Research Networking Programmes

Short Visit Grant

Scientific Report

Proposal Title: ECORD Summer School 2013 in Bremen
"Deep-Sea Sediments: From Stratigraphy to Age Models"

Application Reference N°: 5991

1) Purpose of the visit

Since January 2013, I am working as a PhD student at the Palaeontology working group of Prof. Jörg Mutterlose at the Ruhr-Universität Bochum, Germany. My project is entitled "Size evolution of Cretaceous calcareous nannofossils: implications for oceanic anoxic events". It is fundeded by the Deutsche Forschungsgemeinschaft (DFG). Calcareous nannofossils are small (<30µm) calcareous fossil remains which mainly consist of coccoliths. These are circular to elliptical discs of calcite crystals which are produced by haptophyte algae to cover their cell. Since the Late Triassic until today, these single-celled algae represent one of the most important group of primary producers in the oceans. Their sensitivity to their environment makes them capable of recording changes in their habitat (such as temperature, salinity, pH, turbidity, nutrients...). Therefore they are studied extensively both as recent forms in our oceans and as fossils preserved in marine sediments.

Based on my work as a master student at the Ruhr-Universität Bochum, my PhD project aims to study the size evolution and distribution of several common species of calcareous nannofossils in sediments from the Late Aptian to Early Cenomanian interval. We intend to attribute the morphology of those fossil remains to environmental factors that influenced the living organism.

My visit to the ECORD Summer School 2013 "Deep-Sea Sediments: From Stratigraphy to Age Models" held at the Marum in Bremen intended to provide me with state of the art knowledge on stratigraphy and dating of marine sediments. But why is that important for my research? First of all, precise dating is a prerequisite for any kind of study in palaeontology. Discoveries of new fossil species or catastrophic events are less meaningful if their age or duration can only be roughly determined. On a geologic timescale these errors may easily add up to several millions of years of uncertainty.

In the case of my research, it is absolutely essential to know the age of the studied interval. My task is to track and study possible synchronous size trends at different sites on the globe. Being apart from each other by several thousand kilometres, these sites may not be easily correlated any more. They are for example located in Germany, the western Atlantic or off Australia. In my project, correlation of sections will be performed by biostratigraphy, chemostratigraphy and eventstratigraphy. Therefore it is crucial to my work to get to know and apply the latest techniques. A detailed and precise dating of my sections allows me to enhance the significance of my morphometric studies: I may be able to track if a size change in a nannofossil species at one site occurred prior to / after / synchronous with a size change at another site. Without precise dating, we would only be able to say that those variations occurred roughly at the same time. Seeing a temporal development in size around the globe might give us more information on its causes and mechanisms.

This year's Summer School dealt in particular with dating of deep-sea sediments of the IODP (Integrated Ocean Drilling Program) and its previous projects ODP (Ocean Drilling Program) and DSDP (Deep Sea Drilling Program). These programs were internationally funded and aimed at discovering the earth's history stored in marine sediments by bringing together top-ranked scientists from different countries and disciplines. My research is related to these projects as I am studying material derived from two expeditions, namely ODP leg 122 to the Exmouth Plateau (Indian Ocean) and ODP leg 171B to Blake Nose (western Atlantic).

Within the course of the Summer School, I gave an oral presentation on my research and the results that have been obtained so far. Besides being taught state of the art stratigraphy, I was looking forward to meeting scientists and discussing my research with them. I intended to encounter people who study calcareous nannofossils as well to know more about recent science at other institutions and to be inspired by their work.

2) Description of the work carried out during the visit

The virtual ship

This lab-exercise was inspired by the IODP shipboard methodologies. Every afternoon, we were introduced to what working on an IODP expedition would be like: ranging from describing the core to using elaborate measuring procedures. This exercise was based on working half cores of site 926C (ODP leg 154 to Ceara Rise, cores 16H and 17H). IODP nomenclature includes information on expedition no., site no., hole no., core no., core type and the section (see figure 1).

Section 3 (see figure 1) of the core at hand had a length of 150 cm, which are standard dimensions for cut IODP cores. It did not show any signs of core disturbance. By the first glance, it appeared to be a pale brown fine grained (clay and silt-sized) sediment with medium to thick bedded yellowish/strong brown units. Bioturbation was moderate but present along the entire core, especially visible at unit boundaries which are gradual. All over, tests of planktonic foraminifera were present. Two smear slides were prepared to check the main components. Both slides revealed nannofossils (especially Discoasterids) to be rock-forming. The darker beds showed elevated contents of mineral grains such as brown/reddish Fe-oxides, explaining the difference in color. The sediment was named foraminifera-bearing nannofossil ooze.

Core logging was applied to determine the physical properties of the core. Therefore a core-logging tool by GEOTEK was used (see figure 2). The core half itself was covered with foil to avoid contamination of the measuring and recording devices as those come in contact with the rock surface. Moved by the core pusher, physical properties such as magnetic susceptibility, gamma density, p-wave velocity, electrical resistivity and core diameter were recorded each 3 cm of the core. Some results of that are shown for section 2 to 4 (of ODP Site 926C core 17H) in figure 3. Gamma density (density) varies between 0 and 2 g/ccm, while the actual sediment density varies between 1.5 and 2 g/ccm and very low values represent gaps at the end/beginning of each section. Changes in magnetic susceptibility (MS) and density can be correlated and show a regular pattern indicating cyclicity. High values of MS and density co-occur with dark reddish/brown beds while low values were recorded from the paler units of the core.

XRF core scanning was performed using a Avatech XRF Core Scanner (see figure 4). As it is a non-destructive method it can be applied on archive halfs of cores. It is a fast semi-quantitative method and suits all flat surfaces (thin sections, hard rock and mud cores...). The cores were covered with foil and placed horizontally within the core scanner. Measurement step size was 30 mm. At each position, three measurements with varied energies (10keV, 30keV and 50keV) were performed to detect light elements such as Al - Fe as well as heavy elements such as Sr – Ba. Energy input (photon) excites inner shell electrons of elements to leave their position, which is then occupied by an electron from a higher energy level. A photon is released representing the energy difference of these two shells. This energy is element-specific and is detected within the XRF core scanner. This method does not yield quantitative results as light elements are only detected if they are near-surface while heavy elements can be detected even though they are situated deeper within the material.

The main target of core splicing is to create a complete record of the material recovered during IODP legs. Due to drilling problems, especially tops of cores can be disturbed or entire parts can be lost. Though drilling techniques have improved since the beginning of DSDP (IODP precursor), it is still necessary to drill several holes at one site to assure a complete composite record of the underlying lithology. Based on core logging data, the single cores of different holes are correlated using programmes like CORRELATOR.

Porewater analysis is performed on board as chemical properties may change soon after recovery and decompression. This exercise was carried out on a mud core from the Black Sea as this was still wet (see figure 5). To extract pore water, a syringe was equipped with a filter tube that was wetted before. The filter was placed into the sediment and a vacuum was produced within the syringe. Like that porewater was extracted from the sediment, though the first drops were disposed to not contaminate the results. About 10 ml of porewater are needed to determine all relevant parameters such as pH, alkalinity, salinity, ammonia or phosphate concentration. During this exercise, pH and ammonia concentration were figured out.

3) Description of the main results obtained

Apart from the virtual ship experience, this year's Summer School offered the opportunity to be introduced to the latest concepts in stratigraphy by leading scientists. Here, I see large benefits of this event for my research. These methods are mainly based on biostratigraphic datasets, which really suits my project and my overall interest in biostratigraphy and palaeontology. CONOP (CONstrained OPtimization Solutions) may be used for constructing composite timelines. This is a difficult task, as local stratigraphic sections differ or even contradict one another concerning the sequence of first and last appearances of taxa (FADs and LADs). These discrepancies may on the one hand provide information on faunal migration or restricted habitats of distinct species. On the other hand, it may be due to incomplete preservation and collecting or misidentification of taxa. This then results in crossed correlation lines when trying to correlate several sections. Traditionally, the crossed lines would just be erased, which reduces the resolving power. Another more elaborate and time-consuming method involves adjustment of local ranges rather than neglecting the data to bring all range charts into agreement. All recorded co-occurrences must be honored, while the smallest set of adjustments is done. This is then called “constrained optimization”. For two species in two sections, this can still be done by hand (see figure 6), as there are only 6 possible timeline sequences of first and last appearances to be considered. Extending the range of species B in section 2 would serve to solve the problem. But already when it comes to 3 taxa, 90 sequences are possible. With 7 taxa, there are already 681,080,400 possible sequences to be considered. This alarmingly high number requires technical support. In analogy to the travelling salesman problem, CONOP regards FADs and LADs and other stratigraphic events (isotopic excursions, ash beds, palaeomagnetic reversals ...) as cities which may be connected by routes, whereas the shortest route represents the sequence of events that best fits all local stratigraphic sections. This software program tries to diminish the misfit of section data and simulated timelines. The result is the best fit. However, the simulation may suggest several different but equally good answers, which allows to estimate uncertainties. We were taught how to use the program and what the input file should look like.

All quantitative methods for biostratigraphy try to minimize contradictions with the existing data. But there are different ways to achieve that goal. On the one hand, CONOP uses stratigraphic events (LADs, FADs, marker beds...) and results in a best fit model with least adjustments. On the other hand, Unitary Associations (UA) is based on co-occurrences. In this context co-occurrences are a stronger tool for global biostratigraphy as FADs and LADs alone. It pays tribute to the fact, that FADs and LADs may be wrongly estimated due to locally incomplete data (preservation, low sample size), but co-occurrences of taxa on the contrary are hard evidence (see figure 7). UA makes use of this principle, though this might lead to a lower resolution. At a first step, the program assumes that all taxa have existed continuously at each site between its first and last appearance, though they have not been recorded in each sample. At this point, you have to make sure if UA is the proper program for your purpose. If you want to use short-time disappearances and subsequent re-appearances of the same taxon (e.g. the nannoconid crisis during the early Aptian) for dating, UA is not appropriate. The resulting biostratigraphic zonation contains biozones with a certain assemblage of taxa to which you can assign a given sample.

Besides these advanced stratigraphic concepts, some basic knowledge about biostratigraphy is of importance for my research. When trying to set the boundary of a biohorizon, uncertainties arise due to discontinuous sampling. The inaccuracy (of e.g. the boundary of a biohorizon defined by the LAD of a taxon) increases with increasing interval between the last sample containing an index taxon and the following sample without that fossil. Due to incomplete preservation of an index taxon, a sample appearing devoid of that marker may lead to underestimation of the true stratigraphic range. The measure of this incompleteness can be quantified (after Strauss and Sadler, 1989 and Marshall, 1990), when following assumptions are valid: 1) Fossiliferous horizons are randomly distributed, and 2) samples were collected uniformly throughout the section: $\alpha=(1-C_1)^{-1/(H-1)}-1$ (with α=ratio between confidence interval and observed range; C_1=confidence level; H=number of horizons containing index taxon). If, for example, an index taxon has been found in 10 horizons within an interval of 10m in a section, the 95% confidence interval covers a total range of 10m+2*4m=18m. Besides uncertainties in the position of biostratigraphic levels, there may as well be uncertainties in the meaning of observations. In the case of a species that was observed in a sample but has not lived during time of deposition, the following errors may have occurred: The species was misidentified, it was a specimen reworked from older strata or it was a contamination from younger strata. In case a species was not observed though it had lived during the time of deposition, it may be due to misidentification, bad preservation or the species was too rare. Apart from reworking and contamination, the concept of appropriate index fossils tries to minimize these uncertainties.

4) Future collaboration with host institution (if applicable)

During my PhD project, I will work on material from an ODP leg, which is stored at the IODP Bremen Core Repository (BCR) at the Marum.

5) Projected publications / articles resulting or to result from the grant *(ESF must be acknowledged in publications resulting from the grantee's work in relation with the grant)*

Hopefully, I can integrate the results obtained during my visit at the ECORD Summer School in all publications, that require stratigraphic assignment. What I learned during these two weeks will definitely improve my research.

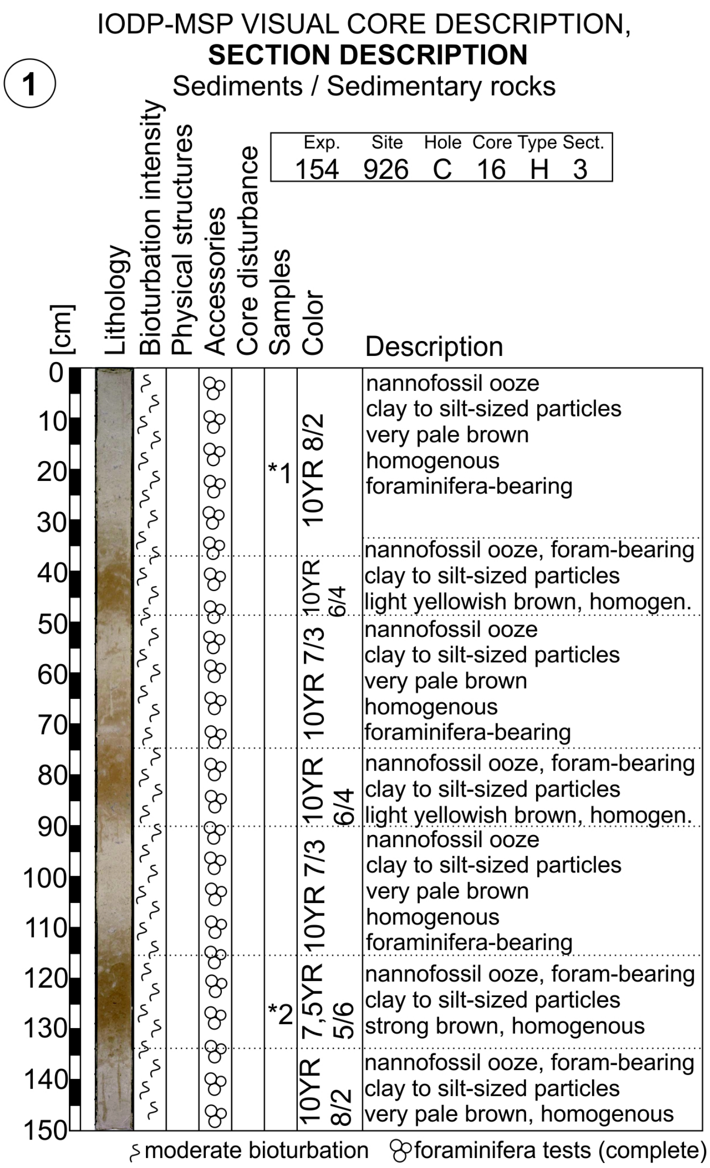
6) Other comments (if any)

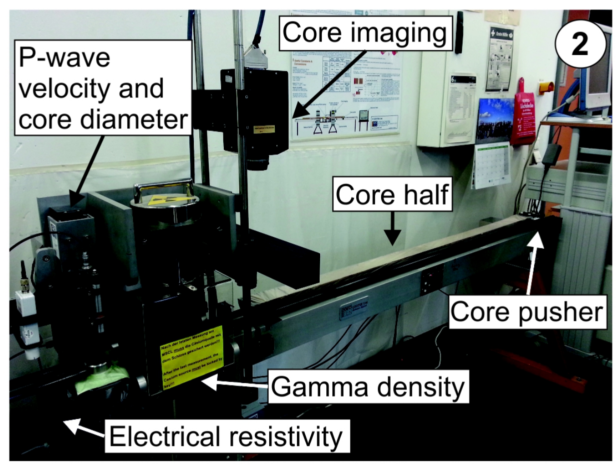
One morning of Summer School was dedicated to the future of IODP expeditions and our research careers. A successful IODP drilling proposal should address an important problem, that at best is interesting for different groups of scientists such as for example palaeontologist, stratigraphers, biologists, petrologists, sedimentologists or structural geologists. As ocean drilling is very expensive and elaborate, IODP will only consider proposals if ocean drilling is required to answer the open scientific question. You should make sure, that there is no other way rather than ocean drilling to successfully address the problem you would like to solve. Preferably, the results obtained during drilling should be exciting and very useful to the scientific community. A good proposal needs good preparation, therefore you should collect as many information as possible about the target region. Is the sediment accumulation rate high enough for your purpose? Is there any information on the age and lithology? How deep lies the target horizon? Is there potential for drilling problems such as oil or gas bearing strata?

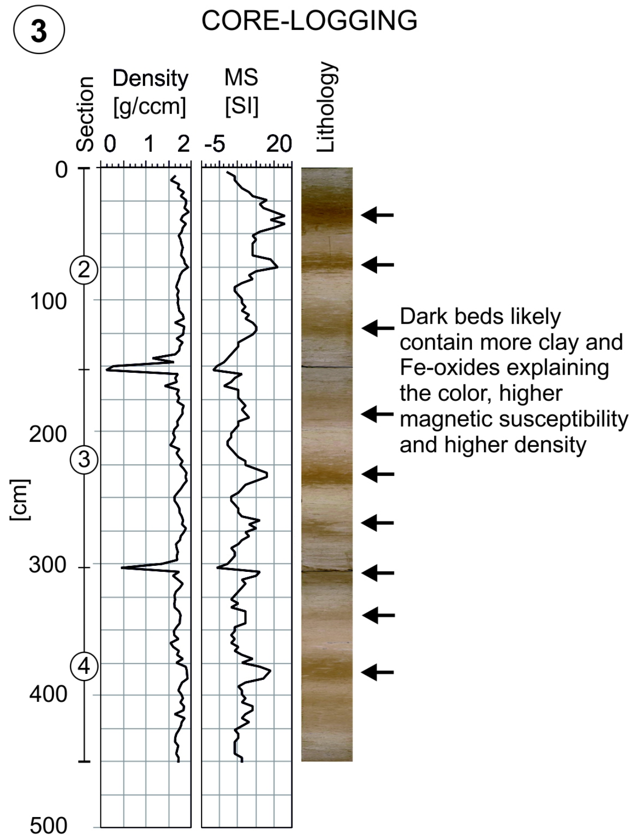
During a group exercise, we were asked to come up with an idea for an IODP drilling proposal. This activity made me realize how important it is to be around researchers with different expertises as I was surrounded by a recent diatom specialist, a cyclostratigrapher, two foraminifera specialists and a Cenozoic nannofossil specialist.

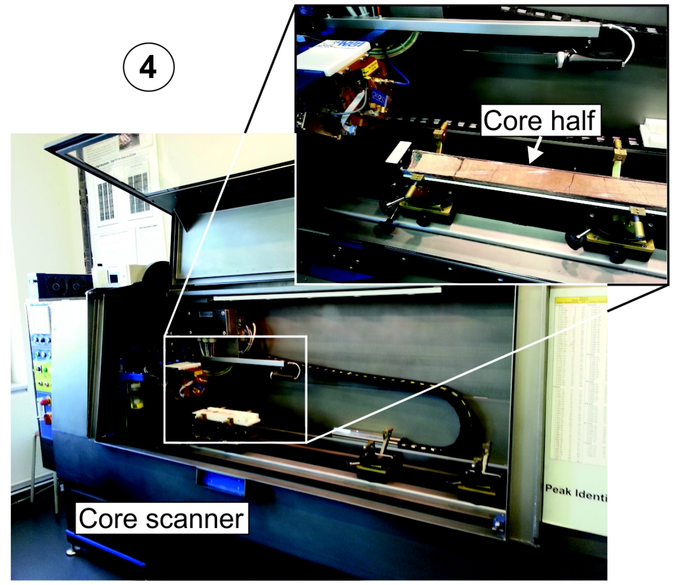
Literature

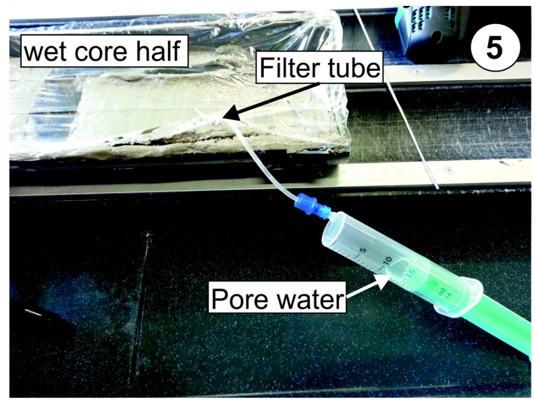
C. R. Marshall, *Paleobiology* **16**, 1 (1990).
D. Strauss, P. M. Sadler, *Mathematical Geology* **21**, 411 (1989).

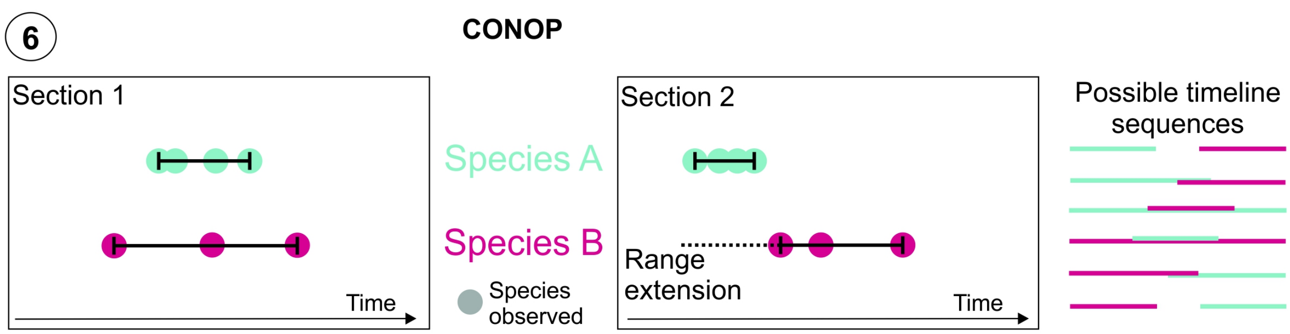


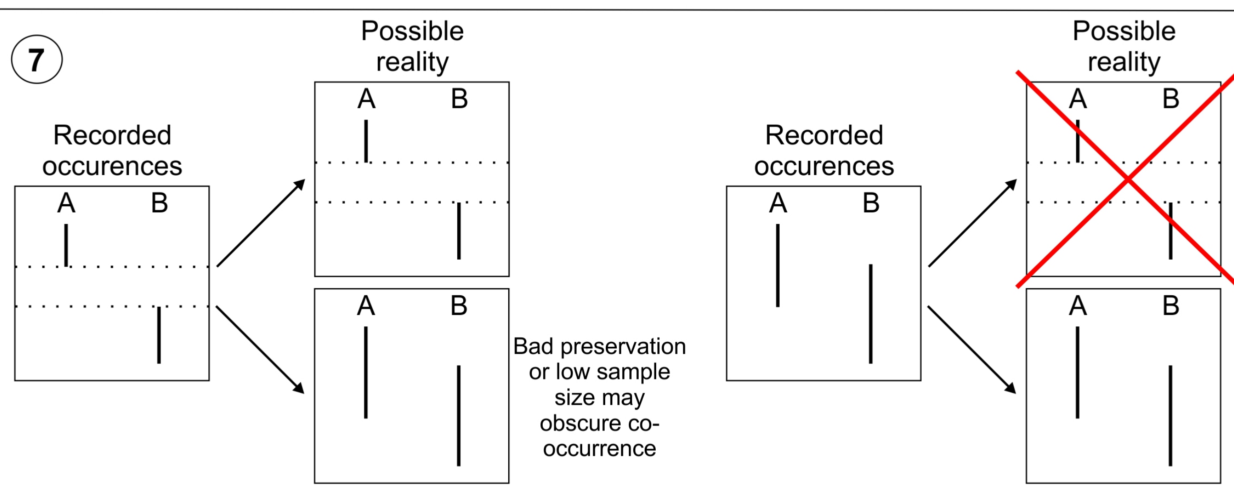



3
CORE-LOGGING
Section
Density [g/ccm]
0 1 2
MS [SI]
-5 20
Lithology
[cm]
0
100
200
300
400
500
2
3
4
Dark beds likely contain more clay and Fe-oxides explaining the color, higher magnetic susceptibility and higher density


4
Core half
Core scanner


5
wet core half
Filter tube
Pore water


6
CONOP
Section 1
Time
Species A
Species B
Species observed
Section 2
Range extension
Time
Possible timeline sequences


7
Recorded occurences
A B
Possible reality
A B
A B
Bad preservation or low sample size may obscure co-occurrence
Recorded occurences
A B
Possible reality
A B
A B