# International Symposium on Foraminifera FORAMS 2014

## Chile, 19-24 January 2014

## Abstract Volume


Edited by:
Margarita Marchant
& Tatiana Hromic

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**Grzybowski Foundation, 2014**

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**Abstract Volume**

Edited by:

**Margarita Marchant**
**Universidad de Concepción,**
**Concepción, Chile**

and

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**Universidad de Magallanes,**
**Punta Arenas, Chile**

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Dear friends and colleagues,

On behalf of the University of Concepcion and the University of Magallanes, we are pleased to bid you a warm welcome to Chile.

The International Symposium on Foraminifera, FORAMS 2014, 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) and Bonn Germany (Forams 2010). It was in Bonn that the General Assembly decided to hold the next meeting in Concepcion, Chile.

FORAMS 2014 will cover all aspects of foraminiferal biology, biostratigraphy, biogeography, ecology and paleoecology, paleoceanography, molecular evolution and systematics, and paleoclimatology. The program includes keynote lectures delivered by renowned scientists in each field. Altogether, almost 85 oral and 70 poster contributions will be presented by about 100 participants from more than 30 countries.

**A bibliographic citation on systematics, taxonomy and biogeography of benthic and planktonic Foraminifera found in Chilean waters of the south Eastern Pacific Ocean**

The first records of Foraminifera in Chilean waters date back to the nineteenth century and correspond to D' Orbigny (1839), who examined samples from Arica, Cobija, and a station in Valparaiso and close to Cape Horn deep water. These data were subsequently collected by Gay (1854). Brady (1884) presents the results obtained during Expedition "Challenger" (1873-1876), which corresponds to the area between the Juan Fernández archipelago and Cape Horn. Subsequently, Egger (1893) analyzed samples taken by the Expedition "Gazelle" (1874-1876). Cushman & Wickenden (1929) analyzed samples from the Juan Fernández archipelago; this study was reviewed and updated by Zapata (1999). Cushman & Kellett (1929) published results on samples collected from the west coast of South America, specifically off the Chilean coast in Lota and Corral. Heron-Allen & Earland (1932) investigated the foraminifera collected by the Expedition "Discovery" and "William Scoresby" (1929-1930) south of Cape Horn. Bandy & Rodolfo (1964) released the results about the qualitative distribution of foraminifera in the area of the Peru-Chile trench. Boltovskoy & Theyer (1965, 1970) studied the Foraminifera from the central area collected during Expedition "Marchile I". Theyer (1971) analyzed the variations

in the size of *Cyclamina cancellata*. Guzmán (1972) conducted a compendium of the genus *Globigerina* mentioned for Chile. Zapata & Varela (1975) conducted a taxonomic analysis of Foraminifera in coastal Maullín Bay. Subsequently, Pujol (1977) studied samples from the Bay of Quintero and Ingle *et al.* (1980) analyzed biofaces of benthic Foraminifera in sediments and water masses in the Atacama Trench. Zapata & Castillo (1986) studied the foraminiferofaune in Cumberland Bay. Zapata and Gutiérrez (1995) studied the littoral Foraminifera of Tocopilla. Zapata & Alarcón (1988) published the results of samples taken in the Strait of Magellan and Zapata *et al.* (1995) analyzed samples from southern Chile. Marchant (1993) recorded the presence of benthic foraminifera in the Bay Scholl. Zapata & Moyano (1996) published the results of the Expedition "Akebono Maru 72" and in 1997 the results of samples collected from the southern coast, making the zoogeography of benthic foraminifera in the South Pacific. Olivares & Zapata (2000) published data on surface sediments off Easter Island. Zapata *et al.* (2000) recorded the presence and history of the reproductive cycle *Tretomphalus bulloides*. Hromic (1996-2009) has made the analysis of foraminifera collected in the south, mainly in the region of southern fjords and channels. Marchant *et al*. (1997, 1998, 2004) analyzed planktonic foraminifera from sediment traps moored at 100 mn against Coquimbo. Marchant (1998 and 2011) conducted a zonation and paleoecological reconstruction by the Paleogene planktonic foraminifera in Magallanes Basin, respectively. Marchant *et al.* (1999) reported the presence of foraminifera in the last 13,300 years. Hebbeln *et al*. (2000 a,b,c) analyzed the present and past sedimentation along the continental slope off Chile, and comparisons made under Normal and El Niño conditions, respectively. Hebbeln *et al.* (2002) paleoproductivity record of the last 33,000 years. Marchant & Guzman (2002) provide a bibliographic index of recent planktonic foraminifera. In turn, Figueroa & Marchant (2003) did this for recent agglutinated benthic foraminifera. Mothadi *et al.* (2005) performed an analysis of productivity in Chilean waters on the basis of oxygen isotopes of planktonic foraminifera. Coloma *et al.* (2005) studied the planktonic foraminifera during 1997-98 Coquimbo area. Figueroa *et al.* (2005-2006) published benthic foraminifera from South Central Chile, including new species. Zapata & Marchant (2006) studied the hemiplanktonic and planktonic foraminifera in sediments of Easter Island. Ricardo-Nuñez *et al.* (2007) studied the extinction *Stilostomella* in northern Chile. Marchant *et al.* (2007) published a systematic history of recent foraminifera of Chile. Tapia *et al*. (2008) studied the vertical distribution of living in sediments of Concepción, Chile of benthic Foraminifera. Gajardo & Marchant (2012) compared the seasonal variations of planktonic foraminifera in 2005-2006 compared to Iquique and Concepción, and Gajardo *et al.* (2013a, b) analyzed the temporal composition of planktonic foraminifera using oxygen isotope and compared under normal and El Niño conditions in Concepcion, respectively. Finally, Harada *et al.* (2013) describe changes Deglacial - Holocene in the Pacific entrance of the Strait of Magellan, Chile.

We hope that you will enjoy your time in Chile and wish all FORAMS participants a fruitful and stimulating event.

Margarita Marchant & Tatiana Hromic

Chairs of FORAMS 2014

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**Margarita Marchant & Tatiana Hromic**

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## Session 1: New Classification of Foraminifera: Bridging Molecules and Morphology

## Keynote Lecture

### Morphology, molecules, and the monothalamous Foraminifera: Overview of works in progress

**Susan T. Goldstein**

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The application of molecular genetics to foraminiferal research over the past 20+ years has revolutionized our understanding of foraminiferal phylogenetics, systematics, and the relationships of foraminifera to other groups of protists. Results have highlighted the strengths and limitations of traditional morphological approaches, and revisions to the supraordinal classification of the polythalamous foraminifera, or the 'crown taxa', that reflect both molecular phylogenetics and morphology have been proposed (Pawlowski et al., 2013, Mar. Micropaleont.). Our understanding of relationships among monothalamous taxa, however, is far more nebulous. The traditional view of foraminiferal evolution proceeding from an atestate ancestor, to an organic-walled form and finally to foraminifera with an agglutinated test has been soundly rejected by molecular phylogenetics. Rather, the agglutinated test evolved multiple times and was subsequently lost independently in distantly related groups (Pawlowski et al., 2003, PNAS). Gross morphological features such as test shape and even the presence or absence of agglutination are therefore meaningless systematic characters for these basal-clade foraminifera.

Monothalamous foraminifera are only sparsely represented in the fossil record and are seldom incorporated in environmental, paleoenvironmental, or biostratigraphic studies. These taxa can be difficult to identify, are not retained in assemblages that have been dried, and are therefore often ignored in ecological surveys of modern foraminiferal assemblages. Nonetheless, surveys utilizing environmental DNA have shown that the biodiversity of this group has been vastly underestimated and may often exceed that of their polythalamous counterparts in settings from the shallow tropics to the deep sea (e.g, Habura et al., 2008, L&O; Lecroq et al., 2011, PNAS). Many 'taxa' are known only as sequences with no known morphology. Further, these foraminifera may be very abundant and play important and diverse ecological roles in their respective ecosystems. They are the modern descendants of early-evolving clades, and a better understanding of all aspects of their biology should shed light on the early evolution of the foraminifera and the ecosystems in which they lived.

The simple gross morphology of the monothalamous foraminifera is underpinned by intricate architectures and construction at the fine-structural level. In many cases, these intricate patterns parallel those clades delineated in SSU rDNA analyses, whereas some patterns are found in multiple clades. Different patterns of growth are also reflected in these intricate constructions (Goldstein & Richardson, 2002, JFR). Since the delineation of the monothalamous clades in 2002, a large number of additional ribosomal DNA sequences have been added from both studies on individual taxa and environmental DNA surveys. Many of these sequences are difficult to align within the framework of the existing clades, suggesting that we are underestimating monothalamous biodiversity at all taxonomic levels. Broader types of information including additional genetic markers and genes, chemical analyses of the array of bioadhesives, organic linings, and organic tests, fine-structural studies on additional taxa, and studies on the functional or ecological diversity monothalamous foraminifera are all needed to fully understand these important organisms.

## Oral Presentations

### Will we ever have a new foraminiferal “Treatise”?

**Michael A. Kaminski**

Earth Sciences Department, King Fahd University of Petroleum & Minerals, PO Box 701, Dhahran, 31261, Saudi Arabia; and Department of Earth Sciences, University College London, Gower Street, London WCIE 6BT, U.K. e-mail: kaminski@kfupm.edu.sa

As is the case with any large group of organisms, it is essential to have a firm taxonomic base that serves as a key to the identification of the genera and contributes to the stability of nomenclature. For the past 25 years, the 2-volume book *"Foraminiferal Genera and their Classification"* published by Loeblich & Tappan in 1987 has served this purpose and is widely regarded as "the Foraminiferal Bible." This book along with their *"Treatise of Invertebrate Paleontology vol. C"* published in 1964, can be found adorning the bookshelf of every serious foraminiferal Micropalaeontologist.

To the detriment of the micropalaeontological community, the task of keeping a current database of the foraminiferal genera has not been continued after the retirement of the Loeblich & Tappan team. As far as I am aware no single person or research group within the foraminiferal community has taken up the reins dropped by Loeblich & Tappan. With the passing of time this task will be an increasingly difficult one.

If the micropalaeontological community wishes to have at its disposal an updated version of *"Foraminiferal Genera and their Classification"* (or any other systematic database of foraminiferal genera) the task of keeping track of and updating the genera will need to be delegated to working groups that concentrate on particular foraminiferal orders or groups of taxa. An example of one such working group is the “Working Group on Foraminiferal Classification” which meets regularly at Grzybowski Foundation meetings to discuss the agglutinated foraminifera. This effort has produced a series of compilations of newly published or reinstated agglutinated genera (Kaminski, 2004, 2008, 2011), and has opened up a forum to discuss changes in the classification of the group (e.g. Pawlowski et al. 2013; Kaminski, in press; Mikhalevich, in press). A reclassification of the agglutinated foraminifera has been recently compiled in which a total of 832 valid genera described up to the year 2010 are placed within seven orders, 18 suborders, 32 superfamilies, 122 families, and 148 subfamilies (Kaminski, in press). This compares with the 624 genera of agglutinated foraminifera considered valid by Loeblich & Tappan (1987). However, to my knowledge, no single person or working group is keeping track of all the changes and updates to the generic classification of foraminifera as a whole. Nobody can answer the simple question “How many genera of foraminifera are there?” Although some working groups are currently dealing with the planktonic foraminiferal genera, unless someone steps forward to update the remaining foraminiferal groups (fusulinids, miliolids, larger and smaller calcareous benthic foraminifera), we are facing the unfortunate situation that *"Foraminiferal Genera and their Classification"* may well be the last book of its kind.

KAMINSKI, M.A. 2004. The new and revised genera of agglutinated foraminifera published between 1996 and 2000. In: Bubik, M., & Kaminski, M.A., Eds., *Proceedings of the Sixth International Workshop on Agglutinated Foraminifera.* Grzybowski Foundation Special Publication, **8**: 257-271.

KAMINSKI, M.A. 2008. The new and reinstated genera of agglutinated foraminifera published between 2000 and 2004. In: Kaminski, M.A. & Coccioni, R. Eds., *Proceedings of the Seventh International Workshop on Agglutinated Foraminifera*. Grzybowski Foundation Special Publication, **13**: 47-55.

KAMINSKI, M.A. 2011. The new and reinstated genera of agglutinated foraminifera published between 2005 and 2008. In: Kaminski, M.A. & Filipescu, S. Eds., *Proceedings of the Eighth International Workshop on Agglutinated Foraminifera.* Grzybowski Foundation Special Publication, **16**: 53-59.

KAMINSKI, M.A. (in press). The Year 2010 Classification of the Agglutinated Foraminifera. Submitted to *Micropaleontology* (IWAF-9 special volume).

LOEBLICH, A.R. and TAPPAN, H., 1987. Foraminiferal Genera and their Classification. Van Nostrand Reinhold

Company, New York, 2 vols, 970 pp. + 847 pls.
MIKHALEVICH, V.I. (in press). New insight into the classification and evolution of the Foraminifera. Submitted to *Micropaleontology.*
PAWŁOWSKI, J., HOLZMANN, M. and TYSZKA, J. 2013. New supraordinal classification of Foraminifera: molecules meet morphology. *Marine Micropaleontology* **100**, 1-10.

## Taxonomy and faunal characteristics of modern Foraminifera in the Bohai Sea of China

**Yan-Li Lei** and Tie-Gang Li

Institute of Oceanology, Chinese Academy of Sciences, Qingdao, 266071, P. R. China; e-mail: tgli@qdio.ac.cn

Taxonomy, species composition and faunal character of modern foraminifera were investigated in seafloor sediments of the Bohai Sea of China. Seventy-four species belonging to 56 genera, 35 families and 9 orders of foraminifera were identified. All the foraminifera species were studied morphologically with illustrations for identification. This is the first report with detailed taxonomical information on modern foraminifera in this sea area. The following families were involved: Almaenidae, Bagginidae, Bolivinidae, Buliminidae, Candeinidae, Cassidulinidae, Cibicididae, Discamminidae, Discorbidae, Ellipsolagenidae, Elphidiidae, Epistomariidae, Gavelinellidae, Glabratellidae, Globigerinidae, Globorotaliidae, Hauerinidae, Lagenidae, Lituolidae, Nodosariidae, Nonionidae, Nouriidaei, Planulinoididae, Polymorphinidaei, Psammosphaeridae, Rotaliidae, Saccaminidaei, Siphogenerinoididae, Siphoninidae, Spiroloculinidae, Textulariidae, Trochamminidae, Uvigerinidae, Vaginulinidae, Verneuilinidae. In addition, a revision of species composition, diversity, and geographical distribution of foraminifera in the Bohai Sea was conducted by comparing and summing up the present investigation and the historical data. Endemic species and temperate faunal characteristics of the foraminifera in Bohai Sea were discussed. Our study would provide reliable data to several relevant disciplines related to the Bohai Sea studies, e.g. marine geology, biology, ecology, micropaleontology, oceanographic and paleoceanography (supported by NSFC41176132; MGK1210; No201303; 2012IO060105).

## Towards a new classification of Foraminifera: Molecular contributions

**Jan Pawlowski** and Maria Holzmann

Department of Genetics and Evolution, University of Geneva, Switzerland. e-mail: Jan.Pawlowski@unige.ch

Molecular phylogenetic studies of foraminifera have been conducted for more than 20 years, generating thousands of gene sequences published in hundreds of papers. Despite this accumulation of molecular data, no alternative taxonomic system has been proposed yet. Here, we will present a new supraordinal classification of Foraminifera based on an updated SSU rDNA phylogeny. According to the new system, multi-chambered orders are grouped in two new classes: Tubothalamea and Globothalamea. Naked and single-chambered Foraminifera possessing agglutinated or organic-walled tests are arranged into a paraphyletic assemblage of “monothalamids”. The new system maintains some multi-chambered calcareous orders, such as Rotaliida, Miliolida, Robertinida and Spirillinida, although their definitions have been modified in some cases to include agglutinated taxa. The representatives of the planktonic order Globigerinida are tentatively included into Rotaliida. The agglutinated Textulariida are probably

paraphyletic. The position of Lagenida is uncertain because reliable molecular data are lacking for this group. In addition to discussing molecular evidence for each class, we will also analyse in more details the relations within Globothalamea, with a special focus on family-level classification of the order Rotaliida.

## Unsuspected phylogenetic links between Paleozoic Fusulinana and Recent Textulariana

**Sylvain Rigaud**[1], Daniel Vachard[2], and Rossana Martini[3]

[1] Earth Observatory of Singapore, Nanyang Technological University, Singapore. e-mail: Sylvain.Rigaud@unige.ch
[2] Université Lille 1, Villeneuve d'Ascq, France
[3] Department of Earth Sciences, University of Geneva, Switzerland

Large benthic agglutinated and microgranular foraminifers show significant morphological and structural similarities. The two groups have yet been regarded as being part of distinct lineages on the basis of a gap exceeding 50 million years in the record of the first large alveolar agglutinated Mesozoic forms (Textulariana) and their last known Paleozoic microgranular homologues (Fusulinana). The discovery of *Wernlina reidae* n.gen., n.sp. in a Late Triassic carbonate platform of Panthalassa (Wallowa terrane, U.S.A.) questions this assumption. This new form, earliest Mesozoic "agglutinated" alveolar foraminifer, incontestably originated from an Endotebidae (Fusulinana). The identification of a Triassic missing link between microgranular and agglutinated foraminifers permits not only to fill the 50 million years gap but also to contest the current foraminiferal classifications.

The classical distinction between microgranular and agglutinated tests is challenged by this discovery. Actually, both the Fusulinana and the Textulariana may possess a microgranular test, potentially containing some optically discernible agglutinated grains and a keriothecal/alveolar texture. Three major hypothesis can explain these striking wall similarities: i) the Textulariana and the Fusulinana have experienced a convergent evolution; ii) the Endotebidae belong to the Textulariana and have been erroneously included in the Fusulinana; iii) all Fusulinana agglutinate microparticules, the microgranular appearance of their wall being related to the nature and size of the grains that they incorporate into their test.

In the latter case, the Fusulinana would have survived the Permo-Triassic and the Triassic-Jurassic major extinction events and still have representatives. In consequence, there would be no major extinct groups of foraminifers and molecular phylogeny, well-combined with fossil data, should permit to retrace the foraminiferal evolution to a very advanced level.

## Morphological distinction of SSU genotypes of Elphidiidae from the Northeast Atlantic shelf seas

**Angela Roberts**[1], William Austin[1,3], Kate Darling[2,1], Katharine Evans[2], Clare Bird[2], and Magali Schweizer[2]

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[3]Scottish Association for Marine Science, UK.

Species found within the Elphidiidae family represent one of the most abundant, ubiquitous and morphologically diverse forms of benthic foraminifera. However, with over 120 species, subspecies and variants referenced in the literature, the current taxonomy of this family can be seen as chaotic. Over the past 20 years there has been a shift away from classical morphologically-based taxonomic studies and in recent years this trend has been heightened as the focus of taxonomic endeavour has shifted towards molecular taxonomy. As a result, and despite improved imaging techniques, there have been limited advancements in quantitatively delineating species based upon their morphology. However, this morphological focus is essential because fossil specimens are primarily allocated into a species based upon their external morphological characteristics. However, recent molecular phylogenetic evidence has shown that morphologically cryptic species exist. This leads us to question both the stability and reliability of current benthic foraminiferal taxonomy.

This study provides an integrated taxonomic approach which aims to resolve some of the taxonomic uncertainties surrounding the Elphidiidae family through a detailed morphological study of 18 distinct genotypes types (based on partial SSU rRNA). To date, a detailed morphometric analysis has been undertaken on 690 specimens collected from the North East Atlantic shelf seas. Morphological characteristics have been measured from SEM images and compromise 31 quantitative and 9 qualitative variables. Through a combination of cluster analysis, principle component analysis and discriminant function analysis, each genotype can be distinguished morphometrically. This study aims to resolve some of the apparently indiscriminate morphological species boundaries by providing a quantitative assessment, detailing some of the interspecific and intraspecific morphological variability found within the group. We hope that by reducing the uncertainty surrounding the morphospecies delineations we can increase the precision of research which utilises both extant and extinct species from the Elphidiidae family.

## Deep relationships of Rhizaria revealed by phylogenomics: Resolving the position of Foraminifera

**Roberto Sierra** and Jan Pawlowski

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Rhizaria is found within the supergroup SAR (Stramenopiles, Alveolates and Rhizaria), one of the five supergroups of eukaryotes. It comprises the majority of amoeboid and skeleton-building protists. The deep phylogeny of rhizarians is unresolved mainly due to its overall lack of molecular data. The clade of Retaria includes two of the most important groups of microfossils: Foraminifera and Radiolaria, for which molecular data are particularly scarce. To bridge this gap, we have produced and massively sequenced Expressed Sequence Tag (EST) libraries for rhizarian species including foraminiferans, *Gromia*, cercozoans, vampyrellids and taxa belonging to traditional Haeckel's Radiolaria: Acantharea, Polycystinea, and Phaeodarea, among others. A multigene matrix was constructed for phylogenetic analysis based on hundreds of protein coding genes. The phylogenomic data set presented here constitutes the largest and most complete available for Rhizaria to date. The best fit models for phylogenetic analyses were calculated and used to estimate the deep phylogenetic relationships of Rhizaria by Maximum Likelihood and Bayesian Inference. Moreover, topology comparisons on alternate plausible hypothesis were conducted using Approximately Unbiased (AU) and SH test. Our analyses confirm the hypothesis of polyphyly of Haeckel's Radiolaria providing the first multigene evidence for the branching of Phaeodarea within Cercozoa. We also confirm the monophyly of Retaria, a clade grouping Foraminifera with other lineages of Radiolaria.

## Morphogenetic bridge between molecules and morphology

**Jarosław Tyszka**[1], Ulf Bickmeyer[2], Jelle Bijma[2], Samuel S. Bowser[3], Martin Glas[4], Nicole Höher[2], Katrina Kaczmarek[2], Gerald Langer[5], Markus Raitzsch[2], Paweł Topa[1, 6], and Jeffrey Travis[7]

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[5] Department of Earth Sciences, University of Cambridge, U.K.
[6] AGH – University of Science and Technology, Kraków, POLAND
[7] Biological Sciences, University at Albany, State University of New York, U.S.A.

The new classification system groups polythalamous foraminifera in two new classes: Tubothalamea and Globothalamea Pawlowski et al. (2013). Although based on molecular phylogenetic approach, the system clearly separates two morphologic patterns recognized in foraminiferal tests and defined by two distinctive chamber formation types. The first one creates tubular chambers, in contrast to the second one, following globular chamber shapes. Fundamentally different chamber morphologies are associated with different patterns of aperture formation. Simple Tubothalamean apertures are located at the end of each chamber and in consequence the distance between them is maximized. The apertures are therefore self-defined by the tube end, the latter one being determined by addition of a new chamber. Globothalamea show a different approach to aperture formation, which is created mostly at the shortest distance from the previous aperture. There are several morphologic and functional consequences to be presented.

Both chamber morphologies are based on fundamentally distinct morphogenetic approaches controlled by complex molecular interactions. We have already determined two basic structural components responsible for chamber morphology, which belong to the cytoskeleton and include microtubules, as well as actin microfilaments. There are no doubts that these components interact with a vast amount of associated proteins responsible for morphogenetic self-organization. Our crucial goal is to identify all essential components and test their interactions *in silico*.

This research collaboration has been supported by REGPOT-2011-1 EU FP7 ATLAB Project no. 285989, NCN, and the Kosciuszko Foundation.

PAWŁOWSKI, J., HOLZMANN, M. and TYSZKA, J. 2013. New supraordinal classification of Foraminifera: molecules meet morphology. *Marine Micropaleontology* **100**, 1-10.

## Monothalamous foraminifera: diversity and molecular phylogeny

**Ivan Voltski**

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Monothalamous foraminifera, or monothalamids, range from giant xenophyophores to tiny allogromiids and play an important yet poorly understood role in all marine habitats, as well as in freshwater and soil. They are characterized by a single chamber enclosed in an organic or agglutinated test, but some of them are naked. Species with sometimes strikingly different test designs cluster into a multitude of clades,

forming the base of foraminiferal phylogenetic tree. Our aim is to provide the overview of our current knowledge on the diversity, taxonomy and systematics of monothalamids.

The past decade has seen the accumulation of molecular data, primarily SSUrDNA sequences, which led to improved ribosomal phylogenies with increased number of different monothalamid clades. Many new species and genera has been described. On the other hand, recent environmental studies yielded lots of sequences belonging to monothalamids but comprising their "untangible" diversity. Some monothalamids clades, such as clade E, have been successfully explored, while others, especially those composed of environmental sequences, remain largely uncharacterized. The unity of several genera recognized exclusively by their morphology is questioned. Regarding the sampling geography, a lot of material has been collected in the high-latitude settings and the deep sea. In contrast, the tropics remain poorly explored. All these studies are the result of targeted approach either linked to a particular geographic region, or dealing with the diversity of a particular group of monothalamids, and their scope was therefore limited.

We keep on searching for structural synapomorphies for different clades. Plus, we explore the vast biodiversity of monothalamids by "turbo-taxonomic" approach, coupling single-cell DNA extractions and sequencing with enhanced morphology documentation techniques. This effort will ultimately result in more stable classification and contribute to the existing taxonomy databases of WoRMS and ForamBARCODING.

## Poster Presentations

### High richness of monothalamous foraminifera in subtropical Brazilian coastal waters revealed by metagenomic (environmental DNA) study

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Foraminifera are characterized by their shells, more specifically termed "tests", which can either be organic, agglutinated, calcareous, and rarely siliceous. Foraminiferal research focuses mainly on hard-shelled, multi-chambered species, usually overlooking the single-chambered monothalamids, with soft, flexible test walls. Throughout the last two decades with the revision of some morphological approaches the monothalamids are becoming more common in the description of foraminiferal assemblages and, with the application of molecular technology this group revealed a huge diversity.

The present study we use an environmental DNA approach to examine the foraminiferal community in 8 sediment samples from subtropical Brazilian coastal waters, with a depth ranging from 7.0 to 30.0 m (Ubatuba region, São Paulo State, South-eastern Brazil). A total number of 115 environmental sequences were found. After grouping at 98% similarity threshold, we obtained 42 phylotypes. The highest diversity was in the sample EF 11, with 13 phylotypes. The average number of phylotypes per coastal sample was 6.25, where most shallow waters (< 15m), reveled a higher diversity than the other samples.

Among the 42 phylotypes, 9 were identified as Globothalamids, with three undetermined textulariids and six calcareous rotaliids: four related to *Gallitellia vivans* and *Stainforthia* sp. and two related to the genus *Virgulina*. The study of monothamids revealed that most of the Southwest Atlantic shallow-waters lineages were undetermined. About 20 phylotypes were placed in the Clade Y, a cosmopolitan group, which morphological identity is poorly known. The samples closer to the coast (<15 m) showed a higher richness than other samples. As most of the monothalamids from Brazilian coast are still unknow, it seems that a special attention to this group should be given to describe the species and maybe use them as potential indicators for ecological and biomonitoring studies.

### Revisiting benthic foraminiferal taxonomy: type material, morphological variability and molecular systematics

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A consistent and robust taxonomy is central to the correct interpretation of foraminiferal species within modern and fossil assemblages. The unit through which the taxonomic affinities, biogeochemical, genetic and morphological properties are communicated is a taxonomic name. It is therefore pivotal that we can associate taxonomic names unequivocally to species, so that a reliable reference system is in place for modern and paleoenvironmental reconstructions. This study uses the benthic foraminifer *Elphidium williamsoni* as an example to illustrate how we can link a morphological and molecular species concept unequivocally to its formal taxonomic name.

*Elphidium williamsoni* Haynes, 1973 is an important indicator in proxy-based relative sea level reconstructions due to its strong and quantifiable relationship with tidal zones and high preservation potential in the fossil record. *E. williamsoni* was originally described by Williamson, 1858 as *Polystomella umbilicata*; it was later reclassified into the genus *Elphidium* and renamed in Williamson's honour by Haynes in 1973. At least eight other names have been associated with this species, due to its phenotypic similarities with other taxa within the *Elphidium* genus. Therefore, to re-establish the taxonomic position of *E. williamsoni*, a combined molecular phylogenetic and morphometric analysis has been performed. Live topotypic specimens have been collected from Haynes' original type site location in the Dovey Estuary, Wales (UK). These specimens were imaged using Scanning Electron Microscopy (SEM) and genotyped (partial Small Subunit rDNA). From the SEM images a series of 31 quantitative and 9 qualitative morphological measurements were taken. These measurements have also been applied to the Environmental SEM images of the type material of *E. williamsoni* and *P. umbilicata* from the Natural History Museum London (NHM) collections. Through a series of multivariate statistics we can illustrate that the living genotyped topotype specimens group morphologically with the type specimens of *E. williamsoni* Haynes, 1973 and *Polystomella umbilicata* from the NHM. Since Williamson's first description of *Polystomella umbilicata* in 1858, we now present the first clear link between morphologically characterised type material (to which the formal name *E. williamsoni* is directly attributable) and the unique genotype of *E. williamsoni.*

## Investigating Planktic Foraminifera cryptic species in sediment samples

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Recently, many cryptic species have been described for the modern oceans planktic foraminifera. However, their presence in sediment samples is not clear. Even if geochemical and morphological features are pointed for recent cryptic species, due to constant evolution of the plankton, it is not possible to assure that this knowledge can be applied to fossil specimens and that we will find the same cryptic species through the geological record. For this reason, presence of cryptic species in the sediment samples should be independently investigated. In this study morphometric features were chosen over morphological features, due to its higher reproducibility and objectiveness, and geochemical analysis such as $\partial^{18}O$, $\partial^{13}C$, Mg/Ca and Ba/Ca where chosen as ecological proxies in substitution to genetic analysis, which is not possible for fossil assemblages. Although not all cryptic species show ecological differences among them, the fact of having ecological differences is the cryptic species characteristic of major implication for paleoceanographic studies. The material being used for this study comprises the last 20 kyrs, probably including the same cryptic species found in modern oceans. Specimens were photographed in stereoscopic microscope coupled with a ZEISS digital camera and manually measured. Preliminary results show that morphospecies found in the core top, *Orbulina universa*, *Globigerina bulloides*, *Globigerinoides ruber*, *Globigerinoides conglobatus*, *Globigerinoides sacculifer*, *Globigerinella calida*, *Globigerinella siphonifera*, *Globigerinita glutinata*, *Globorotalia crassaformis*, *Globorotalia menardii*, *Globorotalia scitula* and *Neogloboquadrina dutertrei*, may be divided in morphometric groups, or morphotypes. In theses morphotypes the main features distinguishing them were the last 3 chambers area and aperture size, parameters based only on test width and height such as lobateness and elongation ratio were not very significant to define morphotypes in morphospecies in question. A member from each morphotype will be geochemically analyzed to investigate whether the morphotypes are ecologically distinct and to what extent this could interfere in paleoclimatic inferences.

# Genotyping benthic foraminifers from the northeast Atlantic as a tool to identify endemism, cryptic speciation and ecophenotypy

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The comparison of benthic foraminiferal assemblages from different locations can be hampered by the diverse regional taxonomic systems used by different workers. Moreover, a taxonomy based on morphology has considerable limitations in cases where different species have similar morphologies or when the same species includes different morphologies. Genetic characterisation can be used to address some of these problems. The present project combines DNA genotyping, SEM imaging and ecological data of the more common species found off the European coasts of the Atlantic (from Svalbard to Portugal and from Iceland to the Baltic Sea), to investigate their distribution and diversity. About 8,000 specimens were SEM imaged and their DNA was extracted for genotyping. A 1000 bp (base pair) fragment located at the 3' end of the SSU rDNA gene, which is a region traditionally used for foraminiferal genotyping, was amplified. The success rate for DNA amplification varied from 10% to 90%, success was generally higher for the intertidal specimens than for the deeper water ones. Amplified sequences were aligned within a benthic foraminiferal database where they were grouped to determine their relationships within and between genotypes. The genera under study revealed a wide range of genotypes, ranging between 1 and 17. This extensive dataset allows the identification of cosmopolitan and endemic species within European waters and also has the potential to reveal the presence of cryptic or pseudo-cryptic species. This unique combination of genetic, morphological, biogeographic and ecological data also allows the long lasting issue of ecophenotypy to be addressed.

## Session 2: Recent and Fossil Foraminifera from South America

## Keynote Lecture

### Benthonic Foraminifera from the Magallanes Basin: Main paleobiogeographic features in Southern high latitudes

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The modern foraminifera are mostly cosmopolitan and their distribution on the continental shelves is related to currents patterns. Foraminiferal zoogeographic provinces are mainly characterized by species abundances rather than by endemic taxa. Only very few modern species are endemic to South America, and they are concentrated in the zoogeographic Malvin Subprovince.

The Magallanes or Austral Basin, located in southernmost South America and shared by Argentina and Chile, comprises a Cretaceous to mid-Miocene marine clastic sequence, which is paradigmatic for high austral latitudes and characterized by foraminiferal assemblages of highly variable degree of endemism. This variability in the degree of endemism either at basinal or austral level is the most outstanding feature of the foraminifera of the Magallanes Basin relative to their affinities and paleobiogeography.

During the Hauterivian-Barremian, strong Gondwanan affinities are evident among the assemblages of the Magallanes Basin, Madagascar, South Africa and India, as was first pointed out by Sigal et al. in 1970. Gondwanan affinities decrease throughout the remainder of the Cretaceous but are still found, particularly during the Aptian-Cenomanian with the Great Artesian Basin, Australia, and during the Santonian-Campanian with southwestern Australia. The Maastrichtian transgression, that covered most of the Patagonia and the Tierra del Fuego Island, comprises genera shared with New Zealand and endemic taxa that mark the paleozoogeographic differences with northern South America.

The Cretaceous/Paleogene boundary event mostly eliminated endemic taxa and gave place to a cosmopolitan Midway-type Paleocene assemblage with very few endemic taxa such as *Antarcticella*, a notorious extinct genus of austral paleobiogeographic distribution and apparent Antarctic origin.

Another turnover is related to the Paleocene/Eocene boundary event. The Paleocene cosmopolitan assemblage was replaced by an early Eocene assemblage comprising typical austral genera that characterize the shallow environments of the remainder Patagonian-Fuegian Cenozoic such as *Cribrorotalia*. Although this genus is shared with New Zealand, no species common to the Magallanes Basin and New Zealand are known.

Since the middle Eocene, the climatic deterioration is reflected by the decreasing diversity and increasing Antarctic aspect of the assemblages. During the early Oligocene, the sudden deepening of the foredeep facilitate the income of Antarctic corrosive waters in the Magallanes Basin, and in early Miocene times, a corrosive water current distributed typical Antarctic taxa such as *Antarcticella antarctica* and *Ammoelphidiella* sp. nov. along the Patagonian Atlantic margin. They have reached latitudes as low as 42°-43°S, and 39°-41°S, respectively, but they became extinct.

As concluding remarks, the decreasing Gondwanan affinities during the Cretaceous are related to the breakup of the Gondwanaland. Particularly the decreasing affinities with New Zealand throughout the Maastrichtian-Paleogene are in part due to the northward drift of New Zealand, contrasting with the scarce mobility of Patagonia that has remained in extratropical latitudes. Since the Paleocene/Eocene boundary, the Patagonian-Fuegian Cenozoic has been characterized by the declining temperatures in high latitudes that promoted a particular endemism given by taxa of apparent Antarctic origin.

## Oral Presentations

### Benthic Foraminifera in OMZ sediments: Control of pore water redox and sedimentary organic matter in the Central Peruvian Upper Margin

**Jorge Cardich**[1,3], Dimitri Gutiérrez[1,2], Alexander Pérez[1,2], Dennis Romero[1,2], Luis Quipúzcoa[2], Juana Solís[1], Abdel Sifeddine[3,4] and Anthony Rathburn[5]

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The exploration for an environmental proxy based on benthic foraminiferal assemblages is of particular significance in paleoceanography. One of the main issues in proxy calibration is the interdependence of controlling parameters, demanding a multiproxy approach for an adequate assessment of the ecological relationship.

The central Peruvian margin represents one of the most productive regions in the world and supports an intense and shallow oxygen minimum zone (OMZ). The sediments are subjected to intense oxygen deficiency, strongly influencing the abundance and diversity of benthic communities. Here we present an approximation for the relation of benthic foraminiferal assemblages with the sedimentary redox conditions and organic matter (OM) quality in OMZ sediments.

Benthic foraminifera were assessed in the years 2009, 2010 and 2011 in two bathymetric transects: off Callao (12°S, 45–175 m) and off Pisco (14°S, 100–300 m). The sedimentary OM was assessed in terms of quantity (chloroplastic pigment equivalents), quality (chlorophyll *a*/phaeopigments ratio), and bulk OM availability (total organic carbon and total nitrogen). Pore water sulfide was used as a proxy of redox conditions. The temporal and spatial features of all the samples allowed us to construct a gradient of redox conditions. The shallower inner shelf sites usually were under anoxia (no $O_2$, sulfide ≥18 nmol $cm^{-2}$), associated to fresh OM; and the deeper outer shelf and upper slope sites clustered in the postoxic state (no $O_2$, sulfide <18 nmol $cm^{-2}$), with high OM preservation. In some cases the sites were under a mixed, 'transition' state. Results showed partial consistency with the TROX-model. All of the species concentrated close to the sediment-water interface. A canonical correspondence analysis and non-parametric correlations showed that *Bolivina costata*, *Nonionella auris* and *Virgulinella fragilis* were characteristic of anoxia/fresh food, whereas *Bolivina pacifica* commanded the assemblage representative of postoxia/preserved OM.

### Miocene Foraminifera from the South-Central Coast of Chile

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Foraminifera are abundant and diverse in the Neogene sedimentary units of south-central Chile (34–43ºS), but their ages and depositional paleoenvironments have been points of contention for decades. This investigation focuses on the microfaunas in three sedimentary basins that are isolated from each other by more than 400 km. The corresponding units are the Navidad, Ranquil, and Lacui formations, mostly exposed as coastal bluffs and benches with nearly horizontal but often massive or indistinct bedding. In

this study, they are collectively and informally referred to as the "Navidad group". Also included in this study is one assemblage from the Santo Domingo Formation and two from the "El Peral beds" (Lo Abarca Formation?).

Regional workers have disagreed on which subepochs these units represent. Suggested ages based on macro- and microfossils have ranged late Oligocene to Early Pliocene. Excluding the El Peral samples, which are slightly younger, two samples devoid of planktic foraminifera, and one sample with only long-ranging planktic foraminifera, all of the remaining 22 planktic assemblages have concurrent ranges that begin or end in the Early Miocene. Seventeen of those ranges are restricted to that subepoch and 3 others range into the early Middle Miocene. $^{87}Sr/^{86}Sr$ ages determined for 18 localities placed 17 in the Early Miocene. The majority of paleontologic and isotopic data obtained suggest that most of the assemblages are of late Early Miocene (Burdigalian) age.

The most abundant macrofossils in the Navidad group are gastropods typical of, but not necessarily restricted to, neritic substrates. Their specimens tend to be widely scattered and they are associated with mixed-depth assemblages of foraminifera, which indicate downslope displacement. The upper depth limits of the deepest-dwelling benthic foraminifera in each assemblage suggest that final deposition occurred at bathyal depths, well below the neritic zone.

The presence of Neogene cosmopolitan deep-water benthic foraminifera in all of the assemblages supports the hypothesis that deep-water masses derived from the Antarctic Circumpolar Current enabled many Neogene deep-water foraminifera to disperse widely in the global ocean. The monograph documenting the 336 benthic and 22 planktic species recognized in this study will be useful for identifying Neogene foraminifera in subtropical/temperate regions in and beyond south-central Chile. Its regional dataset should be useful in future studies on benthic foraminiferal biostratigraphy and biogeography.

## Benthic redox conditions and oceanographic variability in the upper Central Peruvian margin since the nineteenth century

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Subsurface and benthic biogeochemical conditions over the upper Peruvian continental margin are characterized by oxygen deficiency in the bottom waters, strong fluxes of settling organic matter and reducing conditions in the surface sediments. These processes interact among each other and are amplified or relaxed according to the variability of oceanic conditions at different spatial and temporal scales. The present study aims to reconstruct the decadal to multidecadal variation of benthic paleo-redox conditions for the last two centuries, based on laminated sedimentary records of benthic foraminiferal assemblages and redox-sensitive metals (Mo, Re, etc.) in the upper margin off Callao (12°S) and Pisco (14°S). Bio-indicators of anoxic (e.g. sulphidic) and postoxic (non sulphidic) conditions were determined based on calibration work with modern communities and previous information on the spatial distribution of key species. Three major multidecadal periods were determined for both records: i) the mid to late nineteenth century, characterized by the occurrence of massive diatom-rich sedimentation events, development of bottom anoxia, and higher abundance of *Bolivina costata* and *Nonionella auris*; ii) the late nineteenth century to mid-twentieth century, featuring interdecadal variations of redox conditions; and iii) the late twentieth century until the early 2000's, in which redox-sensitive metal records exhibit a trend towards

less reducing conditions, accompanied by higher relative abundances of postoxia foraminiferal species (e.g. *Bolivina pacifica* or *Bolivina plicata*). Remarkably, the first multidecadal period is associated with a higher ENSO activity, whereas the latest one is parallel to the period of coastal cooling and increasing fluxes of productivity proxies. Our findings suggest that besides export productivity, the upper margin benthic redox states are modulated by vertical mixing and/or subsurface ventilation.

## Sea-level oscillation in the Brazilian East-Southeast coast during the Holocene: Micropaleontological data

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In the eastern Brazilian coast Holocene sea level decreased until the Recent with high-frequency oscillations after a maximum level at about 5,100 C14 yrs BP, in accordance with several indicators. Benthic foraminifera in sediments of bays and lagoons helped to interpret these oscillations.

Vitória Bay in Espírito Santo State is a long and narrow estuary formed during the last post-glacial transgression. Radiocarbon dates ranging from 7,240 to 1,010 yrs BP were obtained from two cores. From bottom to top, four foraminiferal biofacies showed a regression phase. The older biofacies, at the bottom, is typical of inner shelf-open sea environments; the next one refers to a brackish environment; at the top, the biofacies represents mangrove-tidal flat environments. Seismic and stratigraphic interpretations indicate that at 4,000 yrs BP there was an open bay. The following phases showed major regressive facies corroborated by the typical biofacies.

Guanabara Bay, in Rio de Janeiro State, is surrounded by large cities including Rio. The radiocarbon date at the depth of 222 cm from one core near the Paquetá Island located in the northern area was 4,210 yrs BP. Dark, corroded and broken foraminifera in coarse and shelly sand represent shallower environment with possible reworked sediments. There is an unconformity in the top of this unit. Those results may represent drop in sea level or high-frequency oscillations, after the high sea level at about 5,100 yrs BP. Two characteristic foraminiferal assemblages with inversely proportional distributions of bioindicator species along the core showed a native environment before the European influence. The Europeans settlement was assessed at the upper core intervals by the dominance of *Ammonia tepida,* which occurs at upper core intervals in several bay regions.

Maricá lagoon is located in Rio de Janeiro State, at 60 km from Guanabara Bay. It comprises a lagoon system that originated in the high sea level. Two cores were studied and results of radiocarbon dates ranging from 2,510 to 1,020 yrs BP. Previous works indicated that at 2,300 yrs BP the relative sea-level rose rapidly and since 2,100 yrs BP has falling down to the present. From bottom to middle of the cores a calcareous foraminifera biofacies characterizes bay or lagoonal environment with marine influence. An agglutinated biofacies from the middle to top represents brackish lagoon with less marine influence. In those cores the period of high-frequency sea level oscillations can be confirmed by the bottom calcareous biofacies followed by the top agglutinated one.

# Foraminiferal evidence supports a tsunami origin for a 2-km-inland buried sand layer in Central Chile

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Central Chile (32°–34°S), located immediately north of the M 8.8 2010 and M 9.5 1960 earthquake rupture zones, is thought to experience only moderate earthquakes. Historical records indicate that Central Chile was struck by earthquakes in 1575, 1647, 1730, 1822 and 1985, but most of these events were M 8.0-8.5 and generated only minor tsunamis. Newly obtained historical evidence indicates that the 1730 earthquake was larger than previously thought; destroying buildings over a 1000 km distance between Copiapó and Concepción. The ensuing tsunami impacted Valparaíso and Concepción locally, but reached as far as NW Honshu, Japan. Here we present foraminiferal evidence from the 1730 tsunami deposit, preserved as a 2-10 cm thick, extensive, tabular sand sheet buried in a low lying valley 30 km north of Valparaíso.

Four stratigraphic units (grey mud, lower red mud, sand sheet and upper red mud) were found within 12 trenches in the valley up to a distance of 2.3 km inland. Contacts between the grey and red muds were gradational; whereas the tsunami sand sharply punctuated the red mud at depths of 10 – 60 cm below the surface. Trenches were logged and sampled for their foraminiferal content and compared to beach, swash and dune (modern and Pleistocene) environments. Foraminifera were absent in all stratigraphic layers except the buried sand sheet, which contained a monospecific assemblage of well preserved *Ammonia tepida* (~15 specimens/5 $cm^3$). All environments contained monospecific assemblages of *A. tepida*, but in varying concentrations and taphonomic condition. Swash samples contained the highest unaltered concentrations (50 individuals/5 $cm^3$); whereas beach and dune samples contained negligible concentrations (<2 specimens/5$cm^3$) and where present, foraminifera were dissoluted, indicating sustained subaerial exposure.

We infer a mixed nearshore to coastal dune provenance for the sand sheet based on: 1) the taphonomic similarity between swash samples and the buried sand; and 2) the lower concentration of foraminifera in the latter. Such lower concentration is likely an artifact of dilution caused by the incorporation of beach and dune sand. Particle size analysis supports a mixed provenance, showing that the buried sand consists predominantly of sand sourced from the dune and beach. Radiocarbon dates constrain the deposit's age to AD 1482-1663 and AD 1673-1952. Additional OSL analysis of the buried sand brackets the age to AD 1600 and 1710. Because the 1730 tsunami is the only historical candidate large enough to flood that far inland, we conclude the sand sheet was deposited by the 1730 tsunami.

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## Late Eocene larger foraminiferal biostratigraphy in Western and Central Cuba

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New biostratigraphic data are presented from Late Eocene shallow water deposits from Western and Central Cuba concerning the distribution of the larger foraminifera collected from six different stratigraphic sections. The larger foraminifera assemblages collected are part of a post-orogenic phase composed of Late Eocene slightly deformed sedimentary rocks which overlie unconformably the Cuban folded belt. The studied sections are included into the Jabaco, Loma Candela, Blanco and Caunao formations.

Selected groups of larger foraminifera-mainly Nummulitids, Orthophragminids and Lepidocyclinids-were analyzed morphometrically in order to assess their systematics and their biostratigraphy. The systematic revision at specific level based on detailed biometric studies on oriented thin-sectioned specimens allows to draw a preliminary biostratigraphical scheme that corresponds to the *Asterocyclina minima* Zone for the Late Eocene in the Caribbean realm. The *Heterostegina-Lepidocyclina-Nummulites-Asterocyclina* assemblage extends the entire length of the Cuban sections. The age of particular larger foraminiferal sites are based on the first occurrence of *Heterostegina ocalana*, *Asterocyclina minima* and *Lepidocyclina chaperi*, on the absence of the genus *Discocyclina* and on the occurrence *of Nummulites striatoreticulatus*, *Paleonnumulites willcoxi* and *P. floridensis*.

The upper part of Loma Candela Formation exhibits Late Eocene larger foraminifera assemblages dominated by nummulitids and is recognized the first appearance of *Heterostegina ocalana* .The lepidocyclinds are the most abundant group in Jabaco, Blanco and Caunao formations and the taxa *Lepidocyclina chaperi* in association with *Heterostegina ocalana* are used to define the latest Eocene.

*Lepidocyclina chaperi* is distinguished from other American lepidocyclinid species with similar characters and proportions of size by its thin embryo walls. In the population from Cuba we have not found any variation in this character. We see no reason to include *L. chaperi* in to the subgenus *Nephrolepidina* with a regular arrangement of the auxiliary chamberlets in the equatorial plane. We use *Paleonummulites* to identify the small, involute nummulitids with comparatively few whorls.

## Posters

### Deep water mass corrosiveness evidence in the Western South Atlantic Ocean

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Carbonate content is a reliable proxy for investigating water mass corrosiveness. Previous studies indicate that poor preservation of $CaCO_3$ in a distinctly signature of a carbonate-corrosive water mass as Circumpolar Deep Water (CDW), whereas good preservation is observed within the North Atlantic Deep Water (NADW). Carbonate dissolution proxies based on calcite and aragonite dissolution have been successfully used to reconstruct deep water circulation patterns. In seawater, aragonite is more soluble than calcite which makes *Hoeglundina elegans* d'Orbigny, a benthic foraminifera with aragonitic test, a reliable proxy for the reconstruction of past water masses corrosives. In attempt to investigate about the carbonate corrosiveness and deep water circulation patterns, microfaunal and geochemical proxies were studied in the GL-854 long piston core (20.37 m sediment core) from the Western South Atlantic Ocean (Santos Basin, water depth 2.220 m), which lies next to the NADW/CPW water masses boundary. The *H.elegans* (>150 μm) relative abundance was compared with the relative percentage of agglutinated, planktonic foraminiferal fragmentation index (FRAG), $CaCO_3$ content of sediments (<63 μm, weight percent) and benthic carbon isotope ($\delta^{13}C_{bent}$) records.

Throughout the entire core, a positive correlation was observed between the *H.elegans* abundance and $CaCO_3$ content. In general, the FRAG index and agglutinated percentage were positively correlated as well. According to $\delta^{18}O_{bent}$ data, the sediment core recorded the last 772 kyr, covering the Marine Isotope Stages (MIS) 19 to 1, and eight glacial terminations. The highest relative abundance of *H.elegans* occurred mainly during the interglacial isotope stages. The preservation patterns of $CaCO_3$ content and the $\delta^{13}C_{bent}$ gradient followed a similar model. Furthermore, the highest values of the FRAG index and agglutinated percentage were observed during glacial periods. Such results indicate that the carbonate preservation was generally higher during the interglacial than glacial times. The decrease of *H.elegans* relative abundance during glacial may be attributed to aragonite dissolution due to bottom water corrosiveness. Finally, the records indicate that all carbonate proxies may be influenced by dissolution. The variation of carbonate preservation suggests, at the depth where the core is localized, a mixing zone with more corrosive (CPW) and less corrosive (NADW) water masses during glacial times.

### Benthic foraminiferal assemblages for the last 770 kyr in the Western South Atlantic Ocean

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Benthic foraminifera distribution (>63 μm size fraction) and $\delta^{18}O$ (*C.wuellerstorfi*) records were studied in the GL-854 long piston core (20.37 m sediment core) from the Western South Atlantic Ocean (Santos

Basin, water depth 2.220 m), where the North Atlantic Deep Water (NADW) flows. The sediments consist of marl, carbonate rich mud and carbonate poor mud layers. The benthic foraminiferal relative abundance data was arranged according the Q-mode Varimax Factor Analysis. Three dominant factors (90% of the total variance) were identified, which represents three benthic foraminiferal assemblages. Although these assemblages alternated throughout the entire core, in some intervals their dominance is more evident. The Factor 2 (*Bolivina* spp. assemblage) corresponds for 14% of the data variance and highest values occurred from the base to the middle part (20.35 to 13.36 m). The Factor 1 (*Globocassidulina crassa* assemblage) stands for 66% of the data variance and exhibits high values from the top to the middle part of the core (0 to 9.56 m). The Factor 3 (*Pseudoparrella exigua* assemblage) represents 9% of the data variance and highest values mainly occurred in the middle part (12.71 to 10.66 m). According the oxygen isotope data, the sediment core recorded the last 770 kyr, covering the Marine Isotopic Stages (MIS) 19 to 1, and eight glacial terminations. The highest values of *Bolivina* spp. assemblage occurred since the final part of the MIS 19 to MIS 15, and during the glacial MIS 14, 12, 10, 8, 6, and in the final part of MIS 9. Probably, this highest value in these times indicates a relatively high organic matter influx at the sea floor and a slightly decrease in dissolved oxygen concentration in the sediment-water interface. This condition changed with a particularly highest value of *G. crassa* assemblage during the beginning of the MIS 8 and then in the MIS 7, when this assemblage became dominant and, indicating an increase of dissolved oxygen level and lower organic matter influx. Despite of few variations, this assemblage was dominant until the MIS 1. The time of change in dominance from *Bolivina* spp. to *G.crassa* assemblages coincide with the replacement phase of the Biozone *Globorotalia menardii* V2 to Biozone V1. Peak values of *Pseudoparrela exigua* assemblage occurred in the MIS 11, 9, and 5, particularly at the sub stage 5.2-5.1, and during the MIS 14, 8 and 6. This highest value may be related not only by the organic matter influx to the sea floor, but to the intermittent delivery of fresh, easily degraded organic matter. Besides to the data shown by assemblages, only after the end part of the interglacial MIS 9 some deep infaunal species like *Bulimina aculeata*, *Bulimina marginata*, *Bulimina striata* and *Uvigerina mediterranea* occurred with large fluctuations, exhibited peaks in the middle part of MIS 8, sub stage 5.2-5.1 and MIS 4, implying high surface productivity during these times.

## Paleoenvironmental interpretations of middle Pleistocene based on benthic foraminifera from the Santos Basin, Brazil

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The Pleistocene was a very dynamic period, characterized by large climatic fluctuations that changed the conditions of the environments on the planet and the distribution of marine biodiversity. The present study aims to examine the benthic foraminifera from the BS-A core, in order to contribute knowledge about the paleoenvironmental characteristics of Middle Pleistocene. The core was collected at 2,141 m depth in the Santos basin and has continuous recovery (20.65 m). We selected 25 samples belonging to Middle Pleistocene, based on the planktonic foraminiferal biostratigraphic zonation.

We identified 26,629 specimens and 147 species of benthic foraminifera, however just three showed a consistent pattern of abundance and distribution (*Epistominella exigua*, *Alabaminella weddellensis* and *Cassidulina californica*). Using data distribution of fauna and regression analysis it was possible to identified three intervals on the BS-A core. The intervals A (oldest, 20.37 to 19.46 m) and C (latest, between ~15.09 to 8.49 m), presented high *E. exigua* abundance, high density of foraminifera specimens per gram of sediment and low diversity. The species *E. exigua* is opportunistic and able to reproduce

rapidly in response to seasonal phytodetritus deposits. This suggests two periods with considerable influx of phytodetritic organic matter to the seafloor and a consequent *E. exigua* dominance. Already the interval B (19.10 to ~15.29 m), presented a more diverse community, with high abundance of infaunal morphogroups, low specimes density and low abundance of *E. exigua*. This data suggest a moment of greater environmental stability, and the absence of a phytodetritic influx, enabling an increase of foraminifera diversity.

The infaunal species *C. californica* presented its highest values in intervals A and B, suggesting that other paleoenvironmental factors had controlling their populations, usually associated with large amounts of total organic carbon in sediment-water interface. An opposition abundance of *A. weddellensis* with *E. exigua* indicates periods that suffered different types of phytodetritc flow, deposited in seasonal pulses (intervals A and C) and interspersed with periods where the deposition occurred more gradually (interval B), possibly associated with oscillation of the phosphorus cycle.

The distribution patterns of the three mentioned species allowed to characterize the Middle Pleistocene of the Santos basin as a period of high marine productivity, with variations in the organic matter input from different backgrounds and varying intensity.

## Recent benthic foraminiferal associations from the continental shelf and upper slope of Southern Brazil: Preliminary results

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The distribution of benthic foraminifera in the ocean floor has been linked to factors such as bathymetry, physic-chemical characteristics of bottom water masses, nutrients supply and others environmental/ecological conditions. This study analysed 27 samples of surface sediments from the outer continental shelf and the upper slope of Rio Grande do Sul and Santa Catarina (RS, SC; 28°S to 34°S), aiming to identify patterns in the distribution of foraminifera associations.

We recovered 2,824 specimens and identified 79 genera and 156 species of benthic foraminifera. The infaunal morphogroup presented higher abundance in 21 samples. The Shannon diversity index (H') showed higher values in almost all samples (H'>2.6), with lower diversity in the samples RS4 (H'=2) and RS14 (H'=1.9). The dominance index (D) showed lower values, with no more than ~24% (RS4, RS5, RS14) and an average of 13% for RS samples and 11% for SC samples. Using cluster analyses was possible to identify two sets of samples, based on the fauna and the depth of the surface samples.

Cluster A is represented by 14 samples with bathymetry between 147 and 324 meters (SC1, SC2, SC4, SC8, RS2, RS3, RS9, RS10, RS12, RS13, RS15, RS17, RS18, RS19). This samples presented calcareous-hyaline shells as the most abundant, followed by porcelaneous, mainly represented by *Pyrgo* spp., *Quinqueloculina* spp. and *Siphonaperta* spp. The cluster A is characterized by the follow species: *Cassidulina curvata*, *Cibicides refulgens*, *Cibicidoides pseudoungerianus*, *Eponides antillarum*, *Globocassidulina subglobosa*, *Melonis affinis*, *Planulina foveolata* and *Uvigerina peregrina*. The cluster B with 13 samples between 377 and 600 meters of depth (SC3, SC5, SC6, SC7, RS1, RS4, RS5, RS6, RS7, RS8, RS11, RS14, RS16), showed a higher abundance of calcareous-hyaline shells, followed by agglutinated foraminifera. These samples are characterized by the association of: *Gyroidina soldanii*, *Neolenticulina chantamensis*, *Pullenia bulloides* and *Uvigerina hispido-costata*. The following step is to identify a relationship between these associations and some environmental condition or water masses characteristic presented in the studied region.

## Environmental study from the Argentinian continental shelf using modern foraminifera and ostracods as proxy data

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Foraminifers and ostracods are microorganisms, which due to their specific environmental requirements, are used as bio-indicators of marine environments. In this study, we evaluated modern sediments from Argentine continental shelf (35° 20´ - 39° 04´ S and 58° 43´ - 55° 33´ W), which were extracted between 15 and 130 m of depth, in order to understand their distribution patterns and ecological preferences.

We detect 61 species of foraminifers corresponding to Orders Rotaliida, Miliolida, Lagenida, Buliminida, Lituolida and Trochamminida. With respect to the distribution of ostracods, 18 species belonging to Superfamily Cytheridae were recognized. Between 15 and 74 m of depth, an assemblage represented especially by *Buccella peruviana* (d´Orbigny), *Elphidium discoidale* (d´Orbigny), *Elphidium gunteri* Cole and *Ammonia parkinsoniana* (d´Orbigny) and the ostracods: *Callistocytoere litoralensis* (Rossi de García), *Ambostracom* cf. *bertelsae* (Sanguinetti, Ornellas and Coimbra), *Oculocytheropteron macropunctatum* Whatley, Chadwick and Toy, *Argenticytheretta levipunctata* Sanguinetti, Ornellas and Coimbra, *Keigia falklandi* (Brady) and *Xestoleberis umbonata* Whatley, Moguilevsky, Chadwick, Toy and Ramos was determinate. Species of genus *Elphidium* and *Ammonia parkinsoniana* are typical of brackish and coastal waters and the ostracods corresponding to littoral species that reflects a shallow environment of inner shelf. A second assemblage was recognized between 80 and 130 m, only forams were present. The foraminifers founded were *Globocassidulina subglobosa* (Brady), *Cibicides dispars* (d´Orbigny), *Uvigerina peregrina* Cushman, *Uvigerina bifurcata* d´Orbigny, *Angulogerina angulosa* f. *angulosa* (Williamson), *Ehrenbergina pupa* (d´Orbigny) and *Pullenia subcarinata subcarinata* (d´Orbigny). All these species are typical of cold waters, reflecting an environmental with typical salinity content of subantartic waters of the outer shelf.

From the microfauna analysis, in the study area, two water masses can be distinguished: the coastal zone water, which is influenced by the discharge of the Río Negro and the waters from the outer shelf corresponding to the Malvinas Current

## On the taphonomy of benthic foraminifera: Comparison of 'living' and dead assemblages in Central Peruvian Upper Margin sediments

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Benthic foraminifera's intimate relation to environmental gradients makes of them really valuable for paleoenvironmental reconstruction. The recognition of a species/assemblage as a reliable paleoproxy demands the adequate preservation of the tests in the sediment in time though. However, even though their optimal fossilization potential, benthic foraminiferal assemblages are prone to thaponomical modification.

Despite of the relevance of this field, the relationship between living and dead assemblages in surficial and subsurface sediments and the response of thaphocenosis to early diagenesis after burial has received little attention.

In this work, we examine living and dead assemblages within the upper 5 cm of sediment in the Peruvian oxygen minimum zone to evaluate preservation. Taphocenosis was assessed in a depth transect off Pisco (14°S, 100-300 m) in 2010. Sediment was retrieved using a multicorer and empty tests were counted at each station in three different sediment intervals: 0-0.5, 1.5-2 and 4-5 cm. Results were compared with the standing stocks of the most representative living (Rose Bengal stained) species.

Typically in this area, an anoxic state is found in the inner shelf and postoxia reigns in the sediments at outer shelf/upper slope. Both biocenosis and taphocenosis differed between both settings (more details on the assemblage composition in Cardich et al., this session). Empty agglutinated tests were only present at the two deeper stations. Calcareous living and dead assemblages did not contrast greatly in the top sediment but showed some change downcore at deeper stations. The taphocenosis' representation of *Bolivina costata*, *Bolivina seminuda*, *Buliminella tenuata* and *Bolivina pacifica* did not vary significantly with sediment depth. On the other side, *Nonionella auris*' thick tests appeared to be over-preserved, meanwhile *Virgulinella fragilis*' tests were always under-preserved. We attribute these differences in tests preservation to living species importance at each redox state, pH in the sediment, test production rates and thickness of the test.

## *Globorotalia crassaformis* optmum event: A new late Quaternary biostratigraphical marker for the southeastern Brazilian Margin

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The planktonic foraminiferal abundance and oxygen stable isotope curves, coupled with absolute AMS $^{14}$C datings, allow us a precise chronology of biostratigraphical events recorded in cores GL-74 and GL-75 collected from Campos basin (southeastern Brazil). Based on planktonic foraminifera assemblage, the biozones X, Y and Z were recognized, corresponding the last interglacial interval, Glacial, and Holocene respectively. The high resolution of the core GL-74 allows us to confirm the return of *Globorotalia menardii* plexus at 8 kyr (AMS $^{14}$C dating) in agreement with new results from the southwestern Atlantic Ocean. This study documents that the third event of disappearance of the *Pulleniatina* plexus (*Pulleniatina obliquiloculata* biohorizon 1 – *YP.1*) occurred simultaneously around 42kyr in the Campos (21°-23°S) and Santos Basins (23°-27°S). Our results also show that the event of higher abundance of *Globorotalia crassaformis* at the base of biozone Y, the so-called *Globorotalia crassaformis* Optimum Event (GcOE) occurred between 82kyr and 71kyr (~11kyr of duration), and it was also simultaneous in both basins. This study supports the GcOE as an important biostratigraphical marker event in the southeastern Brazilian margin and aims at proposing a further subdivision of the last glacial zone Y into Y1, Y2 and Y3 though a further effort have to be accomplished to establish its geographic extent as well as a robust chronology of the GcOE in the region.

## Paleoenvionments reconstructions of Eocene deposits (SERGIPE/ALAGOAS Basin, Brazil), based on foraminiferal assemblages and palinomorphs

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The large morphological variety found in benthic foraminiferal tests is attributed to its ability to adapt to several environmental conditions. The grouping in morphgroups by morphological similarities has shown to be an effective tool in paleoenvironmental reconstructions. Thus, beneath this point of view, the benthic foraminifers from the middle Eocene strata of the well SE-2, Sergipe/Alagoas Basin, were studied. That basin is located in the northeastern Brazilian coast, and comprises Paleozoic to Recent strata. In this work, only the Group Piaçabuçu from the Eocene were investigated. Previous studies identified Paleocene/Eocene climatic evidences of global changes, assessed by planktic foraminifers and palinomorphs. Stratigraphic distributions of main species characterized the studied range in the Middle Eocene.

After conventional treatment for foraminiferal analyses, 13 functional morphgroups were recognized, being the hyaline calcareous morphogroups (CH-A.6, CH-A.5 and CH-B.4) the most representatives. Relations were established between the morphgroups and other foraminiferal groups: planktonic and benthic, epifaunal and infaunal benthics and calcareous-hyaline genera. The foraminiferal abundance events show a positive relation with the terrestrial and marine palynomorph groups. The interpreted paleobathimetric conditions were upper bathyal-outer neritic. Transgressive phase (dominance of planktonic foraminifers in the assemblage and abundance of marine palynomorphs) followed by regressive phase (dominance of benthic foraminifers and abundance of terrestrial palynomorphs) were observed, and the evidence of sediment transport from shallow waters (macroforaminifers). The deposition of sediments in cold waters was confirmed by the abundance of *Enneadocysta* (Dinoflagellate) and *Tasmanites* (Prasinophyta) and by the oxygen isotope data. *Lenticulina* is the most abundant foraminifer genus in almost all the interval. However, there is a positive relationship between continental and marine palynomorphs, and morphogroup abundances of benthic calcareous hyaline, particularly *Bulimina*, *Eponides, Globobulimina* and *Cibicidoides* genera. They indicate high organic productivity and low oxygen bottom waters in the range.

## Cretaceous planktonic foraminiferal biostratigraphy of DSDP Site 356, São Paulo Plateau (South Atlantic)

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Since the mid- to Late Cretaceous time interval records several still poorly understood paleoclimatic and paleoceanographic events, detailed bio-chronostratigraphic studies in sedimentary successions elsewhere are quite relevant to their evaluation. This work presents the biostratigraphic results obtained with a systematic study carried out on planktonic foraminiferal assemblages recovered from Cretaceous strata (Turonian? to Maastrichtian) of the Site 356, São Paulo Plateau, Deep Sea Drilling Program (DSDP),.

Sixty core samples were analyzed and treated following the conventional methodology for calcareous microfossils. Fifty-nine planktic foraminiferal species were identified within the studied interval, enabling the recognition of the following late Turonian to early Danian planktonic foraminiferal zones: *Dicarinella concavata, D. asymetrica, Globotruncanita elevata, Contusotruncana plummerae, Radotruncana calcarata, Globotruncanella havanensis, Pseudoguembelina palpebra, Abathomphalus mayaroensis*, and Pα.

An unconformity spanning at least 0.96 Ma can also be suggested within Core 31 (Maastrichtian in age), due to absence of the *Racemiguembelitria fructicosa* Zone from the studied section. High sedimentation rates were estimated in the Santonian (35.6 m/Ma.; *Dicarinella asymetrica* Zzone) and in the uppermost Maastrichtian (22.5 m/Ma; *Pseudoguembelina hariaensis* Zone) intervals of the studied site, while lower and more constant values are suggested for the Campanian-lower Maastrichtian interval (from 5.4 to 9.6 m/Ma; *Globotruncanita elevata* Zone to *Pseudoguembelina palpebra* Zone). The identification of high sedimentation rates within the *Dicarinella asymetrica* Zone is in accordance to previous studies, which have suggested the same pattern for Santonian strata in some Brazilian marginal basins, including the closely related Santos Basin. The reliability in identifying the *Contusotruncana plummerae* interval zone in Campanian strata of South Atlantic Ocean is also confirmed herein.

## Paleoceanographic changes in Santos Basin (Brazil) over the last ~570 ka

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The Mid-Brunhes Event (MBE, from ~600 to ~200 kyr) represents a major climatic decoupling of climate conditions in different latitudes with glacial-to-interglacial contrasts up to 8°C. It is also marked by strong increase in the accumulation of carbonate in the oceans that might have been caused by the proliferation of phytoplankton. Little is known about long-term temporal fluctuations of productivity and oceanographic changes during the MBE in the southwestern Atlantic continental margin. Based on a integrated analyses (planktonic and benthic foraminifera, oxygen and carbon isotopes and magnetic susceptibility) carried out in two Jumbo Piston Cores collected on continental slope of Santos Basin (Brazil) the paleoceanographic oscillations of the last ~570 kyr. is presented. Stratigraphic control was provided by benthic isotopic records and the integrations of foraminiferal biostratigraphy, and abundance patterns coupled with isotopic records.

These records showed changes in the superficial availability of nutrients and their export to the seafloor during the Pleistocene – Holocene Period (last ~570 kyr, MIS 13-1) and mainly during the MBE. The differences observed in the amplitude of planktonic and benthic $\delta^{18}O$ and $\delta^{13}C$ variations indicate that temperature, salinity and productivity changes occurred successively in the surface and deep water in relation to past climatic changes in Santos Basin. The results revealed long-term (~100 kyr.) oscillations in the superficial productivity along the Middle Pleistocene (increase in the superficial productivity between ~500 to 400 kyr. and ~300 to 200 kyr. and decrease between ~400 to 300 kyr.). These long-term oscillations are interrupted by short-term changes (~30 kyr.) that mark the transition periods (higher productivity between ~425-400 kyr. and ~190-160 kyr., and lower between ~290-260 kyr.). These oscillations in the superficial waters might have promoted different organic matter export to the sea floor and, therefore, leading to higher abundances of both foraminifera and phytodetritus/opportunistic benthic foraminiferal species (*Epistominella exigua Alabaminella weddellensis* and *Cassidulina californica*).

## Biostratigraphic analysis based on Cenozoic planktonic foraminifera from DSDP Holes 356 and 356A (LEG 39)

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This study presents biostratigraphic remarks based on the stratigraphic ranges of the planktonic foraminiferal species recovered from two holes drilled on the southeastern São Paulo Plateau, eastern Brazilian continental margin. Thirty samples were analyzed from the DSDP Leg 39, holes 356A (between 19,50 m and 37,50 m depth) and 356 (between 38 m and 94,50 m depth). The well-preserved planktonic foraminiferal fauna recovered from DSDP holes 356 and 356A enabled the identification of 51 species, assembled into 20 genera and seven families, which stratigraphic ranges suggest a Cenozoic age, from early Miocene to Pleistocene.

The biostratigraphic analysis of the studied assemblages enabled the recognition of the early Miocene M1a subzone and the M2 zone, the middle Miocene M11 zone, the early Pliocene PL1b subzone, and the Pleistocene Pt1 zone. In DSDP Hole 356A, the zones M2 (early Miocene; between 36,72 m and 29,73 m depth) and Pt1 (Pleistocene; between 24,72 m and 20,21 m depth) and the subzone PL1b (early Pliocene; between 28,25 m and 24,72 m depth) were identified. In DSDP Hole 356, the zones M2 (early Miocene; between 65,25 m and 41,75 m depth) and M1 (early Miocene; at 41,75 m depth), as well as the subzones M1a (early Miocene; between 93,75 m and 86,25 m depth) and PL1b (early Pliocene; between 40,25 m e 38,75 m depth) were identified.

From the biostratigraphic analysis, two unconformities were suggested: (a) between the M2 and the M11 zones (early to middle Miocene in age), at the depth of 41,75 m in DSDP Hole 356; (b) between the PL1b subzone to the Pt1 zone (early to late Pliocene in age), at a depth of 24,72 m in DSDP Hole 356A.

## *Antarcticella* and *Ammoelphidiella*, typical austral Cenozoic extinct genera from southernmost South America

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The Patagonia was flooded by Atlantic transgressions in the Maastrichtian-Danian, late mid-Eocene, late Oligocene-early Miocene, and mid-Miocene; only in the Fuegian Andes the permanent marine conditions results in a rather complete Cenozoic sequence. Both areas provide an extended latitudinal and chronological study area, where most of the characteristic and abundant calcareous benthic foraminifera, endemic to southern high latitudes, have a partially or totally tuberculate test surface. They include the extinct genera *Antarcticella*, a small spherical form initially assigned to a planktonic habit, and *Ammoelphidiella,* a trochospiral Elphidiidae, both genera originally described from Antarctica; the origin of *Antarcticella* might be found in a Maastrichtian low spired and tuberculated new genus endemic to northern Patagonia. *Antarcticella* appears abruptly after the Cretaceous/Paleogene boundary, recorded by *A. pauciloculata* (Jenkins) from the Danian of New Zealand, Antarctica and Patagonia; *A. cecionii* (Cañón and Ernst), is constrained to the late early-early middle Eocene of the Fuegian Andes; *A. antarctica* (Leckie and Webb), originally described from the Antarctic latest Oligocene-early Miocene, ranges from the Fuegian late Eocene up to the mid-Miocene, reaching Peninsula de Valdes Basin (43°LS) in the early Miocene. Because micro and megalospheric tests are dissimilar and exhibit some differential

paleogeographical distribution, the abundant microspheric tests are considered the typical form, and the megalospheric ones are informally named: *A. pauciloculata* forma *primitiva,* from the Danian of the Colorado and San Jorge basins; *A. cecionii* f. *noguerense*, from the Fuegian lower and lower middle Eocene; and *A. antarctica* f. *incognita*, from the Fuegian late mid-Eocene. The benthic habit previously assigned to *Antarcticella* is confirmed by: the accentuated dimorphism, unknown in planktonic foraminifera; the opportunistic behavior suggested by its distribution in different paleoenvironments, and by its abundance in organic-rich settings in correspondence with the preferences of similar modern spherical infaunal morphotypes. *Ammoelphidiella*, originally described from the Antarctic Pliocene, is recorded by a new species from the early Miocene of the Austral Basin up to the late early Miocene in the Colorado Basin. The geographic distribution of *Antarcticella* and *Ammoelphidiella* reveals the major penetration of Antarctic waters in the early Miocene on the Patagonian Platform. The tests of both genera share a preferential bioerosion among associated foraminifera and could be one of the causes that contributed to their disappearance in the late Pliocene. Projects PIP 0820 (CONICET, Argentina); CGL2011–23077 and CGL2011-22912 (Spanish Ministerio de Economía y Competitividad, co-founded by FEDER funds).

## Microperforate planktonic foraminifera from the late Maastrichtian-Danian of Bajada del Jagüel, Neuquén, Argentina

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Microperforate planktonic foraminifera characterize the late Maastrichtian and Danian of the Bajada del Jagüel section, Neuquén Basin, a shallow marginal basin at mid southern latitudes. The late Maastrichtian is characterized by the abundance of the triserial genus *Guembelitria,* represented by *G. cretacea* Cushman, *G. blowi* Arz, Arenillas and Náñez and *G. dammula* Voloshina. This genus absolutely dominates the planktonic assemblages in the last two meters of the Maastrichtian, except for a small peak of biserial species at ca. 40cm below the Cretaceous/Paleogene (K/Pg) boundary. The associated benthic assemblages are relatively diverse, suggesting stable conditions.

The first meter of Danian sediments, including the K/Pg boundary bed, contains foraminiferal assemblages of a very low p/b ratio, where planktonics are represented by the serial genera *Guembelitria* and *Woodringina/ Chiloguembelina*. Planktonic species indicative of the *Parvularugoglobigerina eugubina* biozone were not found. Towards the upper part of this first meter, biserial planktonic foraminifera (*Woodringina*/ *Chiloguembelina*) increase in abundance relative to triserials and are associated with a low diversity benthic assemblage dominated by *Antarcticella pauciloculata* (Jenkins). This small opportunistic species endemic to southern high latitudes and apparently of polar origin, was originally assigned a planktonic habit, and later regarded as a benthic species. At Bajada del Jagüel, it abruptly appears just after the K/Pg boundary. This assemblage characterized by *Antarcticella* and planktonic biserials occurs in a horizon with diffuse lamination suggesting deficiency in oxygen content. An acme of biserial planktonics has been described elsewhere in the Danian but local factors cannot be disregarded.

Upwards in the section, p/b ratio increases and planktonic assemblages become more diverse suggesting a relative increase in sea level. They include abundant low trochospiral, normal perforate taxa; among microperforate taxa, *Globoconusa daubjergensis* (Brönnimann) is dominant; serial planktonic foraminifera are also common, including "*Guembelitria"* spp. and *Trochoguembelitria alabamensis* (Liu and Olsson). These planktonic assemblages are associated with the cosmopolitan Midway-type benthic

assemblage. Thus the section provides opportunity to analyze the paleoecology and evolution of the wall texture of microperforate planktonic foraminifera in the late Maastrichtian-Danian from southern mid latitudes.

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## Variations of benthic foraminiferal biomass in response to gradients of organic matter and redox conditions off the Central Peruvian coast

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One ecological aspect in the upper Central Peruvian margin still not well known is the contribution of foraminiferal biomass to the benthic communities within the OMZ, which would furnish valuable information in terms of energy flux and carbon cycling. The presence of strong phytodetrital carbon fluxes and extreme dysoxic bottom waters, make for high densities of benthic foraminiferal communities.

Diversity and vertical distribution of benthic foraminifera on the continental shelf off Callao appeared to be governed by redox conditions and labile organic matter. Clearly, those controlling factors might rule biomass as well and could be very useful to explore differences in foraminiferal communities. Thus, the benthic foraminiferal biomass was assessed in two bathymetric transects off Callao (12° S) and Pisco (14° S) during April 2009, 2010 and 2011 in relation to bottom-water dissolved oxygen (BWDO), quantity (chlorophyll *a* and chloroplastic pigment equivalents (CPE)) and quality (chlorophyll *a*/phaeopigments ratio, carbohydrates (CHO), proteins (PRT)) of sedimentary organic matter (OM) and bulk properties (total organic carbon and total nitrogen) for the top 1cm of sediment. Pore water sulfide ($H_2S$) was used as a proxy of redox condition for their vertical microhabitat. Calcareous and agglutinated foraminiferal biomass was estimated based on maximum length of the cell applying the carbon/diameter ratio for species of similar shape and size previously calibrated. For allogromids, we considered the calculation of the volume of the test by approximating the cell shape to a sphere or prolate spheroid and elongated shapes.

Highest values of total biomass (~ 2000 mg.C $m^{-2}$) were found which are close to the estimates of previous studies recorded for this region suggesting an important budget in terms of organic carbon. Total carbohydrates on sediment showed different profiles correlated with biomass in both areas. Biomass in *Nonionella auris* correlated better with pore water sulfide firming up the importance in other processes such denitrification due to their large biomass. We concluded that biomass as well as the other community parameters seems to be governed by quality of organic matter.

## Preliminary analysis of the latitudinal distribution of the Holocene planktonic foraminifera from the Southern Brazilian continental margin: The water masses influence

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The pattern of latitudinal distribution of planktonic foraminifera is controlled by several environmental parameters, being the temperature of surface waters the most important of them. The southern Brazilian continental margin is under influence of the Subtropical Convergence, also known as Zone of Subtropical/Subantarctic Convergence (ZSCT). A ZSCT results from the mixture of tropical surface warm waters from the north and a cold water mass of subantarctic origin. In this study, 27 sedimentary samples from the outer shelf and upper slope off Rio Grande do Sul and Santa Catarina states (between 28° and 34°S) were studied.

Twenty-six species of planktonic foraminifera (n=4969) were identified, but only the most frequent were used in the faunal distribution analysis. It was possible to share the fauna into two groups, according to the abundance and relative frequency. Species typical from warm waters present higher frequency in the study area (89%; n=4257) and increase their percentage northward, which suggests a predominant influence of tropical waters. This group is characterized by higher incidence of *Globigerinoides ruber*, *Globorotalia menardii*, *Globigerinoides conglobatus*, *Globigerinoides trilobus* and *Neogloboquadrina dutertrei*.

In the southern limit of the study area, it is observed an increase in the frequency of typical cold water species (11%; n=526), meaning the increase of the influence of subantarctic waters, as demonstrated by the occurrence of the species *Globorotalia inflata*, *Globorotalia truncatulinoides* and *Globigerina bulloides*.

## Live benthic Foraminifera from the open continental slope and canyons in the subtropical SW Atlantic

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We present an ecological study of live (Rose Bengal stained) foraminifera from 14 sites collected in the open slope and Almirante Câmara and Grussaí canyons, located at the northeastern part of the Campos Basin, SW Atlantic. The stations were sampled in three replicates along a bathymetric transect, from 400 m to 1300 m water depth, in two occasions, austral autumn/winter of 2008 and summer of 2009. The main objective of our study is to investigate changes on the foraminiferal density, composition and biomass along the two transects as a response to the sedimentological parameters, quantity and quality of organic matter.

The study area is characterized by fine silt, and total organic carbon (TOC) and concentration of total lipids (sum of 38 fatty acids, 17 sterols, 16 *n*-alcohols and phytol) ranging from 4.51 $\mu g\ g^{-1}$ to 22.73 $\mu g\ g^{-1}$ and from 3.4 $mg.g^{-1}$ to12.1 $mg.g^{-1}$, respectively. Higher TOC values and an enrichment of autochthonous lipids derived from primary production and zooplankton/fauna were observed at the canyons in stations collected at 400 m and 1000 m, in comparison to the open slope. Calcareous hyaline and agglutinated species (e.g., *Bolivina pacifica, Cassidulina crassa, Cassidulinoides bradyi*, *Epistominella exigua, Globocassidulina subglobosa, Nonionella opima, Reophax spiculotestus, Trifarina bradyi, Uvigerina peregrina*) are abundant in the open slope and canyons. However, higher density and biomass values and lower diversity values are observed in the canyons. Our data suggest that the submarine canyons have a role in the trapping of labile organic matter, and also show implications on the benthic foraminifera

ecology in the SW Atlantic. . The comprehension of these implications is important in the future monitoring in this area.

This is a contribution of the “Habitats Project – Campos Basin Environmental Heterogeneity" by CENPES /PETROBRAS.

## Early Neogene temperature and trophism by means of planktonic foraminifera in the Colombian Caribbean (NW of South America)

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Planktonic foraminifera have been a fundamental proxy for understanding changes occurred during the closure of the Atlantic-Pacific seaway through the Panama Isthmus. Different studies have been focused on reconstructing ecological, oceanographic and climatic variations that were established by this geographic barrier during the Neogene. Most of these studies have been carried out in the Caribbean offshore through different ocean drilling projects (DSDP, ODP, IODP). However, studies on onshore sequences are still scarce.

Along the Colombian Caribbean (NW South America), different units have recorded oceanic and climatic variations caused by the tectonic closure between the Panama Arc and the South American Plate. In recent years, some continental drilling projects in the San Jacinto fold belt (NW Colombia) performed by the National Hydrocarbon Agency of Colombia have allowed to identify new paleoceanographic and paleogeographic aspects of the stepwise continental connection between Central and South America during the Neogene. Some of these wells comprise bioevents between the last occurrence (LO) of *Turborotalia ampliapertura* (Oligocene) and the LO of *Fohsella peripheroronda* (middle-late Miocene). The benthic vs. planktonic foraminifera ratio suggests transgressive environments with some intervals in which facies indicate shallowing towards the top of the wells. Additionally, temperature and trophic index of planktonic foraminifera indicate that waters were dominantly warm and oligotrophic (e.g. dominance of Globigerinoides spp.); with only two exceptions, the Burdigalian and the Langhian-Serravallian transition, when some species indicative of cold and eutrophic waters appear (e.g., *Turborotaloides* spp.).

Changes in the water domain, from warm/oligotrophic to cold/eutrophic conditions are remarkable in both the Pacific and the Caribbean region. Probably these events are related to the initial establishment of continental barriers, which disrupted and caused a reorganization of the oceanic circulation. Recent studies on the Colombian Pacific margin have established similar paleoclimatic and paleoceanographic conditions in the eastern equatorial Pacific during Neogene. Those conditions are synchronous with those reported in this study. Finally, our new data facilitate bio-geological comparisons between the Pacific and Caribbean margins of Northern South America during the early Neogene.

## Early to middle Miocene oceanographic conditions in the Pacific margin of NW South America through planktonic foraminiferal results

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The onshore stratigraphic section of Ladrilleros–Juanchaco (SW of Colombia) is a terrigenous succession, composed principally of bioturbated marine mudrocks and turbiditic sandstones. This section is the most well preserved sequence from Neogene in the Pacific coast of northern South America. The micropaleontological recovery (planktonic foraminifera, calcareous nannofossils, and diatoms) indicates a temporal range between the Burdgalian (16,27My) and Tortonian (10,88My). The microfossils and facies analyses were also used to determinate paleoenvironmental and paleoceanographic conditions.

We calculate the ratio of warm-oligotrophic vs. cold-eutrophic planktonic foraminifera which allowed us to elaborate a paleoclimate and paleceanographic reconstruction for this section. In general index shows a trend towards colder and more eutrophic conditions along the section studied.

From the bottom (16, 27 My) to the middle part of the section (12, 9 My), the sequence is characterized by dominance of mudrocks and a good preservation of Planktonic foraminifera. The comparison between foraminifera assemblages and other calcareous and siliceous microfossils indicates a strong relation with stratified ocean waters, prevailing warm-oligotrophic conditions. Nevertheless, an important peak in the curve was observed at 12.9 My, where cold species (*Gg. bulloides, Gg. glutinata* and Neogloboquadrinids) decreased in abundance while the warm-oligotrophic species (*Gs. obliquus, Gs. sacculifer, O. universa and Gg. apertura*) were dominant, this event occurs just before the middle Miocene Antarctic ice sheet expansion.

From 12,9 My to the top (10,88 My) of the section the microfossil association suggests cold-eutrophic conditions related to major increases in the primary productivity. In this interval, the preservation and recovery of planktonic foraminifera is low. Furthermore, diatoms and calcareous nannofossils indicate an influence of California and Chile-Perú currents. At the same time, an important regional hiatus (NH3) marked by the abrupt changes in the sedimentation rates and calcareous microfossils preservation can be identified. Also, growth faults, slump and convolute structures are common and suggest tectonic disturbance during the sedimentation.

These evidences can be associated with one of the most remarkable rising pulses of Panama arc and the collision between Caribbean plate against the NW margin of Colombia around to 12,9 My.

## Two vs. three-dimensional biometry on late Eocene larger benthic foraminifera in Western Cuba

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X-ray computer tomography has been developed during the last years into a powerful tool to enhance and understand the paleobiology of larger benthic foraminifera. This method enables a three-dimensional biometric quantification of the morphological features without specific shell preparation and destruction. Equatorial and axial virtual sections are simultaneously visible and there are a number of new parameters which are now measurable such as volumes, surfaces, ornamentation patterns and, concerning larger foraminifera, the full geometry of the canal and stolon system might be displayed. As long known, Tethyan and the Caribbean larger foraminifera had different evolutionary histories but possess similar evolutionary tendencies (e.g., test and embryo size change, sexual dimorphism). Since these two faunal provinces are known (and together with these there are many other provinces in the indo-pacific and in the western-pacific areas) scientists have tried to somehow correlate them to better understand biostratigraphic differences as well as chronostratigraphic boundaries. Can CT techniques help in solving these problems? Are there parameters to measure to better identify evolutionary tendencies of these very similar cells? To tackle such open questions we present here the preliminary results of two and three-dimensional biometry on some important taxa collected in the Caribbean realm to check if two dimensional biometry matches the three dimensional data. Some specimens of *Lepidocyclina (Neolepidina) pustulosa*, *Asterocyclina minima* and *Heterostegina ocalana* have been scanned at the University of Vienna by means of microCT.

On the first two taxa, the following parameters were measured: volume and diameter of the embryonic apparatus; volume, number, width and height of the adauxiliary chamberlets and of the equatorial chamberlets within XX mm from the nepiont. On the specimens of *H. ocalana*, the following characters were measured: proloculus volume and diameter, number and surface extension of pre-heterosteginid chambers, number and surface extension of chamberlets in chamber 14 and volume, width and height of all chambers. We have compared the biometric data obtained by 3D modelling with the classic two dimensional analysis and it seems that several two dimensional parameter have to be possible either reconsidered or might cause larger misinterpretations. However, the correlation of two dimensional with the three dimensional data might be a possible solution to better correlate biometric differences along different faunal provinces.

## Benthic Foraminifera in the southeastern Brazilian continental margin: Environmental controlling factors

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The benthic foraminifera recovered from 15 surface (0-2cm) sediment samples of SW Atlantic (between 23° 20 S and 25º 02 S latitude and 43º 50 W and 45º 10 W longitude) were analyzed along a bathymetric transect, from 45 m to 1132 m water depth, in order to understand their spatial distribution patterns and their relationship to environmental factors. In this region, the current structure is linked to the displacement of the South Atlantic western boundary current system. The Brazil Current (CB, from surface to 500 m depth) flows to southward whereas the Intermediate Western Boundary Current (IWBC, from 500 to 1200 water depth) flows northward. Coastal and shelf break upwelling can occur, with

penetration of the South Atlantic Central Water (SACW) into the euphotic zone in the shallower regions, enhancing the primary productivity in the superficial waters. Living and dead specimens of benthic foraminifera were selected for identification and quantitative analysis from >63 μm size fractions (63 to 500 μm). Multidimensional scaling analyses show the similarity between the samples collected on the shelf and upper/middle slope (Group 1: 45 to 1100 m water depth) and middle slope (Group 2: 621 to 983 m water depth). Food supply seems to be an important environmental factor determining the distribution pattern of the benthic foraminifera. All groups are characterized by the dominance of *Bulimina marginata, Cassidulina laevigata*, *Globocassidulina subglobosa* and *Uvigerina peregrina*. The occurrence of these species seems to be related to seasonal organic matter fluxes/phytodetritus flux and strong currents, both phenomena originated from Brazil Current System (CB, IWBC, meanders and vortex). Group 2 is also distinguished by the species *Reophax scorpiurus* and *R. dentaliniformis*, which probably indicate occurrence of refractory organic matter in the medium slope. The trapping of this refractory organic matter can be promoted by local morphology (gullies/channels).

## Biostratigraphic and paleoenvironmental interpretation of the Pelotas Basin Miocene Section, Brazil

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Integration of microfossils (foraminifera and palynomorphs) and chemostratigraphy analyses is applied in biochronostratigraphic and paleoenvironmental interpretation of the Miocene (Langhian - Burdigalian) section from a core taken from an offshore well drilled in the Pelotas Basin, in the Brazilian southernmost continental margin. The studied core represents an eighteen-meter section of grayish shales containing abundant calcareous microfossils (foraminifera and ostracoda).

A quantitative analysis of biostratigraphically significant planktic foraminifera species was made and seven species were selected to be counted (*Dentoglobigerina baroemoenenis*, *D. altispira*, *Globigerinoides bisphericus*, *Globoquadrina dehicens*, *Praeorbulina glomerosa* s.s., *P. sicana* and *P. transitoria*). The stratigraphic distribution of those taxa in the interval between 1,300 and 1,307.3 m made possible the recognition of two biozones (M5 and M6) and two subzones (M5a and M5b) of middle Miocene age (Langhian). Accessory species such as *Globigerinatella insueta*, *Globigerinoides altiaperturus* and *Globorotalia archaeomenardii* reinforced this biostratigraphic assignment. The highest occurrence of the species *Catapsydrax dissimilis* at 1,307.3 m indicates the top of the biozone M3 of early Miocene age (Burdigalian). Relative ages derived from $^{87}Sr/^{86}Sr$ ratio were obtained from three samples collected from the studied core upper portion (1,300 – 1,304.05 m) and varies from 15.28 to 16.6 Ma (Langhian) corroborating the chronostratigraphic positioning given by planktic foraminifera biostratigraphy.

Regarding the paleoenvironmental interpretation, benthic foraminifera and palynological content provided indications of paleobathimetry and distance from the continent. The benthic foraminifera assemblage is mainly composed of calcareous taxa, especially nodosariids (*Lenticulina, Marginulina, Marginulinopsis* and *Saracenaria*) and subordinately rotaliids (*Cibicidoides*, *Gyroidinoides* and *Siphonina*).

The palynological content was composed of sporomorphs, dinocysts, microforaminiferal linings, phytoclasts and amorphous organic matter (AOM). Among the studied samples, the basal sample (at

1,308.55 m) contains only AOM, while the uppermost samples (1,301.15 m - 1,304.05 m) were palynologically barren. Dinocysts are abundant, particularly the genera *Hystrichosphaeropsis, Nematosphaeropsis* and *Operculodinium,* which indicates an outer neritic environment.

## Session 3: Fjord Foraminifera

## Keynote Lecture

### Fjord foraminifera as environment indicators: pro and contra

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Fjords are valleys eroded by glaciers and flooded by the sea. As such, fjords occur at high and middle latitudes.

The taxonomy of fjord foraminiferal, particularly in the Northern Hemisphere, has been scrutinized. The environment of many fjords and even of their individual basins is studied in detail, including the oceanography, lithology, biota, etc. This advanced knowledge facilitates our understanding of the distribution and dynamics of foraminiferal populations in fjords. The genesis and morphology of fjords are well understood; it is relatively easy to locate coring sites with continuous sedimentation. Silled fjord basins are natural sediment trap and accumulate thick sediment packages that may provide archives with resolutions as high as decades and even years. Anoxia tends to build up in deep fjord basins. The fossil record of foraminiferal faunas is a reliable means to unveil the history of anoxia events. The shores of some temperate fjords are densely populated, and the ecosystems have been impacted. The fossil foraminiferal record is the unique tool to trace back the preindustrial reference conditions, the deterioration of the environment, and finally the effect of amelioration.

Troubles do accompany studies of fjord foraminifera. Fjords often demonstrate strong head-to-mouth gradient in the environmental variables, and many characteristics change in accord. Therefore it stays impossible to single out the driving factor of the foraminiferal distribution. The interplay of local factors creates a complex system: tidal, geostrophic and wind currents deflected by the rugged seafloor, discharge of streams, local blooms. The distribution of foraminifera in this patchy environment is difficult to interpret. Sampling grids should be denser than those in the open sea; replicative sampling is a necessity; this makes fjord studies time consuming. Calcareous foraminiferal shells provide stable isotopic record. Yet the isotopic signal is noised by local processes, as often the case with any coastal waters. The fjords are glacial valleys and as such are restricted to the Polar Regions. Conclusions drawn here are hardly applicable to warm coastal waters.

Foraminifera are helpful indicators of fjord environments, but these studies have own pitfalls we need to be aware of.

## Oral Presentations

### Benthic Foraminifera as palaeoenvironmental indicators of the last Millennium and Holocene

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The first decadal-scale reconstruction of British coastal temperature anomalies spanning the last millennium is presented from a sea loch (fjord) basin, Loch Sunart, NW Scotland (Cage & Austin, 2010). Based on modern observation and the results of previous numerical modeling of fjord circulation, benthic foraminiferal oxygen isotope records are interpreted as a record of summer temperature. We review these results in light of recently published data from a long-lived marine bivalve species, which appear to support the sediment-based reconstruction and its chronology (Reynolds *et al*., 2013).
In this paper, we revisit the role of benthic foraminifera in the generation of this unique palaeoenvironmental record and critically evaluate some of the key aspects of foraminiferal ecology/palaeoecology requiring further research effort. In particular, we focus on the concept of the "seasonal effect" on shell biogeochemistry and the potential uncertainty this introduces to middle- and high-latitude shelf sea palaeoceanography, particularly in light of modern molecular techniques and our morphologically-based concept of the species.

Cage, A.G. and Austin, W.E.N., 2010. Marine climate variability during the last millennium: The Loch Sunart record, Scotland, UK. *Quaternary Science Reviews*. doi: 10.1016/j.quascirev.2010.01.014
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### Foraminiferal communities of modern hydrocarbon seeps from fjord settings of northern Norway, Hola-Vesterålen: A taxonomic and ecologic study

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The present study investigated total (unstained) benthic foraminiferal assemblages from surface sediments (0-1cm, >100 µm size fraction) from Hola-Vesterålen around 68°55 N 14°17 E, Norway at around 220 m. Previous studies have reported active natural hydrocarbon seepage in the Hola area and the stable carbon isotopic composition of methane in the sediments suggests a thermogenic methane source. A control sample site from Ullsfjorden was also studied from 69°46 N 19°47 E, which lies about 278 m.

The seep-assemblage (> 2% abundance) is composed of *Cibicides lobatulus*, *Cassidulina laevigata*, *C. reniforme*, *Discanomalina coronata*, *Textularia agglutinans* and *Trifarina angulosa.* Epifaunal *Cibicides lobatulus* composes around 60% of this assemblage. It prefers coarse sediments and can withstand high energy. Shallow infaunal to epifaunal *Cassidulina carinata* and *C. laevigata* composes around 10% of the

seep-fauna. *Cassidulina carinata* is an opportunistic species preferring moderate to high carbon flux rates. Epifaunal attached *Discanomalina coronata* (~6%) is a living coral facies dweller (indicator species to identify active cold-water coral mounds) withstanding strong bottom currents. *Textularia agglutinans* (~2%) is more abundant in silty clay sand than in silty clay. Infaunal *Trifarina angulosa* (~18%) occupies sandy high energy areas and can withstand permanent winnowing and redeposition.

The non-seep foraminifera assemblage (> 2% abundance) is represented by *Bulimina marginata*, *Cassidulina laevigata*, *C. reniforme*, *Globobulimina notovata*, *Melonis barleeanum*, *Nonionella labradorica* and *Reophax scorpiurus*. Infaunal fauna *B. marginata* (~9%), *M. barleeanum* (~9%), and *N. labradorica* (~16%), are known to be typical for muddy/silty to sandy substrata, to prefer high organic matter input, and to thrive under suboxic-dysoxic conditions. A chemical study of pore water and sediments confirms high concentrations of $H_2S$ and organic carbon.

Seep samples with low diversities also contain deformed individuals of *C. lobatulus* (3.4-6.5 %), similar to those reported for a gigantic oil spill from a tanker or for environments polluted with heavy metals. However, it is an attached form and prefers hard substrates. Thus the variability in the shape of the test in this species is primarily caused by the nature of the substratum. Therefore it is difficult to note the recorded abnormal or deformed species with variable shapes to be as only due to seep-influence, particularly since we do not find deformities in any other species. This can be verified with further isotope studies.

## Distribution of Foraminifera in the Southern Puget Sound, Washington State, USA

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The Puget Sound is the southern portion of the Salish Sea, a complex fjord system located in Washington State, USA, and British Columbia, Canada. Puget Sound is regularly flushed with normal marine waters because of a significant tidal flux. Over the last 150 years the entire Puget Sound system has been subjected to significant anthropogenic impacts. The Puget Sound region continues to have rapid population growth and is home to 6 million people. The combination of rapid growth and a history of anthropogenic impacts highlight the need for the development of biologic models to track the health of the Sound. Unfortunately, there are few published studies of foraminiferal distribution in the Puget Sound. This paper marks the first published record of the foraminiferal fauna in the southern portion of the Puget Sound.

The South Sound is the most distal to open marine connection, and is characterized by narrow channels, restricted inlets, and islands. As a result, despite the tidal flux, water residence times average 36-64 days depending on season. Surface salinity varies seasonally, but bottom water salinity is stable with an annual range of 25-29 ppt. Surface temperatures during the winter sampling period ranged from 7-10$^{o}$ C.

A series of 125 grab samples were collected in the South Sound during December and January in the years 1988-1991 by Robert Harmon (Shoreline Community College). Oceanographic settings range from restricted shallow bays to open inlets with depths from 1-150 meters. Sediment composition ranges from gravel to mud. Generally shallow water samples contain higher percentages of coarse clastic and deeper samples are mud dominated. Shallow samples contain appreciable amounts of plant material. All samples contained at least a limited foraminiferal fauna with a total of 19 genera and 25 species identified. Of these 15 species are calcareous and 10 are agglutinated. Species dominance is high in all samples with most dominated by a few species. The most common species are *Elphidium excavatum, Buccella frigida,*

*Elphidiella hannai, Eggerella advena*, and *Lagenammina arenulata*. Other species occur in high abundance in isolated samples but generally comprise a small part of the fauna. Some samples show sediment indicators of low oxygen conditions. However, the absence of *Ammonia beccarii* prevents the use of the *Ammonia-Elphidium* hypoxia indicator. The Foraminifera distribution in these samples provides a baseline for mapping faunal changes in future sampling. Future work will include examination of samples collected by the Washington Department of Ecology in summer 1999 and 2011 and new winter re-sampling program to evaluate seasonal effects.

## Investigating multiproxy shallow marine Holocene records from the region of the Western entrance of the Strait of Magellan (53°S), Chile

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Shallow marine Holocene records of benthic foraminifera and sedimentological proxies from two locations branching off opposite sides of the Strait of Magellan (53°S) are examined to derive regional rather than local palaeoenvironmental signals.

The general palaeoenvironmental history derived includes oxygen-depleted environments during the early Holocene, when the superfamily *Buliminacea* dominated the assemblages on both sides of the Strait. A tephra stratum chemically linked to the Hudson volcano (dated in the literature at *ca*. 6850 $^{14}$C a BP), in these records seems to coincide with the onset of what can be interpreted as the hypsithermal in this region. This period is represented by higher diversity indeces, assemblages dominated by detritivorous and temperate taxa (genera *Epistominella* and *Cassidulina*) and a higher abundance of species from deeper and more open marine environments. This suggests warmer temperatures and higher productivities when relative sea levels were at a higher stand at a global and regional scale. The presence of mineral-debris material is more common during the late Holocene, after a fall in relative sea levels established present-day conditions. The genus *Casidulinoides*, common in the Southern Ocean, might represent the influence of oceanic currents reaching the Strait. This implies that influence of the Antarctic Circumpolar current (ACC) became stronger in the area only after the mid-Holocene.

Benthic foraminiferal records show that the Churruca site, on the western side of the Strait, remained a stressed (dysoxic) environment since the first foraminiferal colonisation dated at *ca*. 9800 $^{14}$C a BP. Records from the Tamar sites, across the Strait, represent a better-ventilated environment influenced by input from glaciated areas since *ca*. 8700 $^{14}$C a BP (at the base of one of the cores).

## Seasonal variability of benthic foramineferal fauna and its relationship with substrate, depth and MOT in periglacial environment (54,5ºS - 69,5ºW), Chile

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The benthic foraminífera studies in patagonian channels and fjords have been mainly focused still now, to know biodiversity and some general abundance and distribution patterns. For the first time we are analizing the seasonal change and its relationship with the substrate, depth and MOT, in periglacial environment.

The specimens were collected near the Garibaldi Glaciar (54,5ºS – 69,5ºW) in Seno Almirantazgo, Cordillera Darwin, from marine surface sediments from 20-60 m depth, with Van Veen dredge.

A total of 53 samples were collected between autom 2010 to summer 2011, but they were reduced to 25 for calculs. The sediment was sorted in mud, sand and gravel and is calculating the contents of MOT. It was done multivariate analysis (ANOSIM) and ordination test (MDS and RDA).

It was collected a total of 11.288 specimens, classiffied in 76 species, belonging to the suborder Rotaliina (40,2%), Textulariina (28,9%), Lagenina (17,5%) and Miliolina (11,3%).

The highest number of species was collected in winter (44) and the lowest in spring (31). Only about 25%-30% of species have an abundance > 2%. The arenaceous species numbers were relatively constant during the year and the main species were: *Morulaeoplecta bulbosa, Spiroplectammina biformis, Recurvoides subglobossum, Ammobacculites americanus, Recurvoides laevigatum, Reophax dentaliniformis and Recurvoides contortus.* The calcareous species decreased slowly from autom to summer and the main species were: *Nonionella auris, Nonionoides grateloupi, Buccella peruviana s.l., Cassidulinoides parkerianus, Pullenia subcarinata, Globobulimina notovata Angulogerina angulosa, Cibicides dispars, Discorbinella berthelothi, Uvigerina tenuistriata and Uvigerina bifurcata.*

The results show there are no differences related to spatial distribution system (R = 0,159 p = 0,03), and significant differences to seasonal changes (R = 0,754 p = 0,001), except for Spring/Autumn. The MDS (Stress = 0,13) show the same results. According to redundance analysis (RDA), the first two axis of RDA explain the 85% of the variability of foramineferal assemblages.

The percentile of mud and sand and depth were the parameters that contributed most significantly to explain the ordination of the stations. While in smaller gravel and organic matter fraction.

It is concluded that the differences in the seasonal distribution are due mainly to the type of substrate (mud and sand) and depth and to a less extent to gravel and MOT.

## A Holocene benthic foraminiferal record of changing oceanographic and glacial conditions in a Western Antarctic Peninsula Fjord

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Foraminiferal analyses were conducted on samples collected from sediment cores recovered from the western margin of the Antarctic Peninsula during cruise NBP10-01 of the R/V *Nathaniel B. Palmer*. Jumbo piston core JPC 127 was collected from the mouth of Barilari Bay from ~653 m water depth, and JPC 126 was collected from middle Barilari Bay from ~642 m water depth. The cores extend into the Holocene approximately 8000 cal. yBP and 1100 cal. yBP, respectively. Calcareous benthic foraminifera dominate the foraminiferal assemblages with variation in their abundances and some agglutinated taxa shown in principal components analyses results.

In JPC 127 two principal components account for 89% of the variance in the data: PC1is the *Fursenkoina* spp. assemblage; and PC2 is the *Bulimina aculeata* assemblage. In JPC 126 three principal components account for 80% of the variance in the data: PC1 is the *Bulimina aculeata* assemblage; PC2 is the *Fursenkoina fusiformis* assemblage; and PC3 is the *Pseudobolivina antarctica* assemblage.

*Fursenkoina* spp. are often considered opportunists. On the Antarctic margin they often dominate the early benthic foraminiferal assemblage coincident with ice sheet retreat that may be in part due to the production of Fresh Shelf Water (FSW) enhancing their preservation potential. *Bulimina aculeata* dominates in the presence of Upper Circumpolar Deep Water (UCDW). The dominance of *Pseudobolivina antarctica* is interpreted to represent significant ice covered conditions accompanied by High Saline Shelf Water production.

The early Holocene is characterized by the presence of *Fursenkoina* spp. suggesting the production of FSW associated with the retreating Last Glacial Maximum ice sheet. In the middle Holocene the *B. aculeata* assemblage dominates indicating the earliest Holocene incursions of UCDW well into Barilari Bay. Coincident with the Little Ice Age is the *P. antarctica* assemblage and low foraminiferal abundances indicating a return to ice covered conditions. This is followed by alternating occurrences of the *Fursenkoina* spp. and *B. aculeata* assemblages throughout the latest Holocene.

## Detailing the Little Ice Age on the Swedish west coast: a multi-proxy study of a sediment record from Gullmar Fjord

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Gullmar Fjord, on the west coast of Sweden, represents a high-resolution environmental archive due to high sedimentation rates, low bioturbation and negligible tidal activity. In this study we attempt to detail the climatic and environmental changes in NE Europe during the last millennium by using a ca. 8-m long well dated sediment record from the deep fjord basin. According to the $^{14}$C-datings, the record includes the period of the late Holocene characterised by anomalously cold summers and well known as the Little Ice Age (LIA). Using a high-resolution stratigraphy of benthic foraminifera and dinoflagellate cysts along with lithology, bulk sediment geochemistry and foraminiferal $\delta^{13}$C we identify the timing of the cold period, reconstruct its various phases, and discuss the land-sea interactions occurring in the study area during that time. The onset of the LIA is indicated at ~1350 A.D by an increase in abundances of cold-water foraminifer *Adercotryma glomerata* and the cryophilic dinoflagellate cyst *Islandinium* cf. *cezare.* The first phase of the LIA was characterised by a stormy climate and higher productivity, as suggested by a foraminiferal assemblage of *Nonionella iridea* and *Cassidulina laevigata*. The hypothesis of higher productivity is supported by the isotopic and the dinoflagellate cyst records, which show a shift towards

more negative $\delta^{13}C$ values, and a marked increase in the microreticulate cysts of *Gymnodinium nolleri* at the onset of the LIA. The dinoflagellate species *G. nolleri* becomes relict towards the LIA termination and could be also associated with lower surface water temperatures at that time. It is likely that due to land use changes in the second part of the LIA there was an increased input of terrestrial organic matter to the fjord, which is indicated by lighter $\delta^{13}C$ values and an increase of detritivorous and omnivorous foraminiferal species such as *Textularia earlandi* and *Eggerelloides scaber*. The climate deterioration during the climax of the LIA (1675-1704 A.D.) may have driven a decline in primary productivity, as suggested by the increase of agglutinated foraminiferal species, the presence of *Hyalinea balthica,* and a decline of *N. iridea* during that time.

## Early Holocene cold-water coral (CWC) development in northern Norway recorded by benthic Foraminifera, Ostracoda and sedimentary phosphorus

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During the last glacial maximum (LGM), the Lopphavet shelf was at the boundary between the Fennoscandian and the Barents Sea Ice sheets. Although most of the SW Barents sea was ice-free around 15,000 cal. yr BP the timing and pattern of the advances/retreats of the ice-streams during the deglaciation remains in debate. However, the establishment of an interglacial benthic fauna during the Younger Dryas/Preboreal transition is well dated and closely linked to the onset of the modern Norwegian Atlantic current.

We investigated a 282 cm long gravity core recovered in 237 m water depth on an active CWC reef in Lopphavet, Northern Norway. The sediment core is characterized by silty mud from the core base to 67 cm core depth intercalated with 4 distinct IRD layers. The overlying sediment is a biogenic rich sandy mud with occurrence of cold-water coral fragments.

Ninety-four (94) samples at 3 cm intervals were analyzed for phosphorus (P), total organic carbon (TOC) and microfossil (benthic and planktonic foraminifera, ostracoda) content. From the base of the core to 70 cm core depth glaciomarine benthic foraminifera assemblages dominated successively by *Cassidulina renifome-Elphidium excavatum f. clavata* and *C. reniforme-Nonionellina labradorica* show insight in the deglaciation of Lopphavet with glacier-proximal to glacier distal environments. Sporadic occurrences of *Cassidulina laevigata* and *Melonis barleeanum* provide evidence of periodically stronger inflow of the Atlantic water masses. A high-diversified assemblage dominated by *Cibicidoides pachyderma-Cibicides ungerianus* and high contribution of the cold-water coral associated epibenthic species *Discanomalina coronata* highlights the transition to the interglacial sequence.

The mineralogy of the IRD layers was also investigated by light-microscope observations and XRD measurements. Microfossil data provide information about paleo-water temperature, fluctuations in salinity, bottom water oxygenation, sea-ice cover and nutrient supply to the seafloor in Lopphavet during the time interval of 6,800-15,300 cal. yr BP. The optical classification of the ice-rafted clasts of the IRD displays clear differences in composition and origin. The distribution of sedimentary P and organic/inorganic carbon content provide evidence for high productivity periods during the Bolling-Allerod interstadial and during the early Holocene. The development of the CWC coincides with the modification in the organic matter provenance and to increased bottom water oxygenation.

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## The generation of benthic fossil assemblages from living communities: Preservation potential of different microhabitats

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Consideration of benthic foraminiferal fossil assemblage within the upper sediment layers often shows differences with the living community. This is due to differences in species production and preservation among microhabitats occupied by the foraminifera. We investigated foraminiferal production and preservation using a transect of sites on the western European margin of the Fram Straits in the North Atlantic. The primary variable on this transect was changing organic carbon flux to seabed. The foraminiferal living community was documented using rose Bengal and Cell Tracker Green staining. Pore water geochemical profiles (oxygen and carbon isotopes) were measured to quantify seabed geochemical conditions.

We found there are both surficial and infaunal microhabitats across a range of organic carbon fluxes to the seabed. Individual species often live over a range of sediment depths within the habitation zone, and distribution is linked to biostructures in the sediments. Examination of the absolute abundance profiles (AAPs) through the taphonomic zone of the sediments for the empty tests of individual species allowed us to determine what microenvironments yielded the most preservable material for each taxon. The AAPs show both the sediment intervals where each species adds shells to the sediments, and also the degree to which shells undergo taphonomic elimination. Finally, the AAP's allowed us to examine the transformation of the living community into the fossil assemblage.

## Poster Presentations

### Benthic foraminifers from shallow water, Magallanes Strait, Chile

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Although benthic foraminifers from Chilean channels and fjord region have been studied during the last 20 years, almost nothing is documented about shallow water taxa. During summer 2006, it was possible to collect 50 samples of surface marine sediment from Magellan strait, around Carlos III Island, Chile and examine them for to investigate benthic foraminifers. This area is very interesting because it has the influence of Pacific, Atlantic and Antarctic water.

The material was collected from less than 20 m depth (5- 10 and 20 m), washed, dried, sieved and weighted to pick the benthic foraminífera, then they were photografied with SEM. The samples were standarized as specimen per gram.

A total of 57.099 specimens were identified and classiffied in 113 species and 5 suborders: Rotaliina, Lagenina, Miliolina Textulariina and Sprillina. Rotaliina (41%) and Lagenina (28%) were the most abundant taxa. Diversity (H') reach 2 and evenness (J') was more than 60%. Only 4 species have an abundance > 10%: *Globocassidulina rossensis* (12,7%), *Elphidium macellum* (12%), *Ammonia beccarii* (11,4%) and *Cibicides dispars* (10,9%).

Cluster analysis show only one group for depth and for all the area.

The main species in the shallow water, according to Inval (Dufrêne & Legendre 1997) were: *Ammonia beccarii* (65,67), *Buccella peruviana* (63,96), *Cibicidinella variabilis* (62,03), *Cibicides dispars* (67,93), *Discorbis peruvianus* (54,52), *Elphidium macellum* (66,10), *Globocassidulina rossensis* (64,75) and *Lobatula lobatula* (57,78).

This results constrast with previous study in deeper water (20-100 m) in the same area, which report the presence of 76 species, which show as dominant species *Cibicides fletcheri* (23,4%), *Globocassidulina rossensis* (16,8%), *Recurvoides scitulum* (6,7%), *Buccella frigida* (6,4%) and *Angulogerina angulosa* (6,3%).

### Recent Foraminifera assemblages recorded at Reloncavi Fjord (41° S, 72° W), Southern Chile

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The Reloncaví fjord is a highest stratified fjord with a maximum depth at the mouth roughly 450 m and the lowest depths recorded in the head ~50 m. This fjord receives freshwater inputs from the rivers Petrohué, Cochamó, Puelo, and with a river runoff of 250, 35, 670 $m^3 s^{-1}$ respectively and oceanic input from the mouth.

Here, we present the Recent foraminifera assemblage recorded in Reloncaví Fjord following a gradient from the mouth toward the head of the fjord. We compared abundances of foraminifera and other

geochemical proxies (organic carbon, organic matter, N/C ratio, biogenic opal) and oceanographic parameters.

We recollected surface sediments in seven stations (bathymetry 90-260 m) following a section from mouth toward head of the fjord (41.44°S= 72 35W; 41.32-72.19 W). We picked 121 individuals distributed in 10 benthic and 1 planktonic genera. In the stations closer the mouth 2 and 3 the more abundance species were *Bulimina acuelata*, *Globocasidulina rossensis* and *Hoeglundina elegans*. All of these species represents marine cold environments that prefer fine-grain sands as shown by geochemical and sedimentological patterns. For station 3 we only found *Globobulimina pacifica* characterized by living in mud substrate in genera. We recorded higher benthic foraminifera abundance in the mouth with 916 ind $g^{-1}$, and in the station 3 with 10 ind $g^{-1}$ l. We found an important correlation between benthic foraminiferal abundances and grain size, where the highest abundances were registered in the stations closer to the mouth. Thus, the benthic foraminiferal abundance responds mostly to grain size, the source of the organic matter represent by the N/C ratio and salinity influences.

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## A comparison of benthic Foraminifera genotypes across a range of habitats from fjords to open ocean margins

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The foraminiferal fossil record of fjordic environments provides the opportunity for high resolution spatial and temporal palaeoclimate studies owing to their continuous and often rapid accumulation of fine sediments. In some fjordic environments this rapid lay-down of sediment is also coupled with low oxygen levels and hence reduced bioturbidity, and with minimal tidal activity resulting in high resolution sequences.

In order to interpret the fossil record, an understanding of modern forams is necessary, and to date small sub-unit rDNA genotyping has identified morphologically cryptic species within foraminiferal assemblages. To obtain a more comprehensive understanding of the benthic foram assemblages specifically associated with fjords, it is necessary to compare their genetic profiles with those of more open ocean margins and intertidal environments.

We have carried out a genotyping study on living forams to compare a range of fjord, intertidal and more open ocean shelf sampling sites. Forams were collected from sites spanning five biogeographic provinces from the cold waters of the high arctic provinces to the Lusitanean province off Portugal. Fjordic habitats include Svalbard, Shetland, Oslofjord, Bergen, Gullmar Fjord (Sweden), Kiel Fjord, Loch

Sunart and Dunstaffnage (West Scotland). Shelf waters include Svalbard, Iceland, Kattegat, Porcupine (off South-west Ireland), Bay of Biscay, Portuguese margin and the Rhone pro-delta in the Mediterranean Sea. Intertidal samples were collected from a range of sites around the UK, Ireland and the French Atlantic coast. We have used both morphological examination via Scanning Electron Microscopy (SEM) and genetic characterisation to determine the relationship between the genetic characters of the benthic morphospecies distributed within fjords compared with the same morphospecies found in other environments.

## Session 4: Invasions, Dispersal and Biogeographic Range Expansions of Foraminifera: Lessons from Earth History

### Keynote Lecture

# Invasions, Dispersal and Biogeographic Range Expansions of Foraminifera: Lessons from Earth History

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Climate warming and the poleward widening of the tropical belt have induced range expansions in a variety of marine and terrestrial species. Among the predicted effects of rising temperature is the range expansion of species into areas where they previously did not exist. The expansion of species ranges along their cooler boundaries appears to be a prominent consequence of the global warming trend. A rapidly increasing number of studies have shown "fingerprints" of recent climate-driven changes in various biological systems. This includes range shifts of species towards higher latitudes, deeper waters, higher elevation or earlier springtime phenologies. To date, however, only a limited number of studies have addressed the impact of range shifts on foraminifera or the dispersal mechanisms by which these occur. Larger and smaller foraminifera constitute ubiquitous and prominent components of marine ecosystems, and range shifts of these important protists are likely to trigger changes in ecosystem functioning. Range expansions may also have broad implications on native biotas and ecosystem functioning as shifting species may perturb recipient communities.
This keynote presentation explores the rates, magnitude and environmental implications of biogeographic range expansions in foraminifera from data sets of both modern and past ocean environments.
Topics include:

- History of range expansions in foraminifera: Lessons from the fossil record
- Biogeographic shifts and rates of range expansions in foraminifera
- Perturbation of shifting species on recipient communities
- Effects of foraminiferal range shifts on native biotas: Impact on biodiversity of foraminiferal assemblages
- Impact of invasive foraminifera on carbonate production, sediment composition and substrate modifying capabilities: Economical, environmental and ecological perspectives
- Implications for ecosystem functioning: Benefits or harmful effects on natural resources
- Economic impact of foraminiferal range shifts associated with global climate change.
- Predicting range expansions with Species Distribution Modeling

## Oral Presentations

### Shallow-water benthic foraminiferal turnover across the Cenomanian-Turonian boundary at Southern Appenines (Italy)

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There are very few studies about the shallow benthic community response after the massive extinction of the Cenomanian/Turonian boundary. This interval is characterized by a very important perturbation in the global carbon cycle, which produced carbon rich deposits around the world, widely known as Oceanic Anoxic Event II (OAE II) or the Bonarelli Event. Thus, this work bases its purpose: 1) to introduce the Turonian foraminiferal fauna associated with shallow carbonate facies (which is lacking definition so far); 2) how occurs in fossil record accurate by SIS (Strontium Isotopic Studies). A detailed analysis of the benthic foraminiferal assemblages from complete successions of shallow water sediments deposited in the Southern Appenines (Italy) has been carried out; such analysis allows the interpretation as follows:

At the end of the Cenomanian, larger foraminiferal extinction took place in two successive steps separated 150 k.y. In the first step, mainly the extreme k-strategists disappeared (for instance *Cisalveolina frassi* (Gümbel, 1872)), while the second step eliminated all the complex foraminifera (*Pseudorhapydionina*, *Pseudolituonella* and *Chrysalidina*). During the Cenomanian–Turonian boundary interval due to the adverse conditions, disaster microorganisms like *Thaumatoporella parvovesiculifera* (Raineri, 1922) and *Decastronema kotori* (Radoičić, 1959) characterize the deposits.

The recovery phase after the Cenomanian–Turonian extinction started in the Early Turonian, and continued during the middle–late Turonian. The first foraminifera appearing in the fossil record are very small and have simple structures as *Nezzazatinella cf. aegyptiaca* (Said and Kenawi, 1957) and *Pseudonummoloculina cf. spharoidea* Gendrot, 1968. The complex structures arose in the Apennine platform about 2.5 m.y. after the Cenomanian/Turonian boundary, during the middle to late Turonian, like *Reticulinella kaeveri* Cherchi, Radoičić and Schroeder, 1989; *Pseudocyclammina* cf. *sphaeroidea Gendrot*, 1968; and *Scandonea samnitica* De Castro, 1971.

### Dispersal of benthic foraminifera in the western North Atlantic: Pattern, processes, and population dynamics

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Benthic foraminifera are known to disperse in a variety of ways, but largely as small juveniles or propagules in a manner broadly analogous to spawning in marine invertebrates. Propagules settle to the seafloor where they collectively constitute a "propagule bank" that may consist of both autochthonous and allochthonous taxa. Propagule banks can be manipulated experimentally in the lab, and mature foraminiferal assemblages can be grown under different but controlled environmental conditions (Propagule Method of Goldstein and Alve, 2011). Temperature is particularly critical, and the application of non-ambient temperatures can promote the growth of allochthonous taxa, thus providing insight into dispersal patterns. Here, we grew assemblages of benthic foraminifera from propagule banks collected

from 4 sites ranging from 70 – 2200 m water depth south of Cape Cod, Massachusetts (USA) at temperatures ranging from 4 – 25°C. We characterized the taxonomic composition of the *in situ* and experimentally grown assemblages, and selected several morphospecies that grew at elevated temperatures for sequencing (SSU rRNA) to better characterize selected dispersed populations. Our primary goal is to better understand dispersal patterns and capabilities of benthic foraminifera in this shelf to bathyal temperate setting. Half of the species (19 of 38) that grew in the experimental assemblages are allochthonous (absent from the *in situ* living and dead assemblages), and these illustrate three patterns of dispersal, all of which are consistent with current regimes that have been documented in this region. Dispersal from onshore to offshore accounts for most of these allochthonous taxa (e.g., *Miliammina fusca, Buliminella elegantissima, Eggerella advena*). Dispersal from offshore to onshore is less common but may account for the growth of *Gyroidina orbicularis* in experimental assemblages. Dispersal from a warm-water source, most likely via the Gulf Stream, is indicated by several species that grew at elevated temperatures but are absent from the *in situ* assemblages (e.g., *Rosalina floridana, Brizalina lowmani, Bolivina variabilis*). Molecular results show that individuals of *R. floridana*, which grew from all sites, are cohesive and share population-level connectivity. Individuals of *B. lowmani* and *B. variabilis*, however, are genetically distinguishable by site and most likely have different source populations. These warm-water species may be among the first "smaller" foraminiferal species to undergo range expansion as oceans continue to warm. Supported by NSF OCE-0850505 to STG and OCE-0850494 to JMB.

## Biogeography of recent benthic foraminifera from the Indian and Japanese waters: Impact of invasive benthic foraminifera from the West Pacific Warm Pool (WPWP) to the eastern shelf of Japan

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Benthic foraminiferal species from two sources were compared with respect to intraspecific variation, morphological differences, and biogeographical distributions. Forty-one species, which were found both in exposed littoral sediments from the east coast of India (8° N to 19° N) and in shallow-water sediments collected off the southeastern shelf of Japan (35° N), were examined.

The biogeographical distributions of some of the species support the hypothesis that Indo-Pacific species have migrated from the West Pacific Warm Pool at ~15° N to the eastern shelf of Japan, transported by the Philippine Current and, beyond 30° N, by the Kuroshio Current.

## The paleobiogeographic and stratigraphic distribution of early Mesozoic foraminifers: Toward a better understanding of large scale dispersal and recovery processes?

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During early Mesozoic times, the earth was divided into two distinct marine worlds, namely the Tethyan and the Panthalassan domains. Whereas extensive investigations of the foraminiferal content have been led in Tethys, only few studies have focused on Panthalassa, where about 10 million years of the spatial and temporal distribution of foraminifers are unknown.

Our comparative study of Tethyan (e.g., Austria, Italy, Oman, Sulawesi) and Panthalassan (e.g., Japan, U.S.A., Mexico) areas strongly questions existing biostratigraphic and paleobiogeographic frames. Contrary to previous ideas, substantial differences in the stratigraphic and paleoecologic distribution of early Mesozoic foraminifers exist. A shift of several million years in their stratigraphic distribution is observed between Tethyan and eastern Panthalassan areas, which were separated by several thousands of kilometers of open sea. Foraminiferal assemblages also differ, especially in eastern Panthalassa, where typical Tethyan reefal and peri-reefal forms completely lack. Only long range, epiphytic and endemic forms are encountered in those remote parts of Panthalassa.

According to our results, large oceanic distances are a barrier to dispersal except for epiphytic forms, at the mercy of storms, floating seaweeds and water currents. Foraminifers are an unsatisfactory tool for global stratigraphic correlations as ubiquitous foraminifers only rarely have a short stratigraphic range.
A large part of the foraminiferal evolution occurred in the disregarded eastern Panthalassan domain. There, Late Triassic foraminiferal assemblages show strong similarities with Early Jurassic Tethyan associations, indicating that the Panthalassa was a probable refuge area during the Triassic-Jurassic major biotic crisis. As the post-crisis delay of recovery observed in Tethys is comparable in duration to the stratigraphic shift detected between Tethys and Panthalassa, it might be merely related to a delay of dispersal.

## Foraminiferal evidence of environmental changes at the Badenian/Sarmatian (middle Miocene) transition in central Paratethys (Zhabiak, W Ukraine)

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The Paratethys was an epicontinental sea that developed as a relic of the Tethys. It existed between the Early Oligocene and late Middle Miocene times, and until the Middle Miocene it was in communication with the normal marine environments of the Mediterranean Basin and Indian Ocean (Harzhauser & Piller, 2007). The Paratethys was subdivided into several smaller low salinity marine basins, some of them developing their own endemic fauna (e.g., Rögl, 1985; Cicha et al., 1998). The separate evolution of the Paratethyan microfauna has caused an establishment of a regional time-scale, different from the standard Mediterranean chronostratigraphic stage system.

The Badenian/Sarmatian boundary in the Paratethys basin, that marks the transition from normal marine to restricted semi-marine conditions due to isolation of the basin from the world ocean at the onset of Sarmatian time, is still far away from full understanding. The Zhabiak section is located at the northeastern margin of the Carpathian foreland basin (Central Paratethys) in the Medobory Hills region, ca 20 km south to the town of Kremenets' (western Ukraine, Ternopil' province). The Miocene deposits that overlie here the Upper Cretaceous substratum comprise the Upper Badenian sands and clays with lignite seams passing upwards into marine quartz sands, rhodolithic marls and clays with limestone beds as well calcareous bioclastic sands (in the uppermost part). They are usually very rich in normal-marine biota (especially gastropods and bivalves). The Lower Sarmatian deposits (of total visible thickness up to 4 m) start with calcareous sands resembling the underlying Badenian ones (so the Badanian/Sarmatian

boundary is not well visible in terms of lithology/facies). They are covered with marls and clays with small serpulid-microbialite buildups and eventually quartz sands with typical taxonomically-poor Sarmatian biota.

Foraminifers have been studied quantitatively in 52 samples coming from a 20-m-thick section comprising the Badenian/Sarmatian transition strata. Thirty-five species of benthic foraminifera and 5 species of planktonic ones have been recorded. The preservation of their tests is good to moderate. Benthic foraminiferal assemblages are composed almost exclusively of calcareous forms; agglutinated ones are practically lacking. *Elphidium* spp., hauerinids and *Lobatula lobatula* are the most common calcareous benthic foraminifera in the studied material. Planktonic foraminifera represented only by the *Globigerina* species which indicate cool-water, occur rarely in the lower part of the section. *Elphidium reginum*, *E. koberi*, *Anomalinoides dividens* recorded in the topmost part indicate a Sarmatian age for the upper part of the Zhabiak section.

The analysis of foraminiferal assemblages of the section suggests cold water, inner shelf depths with short-term depth and salinity changes. A foraminiferal assemblage from sands of the basal part of the section yielded large-size specimens of benthic Badenian and reworked Cretaceous foraminifers with traces of abrasion; this assemblage suggests a high-energy coastal environment. The second assemblage from grey clays is characterized by common spiny elphidiids indicating deepening of the sea and low hydrodynamic conditions. Rare occurrences of planktonic *Globigerina* spp. in the next assemblage with common *Elphidium*, *Asterigerinata* and hauerinids from muds and mudstones is interpreted as reflecting a continuing slight deepening of the sea. The disappearance of *Globigerina* and abundance of *Elphidium crispum* and hauerinids in the assemblage that follows suggest in turn a shallowing of the basin. The succeeding assemblage which is entirely composed of large-size specimens of Hauerinidae from limestone bed suggests a restricted hypersaline environment. Higher up in the section, the foraminiferal assemblage from marly limestones is characterized by common *Cibicidoides*, *Asterigerinata*, *Neoconorbina* and subordinate hauerinids; it suggests a normal marine inner shelf environment. The next assemblage, from clayey deposits, with very rare *Globigerina* spp. and common *Elphidium crispum* and hauerinids suggests a slight deepening of the sea and/or a presence of currents responsible for the transportation of planktonic forms from a deeper part of the basin. Sandy-clayey deposits and sands lying higher in the section yielded the assemblage with common *Ammonia* spp. and *Elphidium crispum* that suggest a decrease in salinity and brackish shallow shelf environment. Marly and sandy sediments from the topmost part of the studied section contain low diversity assemblage with *Lobatula lobatula* and *Elphidium* spp. and with traces of abrasion of foraminiferal tests; this assemblage indicates shallow shelf high-energy environment.

## Benthic foraminifera from cold-water coral reefs

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Cold-water coral (CWC) ecosystems occur worldwide and are especially developed along the European margins. Their occurrence presents a challenge to understand their development, preservation and possible importance in the geologic record.

The dominant CWC scleractinian *Lophelia pertusa* settles on hard substrates, in environments characterized by elevated currents and high food availability. Along the European margin these CWC reefs grew during different times and with different morphologies: they developed on elevated hard substrata along the upper slope of the Norwegian shelf, and they grew as large carbonate mounds along the Irish margin (Rockall and Porcupine Bank, Porcupine Seabight) and in the Gulf of Cadiz.

The CWC reefs are considered as “hot spots” of biodiversity. In comparison to macrofauna, the microfauna, particularly foraminifers associated with CWC ecosystems, are poorly known.

We present the last 12 years of our studies on foraminiferal assemblages associated with CWC ecosystems along the European margin and in the Mediterranena Sea. The sub-recent benthic foraminiferal assemblages in the Porcupine/Rockall region and along the Irish and Norwegian coasts are related to environmental parameters and on the distribution of sedimentary facies. Benthic foraminifers associated to CWCs is different form that off-reef. In the Porcupine Basin microhabitats and facies can develop over hundreds of meters, whereas, along the Norwegian margin they can change within meters.

Benthic assemblages from CWC reefs show similarities between Holocene sediments from the Alboran Sea and Lopphavet, and of Recent/Subrecent sediments from the Porcupine/Rockall Bank and the Norwegian coasts. They are dominated by epifauna, e.g., *Discanomalina coronata*, *Cibicides refulgens*, and *Lobatula lobatula* but also infaunal species e.g., *Angulogerina angulosa*, *Globocassidulina* spp., *Epistominella* spp., *Cassidulina* spp. are highly abundant. The benthic fauna associated with CWC ecosystems is typical of high-energy and oxygenated settings and high organic matter supply. Therefore, it is interpreted to require similar ecological conditions to CWC.

Although CWC ecosystems occur at different latitudes, the associated foraminifers are similar from Norway to the Mediterranean and can be used to identify CWC ecosystems in the geologic record, when the corals are dissolved like in the Alboran Sea. Selected species of 373 benthic and 28 planktonic foraminifers including those poorly reported in the literature are documented in 42 plates.

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## Foraminifera as Ecosystem Engineers from the Zanzibar Archipelago (Tanzania): Safeguarding tropical reef habitats

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The Zanzibar Archipelago is one of the largest reef settings in Africa and represents the transition from the high-diversity region of the Asian Indo-Pacific to the coastal areas of southern Africa. The archipelago consists of three major islands including Zanzibar, Pemba and Mafia Island. In this project we have studied the spatial distribution, composition, diversity and environmental significance of foraminiferal faunal assemblages in reefal ecosystems.

Quantitative analyses of sediment samples indicate the presence of seven major habitats around the three islands of the Zanzibar Archipelago, characterized by specific indicator taxa: 1.) the nearshore habitat in the vicinity of a Mangrove forest, 2.) the shallow lagoon habitat, 3.) the shallow and extremely warm reef flats, 4.) the smaller apron reefs at Mafia Island, 5.) the high-energy fringing reef east of Zanzibar, 6.) the patch reefs on the sheltered western side of Zanzibar, and 7.) the high diverse fore reefs at Pemba. Because of their high abundances and significant contribution to the stabilization of reefal frameworks in these habitats, some of the indicator taxa are prolific producers of calcium carbonate and are therefore to be considered ecosystem engineers.

Highest productivity and ecosystem functioning was recorded at places dominated by the most significant taxa. The diversity at these places is lower and depends in general more on habitat characteristics related to biotic and environmental constraints than on water depth as the common trend of increasing foraminiferal diversity. Maximum diversity values were obtained from fine grained sediments at around 20 meters. The distribution, diversity and composition of foraminiferal assemblages thus reveal specific patterns and morphological adaptations that provide useful information for paleoenvironmental and paleoclimatic interpretation.

## Changing biogeographic patterns along the coast of southern Africa

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The coastal regions of southern Africa, which cover the southeastern Atlantic (SEA) and the western Indian Ocean (WIO), are among the most diverse and species-rich ecosystems within the world's oceans. Especially the eastern coast has been termed a center of biodiversity. However, the biogeography of benthic foraminifera in this area is relatively unexplored compared to other marine regions and large scale biogeographic surveys are missing to date.

In our studies, we sampled the shallow-water areas off southern Africa along a latitudinal gradient from Kenya to Angola. We compiled a comprehensive biogeographic database for more than 30 species of foraminifera from this region. Analysis of the distribution ranges of various foraminiferal species revealed that they exhibit environment- and ecosystem-driven biogeographic patterns.

Like many other regions of the world's oceans, the coastal areas of southern Africa are subject to ongoing climate warming. This will modify the extent of biogeographic regions and affect established ecosystems: While tropical taxa are currently expanding their distribution ranges towards higher latitudes, temperate faunal communities are already in retreat. We applied Species Distribution Models (SDMs) on 30 selected foraminiferal species to model the current distribution of suitable habitats and potential changes by projecting them on climate scenarios for the next century. The modeled taxa included symbiont-bearing foraminifera and other tropical species from the WIO, as well as smaller, hyaline taxa from the temperate and cool coastal regions of South Africa and Namibia.

Tropical and subtropical species are shown to expand their distribution ranges by several degrees of latitude within the next decades. Cool adapted and temperate species, on the other hand, display potential range contractions, suggesting that their habitats might be at risk in the future. The results revealed that "shifting communities" of benthic foraminifera will emerge, which will lead to a re-shoveling of faunal elements. This ultimately may result in altered biogeographic patterns and newly established biogeographic units off southern Africa.

## Poster Presentations

### Anthropogenic environmental changes and faunal replacement: Benthic Foraminifera records in a temperate estuary of Buenos Aires (Argentina)

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Biological criteria are needed to provide information about the effects of human impact in coastal marine environments. Benthic foraminifera are likely to leave fossil remains in the sediment which can be compared with their living counterparts. Eight subtidal surface samples were collected, as a basis for the interpretation of three sedimentary sections along the Bahía Blanca estuary (38°42'-38°49'S & 62°26'-62°8'W) (Buenos Aires, Argentina). The main objective of this study is to assess the foraminiferal response to environmental changes during the last 6000 yrs BP, comparing fossil assemblages with modern ones and with geochemical data. Fossil foraminiferal faunas in the Bahía Blanca estuary were of relatively low diversity and dominated by species of the genus *Elphidium* de Montfort, 1808, and *Buccella peruviana* (d' Orbigny, 1839*)* among others. Differences between faunas collected in fossil sequences and in recent ones include a strong decrease in relative abundance of *Buccella peruviana* over all Bahía Blanca estuary; the increasing presence of *Ammonia* spp. and the appearance of abundant specimens of *Haynesina germanica* (Ehrenberg, 1840) which were absent all along the fossil record for the area. Previous studies of modern foraminiferal assemblages demonstrate that *Haynesina germanica* is widely distributed and abundant throughout the modern habitats of the estuary. Comparative faunal assemblage analysis from dated core sample material from within the Bahía Blanca Estuary shows that the species has not been present for at least the last 6000 years. This supports the hypothesis that the invasion of *H. germanica*, (that has been accidentally introduced outside its natural range as a probable result of ballast water and/or shipping activities) is ultimately resulting in the biotic homogenization of foraminiferal fauna.

### Paleocene-Eocene larger benthic foraminifera of the Paleogene Adriatic Carbonate Platform (Sopada Section, SW Slovenia)

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The larger benthic foraminifera (LBF) from the Paleocene-Eocene of the Paleogene Adriatic carbonate platform (Sopada section, SW Slovenia) document complexity in shallow-water environmental conditions. The transition from the Thanetian SBZ 4 to Early Ypresian (Ilerdian) SBZ 5 is marked by modestly diversified assemblage of alveolinids, nummulitids and assilinids, first onset of true spherical alveolinids, continuation of persistence of trematophore, complex miliolids and negative δ13C values. The Thanetian SBZ 4 assemblage is composed of diversified assilinids (*Assilina azilensis, Ass. yvettae*), rare *Glomalveolina levis, G. dachelensis, Nummulites catari, Hottingerina lukasi*, *Thomasella*

*labyrinthica,* complex miliolids (*Lacazina blumenthali*) and rotaliids. Close to the termination of the late Paleocene small sized foraminiferal specimens occurred. The LBF assemblage is interpreted as the first stage of the Global Community Maturation (GCM)
During the lowest Eocene (Ypresian) LBF demonstrated differentiation on the generic and species levels. Alveolinidal "boom" (*A. globula, A. dolioliformis*, *A. avellana)*, large assilinids (*A. tectosaga),* surprisingly abundance of "Lazarus spp." as *L. blumenthali*, *Th. labyrinthica, Pseudolacazina donatae* and rotaliids, along with the greatest negative $\delta^{13}C$ values, all these characterize a newly defined SBZ 5A. Abundant and diversified spherical alveolinids (at most *A. aramaea*, *A. dolioliformis, A. varians, A. globula* and *A. avellana*), rare *L. blumenthali*, large *Assilina* ex gr. a*mmonea* and *Nummulites* spp., are distinctive for the successive Ypresian stage, defined as SBZ 5B. In Ypresian SBZ 6 intraspecific variability within spherical and ovoid large forms of alveolinids (*A. daniensis*, *A. solida*, *A. pasticillata* and *A. ellipsoidalis***)** continued to develop.

## Floating bolivinids (*Streptochilus)* in the Pacific Ocean: Evidence of planktic lifestyle of biserial foraminifera

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The genus *Streptochilus*, was named for biserial planktic foraminifera and there are two known species in modern ocean. After 1990's, occurrence of living *Streptochilus* were reported by some research papers from the Indian and Atlantic Ocean, but there are no reports of living species from the Pacific. Here we show the first report of occurrence of biserial form species from oligotrophic water in the Pacific Ocean.

Two types of biserials were recovered by plankton tow observations from the North Pacific (30°N, 145°E, Station S1) during four cruises between 2010 and 2012. One was small, smooth surface and microperforations and it was identified as *Streptochilus globulosus*. The other was flattened, heavily rugose surface ornamentation with no pores, and both edges truncated. It completely differs from the known biserial species including bolivinid foraminifers. In this study, we named this species *Streptochilus* sp. A. expediently.

*Streptochilus globulosus* occurred in all seasons but *Streptochilus* sp. A was restricted only from spring to summer. Vertically, these biserial species were mainly distributed in subsurface water and the maximum occurrence was around 50-150 m water depths. It was in accordance with the Deep Chlrophyll Maximum (DCM) layer in station S1. The small subunit ribosomal DNA (SSU rDNA) sequences of *Streptochilus* sp. A were obtained for comparison with extensive database of benthic species. As a result, *Streptochilus* sp. A was placed at the clade of Bolivinidae, but it was separated from the known lineage of *Streptochilus globigerus* (= *Bolivina variabilis*). This result indicates that biserial foraminifers in the Pacific are different species from those of the Indian Ocean, but they have planktic habitat as well as other bolivinid species.

# At the front of expanding ranges: Shifting community structures at amphisteginid species' range margins in the Mediterranean Sea

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Amphisteginid foraminifera are among the most prolific and ubiquitous foraminifera on coral reefs and tropical carbonate shelves. They are indicative of warm tropical waters and their latitudinal range is strongly governed by water temperature. As key carbonate producers they have often been referred to as living sands and contribute substantially to substrate stability and growth of reefal structures. Climate change and warming of the planet have induced a widening of the tropic belt including a poleward range expansion of amphisteginid foraminifera. One of the most severely affected areas of global change is the Mediterranean Sea, where global warming and the opening of the Suez Canal in 1869 triggered a mass invasion of tropical Red Sea taxa into Mediterranean territories. The "Red-to-Med " invasion of amphisteginid foraminifera has proceeded in northwest direction and has generally followed the counterclockwise current pattern of the eastern Mediterranean Sea (Langer 2008). The Mediterranean range expansion front of amphisteginid foraminifera currently runs from the North African coast off Tunisia to the Pelagian Islands (Linosa, Lampedusa), Malta, the southeastern coast of Sicily, Malta, the Pelagian Islands and Corfu in northwestern Greece.

Recent studies have documented that the invasion and rapid proliferation continues at unprecedented rates and amphisteginid foraminifera have become extremely abundant locally. The successful invasion is reflected in numerical abundances and at many eastern Mediterranean sites they represent between 30 and 70 or even up to 90 % of the total faunal assemblage. Because of their abundance and ubiquity and as prominent producers of calcium carbonate amphisteginid foraminifera were considered ecosystem engineers. However, the resilience of ecosystems to the disruptive forces of key invaders and the impact on impact on native faunal communities remains to be determined. Given their prominent environmental role, rapid biogeographic range expansion and impact on native ecosystems, amphisteginid range expansions and invasions into new territory are likely to trigger changes in community structures and ecosystem functioning. In addition, the relatively high rates of immigrants can lead to competitive exclusion (displacement) of native taxa and pose potential threats to established biotas. We have collected new material from sites off northwestern Greece (Ithaka and Meganisi Islands, Ionia Sea) to document the effect of amphisteginid invasions on established foraminiferal biotas along the front of the expanding range margin. We explore the nature of these recent biotic exchanges and their consequences on the structure of communities, composition and diversity of assemblages for perspectives on the consequences of the mixing of biotas.

## Foraminifera as Ecosystem Engineers: A case study from the Zanzibar Archipelago (Tanzania)

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The Zanzibar Archipelago is the largest reef system in eastern Africa and consists of the three major islands Zanzibar, Pemba and Mafia Island. We have studied the spatial distribution, composition, diversity and environmental significance of foraminiferal faunal assemblages in shallow-water habitats from these islands.

Quantitative analyses of sediment samples indicate the presence of seven major habitats around the three islands of the Zanzibar Archipelago: 1.) the nearshore habitat in the vicinity of a Mangrove forest, 2.) the shallow lagoon habitat, 3.) the shallow and extremely warm reef flats, 4.) the smaller apron reefs at Mafia Island, 5.) the high-energy fringing reef east of Zanzibar, 6.) the patch reefs on the sheltered western side of Zanzibar, and 7.) the high diverse fore reefs at Pemba. Each habitat is characterized by a specific set of indicator taxa. Some indicator taxa are prolific producers of calcium carbonate and contribute a substantial portion to the sedimentary budget of reefal structures. In selected habitats, the foraminiferal $CaCO_3$-input contributes significantly to the balance, accretion and the stabilization of reefal frameworks.

We have identified both habitats and foraminiferal species that play a prominent and economically important role in reefal environments around the Zanzibar Archipelago. We show that these species occur in enormous abundances, modulate the availability of resources and modify their physical habitat. They also impact the structure, diversity and species richness of associated foraminiferal communities and they may aid in the protection of reefal structures and shorelines. Recognition of the carbonate producing capabilities requires foraminifera to be included in future reef management strategies and helps to identify ecologically important key-habitats. Here we analyze the environmental and distributional characteristics of key-habitat forming species and assess their role as ecosystem engineers in the Zanzibar Archipelago.

## Range expansions of larger Foraminifera under current and future climate

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Biogeographic range expansions of tropical and subtropical species are a predicted and realized consequence of global climate change. Climate warming and the poleward widening of the tropical belt have induced range shifts in a variety of marine and terrestrial taxa. Sea surface temperature is a key environmental predictor that affects the biogeographic distribution of many organisms. To project future species distributions, we applied Species Distribution Models (SDMs) to various species of larger foraminifera.

The distribution of most modern symbiont-bearing larger foraminifera is confined to shallow water marine habitats in tropical and subtropical regions (between 30° N and 30° S) and their minimum temperature limits are governed by the 14 to 20° C isotherms. Distribution models were computed under

current climate conditions and projected onto a climate change scenario for 2050 to evaluate potential changes under ongoing climate warming.

The studied foraminifera include *Archaias angulatus*, which is a major faunal element of the Atlantic Ocean and *Calcarina* spp., which is widely distributed within the central Indo-Pacific. Both taxa display potential distributions that cover currently uninhabited regions. Under climate conditions expected for the year 2050, the studied species display latitudinal range expansions both north- and southward. The modeled range extensions suggest that some larger foraminifera may colonize biogeographic regions that so far seemed unsuitable. *Archaias angulatus* and *Calcarina* spp. also show local increases in habitat suitability within their native occurrence ranges, suggesting that their tolerance for maximum temperatures has yet not been fully exploited and that they might benefit from ocean warming. Our findings suggest an increased role of larger foraminifera as carbonate producers and reef framework builders in future oceans.

## Session 5 Biogeography and Evolution of Foraminifera

## Keynote Lecture

### First assessment of the total extent of cryptic genetic diversity in modern planktonic foraminifera

**Michal Kucera**[1], Kate F. Darling[2], Raphael Morard[1], Agnes Weiner[1] and Manuel Weinkauf[1]

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Analyses of sequence variability in fragments of genes coding for the ribosomal small subunit (SSU) and the associated internal transcribed spacer (ITS) revealed the existence of distinct lineages within morphologically defined species of planktonic foraminifera. These lineages appear to have diverged deep in the geological past and show no evidence for interbreeding, indicating that they represent reproductively isolated units. Despite the large consequences of the existence of such "cryptic species" in planktonic foraminifera, the extent of the hidden diversity remains unknown. Here we present a meta-analysis of data from single-cell DNA sequencing for a series of species with extensive global sampling. We show the best constrained evidence to date that the number of "cryptic" genetic lineages akin to biological species in planktonic foraminifera is limited, unlikely to raise the diversity by more than an order of magnitude. Using first-order jackknifing we show that in many of the sampled species, the rate and pattern of discovery is such that saturation is likely to have been reached. These observations combined indicate that planktonic foraminifera genomics is close to the point where we may move from the stage of genotype discovery to large-scale surveys of ecological processes governing the distribution of the genetic lineages. The implied high level of exhaustiveness of sampling in the studied species made it possible to address the question of how the genetic diversity is distributed (allocated) among species and clades and whether its extent within morphological species can be predicted from the age, morphological variability, abundance or habitat properties of the morphospecies. We show evidence for uneven allocation of cryptic diversity among and within morphological species and a lack of correlation between lineage age and diversity, both indicating that the rate of cryptic diversification is not constant among lineages and that the current pattern of cryptic diversification has been largely shaped by historical contingency.

## Oral Presentations

### Jurassic endemism of Saudi Arabian Foraminifera and their migration routes among Intra-shelf Basins

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The faunal differences, including foraminifera, from the Arabian Plate and other Tethyan regions in the Jurassic, allow the identification of this part of Tethys as an Arabian province. These particular differences span the Bajocian (and maybe earlier) to Kimmeridgian (and maybe later) times, when several successive endemic taxa evolved. Endemic species have very limited geographical distribution and, consequently, constrained biostratigraphy due to isolation by either geographical or ecological barriers.

Ecological control of this constrained biostratigraphy in Middle and Upper Jurassic carbonates in Saudi Arabia could be a result of the persistence of these fauna and flora during the Jurassic in shallow platform environments to which the Arabian taxa were adapted. The episodic occurrences of some dominant Arabian ammonite fauna in other Tethyan regions are considered as a sign of environmental control for faunal exchanges. Such faunal exchanges were probably made easier by sea-level changes that occurred because of the lack of a physical barrier. On other hand, various lithostratigraphic and sequence stratigraphic studies of upper Jurassic rocks of the Arabian Plate support the hypothesis that the presence of physical barriers prevented connection between intra-shelf basins and the Tethys Ocean.

In general, the vertical and lateral foraminiferal distributions are similar to other Arabian Province fossil groups in this pattern of endemism. Nevertheless, the foraminifera and associated macro and microfossils from Middle and Upper Jurassic carbonates have shown that (i) faunal endemism was related to the formation of intra-shelf basins; (ii) the Jurassic intra-shelf basins were initially formed as early as the Bajocian age after regional uplifting and erosion of the Lower Jurassic; (iii) these basins underwent major subsidence in the early stages of the Middle and Late Jurassic; (iv) the number of new species and diversity of endemic taxa correspond to relatively deep marine settings within these basins and are not constrained to the shallow marine ambient realm; (v) faunal exchanges were probably made easier among these closed intra-shelf basins through migration route channels, which are identified by regional seismic isochron maps of the Jurassic section in the middle Dhruma and upper Hanifa reflections in eastern Saudi Arabia.

### The Foraminifera of the Baltic Sea

**Peter Frenzel**

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The Baltic Sea is a marginal brackish water sea with an estuarine circulation pattern. The sea is young considering geological time scales, coming into existence during the Pleistocene/Holocene transition. Thermohaline layering and a salinity gradient running from almost marine conditions in the south-west, where the basin is connected to the North Sea, to beta-oligohaline waters in the confined north-east are characteristic for the hydrography of the Baltic Sea.

Despite a long research history in the Baltic area, a comprehensive overview on Foraminifera is still lacking. Our present knowledge on taxonomy and distribution is based mainly on papers by the research

group of Lutze (e.g. 1965) for the Kiel Bight from the 1960s to 1970s, a monograph on the Polish coast by Brodniewicz (1965) and some papers covering the Swedish coast by Hermelin (e.g. 1987). Most publications are scattered over a large range of often smaller biological and geoscientific journals and are in large parts written in other languages than English. An extensive literature review and new sampling enables me to present a checklist for the Baltic Sea foraminifers and their distribution as well as ecological data.

There are 98 foraminiferal species in total reported from the Baltic Sea. Astrorhizina is the group of highest diversity (25 species), followed by Rotaliina (15) and Haplophragmiina (13). Agglutinated species (57) are slightly more frequent than secretoric ones (41). Planktonic forms are extremely rare, despite being typical for sediments of the initial Littorina transgression in the deeper basins. Endemic taxa seem to be non-existent despite there being some rare species described in the 19$^{th}$ century which are known from the Baltic Sea only, however, those allogromiid species are known from aquarium cultivation or from single specimens only.

The diversity of foraminifers decreases following the salinity gradient from south-west to north-east. The same is true for mean abundances. Interestingly, the percentage of agglutinated species within the foraminiferal faunas tends to decrease with decreasing salinity. No foraminifers could be found north of the Aland Sea in the Baltic proper below 5 psu. Living foraminifers at lowest salinities found during our sampling at the southern Baltic coast are *Cribroelphidium williamsoni* at 5 psu and *Balticammina pseudomacrescens* at 2 psu in lagoons and estuaries. Water masses above and below the halocline house very different assemblages.

Salinity and its stability are the main drivers for species distribution. Water temperatures and substrate are also important.

## Biogeography of Cenozoic shallow and deep-water benthic Foraminifera

**Bruce W. Hayward**

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Rigorous assessment of the biogeographic distribution of fossil Cenozoic benthic foraminifera requires a global taxonomic review of a genus or family. In this study I use our reviews of the shallow warm-water family Bolivinellidae, the extinct outer shelf-bathyal family Plectofrondiculariidae, and the extinct deep-water families Chrysalogoniidae, Ellipsoidinidae, Glandulonodosariidae, Pleurostomellidae and Stilostomellidae and partial reviews of the shallow-water genera *Ammonia* and *Elphidium*. These studies indicate that the majority of bathyal and abyssal benthic foraminifera had cosmopolitan distributions. The more limited geographic distributions of some deep-water species may be a reflection of their rarity rather than reality. One exception to the widespread distribution of deep-water foraminifera seems to have been in the Mediterranean Sea where only a portion of the fauna was able to migrate back into it after the Messinian die-off.

Shallow-water (shelf-upper bathyal) benthic foraminifera exhibit more diverse biogeographic patterns, possibly reflecting the roll of chance in successful trans-oceanic dispersal and colonisation events of propagules carried in suspension in the surface ocean currents. Some species are endemic to restricted areas, others may be restricted to regions such as the North Atlantic or South Pacific, occurring in shallow water on either side. Within families or genera it is usually those with the longest time range that have the most cosmopolitan distribution. The disappearance of whole families or genera of shallow warm-water foraminifera (e.g. Bolivinellidae) from major regions of the world (e.g. Atlantic) during their Cenozoic history but survival elsewhere, is harder to explain.

## DNA Barcoding of Foraminifera: An efficient tool for exploring species diversity

**Maria Holzmann** and Jan Pawlowski

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DNA barcoding is a molecular classification tool that uses short standardized sequences for the identification of species. The applications of DNA barcoding are wide-ranging, encompassing taxonomy, ecology, bioconservation and biosafety. The barcoding initiative is administered by the Consortium for the Barcode of Life (CBOL) and reference databases exist for many different groups of fungi, plants and animals. Barcoding databases were also established for some protist groups (*i.e*. diatoms, ciliates, amoeba) but was still lacking for foraminifera. We therefore recently started the Foram Barcoding (FB) project with the aim to create a curated molecular database for modern foraminifera. The FB database only includes forams whose DNA has been extracted and sequenced. A fragment of the 18S rDNA that allows a clear distinction of most foraminiferal species has been chosen as foraminiferal barcode. Additional information includes photos of processed specimens and taxonomic references. A growing FB database will be able to contribute to different areas of foraminiferal research and future applications are easily conceivable in taxonomy, biodiversity, ecology, biomonitoring or biogeography.

## Evolution and phylogeny of Cretaceous (Albian-Coniacian) biserial planktonic foraminifera

**Brian T. Huber**[1] and Shannon J. Haynes[2]

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Cretaceous biserial planktic foraminifera have generally been overlooked in biostratigraphic studies due to their small size and an inadequate knowledge of their taxonomy and stratigraphic distribution. However, detailed SEM comparisons of well-preserved late Albian-Maastrichtian biserial assemblages from geographically dispersed and stratigraphically ordered samples have revealed a much greater complexity in test wall microstructure, chamber shape and arrangement, apertural morphology, and shell growth rates than was previously recognized. As a result, 14 of 39 biserial species have been described as new since 2007 and these have been classified in a total of 18 biserial genera, 15 of which have been described as new since the same year. In order to evaluate the validity of some of the new genera and species, we conducted a detailed biostratigraphic, SEM and morphometric study of exquisitely preserved biserial planktic foraminifera from an upper Albian-Coniacian marine claystone sequence drilled in southwest Tanzania, and we compared these with upper Albian-Coniacian occurrences in deep-sea cores worldwide. Our results confirm that most genera and species that were recently named for the late Albian-Turonian interval are indeed valid. Two mid-Cretaceous biserial speciation events are now recognized, with the first occurring within the *Whiteinella archaeocretacea* Planktic Foraminifer Zone in the latest Cenomanian-earliest Turonian and the second within the lower *Marginotruncana schneegansi* Planktic Foraminifer Zone within the late Turonian. The cause(s) of these speciation events is not apparent and remains the subject of further study.

## Pleistocene occurrences of *Planopulvinulina* and *Hyrrokkin* in a cold-water coral mound, Northern Gulf of Mexico

**Barry Kohl**

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A *Lophelia pertusa* mound (Roberts' Mound) from the northern Gulf of Mexico was cored in 2012. Two sixteen-meter, jumbo piston-cores were taken from the crest and flank of the mound. Each contained broken coral branches in a calcareous matrix. Investigation of the cores produced foraminiferal faunas unique to *Lophelia* mounds worldwide. This is the first cold-water coral mound to be cored and studied in the Gulf of Mexico. Roberts' Mound is located 63 km east of the Mississippi River Delta in 420 m of water with a relief of 30 meters.

Dates are derived from $^{14}C$ and U/Th dating of the coral, and biostratigraphic dating using planktonic foraminifera. The mound-crest core penetrated late Pleistocene sediments as old as Oxygen Isotope Stage 8. Four unconformities coincide with intervals of global sea-level fall and reflect adverse growth conditions for *Lophelia pertusa.*

Two calcareous benthic foraminifera, *Planopulvinulina dispansa* (Brady) and *Hyrrokkin sarcophaga* Cedhagen occur within the *Lophelia* growth intervals, which coincide with warm-water, Pleistocene highstands. Both species are found in washed residues from the matrix enclosing a lattice of coral branches. Neither species was found attached to fossil *Lophelia*. *Planopulvinulina dispansa* has a varied growth pattern and specimens as large as 7 mm occur. Attachment scars are common and the variable morphology reflects the surface of the coral on which it was attached. Juvenile and adult specimens were found in the residues. *Hyrrokkin sarcophaga* is more abundant in the cores and a complete size range was recovered from the residues with the largest attaining 3.8 mm in width. *Hyrrokkin* has been found as part of the foraminiferal assemblages living on *Lophelia* reefs in the Mediterranean Sea and eastern North Atlantic.

*Hyrrokkin sarcophaga,* which is a parasitic foraminifer, has been found on various species of the bivalve *Acesta* in the North Atlantic. But living specimens of *A. bullisi* (Vokes), which occur on a nearby mound, were inspected and no *Hyrrokkin* were found attached to the valves nor were attachment scars observed.

The associated foraminiferal fauna is quite diverse with over 70 benthic species and is dominated by the attached species *Discanomalina semipunctata* and *D. coronata*. To date, neither *Hyrrokkin* or *Planopulvinulina* have been reported from the Gulf of Mexico area.

## Multiple divergence of planktonic Foraminifera corresponds to the Indo-Pacific warm pool development

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Phylogeography is essential for understanding the history of biological responses to changes in the ocean environment. The molecular phylogeography of planktonic foraminifera often reveals the presence and fine-scale distributions of multiple genetic types (cryptic species) within single morphospecies. These species mostly diverged after the Miocene. Exact estimation of their divergence times is crucially

important to examine possible effects of climatic and geological conditions on organismal evolution. Our previous analysis of partial sequences of ribosomal RNA genes (rDNA) did not estimate divergence time in satisfactorily high resolution, probably because of varying evolutionary rates among genes and lineages. To resolve this problem, we analyzed sequences of complete, instead of partial, small and large subunit (SSU, LSU) rDNAs by means of two Bayesian molecular dating techniques under relaxed and strict molecular clock hypotheses.

*Pulleniatina obliquiloculata* mainly occurs in the subtropical-tropical Indo-Pacific Oceans. In this morphospecies, three genetic types I, IIa and IIb exhibit longitudinal clines in frequencies within Indo-Pacific Warm Pool (IPWP). Our phylogenetic analyses based on SSU and LSU rDNA sequences show that these genetic types represent three distinct monophyletic clades (species). Their divergence times fall in narrow ranges between 0.3 and 0.6 Ma, regardless of using single- or multi-genes sequences. The strict molecular clock estimated almost 1.0 Ma older divergence times than the relaxed clock. Our analysis of multi-genes sequences under the relaxed molecular clock provided the narrowest 95 % credibility intervals. In this best estimation, types I and II diverged from each other 3.3-3.4 Ma, and type IIa and IIb 1.4-1.5 Ma. These suggest that their divergence repeated in periods of about 0.5 million years since the thick water mass developed in the IPWP area and the modern subtropical gyre system was built up in the Pacific Ocean. Our results suggest that changes of the ocean environment may have impacted on the divergence of planktonic foraminifera.

## Poster Presentations

### The genus *Globigerinoides* in the late Oligocene – Early Miocene: A proposed phylogeny

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The genus *Globigerinoides* is a long-ranging genus of planktonic foraminifera that is known to have evolved in the Late Oligocene (Zone O7) and to have radiated close to the Oligocene/Miocene boundary (Zone M1). Even though this genus includes species that are widely used as biostratigraphic markers, the beginning of its lineage is presently poorly known. We herewith present the revised phylogeny of this genus based on wall textures and morphologies following the approach adopted by the Paleogene Planktonic Foraminifera Working Group.

We have reviewed the taxonomy, phylogeny and biostratigraphy of Oligocene and lower Miocene *Globigerinoides* and we propose a refined morphological framework that will aid the diagnosis of the *Globigerinoides* group at the beginning of their range. We suggest that the clade radiates from an ancestral form *Globoturborotalita* species in the range interval of *Paragloborotalia kugleri*.

Based on new SEM images of the holotypes, and on detail SEM images of the wall textures, we validate 15 species of *Globigerinoides,* out of which 3 are new. The holotypes of all the species are documented with SEM images. An overall phylogeny of the genus is presented. We propose that the genus undergoes a splitting into two major groups occurring at the beginning of their radiation.

### Exploring the diversity of *Vanhoeffenella*

**Ivan Voltski** and Jan Pawlowski

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*Vanhoeffenella* Rhumbler is a globally distributed deep-sea foraminiferal genus. It has a monothalamous test composed of two transparent membranous ‘windows’, encircled by agglutinated rim with several conical arms. So far, only 4 species have been described. The available molecular data leads to confusion regarding the taxonomic placement of *Vanhoeffenella*: it falls into two clades within the radiation of monothalamous foraminifera, either forming the enigmatic Clade ‘V’ with some environmental sequences or branching with *Notodendrodes* and related genera.

We obtained several SSU rDNA sequences of *Vanhoeffenella* from different geographic locations. Phylogenetic analyses clearly demonstrate the close affinity of *Vanhoeffenella* to notodendrodids. Fine features of test construction provide additional clues for this relation. Our data provide the first insight into diversity of *Vanhoeffenella*, confirming the validity of the type species (*V. gaussi*) and pointing to the existence of several possibly new species.

## Session 6: The Ecology of Planktonic Foraminifera: From Present to Past

### Keynote Lecture

### Planktonic Foraminifera test development and elemental variations during biomineralization

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In the past decade, considerable research has been conducted to elucidate the mechanism(s) of foraminifera biomineralization and the processes that control test elemental composition. Laboratory experiments with living, *Orbulina universa*, have provided us with a unique perspective on this topic. In this presentation, I will present laser ablation ICP-MS data from *O. universa* grown in the laboratory that demonstrate test Mg/Ca banding is a function of calcification during the day and night. Reversing the 12h:12h light:dark regime triggers an immediate reversal in the banding pattern, thereby suggesting the environmental queue is light and not a secondary trigger related to symbiont photosynthesis. Although $Mg^{2+}$ is variable in the test, other divalent cations such as $Sr^{2+}$ or $Ba^{2+}$ do not display any variation. NanoSIMS analyses of specimens grown with double stable isotope tracer spikes, $Mg^{25}$ and $Ca^{43}$, show that $Mg^{2+}$ and $Ca^{2+}$ are derived from the surrounding seawater with a turnover time of less than two hours. These data are inconsistent with either day or night cation pools, suggesting these cations are incorporated into the test via direct seawater transport rather than membrane specific ion transport pathways. Together, these data help constrain the possible biomineralization mechanisms operating in planktonic foraminifera.

## Oral Presentations

### Planktonic Foraminifera as sensitive recorders of climate variability in the Eastern Mediterranean during the last ~90 ka

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Planktonic foraminifera are widely used in Quaternary paleoceanography as carriers of oxygen stable isotope signal. This signal is one of the main tools for establishing chronostratigraphy and determining the nature of global and local glacial and interglacial cycles. In this study, the focus is on the planktonic foraminiferal assemblages which are sensitive recorders of climate and water column properties including the degree of water column stratification and trophic levels.

In order to reconstruct the climate variability of the last 90 ka core, core MDVAL9501 (980m water depth), taken by R/V *Marion Dufresnae,* SE of Cyprus, was studied. A stable oxygen isotope stratigraphy was established by using $\delta^{18}O$ values of *Globigerinoides ruber* correlated with well-dated (U/Th) speleothem records of Soreq Cave and radiocarbon dates.

The sedimentary record in this core covers the last interglacial marine isotope stage (MIS) 5.1, the last glacial and the Holocene. Variations in the planktonic foraminiferal assemblage composition throughout this period indicate that conditions shifted between two main climatic scenarios. During the last glacial cooler, more aerated, less stratified and more mesotrophic water column persisted with distinct seasonality. This is evident from the occurrence of two deep water dwellers *Globorotalia inflata* being abundant from 75 to 50 ka BP and *G. scitula* from 55 to 15 ka BP. *Neogloboqudrina pachyderma, Globigerina bulloides* and *Globigerinata glutinata* occur continuously during the last glacial period. Among the "warm" water species *G. ruber* is nearly the only "survivor" comprising 25-50% of the assemblage with lower values corresponding mainly to minima in Dansgaard-Oeschger events.

During the Holocene the water column was warmer, more stratified, mostly oligotrophic and the seasonality was reduced. The dominating species were *G. ruber* and other "warm water" species that comprise >75% of the assemblage and occurring in low numbers. Only during sapropel S1 (early Holocene) and S3 (MIS 5.1) events, recognized by dark sediment color, low $\delta^{18}O_{G.\ ruber}$ values and higher total organic carbon content the numerical abundance of these species increased significantly indicating a contemporaneous change to more mesotrophic water-column conditions.

### How diverse are the Middle Miocene Orbulinas?

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Several studies on planktic foraminifera taxonomy suggest wall structure as a character to distinguish taxa on generic or even higher levels. Here, we test the hypothesis if cancellate and non-cancellate walls can be used to separate different species or genera among Middle Miocene *Orbulina suturalis* and *O. universa* from the Western Mediterranean and the Central Paratethys. The investigated intervals cover the Langhian to basal Tortonian stages of Spain and the Badenian Stage of Austria. 190 individuals were investigated

biometrically, including wall structure (cancellate, non-cancellate), diameter, test thickness, diameter of apertures and pores of the ultimate, spherical chamber. From 146 of these 190 we recorded wall structure (smooth, "knobbed", cancellate) and pore diameter of the neanic stage. The analysis of the data showed that almost any kind of combination of characters can be observed. All measured biometric parameters show a normal distribution. However, a few slight trends show up: non-cancellate tests are slightly thinner than cancellate tests, Paratethyan tests are thicker than those from the Mediterranean, cancellate neanic stages are more frequent in *O. suturalis*, neanic pore diameters increase with time in non-cancellate *O. suturalis*, and the range of pore size is smaller in non-cancellate tests. A weak general trend of smaller pores and apertures with time in Mediterranean specimens may be related to climatic trends (cooling). We also measured stable oxygen and carbon isotopes in order to identify separate ecologic or genetic groups among the specimens. Preliminary results show distinctly heavier $\delta^{13}C$-values for Paratethyan than for Mediterranean specimens. Other results are in line with previous observations, e.g., heavier $\delta^{18}O$-values for encrusted specimens confirm calcification in deeper waters. Our results facilitate several hypotheses: 1) the parameter investigated might not be appropriate to recognize morphologically different taxa, 2) cancelate or non-cancellate wall structure is not a (genetically fixed) distinctive character at least in *Orbulina* and might be related to trophic or other ecologic parameters, and, 3) all samples are from a single species distributional area and are therefore largely inappropriate to distinguish between several taxa. Since most Middle Miocene *O. universa* specimens show smooth neanic stages and cancellate ultimate chambers in their ontogeny, one may speculate that cancellation is (ecologically?) suppressed in non-cancellate specimens of this species (cf. neoteny).

## Determinants of population size and vertical habitat of planktonic Foraminifera in the Western Pacific Ocean

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The degree to which the population size and vertical habitat of planktonic foraminifera in the water column reflect the vertical distribution of phytoplankton remains poorly constrained. Since many species of planktonic foraminifera are known to consume phytoplankton and/or harbour photosynthesizing symbionts, the expectation would be that their vertical distribution and population size should coincide with that of the phytoplankton. In order to test this hypothesis, we sampled the water column of the western Pacific for planktic foraminifera at 16 station on the RV Sonne cruise 226-3T during a transit from New Zealand to Taiwan. Water properties were obtained by CTD and the pigment concentration in the water by fluorescence measurements of water samples from the CTD rosette, resolving five pigment classes. The concentration of live planktonic foraminifera and empty shells has been determined at each station in 9 depth intervals. Against expectation, across the sampled tropical and subtropical waters, maximum abundances of living planktonic foraminifera were almost always recorded in the surface water (upper 20 m), regardless of the depth of maximum phytoplankton abundance. Besides the obvious decoupling of habitat depth of foraminifera and phytoplankton occurrence, we could also find no correlation between the absolute abundances of foraminifera and the overall chlorophyll concentration across the studied stations. Our sampling covers a period of several weeks, excluding the possibility that the observed pattern is linked to a specific time of the presumed lunar reproductive cycle of planktonic foraminifera. Our sampling covered stations with maximum phytoplankton abundances at the surface (0-

30m) as well as stations with a distinct deep chlorophyll maximum below 70 m (tropical warm pool) and covered subtropical and tropical water masses with markedly different thermal structure. The lack of correlation between phytoplankton and foraminifera abundance cast doubt on the prevailing model of vertical distribution of planktonic foraminifera as well as on the link between their population size in the warm-water provinces and primary production.

## Atlantic Sea surface temperature estimation based on planktonic foraminiferal census off the Iberian Margin during the last 40 KA

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The variation of summer sea surface temperatures (SSTsu) recorded in three cores KC 024-19 (42°08.98'N, 10°29.96'W, 2765 m), PE 109-13 (42º34.32'N, 9º41.4', 2000 m) and PC7-1 (42º40´29´´N, 11º09´48´´W, 1.675 m) off NW Iberian Margin during the last 40 Ka is analysed in this work. These results are coupled/compared with data obtained by Salgueiro et al. (2010; Quaternary Science Reviews 29, 680–695) in three other cores: SU92-03 (43º11.75', 10º6.78', 3005 m); MD95-2040, 40º34.91', 9º51.67', 2465m) and MD95-2042 (37º47.99', 10º9.99', 3146m) In all these cores SSTsu are reconstructed with the modern analog technique SIMMAX 28 (Pflaumann et al., 1996, Paleoceanography 11, 15–35) using the planktonic foraminiferal census data.

For quantitative planktonic foraminiferal identification, the sediment fraction >150 μm was split to obtain at least 300 planktonic foraminiferal specimens that were taxonomically identified. The age models of these cores were determined using a Bayesian approach supported by AMS $^{14}C$ ages. In cores KC 024-19, PE 109-13, SU92-03, MD95-2040 and MD95-2042, these models were also supported by the planktonic $\delta^{18}O$ (*Globigerina bulloides)* records. In order to identify the occurrence of the Heinrich Events (HEs), a combination of different methods was used, such as abundance of coarse lithic particles, percentage of *Neogloboquadrina pachyderma* (sinistral) and magnetic susceptibility. The age model of the HEs was improved by comparison with other cores previously studied in Iberian Margin.

SSTsu values similar to the present are observed throughout the Holocene, in all cores, indicating analogous conditions to the modern ones, except in core PC7-1 (the farthest from the coast). Around the last glacial maximum, SSTsu were not much lower than the current ones. Latitudinal variations of SSTsu were observed during the glacial/interglacial period: a decreasing of 2-3 °C from S to N of the Iberian Continental Margin. The lowest SSTsu were mainly recorded during HEs. But comparing the temperatures experienced in last three HEs in the N Iberian Margin, there is a tendency for the occurrence of lower temperatures in the Interior Basin of Galicia than toward the deep ocean.

## Distribution of living planktonic foraminifera in relation to oceanic processes on the south-eastern continental Brazilian margin (23°S – 25°S and 40°W – 44°W)

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The vertical distribution (0 m to 100 m) of planktonic foraminifera was investigated based on 40 samples that were collected in 08 stations, during the austral summer of 2002, in a geographically small area (23°S – 25°S and 40°W – 44°W) on the south-eastern Brazilian continental margin. Species' abundances are low (less than 10 specimens/$m^3$), which is typical of an oligotrophic area.

The foraminifera assemblage is mainly composed of warm water species (*Globigerinoides* pink and white forms), with a predominance of spinose and symbiont-bearing species. Temperature and inorganic nutrient enrichment of the surface are the main factors that control foraminiferal abundance and diversity, nevertheless salinity can also be considered. The role of the deep chlorophyll maximum (DCM) in the distribution of foraminifera is not always clear, but the increase in the abundance of *G. ruber* (white and pink) seems to be related to deeper DCM, and in conditions of higher salinities (S > 36.5). The ecological habitat of these species is affected by the depth of the mixed layer, with a predominance of the white form in deeper layers. Increases in the foraminiferal diversity are related to the dynamics of the Brazil Current system, which displaces the area of high productivity in the euphotic zone off the coast. The abundances of *Globigerina bulloides*, *Globigerina falconensis, Globigerinella calida* and *Globigerinella siphonifera* follow the nutrient enrichment of the surface water mass, corroborating the importance of these species as paleoproductivity proxies in the study area.

These data confirm the use of diversity measurements and assemblages composition for reconstructing past water column structures in mid-latitude oceans.

## Recent advances in the study of Oligocene Planktonic Foraminifera

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As a follow up to the Paleogene and Eocene Atlases of planktonic foraminifera we have recently completed a revision of the taxonomy, paleoecology, evolutionary relationships and stratigraphic distributions of planktonic foraminifera from the Oligocene Epoch. As was the case in in the previous two Atlases, we have based our research on scanning electron micrographs of most of the type specimens and extensive illustration of exceptionally well-preserved material from around the world. The Atlas of Oligocene Planktonic Foraminifera is composed of 21 chapters in which all the species spanning the Oligocene and Early Miocene are documented.

We preliminarly recognize a total of 127 species, of which 13 are new, and 26 genera, of which 3 are new. Analysis of wall structures forms the basis of our higher classification, dividing the group into microperforate, spinose and nonspinose groups. A revised biostratigraphic zonation of the "O" zones has been developed in parallel with this work. Novel aspects of the taxonomy include:

1) To distinguish among the several globular *r*-strategist taxa occurring in the Oligocene the concept of pore density and pore diameter is introduced in the taxonomic identification of some genera.
2) A new phylogeny for the Late Oligocene to Early Miocene *Globigerinoides* is proposed, three new species of *Globigerinoides* are described as well as some species that were previously overlooked are re-introduced.
3) *Globorotaloides suteri* is revised and reintroduced as a valid species. The origin of the exant taxon *Globorotalides hexagonus* is traced to the *Globorotaloides variabilis* group in the late Oligocene and a new species *Globorotaloides* is described as a transitional form that links *Globorotaloides* to the near-planispiral globorotaloidid genus *Protentelloides*.
4) A new classification of microperforate wall textures is presented and used as the basis for the higher taxonomy of microperforate forms.

## Measuring photosynthesis of symbiont-bearing planktic foraminifers and implications for ecological difference

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Among modern planktic foraminifers, some species have developed photosymbiotic ecology with algae, and the photosymbiosis is assumed to offer a great advantage in inhabiting oligotrophic oceans. However, how the photosymbiosis is involved in the host foraminiferal ecology has not been well understood. Here, we offer new insights for photosymbiosis based on photosynthetic characteristics of symbionts, obtained by in vivo fluorometric analysis (Fast Repetition Rate Fluorometry, FRRF).

We cultured two symbiont-bearing species, *Globigerinoides sacculifer* and *Globigerinella siphonifera*, and conducted FRRF measurement on individual host-algal consortium during the culture period. FRRF

can identify photosymbiosis of individual foraminifer instantly in a non-destructive manner, and gives us various photosynthetic characteristics of symbionts, i.e., maximum fluorescence ($F_m$, index of chlorophyll content), photochemical efficiency ($F_v/F_m$, index of potential photosynthetic activity), and effective absorption cross-section of photosystem II ($\sigma_{PSII}$, capability of the absorbed energy to promote a photochemical reaction).

The $F_m$ was higher in *G. sacculifer* than *G. siphonifera*, indicating that the algal biomass per individual foraminifer was greater in *G. sacculifer*. Although $F_v/F_m$ was not different between the two species, $\sigma_{PSII}$ was higher in *G. siphonifera* than *G. sacculifer*. These results suggest that the potential photosynthetic activity of symbionts was comparable between the two species, but the symbionts in *G. siphonifera* can utilize low light energy more efficiently. In addition, the higher $\sigma_{PSII}$ in *G. siphonifera* indicates that this species can be considered "low-light-adapted" than *G. sacculifer*, which is reasonable for inferred habitat preference of *G. siphonifera*, i.e., relatively deeper habitat than *G. sacculifer*.

These results showed that the symbionts in *G. siphonifera*, chrysophytes, perform photosynthesis but the photosynthetic products are low. Therefore, the host availability of photosynthates from symbionts for nutrition is lower in chrysophytes-bearing *G. siphonifera* than dinoflagellate-bearing *G. sacculifer*, which may indicate the possible differences of trophic strategy (e.g., utilization of photosynthates) of the host foraminifers.

## Posters

### Genetic diversity, seasonality and ecology of *Globigerina bulloides* and *Turborotalita quinqueloba* in the North Atlantic

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The interpretation of planktonic foraminiferal fossil assemblages for palaeoenvironmental studies requires a comprehensive understanding of morphospecies ecology both spatially and temporally. This is particularly true in regions subject to strong seasonality such as in the North Atlantic. In this study, we report on a large data base of genetic information on *G. bulloides* and *T. quinqueloba* specimens, collected during seven different cruises in the North Atlantic from subpolar and transitional waters.

The results show that small subunit ribosomal DNA genotypes of both morphospecies have distinct biogeographical patterns throughout the seasons, indicating that they have divergent ecological adaptations. We found two *G. bulloides* cool water genotypes (Type IIa and Type IIb) and one warmer water genotype (Type Ib) within the northern and eastern regions of the North Atlantic. Although the cool water genotypes occur together at times, there are clear differences in their temperature distribution. Seasonality studies indicate that the lower adaptive temperature range of Type IIa is lower by ~5°C than that of Type IIb. Type IIa therefore advances ahead of Type IIb as the spring plankton bloom extends north and Type IIa is the only genotype found in the most northerly subpolar/polar latitudes today. At their southerly extent, both genotypes interface with the warmer water *G. bulloides* Type Ib within the northern Canary Current in winter. The warmer water genotype Type Ib was also identified off the Canary Islands. There are also two cool water genotypes of *T. quinqueloba* (Type IIa and Type IIb) in the North Atlantic which behave differently from those of *G. bulloides*. Only *T. quinqueloba* Type IIb was present in the extending spring bloom and it was the only genotype found in the extreme north. *T. quinqueloba* Type IIa was found in the summer months south of Iceland yet seemed tolerant of the cold low salinity waters of the East Greenland Current.

The higher latitude North Atlantic sediments therefore represent seasonally overlaid assemblages of two distinct genotypes of both *G. bulloides* and *T. quinqueloba* with different ecologies and potentially distinct geochemistry. This produces a mixed environmental signal within the sediments, with clear implications for palaeoclimate reconstruction. The independent calibration of genotypes would bring enhanced precision to the interpretation of the geochemical signals in this region.

### Short and long-term dynamics of planktonic foraminiferal assemblages off Puerto Rico (Caribbean) – Impact of Hurricane "Sandy"

**Anna Jentzen**[1], Joachim Schönfeld[1], Michal Kucera[2], Agnes Weiner[2] and Dirk Nürnberg[1]

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In recent investigations, a large reduction or absence of the surface dwelling planktonic foraminifera *Globigerinoides ruber*, white variety, was recorded in the tropical Atlantic and Caribbean Sea. This evidence is based on observations that were made during early spring (January – March) in the northern hemisphere. Therefore, plankton sampling was resumed in fall 2012 (October – November) along a transect off southern Puerto Rico to test whether the lack of *G. ruber* white was not attributed to seasonal variations. Furthermore, the population structure and distribution was monitored over a full lunar cycle. During our observation period the hurricane "Sandy" passed the area. Plankton samples were taken on four days with an Apstein net (mesh size of 100 μm) at three different stations on the shelf and upper slope.

Two different depth intervals (0-60 m and 60-100 m) were sampled at two stations. At the shallow station only the upper 5 m of the water depth were sampled. The standing stock of the living fauna varied from 0.6 to 82 specimens $m^{-3}$ and showed a drawdown after the transit of the hurricane "Sandy". A total of 15 planktonic species and 11 benthic species were found in the plankton nets. The assemblage composition and size distribution provides no evidence for reproduction though it was expected being commonly linked to the lunar cycle. A change in species composition was recognised that had taken place since a previous survey in 1994 at the same location and months. In our recent study from 2012, *G. ruber*, pink variety, and *Globigerinoides sacculifer* were the dominating species and *G. ruber*, white variety was rare. In 1994, *G. ruber* pink and white were both the most frequent species. The depth distribution shows that *G. ruber* pink and white, *G. sacculifer* and *Globigerinita glutinata* had the highest standing stock in the surface net. The species *Globigerinella calida, G. siphonifera* and *Globorotalia menardii* preferred the deeper water column. The benthic assemblage was dominated by the meroplanktonic species *Bolivina variabilis.* The species *Tetromphalus bulloides* and *Trifarina bella* were found frequent in the net. After the transit of Hurricane "Sandy" the concentration of benthic specimens increased in the uppermost 60 m of the water column.

## Session 7: Foraminifera Bio-Monitoring Methods

## Keynote Lecture

### The FOBIMO (FOraminiferal BIo-MOnitoring) initiative — a protocol for benthic foraminiferal monitoring studies

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Monitoring the status of marine environments is traditionally based on macrofauna surveys, for which standardised methods have been established. Benthic foraminifera are also good indicators of environmental status because of their fast turnover rates, high degree of specialisation, and their preservation in the fossil record. In spite of the growing interest in foraminiferal bio-monitoring during the last decades, no standardised methodology has been proposed until today. The aim of the FOraminiferal BIo-MOnitoring (FOBIMO) workshop, held in June 2011 in Fribourg, Switzerland, which assembled 37 scientists from 24 research groups and 13 countries, was to develop a suite of standard methods. We present the outcome of the workshop, a list of motivated recommendations with respect to sampling devices, storage and treatment, faunal analysis and documentation. Our recommendations fulfil the criteria imposed both by scientific rigour and by the practical limitations of routine studies. Hence, our aim is to standardise methodologies used in bio-monitoring only and not to limit the use of different methods in pure scientific studies. Unless otherwise stated, all recommendations concern living (stained) benthic foraminiferal assemblages. We propose two types of recommendations; mandatory and advisory. Mandatory recommendations have to be followed if a study wants to qualify as sound and compatible to the norms. The most important mandatory recommendations are that the interval from 0 to 1 cm below the sediment surface has to be sampled, and an interface corer or box corer that keeps the sediment surface intact is to be used for offshore surveys. A grab sampler must not be deployed in soft sediments. Three replicate samples are to be taken and analysed separately. Samples are to be washed on a 63-µm screen, but only the living benthic foraminiferal fauna of the >125 µm fraction is mandatory to analyse. Splits are to be picked and counted entirely, and all counted foraminifera from at least one replicate per station have to be stored in micropalaeontological slides. Census data, supplementary laboratory data and microslides have to be archived. Advisory recommendations are to sample in autumn, to sample a sediment surface area of 50 cm2 or a tube of 8 cm inner diameter, to use >70% ethanol as a preservative, rose Bengal at a concentration of 2 grams per litre for staining, and a staining time of at least 14 days. The split size should be defined by a target value of 300 specimens, heavy liquid separation should be avoided, the 63–125 µm fraction and deeper sediment levels may be considered in some environments. We acknowledge the Swiss National Science Foundation grants IZ32Z0-135895/1 and IZ32Z0_143010.

## Oral Presentations

### Paleoenvironmental reconstruction of Isahaya Bay, Japan over the past 50 years based on benthic foraminifers

**Kazumi Akimoto**

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The Japanese government accepted a judicial decision stating the environment of Ariake Sea rapidly deteriorated after closing the floodgate of the Isahaya Reclamation Area in the innermost part of the sea in 1997. However, the profile of microfossils in two cores obtained near the reclamation area show that the environmental deterioration began before the closing (Akimoto, et al., 2004; Matsuoka, 2004). This study focuses on the environmental change over the past 50 years in the outer area of Isahaya Bay where the environment worsened after the gate closure.

Cores B and G were collected by diving beneath the boundary of the coastal and central bay waters masses and analyzed for $^{210}$Pb and $^{137}$Cs age, grain size, and benthic foraminifers. Q-mode factor analysis with varimax rotation identified four factors that account for 91% of the variability of the data. Factor 1 accounts for 35.5% of the variance, its high loading value (>0.5) present in almost all samples in core B, and the depth intervals from 10-15cm, 22-23cm, and 30-31cm in core G. *Ammonia beccarii*, which inhabits the coastal waters under the influence of daily salinity fluctuations, has a high positive score of this factor. Thus, Factor 1 represents the coastal water mass. Factor 2 accounts for 26.5% of the variance, its high value of loading recognized in the samples above the 1954 horizon in core G and 1960 in core B. The factor is marked by the presence of *Elphidium somaense* and *Trochammina hadai* which inhabit the bottom characterized by rich organic matter at the boundary between the open sea and coastal waters in modern Ariake Sea (Tanaka, et al., 2005). Thus, Factor 2 suggests that the supply of rich organic matter began in 1960. This implies the eutrophication of the seawater began in 1960 in the outer area and expanded to the inner area, related to the water masses boundary location and the amount of organic matter. The pattern of Factor 1 loading corresponds to a ~20-year change of the tide level in the East China Sea. The increase in inflow of open sea water during high tide reduced the range of coastal water and moved the boundary's location to its present position. The pattern of Factor 2 loading indicates that the bay was influenced by pollution originating from human activity. Although no nitrogen and phosphorus data exist before 1970 for the major rivers around Ariake Sea, the Japanese economy rapidly grew from 1954 to 1973. These results suggest that the effect of the Japanese government's open gate environmental recovery plan is limited to a small narrow range of the Ariake Sea.

### Foraminifera on Brazilian coral reefs on the evaluation of environmental health

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Coral reef sites of Brazil were analyzed for their sedimentary environmental health conductive to coral reef growth, using foraminiferal assemblages, FORAM Index (FI – Foraminifera in Reef Assessment and Monitoring), coral cover, geochemical, and sedimentological parameters. The sites analyzed span from the Northeast (Maracajaú, Rio Grande do Norte state, 4.609278 S, 35.207062 W, and Tamandaré, Pernambuco state, 8.739864 S, 35.106232 W), to the East part of the country (Porto Seguro, Bahia state,

16.393931 S, 39.070559 W), and are located close to the coastline. These sites represent a 12 degree latitudinal range and had their results analyzed through Principal Components using relative species abundance, and the aforementioned data, which are all important for biodiversity and risk assessment. Analysis of *Amphistegina* spp., and their taphonomy were used to augment the ecological results of the FI, and permitted the mapping of unstable areas related to coral cover data, evaluated using sites surveyed under Reef Check Brazil protocols. The end product is a map of vulnerable areas, where monitoring efforts should be concentrated.

## Assessing reference conditions of marine systems: Numerical approaches using benthic Foraminifera

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While not a single living system remains unaffected by human activities, it is still challenging to tease apart the influence of anthropogenic forcing to that related to natural variability. In Europe, the publication of Marine Legislations has stimulated the search for effective bio-monitoring tools that can be applied to evaluate ecosystem health of marine ecosystems. These legislations require that reference conditions and potential present-day deviations are defined. Biological compartments such as macroalgae, phytoplankton, sea-grasses and benthic macrofauna are used to assess ecological quality statuses (EcoQS) in marine waters. A recurring problem is that, for most areas, there are no data available from pre-impact times, which often prevent the determination of reference conditions. The fossil record may allow the reconstruction of PaleoEcoQS and thereby the establishment of *in situ* reference conditions. Including the foraminifera method in standard bio-monitoring assessments, will allow reconstruction of *in situ* EcoQS from pre-impacted (reference conditions) until present times even in areas where biological- and instrumental time-series are limited or lacking. Our studies in southern Norwegian fjords showed that benthic foraminifera are as reliable to define present-day EcoQS as benthic macrofauna. The aim of this study is to propose an objective (i.e. not based on expert judgement) method to assess reference conditions and evaluate EcoQS. Here, using datasets from southern Norwegian fjords, we proposed the use of new non-parametric numerical procedures to directly compare benthic foraminifera faunal matrices from reference conditions to matrices from contemporary environments. These algorithms, insensitive to missing data, use a relative reference state determined empirically (i.e., not based on expert judgement) against which each sampling is then tested. We also developed new numerical methods based on multivariate analyses and time series analyses.

## Does AMBI, a commonly used macrofauna-based ecological monitoring measure, work for benthic foraminifera?

**The Fobimo-NE Atlantic group**

**Sergei Korsun**[1], Elisabeth Alve[2], Elena Golikova[1], Silvia Hess[2], Katrine Husum[3], Giuliana Panieri[3] and Joachim Schoenfeld[4]

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It has been shown for decades that benthic foraminiferal assemblages successfully characterise both present and past environmental conditions as well as reflect environmental changes. This is in contrast to macrofauna (the group of organisms traditionally used in standard environmental monitoring) which do not have an abundant fossil record. Still, the foraminiferal approach has not been included as a recommended method in any governmental guidelines for environmental monitoring programs. In 2011, the FOBIMO (FOraminiferal BIo-MOnitoring) initiative (an international group of foraminifera experts) was established in order to address this shortcoming. The group published a suggestion for a standardised protocol for soft-bottom benthic foraminiferal monitoring studies, and the next step is to test biotic indices which, on a global scale, can characterise the ecological status of marine environments equally as effectively as the macrofauna. An obvious first choice was AMBI which is used in macrofauna monitoring all over the world. Our first test of this index comprises all published data from the NE Atlantic shelf and upper slope (from Gibraltar northwards) where gradients of both benthic foraminifera and total organic carbon (TOC) are reported from the same sites. TOC is not an ideal parameter for organic matter contamination but it was chosen because it is the one most commonly reported. Only normal marine samples containing >50 individuals were considered. For each data set, the common species were assigned to one of five sensitivity groups using a slightly modified version of the criteria set in AMBI. Possible impacts of sand content and water depth were considered. Based on these assignments, a global assignment for each species was performed for the whole data set. Tests were run on two published, independent data sets which had not been used in the species assignments; one based on living assemblages and one based on fossil (dead) assemblages in sediment cores representing the last century. The test results show significant correlations between the calculated "AMBI" and associated TOC-values as well as with species diversity indices such as H' and ES(100). Therefore, one of the most commonly used macrofauna-based indices used in environmental monitoring also works when based on benthic foraminifera.

## Benthic foraminiferal response to an oil spill in the Bohai Sea of China

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Benthic foraminiferal may change quickly in response to the changing environment. Therefore they are regarded as potential bioindicators of oil pollution. The Penglai 19-3 oil spill of the Bohai Sea in 2011 is the biggest oil spill within several decades in China. It impacted the marine life, environment and economy. For detecting oil pollution in this sea area, benthic foraminifera were sampled using quantitative layering sampler at 9 stations along the pollution gradients. The sampling was performed six months after the spill. Environmental factors including PAHs (Polycyclic Aromatic Hydrocarbon), oil, sulfides, organic carbon were measured. Foraminiferal abundance, species composition, diversity and assemblage variables were examined in 0.154 mm and 0.061 mm size fractions. Thirty-eight species were identified. Foraminiferal abundance was in the range of 11-41 individuals/g sediment in the >0.154 mm size fraction, and of 146-384 individuals/g sediment in the >0.061 mm size fraction. The statistical analyses demonstrated that the foraminiferal density and diversity significantly correlated to PAHs and organic carbon. *Astrononion gallowayi* and *Buccella frigida* might be good bio-indicator species for oil pollution.

Multivariate analyses revealed that the frequency of the majority of foraminiferal species changed significantly along the oil pollution gradient. The study was supported by grants NSFC41176132, MGK1210, No201303, DOMEP(MEA)-01-01, and 2012IO060105).

## Bulk concentration or bioavailability of PETS: Benefits and pitfalls in environmental micropaleontological studies

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Environmental micropaleontological studies involving the use of Potentially Toxic Elements (i.e., heavy metals) have concentrated efforts in the use of bulk sediment concentrations. It is expected that such approach will overestimate the actual concentration of the target contaminant(s) and this is often assumed to be one of the reason for morphological deformities and/or spatial distribution of benthic foraminifers. High bulk concentration of Potentially Toxic Elements does not translate directly to becoming bioavailable for foraminiferal populations as well as to other macro-/microorganisms. The rationale behind it is that contaminant(s) can be found within sediments in several fractions due to chemical "speciation": residual (e.g., lithics), acid-soluble (e.g., carbonates), reducible (Fe/Mn oxides), oxidizable (e.g., organic matter), and exchangeable (e.g., clay minerals).

The purpose of this presentation is to bring forward in a semi-quantitative way the subtle differences of using bulk vs bioavailable concentrations of Potentially Toxic Elements in sediments. Similarly, physic-chemical parameters and ocean chemistry will be discussed as main control parameters during "speciation".

## Impact of ocean acidification on carbonate production by the large benthic foraminifer *Marginopora vertebralis* in the coastal waters of Fiji

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Increased $CO_2$ emissions into the atmosphere lead to increased concentration of dissolved $CO_2$ in the ocean. Chemical reactions between the dissolved $CO_2$ and seawater transform the dissolved $CO_2$ into $HCO_3^-$ and $CO_3^{2-}$ and produce $H^+$ ions. These ions increase the acidity of seawater and decrease pH. Increased acidity and decreased availability of calcium and magnesium ions affect carbonate and aragonite production by marine calcifiers in the Pacific Ocean. Large benthic foraminifera, such as *Marginopora vertebralis* Quoy and Gaimard, 1830, produce calcite with high magnesium (Mg) content and have an important role in sand building on Pacific Islands. It is thus important to better understand the biomineralization processes in foraminifers for predicting their calcification response to ocean acidification.

To assess the response of benthic foraminifer to changing carbon dioxide levels, we cultured *Marginopora vertebralis* Quoy and Gaimard, 1830 at three different pH levels (pH 7.5,pH 7.8 and pH 8.1 (ambient seawater). The fluorescent compound calcein (~40 micromoles/litre) was added to the culturing tanks to mark the calcite growth during the culturing period. The specimen grown in the laboratory were analysed using laser ablation-inductively coupled plasma mass spectroscopy (LA-ICPMS) and electron probe micro analyser (EPMA) to measure elemental compositions and (B/Ca, Mg/Ca and Sr/Ca) ratios. Results indicate that the shell weight decreased with decreasing pH level. The elemental ratios also decreased with decreasing pH.

## DNA metabarcoding as a tool for monitoring environmental impact associated with fish-farming on community of benthic Foraminifera

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Metabarcoding applies the principle of DNA barcoding to estimate species richness in environmental samples. Recently, the use of DNA barcodes was prompted by the development of next-generation sequencing (NGS). Several NGS-based studies revealed an astonishing diversity of marine eukaryotes. However, the practical applications of metabarcoding in biomonitoring, especially in aquaculture, are still relatively limited.

Traditionally, the impact of fish-farming and any industry with point-source discharges into the coastal environment is evaluated by assessing changes in macrobenthic infauna around the impacted site. Here, we propose to replace the traditional macrofaunal assessment by NGS-based metabarcoding approach using benthic foraminifera. We analysed the impact associated with salmon farms in Scotland and New Zealand on communities of benthic foraminifera, which are known to be abundant, diverse and highly responsive to environmental perturbations. We have developed an approach to identify foraminiferal species based on DNA microbarcodes generated by Illumina technology. Our study revealed changes in foraminiferal community between samples collected in the vicinity of fish-farms and at distant localities. The metatranscriptomic (RNA) data showed a decrease of taxonomic diversity in strongly impacted sites. We also observed a clear difference in abundance of some common species in relation to the distance to cages, redox and C/N values. Based on this proof-of-concept study, we concluded that metabarcoding using foraminifera has potential to become a new promising tool for environmental surveys of fish-farming and other aquaculture activities.

## The size of benthic Foraminifera in a marine area affected by industrial pollution

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In several studies concerning the foraminiferal assemblages of polluted coastal marine areas, it has been noticed the potential reduction of the size of foraminifera also if no biometric analysis has been executed to quantify this aspect. This research is aimed to compare assemblage composition and faunal parameters from the analyses of two different fractions (>125 μm and >63 μm), to verify their similarity. We used data from core AU10, collected in Augusta harbour (Sicily, Italy), which has been affected since the 1950s by strong contamination due mainly to a petrochemical pole, associated to an important harbour activity. Surface sediment contamination is mainly due to mercury (Hg) and Polychlorobyphenils (PCBs) containing up to 200 mg/kg d.w. and 0.8 mg/kg d.w. respectively; much higher values are recorded in the deeper levels.

In this study, the 63-125 μm fraction and the >125 μm fraction were studied separately; then, they were summed to obtain results for the >63 μm fraction. A no relevant sediment transport in the study area is supported by the lack of foraminifera just in the core interval with the highest contamination (Hg > 500 mg/kg d.w., PCB > 7.5 mg/kg d.w.).

A Foraminiferal Size Index, was determined as the rate of individuals found in the finer and coarser fraction ($FSI = N_{63\text{-}125}/N_{>125}$). This parameter showed the highest values (up to 13.5) in the intermediate highly polluted core interval and decreasing pattern towards to the core top, in correspondence of lower contamination. Composition, species richness and diversity (H' and α) of the two assemblages were compared. About diversity indices, the rate of values in the two assemblages (H'-rate and α-rate) were determined together with the % of species lost in the coarser fraction (%LS). Results showed depletion of the coarser assemblage, with consequent different composition and microhabitat preference of the two assemblages. FSI, H'-rate, α-rate and %LS were significantly correlated, indicating that foraminiferal size influences parameters descriptors of environmental quality. The Principal Component Analysis applied on both fractions provided a better discrimination of species groups for the > 63 μm fraction.

The FOBIMO protocol indicates as mandatory the use of the >125 μm fraction for the faunal census aimed to biomonitoring. The present study indicates that an exception to this rule has to be considered for studies on chemically pollutes areas, because the small-sized specimens may be prevailing and a study of the >125 μm fraction would supply unreliable information on environmental quality.

## The effect of sea surface temperature and salinity increase on marine benthic ecosystems: Revisiting the Hadera heat plume (Israel)

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The eastern most part of the Mediterranean is characterized by extreme oligotrophy, high salinity and temperature values that show a gradual rise over the past few decades. This study follows a similar one

conducted in 2007 in a unique natural experimental laboratory setting of the Hadera power plant thermal plume using benthic foraminifera as a model system to investigate the effects of temperature changes. Since that study was conducted a desalination plant started working near the power plant causing a slight increase in salinity. The study is based on a one-year monthly ecological monitoring, of triplicate samples, of living benthic foraminifera from two stations located along the heated beach rock area and one station at a nearby coastal control station representing normal beach rock environment.

The temperature in the plume is significantly higher than of the natural ambient water, reaching 36 ºC and 24 ºC in summer and winter, respectively, compared to 29 ºC and 17 ºC in the control station. The numerical abundances of foraminifera in the plume vary from high values in spring of ~ 300 specimens/g compared to ~ 70 specimens/g in February and July. This differs from the 2007 trend that also shows an increase in the numerical abundance in the most heated station in spring but with overall lower values. In the control station, the numerical abundance is 5-7 times higher in winter and summer and only 2 times higher in spring. Species diversity is higher in the control station than in the polluted ones throughout the year and especially in summer. The assemblage composition in the plume hardly changed with time and the dominating genera are *Lachlanella*, *Pararotalia* and *Tretomphalus*.

*Pararotalia*, a symbiont bearing species, has high tolerance to high temperatures and is living in the heated plume even in the most extreme summer months. A certain decrease in the relative abundance of *Pararotalia* was observed in winter through summer of 2013 compared to the year 2007. This trend results from the proliferation of other groups but also because of the significant decrease in the numerical abundance of *Pararotalia* itself.

## Poster Presentations

### Benthic foraminiferal biomonitoring: A case study in the Gulf of Gabes (Tunisia)

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One of the most dangerous kinds of pollution in the Eastern Mediterranean Sea is due to phosphogypsum (PG), the major waste products deriving from the processing of phosphate rocks to produce phosphate fertilizers. Tunisia has been a leading country for more than a century for phosphate treatment. The more polluted regions are located along the coasts of the Gulf of Gabes (Sfax, Skhira and Gabes), where several industries have discharged large amounts of PG for the last fifty years producing severe environmental stress and triggering eutrophication. Remediation measures were adopted from 2006 to 2008 in the Sfax area.

The aim of our project is to identify changes in living benthic foraminiferal assemblages in pre- and post- anthropogenic impact times in the Gulf of Gabes, and to investigate the response of these organisms to PG pollution in the region. The sampling and sample treatment will strictly follow the FOBIMO protocol (Schönfeld et al., 2012). The concentration of phosphorus in sea water and sediments, organic matter, carbonate, and heavy metal content in sediments will be compared with the mineralogical composition of phosphate rocks, PG components dissolved in the sea-water and with benthic assemblage patterns. Based on the correlation between benthic fauna and geochemical proxies, benthic foraminiferal ecological groups will be identified and used to assess environmental status. Short cores (60-70 cm) dated by $^{137}Cs$ and $^{210}Pb$ will provide essential information about changes in benthic foraminiferal assemblages and in the environment through historical time.

The specific objectives of this project are: a) to assess euthrophication in the Gulf of Gabes using geochemical proxies and benthic foraminifera; b) to trace variation in space (Sfax, Skhira and Gabes) and time (pre- and post- human impact) of benthic foraminiferal assemblages; c) to investigate the effects of uncontrolled PG pollution on benthic foraminiferal assemblages along the Tunisian coasts; d) to evaluate the effects of existing remediation measures on benthic foraminiferal fauna, and to evaluate the timing of assemblage recovery; e) to contribute the FOBIMO Initiative some data to develop "Biotic Indices" based on benthic foraminifera, as a case study within the Initiative; f) to increase public awareness about the health of the Tunisian coasts and on the steps undertaken to protect them.

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### Distribution and ecology of Recent benthic foraminifera in the mangrove swamp of the Red Sea, Egypt

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A study of recent benthic foraminiferal assemblages was carried out on mangrove swamp of the Egyptian Red sea coast. A total of 54 benthic foraminiferal species were identified. The data were obtained for different species in each sample and the statistically significant fractional abundances values (≥5%) were

analyzed using a Q-mode and R-mode cluster analyses. Samples were segregated into two clusters, each having its peculiar benthic faunal assemblage (biotope), reflecting particular environmental conditions. These clusters are: (1) the *Ammonia tepida, Ammonia parkinsoniana,* and *Elphidium advanum* Biotope, found in samples located in areas with waters of low energy, characterizing enclosed intertidal mud flats conditions, with high organic matter content, low oxygen content and muddy bottom sediments (Swampy environment). (2) the *Peneroplis planatus, Peneroplis pertusus*, *Sorites orbiculus, Quinqueloculina laevigata*, *Quinqueloculina rotunda*, *Agglutinella compresa*, and *Agglutinella rubosta* Biotope found in samples collected from depths characterizing near shore area and the most seaward swamp samples. This environment is characterized by low organic matter content (oligotrophic condition), high oxygen content, and calcareous sediment. The study suggests that sediment type, nutrients, water energy, light intensity, and salinity are the main ecological factors controlling the distribution of benthic foraminifera.

## The first assessment of anthropogenic effects on living benthic Foraminifera in Bizerte Lagoon (Northern Tunisia)

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Bizerte lagoon is a Mediterranean transitional lagoonal ecosystem located in northern part of Tunisia (37°8'-37°14'N; 9°46'-9°56'E). The lagoon communicates with the sea through an artificial inlet. The environment is affected by agricultural, industrial and municipal effluents.

The present study aims at investigating the response of living benthic foraminiferal assemblages to changes caused by physicochemical and pollution disturbance. TOC and simultaneously extracted metals/acid-volatile sulphide and total metals in surface sediment from 10 sites of the Bizerte lagoon were evaluated.

The physicochemical parameters at the sampled sites ranged as follows: temperature from 14.7-15.8 ºC, salinity between 28-33.3, Eh from -57.2 to -30 mV, and pH from 7.7-8.2, oxygen pore waters from 0.2-0.55 mg/l. Sedimentary geochemical variables were: TOC between 2.54-5.93%; AVS values between 0-695 µmol/g, highlighting that the acid-volatile sulfide was present at almost every stations (except LB7). Of all the metals that can cause toxic effects on organisms, Fe and Zn showed the highest concentrations in sediments. Total concentrations of reactive metals (Cr, Ni, Zn, Pb, Cu, Fe, Mn and Co) ranged from 80 to 172 µmol/g and Fe was the most available metal (78-168 µmol/g). Sixty benthic foraminiferal species were identified and diversity values (H' between 0.5-3.8) were particularly high at some stations (LB 2, 10, 11).

The living assemblage included typical lagoonal species such as *Ammonia tepida* (dominant all all the sites) and *Elphidium excavatum* and several open sea species, such as *Bolivina striatula, Hopkinsina atlantica, Bolivina compacta, Bulimina aculeata*, *Triloculina trigonula, Spiroloculina depressa, Bolivina dilatata, Bulimina marginata, Fursenkoina squamosa, Nonionella atlantica* and *Nonionella iridea.* Nearly all these species are known to be opportunistic.

Statistical analysis, correlating the most abundant and common benthic foraminiferal species (reaching at least 1% in one station) and abiotic data, highlighted the reduction of diversity and density of foraminifera in most sites affected by high values of TOC, more intense release of sulphides associated with anoxic conditions and by highest concentrations of reactive metals. In particular, the eastern side of the lagoon, which is the most stressed area, was dominated by *A. tepida* and *E. excavatum*. The other species seemed to prefer more oxic and low polluted conditions.

These data provide evidence that some benthic foraminiferal species, usually found offshore, can demonstrate an opportunistic response. They live in this lagoon under unfavourable physicochemical conditions and take advantage of the abundant food.

## Ecological characteristics of symbiont bearing larger benthic foraminifera from *Halophila* seagrass, Gulf of Aqaba, Red Sea

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Seagrasses cover about 0.1–0.2% of the global ocean and develop highly productive ecosystems which fulfill a key role in the coastal environment. The only known seagrass in the Gulf of Aqaba is the species *Halophila stipulacea* that forms meadows over vast areas of the Gulf's shallow habitats. Among the inhabitants of *H. stipulacea* are Larger Benthic Foraminifera (LBF) that populate the seagrasses in high densities. Seagrass and LBF are important contributors to tropical marine environments and are known to respond to anthropogenic stressors.

This research examines the potential use of *H. stipulacea* and their LBF inhabitants as bioindicators for the condition of the marine ecosystems in the gulf. Specifically, monitor seasonal changes in the LBF assemblages living on *H. stipulacea* in respect to different water depths (9 and 18 m), by means of quantitative population and phylogenetic analyses. The investigated sites represent two different habitats of *H. stipulacea* meadows: Station N, at the northern flat shelf, is a continuously disturbed habitat by human activities, ephemeral floods; Station S, located on a steeper shelf adjacent to the fringing reef, represents clean natural and undisturbed condition.

We report here the preliminary results of the first six months of the ecological monitoring. The numerical abundance of LBF at the disturbed st.N is nearly even laterally (with~170 #/g wet *Halophila*) while at st.S the numbers are 3-10 times higher at 9m (up to 700#/g) than at 18 m (<75#/g). These differences might be attributed to the "healthy state" of these stations. *Amphistegina lessonii* is the most common LBF living on the *Halophila*, being more abundant at 18m at st.N and at 9m at st.S. *Amphistegina lobifera*, a common LBF species in the gulf, occurs in this habitat in low numbers. Other LBF living on the *Halophila* are soritids and peneroplids that occur in both locations in moderate to low numbers. *Assilina ammonoides* and *Borelis schlumbergeri* are living only in the northern meadow. In the case of *Assilina*, its presence might be related to its more opportunistic life strategy as recently was observed in the gulf.

## The study of recent Foraminifera in Cuba: Current status and perspectives

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We present here a compilation of published and unpublished data on foraminifera from Cuba to highlight their value as ecological, environmental and paleo/climatic indicators. These data include information on the taxonomy, systematic and zonal distribution of foraminifera as well as their potential use in paleoclimatic reconstructions and research related to climate changes. We report an inventory of 217 species grouped into 133 genera. Investigation on foraminifera is presently poorly developed in Cuba, Therefore our aim is to disseminate the knowledge accumulated to date on modern foraminifera from Cuban waters and to promote this research.

## Benthic foraminifera and heavy metals from the Bay of Bakar (Adriatic Sea, Croatia): Pollution assessment

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The Bay of Bakar is one of the most heavily polluted bays of the Eastern Adriatic. Three major industrial companies potentially endanger the bay. The concentration of major, minor and trace elements (heavy metals) in surface sediments from thirteen stations was discussed in relation to the sediment type and foraminiferal assemblages.

The distribution of major elements in the bay is influenced by geological nature of surroundings. Broader area of the bay is composed of carbonates, with minor appearance of flysch deposits which causes inversely proportional behavior between Ca and all other major elements: Si, K, Al, Mg and Fe.

The highest concentrations of heavy metals (Cu, Pb, Rb, Th, Zn, Zr, Cr, Ti and V) were found in sediments with significant amount of fine-grained fraction and with high content of clay minerals. Consequently, their concentration and distribution in the bay depend not only on pollution sources, but also on amount of clay minerals that carry and accumulate heavy metal association. Heavy metal concentrations throughout the bay generally fall into allowed depositional values defined for marine environments; only stations in front of the coke plant and city harbor exceed threshold values.

Foraminiferal assemblages correspond to geochemical characteristics of the sediment, but the type of substrate controls the community as well. Fine-grained sediments with increased concentrations of heavy metals are inhabited with stress-tolerant species (*Ammonia* and *Haynesina* group). However, high biodiversity of this foraminiferal group, low percentage of deformed specimens, high species richness and the highest foraminiferal densities do not point to any notable changes of the community caused by the pollution. Only decrease of foraminiferal density at station in front of coke plant reveals somewhat stronger influence of pollution at this station. The second foraminiferal group consists of larger number of epifaunal taxa and is found on coarse-grained sediments with lower heavy metal concentrations. Such community composition is related to sandy and gravely sediment fraction, which is more favorable to their habitat.

## Foraminiferal biotopes of the Lagoon of Aveiro (Portugal)

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The Lagoon of Aveiro is a very complex coastal ecosystem located in the middle part of Portugal (40°38'N, 8°45'W). The lagoon has a complex outline; it is an intercrossing of channels and islands, extensive mudflats, salt marshes and old saltpans. The lagoon is connected with the Atlantic through an artificial inlet and is separated of it by a sandy barrier. The marine influence is stronger near the lagoon mouth and diminishes towards the inner areas where the influx of several rivers cause significant decrease of water salinity.

Textural, mineralogical, geochemical, microfaunal (foraminifera) and physicochemical data of 225 sites are analyzed in this work. About 260 species/taxa were identified in the studied area. Selected biotic and abiotic variables were submited to multivariated analyses aiming to recognize, characterize and explain the main benthic foraminiferal biotopes.

Five different biotopes have been recognized: (1) a marsh and inner lagoonal biotope; (2) an urban and marginal urban biotope; (3) an inner to outer lagoon or enclosed lagoon biotope; (4) an outer lagoon, mixed sub-biotope; and (5) an outer lagoon, marine sub-biotope. These biotopes are largely subdivided by the substrate type and are further characterized by local currents, water depth, chemical and physical conditions, river and/or oceanic proximity, and anthropogenic impact. Sediments in confined areas, under higher anthropic influence, are contaminated by trace metals and organic matter. Statistical analyses also evidence that much of the variability in benthic foraminiferal assemblage distribution in this lagoon might be explained to a large extent by the following gradients: 1) confinement degree, with implications for instance in pollutants accumulation and sediment pore-water oxygenation; 2) hydrodynamical conditions; and 3) salinity gradients from marsh to lagoonal conditions. The results evidence that the tidal currents have a direct or indirect influence on foraminiferal distribution in conjunction with rivers flux related to weather conditions. The hydrodynamical conditions influence the substrate stability, patterns of sediments erosion and/or accumulation, food supply to the benthic environment and the accumulation of contaminants, imposing changes in dimension, composition and structure of benthic foraminiferal assemblages.

# Benthic foraminifera as pollution bioindicators in marine sediments along the Mediterranean Coast of Alexandria, Egypt

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A detailed comparative study of benthic foraminiferal populations was carried out at two sites, namely the Eastern harbor and the Montaza Bay, located along the Mediterranean Coast of Alexandria, Egypt. Thirty four surface samples and 4 cores (21-35 cm length) were taken from the Eastern Harbor, whereas 12 surface samples and 3 cores (21-32 cm length) from the Montaza Bay. Eighty benthic foraminiferal species belonging to 40 genera were identified. Planktic foraminifera were very rare, represented by only one species (*Globigerinoides ruber*). The spatial distribution of the recorded benthic assemblages in both surficial and core samples are nearly similar in each area, but remarkably different in the two areas. The eastern Harbor is dominated by members of the Order Rotaliidae (54.1% of the total assemblage). Members of the order Miliolidae comprised the second important component (44.9%). On the contrary, the foraminiferal assemblage in the Montaza Bay is dominated by members of the Order Miliolidae (64.6% of the total assemblage), followed by Order Rotaliidae (34.8%). The Eastern Harbor is polluted, being contaminated by heavy metals (chiefly Cu and Zn), as well as, domestic effluents. This results in low species diversity, α-Fisher index and high percentage dominance, associated with an increase in opportunistic species (*Ammonia beccarii* forma *tepida* and *Bulimina marginata*) and decrease in sensitive species (miliolids). In this contaminated environment, foraminiferal tests were stunted and aberrant forms were frequently found. Species diversity and α-Fisher index are higher in the Montaza Bay (reference site). The study reveals that: (1) benthic foramnifera are very sensitive to heavy metals; (2) benthic foraminifera reflect human-induced perturbation; and (3) benthic foraminifera can be used for monitoring costal pollution.

## Session 8: Advances in Environmental Micropaleontology

## Oral Presentations

### Growth oscillation studies on larger benthic foraminifera: A synthesis of the newest results obtained by CT-investigations

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The use of computed tomography in larger benthic foraminifera (LBF) is not restricted to the visualization of internal structures as three dimensional (3D) representations, but also can be used to measure characters impossible to obtain by classic thin-section methodology. Measurements of volumes, porosity and density can be routine analyses in every CT investigation. For this study, 38 specimens of recent LBF were scanned: 19 *Palaeonummulites venosus*, 7 *Cycloclypeus carpenteri, and* 12 *Heterostegina depressa*. Eight of the latter belong to Prof. Röttger and were sampled in the Hawaii region. The other 4 specimens of *H. depressa* were cultivated by Röttger during the late 90´s at the University of Kiel (Germany). The other specimens all were collected by JH either on the western shelf of Okinawa or in coastal regions of Belau.

For each specimen, all chambers have been analyzed to create 3D models for volume calculation. The chamber volume sequence represents the ontogeny of the foraminiferal cell and is the result of the growth function modified by ecological variation. Changing environmental conditions during growth are therefore represented in the sequence of the chamber volume. We observed that the chamber volume increases according to the Gompertz function following the chamber-building rate modeled by the Michaelis-Menten function. The observed values standardized by the Gompertz function oscillate around the expected values along the time scale. Power spectral analyses have been calculated to find the most significant sinusoidal functions by periods. The results of these calculations show that chamber sizes in the naturally grown specimens oscillate with periodicities that clearly point to tidal cycles, moon cycles and seasonality. Depending on the origin of a sample, the observed cycles vary according to the environmental parameters affecting the sampling locality.

The same calculations made on cultivated specimens reveal, as expected, neither tidal nor precipitation cycles, but instead extremely complex morphological variations in the test. Substantial shape deviations have been observed in the internal geometry of the cultivated specimens, even if the external appearance of the test is nearly perfect. For example, septa can become wavy instead of straight. Moreover, septula are rarely complete and commonly lead to large holes within the test. These observations indicate that misinterpretation of the environment can occur when specimens externally appear nearly perfect, but instead show drastic internal morphological variation caused by local stress.

### Phenological Trends in Foraminiferal Densities from Temperate and Tropical Estuaries

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Time series of foraminiferal densities from tropical Caroni Swamp (eastern Trinidad) and temperate Cowpen Marsh (northeastern England) were compared to determine environmental differences between a

swamp and marsh. At Caroni Swamp, three stations from high, middle and low tidal zones were sampled monthly for three years (March 2011 to 2013) at three sites. At Cowpen Marsh, a transect (31 stations; high to low marsh) was sampled bi-weekly from May 1995 to April 1996. For this study, only the living foraminiferal densities on the 1st of each month were compared. Foraminiferal densities were standardized to 300 $cm^3$. During the rainy season (July to December) a low salinity, high productivity water plume expands from the Orinoco River (Venezuela) through the Gulf of Paria, where the Caroni Swamp opens. At this time the subsurface chlorophyll maximum (SCM) averages 77 ± 12 m, while in a dry season shallower SCM depths are recorded (mean = 39 ± 16 m). At Caroni Swamp, the foraminiferal samples are almost barren (mean 7 specimens/300$cm^3$) in the dry season but richer (mean 895 specimens/300$cm^3$) in the wet season, which is thought to be a result of increased primary productivity from the plume. Kaw Estuary (French Guiana) affected by the Amazon River plume, also shows richer communities in the rainy season (mean 5947 specimens/300$cm^3$) than in the dry season (mean 221 specimens/300$cm^3$). Phytoplankton blooms occur in the North Atlantic during warm spring/summer months. Foraminiferal blooms at Cowpen Marsh coincide with seasonal phytoplankton blooms: mean 5854 and 2431 specimens/300$cm^3$ in July and December, respectively. Foraminiferal population densities are often used to assess the health of an ecosystem. Knowing the influence of fluvial plumes on foraminiferal dynamics at monsoonal wetlands would enhance the applicability of foraminifera to environmental monitoring. A three year-long time series analysis of the Caroni Swamp foraminiferal community will determine if the observed changes in foraminiferal densities are indeed phenological trends to be accounted for in tropical wetlands.

## Distribution of live benthic foraminifera off the Douro River (Western Iberian Margin): The importance of the terrestrial organic matter

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Living (stained) benthic foraminifera assemblages and geochemical characterization of the organic matter (phytopigments, amino acids, $\delta^{13}C_{oc}$, BIT) were investigated on a cross-margin transect off the Douro River (Northern Portuguese margin) in order to assess the role of the quality of organic matter on the distribution of live benthic foraminifera. For this, 5 stations ranging from 50 to 2000 m depth were collected in March 2011 about one month after the Douro River annual flood. Faunal abundances generally decrease from the coast to the slope with maximum total densities of 3051 ind./50 $cm^3$ in the mudbelt ($Q_{50}$=32µm) at 100 m and minimum density of 63 ind./50 $cm^3$ found at 500 m water depth where grain size is coarse ($Q_{50}$=190µm). Faunas of the shallow most station are dominated by *Ammonia becarii, Eggerella scabra, Bulimina aculeata* and *Nonion scaphum* while *N. scaphum* and to a lesser extent *Uvigerina bifurcata* dominate the assemblages at 100 m. The deepest stations are dominated by *Uvigerina mediterranea*, *Hoeglundina elegans* and *Reophax scorpiurus.* In general, live benthic foraminiferal densities are higher where the indicators of organic matter are more concentrated. However, some species appear to have strong affinities with Chl-a (e.g., *N. scaphum, U. bifurcata),* while others (*A. becarii, E. Scabra, B. aculeata*) are more abundant where labile organic matter is high as show by the EHAA/THAA amino acid ratio. The species that show a good correlation with Chl-a also show affinity with organic matter of terrestrial origin as show by the $\delta^{13}C_{oc}$ suggesting 1) that Chl-a measured in the coastal zone is

not only marine and 2) that land plant derived organic matter could be an important source of food for marine benthic communities.

## Preservation potential versus survival: Insights from the vicinity of a hydrothermal vent system in Papua New Guinea

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Shallow-water vent systems have been proposed as natural laboratories to study the effects of a variety of stressors, including elevated $pCO_2$, on benthic communities. Hydrothermal vents in Tutum Bay, Ambitle Island, Papua New Guinea, occur at depths of approximately 10 m and are surrounded by a healthy, fringing coral reef. Foraminiferal assemblages were examined from surface-sediment and cobble-sized samples at locations from within the vent field to 300 m from focused venting, as well as from reference sites, at depths to 28 m. A diverse assemblage of 159 species was identified, representing 107 genera. Species abundances exhibited a logarithmic series distribution, with two species comprising 40% and 20 species comprising 80% of all identified specimens. Foraminiferal shells were absent or extremely rare in sediment samples to 150 m from focused venting, while live specimens were found on solid substratum at low densities even within the vent field. *Amphistegina lessonii* and *Calcarina defrancii*, the two most abundant species overall, made up 53% of the live specimens found in the vent-field rubble samples. Foraminiferal abundance and diversity increased with decreasing hydrothermal influence, which included increasing pH and salinity, and decreasing temperature, as well as decreasing arsenic concentrations in sediment and pore waters

Live specimens of seven species of larger benthic foraminifers, were collected from a nearby reef location, placed in small mesh bags, and deployed for five days at six different sites along a gradient of temperature (29.6°C-60°C) and pH (5.9-8.1) with distance from a major vent. Taxa used in the experiment included *Amphisorus hemprichii*, a species with Mg-calcite porcelaneous shells, three species of *Amphistegina* with hyaline calcite shells, and three species with hyaline Mg-calcite shells (*Heterostegina depressa* and two *Calcarina* spp.). Several specimens of four of the species survived exposure to elevated temperatures of ~60°C and mean pH of 6.2 for five days, while at least one specimen of all seven species survived exposure to ~40°C and pH 5.9. Examination of shells at 600-1000x magnification using scanning electron microscopy revealed fine-scale dissolution in specimens up to 30 m from the vent. Results of this experiment, as well as the assemblage data from the study site, indicate survival potential of some reef-dwelling foraminifers under quite severe environmental conditions, including pH extremes that result in rapid dissolution of their shells following death.

## *Elphidium excavatum* f. *clavata* – Related to oceanographic changes or Tephra deposition on the North Icelandic Shelf

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There is a close relationship between foraminiferal species distribution and oceanographic changes throughout the Holocene in sedimentary records from the North Icelandic shelf. The opportunistic taxon *Elphidium excavatum* f. *clavata* is an important indicator for Late Holocene climatic changes in the area, including changes during the so-called Medieval Warm Period and the Little Ice Age. In addition, increased abundances of this taxon have been observed to be concurrent with basaltic volcanic tephra horizons in the marine shelf sediments. Working on climatic reconstructions, the knowledge of such "non-climatic" effects is crucially important.

Iceland is located at a climatic frontier in the North Atlantic storm-track path at the present-day boundary between Polar and Atlantic surface water masses defined by the relatively warm, saline Irminger Current and the cold, low-salinity East Greenland and East Icelandic currents. Even relatively minor changes in the circulation pattern are likely to be archived in the sedimentary records of this sensitive boundary area.

Explosive volcanic eruptions are frequent in Iceland, and the most common tephra transport onto the shelf is by eruption plumes carried northward across Iceland. Numerous tephra horizons have been detected in marine sediment cores from the North Icelandic shelf, and several of these have been dated and correlated to specific volcanoes by means of geochemistry, and to dated volcanic events.

It appears that *Elphidium excavatum* f. *clavata,* which is usually not common in the outer shelf environments (400 m), is tolerant enough to bloom when the sea floor is disturbed by tephra fall. The percentage contribution can become very high, up to >50%, and the taxon remains an important contributor to the assemblage for some years after the volcanic eruption, until the original assemblage returns to the area. These blooms are apparently a consequence of ecological changes, which are not related to oceanographic and climatic factors. They may be caused by reduced light penetration and decrease primary productivity at the sea surface, leading to lack of nutrients at the sea floor, but they could also be related to change in the roughness of the sea floor, which might lead to a change in the availability of nutrients.

## Benthic Foraminifera from coastal areas of the Aegean Sea (Greece)

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Benthic foraminiferal taxonomy and seasonal distribution is investigated in surface sediment samples from coastal areas in the Aegean Sea with different physicogeographical features; coastal environments of Avdira-Vistonikos Gulf and Kitros-Thermaikos Gulf (northern Aegean) and open lagoonal environment of Vravrona-South Evoikos Gulf (southwestern Aegean). A total of 80 species assigned to 35 calcareous benthic foraminiferal genera were identified and documented. Q-mode Hierarchical Cluster Analysis distinguished three foraminiferal assemblages. Assemblage A: typically shallow-marine, dominated by *Ammonia beccarii*, *Elphidium* spp. and relatively abundant and diverse miliolids (Avdira and Kitros coasts); Assemblage B: open lagoon/shallow marine with constant freshwater input characterized by abundant and well-diversified foraminiferal fauna including the opportunistic *Ammonia tepida*, the algal symbiont *Peneroplis pertusus*, other small epiphytic rotaliids and miliolids (high discharge period in Kitros coast and in open lagoon of Vravrona bay); Assemblage C: low salinity-influenced, strongly dominated by the opportunistic species *Ammonia tepida* (high discharge period in Vravrona bay). The foraminiferal densities, Shannon-Wiener index and species richness showed similar patterns for all the studied sites, with peak values reflecting more favorable conditions in the open lagoon/shallow marine environment. On the contrary, the dominance index higher values in both shallow-marine and less saline environments, reveal prominent effects on the species composition. Our results suggest that variability in coastal foraminiferal composition is primarily controlled by the estuarine-marine interaction.

## A priori determination of bioavailability in foram culture work: Considering metal speciation

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Trace metal speciation is a key factor when conducting culture experiments on marine organisms such as foraminifers and micro- or macroinvertebrates. Numerous environmental and culture studies may have overestimated trace metal concentrations because the concept of bioavailability was not properly defined and understood. Quantification of the carbon dioxide system (pH, alkalinity, dissolved inorganic carbon, and $pCO_2$) was performed prior to bioavailability studies to determine the influence of temperature and salinity on metal-carbonate speciation. These factors have greater implications for metals whose speciation is controlled by carbonate and hydroxide complexation, such as copper and lead. This talk summarizes seawater physicochemical parameters to be considered during culture experiments, emphasizing trace metal speciation, and proposes strategies for improving experimental design. Full consideration of physicochemical parameters encountered at the sediment/seawater interface in coastal and open marine settings plays an integral role in determining the fate of potentially toxic trace metals.

## The influence of microhabitat features on benthic foraminiferal distributions and biofacies along a depth transect of the Central-Southern Mediterranean Sea (Sicily, Italy)

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The Mediterranean Sea is a mid-latitude semi-enclosed basin connected to the Atlantic Ocean and surrounded by the Mediterranean region. The investigation of the central part of the Mediterranean Sea is of particular importance as it divides the Tyrrhenian Sea and the western Mediterranean Sea from the eastern Mediterranean, where different water masses are encountered.

A total of twelve stations were sampled along a ca. 150 m depth transect between the southern tip of Sicily and archipelago of Malta in July, 2013. Physico-chemical parameters of water and sediments were measured in vertical profile and three-replicated sediment samples were collected by box-corer. Total benthic foraminiferal assemblages were studied in order to identify the distribution and biofacies of the most abundant taxa and to relate them to the different water masses. Additionally, the microhabitats of live benthic foraminifera were documented by slicing the core at 0.5 cm intervals from 0 to 1 cm depth, and 1 cm intervals from 1 to 2 cm depth.

The transect allowed to better understand the TROX model for calcareous and agglutinated foraminifera from both the >150 μm and 63-150 μm fractions.

On the basis of the living benthic foraminiferal assemblages coupled with the analysis of the sedimentary organic matter content, it was possible to identify an assemblages succession that probably

reflects the increasing scarcity of trophic resources, typical of this environment, along the inshore/offshore gradient and the importance of the role played by the proximity to the coast for the food recovery.

## Ocean acidification induces biochemical alterations of calcification process in symbiont-bearing foraminifers

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Human activities related to fossil fuel combustion over the last two centuries have lead to an increase in the atmospheric $CO_2$ partial pressure ($pCO_2$). resulting in a decline of seawater pH, a process known as ocean acidification (OA). The increase of $pCO_2$ reduces the carbonate saturation state of seawater. In turn, this might reduce calcification and increasing dissolution rates of marine calcifiers such as foraminifers. However, there is still a lack of understanding of calcification mechanisms to explain species-specific differences observed in manipulative experiments.

To assess the biochemical and physiological impacts of OA in the calcification of symbiont-bearing foraminifers, *Marginopora vertebralis* (dinoflagellate symbionts) and *Amphistegina lessonii* (diatom symbionts) were exposed for 30 days to four different conditions of pH levels ranging from 8.1 (ambient) to 7.5 by bubbling $CO_2$ into the water. We analysed growth rates using surface area and buoyant weight (BW) as parameters. In addition, the activity of enzymes Ca-ATPase and Mg-ATPase was also determined.

Growth rate expressed as surface area was not affected by the lower pH levels. However, *A. lessonii* showed a significant correlation between growth expressed as BW with pH levels after 30 days. BW increase was significantly reduced at pH 7.5. This result shows that this species is either adding thinner chambers or some dissolution process is taking place in the older ones. *M. vertebralis* showed a similar trend, but no correlation was observed. A significant increase of Ca-ATPase and Mg-ATPase activities was observed in *A. lessonii* after 30 days, whereas *M. vertebralis* showed an inhibition of Mg-ATPase under lower pH levels, and no effect on Ca-ATPase activity.

Foraminifers are capable of increasing the intracellular pH yet a lower environmental pH will possibly raise the cost for increasing the pH in the calcification site. The general increase in both enzymatic activity observed in *A. lessonii* demonstrates that this species is indeed spending more energy to exchange ions into the calcification space, and is likely to be affected by the predicted OA. Mg ions are removed from the calcification site possibly due to the activity of Mg-ATPase. This is not particularly essential for *M. vertebralis* as this species precipitate high Mg-calcite. Thus, *M. vertebralis* might be redirecting the energy elsewhere. Although *M. vertebralis* is expected to be more sensitive to OA due to the nature of their shell, it seems to be less affected by the changes in pH levels, at least in a short-term exposure.

# Heat-tolerant symbiosis in the foraminifer *Pararotalia spinigera* from the Eastern Mediterranean

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Symbiont-bearing coral reef Foraminifera are sensitive to global change at levels likely to occur in the near future. However, it remains unclear whether the to-date observed symbiont bleaching threshold >30°C is universal among Foraminifera. To this end, we conducted laboratory experiments on two species *Amphistegina lobifera* and *Pararotalia spinigera* from the eastern Mediterranean. The latter species has been observed to survive in a heat-polluted area at the Israeli coast at temperatures of up to 36°C. Samples were collected from a natural habitat, not influenced by heat pollution at two seasons and used for following laboratory studies: A.) We measured survivorship, growth, photosynthetic yields and pigment content on adult specimen during week-long experiments in a replicated design of sea water aquaria at five different temperatures, B.) We tested survivorship and growth in asexual offspring of *P. spinigera* to three temperatures up to 36°C in incubators during a month-long experiment, C.) We isolated and characterized the symbionts of both species. PAM fluorometry revealed an inhibition of photophysiology in *A. lobifera* but not in *P. spinigera* at 35°C. Results showed that adult as well as juvenile *P. spinigera* were able to grow and calcify under 36°C for several weeks but that the observed ecological optimum in both species lies <30°C. Our analysis reveals that *P. spinigera* hosts a consortium of multiple diatom species as its endosymbionts. In this respect, the endosymbiotic association provides no obvious clue to the higher resistance of *P. spinigera* symbiosis. In conclusion, we present experimental evidence that the symbiosis of *P. spinigera* is inherently more resistant towards increasing temperatures and its heat-tolerance is not limited to the heat-polluted area. The exact mechanisms why this symbiosis is more heat tolerant are not known, but our results indicate that at least one species of benthic Foraminifera is capable to sustain a photosynthetically active endosymbiosis with diatoms up to 36°C.

## Poster Presentations

### 3D models of microboring structures in larger benthic Foraminifera: New frontiers, new problems and new (?) solutions

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Borings within larger benthic foraminifera (LBF) tests are commonly found; however, only little research has been carried out so far. This is largely due to their three dimensional and "hidden" nature. Thin section studies give little information on the three-dimensional (3D) geometry of borings, making categorization and comparison between forms difficult. However, using micro computer tomography (microCT), a technique being increasingly used in paleontology, 3D reconstructions of borings can be made. This technique allows reconstruction by segmentation and internal measurements to be taken in any direction, including volumes, porosity and 3D angles. It is thus an ideal technique for examining the internal geometry of borings found in LBF.

In this preliminary investigation, six specimens including both recent and fossil LBF (*Nummulites perforatus*, Bartonian, Romania; *Alveolina sp*., Lutetian, Tanzania; *Palaeonummulites venosus*, Recent, Japan) that displayed evidence of borings on their outer surfaces were scanned using microCT. Three-dimensional reconstructions of specimens were then performed. For each scanned specimen, the segmentation process (i.e., the virtual extraction of part of the scanned sample) was carried out manually to separate borings from the remaining test. Each boring was segmented as a single object as long as it could be considered to have been made by a single organism – i.e. consistent in form and not cross cutting.

The analysis revealed a wide variety in the geometry of borings and in percentage of the affected test. In *Nummulites perforatus* large boring structures up to 5 mm in diameter were observed, together with some other much smaller features. Such larger borings are commonly normal to the spiral plane whilst smaller connected borings are commonly parallel. In specimens of *Alveolina* sp. the borings are always filled with sediment and cover large parts of the test (up to 42%). In one case the central area of the test is completely obliterated. The recent specimen of *Palaeonummulites venosus* shows only small borings in the test surface, with few borings perforating into the outer whorl. This study indicates that there is a wide variety of borings occurring in LBF tests. As the variety of boring organisms targeting LBF currently remains uncharacterized and may be an important component of the shallow carbonate environment, these features deserves further and more systematic study.

## Benthic Foraminifera assemblages as an environmental proxy in coastal ecosystems: The case of Saronikos Gulf (Aegean Sea, Greece)

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The Saronikos Gulf, including the industrial zone of Elefsis Bay and the Piraeus port, has been considered one of the most heavily polluted regions of Greece. In addition to intensive shipping activities, domestic and industrial effluents were released untreated into the sea until the early 1990s. Benthic foraminifera were collected to assess the environmental conditions of the Saronikos Guf in the framework the EU FP7 PERSEUS: Policy-Oriented Marine Environmental Research for the Southern European Seas, aiming to better understand the changes induced by anthropogenic pressures on benthic ecosystems. Box-core sampling was carried out at 12 stations during the R/V Aegaeo cruise (January 2012, March 2013). From each core at each station, three samples from different depths (0-2, 2-5 and 5-10 cm) were collected and immediately stained with rose Bengal to facilitate distinguishing live from dead foraminiferal tests. A low-abundance, low-diversity foraminiferal fauna was found along the northern part of the coast (industrial zone of Elefsis Bay). The most abundant taxa are stress tolerant, including *Bolivina* spp., *Bulimina* spp., *Nonionella* spp. and *Ammonia* spp., indicating low oxygen conditions. In contrast, the assemblages from eastern Saronikos surface sediments are rich and diverse, including small rotaliids (such as *Rosalina bradyi*, *Asterigerinata mamilla*, *Planorbulina mediterranensis* and *Elphidium* spp.) and agglutinated species, mostly *Textularia* spp., and a large number of miliolids. To evaluate sandy substrates lacking foraminifers that host algal symbionts, we propose the Foram Stress Index (FSI), based upon ratios of stress-tolerant taxa in total assemblages. This index provides a useful tool to evaluate environmental stress in the coastal environments of the Aegean Sea. The FSI can exceed 0.7 in stressed regions, whereas it seldom exceeds 0.2 in environmentally healthy areas.

## Growth of *Heterostegina depressa* under natural and laboratory conditions

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The use of computed tomography (CT) gives the unique opportunity to look into larger benthic foraminifera and measure chamber volumes efficiently. For this study 11 specimens of recent larger benthic foraminifera *Heterostegina depressa* were used, whereof four gamonts were cultivated by Röttger during the early 90's. The rest of the specimens consist of four *H. depressa* from Kekaa Point, which were collected by Röttger in 1991, and four were collected by one of the authors (JH) at Sesoko-Jima. After all specimens have been scanned by microCT, each chamber was extracted (i.e., segmented) and its volume measured. The chamber volume sequence represents the ontogeny of the foraminifer cell and can therefore be used to reconstruct controlling factors that operate during chamber formation. The first results obtained by such analysis, on naturally grown specimens, show values that oscillate around a fixed growth function

and point to sinusoidal periodicities with consistent and significant periods. The values of such periods perfectly match moon cycles and local seasonalities.

Hence, a new kind of ecological proxies can be created. The same analyses on laboratory cultured individuals have been run to check for cyclicity even if none were expected. This is important to proof that the oscillatory patterns discovered in LBF are real ecological signals and to gain insights on how tidal currents, lunar months or seasonal fluctuations might interfere with foraminiferal growth.

Serendipitous observations led to the discovery that the gamonts cultured by Röttger show exceptional morphological alteration in septal growth. Septa and septula are strongly underdeveloped or uncompleted and large connections occur among chambers.

## Surviving strategies of the largest living benthic foraminifer: *Cycloclypeus carpenteri*

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*Cycloclypeus carpenteri* thrives on the seafloor of tropic habitats. Its test can reach a diameter of 10 cm. Due to its very flat shape, it is well adapted to scarce light availability, to very weak hydrodynamic environment and to very fine sandy substrates.

In this study we have imaged 18 specimen of *C. carpenteri* by computed tomography to investigate its internal structures and its chamber growth pattern. Such methodology allows to observe on a 3D basis each chamber and chamberlets and to measure their volume. We have observed that each single individual of the investigated sample has experienced test damage during its lifetime. Regardless of the number of damaged chambers, all scanned individuals have been able to recover their test after one or more injuries. The most impressive damage and consequent recovery evidence is represented in a specimen with 9 consecutive broken chambers. Aim of this work is to quantify if those destruction/recovery events might lead to a modified or decelerated chamber growth rate.

Therefore, a theoretical chamber volume for those broken chambers was estimated to get volumetric data for a growth pattern not affected by breakage. First results from some representative specimens show that even with a test volume loss of up to 40 percent (possibly inflicted either by predation or events related to hydrodynamic stress), the individual was still able, have reach its theoretical volume (i.e., not affected by breakage) by the end of its life. However, considering the whole ontogeny of the cell, even in those specimens with prominent destruction/recovery events, the difference between the cumulative theoretical chamber volume and the cumulative actual chamber volume is not larger than 10%.

This can be seen as a remarkable way to deal with environmental stress. The examination of frequently occurring test injuries and subsequent recoveries could shed light on the survival strategy of *C. carpenteri*. The observations made here could lead to the assumption that the test damages do not affect the growth pattern of the cell. Therefore, accepting the dangers of living in this particular natural habitat and to undergo frequent dangers of test breakage, might still be considered advantageous, given the little effort of recoveries.

## Assessing coral reef health at Caye Caulker-Belize: Preliminary data on the Foram Index

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Caye Caulker, a low-lying coralline island, is the second most populated island (450 people/square mile) off the east coast of Belize and has experienced rapid growth over the past 20 years. This island has no central-waste treatment facility and local residents and tourists rely on septic tank systems for sewage disposal and retention. Coral reefs located approximately one mile off Cay Caulker are located within the Caye Caulker Marine Reserve (a Marine Protected Area) are therefore threatened by this point source of pollution. Previous studies have found high nutrient loads (nitrates and phosphates), fecal coliforms (evidence of untreated sewage), and toxins (i.e., Potentially Toxic Elements) in groundwater. Since groundwater is known to discharge into the surrounding ocean, the Belizean Department of the Environment is concerned about the sewage impact on the health and vitality of the coral reefs in Caye Caulker as these provide incentives and revenue for the tourism industry (900,000 tourists in 2012) and economy of Belize.

Sediment samples were collected from 15 transects between the east and west sides of the island to apply the Foram Index as a bio-indicator of coral reef health while simultaneously determining the presence and concentration of coprostanol, which is an indicator of human-borne sewage. Preliminary data show that foraminiferal density and grain size increase slightly with proximity to the reefs along the eastern side of the island but remain unchanged on the western side. Intermediate FORAM Index values are found throughout the eastern and western coast lines although in some areas the FORAM Index has higher values in proximity to the reefs. Our preliminary results show that the corals reefs of Caye Caulker are experiencing environmental stress. This coincides with several reef areas dominated by algae, bleached corals, and evidence of black- and brown-band disease. Currently, the sediment samples are being analyzed for coprostanol levels to determine if human-borne raw sewage may be considered responsible for reef degradation. This data will be presented at the meeting.

## Foraminiferal population descriptors as tool for organic stress assessment in coastal areas under influence of shrimp farming

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Organic matter flux to the sediment, oxygen availability and sediment grain size are among the most important factors controlling foraminiferal distribution patterns and can be used as indicators of ecological conditions of the benthic environment. The excessive increase of nutrients in the sediment favors the proliferation of opportunistic taxa, with fast reproduction and small size, which tolerates low oxygen concentrations and feed off anaerobic bacteria that degrade organic matter. This study aims to evaluate organic enrichment conditions and possible hypoxia of sediments in a lagoonal sector under the influence of a shrimp farm (Santa Catarina, Brazil). For that, the distribution of sub-environments with distinct compositional and grain size features was compared to the ecological response of Foraminifera through a Benthic Index of Biotic Integrity (B-IBI). The study area was sectored using Cluster Analysis applied to 46 samples in the lagoon and 7 in the shrimp ponds. Variables considered in the Euclidian distance matrix

were: grain size, organic carbon, nitrogen and carbonate contents in sediment. B-IBI integrated the following biotic descriptors: total density, average size of tests, richness, abundance of dominant taxon, abundance of tolerant taxa and abundance of tests with severe morphological anomalies. The lagoon was classified in two depositional sub-environments: sandy (average depth of 0.9 m, mean grain size of 2.2 Φ, organic carbon content between 0.3% - 5.1%); and silty (1.6 m, 5.1 Φ and 4.3% to 9.5%). From the application of a *t*-test it was concluded that B-IBI values differ significantly between these two sub-environments ($t=5.16$; $p=1.2.10^{-5}$) and they are inversely correlated to the organic carbon content ($r=-0.62$). The index values were ranked in three classes of ecological conditions: restrictive environment (<2.6), moderately restrictive (2.6 to 3.9) and non-restrictive (>3.9). Most of the lagoon fitted in the moderate class (58.8%), while only 23.5% of sites were classified as restrictive. All samples from the shrimp farm fitted in the moderate class. The significant correlation between geochemical and biotic descriptors allows the use of both to identify areas susceptible to organic stress. However, the biotic index is advantageous because it also reflects the direct consequences of enrichment on benthic populations.

## Evidence from foraminiferal assemblages in relation to environmental settings in the Sicily Channel

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Relations among benthic foraminifera, oceanographic features, and trace elements were explored by studying benthic foraminiferal thanatocenosis and their coast-wide variations in the Sicily Channel, as well as by analyzing trace elements incorporated in tests of the shallow-infaunal species *Uvigerina mediterranea*. This analysis allows to assess foraminiferal ability to reflect bottom water concentrations of some trace elements in a semi-enclosed basin, such as the Mediterranean Sea.

Seventeen stations were sampled by box corer along four coastal-offshore transect, located in the Sicily Channel. From every sample 50 $cm^3$ of superficial sediment were observed and at least 300 well-preserved tests of benthic foraminifera were picked up. Individual density, species richness and diversity of benthic foraminifera were evaluated. Redundancy Analysis (RDA) and Mantel test were performed to evaluate the relationship with environmental variables. The analysis of trace elements incorporated in the *U. mediterranea* tests was conducted on at least 30 well preserved specimens, picked from 0-2 cm of surface sediment from each station. Mg, Mn, Sr, Cd and Ca included within the tests were analyzed.

High values of ecological indices applied to foraminiferal thanatocenosis highlighted a generally unstressed environment. Moreover, by analyzing the combination of bathymetry, distance from the coast, grain-size, and concentration of organic matter, it was possible to highlight four biofacies which identify specific environmental conditions determining the distribution and abundance of benthic foraminifera.

The analysis of heavy metals in the tests of specimens of *U. mediterranea* showed considerably high Cd concentrations. This reflected a higher concentration within the sediments in the Sicily Channel than those of the world oceans. On the contrary, the Mg/Ca ratio in *U. mediterranea* tests performed to estimate bottom temperature, showed higher temperature ranges than those measured, highligthing the low sensitivity of *U. mediterranea* towards this parameter.

## Spatial variability in oceanographic conditions and benthic productivity in Arvoredo Biological Marine Reserve (Santa Catarina State, Brasil) using Foraminifera as proxies

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The Arvoredo Biological Marine Reserve is located on the central part of the inner continental shelf of the Santa Catarina state in Brazil. This region covers an area of the 17,800 hectares in the South Atlantic Ocean and comprises a small archipelago formed by Arvoredo, Galé, Deserta, and Calhau de São Pedro islands. The study site includes this protected marine area and its surrounds. Influences from continental discharge and oceanographic processescreate intense variations in the structure of water masses. The Coastal Water is present throughout the whole year; Subtropical Shelf Water predominates during the winter and South Atlantic Central Water mainly in summer. Sedimentological, geochemical and micropaleontological data obtained from 36 samples are used to characterize the spatial variability of environmental conditions in the study area and to estimate the sectors with higher benthic productivity. The benthic foraminifer species known as indicators of the high $C_{org}$ flux (e.g. bolivinids and buliminids) were considerate to computation the Benthic Foraminifer High Productivity Index (BFHP; Martins, 2007). The distribution of total organic matter content varies between 0.1% and 20% and biodetritic carbonate varies between 0.8% and 38%. The total density of foraminifera varies between 143 and 17577 tests in $50cm^3$ of wet superficial sediment, distributed through a gradient south/north with higher values in the northern sector of the study area. The richness varies between 16 and 39 species, with the samples inside the Reserve presenting higher values. The values of BFHP index vary between 3% and 74%, suggesting a site with higher benthic productivity located on the north and east sector. The advances in the study of relationships between the distribution and productivity of foraminifera associated to marine landscape characterization may support the crescent discussion about maintenance or enlargement of this marine conservation unit.

## Synergistic effects of climate change and ocean acidification on symbiont-bearing coral reef Foraminifera

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The individual effects of global change stressors are increasingly well documented on a number of different marine species, but the role of the interaction between stressors still remains poorly understood. This is significant, considering that key stressors, such as ocean acidification and temperature rise are likely to change simultaneously. Here we investigated the combined effects of increased sea surface temperatures (SST) and $pCO_2$ on two species of symbiont-bearing coral reef Foraminifera. *Heterostegina depressa,* hosting endosymbiotic diatoms and *Marginopora vertebralis*, hosting dinoflagellates, were investigated for the effects of single and combined stressors on survivorship, growth, respiration, photosynthesis (PAM fluorometry and oxygen production) and chl α content. Specimens were exposed in

a long-term flow-through aquaria study to combinations of two $pCO_2$ (~790 µatm, pH of 7.9 and ~490 µatm, pH 8.1) and two temperature (28 and 31°C) regimes, simulating the effects of both stressors at levels that are predicted to occur by the end of this century. Elevated temperature showed strong negative effects on nearly all measured parameters. Elevated $pCO_2$ had a significant negative effect on growth and apparent photosynthetic rate (APR) in *H. depressa* and a significant positive effect on effective quantum yield (EQY) of the photosystem II in *H. depressa* and chl α content in *M. vertebralis*. The strongest stress responses were observed when the two stressors acted in combination. An interaction term was statistically significant in half of the measured parameters. Further exploration revealed that 75% of these cases showed a synergistic (= larger than the expected sum of the individual effects) interaction between the two stressors. These results indicate that negative physiological effects on symbiont-bearing coral reef Foraminifera are likely to be stronger under simultaneous scenarios of acidification and temperature rise than what would be expected from the effect of each of the stressors individually.

## Session 9: Other Foraminiferal Research

## Oral Presentations

### Benthic Foraminifera as indicators for sub-marine slide events in the northern Gulf of Eilat

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The Northern Gulf of Eilat has high tectonic hazardous potential related to the four main faults dissecting the gulf head, and seems to trigger sediment collapse. We assume that earthquakes are recorded as underwater mass flow sediment units. In this study foraminifera assemblages are used to identify and characterize these displaced sediments. This study's aims are 1) establishing the reliability of symbiont bearing larger benthic foraminifera (LBF) as proxy for paleo-seismicity based on their known habitats and anomalous occurrence in displaced layers; 2) link the occurrence of displaced LBF and timing of past earthquakes in the area; 3) establishing the connection between physical properties of fossil assemblages and the intensities and energy involved in events triggering sediment displacements.

The research is based on Holocene sedimentary records extracted from the basin floor (100-700 m water depth). One of the studied cores was taken from a main canyon dissecting the northern slope at 532 m and the other core from the western slope at 316 m water depth. Foraminifera shells >150 μm are hand-picked from samples all along both cores.

Micro-faunal results were compared to grain size analysis by Kanari *et al*. (2012). The disturbed units are characterized by coarse grain size, higher numerical abundance of LBF and poorer preservation compared to typical deep sea fine sediments. *Assilina ammonoides* and *Amphistegina papillosa* larger than 1 mm appear in the disturbed sediments with the former comprising up to 70% and the later up to 25% of the LBF assemblage. This, unlike their original habitat in the gulf that ranges between ~40 and ~120 m, in accordance with their symbionts' light requirements. The large shell size indicates that high energy is involved in the displacement. The disturbed units also contain up to 40% of yellow-colored LBF shells, as opposed to null in non-disturbed units and living specimens that are of whitish color. Yellowish color is known to be associated with increasing burial time/depth prior to displacement.

These results indicate the reliability of LBF as paleo-seismicity proxy and suggest further lab work and data analysis will shed light on turbidite dynamics, relative magnitudes and recurrence intervals of past mass-flow events and possible correlation with known earthquakes.

### Paleoenvironmental interpretation of the Eocene mud-mounds based on larger benthic Foraminifera (Promina Beds, Croatia)

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Larger benthic foraminifera (LBF) from two spectacularly exposed carbonate mounds that crop out in the SE part of the Promina piggy-back basin (Outer Dinarides, Croatia) were used to define the origin and the mechanisms that produced them. The Promina Beds are ca 2000 m thick and are a regressive

molasse succession of neritic to terrestrial calciclastic deposits of mid Eocene to Oligocene age accumulated in the Dinaric foreland zone.
Limestones with LBF and corals occur in the upper part of the clay/marls neritic succession. In order to estimate the relative bathymetry of deposition and to build a depositional model, textural analysis, nummulitid (*Nummulites* s.str and *Asterigerina/Amphistegina* sp.) and orthophragminid test size and shape, and the types of light-dependent skeletal components were studied. Five types of facies were recognized: Facies #1, packstones in which LBF (nummulitids) make up 20% while small bioclasts (fragments and whole tests) comprise 10 % of the rock volume are dispersed in micrite matrix; Facies #2, a red-algae-rich coral rudstone with a pack-wackestone matrix; Facies #3, well sorted, fine-grained or poorly sorted coarse-grained skeletal packstones with numulitids, bryozoans, coralline algae, and very rare, smaller benthic foraminifera; Facies #4, coral boundstone with abundant red algae in a mud-dominated matrix; and Facies #5, nummulitid packstones, with *Nummulites* sp., *Operculin*a sp. *Discocyclin*a *radians* and *Asterocyclin*a *stellata*, coralline algae, very rare smaller benthic foraminifera. Facies associations, textures, and photodependent components (T/D ratio, test morphology) indicate these cycles with corals and coralline algae to have grown in the mesophotic (facies # 2, #3 and #4) and euphotic (facies #1 and #5) zones and in low energy conditions below fair-weather wave base, where they were only occasionally influenced by exceptional storms. Facies #1 is assigned to a maximum water depth of 10 m and the deposits are winnowed, probably from the action of bottom currents. The prevalent deposits are unsorted *Discocyclina–Asterocyclina* micrites (facies #5), which were deposited at a maximum water depth of 50–60 m suggested by this large, hyaline foraminiferal assemblage.

## Declines in Foraminifera productivity threaten Pacific Reef Islands

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Large benthic foraminifera (LBF) are a diverse group of single-celled protists (>1 mm mature diameter), contain algal endosymbionts, and produce calcium carbonate ($CaCO_3$) tests through biotic calcification or the agglutination of sediment grains. Their distribution is widespread throughout shallow-warm-water tropics and their often prolific growth on coral reefs make them exceptional producers of sediment (~35 Tg $year^{-1}$ globally) and extremely important in maintaining a sand supply to reef islands (*e.g.*, Tuvalu, Marshall Islands, Kiribati). However, increasing evidence suggests some LBF will have difficulty building their calcareous skeleton by 2100 and beyond as oceans continue to warm and acidify. Decreasing productivity could significantly reduce the availability of sand to maintain reef islands, shifting many into an erosionary state, but empirical evidence is lacking and the magnitude and pace of these potential effects is currently unknown.

Here, we have 1) compiled data on the LBF *Baculogypsina sphaerulata* and its role in the sediment budget of a reef and sand cay in the northern Great Barrier Reef, Australia; 2) measured the age of individual *B. sphaerulata* tests across the reef using AMS $^{14}C$ dating to reveal information about temporal lags between LBF production and deposition; and 3) modelled the likely impacts of reduced LBF production on the sand cay sediment budget under various climate change scenarios.

We show that about half of the LBF tests produced on the reef contribute to island accretion over any given time period. Although the maximum test age found on the reef was 430 years (340-525 years), >80% of tests remain on the reef flat for <40 years. The reef island sediment budget is thus strongly linked, temporally, to the productivity of LBF on the reef. When modelling the effects of reduced productivity predicted through to 2100, our data demonstrate little change in net island accretion under the

most passive scenarios, ~50% reduction under moderate scenarios and ~75% reduction under the most aggressive scenarios, with the possibility of a shift to net erosion by mid-22nd century. Given *B. sphaerulata* dominate carbonate beaches throughout the Western Pacific, the social, ecological and economic ramifications of our results would be profound.

## Palaeoceanography of the Equatorial Pacific Ocean: Evidence from Miocene planktonic Foraminifera

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We present the first high-resolution (3 kyr) astronomically-tuned record of $\delta^{18}O$ and $\delta^{13}C$ from planktonic foraminifera for the equatorial Pacific Ocean (16.5–13.5 Myr). Our data provides exciting new information on sea surface temperatures and primary productivity changes at the tropics during the middle Miocene at a resolution not achieved in any previous study, which sheds new light on the middle Miocene climatic transition (MMCT) and associated carbon-isotope excursion.

Reliable sea surface temperature estimates are crucial to any reconstruction and modelling of past ocean salinity and density, water column stratification, thermohaline circulation, and ice volume. Despite extensive studies of benthic foraminifera, existing planktonic foraminiferal records of this interval are extremely scarce and of low resolution, with samples representing time intervals of $2x10^5$ and $5x10^5$ years. Previous studies have been hindered by the absence of biogenic carbonate (*e.g.*, Leg 199). Consequently the impact of global warming and cooling on tropical surface waters and the propagation of orbital cycles in the Earth System are unknown.

In 2009 Integrated Ocean Drilling Program Expedition 320/321 recovered lower-middle Miocene sediments with high sedimentation rates (30 m/myr), continuous recovery, and orbital cyclicity from the east equatorial Pacific Ocean. At Site U1338 planktonic foraminifera are abundant and diverse in the lower and middle Miocene sediments and exceptionally well preserved. Scanning electron microscope studies revealed open pore spaces, little evidence of calcitic overgrowth on the wall surface and in many cases preserved spines (Fox and Wade, in press).

We compare our data from Site U1338 to Site 1146 in the western equatorial Pacific Ocean, to reconstruct bottom and surface water conditions and changes in ocean dynamics across the equatorial Pacific during this highly complex interval of climate history.

## Ecology and faunal assemblages of living and dead benthic Foraminifera in the Arctic Baffin Bay and northern Labrador Sea

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Eight multicorer cores from the arctic Baffin Bay and the northern Labrador Sea were collected during the German RV MARIA S MERIAN cruise MSM09/2 in water depths between 467 m to 2329.5 m. Surface sediments were analysed for living (Rose Bengal stained) and dead benthic foraminifera to give a first insight of modern species distribution in this area. Altogether 158 taxa were identified. Bottom water characteristics, water depth and organic matter flux were the most important environmental factors controlling the distribution of benthic foraminifera in this area. The northern Baffin Bay showed a high abundance of agglutinated species, such as *Hormosinelloides guttifer*, *Lagenammina difflugiformis*, *Cribrostomoides subglobosum* and *Textularia earlandi*. Towards the southern Baffin Bay and northern Labrador Sea an increase of calcareous species, such as *Nonionella iridea*, *Epistominella arctica*, *Stainforthia loeblichi* and *Cassidulina reniforme* was noticeable. Living and dead benthic foraminifera were found at all sampled stations, with increasing densities from the arctic Baffin Bay towards the northern Labrador Sea. However, strong variations in the preservation of calcareous benthic foraminifera were apparent due to carbonate dissolution caused by corrosive bottom waters. The absence of calcareous species in the northern Baffin Bay represented the corrosive nature of Baffin Bay Bottom Waters, which probably are strongly influenced by Artic Waters. In contrast, stations towards the southern study area exhibit high abundances for both living and dead benthic foraminifera pointing out the influence of the warm and high saline Atlantic Waters.

## Microfossils in tidal settings as indicators of sea-level change, paleoearthquakes, tsunamis and tropical cyclones

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Fine-grained sediments deposited in low-energy, intertidal settings are an archive of sea-level change, and the occurrence of paleo-earthquakes, tsunamis and tropical cyclones. Some of the best reconstructions of these coastal processes have been derived from microfossils such as foraminifera that accumulate in salt-marsh and estuarine environments. Early microfossil work in the coastal zone employed pollen as an indicator of vegetation and as a chronostratigraphic marker. Use of diatoms and foraminifera has become increasingly widespread because their distribution is closely linked to tidal elevation. In this presentation, I will discuss the use of microfossils in estuarine and salt-marsh sediments to reconstruct sea level along subsiding coastlines in temperate regions. I also describe how microfossils from isolation basins are used to reconstruct sea level along coastlines experiencing uplifting coastlines. Microfossils can also estimate land-level changes along tectonically active coasts associated with paleoearthquakes. I explain the use of transfer functions for calculating quantitative estimates of past environmental conditions from microfossil data. Finally, we reveal how microfossils are used to reconstruct the recurrence of tsunamis and tropical cyclones from the sedimentary deposits these high-energy events leave behind.

## Foraminiferal vs. geochemical proxies and the 'Anoxic benthic foraminiferal paradox': A case study from the high productivity deposits in Israel

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In this study we established a detailed chronostratigraphic framework for the high productivity sequence deposited across the southern margin of the Tethys, covering a N-S transect of 150 km, and dated as latest Santonian (83Ma) to middle Maastrichtian (68 Ma).

A multidisciplinary approach was used for studying the organic-rich succession including benthic foraminifera and geochemical analyses. Morphotype analysis and implementation of known ecological preferences of the most abundant species appearing in the section, coupled with cluster analysis, imply a major regional faunal turnover and a drastic change in redox conditions to more aerated bottom waters, at the base of the *Pseudoguembelina palpebra* Zone. The lower part of the section is dominated by buliminds (with *Praebulimina prolixa* reaching 90%), attesting to low bottom water $O_2$ levels. This is replaced by assemblages containing a higher diversity and dominated by epibenthic to shallow endobenthic trochospiral forms such as *Gyroidinoides, Gavelinella, Oridorsalis, Alabamina, Osangularia, Paralabamina* and *Nuttallides*, or shallow endobenthic cylindrical forms such as *Shiphonodosaria* and *Nodosaria longiscata*, attesting to higher bottom water oxygen levels.

On the other hand, factor analysis of TOC and trace elements imply that the conditions in the upper level were even slightly less aerated than the lower, presenting a paradox.

A possible explanation, not directly linked to $O_2$ levels, is that a shift in primary producers from diatom to nannoplankton dominated phytoplankton occurred between these two intervals. The depth profile of biomarkers in a nearby and correlated deposit, suggests diatoms as the dominant phytoplanktonic form in the lower interval coupled with extensive bacterial abundance, and their substantial mutual decrease in the upper part. Additionally, the regional co-occurrence of organic-rich carbonates in the upper level is reported as an analog to lower nutrient nannofossil-rich belts in modern upwelling systems. We suggest that in addition to $O_2$ availability and food flux, the type of available food has a substantial influence on benthic foraminiferal communities.

## Foraminifers as tsunami indicators from onshore deposits of the coast of Thailand

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Due to tectonic activity along plate boundaries, the coast of Thailand is particularly vulnerable to tsunami events. To better determine the flow dynamics and sediment sources of these tsunamis, onshore deposits of the 2004 Indian Ocean tsunami (IOT 2004) from Bang Ban Sak, western Thailand, were investigated in

respect of their granulometry, geochemistry and micropaleontology. The main micropalaeontological group studied is foraminifera, because only this group occurred in high diversity and high abundance in the samples. Foraminiferal assemblages (and sedimentary parameters) found in deposits of potential paleo-tsunamis and modern IOT 2004 deposits were compared with reference samples from various modern environments using statistical methods (cluster analysis and PCA) to estimate the source areas of the tsunamites. The analyses of foraminiferal associations reveals three clusters: (1) the modern shelf samples characterized by high abundances of *Globigerinella* sp., *Asterorotalia gaimardi*, *Cibicides praecinctus*, *Cancris carinatus* and *Textularia* sp., (2) the beach and near-shore reference samples, as well as the coarse-grained sections of the IOT 2004 and two older events dominated by *Pararotalia* sp., *Amphistegina* spp., *Asterorotalia* spp. and *Alveolinella quoii* and (3) the fine-grained sections of the IOT 2004 and two older event layers containing intertidal taxa such as *Haynesina* and *Haplophragmoides* besides high numbers of *Cibicides* spp., *Elphidium advenum*, *Ammonia* spp., *Rosalina* spp., *Eponides* sp., *Bulimina* spp. and *Quinqueloculina* spp. While most palaeoevent deposits, similar to the sediments of the IOT 2004, comprise littoral taxa living in up to 45 m water depth (as indicated by modern reference samples), one of the inferred palaeotsunami deposits contained littoral fauna only and thus could as well are the remains of strong storms. We can state foraminiferal analysis as a valuable tool for identifying past tsunami deposits. Providing modern reference samples from shallower water in our case a much more detailed reconstruction of wave bases and hence tsunami magnitudes would be possible.

## Foraminiferal studies on Holocene sediments from the Byzantine and Roman Harbour of Ainos (Enez, Turkey)

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The antique city of Ainos was an important harbour in Eastern Thrace due to its location close to the Aegean coast and the river Hebros. The heyday of the antique city of Ainos lasted from about 500 BC to 400 AD. One of the reasons for the decline of Ainos was the siltation of the harbour caused in the seaward migration of the Hebros delta. The modern coast is formed by two lagoons and a series of small residual ponds temporarily influenced by both seawater and freshwater by river input and precipitation. Location, sediment structures and reconstructed salinities reflect several stages of lagoon development. A case study of modern foraminifer associations and conductivity measurement of lagoons and lakes surrounding Enez are used to calibrate fossil associations as proxies of Holocene evolution of the two main lagoons. The foraminifer-based palaeoenvironmental reconstruction is used for evaluating the harbor availability and situation during Byzantine and Roman times. Occasional occurrences of marine foraminifer species within the lagoonal succession dominated by *Ammonia tepida*, *Haynesina germanica* and *Aubignyna perludica* indicate sea level changes already before harbour activities start.

## Mathematical distances, not transformed, in relation with depth, in Recent species of the genus *Elphidium* in the western Mediterranean Sea

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Three species and one subspecies to the genus *Elphidium* from surficial sediments in the Western Mediterranean Sea in the Motril-Nerja shore line – 200 m depth area (Spain) have been identified. These species are: *E.crispum, E. complanatum, E. macellum* and *E. macellum aculeatum.* An attempt is made to determine the mathematical distances, not transformed, between each two species in relation with depth, from their relative frequencies in percent, from the quantitative distribution of each species to 7 depths: 5, 10, 25, 50, 100, 150 and 200 m depth.

The distance *d* between two species *i* and *k*, is determined using the following formula, with relative frequencies, *f*, in percent at each depth:

$$di,k = \sqrt{\sum_{j=1}^{7} (fi,j - fk,j)^2}$$

The maximum distance between each two species corresponds with the minimum affinity. Mathematical distance and affinity are inversely proportional. The distances have been normalized between 0 and 1.The affinity value should be equal to zero if the two species have identical distribution at the same depths, and more than zero and less than one if the two species are unequally distributed.

Values of normalized distances between each two species are: *E. macellum* - *E. macellum aculeatum* (0.53); *E. crispum – E. macellum* (0.61); *E. crispum – E. complanatum* (0.64); *E. complanatum – E. macellum* (0.72); *E. crispum – E. macellum aculeatum* (0.77) and *E. complanatum – E. macellum aculeatum* (1).

Maximum affinity is between (species and subspecies), *E.macellum – E. macellum aculeatum.*
Maximum affinity between two species, *E.crispum – E. macellum.*
Minimum affinity is between *E.complanatum – E. macellum aculeatum.*

## Strong meridional overturning circulation during the last glacial period indicated by benthic Foraminifera from the northern Labrador Sea

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The large ice sheets and extensive sea-ice cover of the North Atlantic during the Last Glacial period had a significant influence on global ocean circulation. Many studies have indicated that convection in the North Atlantic was limited during the last Glacial Maximum (LGM) and that the Atlantic Meridional Overturning Circulation was slower than today. Although it is today believed that some deep-water production took place during the LGM; its strength and location is still a matter of debate. There are also large discrepancies in results from different model simulations ranging from significantly colder to anomalously warm LGM sea-surface conditions over parts of the North Atlantic region.

The Labrador Sea today plays a crucial role for North Atlantic deep-water formation as it affects the mid-latitude main core of the Gulf Stream warm-water transport route. Sea-surface temperatures and freshwater/iceberg export from the Arctic strongly affects the intensity of the deep convection in the Labrador Sea. Based on benthic foraminiferal analyses supported by multi-proxy studies of gravity cores from the northern Labrador Se and Davis Strait, retrieved from water depth of ~2400 and ~1000 m, respectively, now indicate that deep and intermediate water circulation was more vigorous than today. During the LGM as well as during parts of Marine Isotope Stage 3, the benthic foraminifera indicate a significantly higher influx of Atlantic-source deep and intermediate water masses compared to the Holocene. Planktic foraminiferal assemblages during the same periods indicate cold surface waters, with strong but not perennial sea ice cover.

Thus we suggest that brine-related deep convection during late MIS 3 and most of MIS 2 favoured subsurface Irminger Sea Water advection into the subpolar gyre – *i.e.* also during most of the LGM and H1. This means that both during parts of MIS 3 and during LGM deep-water advection in the Labrador Sea was in fact stronger than at present.

## Surface and subsurface water circulation in the eastern tropical Atlantic during the Late Quaternary based on planktic foraminiferal analyses

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Planktonic foraminiferal assemblages from casq core MD03-2708CQ, retrieved off the Ogooué River mouth (01°10.33′S; 08°19.01′E; 920 m water depth) off West Africa, were analysed in order to reconstruct climate variability in the eastern equatorial Atlantic.

During the Last Glacial Maximum (25–19.1 kyr BP) the assemblage suggests a high influx of Antarctic Intermediate water (AAIW) into the eastern equatorial Atlantic region triggered by trade wind-induced upwelling causing a high productivity and comparatively low sea surface temperatures (SST) of 25–26°C. A shallow thermocline separated the AAIW from a relatively thin surface and subsurface water layers.

The deglacial period (19.1–10.8 kyr BP) experienced reduced upwelling and a significantly decreased AAIW inflow into the Gulf of Guinea causing a thickening and warming of the surface water layer and a low productivity. This was presumably linked to weaker trade winds and strong summer monsoons during

this period, also resulting in a warm and moist climate in the nearby continental West Africa. Two minor, short-term SST maxima in the eastern tropical Atlantic coincide temporally with the Heinrich 1 event and the Younger Dryas. These conditions concur with setbacks in the northward movement of the ITCZ.

During the Holocene (10.8 kyr BP to the present) the inflow of AAIW into the Gulf of Guinea was again strengthened and modern oceanographic conditions became fully established ca. 5.2 kyr BP. Slightly lower SST and a higher productivity suggest a stronger trade wind system, effecting regional cooling and drier climate in the region of Gulf of Guinea.

## Quaternary environmental changes reflected by central Red Sea deep-water benthic foraminifera

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The Red Sea is a unique natural laboratory, which amplifies the effects of sea-level changes and monsoon-driven circulation changes on the marine environment. Previously, paleoceanography of the Red Sea has been reconstructed based on various planktonic microfossil assemblages *i.e.,* pteropods, calcareous nannoplankton, diatoms, planktonic foraminifera. However, until now, relatively little is known about the impact of the Quaternary climate changes on the deep-sea environments of the Red Sea. In particular, it is still not known to what extent the monsoon-driven paleo-productivity patterns that have hypothesized to have controlled the environmental conditions in the central Red Sea are reflected by benthic foraminifera, which are excellent tracers of trophic conditions in deep-sea environments.

Therefore, we studied the benthic foraminiferal assemblages (size fraction >63 μm) of samples recovered from the core GEO TÜ KL09 drilled in the central Red Sea. The primary aim was to determine whether the benthic foraminiferal assemblages allow robust paleo-productivity reconstructions across intervals where nuisance variables in the surface waters overprint the productivity-related signal in planktonic assemblages. The relationships between the benthic foraminiferal assemblages and changes of various paleoenvironmental parameters including productivity and salinity on glacial-interglacial time-scales in central Red Sea were inferred using quantitative assemblage analysis methods, Benthic Foraminifera Accumulation Rate (BFAR), and morphogroup analysis of agglutinated foraminifera.

## Poster Presentations

### Foraminiferal biofacies from the Callovian deposits in Central Saudi Arabia

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The upper part of the Middle Jurassic succession in central Saudi Arabia is characterized by cliff-forming, coral and stromatoporoid bearing limestones assigned to the Tuwaiq Mountain Formation. This study focused on the micropaleontological analysis of a middle Callovian cored well section, revealing a range of different biofacies assemblages.

Biofacies include the benthic foraminifera *Trocholina elongata*, *Kurnubia palastiniensis*, *Redmondoides lugeoni*, *Pfenderina trochoida*, and *Meyendorffina bathonica*. Stromatoporoids include the branched species *Cladocorposis*. Monaxon and tetraxon sponge spicules are also present in this formation. A Callovian age has been assigned, based on the extension range of *Meyendorffina.*

Quantitative data were generated from biocomponents and analyzed by multivariate statistical methods (Q-mode hierarchical cluster analysis, which relates sample intervals to each other on the basis of species in common). The resulting dendogram showed a coefficient of 0.83 and at < 50% dissimilarity revealed four distinct clusters. The base of the studied section (Cluster 1) is characterized by morphotypes of *Bositra buchi* and *Trocholina obesa*. Cluster 2 is dominated by pellets. Cluster 3 is represented by *Meyendorffina*, and the upper part of the section (Cluster 4) contains common occurrence of ostracods, *Siphovalvulina,* and an increase in abundance of *Kurnubia palastiniensis*. These clusters represent distinct foraminiferal assemblages that are interpreted as reflecting different ecological conditions, associated with bathymetry, shelf morphology and substrate. Although sedimentation is generally assigned to a low-energy carbonate shelf in the lower part, presence of *Bositra buchi* supports deeper intra-shelf basin conditions, which grades upward into moderate-energy settings, characterized by occurrence of ostracods.

### New data from Middle to Late Cretaceous Hamimats, Tebessa and Mellegue Chains (Eastern Saharian Atlas, Nigeria)

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Thanks to the study of six stratigraphical outcroup sections from eastern Algeria (Tebessa district), the present work aims at first to provide a stratigraphical analysis of these sedimentary deposits and, consequently, the palaeoenvironmental reconstruction of depositional context. To achieve this goal, several hundreds of samples were processed to determine precisely their respective microfaunal content. In these levels dated of Middle to late Cretaceous in age, some 150 foraminiferal species, planktonic as well as benthonic, were identified, twenty ostracode species and ten radiolarian species. The planktonic foraminifera permit to recognize several different biozones ranging from late Albian (*Pseudothalmaninnella ticinensis* biozone) at Oenza section to Santonian (*Dicarinella asymetrica* biozone) at Telidjene section. The biostratigraphical framework is thus relatively precise and helps précising for instance the position of some inconsistent boundaries within the sedimentary pile.

The analysis of abundance patterns among the different microfossil groups, combined with other

analytical data (carbonate rate or TOC rate measurements) provides baseline data to document the coeval palaeenvironments that, as a consequence, appear rather stable during the whole time interval at stake. Theses deposits had been indeed accumulated in a deep sedimentary environment (outer platform to middle slope), characterized by recurring low oxygen levels near the sea floor, and a high productivity at the surface (upwelling zone). Some severely anoxic events have even leaded the benthos to the brink of a complete disappearance, especially round the Cenomanian /Turonian Boundary, defined by the outcome of a global anoxic crisis (OAE2). This very special event was perfectly delimited within four study sections by means of different biological markers, such as the disappearance of the last rotaliporids, the presence of 'filaments', or the bloom of *Heterohelix*. Accordingly, several other anoxic events, of minor amplitude, were also evidenced (OAE1d, OAE3). On the whole, the main original objectives are thus achieved, even though some peculiar questions are still hanging out.

## Paleoenvironmental changes in Pliocene Foraminifera from NW Saudi Arabia

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Pliocene deposits from northwestern Saudi Arabia include marine, brackish and fluvial sediments. The purpose of this study was to establish the paleobiogeographic and paleoenvironmental changes based on quantitative analyses of foraminiferal assemblages.

Paleodepth was estimated using bathymetric ranges of benthic foraminifera and the relative abundance of planktonic foraminifers. The proportional abundance and distribution of infaunal and epifaunal benthic foraminiferal species were used for estimating water oxygen content and organic flux. Due to the absence of foraminiferal markers, the age is based on palynological studies. Benthic foraminiferal depth zonations and classification are based on literature data.

According to published models, oligotrophic environments are regulated mainly by food supply, but do not display oxygen limitations. Their benthic foraminiferal assemblages are rich in epifaunal species, whereas eutrophic habitats are regulated by critical oxygen levels and infaunal species tend to dominate. In the studied area, assemblages from the upper part of the section were characterized by very low planktonic/benthic ratios and diversities of benthic foraminifers, dominated by *Elphidium-Ammonia* associations. Miliolids are rare and agglutinated species are absent. Such assemblages are characteristic of marginal marine to inner neritic conditions. However, conditions change in the lower part where proportions of infaunal and low oxygen tolerant taxa (*e.g.*, *Nonion commune*) increase strongly.

A possible reason may have been intensified organic flux caused by increased fluviatile input and primary productivity. However, palynological results suggest an assemblage of inner-middle neritic marine environment (*Polysphaeridium zoharyii,* and long process type of *Lingulodinium machaerophorum*) with no increases in freshwater input. Therefore, we suggest that appearance of a stratified water column as a result of restricted circulation linked to monsoon dynamics and/or silled basin may lead to a light oxygen depletion in the environment.

## Lower Permian foraminifers of the Kiyasar area (Northern Iran): Implications for the biostratigraphy of the Emarat Formation (Dourd Group)

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The lower Permian successions are well exposed along the Alborz Mountains in northern Iran. The studied area is located in the Kiyasar area, south of Sari town, northern Iran. The Emarat Formation is one of the formations forming part of the Dorud Group. This formation has a thickness of 30 m in this region, where it consists of oncolitic-fusulinid limestones in its lower and middle parts, at the top of this section has been observed about 5 m of dark thick bedded limestone. In the studied area, the Emarat Formation unconformably rests on the Toyeh Formation, and is, in turn, unconformably overlain by the Shah Zeid Formation.

The foraminiferal taxa recorded from this formation in the studied region include (in taxonomic order): *Staffella* sp., *Climacammina* spp., *Deckerella* sp., *Sphaerulina* cf. *crassispira*, *Nankinella* sp., *Schubertella* sp., *Darvasites* ex gr. *contractus*, *D.* sp., *Pseudoschwagerina* sp., *Zellia* cf. *colaniae* and *Pachypholia* cf. *schwageri*, Many complex biosolites constructed by various cyanobacteria, especially *Bevocastria* sp., around nuclei generally composed of phylloid algae, are also characteristic of the microfacies. According to these taxa, we constrain their age to the earliest Artinskian (= Burtsevian Russian substage; also equivalent of the lower Zweikofel Formation in the Carnic Alps). This dating extends upwards the age of the Emarat Formation, which was previously assigned to the late Asselian-early Sakmarian.

## The turning point: Using coiling direction in *Paragloborotalia siakensis as a* biostratigraphic tool

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The coiling directions of foraminifera are one of the most studied morphological features for both palaeoclimate studies and local stratigraphic correlation; however there are many contradictory results. It was Bolli who first suggested in 1950 that some lineages of foraminifera are typically characterized by an initial phase of random coiling, which is often followed by the development of a preference for either direction. Unfortunately, the trends indicated by Bolli in his synoptic text-figures are not supported by published data counts or sample locations, hence it is difficult to assess their significance and reliability.

Using samples from Integrated Ocean Drilling Program (IODP), we have measured the coiling directions of Miocene planktonic foraminifera *Paragloborotalia siakensis* from sites in the Eastern (Site U1338) and Western Pacific (Site 1146) oceans at 3 kyr resolution, with a view to testing the supposed trends and investigating their potential for biostratigraphic correlation.

We found that specimens at show a clear transition from approximately random coiling to sinistral predominance, within a 6000 year interval during the middle Miocene.

## Planktonic foraminiferal biostratigraphy and paleoecology of the Miocene sequence in the area between Wadi Gharandal and Bir Haleifiya, Gulf of Suez Region, Egypt

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An integrated biostratigraphical analysis based on the planktonic and larger foraminifera from three surface sections in the area between wadi Gharandal and Bir Haleifiya, Gulf of Suez region, Egypt, namely wadi gharandal, gebel zeita and bir halefiya sections, provides a well-defined zonal scheme of the Miocene successions in the study area. Lithostrtigraphically, the Miocene sequence could be differentiated into four rock units representing shallow and deep marine facies. These are from base to top as follows: Nukhul, Rudeis, Kareem formations (Gharandal Group) and Belayim formation (Ras Malaab Group). The examination of the studied samples has led to the identification of forty four planktonic foraminiferal species and subspecis belonging to twelve genera. The preserved planktonic foraminifers through the studied sections ranges from good to moderately well diversified enabled biostratigraphic zonation of the Miocene sequence. On the basis of the vertical stratigraphic distribution of the planktonic foraminiferal species, the studied sections could be subdivided into six planktonic foraminiferal biozones following the Mediterranean (MMi) zonal schemes, from base to top as follows: (1) Globigerinoides primordius Zone (MMi1) (Early Miocene, Aquitanian), (2) Globigerionides altiaperturus - Catapsydrax dissimilis Zone (MMi 2b), (3) Globigerinlides tribobus Zone (MMi 3) (Early Miocene, Burdigalian) (4) Prearobulina glomerosa s.l. Zone (MMi 4), (5) Orbulina suturalis - Globoratalia fohsi peripheroronda Zone (MMi 5), (Middle Miocene, Langhian), and (6) Globoratalia siakensis Zone (MMi 6), of Middle Miocene (Serravallian) age. The Lower/Middle Miocene boundary is defined by the first occurrence of *Praeorbulina glomerosa* and is discussed within the text.

Two larger foraminiferal zones were recognized in the studied successions (Wadi Gharandal and Bir Halefiya sections), from base to top, SB 24 Zone in the Aquitanian and SB 25 Zone in the Burdigalian, according to the European shallow benthic foraminiferal zonation (SBZ). By integrating the established foraminiferal zonal schemes, the stratigraphical ranges of some larger foraminifera with planktonic foraminiferal zones have been calibrated. According to the integrated zonation, *Miolepidocyclina burdigalensis, Miogypsina intermedia* and *Borelis curdica* first occur in the MMi 1 and MMi 2b zones, whereas *Nephrolepidina* spp. last occur within the same subzone (MMi 2b). Correlation of the identified larger and planktonic foraminiferal biozones indicates strong similarities with that of Mediterranean affinities.

## Planktonic Foraminifera in Northern Chile and their association with the Oxygen Minimum Zone (OMZ)

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Triggered by coastal upwelling, the Humboldt Current System is one of the most productive areas in the global ocean. This high productivity in turn leads to the establishment of one of the most extensive Oxygen Minimum Zones (OMZ) that is located off the Chilean and Peruvian coasts. In this study, the sensitivity of planktonic foraminifera to low oxygen conditions off northern Chile is assessed qualitatively and quantitatively. The planktonic foraminifera assemblage off northern Chile has been investigated in

five different depth intervals and related to the strength and position of the OMZ. The planktonic foraminifera were collected by plankton nets during RV SONNE cruise SO-211 (November 2010) off Antofagasta, Taltal, Copiapo, and Coquimbo. Regarding the qualitative analysis, we identified 12 species of planktonic foraminifera corresponding to 9 genera. Quantitatively, abundance does not follow a latitudinal pattern. The maximum abundance was found off Copiapo, however, for abundance as well as for diversity no statistically significant differences have been found between the individual sampling sites. Furthermore, the pattern observed does not reveal the expected decrease in abundance and diversity with increasing water depth. Regarding the OMZ, a clear link was found off Antofagasta and Copiapo, where a decrease in oxygen resulted in a reduction of planktonic foraminifera abundance. Otherwise, off Coquimbo and Taltal abundances were enhanced even in the presence of the OMZ.
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## An Overview and Checklist of Recent and Holocene South African Nearshore Foraminifera

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The presented review comprises literature data from sampling stations along the South African coast from estuaries, lagoons and the littoral zone down to 30 m water depth. The overview covers surface and late Holocene samples. Despite the low number of checked publications (9), there are many more publications on deeper water foraminifers off South Africa, this literature review seems to be almost exhaustive. We present the list of publications on our poster and would be grateful for any additions during FORAMS 2014.

The compiled check list contains 201 species, including fifteen planktonic. The highest number of species (152) was found in estuaries, followed by marine bays (72) and the open shelf (39). The lowest diversity (29 species) characterises the restricted lagoons. Our data set comprises much more detailed studies in the estuaries than in shallow marine waters; this sampling bias could be the reason for higher numbers in the estuaries. The low diversity of the brackish water lagoons, however, is characteristic of this environment. Index species of the brackish lagoons are *Trochammina inflata*, *Haynesina germanica,* and *Miliammina fusca*. Frequently associated taxa are *Ammonia* spp. and miliolids. The estuaries show a mixing of lagoonal and nearshore taxa, typical for the latter are planktonic forms. *Elphidium* and *Cibicides* are lacking in the restricted lagoons. Typical taxa for the marine bays are *Elphidium*, bolivinids and miliolinids. The open and shallow marine waters show lower frequencies of miliolids and *Cibicides* is ubiquituous. Using test composition, lagoonal associations contain distinctly higher proportions of agglutinated forms (mean 34%) than in the other waters (8-13%). Data points of shallow shelf, bays and estuaries lie close to each other in Murray's ternary diagram. Estuaries have slightly lower proportions of miliolids than the marine waters.

The literature review demonstrates the need for further Recent distribution and ecology studies on nearshore foraminifers from South Africa. It is recognisable, however, that a discrimination of restricted, sheltered and open marine environments is possible by species occurrence data. Analysing fossil associations from cores will enable reconstructions of salinity and transport processes.

## The Neogene marine deposits in the South-Central Gulf of California: Geochronological and biostratigraphycal constraints

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Controversial ages based mostly on calcareous microfossils recovered from the marine deposits that crop out in Del Carmen and Monserrat islands (south-central Gulf of California, Mexico) have been revised in order to better assess the chronostratigraphic framework.
In Del Carmen Island, two lithostratigraphic sections were measured in the eastern area of Bahía Salina and in northeast Punta Perico. Another section was measured in a yellow marlstone exposed in the northern area of Monserrat Island, located 30 km south of Del Carmen Island.

$^{87}Sr/^{86}Sr$ isotopic ratios of well-preserved foraminiferal shells were measured, providing a 5.21 (+0.68-1.84) Ma age for the base of the exposed rocks in Bahía Salina, whereas the co-occurrence of *Streptochilus latus* and *S. globigerus*, coupled with *Sphaeroidinella dehiscens s.l.*, suggest an age for the section around 5.3 Ma. In Punta Perico, the $^{87}Sr/^{86}Sr$ isotopic ratios gave an age of 5.65 (+0.41-0.89) Ma, whereas the presence of *Pulleniatina primalis, Neogloboquadrina acostaensis* and *Streptochilus latus* supports this age.

In Monserrat Island, the $^{87}Sr/^{86}Sr$ isotopic ratios gave an age of 5.67 (+0.60-1.52) Ma for the base of the section, whereas the *Streptochilus latus* presence indicates an upper limit age between 5.3 and 5.4 Ma for the top of the section.

Planktic foraminiferal assemblages as well as isotopic ages indicate a Late Miocene age for the Monserrat Island marine deposit and a Late Miocene to earliest Pliocene age for the Del Carmen Island deposits, instead of Late Pliocene reported previously.

Inferred depth based on benthic foraminifera at both localities suggests a deeper basin in Del Carmen than in Monserrat (≈150 to 500 m), indicating that basin development in the south-central region is in agreement with marine incursion across the Gulf of California by ≈6 Ma, related to an intense previous phase of Proto-Gulf continental extension.

## Biostratigraphical, lithological and paleoecological aspects of an Upper Cretaceous deposit from the Palmyride area, Syria

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This study represents a detailed micropaleontological investigation of planktonic foraminiferal assemblages from the Upper Turonian to Maastrichtian interval of two deep exploration wells (Al Mahr-1 and Palmyra-1) in the Palmyride area of Syria. The investigated strata are divided into three units: 1) the upper part of the Judea Formation (Upper Turonian–Coniacian); 2) the Soukhne Formation (Santonian–Lower Campanian); and 3) the Shiranish Formation (Upper Campanian–Maastrichtian). The presence of rich and highly diverse foraminiferal associations enabled biostratigraphical zonation of the Upper Turonian to Maastrichtian deposits based on the presence of index-taxa and/or the entire microfossil

assemblages. The results represent the first detailed biostratigraphic zonation based on planktonic foraminifera from the Palmyride area. Nine biozones have been established: 1) *Dicarinella concavata* Zone; 2) *Dicarinella asymetrica* Zone; 3) *Globotruncanita elevaata* Zone; 4) *Contusotruncana plummerae* Zone; 5) *Radotruncana calcarata* Zone; 6) *Globotruncanella havanensis* Zone; 7) *Pseudoguembelina palpebra* Zone; 8) *Racemiguembelina fructicosa* Zone and 9) *Abathomphalus mayaroensis* Zone. The biostratigraphic zonation is compared with the standard zonation.

Documenting changes in planktonic foraminiferal assemblages and lithological alterations are critical for paleoclimatic and paleooceanographic interpretations. The late Turronian to early Campanian foraminiferal assemblages (biozones I-III) suggest tropical to subtropical climate and deposition in outer shelf environments. The well-preserved and highly diversified late Campanian to early Maastrichtian foraminiferal assemblages (biozones IV-IX) imply a well-stratified water column while the lithological characteristics of the deposits indicate outer shelf to upper bathyal environments. A decrease in the number of planktonic species during the late Maastrichtian indicates cooling and deterioration of paleoceanographic conditions. Phosphate grains are present in the Soukhne Formation (Santonian–Lower Campanian) and are an important indicator of specific geological and paleoenvironmental conditions, such as oxygen deficiency, upwelling and transgression. The results of this detailed stratigraphic analysis, including biostratigraphy and litostratigraphy, provided insights into the nature of deposition along the northern passive margin of Gondwana during the Cretaceous, and the determinations of the composition and diversity of foraminiferal assemblages allowed important new paleoecological and paleoclimatic interpretations.

## Middle Miocene benthic foraminiferal communities and their response to shallowing-upward trends – example from Croatia

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During the Middle Miocene, Northern Croatian Medvednica Mt. was an island within the Pannonian Basin, situated at SW margin of the Central Paratethys Sea. Miocene sedimentary rocks (Upper Badenian *Bulimina – Bolivina* zone), from the SW slopes of Medvednica Mt. clearly reflect a transgressive-regressive cycle with emersion during the late Middle Miocene (Badenian/Sarmatian boundary in local Paratethys stratigraphy; equivalent of Middle Serravalian Mediterranean substage).

Shallow marine sediments of the Upper Badenian *Ammonia beccarii* ecozone were transgressively deposited over the Mesozoic carbonate basement. Marginal marine, extremely stressed, highly oxygenated environment of normal salinity (lower part of the Borovnjak section) is represented with *Elphidium–Asterigerinata–Ammonia* community, with low diversity and strong domination. Locality Gornje Vrapče reflects a contemporary restricted marine inner shelf environment (lagoon or deep bay). After the initial transgression, stable conditions were established with highly diverse *Elphidium–Asterigerinata* community, typical for environment with sufficient oxygen content and diverse food supply.

Regression in the upper part of studied sections is in concordance with global sea-level fall. In marginal shoal area (Borovnjak locality) variations in salinity appear, finishing with brackish conditions. Biota is defined as *Ammonia–Elphidium* community. Deeper and more sheltered environment of Gornje Vrapče reflects regressive trends in cyclic lamination. Laminae differ in colour, calcium content and foraminiferal communities (*Heterolepa–Bolivina* community / *Bolivina–Cassidulina* community / *Elphidium–Asterigerinata* community). The uppermost part of the section is represented with coralgal biolitite, and, finally, emersion between the Upper Badenian and Lower Sarmatian deposits. Dominant controlling factors of foraminiferal communities in laminated part of section were fluctuations in bottom

oxygen content (BFOI 54.75–93.94), and changes in quantity and quality of food supply. Possible causes can be significant periodical input of terrestrial material and/or seasonal oxygen depletion at sea bottom.

## Assessing modern foraminiferal distribution as a tsunami indicator for coastlines facing the Japan Trench

**Jessica E. Pilarczyk**[1,2], Yuki Sawai[3], Benjamin P. Horton[1,2], Yuichi Namegaya[3], Tina Dura[1,4], Osamu Fujiwara[3] and Christopher H. Vane[5]

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Along the northern segment of the Japan Trench, the subduction of the Pacific plate under the Eurasia plate has frequently generated tsunamigenic-earthquakes up to ~M 8.0. In contrast, the middle and southern segments of the Japan Trench were considered relatively inactive until the 2011 Tohoku-oki event generated a M 9.0 multisegment earthquake and one of the largest tsunamis in recorded history. Geologic evidence on the Sendai plain revealed an event in A.D. 869 that could have forecast the severity of the Tohoku-oki tsunami in 2011. Seismic models indicate that the Tohoku-oki earthquake may have transferred stress southwards down the fault causing an anomalous increase in stress along the potentially locked southern segment of the Japan Trench. This scenario could produce an earthquake in the near future that would be comparable in magnitude to the Tohoku-oki event. Reconstructing the history of individual great earthquakes and accompanying tsunamis over many earthquake cycles provides the full assessment of the seismic hazard.

We collected modern surface samples along two transects located in the Kujikuri Beaches region (eastern Japan) and documented the foraminiferal distributions along the coastal zone. Foraminiferal analysis discriminated among subtidal, foreshore, backshore and dune environments. Highest standing crops of foraminifera were found in subtidal samples and markedly decreased landward. Subtidal and foreshore living and dead assemblages were dominated by *Pararotalia nipponica, Quinqueloculina* sp. and planktics. Dead assemblages from the backshore and dune areas contained species with robust tests that favor preservation (*e.g.*, *Pararotalia nipponica*, *Ammonia parkinsoniana* and *Lenticulina* sp.). Taphonomic analysis indicated that subtidal and foreshore samples contained higher abundances of unaltered and fragmented foraminifera. The majority of foraminifera in backshore and dune samples were corroded, indicating subaerial exposure. The foraminiferal assemblages and their taphonomic characteristics can be used to reconstruct the paleoenvironment of the Kujikuri Beaches region. We have found two anomalous sand beds (~2-3 km inland) preserved in low-energy environments where they would not normally occur (*i.e.* rice paddies), indicating deposition by a tsunami.

This work was supported by the National Science Foundation (# EAR1303881).

## Benthic Foraminifera associated with a cold-water coral (CWC) ecosystem in the Melilla Mounds field, Western Mediterranean Sea

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The Melilla Mounds Field (MMF) located on the Southeastern margin of the Alboran Sea is a cluster of biogenic deep-water carbonate buildups. They form elongated and dome shaped mounds around 2-6 km long, 100– 250 m wide and up to 100 m high and are partially buried under fine grained sediments. This area was the target of the FP7-EU Eurofleets "Mediterranean Gateway cruise" (June 2013) when several gravity cores and box-cores were retrieved. This study represents preliminary results and focuses on a 610 cm long gravity core mainly composed of a greenish grey clay matrix with intercalation of cold-water coral debris recovered at 251 m water depth from the MMF. Benthic and planktonic foraminiferal investigations were performed with a 20 cm sample resolution. Our results show that *Neogloboquadrina incompta* is dominant from the base of the core up to 220 cm of the core and indicating generally high nutrient availability at the surface. *Globorotalia inflata* dominates from 220 cm to the top of the core pointing to changed environmental conditions. Three distinct benthic foraminiferal assemblages have been identified in the core: 1) from the base to 420 cm, assemblages are dominated by *Lobatula lobatula-Rosalina brady* indicative of an environment with strong bottom currents, 2) from 260-420 cm a highly diversified assemblage is dominated by *Discanomalina coronata-Cibicidoides pachyderma* representative of active and flourishing cold-water coral settings, and 3) from 260 cm to the top of the core a *L. lobatula-Ammonia tepida* assemblage highlights a change in the sedimentary regime, with possibly more turbid waters. The Total organic carbon (TOC), Hydrogen Index and Oxygen Index obtained from standard Rock-Eval pyrolisis corroborate a higher contribution of continental-derived organic matter in the interval 0-220 cm, whereas in the underlying sediments the organic matter has a clear marine derivation.
Funding for this research is provided by the Swiss NSF project 7352 and the University of Fribourg.

## Palaeoenvironmental implications of Upper Cretaceous–Paleogene foraminifera from the Labrador Margin

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The Upper Cretaceous foraminifera from the Harbor M-52 well in the Hopedale Basin in the Labrador Sea were previously analysed, and classical deep-water agglutinated foraminiferal (DWAF) biofacies, namely the flysch-type fauna (Gradstein and Berggren, 1981) and the high-latitude slope assemblages (Kuhnt et al., 1989), were defined partly based on them. The quantitative data of the assemblages were, however, not published in the original studies, and the assemblages were described only qualitatively due to the large number of wells examined. Thus the objectives of this study are to describe the composition of assemblages and the biostratigraphic distribution of species, and to discuss their implications for palaeoenvironmental and palaeobathymetric changes during the Late Cretaceous rifting events and the

latest Cretaceous–Eocene sea-floor spreading along the Labrador Margin based on the results of a semiquantiative morphogroup analysis.

A total of 245 benthic and 24 planktic foraminiferal taxa were identified from the Upper Cretaceous and Paleogene of the Hopedale Basin. Most of the benthic species identified were cosmopolitan, known from the contemporaneous intervals of the North Atlantic and the western Tethys. The highly diversified foraminiferal assemblages were consistently dominated by DWAF. Calcareous benthic and planktic taxa are often rare, while the former being more common than the latter. The interval that was previously estimated as the Maastrichtian is now regarded as the lower–middle Campanian (10750–10660 feet) based on the concurrence of *Caudammina gigantea* and *Uvigerinammina jankoi*. A late Campanian to Maastrichtian age is suggested for the overlying sequence up to 10480 feet based on the presence of *Caudammina gigantea,*

The consistent dominance of tubular forms, the common occurrence of infaunal forms and the presence of all the other morphogroups together indicate a mesotrophic, relatively well-oxygenated environment with bottom currents for the entire studied interval. The high diversity and the dominance of DWAF, especially tubular forms, and the high proportion of agglutinated and calcareous epifauna in the Alexis and Markland formations are features similar to those of "Association F" of Koutsoukos & Hart (1990) which is characteristic of Late Cretaceous middle to lower slope environments. The common occurrence of *Reticulophragmium*, *Budashevaella* and streprospiral forms in the Cartwright Formation, which is characteristic of "Foraminiferal Biofacies 3" in the Eocene outer neritic–upper bathyal facies in the Barents Sea (Nagy et al., 2000), together with a general decreasing trend in diversity and the relative abundance of tubular forms, indicate regional shallowing that may well be related to the Selandian–earliest Thanetian regression.

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## Benthic Foraminifera records in marine sediments during the Holocene from Pescadero Basin, Gulf of California, Mexico

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Gravity core T-56 (256 cm length) was collected in Pescadero Basin located on the western side of the Gulf of California within the oxygen minim zone (OMZ) at 597 cm depth, aboard of the R/V "El Puma".

The aim of this study is evaluating changes in oxygenation related to the productivity during Holocene, using benthic foraminiferal assemblages and organic carbon as proxies of organic matter flux and bottom water oxygenation. In general, the core is characterized by silty-clay sediments, and it exhibits a turbidite between 130 and 235 cm, distinguished by sandy sediments and reworking material. From 130 cm to the top shows a visible laminated structure. The chronology is based on six AMS radiocarbon dates, and estimated sedimentation rates are 0.22, 0.18, 0.17 and 0.05 mm/yr, the core covers the past 10,600 years.

Preliminary results suggest three major scenarios. During the early Holocene, dominance of species such as *Cassidulina laevigata* var. *carinata, C. delicata* and *C. crassa* (up to 60 %) and low concentations of $C_{org}$ suggest low productivity conditions in the region. In the middle Holocene, *Bolivina* subadvena (megalospheric form) dominate and concentration of $C_{org}$ is relatively high in comparison with the previous period, an enhance in the productivity. During the late Holocene, sediments were characterized by the dominance of B. *subadvena, B. seminuda, B. seminuda* var. *humilis, B. plicata,* and the highest values of $C_{org}$, suggesting the highest productivity values.

## Benthic Foraminifera in surface sediments collected off northern Chile

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The coastal upwelling system of the Peru–Chile Current belongs to the most productive regions in the world oceans. In spite of this remarkable fact only very little is known about the sediment composition in its southern part off the coast of Chile. To increase the knowledge about this region a multiparameter study of the surface sediment distribution along the Chilean continental slope between 27 and 25ºS has been carried out. Here, we report about the benthic foraminifera collected during the German CHIMEBO Expedition with R/V Sonne (Hebbeln *et al*., 2011). Samples were obtained with a multicorer between 539 m and 1,200 m depth. The analysis of the surface sediments (0-1 cm) revealed 170 species of benthic foraminifera. The study area is characterized by a high relative abundance of the Order Rotaliina, with the dominant species being *Pullenia bulloides* and *Uvigerina peregrina*. The density of the benthic foraminifera fauna along the continental slope ranges between 381 and 11 ind./cm$^3$ at 25°S latitude (Taltal) and between 61 and 31 ind./cm$^3$ at 27°S latitude (Caldera). The results show that the distribution of benthic foraminifera is directly related to the oceanographic characteristics of the study area. *Pullenia bulloides* appears to be best adapted to the comparably low oxygen contents, which obviously reduce the competition in the respective substrates. *Uvigerina* spp. species appears to be independent from the bottom water oxygen content in both environments. These results will be complemented with those derived from the earlier PUCK cruise of R/V Sonne (Hebbeln *et al*., 2001), during which 91 additional multicorer samples have been taken between Antofagasta and Guaitecas Islands (22 º - 44 º S).
This research has been supported by FONDECYT REGULAR N° 1130511.

# Benthic Foraminifera and nematofauna composition associated with Thioploca mats on the continental shelf sediments off Central Peru

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The benthic subsystem off Central Peru combines important geochemical characteristics, such as low oxygen levels (<0.5 $ml.l^{-1}$), presence and concentration of pore water hydrogen sulfide and high organic matter flux to sediments. This realm is also characterized by low species richness of macrobenthic communities, which are dominated by giant filamentous bacteria *Thioploca*. In this scenario, benthic Foraminifera and Nematoda share affinity for certain microhabitats.

The distribution of benthic foraminifera and marine nematofauna in relation to *Thioploca* biomass, macrofauna density sedimentary phytodetritus (chlorophyll-*a* and chlorophyll-*a*/Phaeopigments ratio) and hydrogen sulfide ($H_2S$) was assessed on the continental shelf off Callao (12 ° S) and Pisco (14 S), in April and in August 2011. Average Living Depth index ($ALD_5$) was applied in the upper 5 cm in order to analyze the vertical distribution.

In both horizontal and vertical scales, the dominant calcareous foraminifera *Bolivina costata* and *Nonionella auris* and the family Desmodoridae (Nematoda) were associated with high sedimentation conditions of fresh organic matter and reducing conditions near the sediment-water interface. These groups co-occur with *Thioploca* spp. mats in this microhabitat at the sediment-water interface (top one centimeter). Instead, the families Oxystomatidae and Chromadoridae (Nematoda) tended to be distributed deeper in the sediment at greater distances from the coast, suggesting an adaptation to feeding on more refractory organic matter. The calcareous foraminifera prevailing farther from the coast was *Bolivina seminuda*, with a high dominance. Empty sheaths of *Thioploca* spp. characterized the microhabitats associated to Oxystomatidae, Chromadoridae and *Bolivina seminuda.*

The association to redox conditions and to food quality exhibited by major calcareous foraminifera species, nematofauna families and *Thioploca* mats plays a key role in the characterization of ecological niches in the sedimentary upper edge of the oxygen minimum zone off Peru.

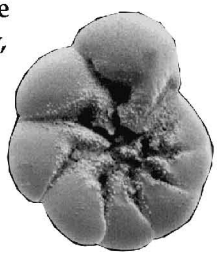
# Author Index

# 7th Course

# International School on Foraminifera

## Urbino, 3-21 JUNE, 2014

The 7th Course on Foraminifera is designed to provide an overview of the Taxonomy, Ecology, Biodiversity, and Geological History of Benthic and Planktonic Foraminifera. This intensive course is intended for students interested in Micropalaeontology, Palaeoceanography, Palaeoecology, Climate History, Biology, and Environmental applications. The aim is to provide a primer on the study of foraminifera and examples of how foraminifera can be used as (paleo)environmental and (paleo)oceanographical proxies. We review the current classification schemes of the foraminifera, discuss their ecology and life history, review their usefulness for biostratigraphical applications, and use case studies to investigate the geological history of the group with lab and practical sessions. The entire course consists of approximately 50 hours of lectures and 50 hours of practicals.



### Course Structure

Four distinct courses are planned: *Foraminiferal Introduction* (4-8 June), *Larger Benthic Foraminiferal Course* (9-12 June), *Smaller Benthic Foraminiferal Course* (13-16 June) and *Planktonic Foraminiferal Course* (18-21 June).

### Teaching format

The course consists of lectures and practical classes covering the taxonomy, distribution, ecology, and paleoecology of foraminifera. Microscope lab sessions provide the opportunity for participants to learn the foraminiferal genera and species, and view Cretaceous to Neogene foraminiferal assemblages from Petroleum Exploration areas and ODP sites as well as Quaternary and modern assemblages. At the end of each lecture session, different tasks will be assigned to participants to reinforce the knowledge learned. Course materials include the lecture powerpoints and numerous pdf reprints of classic papers.

### Correspondence and information

Dr. Fabrizio Frontalini - Università di Urbino, Campus Scientifico, Localita' Crocicchia, 61029 Urbino, (Italy)
fabrizio.frontalini@uniurb.it or isf@tmsoc.org Tel: (+39) 0722 304309, Fax: (+39) 0722 304220

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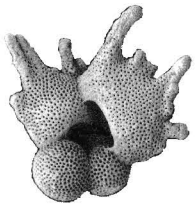

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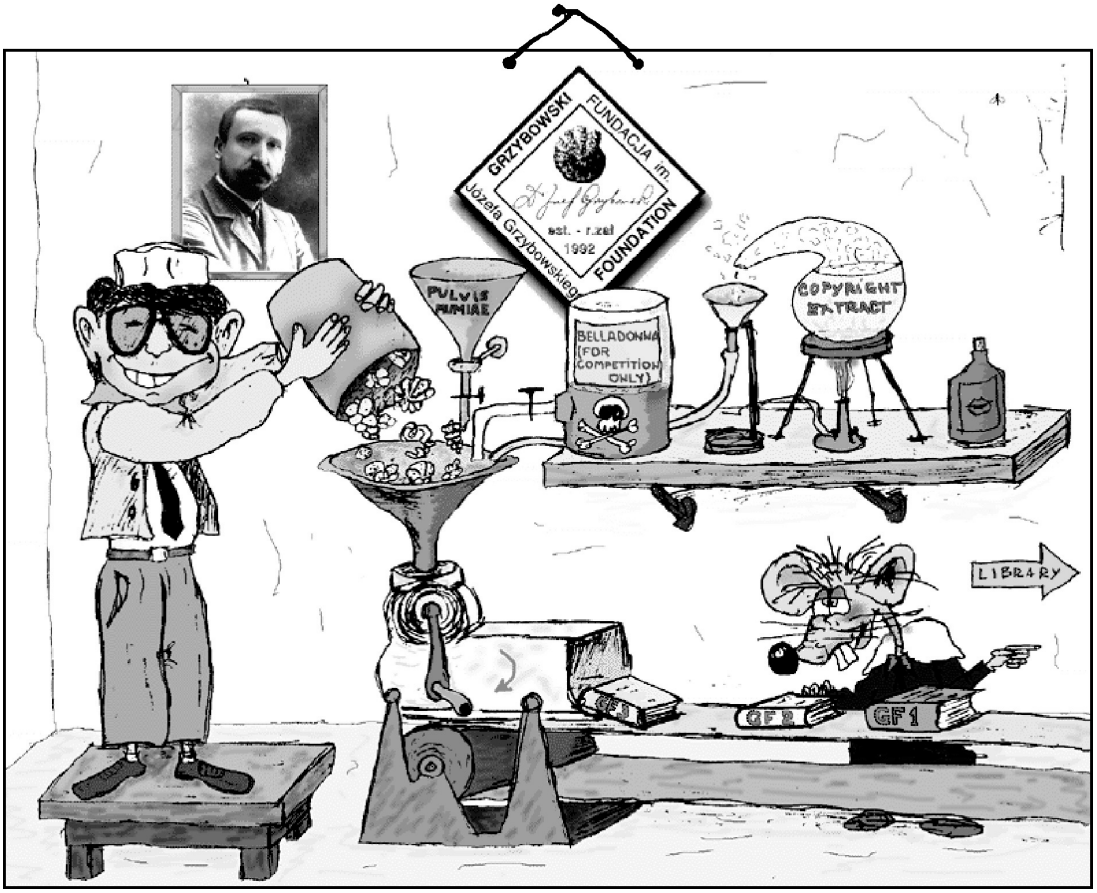


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6. *"A Guide to Excursions in the Polish Flysch Carpathians"* by Andrzej Slaczka & M.A. Kaminski (1998). Format: A5, 180 pp. Paperback Price: £10.00.

7. *"Proceedings of the Fifth International Workshop on Agglutinated Foraminifera"* edited by M.B. Hart, M.A. Kaminski & C.W. Smart (2000). Format: A4, 478 pp. Price: £49.00 (Libraries: £59.00).

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