Micro- to Macro-scale Foraminiferal Distributions: Patterns and Processes

A Session in Honor of the Research Contributions of Dr. Martin A. Buzas

Chaired by Laurel Collins, Stephen Culver and Brian Huber

The research of Dr. Martin A. Buzas over the past 40 years has dealt with the distribution of foraminifera across all scales, from a single cc to an entire ocean, and from the present to the past. This session is designed to showcase new findings and new methodologies in benthic and planktic foraminiferal distributional studies from Mesozoic and Cenozoic strata and modern oceans. The session commences with an overview of Marty Buzas’s research contributions followed by papers dealing with, but not limited to, the following topics: patterns of distributions, both small and large-scale; processes controlling distributions; quantitative approaches and interpretive techniques; and molecular approaches.
Micro- to macro-scale foraminiferal distributions:
The contributions of Martin A. Buzas

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The research that Marty Buzas has published over the past more than 40 years has influenced us greatly. That research has many strands that we cannot deal with in a single symposium. The theme of this session is micro- to macro-scale foraminiferal distributions, a theme that is interwoven throughout Marty’s research career. Distributions are something that Marty is very fond of. He was trained in statistics as well as foraminifera and so it was inevitable that he would combine his knowledge of statistical distributions with foraminiferal distributions at several different scales. He has studied the distribution of foraminifera at microscales, horizontally within a 10 cm² area of the sea floor or vertically, cm by cm within a 20 cm core. He has also worked at the mesoscale, quantifying, through the pioneering use of the General Linear Model, the relationship of foraminiferal distributions and environmental variables in space and time. This research led to the hypothesis of pulsating patches. He has worked at the macroscale with S. J. Culver, defining the distribution of benthic foraminiferal provinces, showing that all foraminiferal distributions particularly around the coasts of North and Central America belong to the same statistical distribution. Their work has documented the assembly and disassembly of communities and the latitudinal patterns of deep-sea benthic foraminiferal diversity in the Atlantic basin. Most recently, with his coauthor, mathematical statistician L. C. Hayek, Marty has delved deep into the intricacies of species diversity and solved a 50 year-old supposedly intractable problem of mathematically relating species richness with species evenness. This work led to the introduction of new approaches to understanding community structure and recognizing boundaries between adjacent communities (SHE analysis).

Many of us work long hours and publish many papers over our careers but few of us truly influence the fundamentals of our science. Marty Buzas is one micropaleontologist whose work will be of lasting significance.
From blue skies science to practical application: Increasing need for retrospective environmental micropaleontological monitoring (REMM)

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The European Water Framework Directive (WFD) focuses on the protection of groundwater, inland surface waters, estuarine waters, and coastal waters. One of the central themes in the implementation Guidance document concerning “Transitional and Coastal Waters” is defining biological reference conditions. This is in contrast to governmental bodies’ traditional sole focus on contemporary environmental monitoring and opens new possibilities for environmental micropaleontology.

Improved knowledge of benthic foraminiferal ecology, combined with dating and geochemical methods to trace changes in environmental parameters back in time, has strengthened our ability to perform paleoecological interpretations integrated with a time-scale. As a result of this, we see a growing body of retrospective studies from all over the world, linking faunal changes over the past few centuries to natural and/or anthropogenic causes. Yet, our main audience for these papers is our scientific colleagues. However, the European initiative appreciates that information about “background conditions” and natural variability is crucial when planning improvement strategies; this represents a major opportunity for micropaleontologists to get retrospective studies incorporated into governmental guidelines for environmental investigation. This will create new employment opportunities for our students.

A major challenge now is to make our governmental authorities aware of the unique potential micropaleontology has to approach some of the problems they are facing. Retrospective Environmental Micropaleontological Monitoring (REMM):

1) can provide biological reference conditions for any given soft bottom area with net sediment accumulation (> about 1mm/yr) several hundred years back in time;

2) can provide data on natural variability as well as high resolution time-series of environmental change in estuarine and coastal sediment accumulation areas;
3) is extremely cost efficient as compared to traditional biological monitoring;
4) is gentle on the environment - only involves physical disturbance of a fraction of the soft bottom habitat as compared to traditional biological sampling.

In order to make our methods attractive and applicable, we need to specify strengths and limitations, establish good ecological calibration sets, and to improve our quantitative approaches. Marty Buzas has educated us on the latter and it is now up to us to take it a step further. Improved knowledge of quantitative relationships between faunal and environmental parameters is particularly needed. The Norwegian Pollution Control Authority’s classification system for environmental quality includes a classification for soft-bottom macrofauna. It is currently being modified and incorporated into the implementation strategy for WFD. Recently, this system has been applied to modern benthic foraminiferal assemblages as well as to fossil ones in dated sediment cores from sill basins along the southern Norwegian coast. Distributional data show a significant correlation between several faunal parameters and annual dissolved oxygen minimum concentrations (bottom water). Application of the governmental classification system for environmental quality shows the same pattern whether used on soft-bottom macrofauna or on benthic foraminifera. These ecological training sets have allowed reconstruction of the successive environmental change (transition from one environmental class to another) within areas of different present-day environmental status. These results are very promising and illustrate the significance of REMM.
Biostratigraphic, paleoclimatic and paleobathymetric events in the upper continental slope, north Bahia, Brazil

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The foraminiferal fauna present in 1.90 m long cores from the north coast of the State of Bahia, were analyzed for developing a biostratigraphic zonation and interpreting paleoclimatic and paleobathymetric events that occurred during the Quaternary in this part of the Brazilian Continental Margin. Four sample stations were piston cored from the upper continental slope: cores 132 (730 m deep), 141 (790 m deep), 147 (640 m deep) and 160 (480 m deep). From forty samples selected from the cores, 10,544 foraminifer specimens were picked up and 312 taxa were identified representing 96 genera and 302 species. The frequency and distribution patterns of the planktonic foraminifera suggest the presence of assemblage indicators that may be correlated with international Quaternary biozones. The frequency variations of planktonics indicate warm water as *Globigerinoides ruber* and *Globorotalia menardii* s.l. show an increasing frequency from the top to 40 cm of cores 132, 141 and 160, and to 60 cm depth of core 147. The presence of *Globorotalia menardii f. fimbriata* and *Globorotalia menardii f. ungulata*, which occur only in the Holocene, suggests warm water conditions for this core interval, as well as absence of *Globorotalia inflata*, which is a bioindicator of cold water. This is a suggestion that this core interval might be correlated with the international biozone Z of Quaternary time (Holocene – Interglacial). Likewise, the variations observed in the frequency of the cold water planktonic bioindicators, *Globigerina bulloides* and *Globorotalia truncatulinoides*, show an increasing frequency from 40 cm depth in the cores 132, 141 and 160 to their bottoms and from 60 cm deep until the bottom of core 147. This observation suggests that this core interval might be correlated with international Y zone (Pleistocene – Glacial) of the Quaternary. Variations observed in the relative frequency of benthonic versus planktonic species show predominance of benthonics at the bottom of cores 141, 147 and 160. Moreover, changes in the high proportion of
benthonic species in the bottom of cores 141 and 147, to increased frequency of planktonic ones at the top of these cores suggest eustatic sea level variations, which may be correlated with Quaternary global climatic changes, with the paleoclimatic Pleistocene Glacial at the bottom and the climatic Holocene Interglacial in the top. The frequency variations of the benthonic depth indicators such as *Uvigerina peregrina* and *Bolivina subaenariensis* show an increased frequency from the top to 20 cm depth in core 160, indicating an interglacial period (Holocene) and a sea level increase. In this same core the species *Bulimina marginata*, *Bulimina patagonica* and *Bulimina subaenariensis* show an increase in their frequency from 1m deep to its bottom, indicating a decrease in water temperature (Pleistocene), reduction of eustatic sea level and an increase in productivity. Therefore, based on these results, it is suggested that during the Holocene in the north coast of the State of Bahia, a high eustatic sea level and warm waters predominated. Otherwise, during the Pleistocene low eustatic sea level, cold water and a high productivity pattern predominated. $^{14}$C foraminiferal dating and $^{18}$O analysis are needed to confirm the findings of this work.
Foraminiferal assemblages in subsurface sediments of the upper continental slope, north Bahia, Brazil

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This work presents the analysis of one piston core (1.90 m long) from the upper continental slope at the north coast of the State of Bahia, which was collected at 730 m deep, approximately 9 km from the continent. Ten samples were selected at 20 cm intervals, for defining correlation of the foraminiferal benthonic assemblages with bathymetric, sedimentologic and hydrodynamic parameters. The patterns of distribution and the frequency of the foraminiferal species indicate assemblages mainly characterized by > 1% relative frequency. The sediments are composed of olive gray carbonate mud mainly with foraminiferal tests and mollusk debris from the top to 40 cm depth, and an olive dark (40 – 60 cm) to brownish black (1.20 m) siliclastic mud, with plant fragments to its bottom. The frequency of the bentthic species increases at 60 cm, 1m and 1.60 m depths in the core.

- At the core top, there is a bentthic assemblage with five foraminiferal species that include in decreasing order of abundance: *Cassidulina crassa, Bolivina pseudoplacitica, Eponides frigidus, Bolivina doniezi* and *Bulimina patagonica*.

- Sample 2 (20 cm deep) has a bentthic assemblage with eleven species: *Bolivina subaenariensis, Bulimina marginata, Cassidulina subglobosa, B. patagonica, Cibicides pseudoungerianus, Planulina faveolata, Trifarina bradyi, Uvigerina peregrina, Bolivina ordinaria, Eponides frigidus de:*and *Laticarinina halopora*.

- Sample 3 (40 cm deep) has ten species: *Bolivina subaenariensis, C. pseudoungerianus, Sphaeroindina bulloides, B. patagonica, Cassidulina norcrossi australis, E. frigidus, B. marginata, Cassidulina curvata, L. halopora* and *Pullenia bulloides*.

- Sample 4 (60 cm deep) has eighteen species: *B. patagonica, B. subaenariensis, B. marginata, Bulimina affins, Bolivina subreticulata, Cassidulina laevigata, Bolivina difformis, C.*
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subglobosa, C. pseudoungerianus, Brizalina striatula, Bulimina buchiana, E. frigidus, Angulogerina angulosa angulosa, Bulimina aculeata, Bulimina costata, C. crassa, Eponides repandus and Melonis affine.

- Sample 5 (80 cm deep) has just one species: Sphaeroidina bulloides.
- Sample 6 (1 m deep) has nine species: S. bulloides, B. affins, B. aculeata, C. pseudoungerianus, B. marginata, B. patagonica, B. subreticulata, C. curvata, U. peregrina.
- In samples 7 (1.20 m deep) and 8 (1.40 m deep) was found only one planktonic species and no benthonics.
- In sample 9 (1.60m deep) the benthonic assemblage has eight species: C. pseudoungerianus, C. laevigata, E. frigidus, Sigmavirgulina tortuosa, C. subglobosa, Ammonia tepida, Angulogerina angulosa occidentalis, Cibicides lobatulus.
- And in sample 10 (1.80 m deep) four species were identified: A. tepida, C. subglobosa, C. pseudoungerianus, Gyroidina umbonata.

It was observed the predominance of the infaunal genera Bolivina, Uvigerina, Bulimina and Cassidulina commonly found in muddy sand substrates, characteristic of cold-temperate or cold-warm waters. The presence of the genera Bolivina, Uvigerina and Bulimina in samples 2 (20 cm) and 6 (1 m) reflect a deep environment, probably with little oxygen and/or a high rate of influx of organic matter. The change from a carbonate mud at the top of the core to a siliciclastic mud at its bottom, and the absence of benthonic and planktonic assemblages in the depositional intervals of 80 cm, 1.20 m and 1.40 m deep, suggests environmental changes probably related to a reduction in the eustatic sea level.
Foraminifera on coral reefs of Brazil: The FOCO project

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Coral reefs have been considered worldwide as good climatic bioindicators because they bear markings in their skeletons of interannual, decadal and higher time scales. These growth bands provide a continuous stratigraphic register of Quaternary climatic oscillations, but sampling procedures to obtain such a record involve some damage to living coral organisms. In this aspect the foraminifera are considered useful alternative bioindicators as they have the same metabolic requirements as corals, but sampling procedures produce no negative environmental impact. Foraminifera also present a more rapidly growing standing crop and also register shorter term changes on these environments. The Ministry of Environment of Brazil in 2004 began a program to identify possible bioindicators of climatic changes along the Brazilian coast line, and to promote their subsequent use as powerful tools for monitoring programs and coastal management. The sponsoring of the FOCO Project, which consisted of undertaking samples from reefs of Brazil since 2000, now allows for improved sampling of other areas. The objective of the FOCO Project is to carry out a survey of the quantitative and qualitative distribution of benthic foraminifera in reef sediment and test the applicability of this climatic observation in Brazilian coral reef areas. This supplements their use for base mapping environmental impact fronts using GIS in a 1:25.000 scale for coral reefs along the Brazilian margin through the observation of bleaching and/or deformation of tests, mainly in the genus *Amphistegina* spp. In this paper we present these results for the four different Brazilian coral reef systems analyzed, which
encompass APA Costa dos Corais (PE) and Porto Seguro (BA) as well as Fernando de Noronha (PE) and Abrolhos Bank (BA), in order to verify if *Amphistegina* spp. can be used for this diagnosis in South Atlantic waters. A total of 72 reef sediment and 18 geochemical samples per area were collected in January 2005 and in July 2005. Samples were collected using scuba equipment, and parameters measured on site include visibility, water temperature, salinity and dissolved oxygen, both at the surface and at depth, while sampled sediments are analyzed for carbonate, phosphorus, and organic matter, as well as mineralogy and grain size. At the laboratory, foraminifera were identified under a stereomicroscope to the species level. The results suggest that *Amphistegina* spp. can be used as a low cost bioindicator to evaluate the health of Brazilian reefs, and also that photic stress can be the cause of the high number of bleached, small size and broken tests in *Amphistegina* spp. specimens.
Deep-sea benthic foraminifera are particularly suitable for paleoecological and paleoceanographic investigation because they are cosmopolitan in distribution, occur commonly in marine sediments and have a high preservation potential. Numerous investigations have dealt with the effects of different environmental parameters on the benthic foraminiferal assemblages in an effort to explain their distribution patterns and ecological preferences. Nevertheless, a thorough study of modern assemblages is necessary to acquire a better understanding of the factors influencing the distribution of deep-sea benthic foraminifera, especially from poorly investigated regions such as the western South Atlantic Ocean.

This study presents the distribution patterns of deep-sea benthic foraminifera assemblages in the late Quaternary, recovered from piston cores #CAM257 (22°26’42"S, 38°56’17"W) and #CAM275 (22°33’48"S, 39°11’44"W) drilled in the lower continental slope of Campos Basin, in the southeastern Brazilian continental margin. Detailed geochemical studies (ä¹⁸O) carried out on Orbulina universa and Cibicidoides wuellerstorfi tests throughout the studied section allow inferences on ecological preferences relative to climatic and environmental conditions. The recorded main changes of foraminiferal distribution patterns are related to local and global climatic and eustatic variations during the late Quaternary (~150 Ka), as well as the paleoenvironmental imprint of glacial and interglacial intervals in the studied section.
Foraminiferal monitoring of ecosystems: Mission-Aransas National Estuarine Research Reserve, Texas

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On the Texas coast north of Corpus Christi, a National Estuarine Research Reserve (NERR) has been established. Several bays, including, Aransas, Mission, Copano, Redfish, and Mesquite Bays, are part of the reserve, which encompasses diverse habitats such as mangrove swamps, seagrass beds, and oyster reefs. Some of the sites within the Mission-Aransas NERR that have already been subject to human impact are designated as buffer zones, while the more pristine sites will be used for scientific studies such as this one. The purpose of this study is to establish baseline data for foraminiferal population distributions in Aransas, Copano, and Mesquite Bays (and eventually all of the NERR bays), and to use this data for future monitoring of the reserve. Past research by Phleger (1956) reported living numbers of foraminifers in Aransas and Mesquite Bays, and some of his stations are being re-sampled for this paper. Phleger found that average populations in Aransas and Mesquite Bays were 110 and 85 specimens per 10 ml, respectively. These densities are similar to those found so far in the current study, which average 99 individuals per 10ml in Aransas Bay. Species richness from the 1950s (approximately 15 species in each bay) is also comparable to that of today (approximately 13 species per bay), with the predominant genera usually being *Ammonia* and *Elphidium*. As the present research progresses in the coming months, it will be interesting to see if abundance and diversity correlate with environmental parameters such as salinity and nutrient availability. Since the estuaries in the NERR are important recreational areas, nesting sites, and spawning grounds for shellfish and finfish, it is critical to monitor these ecosystems for future use.
Divergence of late Miocene Caribbean and tropical Eastern Pacific shallow-water benthic foraminifera

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In the Paleogene to earliest Neogene, benthic foraminiferal and molluscan faunas from the Caribbean and Eastern Pacific were reported to be quite similar, because a tropical seaway connected the two oceans across the area that is today southern Central America. About four million years ago the Central American Seaway closed completely, and today the two faunas are quite different in composition. This study compares Neogene benthic foraminiferal faunas of formations from either side of the Central American isthmus that are from the same time intervals and paleobathymetric zones, to look at changes in faunal composition, diversity and the proportion of endemism up through the time of seaway constriction and complete closure.

Formations on the Caribbean side of Central America are from the Limón Basin of Costa Rica, and the Bocas del Toro Basin and Panama Canal Basin of Panama. The time period covered by these formations is from early Miocene to late Pliocene, and from middle neritic to lower bathyal water depths. Because there are no comparable, well-oxygenated Neogene depositional basins on the Pacific coast of Central America, benthic foraminiferal assemblages primarily from formations of coastal Ecuador are used for comparison with the Caribbean formations. Ecuador was the furthest that tropical waters extended south on the Pacific side of Central America, just north of stronger influence by the Peru Current. The time interval covered by Ecuador formations is also early Miocene to late Pliocene, from middle neritic to lower bathyal depths.

The prediction, based on preliminary results, is that species distributions should indicate a stage of developing endemism in late Miocene Caribbean and Pacific faunas. For example, the deeper, outer neritic faunas of the late Miocene Angostura Formation of the Borbón Basin, northwestern Ecuador, show less similarity with the Caribbean than do the shallower, middle neritic faunas of the same formation. Deeper faunas should have been affected first by the rise of the sill that severed the connection between Caribbean and tropical Eastern Pacific faunas. Diversity is also predicted to have been more similar between the Caribbean and tropical Eastern Pacific prior to seaway constriction, and to have diverged in the late Miocene to early Pliocene.
Recent foraminifera from the Croatian Adriatic seacoast

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The need to assess the impact of pollution (industrial, agricultural, and other anthropogenic chemicals) in the Adriatic Sea leads to the study and use of foraminiferal assemblages as environmental quality indicators in coastal settings. From the time of Dezelic (1896. *Foraminifere Jadranskog mora. Glasnik Hrvatskog naravoslovnog drustva, Zagreb, 9: 97*) until the 1990s and the appearance of *Mediterranean Foraminifera* (Cimerman & Langer, 1991. *Mediterranean Foraminifera. Dela – Opera, Ljubljana, 30: 118*), the study of foraminifera has included sporadic collecting of samples from particular sites (Cimerman *et al.*, 1988. *Rev. Paléobiol.*, vol. spec. 2, Benthos ’86: 741-753) during a very short time interval or collecting of samples from a site over an extended period of time (Daniels 1970. *Götting. Arb. Geol. Paläont.*, Göttingen, 8: 109). The knowledge we gained from such studies was general, such as that 583 Recent foraminiferal species (19 are planktonic forms) live in the Croatian coastal region of the Adriatic Sea. The growing interest in the subject of environmental changes and concern for Croatia’s main export product (tourism) suggested the need for systematic investigation of foraminiferal assemblages. From Croatia’s 1000km long, geomorphologically diverse coast with more than 1000 islands, we have chosen four particular sites to initiate monitoring. The sites were chosen to show the relationship between enclosed circulation patterns, karstic drainage (subsurface and surface), and anthropogenic influence (eutrophication). We studied (from northwest to southeast): the Mirna river estuary (intensive agriculture locally), Plomin Bay (“measurable” river input and power plant contamination), Rijeka Bay (municipal sewage and effluent from the busy cargo port), and Mljet lakes (restricted marine environment with summer stratification and sporadic agricultural activity). Scuba divers collected sediments from several stations in
a transect from the most landward station towards the open sea (down to 55m depth), and we studied stained and unstained and total assemblages from samples prepared according to standard procedures (around 300 specimens obtained by splitting after washing the samples over 0.063mm sieve). The foraminiferal assemblages from sites where freshwater input is considerable show the following characteristics:

1) an *Ammonia beccarii* association typical for lagoons along the Mediterranean coast (Murray, 1991. *Longman Scientific and Technical, Harlow, Essex: 391*) is identified in the region closest to the discharge area;

2) the assemblages are composed of a great number of megalospheric forms of *A. beccarii*;

3) dead tests are much more common in the assemblage then living ones (regardless of season when sampling takes place);

4) there is a predominance of species belonging to Rotaliina over Miliolina (Textulariina specimens do not exceed 10%);

5) indices of biodiversity imply marginal to normal marine conditions;

6) an *Ammonia/Elphidium* ratio from 46% to 92%;

7) dissolved tests are less than 5% of the living assemblages; and

8) species diversity corresponds positively with Fe, Mn concentrations in the sediments from Rijeka Bay and negatively with Pb concentrations (relative abundance of deformed tests is less than 1%).

It is clear that constant fresh water input is a stressful influence, but neither intensive agricultural or industrial activities in the vicinity nor intensive marine traffic have left a noticeable impact on the foraminiferal morphologies. Foraminiferal assemblages from restricted marine settings are characterized by a low biodiversity index, depth dependence of “specialist” miliolids over rotaliids, and in temporarily hypoxic lagoons, the presence of species tolerant of low oxygen conditions (in “dead” assemblages).
Quaternary climate instability as the driver of genetic diversification in *Neogloboquadrina pachyderma* (sin)

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Molecular genetic analysis shows that many planktonic foraminiferal morphospecies represent complexes of several distinct genetic types with distinct ecologies and distributions. Such cryptic diversity is common in most planktonic protists. Global biogeographical patterns provide many clues to their specific adaptations in the present day but not always to the past processes which may have created them. Planktonic foraminifers are ideal taxa for addressing these issues as their evolutionary history can be traced back in time with high resolution using their outstanding fossil record. In combination with paleoceanographic evidence, it is possible to interpret the modern molecular studies in an historical oceanographic context and gain an insight into the links with past global climatic or tectonic events.

*Neogloboquadrina pachyderma* (sin) currently dominates the high latitude assemblage and has played a pivotal role in the reconstruction of past climate in these regions. It first appeared approximately 10 million years ago and phylogeographic evidence indicates that it may not have been a true polar adapted morphospecies throughout its existence. The common ancestor of all the modern day *N. pachyderma* (sin) genotypes was bipolar and thus had a subpolar ecology. At the onset of Northern Hemisphere glaciation, Atlantic Arctic and Antarctic populations became isolated and some genotypes developed an extreme polar affinity. Others retained a more subpolar ecology but with a more restricted temperature range than the bipolar subpolar morphospecies. Genetic diversity therefore arose in *N. pachyderma* (sin) through a stepwise progression of diversification associated with the onset of Northern Hemisphere glaciation and the glacial-interglacial climate dynamics of the Quaternary period.
Annual shifts in inter-tidal foraminiferal diversity in the west coast of India

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Environmental conditions are known to influence foraminiferal assemblages and their diversity. Seasonal fluctuations however, are not well studied in tropical intertidal habitats. The southern West Coast of India has narrow coastal plains bordered on the east by the Western Ghats, which rise to an average height of 900m above sea level. This generates monsoon precipitation from southwesterly winds that last for about four months beginning in the first week of June. Due to a steep gradient of the Western Ghats numerous swift-flowing rivers course through a highly productive region that includes the coastal plains and they traverse a distance of about 60 km before reaching the sea. They provide large inputs of various micro- and macro-nutrients. The monsoons thus considerably alter the hydrobiologic profile of the Arabian Sea. Thus the West Coast of India provides an interesting region for study of correlation of monsoon and foraminiferal diversity. It is all the more significant as paleomonsoon data are often interpreted from proxy foraminifera.

In the present investigation, seasonal variations in diversity and abundance of total foraminiferal populations (TFN) were studied at an estuarine (River Sal) and a non-estuarine site (Utorda) along the coast of Goa, India, between October 2004 to September 2005. The observations were correlated with various parameters such as sediment texture, organic matter, calcium carbonate, water temperature, salinity, dissolved oxygen, calcium, silicate and phosphate content. Quantitative analyses of all samples were carried out by following standard methods and biodiversity indices were calculated.

At the estuary, lesser diversity of foraminifera represented by 25 species (23 benthic and 2 planktonic species) belonging to 15 genera, 9 families and 2 sub-orders were found. In contrast, 55 foraminiferal species (51 benthic and 4 planktonic species) were recorded at a non-estuarine site. They belong to 25 genera, 11 families and 4 sub-orders. Spiroloculina tricarinata, Quinqueloculina vulgaris Rotallidium annectans, Rotallinoides papillosus, Ammonia beccarii, A.dentata, Elphidium discoidale, Amphistegina radiata,
and *Poroeponides lateralis* were found in abundance at both the locations but their TFN was higher at the non-estuarine site. *Lagena leavis, Cancris auriculus* and *Rosalina* sp. were found only at the non-estuarine site, though in lesser numbers. Planktonic forms-*Globigerina bulloides* and *Globigerinoides ruber*-were found at both sites. Well-marked seasonal variations of foraminifera were also observed at both sites. Lowest densities and diversities were observed during monsoon and highest densities and diversities of foraminifera were found during post-monsoon (winter). Highest TFN was recorded in January 05. The post-monsoon period is characterized by the presence of *R. annectans, R. papillosus* and *E. discoidale* in abundance.

Maximum rainfall was recorded during the month of July (1223.7 mm at estuarine and 1096.9 mm non-estuarine sites respectively). This also reflects the rainfall pattern in the plains and the Western Ghats. Foraminiferal data for monsoon and non-monsoon periods show a profound correlation with sedimentological and hydrological data. Species diversity and total foraminiferal number were higher at the non-estuarine site through all the seasons and deformed forms were scarce. Decreased salinity, and changes in other environmental parameters resulted in low species diversity and TFN at the estuarine region. Relict foraminifera were found predominantly during the monsoon. This is probably due to tidal transportation of benthic relicts. Observed morphological abnormalities are attributed to environmental stresses such as low salinity, low Ph and low calcium. The study reveals that a moderate increase in salinity, organic matter, calcium carbonate and dissolved oxygen are positively correlated with an increase in diversity and abundance of species following the monsoon.
Stable isotope composition of Cretaceous benthic foraminifera: Biological and environmental effects

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The stable carbon and oxygen isotope composition of different benthic foraminiferal species of the latest Campanian and earliest Maastrichtian from Ocean Drilling Project Hole 690C (Weddell Sea, southern South Atlantic, ~1800 m paleowater depth) have been investigated. The total range of measured isotope values of all samples exceeds ~4‰ for δ13C and 1.1‰ for δ18O. Carbon isotope values of proposed deep infaunal species are generally similar or only slightly lower when compared to proposed epifaunal to shallow infaunal species. Inter-specific differences vary between samples probably reflecting temporal changes in organic carbon fluxes to the sea floor. Constantly lower δ13C values for Pullenia marssoni and Pullenia reussi suggest the deepest habitat for these species. The strong depletion of δ13C values by up to 3‰ within lenticulinids may be attributed to a deep infaunal microhabitat, strong vital effects, or different feeding strategy when compared to other species or modern lenticulinids. The mean δ18O values reveal a strong separation of epifaunal to shallow infaunal and deep infaunal species. Epifaunal to shallow infaunal species are characterized by low δ18O values, deep infaunal species by higher values. This result possibly reflects lower metabolic rates and longer life cycles of deep infaunal species or the operating of a pore water [CO3^2-] effect on the benthic foraminiferal stable isotopes.

Pyramidina szajnochae shows an enrichment of oxygen isotopes with test size comprising a total of 0.6‰ between 250 and 1,250 µm shell size. Although δ13C lacks a corresponding trend these data likely represent the presence of changes in metabolic rates during ontogenesis. These results demonstrate the general applicability of multi-species stable isotope measurements of pristine Cretaceous benthic foraminifera to reconstruct past microhabitats and to evaluate biological and environmental effects on the stable isotope composition.
Quaternary deep-sea benthic foraminifera from the southeast Pacific Ocean: Distribution and dominance

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The Southeast Pacific Ocean is one of the lesser known regions in the present day world ocean. In this paper, the Quaternary deep-sea benthic foraminifera fauna is studied in this area, between 18°S – 55°S and 72°W – 77°W. Seven Eltanin cores were studied from the Chile Basin, Peru-Chile Trench, Chile Ridge, Southeast Pacific Basin and Chilean continental slope, between 1,223 and 4,841 meters of water depth. Ninety seven benthic deep-sea species were identified. The Quaternary faunal dominance in the region is compounded by *Eponides weddellensis* and *Epistominella exigua* at depths between 3,000 and 4,000 meters, with *Osangulariella umbonifera* as accompanying species. In several sites, the stratigraphic distribution of *E. weddellensis* and *E. exigua* show a negative correlation or an alternate faunal dominance during the middle and upper Pleistocene. This suggests different ecological characteristics for each species. In the actual biogeographical distribution, both species are assigned as “opportunistic phytodetritivorous species”. In one site at the Chile Basin (E3-9 core), *E. weddellensis* and *E. exigua* lose their alternate and dominant faunal characteristics just below the *Stilostomella* extinction event level. A relationship between the stratigraphic behavior of both species and the extinction event is suggested for this region. In the Chile Basin, north of the region at depths greater than 4,000 meters, only a poor agglutinated benthic foraminiferal fauna is present in a top core sample (E3-7). It is characterized by *Psammosphaera* sp. and *Glomospira gordialis*, with low percentages of *Adercotryma glomeratum*, *Ammobaculites filiformis*, *Reophax* sp., *Pelosina* sp. and *Karrierella* sp. The CCD in this region is at 4,000 meters. In the south, on the Chilean continental slope at depths of about 1,200 meters (E5-4 core), the faunal in lower Pleistocene sediments is dominated by *Cassidulina reniforme* and *Trifarina angulosa*, with *C. subglobosa* and *Uvigerina hollicki* occurring as accompanying species. *Cassidulina reniforme* is a typical glaciomarine species. The latitude of site E5-4 (48°S) coincides with the region where the Patagonian Ice Sheet extended to the Chilean shelf-break during the Pleistocene. Benthic foraminiferal faunas from the Southeast Pacific present several features that add new insight to environmental controls on foraminiferal species distributions.
Deep-sea benthic foraminifera faunas and stable isotopes from the Portugal margin

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The ecology (faunal density, composition, microhabitats) of benthic foraminifera from three deep stations (1,000 m, 2,000 m and 3,000 m) off the Portugal margin (Northwest Atlantic, 37-38°N) has been studied. Six cores were picked for each station. In order to improve the understanding of factors controlling the spatial distribution of the faunas, the chemistry of the sediment (O2, NO3, …), as well as stable isotopes (δ18O, δ13C) have been analysed for species of four key genera that have different microhabitats (Cibicidoides/Fontbotia, Uvigerina, Melonis, and Globobulimina).

Faunal densities decrease with increasing water depth, following the diminishing organic matter flux that reaches the sea floor at greater depths. However, one core at station FP9 (3,000 m) exhibits a surprisingly high density due to the presence of a worm burrow, with the appearance of opportunistic species such as Pullenia bulloides, Fursenkoina sp., and Pyrgo elongata. In each station the deep infaunal Globobulimina affinis shows a maximum of abundance at the “oxygen zero” depth, which is in agreement with previous studies.

Interspecific differences in stable isotopic composition are related to the different microhabitats, with the deep infaunal species (Globobulimina affinis) having lighter values than shallow infaunal species (Uvigerina mediterranea). The Uvigerina species, however, show a wide scatter in δ18O as well as δ13C. This may be a function of the size of the specimen measured, but further analyses are needed to confirm this trend.
Paralic foraminiferal record of seven large Holocene earthquakes in eastern New Zealand

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Most previous studies using foraminifera to help identify and quantify Holocene earthquake displacements in tectonically-active coastal areas have focussed on the record in high tidal marsh environments. In this study we show that it is sometimes also possible to utilise low-tidal and shallow-subtidal faunas to identify large vertical displacement events.

Foraminiferal assemblages in eleven cores (3-7.5 m deep) of Holocene sediment from brackish Ahuriri Inlet in Hawke’s Bay, eastern New Zealand, provide a record of 8.5 m of subsidence followed by 1.5 m of uplift in the last 7500 cal years. Modern Analogue Technique was used to estimate paleotidal elevation (subtidal to extreme high water spring level) of the 97 richest foraminiferal assemblages in the cores. The modern dataset comprised census counts on 272 faunas from New Zealand sheltered harbour and estuarine environments. The most precise elevational estimates are for marginal high tidal salt marsh assemblages and the least precise are from low tidal and subtidal assemblages from near the centre of the inlet. These paleoelevation estimates combined with sediment thicknesses, age determinations (from tephrostratigraphy and radiocarbon dates), the New Zealand Holocene sea level curve, and estimates of compaction, identify the Holocene land elevation changes and earthquake-displacement events in each core.

Because of the lower precision of elevational estimation in subtidal, low-tidal and terrestrial environments, no single core contains a precise record of all the large displacement events. By combining the records from all cores, however, we recognise the following major, earthquake-related displacements:

~7200 cal yrs BP (>-0.6 m displacement); ~5800 cal yrs BP; ~4200 cal yrs BP
FORAMS 2006
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(≈ - 1.5 m); ≈3000cal yrs BP (≈-1.6 m); ≈1600cal yrs BP (≈ -1.7 m); ≈600cal yrs BP (≈-1 m); 1931 AD Napier Earthquake (≈+1.5 m). The six, large (possibly subduction interface) subsidence events in the last 7200 years have had a return time of 1000-1400 years. In addition to recognising subsidence events, the foraminiferal record also documents 1.5 m of uplift during the devastating 1931 Napier Earthquake, which was caused by near-surface slip on a local thrust fault.
Quantifying Holocene sea-level change using intertidal foraminifera: Lessons from the British Isles

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Salt-marsh foraminifera have been used to reconstruct Holocene sea-level changes from coastlines around the world. In this work, we compile the results of surface foraminiferal surveys from fifteen study sites located on the east, south and west coasts of Great Britain, and the west coast of Ireland. These data, which comprise 236 samples and 84 species, are used to summarize the contemporary distributions of intertidal foraminifera around the British Isles, and to examine the environmental controls governing them.

Seasonal and sub-surface foraminiferal data suggest that foraminiferal dead assemblages provide the most appropriate dataset for studying patterns of foraminiferal distributions in the context of sea-level reconstruction. In contrast to live populations or total assemblages, the dead assemblages are less affected by seasonal fluctuations and post-depositional modifications. Sub-surface foraminiferal data also indicate that foraminifera at the study sites live primarily in epifaunal habitats. Consequently, foraminiferal samples comprising the upper centimeter of sediment are appropriate analogues for the study of past sea-level change employing fossil assemblages contained within intertidal deposits.

Surface dead assemblages from the fifteen study sites indicate a vertical zonation of foraminifera within British and Irish salt-marshes that is similar to those in other mid-latitude, cool temperate intertidal environments. Whilst the composition and vertical ranges of assemblage zones vary between sites, two general sub-divisions can be made: an agglutinated assemblage restricted to the vegetated marsh; and a high diversity calcareous assemblage that occupies the mudflats and sandflats of the intertidal zone. Three of the fifteen study sites permit further subdivision of the agglutinated assemblage into a high and middle marsh zone (Ia) dominated by *Jadammina macrescens* with differing abundances of *Trochammina inflata* and *Miliammina fusca*, and a low marsh
zone (Ib) dominated by *M. fusca*. The calcareous assemblage is commonly comprised of *Ammonia* spp., *Elphidium williamsoni* and *Haynesina germanica*, in association with a wide range of minor taxa.

The vertical zonations of the study areas suggest that the distribution of foraminifera in the intertidal zone is usually a direct function of elevation relative to the tidal frame, with the duration and frequency of intertidal exposure as the most important controlling factors. This relationship is supported by canonical correspondence analyses of the foraminiferal data and a series of environmental variables (elevation, pH, salinity, substrate and vegetation cover).

These modern foraminiferal data are used to develop predictive transfer functions capable of inferring the past elevation of a sediment sample relative to the tidal frame from its fossil foraminiferal content. The results indicate that transfer functions perform most reliably when they are based on modern data collected from a wide range of intertidal environments. The careful combination of foraminiferal estimates of paleomarsh-surface elevation with detailed lithostratigraphy and chronostratigraphy can produce high-resolution records of relative sea-level change with sufficient resolution to detect low-magnitude variability but long enough duration to reliably establish climate-ocean relationships and secular trends. Thus, the transfer function approach has the potential to link short-term instrumental and satellite records with established longer-term geologically based reconstructions of relative sea level.
During the last decades, the very oligotrophic shallow water environment of the SE Levantine basin has been subjected to both natural as well as man-made eutrophication influences covering the full range of trophic levels. Living benthic foraminifera are known to respond to environmental factors, and are abundant and diverse in the Israeli shallow shelf. The present study aims to record the response of this group to changes in seasonality and trophic levels in the inner shelf, using them as sensitive tracers of the natural and perturbed conditions. For this purpose, 3 permanent stations along the Israeli coast varying between oligotrophic and hyper-eutrophic conditions are sampled bimonthly by the R/V Shiqmona, including water column and sediment parameters. Total standing stocks (TSS), simple diversity and in-sediment distribution depth of living benthic foraminifera vary remarkably along the inner shelf, tracking the trajectory of eutrophication. While the oligotrophic environments show high seasonality, TSS and biodiversity, the anthropogenically eutrophic environments show small seasonal variations and low to moderate TSS and simple diversity values.
Relationship of benthic foraminiferal diversity to paleoproductivity in the Neogene of the Caribbean deep-sea

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Diversity trends in late Miocene to Pliocene, Caribbean deep-sea benthic foraminifera >63 μm, as interpreted from the indices Fisher’s α, Shannon-Weiner index, S and N, generally parallel paleoproductivity proxies (benthic foraminiferal infaunal/epifaunal species ratio, benthic foraminiferal accumulation rates, flux of organic matter to the seafloor and benthic δ13C). Paleoproductivity never reached a eutrophic threshold value above which we would predict opposite trends of high paleoproductivity and low diversity. Instead, results are similar to those from other oligotrophic settings in that a positive and statistically significant Pearson’s Product Moment Correlation (r) is noted between paleoproductivity proxies and diversity. Increased relative abundances of *Epistominella exigua*, a proxy for seasonal phytodetrital flux to the seafloor coincides with increased diversity suggesting that pulsed paleoproductivity enhanced diversity or at least did not cause it to decrease. Additionally, even during the Late Miocene Carbon Isotope Shift (7.6-6.7 Ma, an interval of enhanced paleoproductivity experienced globally, including the Caribbean), Caribbean diversity increased while the more eutrophic setting of the Pacific displayed decreased benthic foraminiferal diversity. Thus, it appears that below eutrophic levels, diversity is positively correlated with diversity.

This pattern of Caribbean diversity and paleoproductivity was compared to the timing of the late Miocene – early Pliocene constriction and closure of the Central American Seaway, which separated Caribbean and tropical Pacific waters completely by about 4.2 Ma. Diversity and paleoproductivity in the Caribbean was high until about 7.9 Ma and sharply declined 7.9-7.6 Ma. Thereafter, until 4.2 Ma, both diversity and paleoproductivity generally increased until after 4.2 Ma, when they gradually decreased. A comparison between the deep-sea Pacific (DSDP Site 503) and Caribbean (ODP Site 999) for the interval 8.25–2.5 Ma reveals greater fluctuations in the Caribbean benthic diversity as compared to the Pacific, especially after 4.2 Ma, probably reflecting the greater effect of seaway closure on the Caribbean. Thus, it appears that constriction of the Central American Seaway generally increased both paleoproductivity and benthic foraminiferal diversity, and complete seaway closure caused their decline.
Spatial and temporal distribution of benthic foraminiferal faunas in the Bay Biscay

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This presentation gives an inventory of 10 years of research on the ecology of benthic foraminifera in the Bay of Biscay. The density, composition and microhabitats of living faunas collected at more than 25 stations from outer shelf, continental slope and abyssal environments, will be explained by the quantity, quality and periodicity of the organic flux to the ocean floor. Faunas collected in submarine canyons substantially differ from open slope faunas, mainly due to the focussing of refractory organic particles in these environments. A large part of this low quality organic matter will be degraded by anaerobic pathways at several depth in the sediment. Some deep infaunal taxa play an important role in these slow remineralisation processes. A more detailed study shows also important differences between the various canyon sub-environments, where sediment instability seems to be a dominant controlling parameter. Canyon axis environments, that are repeatedly disturbed by abrupt sediment depositional events, are inhabited by extremely rich, but low diverse faunas, that are restricted to the sediment surface. Stations that are more sheltered from such abrupt depositional events, are characterised by much poorer, but more diverse fauna, with a well established microhabitat succession. An 8 year long temporal survey of stations at 140, 550 and 1000 m water depth shows that the benthic foraminiferal faunas respond to the spring phytoplankton bloom by a period of accelerated growth and reproduction. *Epistominella exigua*, *Nonionella iridea*, *Uvigerina mediterranea* and *Uvigerina peregrina* show the strongest response to these events, underlining their opportunistic life strategy. Although mesoscale patchiness (decimetres to decametres) is sometimes important, it does not prevent us to observe temporal variability, which in most cases has a much higher amplitude.
Taphonomy of benthic foraminiferal tests from the Jurujuba Sound, Guanabara Bay, Rio de Janeiro, Brazil

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Besides the potential for post-mortem transport, foraminiferal tests deposited in shallow water conditions are also potentially subject to abrasion, fragmentation, bioerosion and dissolution/corrosion. The extent in which these processes act on the foraminiferal tests will depend on some intrinsical factors, such as, composition, microstructure, architectures, ornamentation, shell thickness, and test porosity. Microhabitat, substrate and water biogeochemical conditions, and exposure time to the taphonomic processes mentioned above play a role in the preservation of foraminiferal tests. In other words, the destruction of foraminiferal tests depends on the interplay of extrinsical and intrinsical factors. The resulting taphocoenoses may be a modified and biased portrait of a given living assemblage in terms of taxonomical and ecological composition. In the tropical shallow water, marine environments dissolution/corrosion of the calcareous tests is one of the main processes acting in the destruction of benthic foraminiferal tests. In this study, we present a taphonomic analysis of benthic foraminiferal tests found in one 1.88 m-thick, sandy core of the Jurujuba Sound (22°48’37”S, 43°08’25”W), Guanabara Bay (Rio de Janeiro State). This area was chosen taking into account the impact by urban sewage discharges. Foraminiferal faunas, their taphonomy and associated geochemical analysis may all be combined to reveal the extent of these anthropogenic impacts on the study area. Analyses include sediment grain size, heavy metals, taxonomic composition and the study of the taphonomic signatures (e.g., abrasion, fragmentation, dissolution/corrosion) of individual foraminiferal tests. Special attention was given to the tests found in the upper 50 cm of the sediment core,
which correspond to the taphonomically active zone (TAZ). The foraminiferal fauna is dominated by calcareous species (*Ammonia tepida*, *Elphidium* spp. *Quinqueloculina seminulum*). Results suggest that the microfaunal composition, abundance and density in the studied superficial sediment layers is related to acid (pH <7) pore water conditions, with associated high concentrations of Zn. Not surprisingly the foraminiferal tests are typically corroded or broken. Consequently, the preserved microfaunas in the analyzed core are biased in relation to the original living benthic assemblage. Finally, the composition and density of the foraminiferal tests will not necessarily mirror the natural conditions of a given area, but rather may be influenced by the sediment geochemistry and the taphonomic processes operating in the study area. These observations have obvious implications for the paleoecologic analysis.
Relating microfossil distribution patterns to deep-water depositional processes: A new biofacies model based on Oligocene-Miocene deposits

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Micropaleontologic studies of wells from the Atlantic Basin reveal large-scale variations in microfossil abundance patterns in deep-water mudstones that cannot be adequately explained using traditional paleoenvironmental models (e.g., water depth). Integration of foraminiferal, calcareous nannofossil and palynologic data with e–log and seismic control suggests a relationship between the presence or absence of deep-water slope channel systems and the distribution of these microfossil groups. Depositional processes related to the slope channel systems appear to create different paleoecologic conditions that govern the distribution of major microfossil groups. Recent research on slope channel hydrocarbon reservoirs provides an opportunity to evaluate microfossil distribution patterns relative to deep-water depositional environments.

A new biofacies model is developed that recognizes the important links between paleoecology, sedimentary processes, and Environment of Deposition (EOD). Analyses of ditch cutting samples from wells in the bathyal (slope) environment have identified the following microfossil groups to be significant: planktonic, calcareous benthic and agglutinated benthic foraminifera; calcareous nannofossils; algae, spores, pollen, and kerogen (organic matter types). Five biofacies types are defined in non-reservoir facies based on abundances of these indicator groups. Three biofacies types are defined from intra-reservoir mudrocks. Based on this study the most important environmental factors determining microfossil distribution are:

1) sedimentation rate;
2) sediment source (terrestrial versus open marine); and
3) availability of oxygen on the sea-floor and within the sediment.

This biofacies model has been applied successfully in several deep-water basins and is a potentially useful tool in hydrocarbon systems analysis of risks related to the presence and quality of source, seal and reservoir.
Recent benthic foraminiferal assemblages in the nearshore inner shelf in and around Alang shipbreaking yard, Gulf of Khambat, India

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Coastal, estuarine and other marginal marine environments are recipients for various kinds of anthropogenic wastes, resulting in severe negative impacts on the resident biota. Due to their abundance and better preservative potential, foraminifera serve as one of the most sensitive and inexpensive tracers in evaluating environmental stresses in the marginal marine environment.

Recent benthic foraminiferal studies were carried out during winter (December) and the pre-monsoon time (April) for 15 stations along 5 transects in and around the Alang shipbreaking yard, the largest of its kind in the world. Two control transects (TI and TV), one each at the northern and southern ends of Alang, as well as three other transects (TII, TIII and TIV) were selected within the core zone to study benthic foraminiferal assemblages from the intertidal to areas 5km offshore. The shipbreaking activities induced considerable ecological inhospitability due to pollution from heavy metals, oil and tar. Additionally, high tides and large suspended solids were also found to be unfavourable for the benthic foraminifera.

A total of 49 species of Recent benthic foraminifera belonging to 25 genera, 13 families and 3 suborders were identified. Poor faunal density and diversity, poor health, absence of agglutinated forams, and formation of a ‘foram dead zone’ depicted the magnitude of environmental perturbation from the study sites. Of the five transects, the TII transect emerged as the most ecologically hostile, whereas the TI (control) transect was the most healthy.

Ammonia beccarii, Bolivina striatula, Elphidium simplex, Florilus schapha, Nonionellina turgida, Quinqueloculina seminulum and Triloculina brevibentata were the most abundant species. Ammonia beccarii and Nonionellina turgida appeared to be the opportunistic species of this stressed marginal marine environment, managing to withstand the ecological crisis with a reasonable amount of success.
Distribution and ecology of benthic foraminifera in the vicinity of Guadiana River (northern Gulf of Cadiz)

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A comprehensive knowledge of the ecology and the distribution of modern foraminifera is essential for ecological and environmental interpretations of modern and ancient environments. The aim of this work is to investigate the distribution and the ecology of living (stained) benthic foraminifera (>63μm), revealing the environmental conditions, based on a set of samples collected in February 2001 on the Guadiana shelf, between 12 and 90 m water depth.

The study area is located in the Northern Gulf of Cadiz, in the vicinity of the Guadiana estuary mouth. The region is characterised by waves of low to medium energy, with the prevailing onshore wave conditions inducing a net annual drift from W to E. Oceanographically, it is influenced by North Atlantic Surface Water, a strong southeasterly inflow over the continental shelf, which occurs in the upper 300 m of the water column. Morphologically, this shelf is complex and influences the sediment distribution, with a succession of terraces between 30 and 50 m delimiting a sandy inner shelf from a muddy middle shelf.

The stained benthic foraminifera fauna from the Guadiana continental shelf (abundance > 5%) is diverse and occupies a variety of niches. Bolivina ordinaria is the most abundant species with values of 50%, occurring at different depths with no relation to sediment type. Cribrononion gerthi and Eggerelloides scaber showed higher abundances (7.25 and 8.5%, respectively) at water depths around 20m, associated with a mixture of coarse sediments and mud. Spiroxostoma croarae showed the same behaviour; however, the highest abundance of 20% was observed at 36m water depth. Bolivina dilatata, Brizalina spathulata, Nonionella iridea and Nonionella stella were most commonly found above 45m water depth, associated with mud and sandy mud. Around 40m water depth, Rectuvigerina phlegeri and Saccammina atlantica showed the higher abundances to the east of the Guadiana River mouth, associated with sandy mud sediments. In general, the number of benthic foraminifera per 10cm³ increased seaward and had the lowest values near the Guadiana River mouth.
The observed living benthic foraminiferal faunas are similar to total assemblages described by other studies in the same and adjacent areas (Mendes et al., 2004. *Mar. Micro.*, 51: 171-192), although the abundance and distribution of the same species are different. The higher percentages of *B. ordinaria* and *N. iridea* compared with total assemblages described by Mendes et al. (2004) could be related to the different dates of sample collection, suggesting that the variation in abundance of these species could be related to reproductive periods. The biocenoses of *C. gerthi* and *E. scaber* had similar distributions to total assemblages, indicating that they live in this area and are not affected by transport. Species such as *Planorbulina mediterranensis*, described by Mendes et al. (2004) in shallow areas, showed lower abundances (<3%) in the present study, indicating that only some species are affected by tidal or wave-induced currents, depending on weight and form. The observed east-west asymmetry in the distribution of *R. phlegeri* could be related to the sediment type and also the high values of organic matter observed in connection with this species by Villanueva & Cervera (1999. *Bol. Inst. Esp. Oceanogr.*, 15(1-4): 191-202) in the northeastern Gulf of Cadiz.

The continuation of this work is essential to understand why and in which way the surficial distribution of living benthic foraminifera reflects the environmental conditions of this area.

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Latitudinal and sediment depth gradients in foraminiferal assemblage of the southeast Atlantic

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During Meteor cruise 63/2 to the Southeast Atlantic in March 2005, sixty-one sediment cores were sampled to study foraminifera. Repeated multicorer hauls between S 30° and the equator yielded samples for the reconstruction of oceanic parameters by use of planktic and benthic foraminifera and crucial sediment parameters. As samples were taken in horizontal slices (0–5 cm: 0.5 cm steps; 5–15 cm: 1 cm steps; 15–35 cm: 5cm steps) changes in sedimentation and productivity can be reconstructed. Assuming expected sedimentation rates below 3cm/1.ka (Ruddiman, 2001. *Earth’s climate*; W.H. Freeman & Co., New York; Pierre et al., 2001. *Proc. ODP, Sci. Results* 175: 1-22), the time spanned may be at least 10 kyr. All sample sites are between 5,000 and 5,600 m water depth. Nevertheless, calcareous foraminiferal tests are a frequent component of grain fractions >125 μm. This indicates that the calcite compensation depth (CCD) lies deeper than 5,600 m in the studied areas of the Southeast Atlantic. This assumption is supported by the fact that even fractured, aragonitic pteropod shells were found in some surface sediment samples. Sample sites were chosen along a north-south transect to document interactions between faunal alteration and sedimentary and oceanic parameters. The investigated samples show clear differences in sedimentation and faunal composition for the three investigated deep-sea basins.

Sedimentation: Whereas samples from the Guinea Basin show constant sedimentation dominated by carbonate secreting organisms (mainly foraminifera and Coccolithophorida), Angola and Cape Basin samples show a different situation. In northern Angola as well as in northern Cape Basin, surface samples are composed of mainly biogenic opal in the sand fraction and various contents of terrigenous material in the sand, silt and clay fractions. At sediment depths of 7-8 cm in the Cape Basin and 10-11 cm in the Angola Basin, a complete change in sediment composition is obvious with a nearly equal silicate/carbonate ratio. At a sediment depth of 14 cm in the Angola Basin, sediments are similar to those of the Guinea Basin, with a high calcareous biogenic proportion. The change in sediment composition is also manifested in different sediment colours, varying from brownish-black in surface sediments to dark yellowish brown at
20 cm sediment depth. A similar situation is observed in the sediment record of the northern Cape Basin at S 30°. A change from siliceous to carbonate sedimentation with increasing sediment depth is visible. Various proportions of terrigenous material of all grain size fractions are obvious. In general, an increase in the content of clastic sedimentation with increasing latitude was observed.

Foraminifera: For a first, semiquantitative analysis, one core from each investigated abyssal basin was processed. Compared to the Guinea and Angola basins, a loss of warm-water species in the planktic foraminiferal assemblages in favour of transitional species was observed in the northern Cape Basin. At a sediment depth of 15 cm in the Cape Basin, mainly *Globorotalia scitula*, *Globorotalia inflata* and *Globorotalia truncatulinoides*, and ancillary *Orbulina universa* and *Globigerinella siphonifera*, dominate in the sediment fraction > 250 μm. In Angola Basin sediments, *Globorotalia scitula* as well as *Globorotalia truncatulinoides* and *Globigerinella siphonifera* are absent, whereas *Globorotalia tumida*, *Globorotalia cultrata*, *Sphaeroidinella dehiscens*, *Neogloboquadrina dutertrei* and *Globorotalia crassaformis* appear. A minor change in planktic foraminifera assemblages is obvious between the northern Angola and the Guinea basins. All species occurring in the Angola Basin are present in the Guinea Basin except *Globorotalia inflata*. *Pulleniatina obliquiloculata* and *Globigerinoides ruber*, and ancillary *Globigerinoides sacculifer*, appear in the Guinea Basin but neither in the Angola nor in the Cape Basin.
Coral reefs are among the most ecologically diverse ecosystems on Earth, where the occurrence of symbiotic relationships allows recycling and efficient use of limited nutrient resources. Current problems related to coral reefs include physical, chemical and biological damage caused by anthropogenic influences or natural impacts, in addition to temperature oscillations. The present work is part of PROBIO, a major program sponsored by the Brazilian Environmental Ministry. PROBIO has an objective of identifying along the Brazilian coastline possible bioindicators of climatic changes, and subsequently applying them as powerful tools for monitoring programs and coastal management. This paper is one of the results of the FOCO Project (sponsored by PROBIO), in which we present the application of the FORAM INDEX (FI) mapping impact fronts using GIS at a 1:25,000 scale. The FI is applied to four different Brazilian coral reef systems, APA Costa dos Corais (PE) and Porto Seguro (BA) coastal areas, as well as in offshore reefs from Fernando de Noronha (PE) and Abrolhos Bank (BA), in order to verify and compare health conditions. A total of 72 reef sediment samples were collected and 18 geochemical analyses conducted for each area in January 2005 and July 2005, to account for summer and winter seasonal variability. Samples were collected using scuba equipment, and parameters measured on-site included visibility, water temperature, salinity and dissolved oxygen, both at the surface and at depth, while sampled sediments were analyzed for carbonate, phosphorus, and organic matter, as well as
mineralogy and grain size. At the laboratory, foraminifera were identified under a stereomicroscope to the specific level. After that, foraminifera genera were separated into functional groups and submitted to the index, with values ranging from 2.0 to 9.07, as in the Abrolhos Bank reefs. The environmental protection area at APA Costa dos Corais had the worst FI values (2.26-6.70) in comparison to the other areas. This may be explained by tourism pressures, a fishery and loss of biodiversity, which contributes physically to damaging the coral colonies, and by the historical culture of sugar cane plantations that supply an excess of nutrients and organic matter to rivers which reach this site. The results suggest that foraminifera can be used not only as a low cost bioindicator to evaluate the health of Brazilian reefs but also as a powerful tool for coastal management.
Bioevents correlation of planktic foraminifers and radiolarians from the Cenomanian to Turonian, southeastern Mexico

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The correlation of extinction and diversification events of planktic foraminifers and radiolarians from the Cenomanian to the Turonian, in wells and outcrops of Southeastern Mexico, is related to the global Cenomanian-Turonian Oceanic Anoxic Event (OAE2). Patterns of diversification and extinction events of planktic foraminifers (Rotalipora, Whiteinella, Hedbergella and Heterohelix) and radiolarians were analyzed and correlated in wells of the Sonda de Campeche and outcrops of Southeastern Mexico. These events were identified within the Rotalipora brotzeni, Rotalipora cushmani, Whiteinella archaeocretacea and Helvetoglobotruncana helvetica zones from the Cenomanian to the Turonian. Based on the abundance patterns and the interpretation of gamma ray logs, maximum flooding surfaces and condensed sections were interpreted. The transgressive sequence from the Albian to the Turonian interpreted for this time caused changes in the sedimentation and the paleoecology of the area and consequently, the diversification and gradual and/or total extinction of planktic foraminifers and other microfossils.

During the upper Cenomanian, within the Rotalipora cushmani Zone in the Rotalipora greenhornensis Subzone, several abundance peaks of radiolarians and heterohelicids and hedbergelids were identified. These abundance peaks occurred during deposition of bituminous and argillaceous limestones containing pyrite and organic matter, possibly in low-oxygen conditions. The abundance peaks of radiolarians and heterohelicids are intercalated with abundance peaks of rotaliporids and praeglobotruncanids in more calcareous limestones. These changes are interpreted as a consequence of sea level changes.

In the upper part of the Rotalipora greenhornensis Subzone, an abundance peak of radiolarians with Heterohelix moremani and H. reussi represents a flooding surface and maybe a sequence boundary. In the uppermost Cenomanian within the Rotalipora cushmanni Zone, in the lower part of the
Dicarinella algeriana Subzone, there is a diversification event of Rotalipora cushmani, which then became extinct at the end of the Subzone. The extinction of R. cushmani is considered to be a global event that preceded the global Cenomanian-Turonian Oceanic Anoxic Event (OAE2). The OAE2 is represented in southeastern Mexico by diversification and abundance events of silicified and calcified radiolarians deposited in black shales with a high organic matter content, pyrite and lenses of chert, deposited in low-oxygen conditions and belonging to the Whiteinella archaocretacea Zone.

The Cenomanian-Turonian event in this area was interpreted as a maximum flooding surface that represents a condensed sequence, characterized by an abundance peak of silicified radiolarians and fragments of fishes, as well as Whiteinella. For the lower-middle Turonian within the Helvetoglobotruncana helvetica Zone, more stable oxygen conditions are evident by the diversification of marginotruncanids and the presence of more calcareous limestones containing Helvetoglobotruncana, Marginotruncan and Dicarinella.
Bipolar distribution of deep-sea benthic foraminifera

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Biodiversity in deep-sea sediments is extraordinarily rich at a local scale. It is disputable, however, to what extent the high local species richness of abyssal faunas can be extrapolated to larger spatial scales. The accurate assessment of regional and global deep-sea diversity is impeded by a lack of data on dispersal ranges of species at the ocean floor, particularly at the genetic level. To test the capability for long-distance dispersal of deep-sea foraminiferal species, we examined the genetic diversity of Arctic and Antarctic populations of three common, deep-sea rotaliids, *Epistominella exigua*, *Cibicides wuellerstorfi* and *Oridorsalis umbonatus*, collected during recent R/V Polarstern cruises, including the ANDEEP III campaign in the Southern Ocean. Our analyses revealed no significant genetic differences between polar populations of the examined morphospecies, even in an extremely variable ITS region of the ribosomal DNA. This result provides strong evidence that a high gene flow occurs between populations of deep-sea species separated by long distances. The genetic homogeneity of Arctic and Antarctic deep-sea foraminifera suggests that deep-sea biodiversity may be more modest at regional and global scales than present estimates suggest.
Surface distribution of foraminifera from the Morbihan’s Gulf, France: Study for paleoenvironmental reconstructions

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The Morbihan’s Gulf is a complex, shallow ria system on the NW coast of France, which was flooded by the sea and partially infilled over the last few millennia. The recent history of the coastal depositional environments has never been done in this Gulf. There is a need for calibrating fossil foraminiferal assemblages with local present ones and their relationship with present sedimentary environments before reconstructing paleoenvironmental conditions in a complex paralic environment.

The eastern part of the Morbihan’s Gulf is characterized by the presence of numerous channels under the influence of tidal and freshwater inputs. These channels are bordered by sheltered mud flats or exposed mud flats, according to the coastal morphology. Also, Zostera marina occupies some inner sheltered mud flat zones. Two hundred surface sediment samples were collected from February 2002 to July 2004, at water depths ranging from 1 m (subtidal zone) to 15 m (channel), with a mean distance of 500 m between each sample.

A total of 63 species were identified and only 49 showed living specimens. Five species are dominant and 15 are common. The distributions of living and total assemblages (for every dominant and common species) do not differ significantly. This low difference allows the use of foraminifera in paleoenvironmental reconstructions. A high percentage of hyaline species represents the general distribution with a great dominance of the genera Ammonia and Elphidium. Specific distinction between A. tepida and A. beccarii shows an environmental significance. Ammonia tepida is present in all samples, but it is largely dominant in restricted areas (sheltered mud flat) with fine paralic sediments. Ammonia beccarii occurs in tidal channels with coarser and more heterogeneous sediments. The genus Elphidium is also well represented in almost all samples with E. excavatum, which occurs in channels under the influence of both tidal and freshwater inputs. A Zostera marina seagrass bed is characterized by the living occurrences of Eggerelloides scabrus.
In the case of channels under the influence of freshwater inputs, the dominant species is *Haynesina germanica*. Thus, this detailed study of the present distribution of major benthic foraminifera in the Morbihan’s Gulf will allow paleoenvironmental reconstructions according to the characteristics of the coastal depositional environments.
Dissolution control on planktonic foraminiferal micro-scale distributions: Two case studies from the NW Pacific Paleocene deposits

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Various oceanographic parameters have been shown to be important in determining the composition of planktonic foraminiferal assemblages, including temperature, thermocline structure, surface stratification, seasonality and upwelling. Carbonate dissolution processes are of primary importance in deep waters as they influence the presence or absence of foraminifera and the preferential dissolution of certain species. With the aim to understand how the patterns of distributions of Paleocene planktonic foraminifera are influenced by dissolution, a detailed study was performed on deposits from the Shatsky Rise (Northwest Pacific) recovered during Ocean Drilling Program Leg 198. A pulse of intense carbonate dissolution caused by an abrupt shoaling in the depth of the lysocline and calcite compensation depth (CCD) is observed during the early late Paleocene and at the Paleocene/Eocene boundary.

The early late Paleocene sedimentological record is marked by a prominent 5- to 25 cm-thick dark brown clay-rich calcareous nannofossil layer, which falls in the lower part of planktonic foraminifera Zone P4. The dissolution at the Paleocene/Eocene boundary affects a 3-to 4 cm-thick interval of yellowish calcareous ooze and an overlying 3-to 5cm-thick brown clayey calcareous ooze, and is associated to the negative carbon isotope excursion (CIE) that identifies the Paleocene/Eocene Thermal Maximum event (PETM).

A high-resolution centimeter-scale quantitative analysis of the planktonic foraminiferal assemblages was performed in these two time-intervals in order to:

1) evaluate the susceptibility to dissolution of the species within genera at different water depths;
2) compare the dissolution effects on the same taxa at different time-intervals; and
3) figure out significant changes in faunal composition, even though the original faunal composition was altered by dissolution.

Results show that low-latitude tropical and subtropical planktonic foraminiferal species vary in their susceptibility to dissolution. In general, when the dissolution rate of carbonate exceeded the rate of supply of calcium
carbonate, an increase in foraminiferal dissolution and fragmentation is observed. Planktonic foraminifera from the early late Paleocene interval are characterized by a low-diversity, largely dissolved assemblage dominated by representatives of the genus *Igorina*. The abundance of igorinids is emphasized by the rarity and/or absence of the other genera and by the low number of total specimens (often <300 specimens) in the residues that contain common to abundant test fragments of morozovellids. Among the igorinids, *I. tadjikistanensis*, and *I. pusilla*, are the most dissolution-resistant taxa and are the only species recorded in the dissolution interval. Conversely, *Igorina albeari*, morozovellids, acarininids, globanomalins, subbotinids, and chilouembelinids are interpreted as more dissolution-susceptible taxa.

The 3-to 8 cm-thick dissolution interval at the Paleocene/Eocene boundary is characterized by a high diversity planktonic foraminiferal assemblage dominated by specimens of the genera *Morozovella*, and *Acarinina*, whereas a marked decrease in abundance is observed in the subbotinids group. Dissolution results in breakage of *Morozovella* tests and poor preservation of certain species of morozovellids, acarininids and subbotinids. It also highlights significant variations in dissolution susceptibility of various species without overprinting the major changes in faunal composition and test sizes observed across the Paleocene/Eocene boundary.
The present work analyses the influence of hydrodynamic conditions on the proportion of foraminifera in the sediment of two coastal reefs from the northern Bahia State, northeastern Brazil. The Itacimirim reef is 1,114 m long and 471 m wide, while the Praia do Forte beach reef is 686 m long and 128 m wide. Both of them occur in the fore reef zone in waters less than 10 m deep, while the back reef zone is inclined towards the siliciclastic sand beach, so it is surrounded by sand. The reef tops stay exposed during the low tide, which reveals great colonies of coral truncated by erosion, and between them, little pools and a channel inhabited by living corals and algae. The collecting was carried out in the winter (May and July) and summer (November and December) periods of 1999. Fourteen samples were collected along a delimited transect across the length of the reefs. The surficial sediment samples were taken from the top and the bottom of the recifal pools. At the laboratory, the samples were washed under a stream of water, dried, weighed and submitted to the pattern technique of grain size analysis. The first 300 grains of the fraction over 0.062 mm in size were identified as one of the following groups: Halimeda, red algae, bryozoans, corals, crustaceans, echinoderms, sponges, foraminifera, molluscs, polychaetes and quartz. The quartz grains were predominant, varying in the winter vs. summer period, with 58.23% and 70.36%, respectively, from the Praia do Forte beach, and 44.90% to 45.39% in Itacimirim. Concerning carbonate grains, only red algae and molluscs in the winter and red algae in the summer had average percentages over 5% on the Praia do Forte beach. In Itacimirim, of the red algae, molluscs, and Halimeda in the winter, only the two first groups in the summer had percentages over this value. The foraminifera showed average percentages of 2.56% and 1.88% on the Praia do Forte beach and 2.48% and 3.31% in Itacimirim; the lowest percentages (Praia do Forte beach) and highest percentages (Itacimirim) of these organisms were both obtained in the summer period. Considering grain size, the percentages of carbonate grains decrease.
when the grain size of the sediment decreases, so carbonate grains predominate in the gravel and coarse sand fractions on the Praia do Forte beach reef, and the gravel and coarse to medium sand fractions in Itacimirim. The foraminifera are the most abundant of all groups, in the gravel fraction (4.5% in the winter and 3.0% in the summer) on the Praia do Forte beach and the medium sand fraction (3.8% and 4.9%) in Itacimirim. The analysis of the foraminiferal fauna established that specimens develop preferentially around 30 m water depth and are transported with the sediment. In the studied reefs, sediment grain size has a great influence on the coastal drifts from waves of the southeast in the winter and of the east in the summer, but the coastal drift has a northeast-southeast direction. Therefore, the action of seaside drift is responsible for the seasonal variation of the foraminifera in the sediments, but they are the most abundant organism in the coarser fraction due to the low incidence of siliciclastic grains in this fraction.
Regional and landscape patterns of diversity, distribution and abundance are described for epiphytic foraminiferal biotas living on blades of the seagrass *Thalassia testudinum* collected from Jupiter Sound, Indian River Lagoon, Florida; the central region of the Mesoamerican Barrier Reef Complex, Belize; and the Bocas del Toro Archipelago, Panama. The total species richness recorded-to-date in Jupiter Sound is $S=23$, the total species richness recorded-to-date in Belize is $S=41$; and the total species richness recorded in the Bocas del Toro region is $S=25$. The total richness of the combined data sets is 55 species, 12 of which were broadly distributed and found at all three sites. Seven species occurred only in Jupiter Sound; 21 species occurred only in Belize; and 6 species occurred only in the Bocas del Toro region. The Jupiter Sound site and the Belize sites shared three species in common, compared to 21 species shared between Belize and Bocas del Toro, Panama. These latter two more tropical sites were more closely linked in cluster and non-metric multidimensional scaling analyses.

Values of Shannon’s $H$ ranged from 0.25-2.4, with the highest values calculated for mangrove sites in Belize. The lowest values of Shannon’s $H$ were recorded at disturbed sites in: Florida (post-hurricane recovery), Belize (heavy grazing & eutrophication), and Panama (heavy grazing, turbulence & low salinity). Values of evenness ranged from 0.11-0.68, with the highest values occurring at Cat Cay, Pelican Cays, Belize, and Rio Oeste, Bocas del Toro, Panama. The lowest values of evenness were recorded from a collecting locality in a mangrove channel near Bastimentos, Panama, and off Man O’War Cay, Belize. Mean densities of epiphytic foraminiferans ranged from 0.01-8.00 foraminiferans/cm$^2$ seagrass blade, with both the highest and lowest densities being recorded in the Bocas del Toro region of Panama. Mean foraminiferal densities were also high off Man O’War Cay relative to other sites in Belize, presumably as a response to nutrient enrichment from the guano-laden island.
At the Jupiter site, mean densities of epiphytic foraminiferans were the highest during the spring and early summer months of 2001, while the lowest densities recorded-to-date occurred in spring 2005 following Hurricanes Jeanne and Frances (Fall 2004).

In both Belize and Panama, the epiphytic foraminiferal biotas could be differentiated into characteristic mangrove-associated and open-water biotas, with relatively higher diversities and densities characterizing the mangrove sites. A latitudinal gradient in biodiversity was not observed for the epiphytic foraminiferal biotas living on *T. testudinum* in the tropical Western Atlantic, as has been observed for many other terrestrial and marine taxa, including benthic foraminiferans. The significance of this observation is unknown, but is a hypothesis that can be tested further with increased sampling effort at additional localities between these widely spaced sites.
Ecological studies on Recent foraminiferal assemblages along the Mediterranean continental shelf of Egypt

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A suite of 41 bottom samples, collected along the Mediterranean continental shelf of Egypt (depth range 12-120 m) have been examined for their benthic and planktic foraminiferal content. A total of 107 species were identified. Census data were obtained for different species in each sample and the statistically significant fractional abundance values (≥ 5%) were analyzed using Q-mode cluster analysis. Samples were segregated into four clusters, each having its peculiar faunal assemblage (biotope), reflecting particular environmental conditions. R-mode factor analysis has enabled recognition of nine environmentally significant species assemblages. Generic predominance suggests a biogeographic boundary between the Nile Delta and west coast areas, and bathymetric boundaries in both the Nile Delta and west coast areas. The study reveals that water depth, type of substrate, nutrients, salinity, turbidity, light intensity and water energy are the main environmental factors controlling the distribution of foraminiferal taxa.
Morphotype analysis of calcareous benthic foraminifera in the Carapita Formation, eastern Venezuela Basin

Dennis Sánchez

In northeastern Anzoátegui and monagas states the Carapita Formation is a transgressive marine shale unit of early to middle Miocene age. It forms a west-to-southwestward thinning wedge between a transgressive sandstone-shale unit below (Capaya Formation) and a regressive sandstone-shale unit above (Uchirito Formation).

The microfauna of the Carapita Formation in its type area is rich, and weathered samples normally yield a great diversity of calcareous foraminifera. The richest suites have been reported from clean, conchoidally fracturing, very dark colored shales devoid of the common clay - ironstone nodules and lenses. The presence of these iron-rich concretions apparently causes excessive oxidation of the microfauna, with the result that they are often very difficult to identify to the species level.

Data used in this study include seismic lines, foraminiferal, calcareous nannofossil and palynological samples, and well logs from 17 wells. Outcrop or core (conventional or sidewall) are the preferred sample types for micropaleontological examinations but, typically in this study, only cuttings samples were available. In a section of this type, caving during drilling and, thus, contamination of cuttings by overlying strata, is always a problem. Casing point locations were used by interpreters for evaluating the in situ nature of the fauna. Foraminiferal sample preparations followed standard techniques.

The morphotype data are based on species abundances. Species percentages were recalculated on the basis of the total calcareous specimens in each sample, each species was placed into a morphotype category, and finally the total percentage of each morphotype in each sample was determined.

The methods used in this study follow those outlined in Corliss & Chen (1988). Five morphotypes are defined in this work and include: convex, biconvex, elongate (uniserial/biserial), planospiral and trochospiral. The convex/biconvex and planospiral morphotypes generally show values < 50% for shallow depths (< 100 m), but gradually increase with increasing water depth. The elongate (uniserial/biserial) morphotype has values of generally > 40% in deep water (> 200 m), and finally the trochospiral morphotype is generally found with values < 10% in the whole study area and is rare or absent in deep water (> 200 m).
Vertical distribution of planktonic foraminifera in the southwestern Atlantic

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Planktonic foraminifera were studied in 80 samples collected in the southwestern Atlantic (23°–25° S, 40°–44° W), from depths of between 0 and 100 m. The samples were collected during the austral summer and winter, along transects from the inner shelf to the middle slope. A Multiple Opening-Closing Net (Multi-net) was used to obtain planktonic foraminifera. The equipment has five nets of 64 µm mesh size, and the depth intervals sampled were 0–20 m, 20–40 m, 40–60 m, 60–80 m and 80–100 m. Sea water temperature, salinity and chlorophyll-a data were also measured at each station.

The Brazil Current (BC) flows along the southwestern Atlantic continental margin and it transports Tropical Water (TW, T=25.0°C, S=37.1) at upper levels. In the study area, the BC develops a convoluted pattern of meanders with associated upwelling and downwelling processes. Between November and March, the South Atlantic Central Water (SACW, T= 6–20°C; S= 34.6–36.0) moves toward the coast, keeping the Tropical Water relatively distant from the coastline.

Due to the high proportion of juvenile specimens (unidentified) in the 63–100 µm size fraction, samples were filtered through a sieve of 100 µm mesh size. All specimens of >100 µm were counted, identified and calculated as total individuals per m³ in the samples collected on the summer and winter cruises. However, accurate identification was not possible for the samples collected in the winter, as most of the individuals were juveniles. Foraminiferal standing stock from the multi-nets of the summer and winter cruises attained 4.5 and 1.78 individuals/m³, respectively. In general, for the summer cruise, higher standing stocks were observed at stations located on the middle slope. This pattern was not observed in samples collected in winter due to the low foraminiferal standing stock identified in this season. For this reason, data obtained on the winter cruise will not be presented here.
The optimum conditions of temperature and salinity for the planktonic foraminifera in the study area seem to be around 26°C and 37 psu, respectively. Apparently, levels with high standing stock values show low chlorophyll-a concentration. However, no relation was found between the abundance of the species and chlorophyll-a concentration. The most numerous species identified were *Globigerina bulloides*, *Globigerinoides ruber* (pink), *Globigerinoides ruber* (white), *Globigerinoides sacculifer*, *Globigerinoides siphonifera* and *Globorotalia menardii*. *Globigerinoides ruber* (pink), *Globigerinoides ruber* (white) and *Globigerinoides sacculifer* prefer to live in shallower (0–20 m water depth) and warmer (25º–26ºC) waters. They prefer salinity between 36.5 and 37.0. *Globorotalia menardii* prefers deeper waters (0–40 m) and slightly lower temperatures (24º–25ºC) and salinities (35.0–36.0). *Globigerina bulloides* and *Globigerinoides siphonifera* seem to be adapted to lower temperatures. *Globigerina bulloides* prefers to live within a temperature range of 17.5º–25ºC and *G. siphonifera* was dominant between 18.0º–21ºC. In terms of salinity, *G. bulloides* was more abundant between 36.0–37.0 and *G. siphonifera* was more adapted to 36.5. In terms of vertical distribution, *G. bulloides* had a shallower habitat (0–40 m water depth) than *G. siphonifera*, which prefers to live at 40–60 m water depth. Thus, these species can probably be considered as markers of upwelling along the southeastern Brazilian continental margin.
Mid-lower bathyal benthic foraminifera of the Campos Basin, southeastern Brazilian margin: Biotopes and controlling ecological factors

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The benthic foraminiferal assemblages recovered from forty-one surface sediment samples of the Campos Basin, southeastern Brazilian continental margin, were analyzed to interpret their distribution patterns and controlling ecological factors (environmental gradients). Living and dead specimens of benthic foraminifera were selected for identification and quantitative multivariate analyses from the >63 µm size fractions. Q-mode cluster and canonical correspondence analyses show the clear dissimilarity between samples/faunal assemblages located on the middle (750–1050 m water depth) and lower slope (1350–1950 m water depth). R-mode cluster and canonical correspondence analyses reveal two major foraminiferal groups characterizing these environmental settings.

The first group, dominated by Globocassidulina subglobosa, is present in the shallower regions studied (middle bathyal), and is characterized by the influence of the Antarctic Intermediate Water, with total phosphate values varying between 1.27 µmol.kg⁻¹ and 2.29 µmol.kg⁻¹. Sediments are sandy with highly variable organic carbon content (between 2.2 mg.g⁻¹ and 18.1 mg.g⁻¹). The dominance of different species of the genus Bolivina, Cassidulina laevigata and Globocassidulina subglobosa on the middle slope, and their association with Cibicidoides kullenbergi, Epistominella exigua and Uvigerina proboscidea, seems to indicate seasonally variable organic matter fluxes, with strong bottom currents and apparently oxic bottom waters.

The second group, dominated by Bolivina spp., occurs predominantly at the deeper stations sampled (lower bathyal), under the domain of the North
Atlantic Deep Water. The sediments exhibit in general high mud and relatively high organic carbon contents. The total phosphate values measured in the water column vary between 1.09 µmol.kg⁻¹ and 2.3 µmol.kg⁻¹. The faunal assemblage is preferentially composed of epifaunal or shallow infaunal deposit feeders (e.g., Bolivina spp., Eponides weddellensis, Lenticulina cultrata) and suspension feeders, adapted to the oligotrophic, epipelagic conditions and high dissolved-oxygen levels of the bottom waters (e.g., Rhabdammina spp., Rhizammina sp.). The assemblage seems to reflect a more stable ocean floor in the deeper region of the basin, probably due to decreased current velocities, reflected in a relative increase in the mud and organic carbon contents of the sediment, and the widespread oligotrophic oceanic conditions under the dominance of the North Atlantic Deep Water. The common occurrence of Rhizammina spp. could also suggest substrates with little reworking by deposit feeders in deeper areas of the basin.

Food supply, energy state (substrate stability) at the benthic/pelagic boundary and the grain size (sand/mud content ratio) of the substrate seem to be the most important environmental gradients controlling the distribution patterns of the benthic foraminiferal assemblages in the deep sea of the Campos Basin.
Benthic foraminifera in a human-dominated environment: Long Island Sound

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Long Island Sound (LIS) is a marginally marine urban estuary, with Long Island (NY) as its southern coastline, New York and Connecticut along its northern coast. LIS has a narrow opening to the West (East River), but most exchange with the ocean occurs at its eastern end, resulting in an east-west gradient in salinity. There is also an east-west gradient in indicators of contamination in the surface sediments (e.g., trace metals). Western LIS is close to the main population center (New York City), but also is a focusing region for fine-grained sediments. Since the 1970s, western LIS and to a lesser extent, central LIS, suffer summer hypoxia or even anoxia. We used sediment cores in westernmost and central LIS to document environmental changes over the last millennium, including the time of European settlement, using microfossil, geochemical, sedimentological, and trace element proxies. Sediment ages were determined using metal pollution records and radiometric carbon dating. In the marginal marine environment of LIS, benthic foraminiferal faunas are low-diversity, with slightly higher diversity towards its eastern end. Before European settlement, the assemblages were dominated by *Elphidium excavatum* (feeding on living diatoms) at shallow depths, where the light penetrates to the bottom (10-15 m). At greater depths, faunas in westernmost LIS were dominated by *Elphidium incertum* and/or *Buccella frigida*, by *Buccella frigida* and/or *Eggerella advena* over most of LIS. In almost all cores, the absolute abundance of benthic foraminifera and the relative abundance of *E. excavatum* increased from the early-mid 1800s on. In addition, *E. excavatum* became common at greater depths, where older faunas had been dominated by the agglutinant *E. advena*. The faunal changes coincided with an increase in contaminant trace metal concentration, with human population growth in the region, with a marked decrease in salinity in westernmost LIS, and with the beginning of low oxygen conditions as indicated by carbon isotope values in foraminiferal tests. Accumulation rates of organic carbon and nitrogen
increased several fold, especially in westernmost LIS. These data suggest that the benthic foraminiferal faunal changes were probably caused by eutrophication, increasing the diatom supply to *E. excavatum*. Assemblages showed additional, major changes in westernmost LIS beginning in the late 1960s. Foraminiferal abundance decreased, but *Ammonia parkinsoniana*, formerly absent or rare, became common to dominant, possibly because diatom abundance began to decline at high N/Si values. Decreased dominance of primary producers by diatoms then affected organisms that feed on them (including *E. excavatum*) and reverberated through the whole ecosystem.
Abundant and highly diversified “flysch-type” foraminiferal and palynological assemblages are recorded in the marine Paleocene-Eocene succession of four core sections drilled in the Sergipe and Campos basins, eastern Brazilian margin. Their occurrences are frequently associated with deep-water siliciclastic deposits.

The foraminiferal assemblages are documented, and a morphogroup analysis is carried out. Important markers of environmental changes include: variations in taxonomic composition and species diversity; the distribution pattern of the foraminiferal morphogroups and interpreted microhabitats, and associated feeding strategies. The characteristics of the foraminiferal and palynological assemblages and their relationships with turbidites are important in assessing the global impact of locally recorded paleoceanographic events as those related to the Paleocene-Eocene boundary.

Maximum species diversity among the agglutinated assemblages and a high number of suspension feeder morphogroups are recorded in uppermost Paleocene dark gray marlstones. These are locally associated with intervals of increased accumulation rates of coarse to fine-grained turbiditic sandstone bodies (thick turbidite sequences) in deep basinal settings (middle–lower bathyal environments). The taxonomic composition of the benthic foraminiferal assemblages indicates their cosmopolitan biogeographic distribution, showing close affinity with those of the Tethyan, Southern and Northern temperate realms. A large number of the recorded species have a common biogeographic distribution in slope and abyssal settings.