
Smith College

Lorna Kearns  
The University of Texas at Austin

Clay Kelly  
University of Wisconsin–Madison

Sev Kender  
University of Exeter

Chen Kenigsberg  
Ben-Gurion University of the Negev, Israel

Kebelele Kesen  
Indian Institute of Technology Bombay

Anna Khokhlova  
University of the Balearic Islands

David King  
UCL Earth Sciences

Sergei Korsun  
Shirshov Institute of Oceanology

Olga Koukousioura  
Aristotle University of Thessaloniki

Eduardo Koutsokos  
Heidelberg University

Szabolcs Attila Kövecsi  
Babeș-Bolyai University

Mathias Kranmer  
Natural History Museum of Vienna

Vasilisa Kramara  
Ben-Gurion University

Isabela Santos Kropiwiec  
University of São Paulo

Tristan Lam  
Eckerd College

Grace Lamyman  
University of Leeds

Mary Kelsey Lane  
Oregon State University

Martin Langer  
University of Bonn

Dewi Langlet  
Okinawa Institute of Science and Technology Graduate University

Marcin Latas  
UCL

Lazaro Laut  
University of Rio de Janeiro
Mark Leckie
University of Massachusetts Amherst

Somin Lee
Hanyang University

Lizette Leon-Rodriguez
Ellington Geological Services

György Less
University of Miskolc

Baohua Li
Nanjing Institute of Geology and Palaeontology

Yohan Lichterfeld
CEREGE

Michael Lintner
University of Vienna

Fabrizio Lirer
Sapienza University of Rome

Nguyen Ngoc Loi
Institute of Oceanology Polish Academy of Sciences

Ana Lopes
University of Salamanca

Christopher Lowery
University of Texas Institute for Geophysics

Zhengbo Lu
Nanjing University

Valeria Luciani
University of Ferrara

Fernanda Luft de Souza
Unisinos University

Helen Lyman
University of Queensland

Ayumi Maeda
Geological Survey of Japan

Wojciech Majewski
Institute of Paleobiology

Nicoletta Mancin
Pavia University

Sneha Manda
Ben-Gurion University

Giulia Margaritelli
CNR - IRPI

Angelique Rosa Marin
University of South Florida

Pierluigi Martinielli
University of Torino

Michael Martinez-Colon
Florida A&M University

Guillem Mateu Vicens
University of the Balearic Islands

Christopher McCauley
University of Texas at Arlington

Julie Meilland
University of Bremen

Romana Melis
University of Trieste

Edouard Metzger
University of Angers

Yvonne Milker
University of Hamburg

Christian Millo
University of São Paulo

Yusei Miyamoto
Faculty of Science, Chiba University

Meryem Mojtahid
University of Angers

Giulia Molina
University of Algarve

Raphael Morard
University of Bremen

Kazuyoshi Moriya
Waseda University

Elsa Muller
Lund University

Savannah Myers
Università Politecnica delle Marche

Yukiko Nagai
Japan Agency for Marine-Earth Science and Technology

Mathias Nagy
University of Vienna

Mariapia Nardelli
University of Angers

Galina P. Nestell
University of Texas at Arlington

Katharina Neumueller
Leibniz Centre for Tropical Marine Research, Bremen, Germany

Kurt Søren Svensson Nielsen
Frederikssund Gymnasium

Hidetaka Nomaki
JAMSTEC

Phoebe O’Brien
University of Gothenburg

Bryan O’Malley
Eckerd College in Florida

Laura Pacho Sampedro
Royal Netherlands Institute for Sea Research

Tina Palme
University of Vienna
FORAMS 2023

June 26th–30th, 2023 - Perugia, Italy

FORAMS 2023 continues the tradition of the highly successful meetings previously held in Halifax (Benthos '75), Pau (Benthos '81), Geneva (Benthos '86), Sendai (Benthos '90), Berkeley (FORAMS'94), Monterrey (FORAMS '98), Perth (FORAMS 2002), Natal (FORAMS 2006), Bonn (FORAMS 2010), Concepción (FORAMS 2014), and Edinburgh (FORAMS 2018). During the last meeting in Scotland, the general assembly voted to hold the next meeting, FORAMS 2022 (now FORAMS 2023), in Perugia, Italy.

It is with great pleasure and honour that Perugia hosts this important scientific event, which certainly will contribute to spread even further the knowledge and the science among all countries represented at the meeting.

FORAMS 2023 will see 223 oral presentations and 162 poster presentations hosted into 25 scientific sessions, with more than 330 participants. Two of the proposed field trips were activated to visit the Carso area (near Trieste, pre-congress) and the world-famous Bottaccione section (close to Gubbio, post-congress).

The presentations will cover any topics related to extant and fossil foraminifera, including biostratigraphy, taxonomy, evolution, mass extinctions, paleoclimatology, paleoceanography, paleogeography, geochemistry, biology, ecology, symbiosis, biomineralization, environmental monitoring, extreme environments, polar environments, automated recognition, molecular systematics, from all over the world.

We thank all the participants hoping this conference will be again an enjoyable place to exchange scientific knowledge, to stimulate younger researchers to build new collaborations, and to demonstrate the vitality of our scientific community.