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REPORT AND PRELIMINARY RESULTS OF RV POSEIDON CRUISE P398, LAS PALMAS – LISSABON, 1 – 16 APRIL 2010.

PAPOCA, Production and preservation of organic carbon in relationship to dust input and nepheloid layers in the upwelling area off NW Africa

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R/V POSEIDON

Cruise Report P398

PAPOCA

Production and preservation of organic carbon in relationship to dust input and nepheloid layers in the upwelling area off NW Africa

Las Palmas - Lissabon

1 – 16 April 2010

Cruise within the framework of the DFG financed research center MARUM and the intenational Graduate College: EUROPROX: “Proxies in Earth History”

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1. Participants

Name	Discipline	Institution	Nationality
Zonneveld, Karin	Micropalaeontology/Palynology	GeoB/MARUM	NL
Bogus, Kara	Micropalaeontology/Palynology	GeoB/MARUM	USA
Dekeyzer, Stafanie	Micropalaeontology/Palynology	GeoB/MARUM	B
Goldhammer, Tobias	Geochemistry	GeoB/MARUM	D
Hirschmann, Katrin	Sedimentology	GeoB/MARUM	D
Kallweit, Wiebke	Geochemistry	GeoB/MARUM	D
Versteegh, Gerard	Organic Geochemistry	GeoB/MARUM	NL
Schröder, Friedrich	Geochemistry	GeoB/MARUM	D
Sokoll, Sarah	Microbiology	MPI	D
Günter, Marcel	Microbiology	MPI	D

Figure 1. Cruise participants of Leg P398 after the last station and storage of the scientific equipment, just previous to port arrival.

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2. **Research Program**

2.1. Introduction.

The apparent rise in global temperature during the second half of the last century continues to fuel world-wide discussions about the causes and effects of global climate change. Although it is obvious that human activity influences the natural system by increasing the atmospheric CO_2 concentration, large uncertainties remain about to what extent human activity is responsible for the current climate change. This is partly due to our poor understanding of the exact magnitude and effects of natural climate forcing mechanisms for instance how they might affect the global carbon cycle. During the last decades it has become clear that the ocean plays a crucial role in steering global climate and the global carbon cycle. Especially upwelling areas are of major importance as regions of high primary production and major export of carbon to the ocean floor.

The region off NW Africa is one of the most productive regions on Earth as result of the presence of coastal upwelling and the year round terrestrial dust input. Both upwelling and dust input fertilize the ocean by nutrient and trace elements such as iron and phosphorus. However, the relationship between upper ocean fertilization, marine bioproduction and transport and burial of the upper ocean produced marine carbon is far from being completely understood. Notably the early diagenetic induced alteration of the total organic carbon flux as well as the modification of the chemical, organic geochemical, isotopic and elemental character of the organic matter (OM) and marine carbonate during transport though the water column and at the sediment/water interface is far from clear.

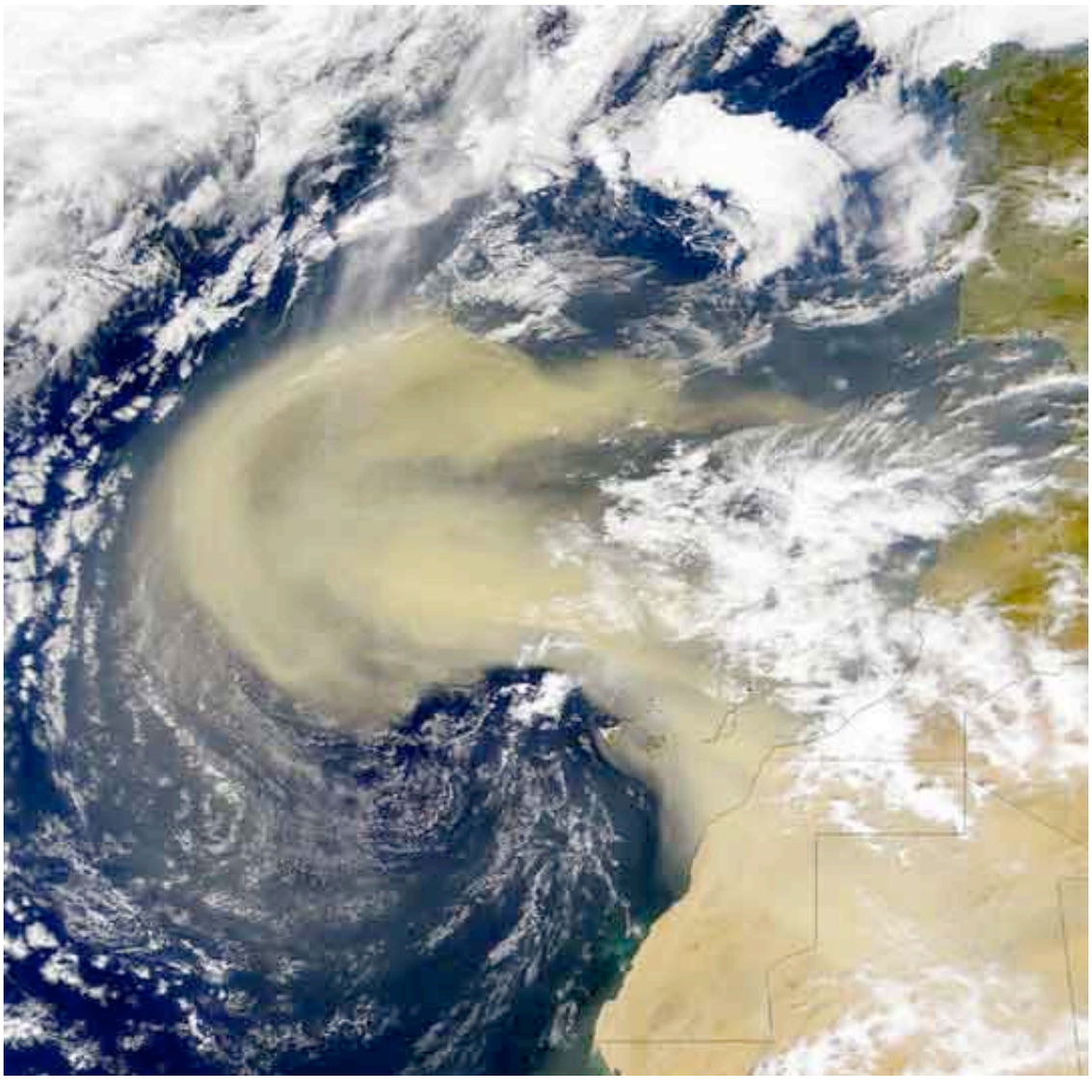


Fig. 1 NASA (SeaWiFS) satellite image of a dust storm over NW Africa from February 26, 2000 (SeaWiFS Ocean Color team)

The NW African upwelling region is positioned directly north of the northernmost extension of the intertropical convergence Zone ITCZ and lies within the present-day location of the major Saharan dust plume to the Atlantic Ocean (Figure 1). Thanks to satellite imagery, we nowadays have a fairly good idea where the major sources of Saharan dust are, and where the dust particles are being transported to. What we know surprisingly little about is the influence of aeolian dust on the particle scavenging, aggregation and transport through the water column of marine organic matter (OM). Furthermore, it is far from clear is in how it influences OM degradation. Recent studies suggest that terrestrial input might increase sinking rates from larger organic rich particles reducing their residence time in the water column (Fischer and Karakas, 2009). Furthermore, minerals can play a role of protecting organic matter of degradation by sorbing OM. It has been suggested that sorbed OM, or OM within pores or interlayers of minerals my be physically protected from hydrolytic enzymes (e.g. Hedges; Keil, 1999) However, these mechanisms are still controversial and more detailed information about the relationship between dust input and OM sedimentation and burial is required.

A factor that largely affects OM preservation is oxygen availability. Oxygen availability determines the respiratory types of benthic micro and macro organisms, with anaerobic consortia of micro-organisms being less efficient than aerobic micro-organisms and micro- and macrofauna. It has been suggested that redox oscillations, may enhance degradation by promoting symbiosis of aerobes and anaerobes (see overview in Zonneveld et al., 2010). The residence time of organic matter in the water column strongly influences the exposure time of OM to aerobic conditions. For high productivity areas it has been suggested that some organic components can remain for several thousand years in suspension in the water column related to the existence of nepheloid layers at intermediate water depths (Inthorn et al., 2006a, b). Within nepheloid layers individual organic matter compounds appear to show a difference in resistance to early sedimentary diagenesis during vertical transport.

Apart from influencing the rate of total carbon burial in marine sediments differential degradation of organic components also influences the concentrations of several proxies used in palaeoceanographic studies as well as their proxy signals. For instance, by establishing compound specific radiacarbon-based age assessments (Mollenhauer et al., 2008) could document differential preservation rates of surface ocean productivity proxies alkenones, membrane lipids of pelagic crenarchaeota (crenarchaeol) in nepheloid layers. Alkenones and crenarchaeol form the basis of the two sea surface temperature proxies Uk37 and Tex86 that are often used in palaeoclimatic studies to reconstruct past upper ocean temperatures. Alkenones are produced by coccolithophores, a predominant group of calcifying phytoplankton. Although increasing information is available on the distribution of living coccolithophores in the present ocean as well as in the understanding of their ecologic control, this knowledge is limited to certain distinct regions and reflects a shortage of suitable studies on natural populations (e.g. Böckel and Baumann, 2007). In the Canary Islands region and off Cape Blanc this knowledge is limited to mainly seasonal and interannual fluctuations in coccolithophore fluxes, including species composition and abundance, as well as the timing and intensity of coccolithophore production periods. Studies of their distribution in the plankton are however extremely scarce.

A major part of the organic matter flux is degraded within the benthic boundary layer (BBL) and within surface sediments. The rate and speed of degradation processes are strongly influenced by the oxygen conditions in the vicinity of the ocean floor. The effect of these processes on the preservation of different particulate organic matter (POM) types appears to be component specific (e.g. Versteegh and Zonneveld, 2002). Of the organic matter components analysed so far, different species of organic-walled dinoflagellate cysts have documented to be the end members in vulnerability against aerobic degradation. Dinoflagellates are unicellular algae that live in the upper part of the water column where they can produce cysts within the sexual part of their life cycle. Since the morphology of the cysts is species specific and their distribution is strongly dependent on the environmental characteristics of the water column, fossil cyst associations are extremely useful to establish highly detailed palaeoceanographic reconstructions, especially in high productivity area's. Differential vulnerability against aerobic degradation of these cysts could so far be documented to occur post depositionally only (Zonneveld et al., 2008). However, degradation studies on dinoflagellate cysts concentrated so far on sediments only and no studies are available that give information about the processes taking place within the BBL.

Apart from influencing the composition and character of POM, the processes taking place within the BBL can strongly influence the character of dissolved organic matter (DOM). Previous investigations assign important biogeochemical transfer processes on the transition zone of the lowest 2-3 m of the water column (Lavik et al., 2008). Especially nutrient-type elements show steep gradients within the bottom waters of the BBL. Fluid-derived dissolved nitrogen, phosphorus and iron species diffusing into the water column are subject to vertical mixing and/or lateral transport

which might return them back into the surface-waters where they are essential for marine primary production. Given the high atmospheric Fe input in this region it is of special interest to trace the fate and behavior of Fe in sediments and bottom waters. Fe-chelation with organic compounds may affect the composition and efflux of soluble iron from the sediments and it is unresolved to what extend iron is trapped in sediments and bottom waters and thereby altering the N, P, Fe ratio of surface waters. Furthermore, DOM may play a crucial role as an intermediate of sedimentary organic matter and associated nutrient release. The formation of refractory DOM sequesters N, P, Fe and other nutrients from active cycles, whereas the availability of labile DOM is a controlling factor for microbial productivity. Although the finding of strong indication to alteration processes on the primary signal from interstitial waters which are mainly driven by microbial organic matter degradation, little is known about the biogeochemical processes controlling the abundance of these nutrients and DOM in the BBL and the role of microorganisms in these processes.

Developing, evaluating and adapting marine proxies is the central theme of the DFG funded international graduate college “Proxies in earth History”. Within this project two proxy methods are being developed that focus on the relationship between the upper ocean environmental conditions and the elemental and isotopic composition of the calcareous fossilisable remains of coccolithophorids and calcareous dinoflagelates. Both phytoplankton groups live in the upper part of the water column. Pilot culture studies have revealed that the stable oxygen isotopic and elemental signals of the calcareous remains of these groups reflect upper ocean temperature conditions on species level (e.g. Zonneveld et al., 2007; Gussone et al., 2010)). Information about in-situ conditions in the water column is however absent.

2.2. Aims.

To obtain insight into the processes described above, the following aims have been addressed:

1. Obtain more insight into the effects of early diagenetic processes within intermediate depth nepheloid layers on the flux and character of the organic matter flux. For this the following questions are being addressed:

- How do remineralization and dissolution processes during transport and sinking influence the relative abundances of selected organic compounds?
- How do the particles change on their way through the water column?
- Which processes govern the remineralization of organic carbon in particles during sinking and following resuspension from near-shore areas?
- Are the nepheloid layers composed mainly of fresh organic matter or do they contain substantial amounts of re-suspended pre-aged sediments?

2. To evaluate the effects of the bottom water oxygen concentrations on the fixation or cycling of major elements and organic matter in the Benthic Boundary Layer and in surface sediments. For this the following questions are addressed:

- How important is the release of nutrients N and P upon organic matter mineralization in the BBL relative to nutrient release from the underlying sediments?
- Is a fraction of sedimentary organic matter transformed into refractory soluble molecules that sequester nutrients on historic time scales during organic carbon decomposition?
- Are the concentration of these molecules elevated in pore waters and the BBL compared to the water column?
- What role in oceanic N-loss do anaerobic microbial processes in the BBL play? Which processes are responsible for N-loss - heterotrophic denitrification, autotrophic denitrification and/or anammox – from suboxic BBL waters?
- Is there selective degradation of particulate organic matter components, notably palynomorphs within the benthic boundary layer and how is this related to the prevailing oxygen concentrations.

3. Obtain insight in the stable isotopic and elemental composition of the fossilisable calcareous remains of coccolithophorids and calcareous dinoflagellate cysts in relation to the environmental conditions and physical and chemical composition of the water column in which they are being formed.

3. Scientific program

Research activities have been carried out along two transects;

Transect 1.

This transect crosses the lower shelf and upper slope off Cap Blanc (~100-1500m water depth). Oceanographic data from frequent surveys in the research area reveal that there is a pronounced oxygen minimum zone between ~150 and ~700 m depth in this region (Figure 3). The intensity of this OMZ reduces rapidly in the northern direction.

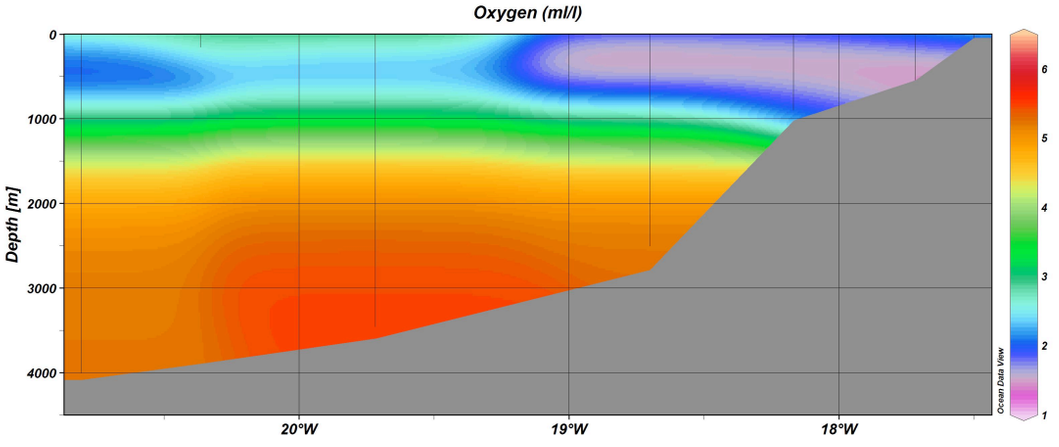


Figure 3. Water column oxygen concentrations off Cape Blanc (Zonneveld et al., 2010)

On this transect stations have been have been studied in detail in four defined environments: a) the upper boundary of the OMZ with the highest particle fluxes from the surface waters, b) the central OMZ always expelled to suboxic conditions, c) the lower boundary with less particle fluxes and d) the well ventilated deep ocean (Figure 4). Along the transect the fate of nutrient N, P, and Fe in the Bottom Boundary Layer, have been studied. For this bottom waters have been sampled using a newly designed Bottom Water Sampler. Additionally, we in-situ pumps and a CTD-rosette system have been deployed to retrieve samples of the suspension load and to get preliminary information on the geochemistry of the water column especially of the nepheloid layers. A MUC has been deployed to sample surface sediments allowing pore water extraction and the calculation of diffusive flux rates. A combination of nutrient chemistry, (trace) metal chemistry, in situ measurements, in situ and laboratory experiments with stable- and radio-isotope labeled substrates and molecular biology to obtain insight in the microbiological processes occuring in the BBL and underlying sediments (FISH/cloning sequencing/qPCR). Part of the Multicore material has been deep frozen and stored for further organic-geochemical and palynological laboratory experiments. From these samples individual organic-geochemical compounds as well as palynomrphs will be analysed downcore on millimeter resolution to obtain information about the effect of early diagenetic processes on the molecular structure as well as on the associations of terrestrial and marine palynomorphs. To obtain information about the oxygen penetration depth in bottom sediments oxygen measurements have been preformed on cores collected by the MUC. These analysis have been carried out with a fiber optic oxygen sensor (FIBOX3) using a micromanipulator.

Transect 2.

To obtain more insight into the structure and processes occurring within the nepheloid layers, samples have been collected along a second transect that runs from south to North and crosses the area of maximal Saharan dust input.
To determine the flux and composition of aerosols that are transported from the NW African continent over and into the Atlantic Ocean, two dust collectors have been deployed.
On this transect 17 Stations have been studied on their water column characteristics using a CTD-rosette system with additional turbidity, oxygen and chlorophyll-a sensors (Figure 4). In-situ pumps have been used as well to collect mineral and organic matter particles within the nepheloid layers and the upper water column to investigate the relationship between terrestrial input, upper ocean productivity and transport through the water column with special focus on the mineral composition of intermediate depth nepheloid layers.
Furthermore, abundance measurements of organic compounds have been coupled with compound-specific stable isotope analysis of selected compounds in order to monitor and quantify selective degradation and possible effects on the isotopic signature. Radiocarbon measurements will be used to distinguish between freshly produced organic carbon and pre-aged material.

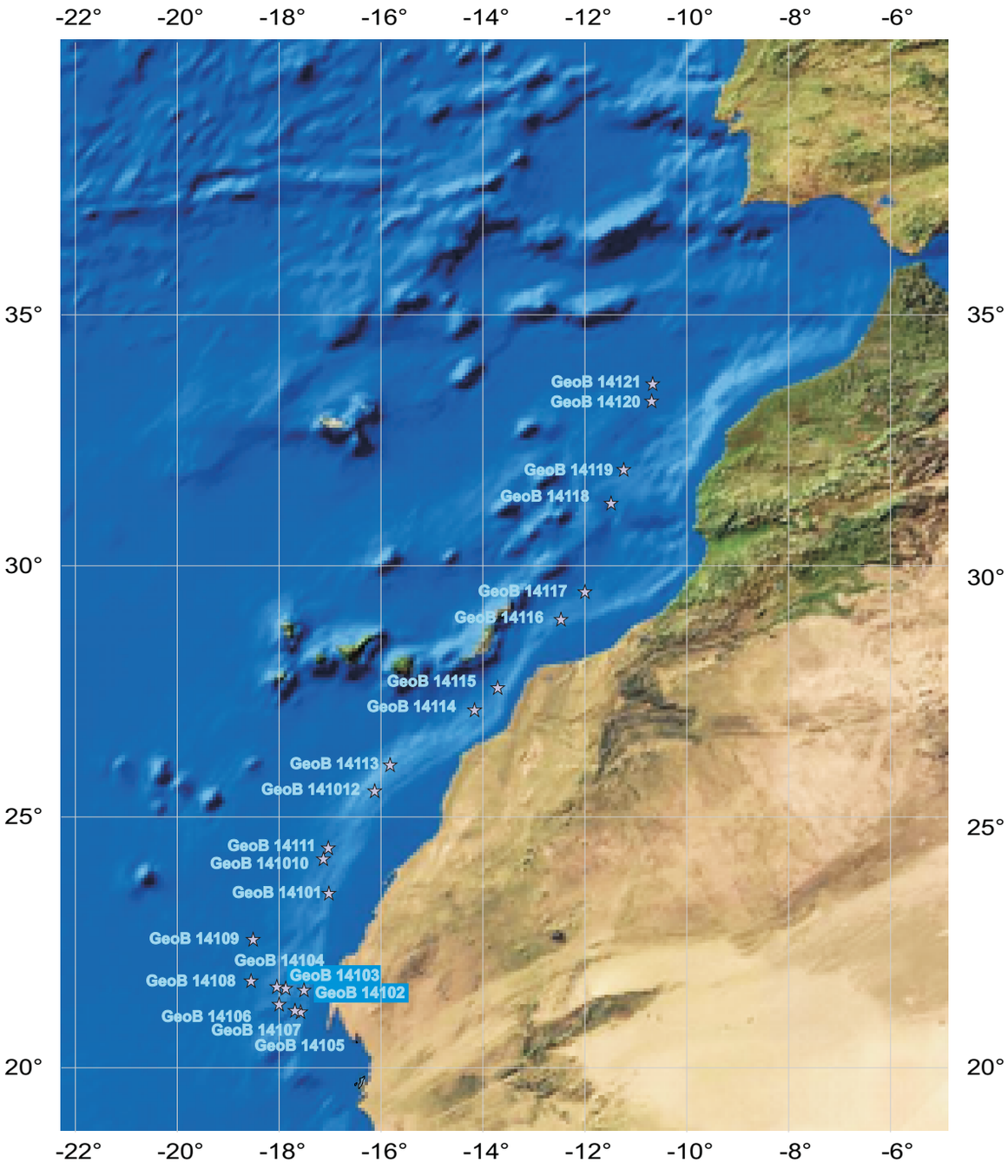


Figure 4. Sample position of Cruise P398.

Detailed information about the production and elemental and isotopic composition of calcareous phytoplankton contemporaneous information about the vertical distribution of coccolithoporids and calcareous dinoflagellates in the upper water column as well as the chemical, physical and isotopic composition of the water column have been collected using a CTD/Rosette casts at all stations of transect 2. The use of in-situ pumps will allowed high volume filtration at water depths of highest coccolithophorid and calcareous dinoflagellate cyst concentrations. This enables the assessment of the isotopic and elemental composition of the water column in coccolithophorid and calcareous dinoflagellate cyst carbonate.

4. Dust sampling

Jan-Beerend Stuut, Inka Meyer and Katrin Hirschmann

Terrigenous sediments deposited in marine sediments in the (sub)tropical oceans are a mixture of a pelagic component brought in by the wind and a hemipelagic component brought in by rivers and supplied from the shelf. The analysis of eolian dust allows the estimation of aridity in eolian source regions and the intensity of the transporting winds through grain-size measurements, so they can be used to reconstruct changes in continental climate.

For validating the terrigenous sediment fraction in marine sediment cores, present-day dust samples were collected using two dust collectors that were placed on the observation deck. An engine inside both dust collectors sucks the surrounding air. This air passes through a filter on which the dust is caught. The dust-collectors are connected with a windvane to prevent particles from the ship's chimney to contaminate the filters. This way, the wind direction that is to be sampled can be selected, only wind from up front was sampled. As soon as the relative wind direction was from behind, the dust collectors were automatically switched off.

Two kinds of filters are used for several investigations. A glass-fibre filter is used for future analyses of organic components in the dust, while the cellulose filters are used for grain-size measurements, chemical and mineralogical analyses. Sample point and filter types are given in Table 2.

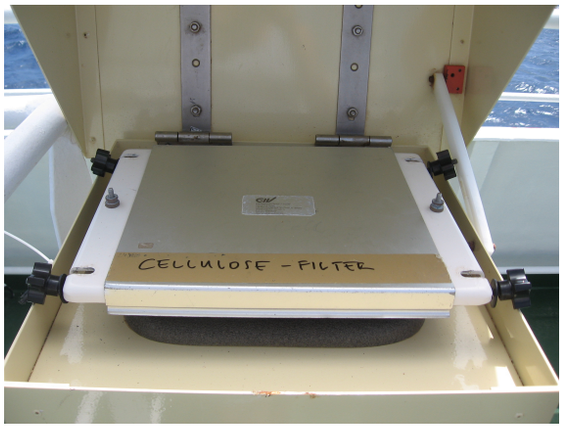


Figure 5. Dust samples with cellulose filter (photo: Inka Meyer).

5. Water column sampling

Karin Zonneveld

Organic and inorganic components from terrestrial origin can be transported into the marine system by wind and rivers. In the study region wind transport forms the major transport mechanism by episodically transporting large amounts of particles into the upper water column. Recent studies have revealed that these particles are most probably not transported down through the water column immediately but that there are several layers within the water column where these particles remain in suspension. It is suggested that the residence time of these particles within these so called nepheloid layers might be up to several thousands of years. For adequate subsampling of these layers with the help of in-situ pumps and a Rosette containing 18 Niskin bottles (10 l volume), the temperature, density, chlorophyll and oxygen differences of the upper 600m of the water column was determined using a CTD (seabird 911+).

5.1 Water column characteristics

Karin Zonneveld

The surface water circulation of the research areas of legs P398 is predominantly determined by the southward flowing Canary Current that bends from the continental margin to the southwest at about 21°N. In the study region south of the Canary Islands, a dominant feature of the region is the presence of coastal upwelling of cool and nutrient-rich subsurface water, which results in high bioproductivity on the shelf. The “primary upwelling” band is 20-30 km wide. Further offshore a second upwelling band can occur along the shelf break. A dominant steering role of upwelling length and intensity are the trade winds that have an equatorward direction. Between 20°N and 24°N upwelling occurs throughout the year with maximum intensity during spring and autumn.

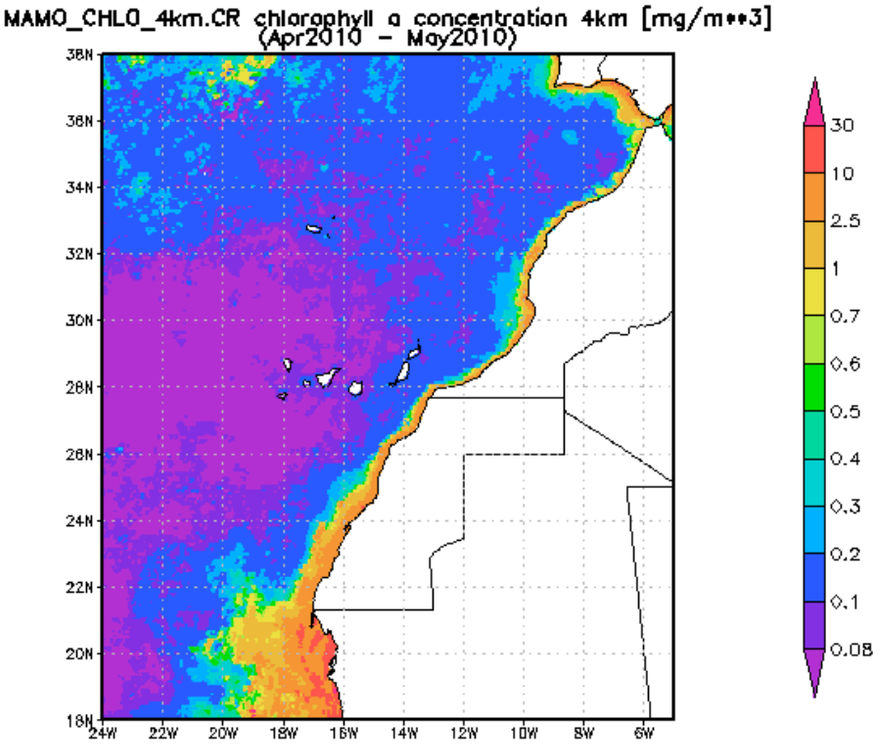


Figure 6. Compiled upper ocean chlorophyll-*a* concentrations registered by the MODIS aqua 4km resolution satellite (Giovanni Ocean Color Radiometry Online Visualization and Analysis, http://gdata1.sci.gsfc.nasa.gov/daac-bin/G3/gui.cgi?instance_id=ocean_month) between 01. April and 1 May 2010.

Subsurface waters in the southern region consist of South Atlantic Central Water (SACW) and North Atlantic Central Water (NACW). The SACW is transported poleward off Cape Blanc at depths between 200-400m whereas NACW follows the Canary Current equatorward at depths between 100 and 600m. The most intensive mixing of their waters takes place at a latitude of 22°N – 23°N. The SACW is characterised by high nutrient concentrations compared to the NACW. Enhanced productivity off Cape Blanc occurs when SACW feeds the onshore transport of upwelled water. This occurs especially during winter and spring. Characteristic for this region are “giant filaments” of relatively cold, chlorophyll-rich surface water. These giant filaments persist throughout the year and can be observed as far as about 450 km offshore. The occurrence of these filaments is strongly related to the general upwelling pattern with maximal occurrences between about 20°30’N and 22°N.

A Seabird SBE-19 CTD profiler was deployed at 21 stations. The CTD profiler is equipped with sensors for conductivity, temperature, pressure and oxygen. An additional WETLAB fluorometer was attached. The fluorometer measures chlorophyll concentrations and enables us to detect phytoplankton and the depth of the DCM. In this way, the CTD profiler could be used to determine the sampling depths for the calcareous dinoflagellate *T. heimi*i. Also, an additional WETLAB turbidity sensor was attached to the CTD profiler, in order to detect nepheloid layers in the water column. The CTD profiler is able to provide data during deployment via a cable connected to a PC

on board. Afterwards the raw data of each downcast were converted into Excel spreadsheets with the program Seabird.

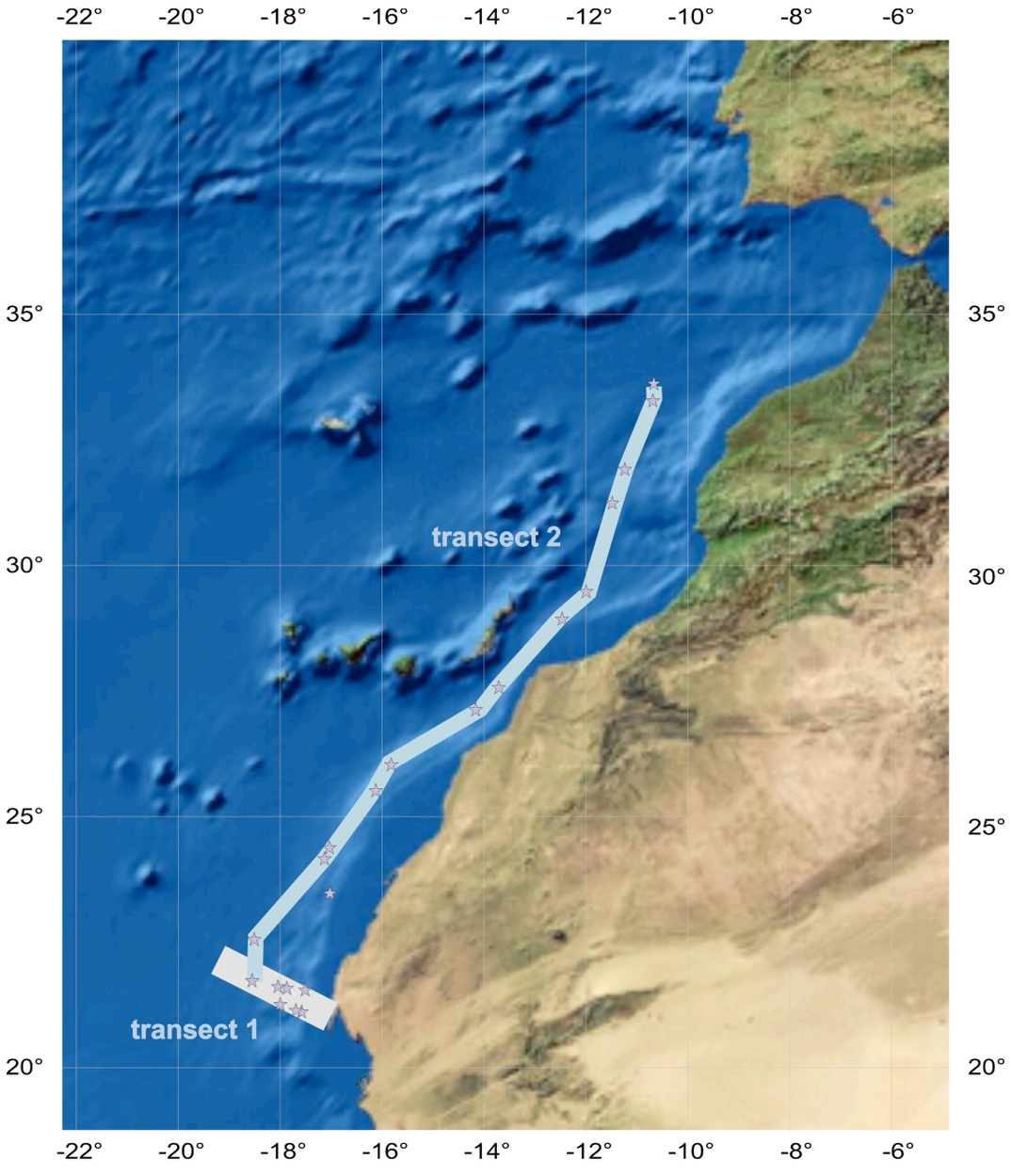


Figure 7. Map depicting sample locations along transect 1 and transect 2.

Transect 1.

The temperature and salinity profiles at transect 1 are relatively uniform. Slightly lower temperatures and salinities can be observed at the surface in the most coastal sites (Figs. 8, 9). This correspond to a band of near the coast upwelling that can be observed just east of the sample positions (Fig. 6). An clear oxygen minimum zone can be observed that ranges between 130 ~ 600 m depth in the most coastal regions to 140 - 400 m depth at the most offshore side (Fig. 10). Oxygen concentrations are minimal in close vicinity to the coast, near the band of active upwelling. As can be expected, high Chlorophyll a concentrations can be observed in the upper water layers. Highest concentrations can be observed around 17.8W and 18.6 W which correspond to the presence of upwelling filaments crossing the sampling sites at times of deployment (Fig. 6). Low chlorophyll-a concentrations are observed at the most coastal station at the edge of the active upwelling cell. Turbidity measurements indicate the presence of several nepheloid layers that appear to have a variable depth on the individual stations (Fig. 11). On the most offshore site turbidity maxima are observed at 280m, 340m, 644m and 1080m depth. In the central part and more onshore part of the section a pronounced nepheloid layer has been observed in the water column between 380 and 491m depth.This turbidity maxima becomes less thick with increasing distance to the coast.

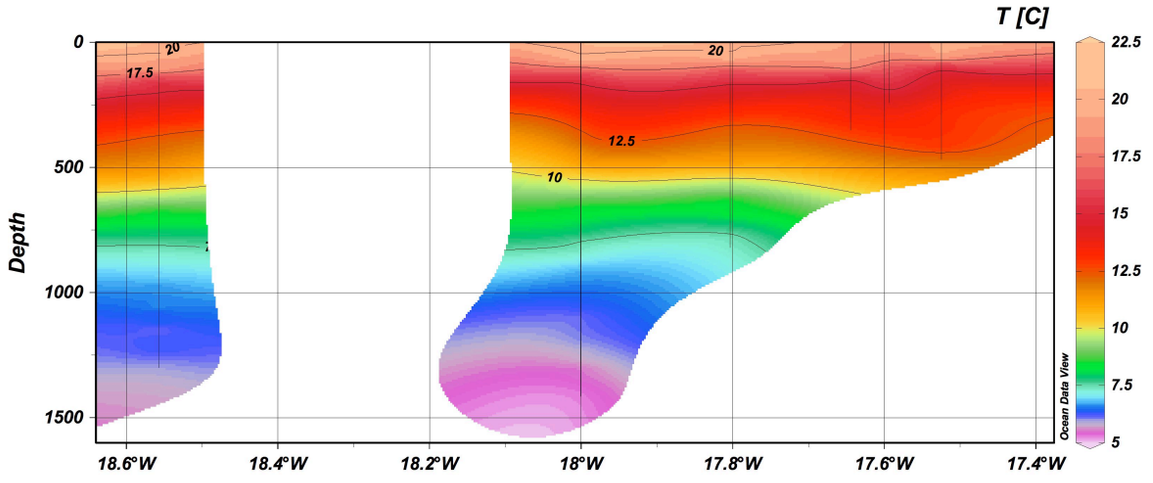


Figure 8. Cross section of the water column along transect 1., temperature (°C).

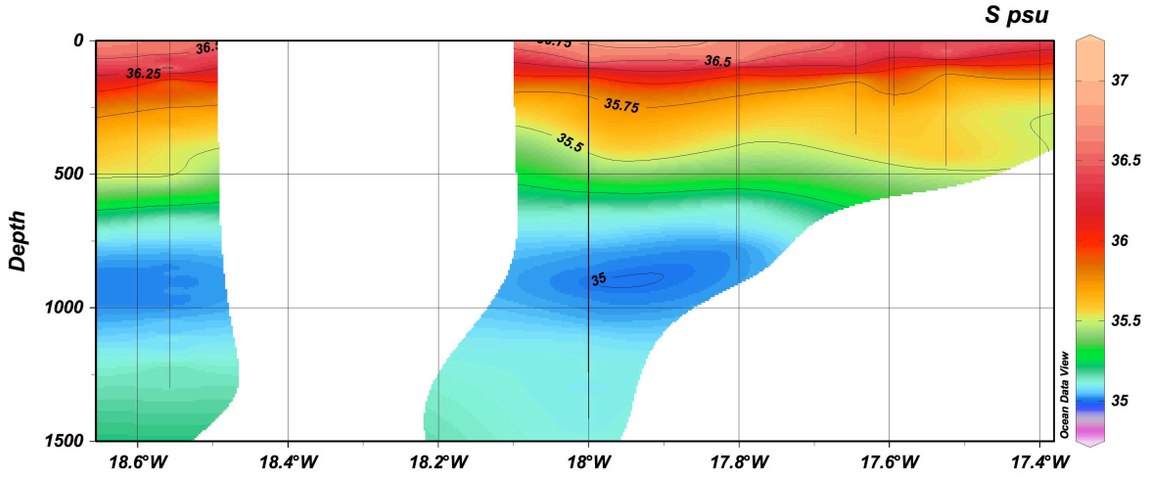


Figure 9. Cross section of the water column along transect 1., salinity.

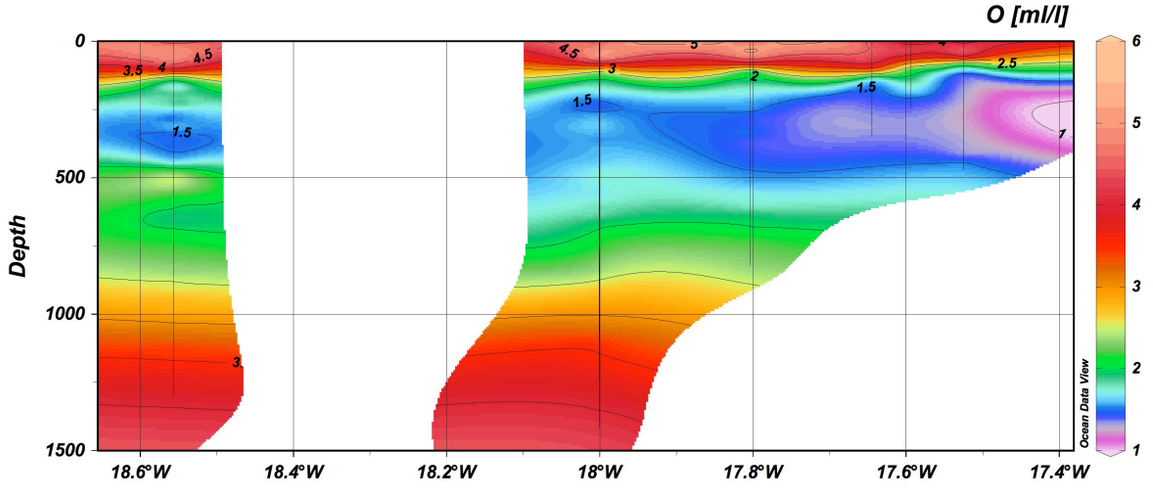


Figure 10. Cross section of the water column along transect 1., oxygen concentration (ml/l).

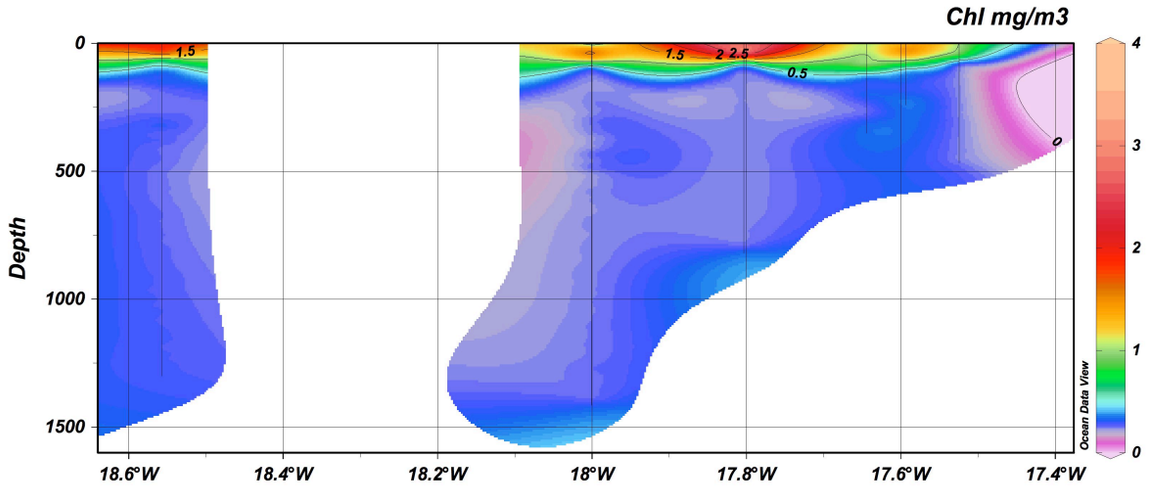


Figure 11. Cross section of the water column along transect 1., Chlorophyll-a concentration (mg/ m^3).

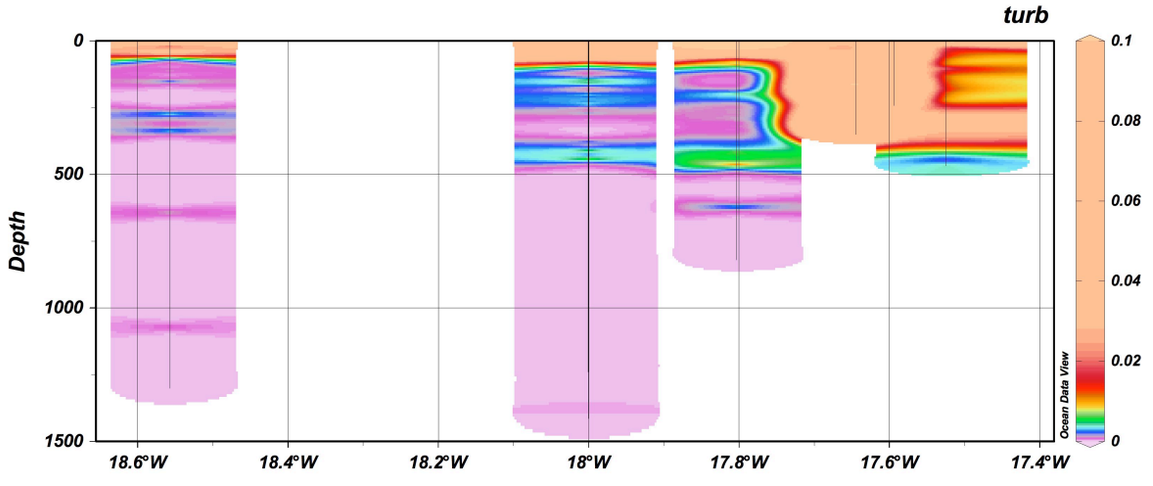


Figure 11. Cross section of the water column along transect 1., turbidity

Transect 2.

Upper water surface temperature and salinity generally decrease from south to north. Exceptions are formed by the most southerly and most northerly sampling sites were temperatures are clearly reduced in comparison to the sites in their vicinity (Fig. 12, 13). Three regions with reduced subsurface temperatures and salinities can be observed at 27.6°N and south of 24.2°N (around 23°N and at 21.7° N). It is likely that these relatively cold, low saline waters might be transported from greater depths to the surface as a result of the presence of active coastal upwelling. Along the whole transect reduced subsurface oxygen concentrations can be observed below about 170 m depth in the most northern station to 80 m in the most southern station (Fig. 14). Oxygen concentrations in this layer increase from south to north. Minimal values of oxygen concentrations of less than 1 ml/l can be observed around 23° N and 21.7 °N .
Along the whole transect 2 a clear deep chlorophyll maximum can be observed between about 30 and 70m depth (Fig. 15). Chlorophyll-a concentrations in this DCM are however highly variable with distinct cells of maximal concentrations 23.4°N, 24.3°N, 25.5°N, 31.2°N, 33.4°N and 33.7°N. At the most southern and northern stations of the transect high chlorophyll-a concentrations can be observed at the water column surface which supports the earlier suggestion of to the presence of upwelling filaments at the sampling sites.
Deep water turbidity maxima can be observed in the most southerly stations only at 21.7° N (275m, 334m, 643m, 1075m) and 22.3° N (460m).

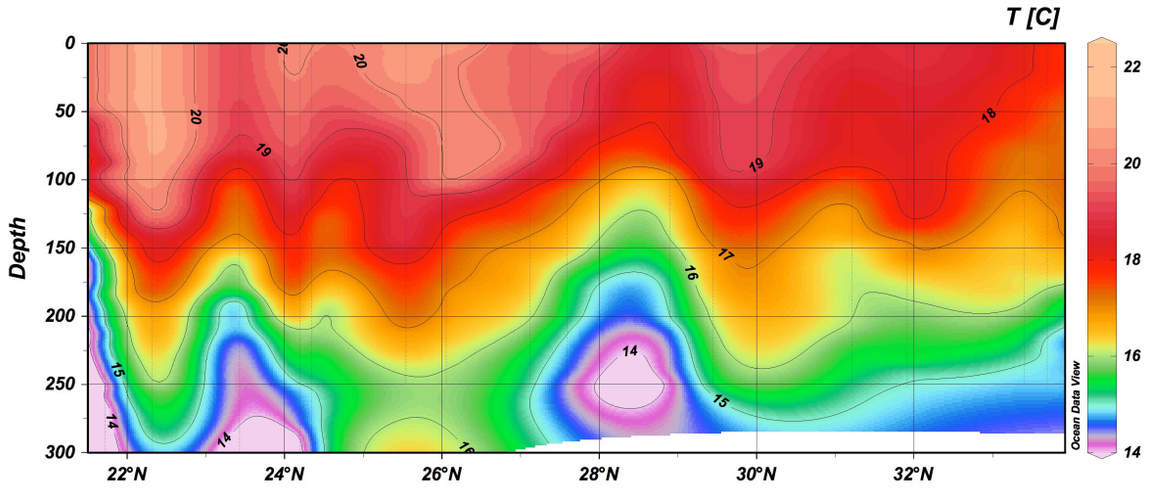


Figure 12. Cross section showing the upper 300 m of the water column along transect 2; temperature (°C).

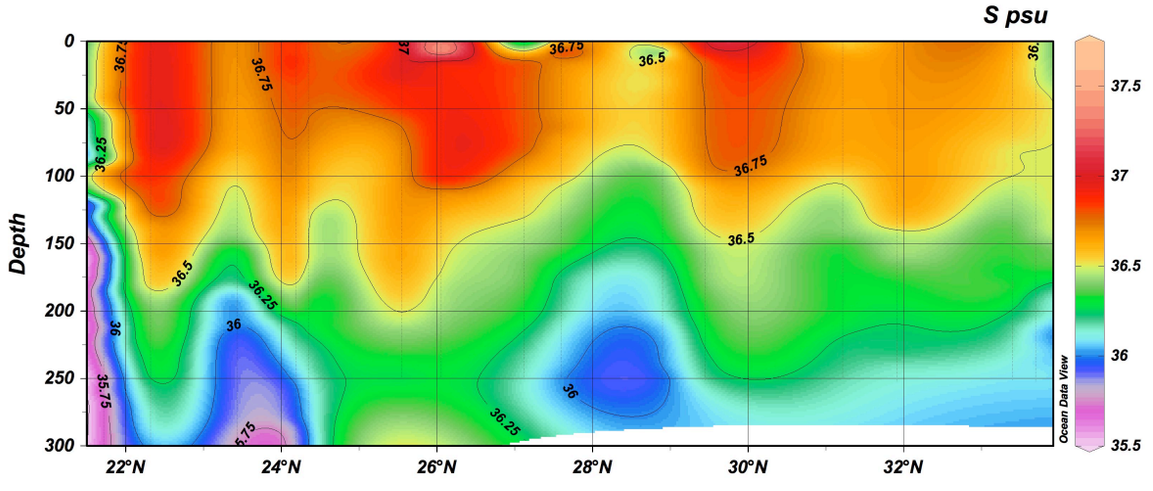


Figure 13. Cross section showing the upper 300 m of the water column along transect 2; salinity.

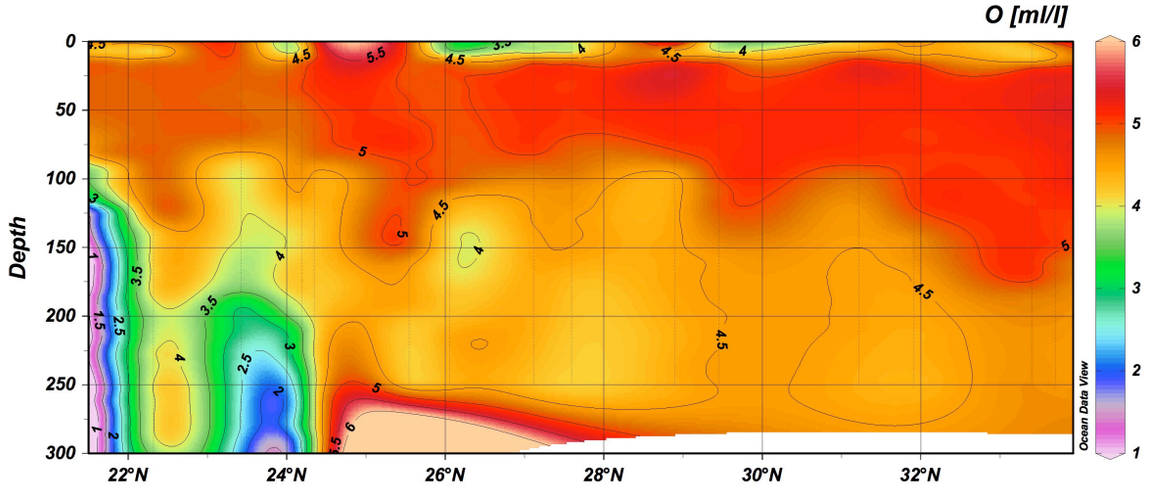


Figure 14. Cross section showing the upper 300 m of the water column along transect 2; oxygen (ml/l).

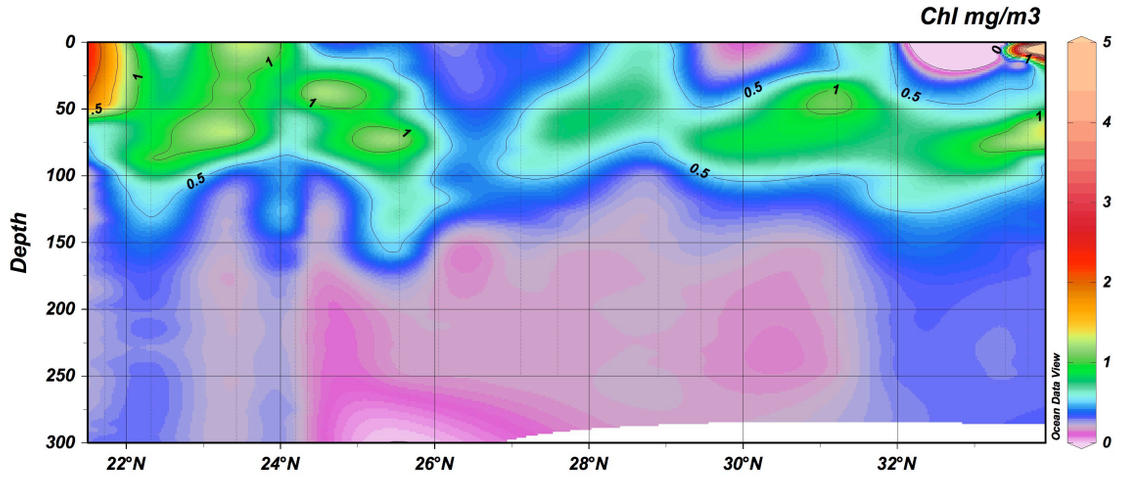


Figure 15. Cross section showing the upper 300 m of the water column along transect 2; chlorophyll-a (mg/m^3).

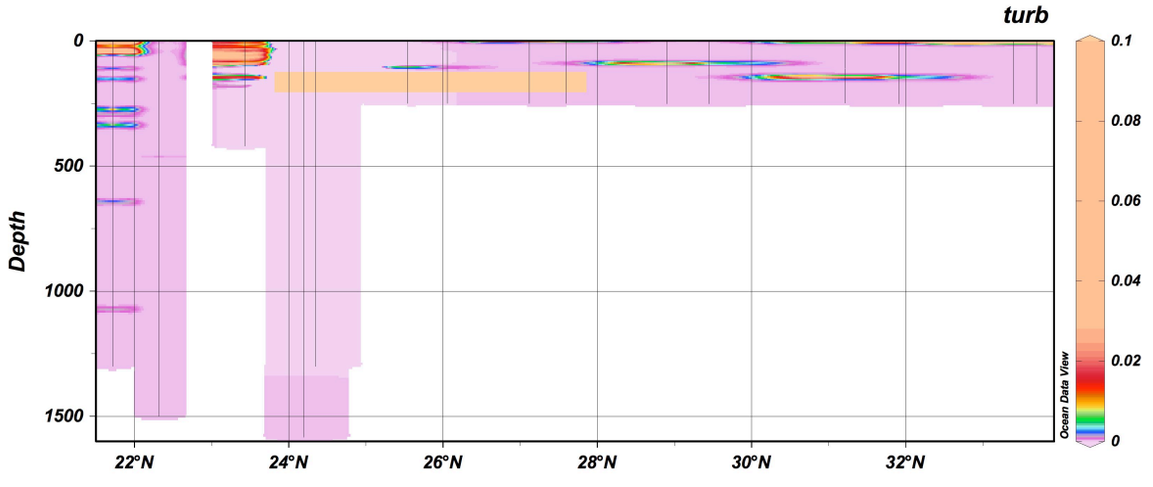


Figure 16. Cross section showing the upper 300 m of the water column along transect 2; turbidity

5.2 In-situ Pump sampling

Stefanie Dekeyzer

During cruise P398 eight in-situ pumps were available to retrieve additional water column samples. Depending on weather conditions and the amount of in-situ pump samples needed, pumps were attached to the CTD-rosette wire during the second CTD-rosette deployment OR to a wire with a heavy weight attached to the end. Two of the in-situ pumps contained additional reservoirs allowing to take water samples at the pumping depth. Filter types used were polycarbonate filters, glass fibre filters and cellulose nitrate filters, depending on the purpose of the analysis of the filters. In-situ pump samples were taken for geochemical studies, nepheloid layer studies and calcareous dinoflagellate studies.

In-situ pumps POS 398
Las Palmas-Lisbon
01.04.2010 - 16.04.2010

	Water depth (m)	Time (min)	Max. pump rate (l/min)	Total vol. pumped (l)	sampled for
GeoB 14102-2					
Jochen	200	150	7	794.7	org. geochem.
Norbert	300	150	7	513.98	org. geochem.
Jimmy	400	150	7	879.55	org. geochem.
Frauke	210	150	5	697.97	sedim.particles
Fred	310	150	5	114.23	sedim.particles
Hulda	410	150	5	707.66	sedim.particles
GeoB 14103-3					
Jochen	478	120	7	696	org. geochem.
Norbert	468	120	7	694.06	org. geochem.
Jimmy	458	120	7	703.62	org. geochem.
Frauke	700	120	4	566.12	sedim.particles
Fred	550	120	4	135.68	sedim.particles
Hulda	340	120	5	566.13	sedim.particles
GeoB 14103-4					
Jochen	40	90	7	238.39	dinoflagellates
Norbert	60	90	7	240.44	dinoflagellates
Jimmy	30	90	7	495.68	dinoflagellates
Frauke	470	90	4	450.5	sedim.particles
Fred	120	90	4	424.59	sedim.particles
Hulda	80	90	5	423.13	sedim.particles
GeoB 14104-3					
Jochen	215	90	7	526.12	org. geochem.
Norbert	443	90	7	527.68	org. geochem.
Jimmy	920	90	7	527.71	org. geochem.
Frauke	900	90	4	424.6	sedim.particles
Fred	1300	90	5	156.8	sedim.particles
Hulda	650	90	5	424.6	sedim.particles
GeoB 14104-4					
Jochen	20	90	5	316.73	dinoflagellates
Norbert	60	90	5	163.35	dinoflagellates
Jimmy	50	90	5	337.17	dinoflagellates
Frauke	300	90	4	418.48	sedim.particles
Fred	80	90	5	43.6	sedim.particles
Hulda	453	90	5	424.6	sedim.particles
GeoB 14106-3					
Jochen	380	90	7	527.67	org. geochem.
Norbert	152	90	7	508.69	org. geochem.
Jimmy	210	90	7	527.68	org. geochem.
Frauke	850	90	4	424.6	sedim.particles
Fred	1210	90	5	149.2	sedim.particles
Hulda	620	90	5	424.6	sedim.particles

Table 1. In-situ pump stations.

5.3 Rosette water sampling

Stefanie Dekeyzer

The CTD profiler was coupled to a rosette sampling system (HydroBios No. 436918A) equipped with 18 Niskin bottles (10 liters each). Rosette water samples were retrieved at 17 stations (Table 1). At stations GeoB 14101, 14109, 14110 and 14121 no Rosette water samples were retrieved.

At stations GeoB 14102 through 14108, GeoB 14119 and GeoB 14120 the CTD-rosette system was deployed twice at every station. During the first deployment at these nine stations, the entire water column was profiled and sea water parameters were measured, without taking water samples. Also during the first deployment, the depth of the DCM, based on the chlorophyll concentration, and the depths of the nepheloid layers, based on the turbidity measurements, were determined. During the second deployment at these nine stations, Rosette water samples were taken from specific water depths for dinoflagellate and geochemistry studies.

At stations GeoB 14111 through 14118, the CTD-rosette system was only deployed once at every station. During the donwcast the entire water column was profiled: sea water parameters were measured and the depths of the DCM and the nepheloid layers were determined. During the upcast rosette water samples were taken from specific water depths for dinoflagellate and geochemistry studies.

5.4. Dinoflagellate sampling

Stefanie Dekeyzer

Dinoflagellates are one of the major groups of the marine phytoplankton (for an overview see e.g. Evitt, 1985; Dale, 1986). These unicellular, biflagellate organisms undergo two different stages during their life cycle: a motile vegetative-thecate stage and a resting cyst stage which can either be calcareous or organic-walled. During this cruise, our main focus was on the calcareous dinoflagellate species Thoracosphaera heimii. Since previous research has indicated that this species shows highest abundances around the deep chlorophyll maximum (DCM; e.g. Zonneveld, 2004; Kohn and Zonneveld, 2010), we were particularly interested in sampling at the DCM and the area above. For this reason, rosette water samples and in-situ pump samples positioned at and above the DCM were taken. All samples will be analysed as to the content of calcareous dinoflagellate cysts, and in particular T. heimii, in order to investigate their lateral and vertical distribution and the interaction of the species association with related environmental parameters, such as temperature, salinity and chlorophyll-a. This may lead to a better paleoceanographic interpretation of the fossil assemblages of dinoflagellates.
Furthermore, the stable isotope and elemental composition of calcareous dinoflagellates, and in particular T. heimii, are increasingly being used in paleoclimatical and paleoceanographical studies. However, the relationship between the elemental and isotopic composition of T. heimii and the ambient water column is still not well understood and thus requires further investigation. All water samples, both rosette and in-situ pump samples, will be analyzed as to the stable isotope and elemental composition of the T. heimii shells.

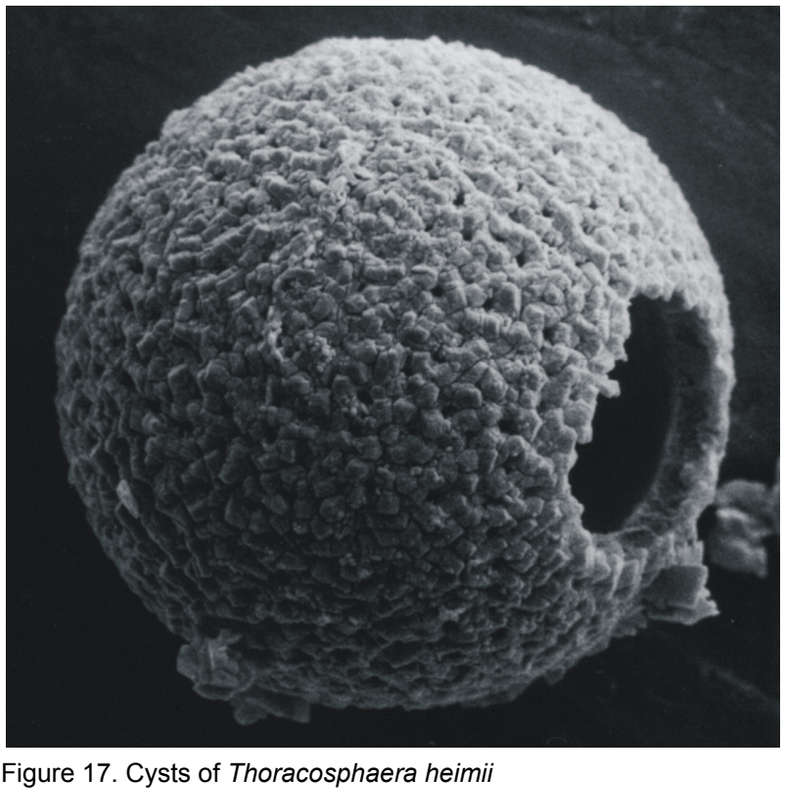


Figure 17. Cysts of *Thoracosphaera heimii*

6. Marine Biogeochemistry

Tobias Goldhammer, Friedrich Schröder

Research activities of the projects MARUM GB2 and EUROPROX III-17 were organized in three divisions that are described below. We aimed to investigate the turnover of nutrients nitrogen (N), iron (Fe) and phosphorus (P) in the Benthic Boundary Layer (BBL) that supposedly links fluxes of these elements from sediments to the water column.
We sampled the BBL with a Bottom Water Sampler (BWS), and deployed in-situ pumps and a CTD-rosette system to retrieve samples of particulate material and to characterize the chemistry (e.g. oxygenation) of the water column. We also used a multi corer for the sampling of surface sediments and pore waters. Our approach embraces nutrient chemistry, (trace) metal chemistry, stable isotope analyses, in situ measurements, incubation experiments with stable- and radioisotope labeled substrates, and molecular biology. In total, we retrieved samples on seven stations (GeoB14101, 14102, 14103, 14104, 14105, 14107 and 14110) of the southern transect.

6.1. Coupling of phosphate and iron fluxes in the water column, benthic boundary layer and the seabed

The availability of Fe and P controls marine productivity, and variations in their relative abundance affect species composition of phytoplankton communities. The fluxes of both elements are closely coupled, due to strong interaction of Fe mineral surfaces with dissolved PO_4^{3-}. We plan to investigate the fate of these nutrients in the BBL, where little is known about the biogeochemical and microbial processes that supposedly control both deposition and return flux of Fe and P, from the overlying water column to the sediments and vice versa.
We therefore retrieved a continuous set of samples of the water column, the BBL, and the sediment surface – bulk water samples, suspended particulate matter, and pore water and solid phase of surface sediments. We aim to characterize the coupling of Fe and P and fluxes through the (upper) water column, the reactive BBL, and into and from the seabed, and set special focus on the role of BBL
microbial processes that drive the P return flux to overlying waters. We will analyze Fe and P speciation and the role of organic-bound P in particulate matter, and will combine classic geochemical quantification with the recently established phosphate oxygen isotope biosignature ($\delta^{18}O_P$). Our sample set will be the first to describe this parameter in a continuum from surface waters to the seabed.

6.1.1. Sampling of sediments, bottom water and water column

Large volume water column samples (up to 20 L) were retrieved from hydrocasts. A split of approx. 30 mL was immediately filtered (0.2 µm syringe micro filter) and kept for further processing onboard and onshore.
The Bottom Water Sampler (BWS) for sampling of the BBL comprised six Niskin-type bottles that are mounted horizontally to a rotating pole in levels of 25, 45, 70, 100, 155 and 210 cm above seafloor. A sail aligned the sampler according to the prevailing bottom currents for isokinetic sampling. A bottom contact switch triggered a preset countdown that delays the closing of the bottles after touch down of the sampler on the sea floor. This enabled re-suspended sediment to drift away and ensured virtually undisturbed sampling. We conducted four successful deployments of the BWS at stations GeoB14101, 14102, 14103 and 14105. After recovery of the device on deck, the bottles were detached and carefully transported to the aft deck close to the laboratory, where they were lashed for split sampling.
Surface sediments were retrieved with a multi corer at stations GeoB14102, 14103, 14105 and 14107. After recovering the device on deck, the tubes were brought to the laboratory and kept upright in the sink. Rhizon micro suction samplers (5 cm length, 0.2 µm porous polymer) were carefully inserted through sampling holes every centimeter in the upper 10 and every 2 to 4 cm down to the bottom. Three way Luer-lock stopcocks were connected to the adapters of the rhizons for proper closing and simultaneous connection of two syringes. First, a 20 mL syringe was attached, evacuated and kept open with a spacer. After the first 0.5 mL was sampled, it was discarded through the stopcock and vacuum was reapplied. After 1 mL was sampled, the pore water was transferred into 1 mL disposable syringes using the three-way stopcock, sealed with a cap, and instantly analyzed for dissolved iron. The syringes were then left connected to the rhizons until about 10 mL of pore water had been retrieved, which took about 10 min.
On parallel cores, we sampled large volumes of pore water (approx. 60 mL) for analysis of oxygen stable isotopes in dissolved inorganic phosphate using the rhizon technique described above. For obtaining such large volumes, we took integrated samples by using two rhizons beside each other and attributed the sample to the respective depth interval.
Sediment samples were collected at each station from a parallel core. We extruded the sediment in slices of 1 cm using an upright piston and collected them in 30 mL plastic cups.

6.1.2. Onboard analyses

Dissolved iron (Fe^{2+}) was detected photometrically (Merck SQ 118 photometer) at a wavelength of 565 nm. An iron sensitive color complex was formed by adding 1 mL of plain sample to 50 µL of a ferrospectral reagent in disposable polystyrene cuvettes. In case of high iron concentrations, the original sample was diluted with oxygen free pure water to match the respective calibration range.

Dissolved phosphate (PO_4^{3-}) was determined photometrically (Merck SQ 118 photometer) using the classic molybdenum blue method. About 1 mL of sample was mixed with 50 µL of an ammonium molybdate solution in a disposable polysterene cuvette, and spiked with 50 µL of an ascorbic acid solution. The phosphomolybdate complex was thus reduced to molybdenum blue, which was determined at a wavelength of 820 nm.

Dissolved oxygen (O_2) was quantified using a modification of the original Winkler titration protocol described in Grasshoff et al. (1999). Immediately after retrieval of the bottom water samples, a graduated bottle with glas stopper was thoroughly flushed with sample, filled and carefully closed with the stopper. Sample O_2 was then fixed by adding 1 mL of manganese chloride solution and 1 mL of potassium iodide/potassium hydroxide solution and stirring the sample on a magnetic stirrer plate. During settling of the precipitates, the bottles were kept in a dark refrigerator for approx. 3 h. The precipitates were then re-dissolved with 1 mL of sulfuric acid, amended with a starch indicator solution (sensitive for free iodine) and titrated against a 0.01 M sodium thiosulfate solution. The endpoint was detected visually when (a) the blue coloration of the indicator had disappeared and (b) the solution stayed clear with further amendment of sodium thiosulfate. The volume of thiosulfate solution was recorded and used to calculate the concentration of dissolved O_2 in the sample.

6.1.3. Sample conservation and storage for further laboratory analyses

Solid sediment samples for elemental analysis and the determination of iron and phosphate mineral phases and organic matter quality were immediately frozen at 40 °C.
Beside the water aliquots used in onboard analyses, we collected the following sample splits for onshore laboratory analyses: 40 µL of sample diluted with 3960 µL for anion analysis, 1 mL of sample diluted with 9 mL of 1% HNO_3 for cation analysis, 2 mL of sample preserved with zinc acetate solution for DIC analysis, and 4 mL of sample for water $\delta^{18}O$ determination. The rest of the sample was kept without addition of preservatives. The large volume water samples for phosphate $\delta^{18}O$ analysis were filtered (0.2 µm cellulose acetate membrane) using either a modified in situ pump, pressure filtration or vacuum filtration, and filled into acid-washed (diluted supra pure grade HNO_3) HDPE bottles or 10 L canisters. An overview of samples and planned analyses can be found in Table 2.

Table 2. Samples and parameters measured onboard and onshore in samples of water column (ROS, ISP), BBL (BWS), pore water and sediments (MUC)

	onboard data		lab data							
station	*aqueous*		*aqueous*				*particulate/solid*		*isotopes*	
	Fe^{2+}	PO_4^{3-}	NH_4^+	DIC	anions	cations	elements	Fe/P species	$\delta^{18}O_P$	$\delta^{18}O_W$
14101	BWS	BWS	BWS	BWS	BWS	BWS			BWS	BWS
14102	ROS BWS MUC	ROS BWS MUC	ROS BWS MUC	ROS BWS MUC	ROS BWS MUC	ROS BWS MUC	ISP BWS MUC	ISP BWS MUC	ROS, ISP BWS MUC	ROS BWS MUC
14103	ROS BWS MUC	ROS BWS MUC	ROS BWS MUC	ROS BWS MUC	ROS BWS MUC	ROS BWS MUC	ISP BWS MUC	ISP BWS MUC	ROS, ISP BWS MUC	ROS BWS MUC
14105	ROS BWS MUC	ROS BWS MUC	ROS BWS MUC	ROS BWS MUC	ROS BWS MUC	ROS BWS MUC	ISP BWS MUC	ISP BWS MUC	ROS, ISP BWS MUC	ROS BWS MUC
14107	MUC	MUC	MUC	MUC	MUC	MUC	MUC	MUC		

6.1.4. Preliminary onboard results

Water column samples—Dissolved iron (Fe^{2+}) was absent in all samples retrieved from the rosette hydrocast. As dissolved O_2 was measured in CTD casts prior to water sampling (see Chapter Y), it was not surprising that we did not detect Fe^{2+} in the water column (Figure 18). Phosphate (PO_4^{3-}) concentrations were in a range of 0.5 to 2.2 μmol L^{-1} as known from earlier cruises to this region. The concentrations generally increased with water depth (Figure 18).

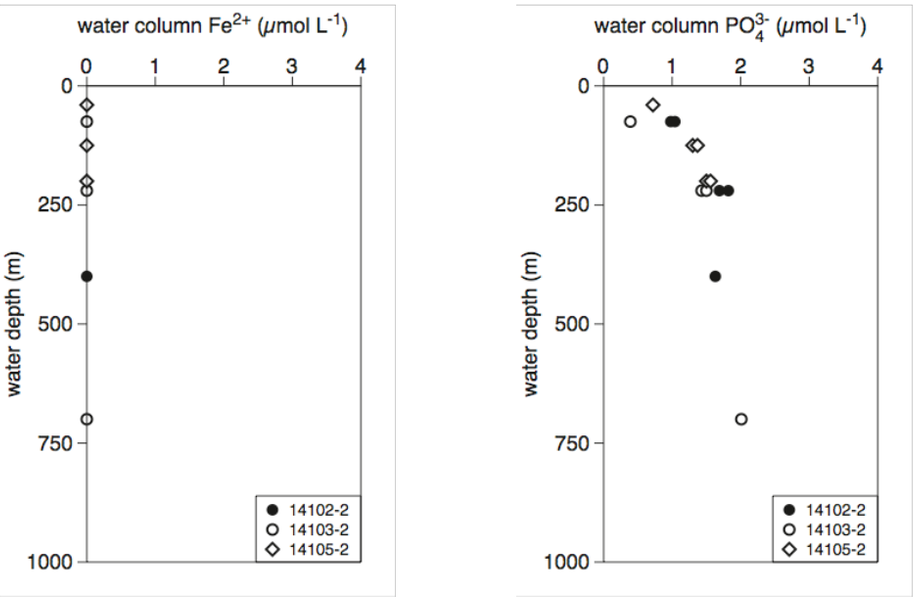


Figure 18. Concentrations of dissolved iron (left panel, Fe^{2+}) and phosphate (right panel, PO_4^{3-}) in water column samples of station GeoB14102, 14103, and 14105.

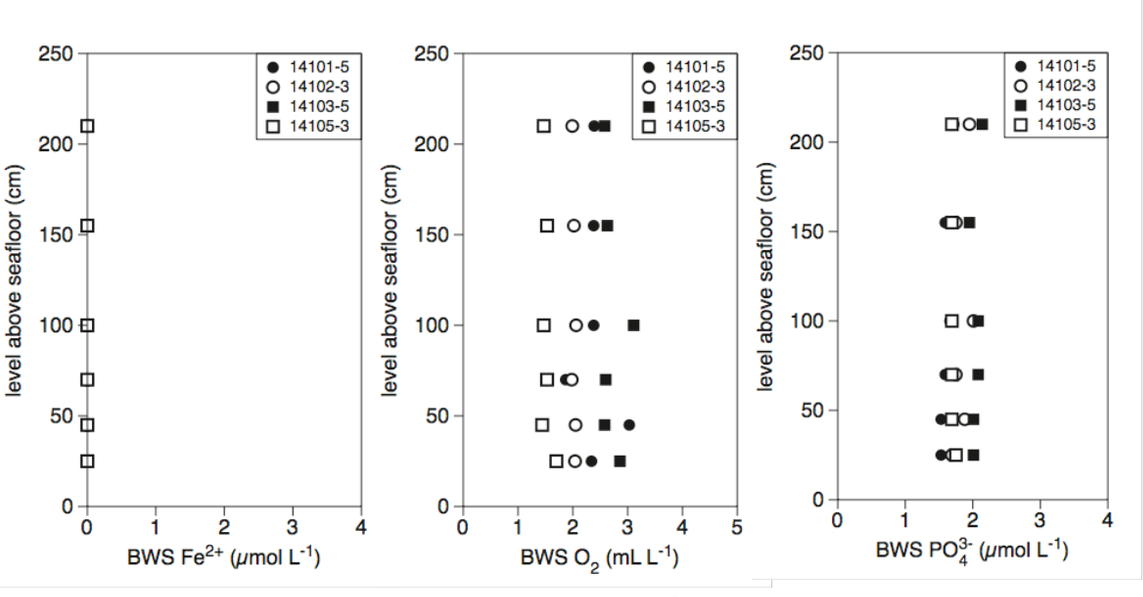


Figure 19. Concentrations of dissolved iron (left panel, Fe^{2+}), dissolved oxygen (mid panel, O_2) and phosphate (right panel, PO_4^{3-}) in bottom water samples of station GeoB14101, 14102, 14103, and 14105.

Bottom water samples

As in the water column, we did not detect free dissolved Fe^{2+} in the bottom water (Figure 19). This observation matched the presence of dissolved O_2 in the bottom waters. Lowest concentrations (1.4 to 1.7 mL L^1) were found at station GeoB14105; highest concentrations (2.6 to 3.1 mL L^1) were found at station GeoB14103 (Figure 19). Phosphate did not reveal pronounced profiles in the bottom water, and was in an order of magnitude similar to the deep water column samples (Figure 19).

Sediment pore water samples
We analyzed pore water concentrations of Fe^{2+} and PO_4^{3-} in undisturbed cores of surface sediment. Except for Station 14102 - where we could not detect Fe^{2+} in the pore water samples, probably due to deep oxygen penetration into the coarse, sandy sediments - all sites revealed classic downcore pattern that suggested iron reduction in the upper 5 to 10 cm of the seabed (Figure 20). The corresponding phosphate profiles of matched our expectation of high concentrations in the upper sediment layers, where mineralization of organic matter and reductive dissolution of iron oxide minerals are main sources of PO_4^{3-} to the pore waters (Figure 20).

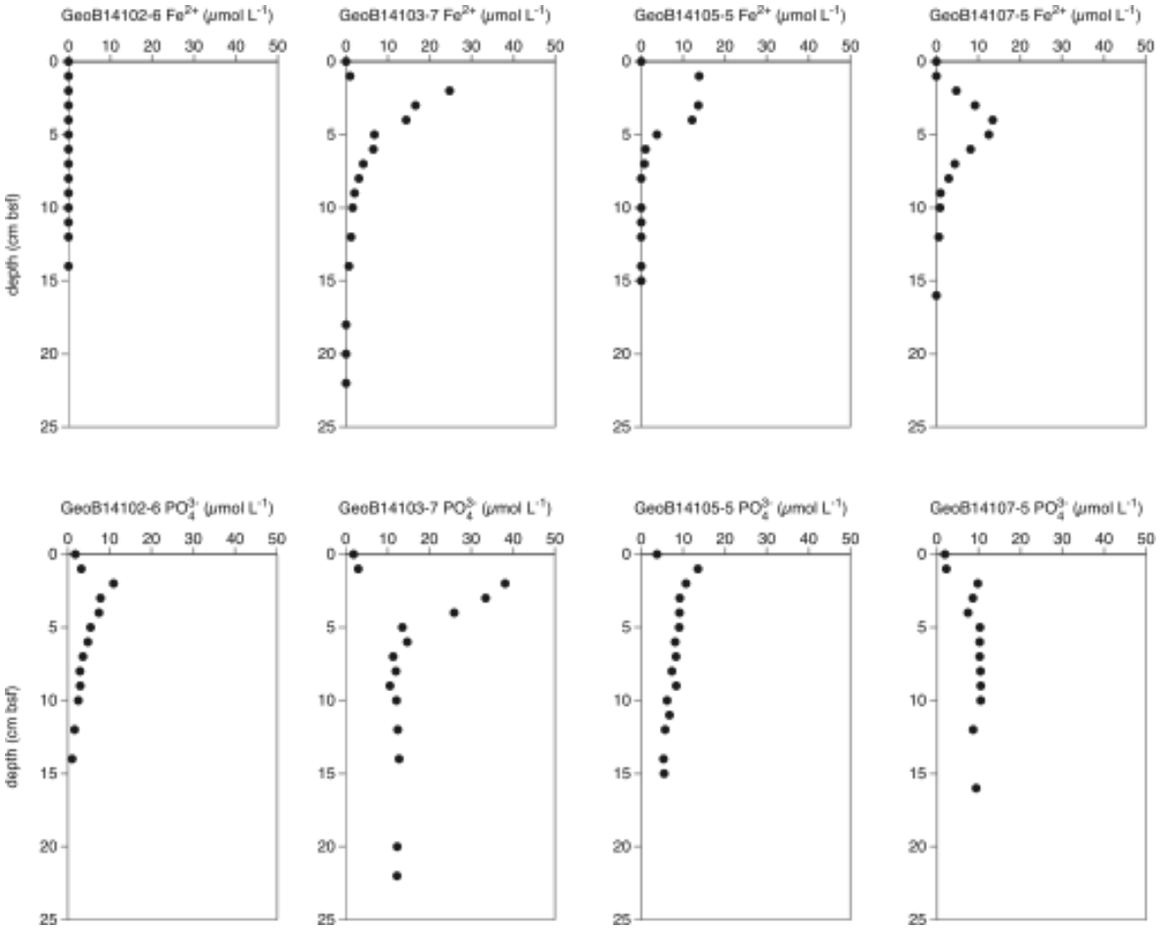


Figure 20. Pore water concentrations of dissolved iron (Fe^{2+}, top) and phosphate (PO_4^{3-}, bottom) in surface sediment cores at stations 14102, 14103, 14105 and 14107 (left to right).

7. Marine microbiology and biogeochemistry

Sarah Sokoll and Marcel Günter

Nitrogen (N) is a component of all organic material, therefore this element and the various processes responsible for the conversion of nitrogen into its different oxidation states are of great interest for the marine biogeochemistry. Among all the different processes in the highly complex N-cycle the two known processes responsible for the N-loss denitrification and anammox are in our focus. So far the knowledge of the nitrogen turnover in the BBL is poor and only few studies are published regarding the N-loss in the sediments of the northwest African continental margin.
In order to investigate the various processes in the N-cycle mediated by microorganisms, we conducted incubation experiments with sediment and water samples using ^{15}N stable isotopes. With this approach it will be possible to calculate rates of the N conversions by measuring the ^{15}N percentage in different N compounds. Moreover we will be able to analyse and characterize the microbial communities in terms of abundance and phylogeny in sediment and water samples taken across the continental margin.

7.1. Sampling, processing and conservation

For nutrient analyses in the lab we retrieved water samples of the water column from Niskin bottles of the rosette as well as from 6 depths of the BBL with the BWS as described in an earlier section (X.1.1). The samples were immediately frozen, stored at -20°C and shipped on dry ice for further analyses in the lab. Water samples for ammonium analyses were taken in 50 ml acid-washed (10% HCl) centrifuge tubes and processed on board as described below.
At four stations on transect 1 (GeoB14101, 14102, 14103 and 14105) samples were taken with the BWS at the depths 25, 70 and 155 cm above seafloor for ^{15}N incubation experiments. Therefore water was sampled in serum bottles, different ^{15}N labeled compounds were added and incubated in gastight vials (exetainers). The microbial activities in the exetainers were stopped at certain time points by addition of mercuric chloride. In addition unfixed and fixed (2% paraformaldehyde, PFA) water samples of the same depths were filtered through polycarbonate filters (GTTP-type, ∅ 45 mm, 0.22 µm pore-size) for DNA extractions and fluorescence in situ hybridization (FISH) analyses, respectively. All filters were stored at -40°C and shipped on dry ice. Further more samples for nutrient analyses and ammonium determination were taken from all six BWS depths at these stations.
Sediment samples were taken with a multicorer at four stations on transect 1 (GeoB14102, 14103, 14105 and 14107). For DNA and RNA extractions 6 cm diameter cores were sliced at a 2 cm resolution down to 8 cm depths, transferred to sterile centrifuge tubes, stored at -40°C and shipped on dry ice. Incubation experiments were performed with sediment samples taken also at a 2 cm resolution but from the 10 cm diameter sediment cores. The sediment was transferred into gastight bags, which were sealed afterwards. Degassed and non-degassed bottom water, according to the experimental design, was added and the remaining air was released through the glass-port in the bags. The labeled substances were added through the gastight port. Subsamples were taken through the port at certain time-points, transferred to exetainers and the reactions were stopped by addition of mercuric chloride.
On transect 2 at two stations (GeoB14113 and GeoB14115) incubation experiments were conducted with water column samples. Therefore different combinations of ^{15}N and ^{13}C labeled compounds were added and incubated in serum bottles for determination of bulk incorporation and Halogen In Situ Hybridization Secondary Ion Mass Spectroscopy (HISH-SIMS) analyses, respectively. In addition samples were incubated in exetainers for rate measurements as described above. The samples for bulk incorporation were retrieved by filtration through pre-combusted glass-fiber filters (GF/F-type, ∅ 25 mm, 0.22 µm pore-size). The HISH-SIMS samples were fixed with 1% PFA and filtered through gold-palladium coated polycarbonate filters (GTTP-type, ∅ 25 mm, 0.22 µm pore-size). Moreover samples for DNA extraction and FISH analyses were taken. An overview about the taken samples is given by table 3.

Table 3: Overview about the samples taken during cruise P398 for analyzing onboard and in the MPI. BWS: bottom water sampler, ROS: CTD-rosette, MUC: multicorer

Station	Gear	Samples							
		NH_4^+	Nutrients	Incubations	HISH-SIMS filter	FISH filter	DNA filter	DNA samples	RNA samples
GeoB14101-5	BWS	x	x	x		x	x		
GeoB14102-2	ROS	x	x						
GeoB14102-3	BWS	x	x	x		x	x		
GeoB14102-4 to 6	MUC			x				x	x
GeoB14103-2	ROS	x	x						
GeoB14103-5	BWS	x	x	x		x	x		
GeoB14103-6 to 7	MUC			x				x	x
GeoB14105-2	ROS	x	x						
GeoB14105-3	BWS	x	x	x		x	x		
GeoB14105-4 to 6	MUC			x				x	x
GeoB14107-2	ROS	x	x						
GeoB14107-3 to 5	MUC			x				x	x
GeoB14113-1	ROS	x	x	x	x	x	x		
GeoB14115-1	ROS	x	x	x	x	x	x		

7.2. Onboard analyses of ammonium in the water samples

During the cruise we were able to determine the ammonium concentrations in water samples of the water column and the BBL fluorometrically according to Holmes et al. (1999). The fluorescence complex formed by ortho-phthaldialdehyde (OPA) and ammonium was measured with a Turner Designs fluorometer. Samples were measured against standard sets with low concentrations (32.2, 62.4, 124.7 and 186.5 nM) and higher concentrations (0.25, 0.50, 0.75, 1.00 µM) of ammonium. Sample and standards with volumes of 40 ml in acid-washed (10% HCl) centrifuge tubes were spiked with 10 ml of the working solution containing OPA, sodium sulfite and sodium tetraborate and stored 3 to 12 h at 4°C to allow the forming of the complex prior to the fluorescence measurement.

7.3. Preliminary results of onboard ammonium measurements

Ammonium concentrations in the samples of the BWS varied between 104 and 1513 nmol l^{-1} NH_4^+, whereas the samples of the water column carried out concentrations ranging from 41 to 1183 nmol l^{-1} NH_4^+. A profile for ammonium concentrations with increase of ammonium concentrations towards the chlorophyll maximum and again in the BBL is shown in Figure 21.

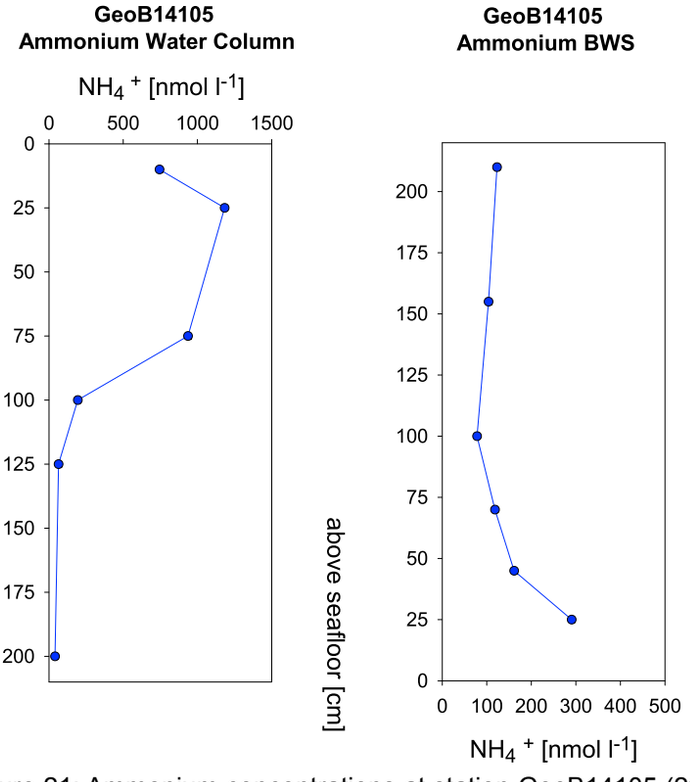


Figure 21: Ammonium concentrations at station GeoB14105 (262 m water depth) of the rosette and BWS samples.

8. Sampling of particulate material with In Situ-Pumps for analysis of element concentrations

Wiebke Kallweit

Marine sediments are an important archive for the reconstruction of palaeoclimatic conditions. Variations in the abundance and composition of terrigenous material within sediments can be used to reveal information about climate changes in the earth's past and its influence on e.g vegetation and continental runoff. Nevertheless, a substantial amount of terrigenous material is altered during transport, but the extent of these alterations and its impact on the reconstruction of palaeoclimatic conditions is only partially known. It is therefore important to gain more information about the changes in element concentration that occur throughout the water column. These can be compared to the primary signal of terrigenous material transported to the ocean and the sedimentary signal used for palaeoclimatic reconstructions.
During cruise P398 samples of particulate matter from the water column were taken at five stations. For this purpose In Situ-Pumps were equipped with cellulose actetate filters (pore diameter 0.45 µm). Sampling depths were chosen based on CTD-profiles where the positions of nepheloid layers in the water column became visible. After deployment filters were dried and stored in plastic bags at

4°C. At the University of Bremen total digestions will be carried out and element concentrations will be measured by ICP-OES.
Table 4. In-situ Pump samples of geochemistry analysis.

station	Latitude (°N)	Longitude (°W)	sampling depth (m)
GeoB14102-2	21°34.2510’	17°31.5041’	210, 310, 410
GeoB14103-3	21°36.2051’	17°48.2039’	340, 550, 700
GeoB14103-4	21°36.2082’	17°48.2088’	80, 120, 470
GeoB14104-3	21°38.0058’	18°02.0040’	650, 900, 1300
GeoB14104-4	21°37.9992’	18°02.0148’	80, 30, 453
GeoB14106-3	21°20.9969’	17°59.9862’	620, 850, 1210
GeoB14106-4	21°20.9981’	17°59.9951’	130, 240, 380
GeoB14110-2	24°11.4672’	17°11.3208’	300, 1034, 1250, 1550

9. **Geological sampling**

Gerard Versteegh, Karin Zonneveld

A multicorer was deployed to recover the sediment-water interface, the undisturbed sediment surface, and the overlying water. The device used during the cruises was equipped with six large and four small (10 and 6 cm inner diameter, respectively) 60 cm long plastic tubes. Some tubes were pre-drilled for pore-water analyses. However, at some stations these particular tubes were not filled with sediments and new holes had to be drilled in order to apply the rhizon technique. In general at each station the cores were shared amongst the different scientific disciplines.

Oxygen measurements have been performed with a fiber optic oxygen sensor (FIBOX3) using a micromanipulator. Oxygen concentrations were completely depleted within the upper mm of the sediment within the OMZ that exists on the Mauretanian shelf. Within the suboxic zone in the lower part of the OMZ at the outer shelf, oxygen penetrates until about 7 cm. Oxygen penetration reaches about xx mm within cores GeoB xxxx and GeoB xxx where bottom waters are well oxygenated. Oxygen measurements have been performed with a fiber optic oxygen sensor (FIBOX3) using a micromanipulator. Oxygen concentrations were completely depleted within the upper mm of the sediment within the OMZ that exists on the Mauretanian shelf (site GeoB 14105-5). Within the suboxic and oxic zones in the lower part of the OMZ and below the OMZ at the outer shelf, oxygen penetrates until about 16 mm and 28 mm within cores GeoB 14103-7 and GeoB 14107-3 respectively.

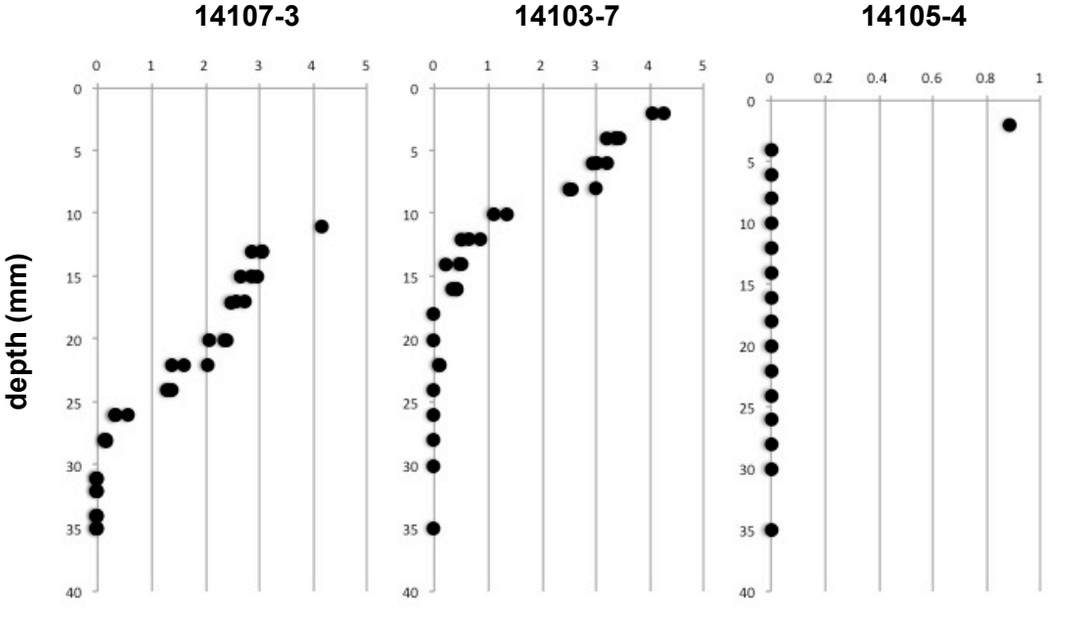


Figure 22. Oxygen concentrations in bottom sediments.

GeoB 14102-4, 5, 6

Date: 04-April-2010 Pos: 21°34.19′ N, 17°31.53′ E
water depth: 485m Core length: 18cm

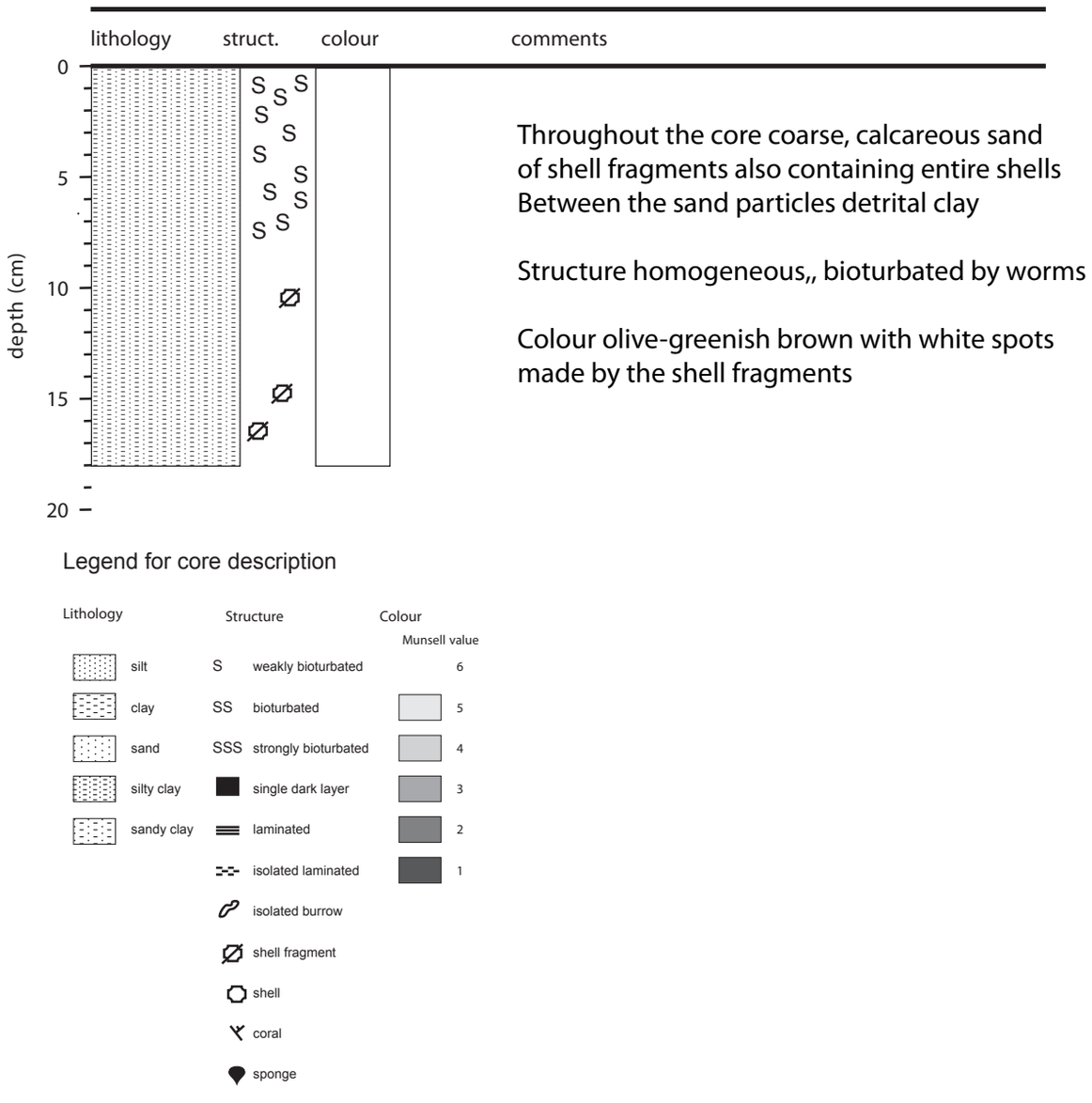


Figure 23. Core description of MUC GeoB 14102

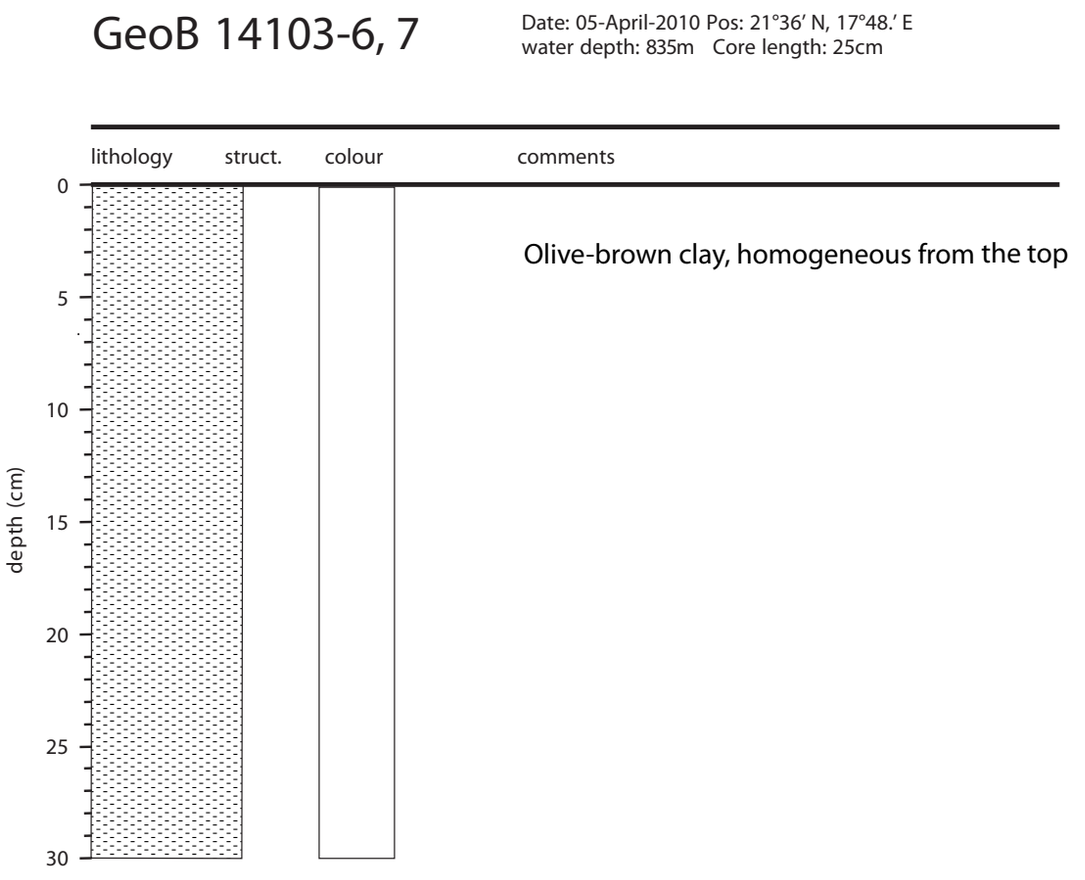


Figure 24. Core description of MUC GeoB 14103

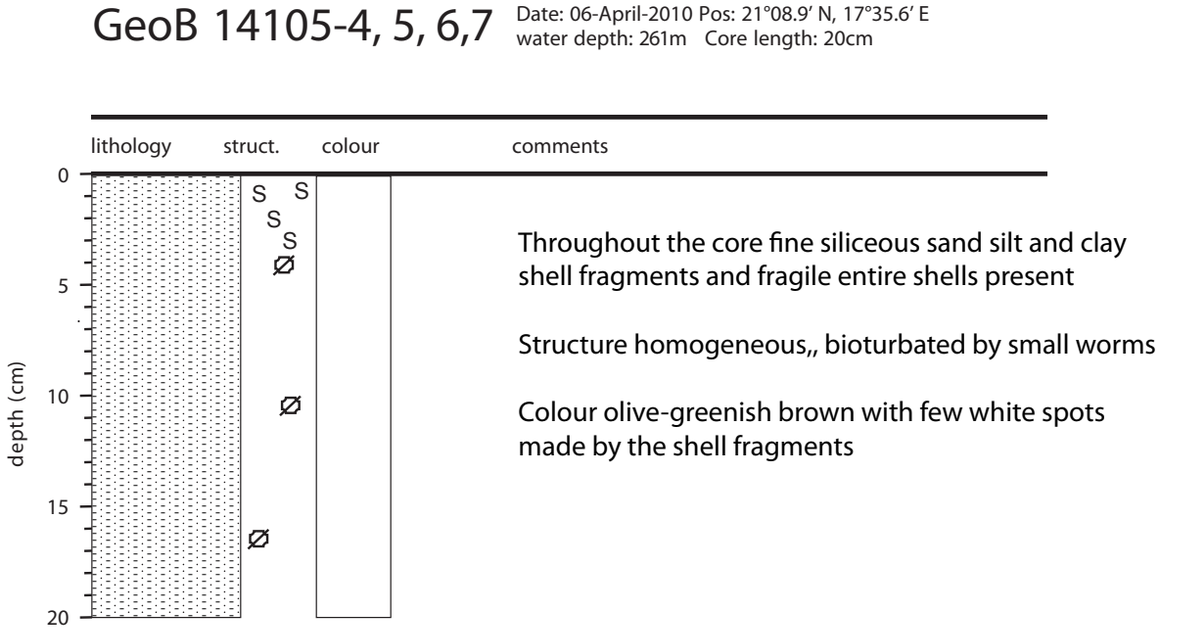
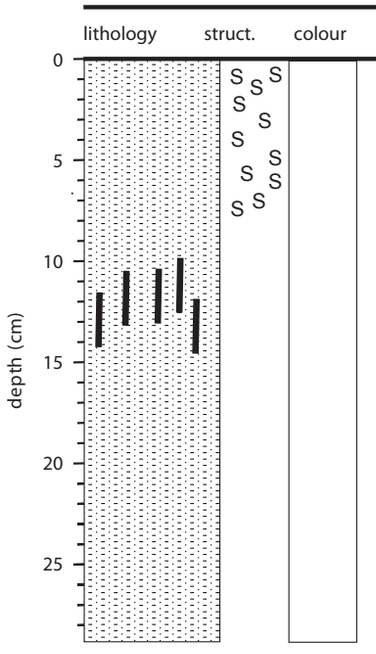


Figure 25. Core description of MUC GeoB 14105

GeoB 14107-3, 4, 5

Date: 07-April-2010 Pos: 21°10.2′ N, 17°38.6′ E
water depth: 361m Core length: 20cm



Throughout the core fine silliceous sand and some shell fragments, mixed with clay. (The material is sandy enough to be problematic with multicoring since it does not stick to the tubes)

Structure more or less homogeneous, heavily bioturbaed by small, needle sized worms sticking out of the surface and larger infauna.

Colour olive-greenish brown with white spots made by the shell fragments

Between 10 and 15 cm, black vertical stripes of reduced sulphur or manganese

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12. Appendices

Table 5. Station list. Abbreviations used: MUC: multicorer, CTD/ROS: rosette water sampler + CTD, ISP: in-situ pumps, WS: water sampler with bucket, DC, Dust collector , BWS: Bottom Water Sampler.

Station GeoB No.	Station Ship No.	Date	Device	Time [UTC] seafloor / maximum wire length	Latitude [N] digital - ship log	Longitude [W] digital - ship log	Water depth [m]	Samples / Core recovery
14101-1	118-1	03.04.10	CTD	01:55	23.43323	-17.08353	454.0	
14101-2	118-3	03.04.10	ISP	03:45	23.43313	-17.08343	453.0	
14101-3	118-4	03.04.10	BWS	07:32	23.43322	-17.08340	453.0	no recovery
14101-4	118-6	03.04.10	MUC	09:09	23.43342	-17.08427	454.0	no recovery
14101-5	118-7	03.04.10	BWS	11:22	23.43347	-17.08345	453.0	
14101-6	117-1	02.04.10	DC	15:57	24.53353	-16.64632	1143	
14102-1	119-1	04.04.10	CTD	03:10	21.56948	-17.52518	484.0	
14102-2	119-2	04.04.10	Ros/ISP	03:54	21.57122	-17.52487	487.0	
14102-3	119-3	04.04.10	BWS	08:31	21.57005	-17.52508	504.0	
14102-4	119-5	04.04.10	MUC	09:59	21.56992	-17.52548	506.0	partly recovery
14102-5	119-6	04.04.10	MUC	11:42	21.56982	-17.52535	486.0	partly recovery
14102-6	119-7	04.04.10	MUC	12:31	21.56978	-17.52527	485.0	partly recovery
14103-1	120-1	04.04.10	CTD	21:48	21.60363	-17.80353	835.0	
14103-2	120-2	04.04.10	CTD/Ros	22:46	21.60333	-17.80363	835.0	
14103-3	120-3	04.04.10	Ros/ISP	23:38	21.60345	-17.80327	834.0	
14103-4	120-4	05.04.10	ISP	03:54	21.60340	-17.80353	854.0	
14103-5	120-5	05.04.10	BWS	07:41	21.60318	-17.80360	834.0	
14103-6	120-6	05.04.10	MUC	08:57	21.60328	-17.80402	835.0	partly recovery
14103-7	120-7	05.04.10	MUC	09:57	21.60305	-17.80392	855.0	partly recovery
14104-1	121-1	05.04.10	CTD	13:56	21.63323	-18.03332	1458	
14104-2	121-2	05.04.10	CTD/Ros	15:05	21.63327	-18.03343	1436	
14104-3	121-3	05.04.10	ISP	15:47	21.63338	-18.03333	1435	
14104-4	121-4	05.04.10	ISP	19:20	21.63333	-18.03367	1435	

14105-1	122-1	06.04.10	CTD	04:59	21.14877	-17.59403	263.0	
14105-2	122-2	06.04.10	CTD/Ros	05:58	21.14868	-17.59327	261.0	
14105-3	122-3	06.04.10	BWS	07:21	21.14855	-17.59293	261.0	
14105-4	122-4	06.04.10	MUC	08:13	21.14840	-17.59278	282.0	partly recovery
14105-5	122-5	06.04.10	MUC	08:47	21.14850	-17.59300	261.0	partly recovery
14105-6	122-6	06.04.10	MUC	09:21	21.14848	-17.59298	259.0	partly recovery
14105-7	122-7	06.04.10	MUC	09:46	21.14877	-17.59317	259.0	partly recovery
14106-1	123-1	06.04.10	CTD	15:24	21.35027	-17.99993	1269	
14106-2	123-2	06.04.10	CTD/Ros	16:25	21.34995	-18.00003	1269	
14106-3	123-3	06.04.10	ISP	16:45	21.34995	-17.99982	1268	
14106-4	123-4	06.04.10	ISP	19:46	21.35002	-18.00002	1260	
14107-1	124-1	07.04.10	CTD	05:14	21.17047	-17.64432	383.0	
14107-2	124-2	07.04.10	CTD/Ros	05:59	21.17063	-17.64423	360.0	
14107-3	124-3	07.04.10	MUC	07:09	21.17053	-17.64425	359.0	partly recovery
14107-4	124-4	07.04.10	MUC	07:46	21.17078	-17.64453	359.0	partly recovery
14107-5	124-5	07.04.10	MUC	08:18	21.17053	-17.64413	361.0	partly recovery
14108-1	125-1	07.04.10	CTD	17:32	21.70043	-18.56750	2690	
14108-2	126-1	07.04.10	CTD	20:02	21.71718	-18.55708	2690	
14108-3	126-2	07.04.10	Ros/ISP	20:55	21.71683	-18.55640	2690	
14109-1	127-1	08.04.10	CTD	09:00	22.53815	-18.08768	2640	to 1500 m, upcast 0.3m/s
14109-2	127-2	08.04.10	ISP	11:02	22.53588	-18.08945	2645	to 1500 m
14110-1	128-1	09.04.10	CTD	06:58	24.19433	-17.18957	1606	to 250 m
14110-2	128-2	09.04.10	ISP	09:00	24.19105	-17.18848	1597	to 250 m
14111-1	129-1	09.04.10	CTD/Ros	14:27	24.35840	-17.09985	1735	to 250 m
14111-2	129-2	09.04.10	ISP	15:41	24.35857	-17.10032	1736	to 250 m

14112-1	130-1	10.04.10	CTD/Ros	06:58	25.54492	-16.18542	1117	to 250 m
14112-2	130-2	10.04.10	ISP	07:33	25.54503	-16.18588	1118	to 250 m
14113-1	131-1	10.04.10	CTD/Ros	15:05	26.05802	-15.69787	1212	to 250 m
14113-2	131-2	10.04.10	ISP	15:30	26.05880	-15.69833	1214	to 250 m
14113-3	131-3	10.04.10	WS	15:00			1201	surface
14114-1	132-1	11.04.10	CTD/Ros	06:58	27.12082	-14.20425	1748	to 250 m
14114-2	132-2	11.04.10	ISP	07:30	27.12082	-14.20328	1748	to 250 m
14115-1	133-1	11.04.10	CTD/Ros	15:25	27.59545	-13.72372	1105	
14115-2	133-2	11.04.10	ISP	15:56	27.59607	-13.72253	1100	
14115-3		11.04.10	WS	15:40				
14116-1	134-1	12.04.10	CTD/Ros	06:58	28.90237	-12.48418	430.0	
14116-2	134-2	12.04.10	ISP	07:27	28.90103	-12.48772	428.0	
14116-3		12.04.10	WS	07:45				
14117-1	135-1	12.04.10	CTD/Ros	15:05	29.44853	-12.05133	1598	
14117-2	135-2	12.04.10	ISP	15:34	29.44948	-12.05432	1612	
14117-3		12.04.10	WS	15:45				
14118-1	136-1	13.04.10	CTD/Ros	06:58	31.21682	-11.48643	2229	
14118-2	136-2	13.04.10	ISP	07:30	31.21678	-11.48303	2224	
14118-3	136-3	13.04.10	CTD/Ros	09:49	31.21723	-11.48495	2227	
14119-1	137-1	13.04.10	CTD	15:13	31.91717	-11.26570	2823	
14119-2	137-2	13.04.10	CTD/Ros/ ISP	17:44	31.91690	-11.26668	2822	
14119-3		13.04.10	WS	18:18				
14120-1	138-1	14.04.10	CTD	08:24	33.40578	-10.79633	4318	
14120-2	138-2	14.04.10	CTD/Ros/ ISP	08:50	33.40800	-10.79898	4318	
14121-1	139-1	14.04.10	CTD	13:42	33.69635	-10.69395	4354	
14121-2	139-2	14.04.10	ISP	14:00	33.69653	-10.69673	4354	
14121-3		14.04.10	DC	14:00	33.69653	-10.69673	4354	

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