GEOMAR REPORT

FS SONNE
FAHRTBERICHT SO129
CRUISE REPORT SO129

BIGSET

BIOGEOCHEMICAL TRANSPORT
OF MATTER AND ENERGY IN THE DEEP SEA

PORT SULTAN QUABOOS - DUBAI
JANUARY 30 - MARCH 9, 1998

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Edited by
Olaf Pfannkuche and Christine Utecht
with contributions of cruise participants

GEOMAR
Forschungszentrum
für marine Geowissenschaften
der Christian-Albrechts-Universität
zu Kiel

KIEL 1999

GEOMAR REPORT 80

GEOMAR
Research Center
for Marine Geosciences
Christian Albrechts University
in Kiel

Redaktion der Serie: Gerhard Haass

GEOMAR REPORT
ISSN 0936 - 5788

GEOMAR
Forschungszentrum
für marine Geowissenschaften
Wischhofstr. 1-3
D - 24148 Kiel
Tel. (0431) 600-2555, 600-2505

Managing Editor: Gerhard Haass

GEOMAR REPORT
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GEOMAR
Research Center
for Marine Geosciences
Wischhofstr. 1-3
D - 24148 Kiel
Tel. (49) 431 / 600-2555, 600-2505

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1. Introduction

The 129th expedition of RV SONNE started on 31 January 1998 in Muscat (Sultanate of Oman) and ended on 8 March 1998 in Dubai (United Arab Emirates). The expedition was dedicated to the research programmes „Biogeochemical Transports of Matter and Energy in the Deep Sea" (BIGSET) and German Joint Global Ocean Flux Study - Arabian Sea (German JGOFS-Arabian Sea).

BIGSET is a joint programme of two research institutes and five university institutions (coordination, GEOMAR, Kiel) within the new national research focus „Deep Sea Research" sponsored by the Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie (Table 1). BIGSET is concerned with the biogeochemical processes in the ecosystem of the deep sea. Main objective is the fate of sedimenting organic matter. Investigations concentrate to the abyssopelagic and benthic realm with the benthic boundary layer (BBL) as a focal point. The BBL is operationally defined as a zone extending from the clear water minimum (about 500 m above the sea floor) to about one metre into the sediment, containing the nepheloid layer, the bottom contact water and the bioturbated sediment horizons (Fig. 4). The activity of various groups of organisms inhabiting the BBL from the bacteria to the megabenthos and the nekton acts as a generator of the chemical fluxes and partly also for the physical mixing processes. The quantification of biochemical and geochemical fluxes (esp. carbon compounds, opal) within the BBL, the identification of the role of different ecological groups and their interactions are key questions. The results will enlarge our knowledge of deep ocean fluxes and of the early diagenesis of pelagic sediments, thus also being important for a better interpretation of the geological record.

Main objectives of BIGSET are:

I. Investigations on the functional interrelations within the ecosystem deep sea
II. Parameterization and quantification of the bentho-pelagic coupling to describe the net fluxes of inorganic and organic matter, esp. carbon compounds and opal, on different time and space scales within the benthic boundary layer
III. Enhancement of our knowledge and modelling of diagenetic processes of deep-sea sediments
IV. Development and use of advanced deep-sea technologies
V. Modelling of benthic fluxes on different scales (small scale, basin wide)

Tab. 1: BIGSET programme. The joint programme is coordinated by GEOMAR and is comprised of the following subprojects (**SP**):

Coordination joint programme BIGSET (O. Pfannkuche, GEOMAR)
SP-1 Fluxes of matter through the benthic community (GEOMAR)
SP-2 Benthic resuspension, bioturbation and irrigation (Universität Rostock)
SP-3 Microbial early diagenetic processes (Institut für Ostseeforschung, Warnemünde)
SP-4 The preservation potential of primary climatic and environmental signals in the deep sea (Universität Hamburg)
SP-5 Near bottom particle flux, habitat demands and early diagenetic processes in the benthic deep sea foraminiferal community (Universität Tübingen)
SP-6 Interactions between the seasonality in benthic turn over rates and the distribution of trace elements in deep-sea sediments (Universität Bremen)
SP-7 Reactions and fluxes in surface sediments: Geochemical measurements and modelling of the biogeochemical system (GEOMAR)
SP-8 Biogenic, lithogenic, aeolic and hydrothermal signals of trace elements in deep sea sediments (Universität Oldenburg)

2. Objectives

The expedition SONNE SO129 aimed to assess carbon, nutrient and trace metal fluxes in the benthic boundary layer of the deep Arabian Sea, an oceanic area with episodically largely enhanced biogeochemical fluxes by the monsoon system.
Cruise SO129 was dedicated to the study the NE monsoon situation. BIGSET investigations were executed at 5 permanent stations in the central basin of the Arabian Sea since 1995 (Fig 1).

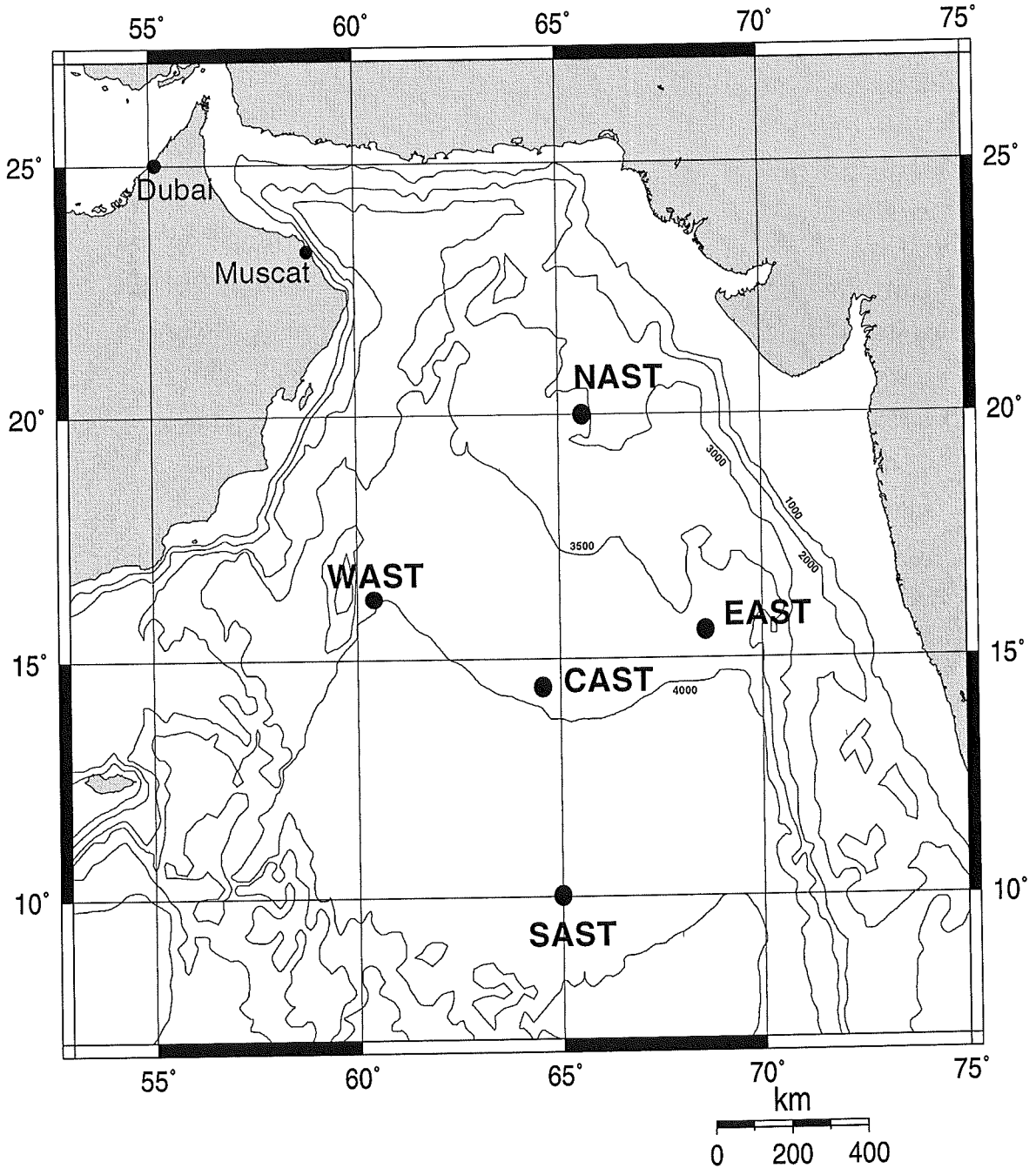

Fig.1: BIGSET main stations (Arabian Sea)

Since a couple of years investigations of vertical particle flux with sediment traps were carried out at stations WAST, CAST and EAST by a joint Indian/German project. The area of WAST and CAST was also a focal point of international JGOFS research in 1995 and of German JGOFS in 1995 and 1997. JGOFS will provide data mainly on the processes and fluxes in the upper mixed layer.
Since 1995 the benthic system of the deep Arabian Sea has been studied on four expeditions:

BIGSET Pilotphase
Cruise METEOR M31/3, 6 March - 22 March 1995 (HEMLEBEN et al. 1996)
Cruise METEOR M33/1, 9 September - 31 0ctober 1995 (LOCHTE et al. 1996)
BIGSET Programme
Cruise SONNE SO118, 31 March - 11 May 1997 (PFANNKUCHE & UTECHT 1998)
Cruise SONNE SO129, 31 January - 8 March 1998 (this report)

Besides the five main stations (Fig. 1) the deep basin (≤3000 m) of the Arabian Sea was covered by a grid of intermediate stations in order to enlarge the data base for basin wide extrapolation of biogeochemical fluxes. All stations investigated during the BIGSET Pilotphase and the BIGSET Programme are shown in Fig. 2.

List of all benthic stations / Arabian Sea
BIGSET Pilotphase and BIGSETProgramme

A 14°58.23'N / 54°22.25'E
B 15°49.56'N / 56°59.63'E
C 16°10.09'N / 59°46.31'E
D 17°45.06'N / 58°09.02'E
E 16°32.00'N / 55°19.86'E
WAST-S 16°03.04'N / 60°16.10'E
WAST-T 16°10.49'N / 59°46.00'E
SW 13°05.00'N / 62°45.00'E
WC 15°20.00'N / 62°20.00'E
NW 18°00.00'N / 62°49.00'E
WS 14°27.00'N / 61°39.23'E
SE 12°50.52'N / 66°48.02'E
EC 15°02.49'N / 66°42.79'E
NC 17°45.00'N / 65°44.97'E

NAST 20°00.00'N / 65°35.00'E
WAST 16°13.00'N / 60°16.00'E
CAST 14°25.00'N / 64°34.00'E
EAST 15°35.00'N / 68°34.00'E
SAST 10°02.00'N / 65°00.00'E

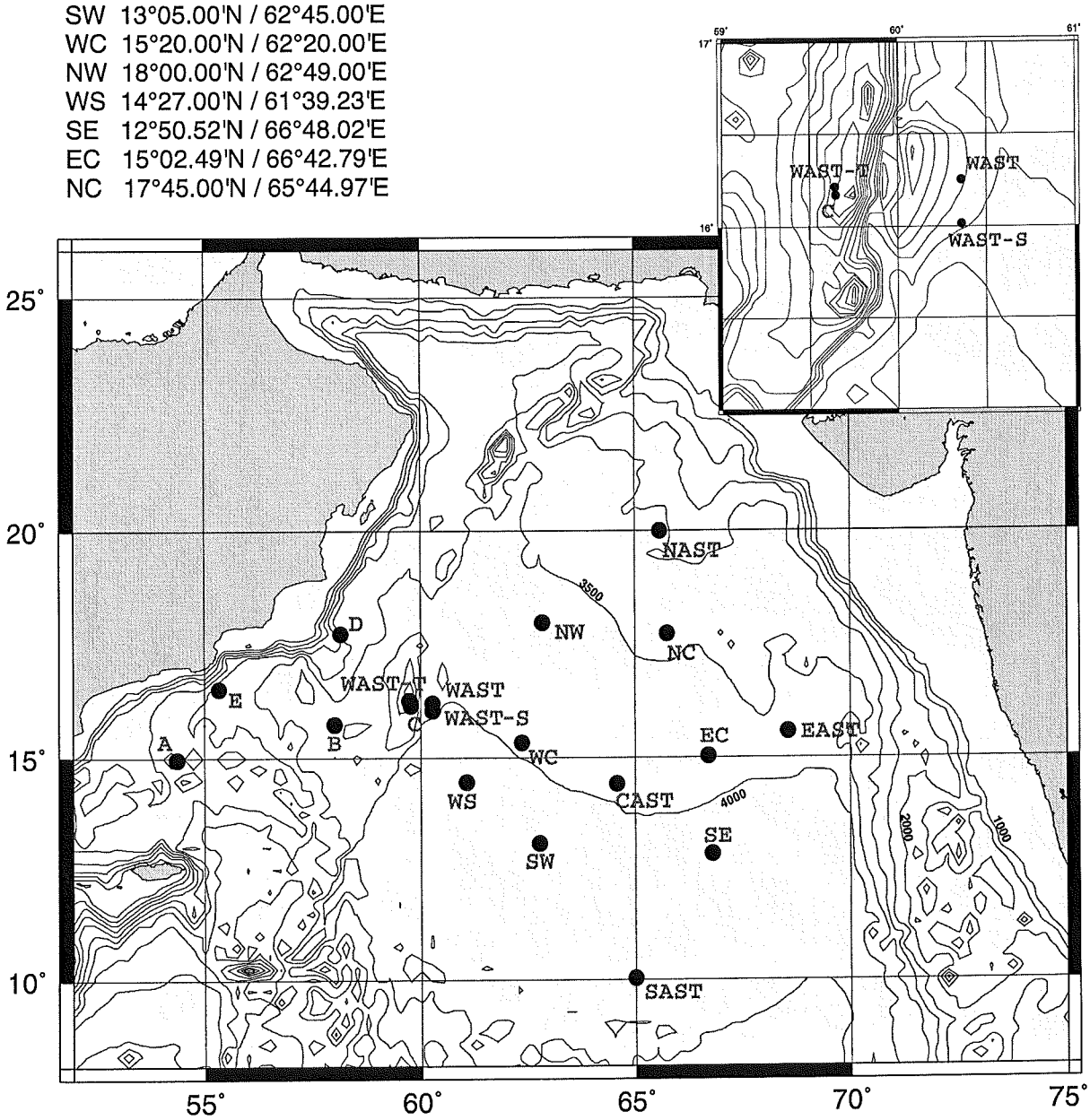

Fig.2: Benthic stations in the Arabian Sea investigated during BIGSET Pilotphase and BIGSET Programme.

The main driving force for hydrographical and biogeochemical processes in the Arabian Sea is the activity of the monsoon winds. The strong winds of the SW monsoon (June-September) and the NE monsoon (November-March) enhance new production in the euphotic zone resulting in an increased particle export from the upper mixed layer into the deep ocean.
A second production maximum appears during the NE monsoon (Fig. 2), with the NE winds induced by the winter cooling of the northern hemisphere playing an important role for thermohaline mixing. Because of this highly seasonal variability and the enhanced particle fluxes during the monsoon periods, which belong to the highest known sedimentation rates into the deep sea, the Arabian Sea represents a key area for our understanding of global biogeochemical fluxes into the deep sea. Samples from moored sediment traps (JGOFS-Indik, Indian/German cooperation) collected in time series provide us with information of the seasonal distribution and the amount of material transported into the deep sea. Above that, they reflect mixed surface layer processes (variations of the primary production, terrestrial entry) with little temporal delay and high temporal resolution. A comparison between primary productivity, export productivity, flux rates in different water depths and accumulation rates on the sediment surface therefore facilitates estimating the deposition at the sediment/water interface.
BIGSET benthic investigations of early diagenetic processes mediate between short time scales of oceanic surface layer processes and the long time scales of processes in sediment layers beneath the bioturbated and bioirrigated sediment surface. Besides benthic remineralisation rates, bioturbation, bioirrigation and pore water fluxes; the following aspects are of special interest in the BIGSET programme: The amount of trace elements in the organic material, the knowledge of steering mechanisms of the elements' contribution between solid phase and pore water. Another important aspect is the reconstruction of the sedimentation entry paths (aeolic-seasonal, fluvial-seasonal up to episodic, turbidical-episodical) which can be quantified by the trace element relations.
Below the biologically active sediment layer the remaining material is buried for geological time scales. In consequence deep-sea sediments represent the largest carbon storage of our planet. They also preserve the record of past climatic changes. Evidence has increased in the last years that global environmental changes happened much more rapidly and in the order of decades to centuries. In consequence the interpretation of carbon deposition under paleo-oceanographic and paleo-climatic conditions must consider the knowledge of the modification of the sedimentation signal by the „benthic filter".

Regarding the carbon flux bathy- and abyssopelagic zooplankton and nekton inclusive its benthopelagic components act as a mediator between the productive oceanic surface layer and the benthos. This objective is investigated by the zooplankton subproject of German Indian Ocean JGOFS. Plankton organisms use carbon, fixed in sinking particles through ingestion, assimilation and in metabolic processes. Through ingestion and defecation of particles zooplankton contributes with a specific pathway to the transport processes. To estimate the influence of zooplankton and nekton organisms on the carbon flux a quantification of its carbon requirements in relation to the measurable carbon entry (from sediment traps) and in relation to the other fauna components is necessary.
The following three basic particle fluxes were investigated in the near-bottom interface in the benthic boundary layer, which is defined as a region reaching from the clear-water minimum zone (CWM) across the nepheloid layer down to app. 1 m depth into the sediment:

- The particle flux into and in between the benthic boundary layer
- The remineralisation and solubilisation of particles in the BBL
- The deposition/accumulation below the BBL

The deep-sea floor is especially suitable for the investigation of oceanic material fluxes because of various reasons. The sediment/water interface is a stable physical boundary, at which mass fluxes can be measured by different techniques.
Two different methods are used in the BIGSET programme:
Modelling of pore water fluxes through measurements of nutrient concentration gradients and *in situ* measurements of benthic oxygen consumption rates in benthic chambers. The transport of dissolved material at the sediment/water interface originates from a combination of degradation processes of fast and slow decomposable organic material. The measured exchange rates can integrate variations of deposition rates, which facilitates estimating intermediate flux rates.
The sum of all carbon transport processes in the water column determines the rate of benthic deposition and mineralization. These processes include vertical and lateral transport of particles by physical properties as well as by organisms.

The main scientific objectives of the SONNE cruise 129 were:

I. Particle transport in the lower water column and the near-bottom interface

- determination of the vertical particle flux 500m above ground
- modification of the horizontal particle flux in the sediment-close bottom water
- modification of the resuspension in the sediment-close bottom water
- comparison of vertical and horizontal particle entries in the surface sediments
- modification of controlling factors regulating the particle fluxes and their changes

II. Deposition and Degradation of particulate organic substance

- measuring of *in situ* respiration rates of the sediment community
- microbial degradation of particles in the lower water column and in the surface sediments (aerobic degradation, nitrate reduction, sulfate reduction, methanogenesis)
- determination of qualitative and quantitative interrelations between POM-deposition rates and biochemical activity parameters (ETS, ATP, hydrolysis-enzyme-activities)
- investigation of the POM composition in sinking particles and surface sediment (POC, N, DOC, aminoacids, carbohydrates, HEXOSAMINE, C/N, $d^{13}N$, $d^{13}C$)
- investigation of the relation between POM deposition rate and POM composition
- formulation of kinetic rules for the POM deposition (rate as a function of POM-age, POM-composition, electronacceptor availabilty, POM-flux at the sediment/water interface, sedimentation rate)

III. Carbonate- and opal-solution

- determination of the carbonate and opal solution rates at particles from the lower water column and surface sediments
- review and if necessary a new formulation of the kinetic rules of the carbonate and opal solution

IV. Biogenic transport processes in the surface sediment

- quantification of the particle mixing by benthic organisms in the surface sediment (bioturbation, bioresuspension)
- quantification of the pore water and bottom water motion by benthic organisms (bioirrigation)
- review and if necessary a new formulation of the mathematic models of bioturbation and bioirrigation (Fick'sche Gesetze, nonlocal mixing)

V. Biology of the deep sea ecosystem

- analysis of structure and distribution of organisms in the lower water column (zooplankton and nekton) and in surface sediments (megafauna, macrofauna, meiofauna, bacteria)
- analysis of the trophic relations between selected groups of organisms
- description and quantification of biogenic structures and their role as intermediator of particle fluxes

VI. Paleo-oceanographic proxies and tracers

- determination of the trace element transports in particles from the water column into the sediment
- modification of the interchange between particulates bound and dissolved trace elements in the water column as well as in the surface sediment
- determination of the preservation potential of proxies during their transport through the water column and the early diagenesis in surface sediments
- formulation of a model, that quantifies the preservation and resolution of trace elements in the sediment under different milieu-conditions and therefore facilitating an improved interpretation of the paleo-signals in the sediment

VII. Assessment and modelling of biogeochemical processes in surface sediments

- assessment of material flux and turnover rates in the surface sediment
- analysis of the functional relations between the important physico-chemical factors, reactions and material transport in the surface sediment
- formulation of a kinetic model for the biogeochemical processes in the surface sediment based on the beforehand determined reaction kinetics and the beforehand achieved mathematic formulation of biogenic material transport

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PFANNKUCHE O. and C. UTECHT (1997) Cruise report SONNE 118. GEOMAR Forschungszentrum für marine Geowissenschaften der Universität Kiel, *GEOMAR Report,* **71**, 188pp.

3. Participants and participating institutes

Participants SONNE 129, scientific crew

Pfannkuche, Dr. Olaf	GEOMAR, Kiel (chief scientist)
Bayer, Katharina	IGP, Universität Tübingen, Tübingen
Boetius, Dr. Antje	IOW, Institut für Ostseeforschung, Warnemünde
Cremer, Axel	GEOMAR, Kiel
Cummerow, Svenja	IHF, Universität Hamburg, Hamburg
Dittert, Lars	Universität Bremen, Bremen
Grandel, Sibylle	GEOMAR, Kiel
Janßen, Felix	GEOMAR, Kiel
Kähler, Anja	GEOMAR, Kiel
Koppelmann, Dr. Rolf	IHF, Universität Hamburg, Hamburg
Kurbjeweit, Dr. Frank	IGP, Universität Tübingen, Tübingen
Lochte, Prof. Dr. Karin	IOW, Institut für Ostseeforschung, Warnemünde
Lunau, Angela	GEOMAR, Kiel
Phillip, Eva	GEOMAR, Kiel
Queisser, Wolfgang	GEOMAR, Kiel
Rickert, Dirk	GEOMAR, Kiel
Schäfer, Dr. Petra	IBM, Universität Hamburg, Hamburg
Schale, Holger	ICBM, Universität Oldenburg
Schroll, Gunnar	IBM, Universität Hamburg, Hamburg
Setzkorn, Dorothea	IOW, Institut für Ostseeforschung, Warnemünde
Springer, Dr. Barbara	GEOMAR, Kiel
Treude, Tina	GEOMAR, Kiel
Turnewitsch, Robert	GEOMAR, Kiel
Viergutz, Thomas	GEOMAR, Kiel
Witte, Dr. Ursula	GEOMAR, Kiel

Addresses of participating research institutes:

GEOMAR, Forschungszentrum für marine Geowissenschaften
Wischhofstraße 1-3
D-24148 Kiel, Germany

IBM, Institut für Biogeochemie und Meereschemie der Universität Hamburg
Grabenstraße 27
D-20357 Hamburg, Germany

ICBM, Institut für Chemie und Biologie des Meeres der Universität Oldenburg
Carl-von-Ossietzky-Straße 9-11
D-26111 Oldenburg, Germany

IGP, Institut und Museum für Geologie und Paläontologie der Universität Tübingen
Sigwartstraße 10
D-72076 Tübingen, Germany

IHF, Institut für Hydrobiologie und Fischereiwissenschaft der Universität Hamburg
Zeiseweg 9
D-22765 Hamburg, Germany

IOW, Institut für Ostseeforschung, Warnemünde
Seestraße 15
D-18119 Rostock-Warnemünde, Germany

Universität Bremen, Fachbereich Geologie
Klagenfurter Straße 17
D-28359 Bremen, Germany

Universität Rostock, Fachbereich Meeresbiologie
Freiligrathstraße 7/8
D-18055 Rostock, Germany

Participants SONNE 129, ship's crew:

Kalthoff, Dierk. (master)
Angermann, Rudolf
Baade, Stephan
Blohm, Volker
Bosselmann, Norbert M.J.
Both, Michael
Hartwig, Karl-Heinz
Hoedl, Wolfgang
Hoffmann, Hilmar W.
Hoppe, Jan
Huxol, Werner H.
Klein, Andreas
Ladewich, Norbert
Lange, Gerhard H.
Lindemann, Erhard W.
Neitzsch, V. Bernd
Osterhues, Wilfried
Prechtl, Hans-Jürgen
Priebe, Roland
Reichmacher, Wolfgang
Rex, Andreas
Riedler, Heinrich
Rosemeyer, Rainer-Franz
Schade, Peter U.
Stammer, Kurt
Szych, Uwe
Thaysen, Uwe-Otto
Tiemann, Frank E.
Wleden, Wilhelm

Address:

Reederei Forschungsgemeinschaft GmbH
Postfach 330660
D-28336 Bremen

4. Narrative

The scientific party of SONNE cruise No. 129 boarded the ship in the morning of 30 January 1998 at Port Sultan Quaboos (Muscat, Sultanate of Oman). The group consisted of 25 scientists, technicians and students representing the research programmes BIGSET (Biogeochemical Transports of Matter and Energy in the Deep Sea) and G-JGOFS-Indic (German Joint Global Ocean Flux Study- Indic). Both programmes are sponsored by the Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie.

In the course of the day six containers of equipment were unloaded and two laboratory containers were installed on the RV SONNES´s working deck. Until the evening of 31 January all major sampling gear was assembled and all laboratories were prepared. At 19.18h (31 Jan.) RV SONNE left Port Sultan Quaboos and headed towards our first station WAST at 16°13´N/60°16´E (Fig. 1).

After a smooth passage we arrived at WAST at 16.00h of 2 February. Station work started with a deep CTD/rosette water sampler cast. In the next days sediment samples were taken with a multiple corer and a maxi corer, a new sampling device, which can sample with three liners of 30 cm diameter. Water samples were retrieved with the CTD/rosette water sampler and with the bottom water sampler. A fluorescence probe was incorporated into the CTD/rosette at shallow hauls (250 m) to measure chlorophyll profiles. Meso-zooplankton distribution of the whole water column was studied by employing a 1 m^2-double-MOCNESS. An Agassiz trawl was towed to sample megafauna. A sediment trap was moored 500 m above the seafloor programmed for sampling intervals of three times during seven days. Three different free falling vehicles were deployed: a new version of the GEOMAR chamber lander (FFR), an observation system (FFB), and a fish trapping system (FFF). The FFR consists of a basic tripod system that can carry four autonomous benthic chamber systems for the measurement of respiration and pore-water fluxes at the sediment/water interface. The FFB is based on the same basis lander as the FFR. The FFB carries a baited tray/trap (tuna fish carcass) to observe large food fall degradation by megafauna organisms, a stereo-camera system for the observation of benthic activity and an ADCP to record near seabed current velocities. The FFF of rectangular construction is deployed on the sea floor. It carries two baited weir baskets to catch demersal necrophagous fish and crustaceans.

On February 6 RV SONNE steamed to the next sampling station WAST-T a seamount which is located about 30 nm west of WAST. Sediment samples were taken in 1920 m water depth and the two water sampler devices were employed to sample the BBL up to 500 m above the seabed. Station work at WAST-T was

finished at midnight of February 8. Following we steamed back to WAST where we continued our investigation programme until midnight 08.02.
RV SONNE headed in southeastern direction to our next main station SAST at 10°N/65°E. En route we stopped at 14°27´N/61°39´E (09.02.) to take sediment samples with the multiple corer. SAST was reached in the evening of 10.02. The sampling programme (without the use of the MOCNESS system) followed the scheme of WAST. The assignment of the new OFOS system, a towed near seabed observation system carrying a still camera, two video cameras and a CTD, failed due to water penetration into the pressure housing of the telemetry. Station work at SAST was completed after the successful recovery of the three freefall systems and of a three days deployment of the sediment trap (500 m above the seabed). In the evening of February 14. RV SONNE sailed in northeastern direction to station EAST at 15°35´N/68°34´E. Another multiple corer sample was taken en route on February 15 at 12°50´N/66°48´E. Station EAST was reached at mid day February 16. The same investigation programme as at SAST was conducted. Additionally we produced a bathymetric map of the EAST area after several tracks with HYDRO-SWEEP-System covering an area of about 50 nm^2. At EAST, the OFOS system was towed successfully for the first time. Station work at EAST was finished in the evening of February 18.
Following we steamed in western direction to station CAST at 14°24´N/64°34´E. En route we took another sediment sample with the multiple corer at 15°02´N/66°42´E. Being a focal point of plankton investigations several MOCNESS-hawls were towed at station CAST, whereas all other activities followed the scheme of the previous stations. Station works at CAST were conducted from the evening of February 19 until early morning of the 25th. Following we visited stations WAST and WAST-T again. From morning of February 26 until the morning of the 28th we repeated our sediment sampling from our first visit, retrieved our sediment trap mooring and conducted a shortened water-sampling programme. The FFR and FFB were deployed and three MOCNESS hawls were towed again.
On February 28 we left WAST and headed Northeast to sample sediments at another intermediate station at 17°45´N/65°45´E. Following this station (01. 03.) we headed north toward our last station NAST at 20°/65° 35´E, which was reached on March 2. At NAST, we repeated the sampling scheme of EAST. In the morning of March 5 we finished the station works and RV SONNE took course through the Straits of Hormuz to Dubai.
RV SONNE docked in the afternoon of March 8 in Dubai. During the rest of the day and in the morning of March 9 the scientific equipment of the cruise was loaded into six containers. The scientific party left RV SONNE in the afternoon of March 9 thus finishing SONNE cruise SO129.

Favoured by good weather conditions and the calm sea state the cruise SONNE 129 proved to be extraordinary successful. In total 104 stations were sampled with 169 individual gear deployments comprising of: 42 multiple corers, 16 maxi corers, 6 boxgrabs, 6 oxygen profilers, 19 landers, 34 CTD/rosettes, 12 bottom water samplers, 12 double 1m^2-double-MOCNESSES, 3 Apstein nets, 4 Agassiz trawls, 10 OFOS and 5 sediment trap deployments.

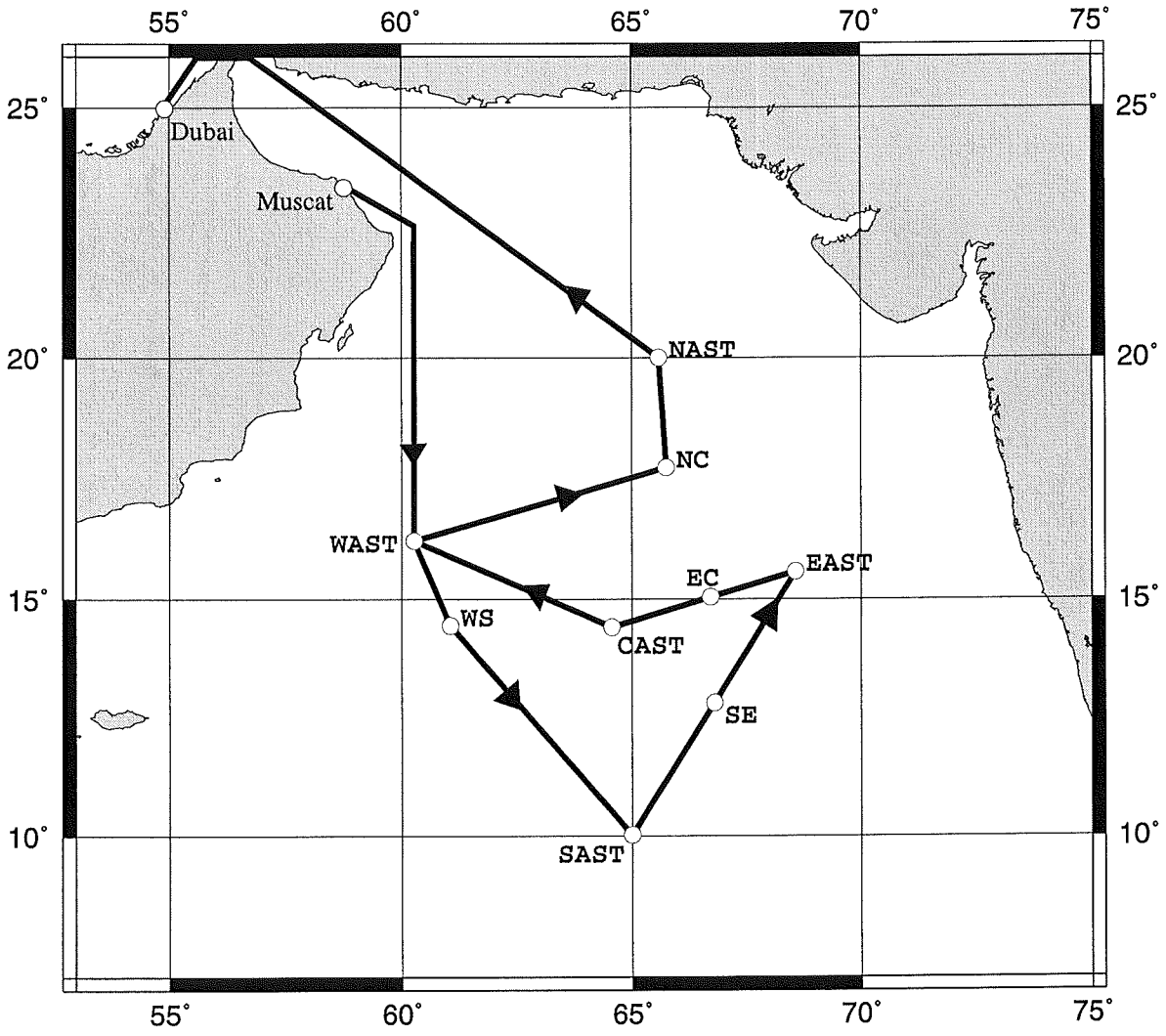
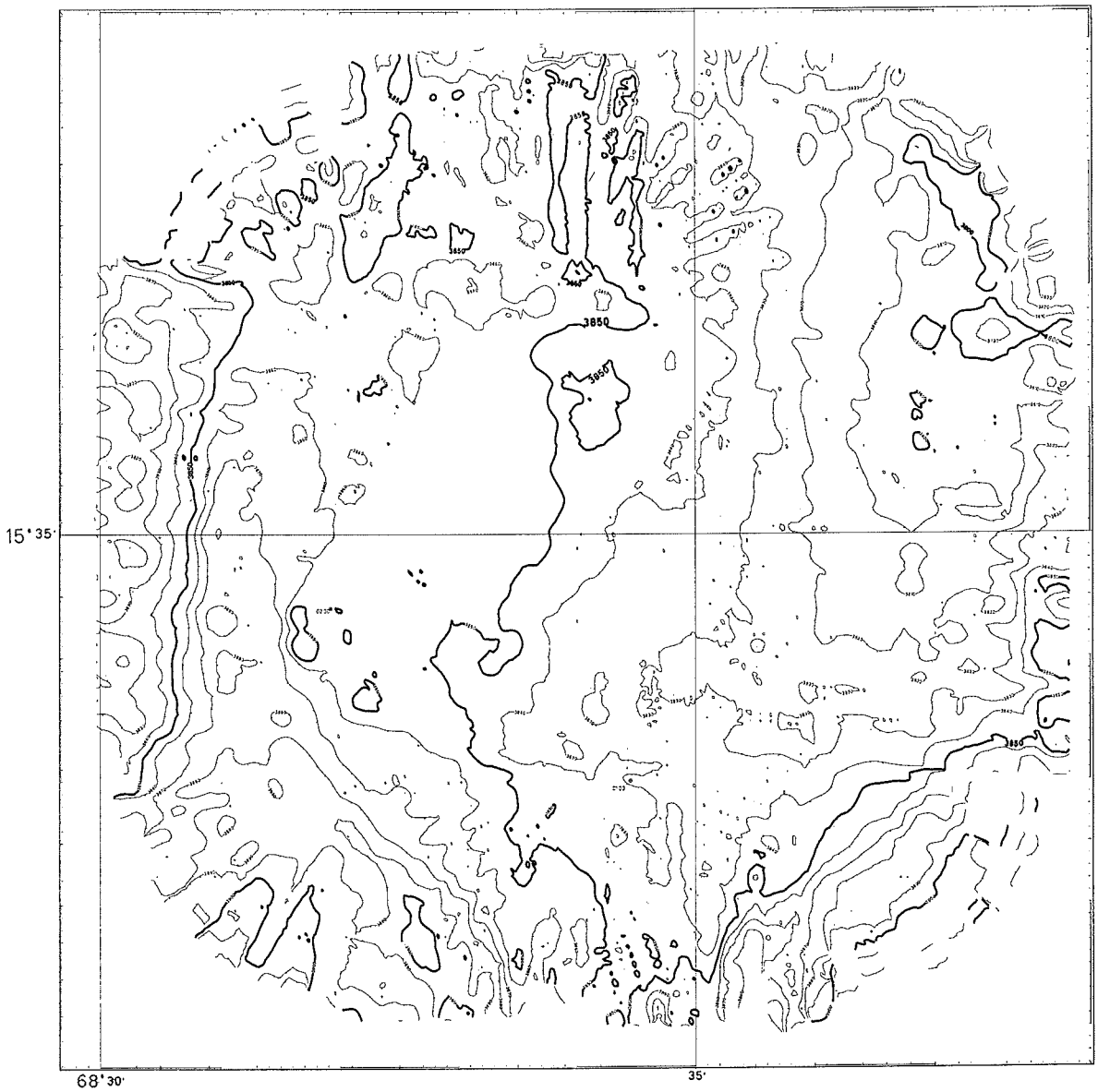


Fig.1: Cruise track and sampling stations SO129

5.1 Bathymetry of EAST, HYDROSWEEP swathmapping

A bathymetric survey was carried out with the multibeam „HYDROSWEEP"-system at EAST in order to complete mapping of all main sampling stations. Parallel tracks, each surveying an area twice as wide as the water depth, were driven over the EAST site to determine the bathymetry around central benthic sampling area. For a successful determination the measured areas have to overlap which reduced the net track width to a factor of about 1.5 of the water depth.

The bathymetric map shown in Figure 1 was prepared by the scientific technical services on RV SONNE in different formats. It is stored in HPGL format, a vector based picture format. The raw data are tape-recorded for further evaluation. Plots with a scale of 1:100.000 are also available.



Bathymetry EAST; Contour interval 10m; Scale 1:25.000; Mercator Projection at 16 °N

Fig.1: Bathymetry of EAST

5.2 Biological fluxes in the bathypelagic zone of the Arabian Sea (JGOFS-Indic)

Rolf Koppelmann, Svenja Cummerow* and Tina Treude#*
** Institut für Hydrobiologie und Fischereiwissenschaft, Universität Hamburg*
 # GEOMAR Forschungszentrum für marine Geowissenschaften, Kiel

Research Programme

The deep-sea below 1000 m, the bathypelagic zone, is the largest and most poorly known ecosystem on earth. Due to its vast volume of approximately 988 million km^3, and hence, its enormous capacity of storing carbon (today approx. 38 000 Gt. C are stored in the deep-water; SCOR 1992), the bathypelagic realm is very important for balancing the carbon flow in the ocean. In the epi- and mesopelagic zones, carbon is bound for several years or tens of years, in the sediments it is bound for millions of years. However, the exchange time of water in bathypelagic zone is several hundreds of years (see also LAMPITT & ANTIA 1997) - a time span which is relevant for human life.

Particulate organic carbon, which is transformed from inorganic carbon by biological activity in the epipelagic zone of the ocean, partly sinks into greater depths. This pathway of particle flux will be analysed and quantified by the JGOFS-Indic working group (see HAAKE et al. 1993). On the way through the water column, these particles are re-mineralised, modified, or build up to new living biomass by the activity of microorganisms, zooplankton and nekton. The modification and transfer of biomass is influenced by trophic relationships; whereby parts the organic carbon are released as CO_2 by the metabolism of the animals. The German JGOFS-Indic working group 14 focuses on the role of the medium-sized zooplankton on these processes. Only a small amount of the organic material reaches the sea bottom and will be stored by biological and biogeochemical activity in the sediments; these mechanisms are investigated by the project BIGSET.

There is a lack of quantitative data on processes and on the distribution of deep-sea zooplankton in the Arabian Sea below 1000 m (see ANGEL 1984; SCOR 1995). In the framework of JGOFS, our project investigates the deep-sea zooplankton of the Arabian Sea on a temporal and spatial basis in order to (1) describe the distribution of biomass and individuals, (2) determine the amount of carbon which is respired or stored as biomass, and (3) study the pathways of carbon by zooplankton within the pelagic foodweb.

Station work and preliminary results

Introduction

The cruise SO129 is the last of a series of three cruises to examine the distribution of deep-sea zooplankton and its carbon utilisation. The cruise covers the NE monsoon in February, the intermonsoon periods in October and April were investigated during METEOR cruise M33/1 (October 1995; KOPPELMANN & WEIKERT 1997) and SONNE cruise SO118 (April 1997), respectively. Since sampling in the bathypelagic zone is very time-consuming, we have focused our investigation on the two main stations, WAST and CAST (Tab. 1). Additional samples were obtained at NAST.

Tab. 1: 1m^2-double-MOCNESS (333 µm) samples from the Arabian Sea.

Haul	Ship Station	Date	Local Time	Region	Sampled Depths
MOC01	02	02.02.98	22:05-02:37	WAST	1850-0 m
MOC02	15	05.02.98	07:09-11:18	WAST	1850-0 m
MOC03	17	05.02.98	19:59-04:16	WAST	4000-1850 m
MOC04	22	07.02.98	16:30-23:31	WAST	4000-1850 m
MOC05	57	19.02.98	22:57-02:45	CAST	1850-0 m
MOC06	63	21.02.98	09:23-13:35	CAST	1850-0 m
MOC07	66	22.02.98	04:09-11:59	CAST	3930-1850 m
MOC08	70	23.02.98	21:36-05:24	CAST	3900-1850 m
MOC09	76	24.02.98	19:30-02:41	CAST	3920-0 m
MOC10	81	26.02.98	16:38-00:15	WAST	4000-1850 m
MOC11	83	27.02.98	09:40-13:16	WAST	1850-0 m
MOC12	98	04.03.98	09:07-13:13	NAST	3150-0 m

Methods

We used a 1 m^2-double-MOCNESS (WIEBE et al. 1985) with eighteen 333 µm nets and two 100 µm nets to obtain horizontal and oblique mesozooplankton samples (see sampling scheme, Fig. 1). The two 100 µm nets were used to catch smaller sized zooplankton for biogeochemical and taxonomical analyses. These are the first 100 µm net samples down to 4000 m in the Arabian Sea. Sampling speed amounted to 2 kn. Oblique tows were taken to quantify the standing crops of the mesozooplankton biomass and the abundance of different taxa and to describe the vertical distributions in the water column. Horizontal sampling was performed to get specimens for biochemical analyses. The fraction <5 mm of these zooplankton samples were split in 1/2 or 1/4 samples. One subsample was used to measure the electron transport system activity (ETSA). Another subsample was used to determine the wet, dry and ash-free-dry weights. The ETS activity is used to calculate the potential respiration rate of zooplankton. The analysis was done

following the method of PACKARD (1971), modified by KENNER & AHMED (1975). The enzymatic activity was corrected for *in situ* temperature using the Arrhenius equation assuming an activation energy of 13.2 kcal mol^{-1} for bathypelagic zooplankton (PACKARD et al. 1975) to determine the oxygen consumption in µl O_2 per unit time and volume, per unit time and wet weight (WW), and per unit time and dry weight (DW).

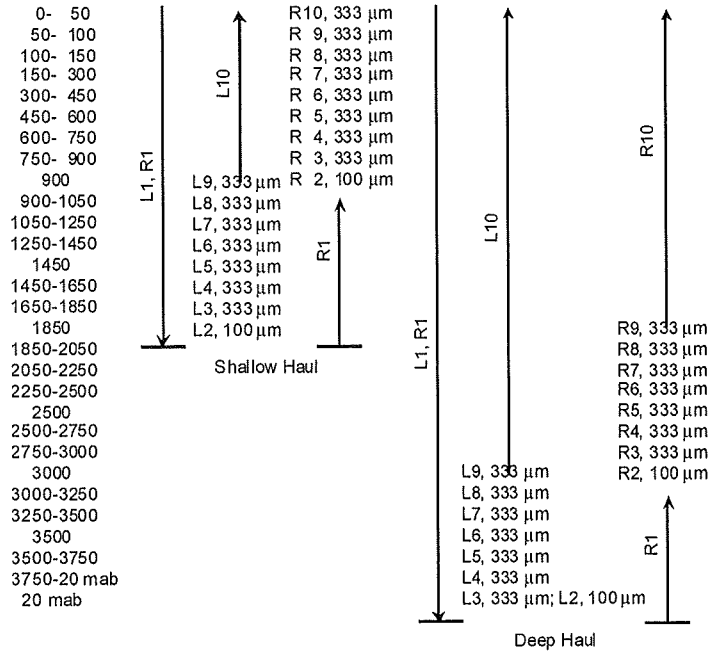


Fig. 1: Sampling strategy of 1 m2-double-MOCNESS hauls.
L= left nets. R= right nets

To determine the trophic level of different zooplankton size classes, one additional oblique haul was taken at CAST (MOC09; Tab. 1). The samples were passed through a set of sieves resulting in fractions of >5, 5-2, 2-1, 1-0.5, and <0.5 mm, then deep-frozen, and finally pulverised for the analysis of the $\delta^{15}N/^{14}N$ stable isotope composition.
The MOCNESS is equipped with SEABIRD conductivity (SBE 4), temperature (SBE 3) sensors, and a pressure indicator. Hence, this device can also act as an environmental sensing system (WIEBE et al. 1985).

Preliminary results

Compared to the earlier cruises, the abundance of zooplankton in February (So129) during the NE monsoon was less than in October (M33/1) after the SW monsoon, but higher than in April (So118) after the NE monsoon. Zooplankton in the upper bathypelagic zone contained a visible amount of lipids in October and

February and distinctively less in April. Upon completion of the forthcoming analyses, the data will be available via the German JGOFS data manager (http://www.ifm.uni-kiel.de/pl/dataman/dmpag1.html).

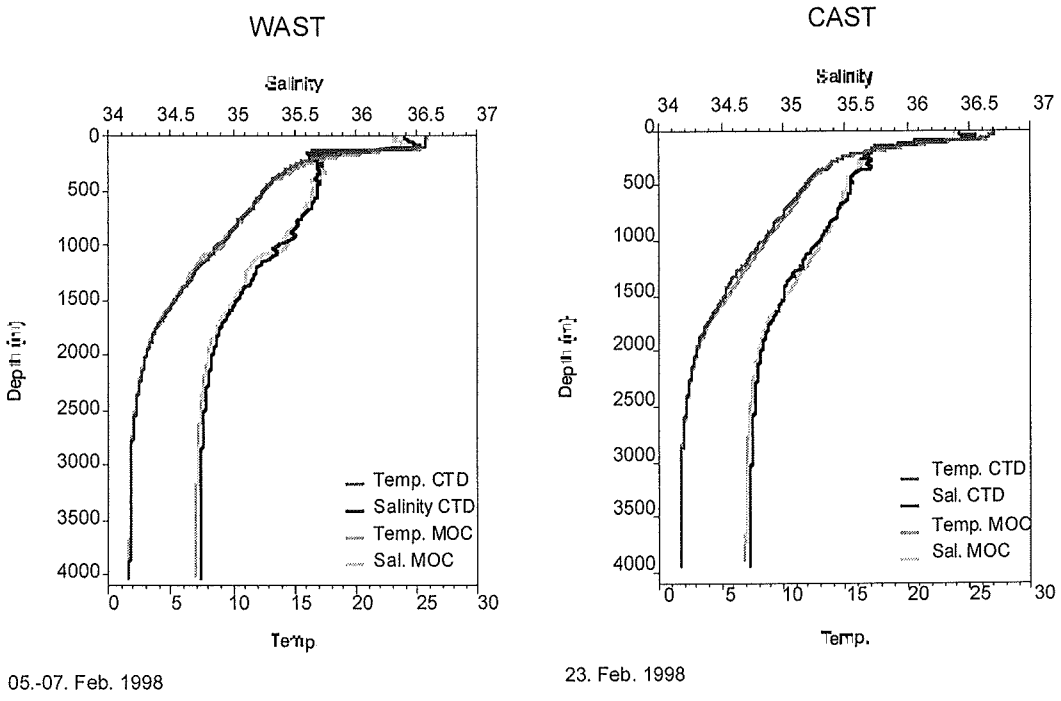


Fig. 2: Vertical profiles of temperature and salinity at WAST (left) and CAST (right) measured by MOCNESS and CTD sensors.

Salinity and temperature were recorded with the MOCNESS sensors. The values are plotted against the depth, and for comparison, the data measured by a SEABIRD CTD are added. Fig. 2 shows the plots for WAST and CAST. Surface temperature at CAST at the end of February was slightly higher (27.0°C) compared to WAST in early February (25.6°C). At WAST, the upper 100 m were mixed, at CAST the profile was stratified. Salinity shows at both stations a subsurface maximum at ~50 m. Between 100 m and 200 m a sharp decline in temperature and salinity was visible at both stations. Between 200 m and approximately 2000 m, the decrease of temperature and salinity was lessened. The data show some minor variabilities with depth, especially in salinity. At greater depths, temperature and salinity remain stable with 1.7°C and 34.7 PSU, respectively. The CTD and MOCNESS data show a high coherency. The temperature profiles are nearly the same, except for the depth range between 300 and 1500 m, where higher variabilities occurred. The salinity profiles are of the same shape, however, the MOCNESS data are about 0.04 to 0.1 PSU lower than the CTD data.

Conclusions

The data of the three cruises provide us with valuable information on spatial and temporal distributions, compositions, and activity rates of zooplankton down to 4000 m depth in the Arabian Sea. First results indicate that the Arabian Sea is an environment of high spatial variability, influenced by different productivity regimes at the surface (KOPPELMANN & WEIKERT 1997). Temporal differences in the vertical distribution of zooplankton were only detected for zooplankton numbers at WAST, so far. This station shows also the highest annual change in particle flux rates. The ETS activity of mesozooplankton shows high temporal variability at WAST and CAST, however, these results are at the beginning of the evaluation and have to be validated.

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5.3 Preservation potential of the primary climatic and environmental signals in deep-sea sediments

Petra Schäfer and Gunnar Schroll
BIGSET, Institut für Biogeochemie und Meeresforschung, Universität Hamburg

Research Programme

The subproject addresses the question of the preservation of environmental and climatic signals in sediments reaching the deep sea via settling particles. The particle flux to the deep-sea benthic boundary layer is measured and its biogeochemical composition is compared with that of the standing crop of suspended particles and particle deposits in surface sediments. Additional information on early diagentic processes affecting the preservation is obtained from the carbon and nitrogen isotopic composition of sinking particles and sediments as well as from the labile constituents of organic matter in sediments and pore waters.
The objectives of the cruise were:

- Deployment of short-term moorings with sediment traps, current meters and deep-sea pumping systems at the stations WAST, SAST, EAST, CAST and NAST.
- Collection of suspended particles from the surface layers and from the deep-sea boundary layer
- Sampling of sediments and sediment pore waters.

Station works and methods

Particle flux

In order to determine the vertical particle flux to the benthic boundary layer sediment traps were moored approx. 500 m above the sea floor. The particle flux and especially the flux of organic carbon are basic parameters for the benthic studies of all sub-projects of BIGSET.

Short-term sediment trap moorings were successfully deployed at each of the five main stations of cruise SO129 (Tab. 1). During the first visit of station WAST one mooring was deployed for a longer period. It was recovered during the second visit of the station after 24 days. Three samples at intervals of eight days each were retrieved. Sediment traps at the other stations were deployed for 2-4 days which allowed the collection of one sample each. At NAST, two samples from different depths were collected.

Tab. 1: Mooring system information, Arabian Sea, SO129

Station	WAST	SAST
Mooring name	WAST-ST-03	SAST-ST-01
Mooring position	16°14.653' N 60°17.059' E	10°04.00' N 65°00.02' E
Deployment	03.02.98, 09:15-10:40	11.02.98, 08:55-10:17
Deployment station	5	33
Recovery	28.02.98, 07:02-08:54	14.02.98, 14:25-16:11
Recovery station	87	43
Water depth (m)	4043	4425
Trap depth (m)	3480	3887
Distance to seafloor (m)	561	538
Sampling start	04.02.98, 06:00	11.02.98, 12:00
Sampling end	28.02.98, 06:00	14.02.98, 12:00
Sampling duration (d)	3 x 8	3

Station	EAST	CAST
Mooring name	EAST-ST-01	CAST-ST-02
Mooring position	15°34.542' N 68°33.264' E	14°26.114' N 64°34.030' E
Deployment	16.02.98, 13:00-13:28	20.02.98, 07:07-07:33
Deployment station	47	61
Recovery	18.02.98, 14:56-16:33	24.02.98, 16:22-17:26
Recovery station	54	74
Water depth (m)	3865	3955
Trap depth (m)	3318	3417
Distance to seafloor (m)	538	538
Sampling start	16.02.98, 15:00	20.02.98, 12:00
Sampling end	18.02.98, 15:00	24.02.98, 12:00
Sampling duration (d)	2	4

Station	NAST
Mooring name	NAST-ST-02
Mooring position	19°59.951' N 65°35.611' E
Deployment	02.03.98, 07:12-07:55
Deployment station	91
Recovery	05.03.98, 06:18-08:13
Recovery station	104
Water depth (m)	3185
Trap depths (m)	2118, 2647
Distance to seafloor (m)	1067, 538
Sampling start	02.03.98, 11:00
Sampling end	05.03.98, 05:00
Sampling duration (d)	2.75

After initial macroscopic description of the sediment trap samples (Tab. 2) they were split and filtered.

Tab. 2: Description of sediment trap samples (visual)

Sample	SAST-ST-01#1	EAST-ST-01#1	CAST-ST-02#1	WAST-ST-03#1	WAST-ST-03#2	WAST-ST-03#3
Date of sample description	14.02.	19.02.	25.02.	28.02.	28.02.	28.02.
Supernatant volume (%)	99	97	92	97	95	85
Supernatant volume (ml)	238	233	220	233	228	205
Supernatant color	clear	clear	clear	clear	clear	clear
Subsample	-	-	-	-	-	-
Particle volume (ml)	2	7	8	7	12	35
Particle color	brown-green	green-brown	brown-green	brown-green	brown-green	brown-green
Large amorph. aggregates	M	M	M	m	m	M
Small amorph. aggregates	m	M	M	M	m	M
Fecal pellets (> 1 mm)	M	M	M	m	M	M
Fecal pellets (< 1 mm)	T	T	m	m	M	M

Sample	NAST-ST-02/sh-#1	NAST-ST-02/dp-#1
Date of sample description	05.03.	05.03.
Supernatant volume (%)	92	92
Supernatant volume (ml)	220	220
Supernatant color	clear	clear
Subsample	-	-
Particle volume (ml)	20	20
Particle color	brown-green	brown-green
Large amorph. aggregates	-	-
Small amorph. aggregates	M	M
Fecal pellets (> 1 mm)	T	T
Fecal pellets (< 1 mm)	T	T

Amount: M = major (50 - 100%), m = minor (10 - 50%), T = trace (< 10%)

For analyses of dissolved organic compounds the supernatant was filtered through glass microfibre filters (GF/F, 0.7 µm, pre-combusted at 450°C) and filled in 10 ml glass ampoules (pre-combusted at 550°C). The ampoules were sealed under nitrogen and stored frozen. One aliquot of the supernatant was analyzed onboard for dissolved nutrients by A. Lunau and D. Rickert (BIGSET SP 7). The samples

were split using a rotary splitter. The sub-samples were filtered on preweighed polycarbonate filters and dried (60°C) for further biogeochemical analyses. The processing and distribution of the sample splits for the various analyses of subproject 4 and three other subprojects of BIGSET (SP 1, SP 2 and SP 3) are listed below:

SAST-ST-01, #1

< + > 1mm, total	filtered and dried

EAST-ST-01, #1

< + > 1mm, 88.83%	filtered and dried
< + > 1mm, 0.23%	microbiology and microscopy (SP 3)
< + > 1mm, 1/16	potential hydrolytic activity (FDA, SP 1)
< + > 1mm, 1/64	chloroplastic pigments (SP 2)
< + > 1mm, 1/32	Thorium (SP 2)

CAST-ST-02, #1

< + > 1mm, 1/2	filtered and dried
< + > 1mm, 38.83%	filtered and dried
< + > 1mm, 0.23%	microbiology and microscopy (SP 3)
< + > 1mm, 1/16	potential hydrolytic activity (FDA, SP 1)
< + > 1mm, 1/64	chloroplastic pigments (SP 2)
< + > 1mm, 1/32	Thorium (SP 2)

WAST-ST-03, #1, #2 and #3

< + > 1mm, 1/16	potential hydrolytic activity (FDA, SP 1)
< + > 1mm, 1/64	chloroplastic pigments (SP 2)
< + > 1mm, 1/32	Thorium (SP 2)

WAST-ST-03, #1

< + > 1mm, 1/2	filtered and dried
< + > 1mm, 38.83%	filtered and dried
< + > 1mm, 0.23%	microbiology and microscopy (SP 3)

WAST-ST-03, #2

< + > 1mm, 1/2	filtered and dried
< + > 1mm, 37.70%	filtered and dried
< + > 1mm, 0.20%	microbiology and microscopy (SP 3)

WAST-ST-03, #3

< + > 1mm, 3x1/4	filtered and dried
< + > 1mm, 13.87%	filtered and dried
< + > 1mm, 0.20%	microbiology and microscopy (SP 3)

NAST-ST-01, #1, shallow and deep

< + > 1mm, 1/2	filtered and dried
< + > 1mm, 38.13%	filtered and dried
< + > 1mm, 0.94%	microbiology and microscopy (SP 3)
< + > 1mm, 1/16	potential hydrolytic activity (FDA, SP 1)
< + > 1mm, 1/64	chloroplastic pigments (SP 2)
< + > 1mm, 1/32	Thorium (SP 2)

Preliminary results

Shipboard studies

The total liquid sample (SAST) or one aliquot of the liquid sample (1/16 at EAST, CAST, WAST and NAST) was inspected jointly with F. Kurbjeweit (SP 5) using a stereo microscope. The identified constituents are described below in the order of their abundance:

SAST-ST-01, #1:
1.+2. fecal pellets, > 1 mm
1.+2. large amorphous aggregates, > 1 mm (containing radiolaria)
3. foraminifers (e.g., Globigerinella digitata, Globigerinoides sacculifer)

EAST-ST-01, #1:
1. small amorphous aggregates
2.+3. foraminifers (e.g., Globigerinoides menardii, Globigerina bulloides)
2.+3. rests of fecal pellets
4. radiolaria

CAST-ST-02, #1:
1. small and large amorphous aggregates
2. and 3. small foraminifers
2. and 3. pteropods
4. fecal pellets

WAST-ST-03, #1:
1. small and large amorphous aggregates
2.+3. foraminifers (e.g., Globigerina bulloides, Globigerinella digitata, Orbulina universa)
2.+3. pteropods (Limacina)
4. fecal pellets

WAST-ST-03, #2:
1. small and large amorphous aggregates
2. pteropods, (Limacina, Clione)
3. foraminifers (e.g., Globigerina bulloides, Globigerinella digitata, Orbulina universa, Globigerinoides sacculifer)
4. fecal pellets

WAST-ST-03, #3:
1. small and large amorphous aggregates
2. pteropods in different sizes (Limacina, Clione)
3. small foraminifers (dominated by *Globigerina bulloides*)
4. fecal pellets
more aggregates, more pteropods than in samples #1 and #2, no radiolaria

NAST-ST-02, #1, shallow:
1. small amorphous aggregates
2. pteropods (Limacina, Clione)
3. small fecal pellets
4. radiolaria
5. few foraminifers
fragments of the diatom Rhizosolenia and rests of radiolaria

NAST-ST-02, #1, deep:
1. small amorphous aggregates
2. pteropods (Limacina, Clione)
3. very small formaninifers (mostly juvenile forms, e.g., *Globigerinoides menardii, Globigerina bulloides*)
4. fecal pellets
5. radiolaria
fragments of the diatoms Rhizosolenia and Chaetoceros (a pennate diatom), tintinnid tests and rests of radiolaria

Laboratory studies

The weight of the dried material (< 1 mm) from the filter was used to calculate the total flux (Fig. 1). Analyses of organic carbon, nitrogen, carbonate, biogenic opal, lithogenic material, amino acids, hexosamines and carbohydrates as well as of stable carbon and nitrogen isotopes will be carried out at home.

Total fluxes were lowest at SAST (14.6 mg m^{-2} d^{-1}, Fig. 1). At EAST the fluxes were higher (57.7 mg m^{-2} d^{-1}). At CAST and from February 4-20 at WAST fluxes varied between 78.9 and 93.3 mg m^{-2} d^{-1}. Highest fluxes were measured at WAST from February 20 to 28 (145.8 mg m^{-2} d^{-1}) and at both depth at NAST from March 2-5 (142.2 and 149.0 mg m^{-2} d^{-1}, respectively).

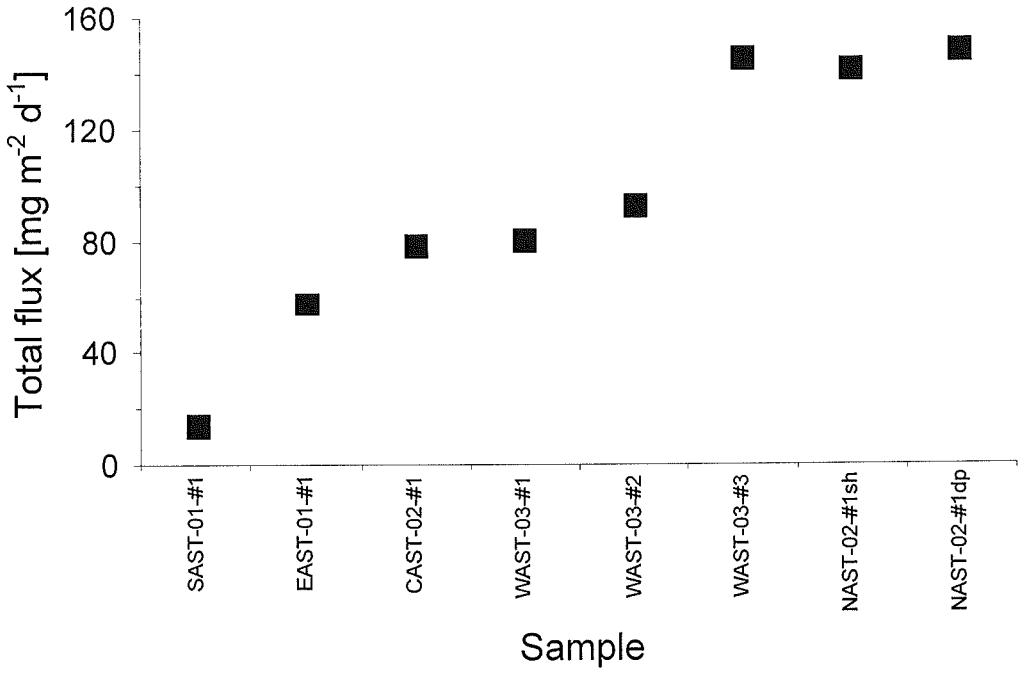

Fig. 1: Total particle flux in the Arabian Sea during SO129. Station and mooring descriptions see Tab. 1.

Conclusions

The sinking particles consisted mainly of small amorphous aggregates, foraminifers, pteropods and fecal pellets. Particle fluxes measured at stations NAST, CAST and during the end of February at station WAST were higher than those measured during April and May 1997 (SO118) indicating that biological productivity in surface waters of the Arabian Sea during cruise SO129 was higher than during cruise SO118. Compared to the other stations EAST and SAST exhibited the lowest particle fluxes.

Suspended particles

At each of the five main stations at least one filter with suspended matter from three near-bottom depths (5, 55 and 500 m above ground) was taken for the analyses of amino acids, hexosamines, carbohydrates and stable isotopes (Tabs. 3 and 4). The data will be interpreted together with the results of subproject 2 (C_{org}, N, Thorium) and 7 (inorganic components). Suspended particles were also sampled in near-surface profiles (20 m, fluorescence maximum, 60 m, 100 m, 200 m). Sampling for DOC was done at stations CAST, WAST and NAST in 10-12 different depths above ground.

Tab. 3: Collection of suspended particles. Dates on which the various water depths were sampled at the five main stations and at station WAST-T.

Station	Depth (m) = 5 m a.g.	Depth (m) = 55 m a.g.	Depth (m) = 500 m a.g.
WAST	04.02.98	07.02.98	07.02.98
WAST-T	06.02.98	-	-
SAST	11.02.98	13.02.98	14.02.98 (2x)
EAST	16.02.98	18.02.98	18.02.98 (2x)
CAST	20.02.98	23.02.98	22.02.98 (2x)
NAST	02.03.98	03.03.98#	03.03.98 (2x)

Station	Depth (m) = 20,60,200,700	Depth (m) = 2xFM, 100 or 250	DOC at 10-12 depths
WAST	04.02.98 27.02.98∞	08.02.98 27.02.98	- 27.02.98
SAST	14.02.98	10.02.98	-
EAST	16.02.98*	16.02.98	-
CAST	24.02.98	19.02.98	22.-23.02.98
NAST	04.03.98+	02.03.98	02.-03.03.98

a.g.= above ground
FM: Fluorescence maximum
*: no sample at 700 m
∞: no sample at 20 m, no sample at 700 m
+: additional sampling at 10 m, 40 m and 50 m
#: additional sampling at 25 m above ground

Methodology and description of the work carried out

Water samples were taken with a rosette water sampler equipped with 10-L Niskin bottles from selected depths. For sampling of suspended matter seawater was filtered using preweighed glass microfibre filters (GF/F, 0.7 µm, pre-combusted at 450°C, 4.5 h). The filters were rinsed with double deionized water and dried at 60°C. For DOC analyses water samples were filtered through glass microfibre filters (GF/F, 0.7 µm, pre-combusted at 450°C). The filtered seawater was filled in 10 ml glass ampoules (pre-combusted at 550°C). The ampoules were sealed under nitrogen and deep-frozen.

Analyses of amino acids, hexosamines, carbohydrates and stable isotopes in suspended particles are being carried out.

Tab. 4: Water sampling

Station and date	Station	Position	Water Depth (m)	Sample depth (m)	Volume (ml)	Above ground (m)
WAST-P 04.02.98	13/#1 CTD-03	16°12.98'N 60°15.90'E	4044	4028	58500	5
WAST-P 04.02.98	13/#3 CTD-04	16°12.98'N 60°15.93'E	4048	19 59 197 694	24000 29100 38500 47900	
WAST-T 06.02.98	19/#5 CTD-05	16°10.55'N 59°45.95'E	1916	1898	58375	5
WAST-P 07.02.98	23/#1 CTD-06	16°12.99'N 60°15.87'E	4042	3532 3975	58270 57200	500 55
WAST-P 08.02.98	23/#4 CTD-07	16°13.00'N 60°15.95'E	4046	#28/1 #28/2 252	17000 16850 40000	
SAST 10.02.98	27 CTD-08	10°02.08'N 64°59.91'E	4426	#77/1 #77/2 102	21150 21150 48200	
SAST 11.02.98	34/#4 CTD-09	10°01.93'N 65°00.00'E	4425	4408	59600	5
SAST 13.02.98	40/#6 CTD-11	10°02.01'N 65°00.00'E	4423	4358	59300	55
SAST 14.02.98	40/#7 CTD-12	10°01.98'N 64°59.99'E	4424	3909	58950 59100	500/1 500/2
SAST 14.02.98	45/#2 CTD-13	10°01.70'N 65°00.87'E	4422	20 60 200 700	28850 27495 38700 49000	
EAST 16.02.98	49/#3 CTD-14	15°34.97'N 68°34.01'E	3848	21 #50/1 #50/2 60 100 199	27900 18550 18250 27975 37900 38950	
EAST 16.02.98	49/#5 CTD-15	15°34.99'N 68°34.00'E	3848	3820	58850	5
EAST 18.02.98	52 CTD-17	15°35.02'N 68°34.01'E	3848	3342/1 3342/2	59100 58450	500/1 500/2
EAST 18.02.98	55 CTD-18	15°35.04'N 68°33.93'E	3850	3778	59100	55

#: Fluorescence maximum

Tab 4: *continued*

Station and date	Station	Position	Water depth (m)	Sample depth (m)	Volume (ml)	Above ground (m)
CAST	57/#1	14°25.31'N	3949	#31/1	21100	
19.02.98	CTD-19	64°37.80'E		#31/2	22000	
				101	58770	
CAST	62/#4	14°24.99'N	3950	3934	58800/DOC	5
20.02.98	CTD-20	64°34.00'E		3940	DOC	9
CAST	62/#5	14°24.99'N	3956	3842	DOC	100
20.02.98	CTD-21	64°33.94'E		3887	DOC	55
				3902	DOC	40
				3917	DOC	25
				3928	DOC	14
CAST	68/#5	14°25.02'N	3958	3453/1	56800	500/1
22.02.98	CTD-22	64°34.05'E		3453/2	57900	500/2
CAST	68/#6	14°25.01'N	3958	2948	DOC	1000
23.02.98	CTD-23	64°34.02'E		3445	DOC	500
				3694	DOC	250
				3888	57800	55
CAST	71/#2	14°24.98'N	3958	21	27700	
23.02.98	CTD-24	64°33.96'E		61	28600	
				200	38750	
				699	48500	
WAST-P	82/#1	16°12.97'N	4042	#28/1	22650	
26.02.98	CTD-25	60°16.00'E		#28/2	22000	
				63	29050	
				102	49600	
				201	48000	
WAST-P	86/#1	16°13.38'N	4044	3988	DOC	45
27.02.98	CTD-26	60°16.48'E		4008	DOC	25
				4019	DOC	14
				4024	DOC	9
				4027	DOC	5
WAST-P	86/#2	16°13.35'N	4045	3040	DOC	1000
27.02.98	CTD-27	60°16.53'E		3538	DOC	500
				3688	DOC	350
				3937	DOC	100
				3982	DOC	55
				3997	DOC	40

#: Fluorescence maximum

Tab 4: *continued*

Station and date	Station	Position	Water depth (m)	Sample depth (m)	Volume (ml)	Above ground (m)
NAST 02.03.98	89/#1 CTD-28	19°59.46'N 65°34.56'E	3188	#31/1 #31/2 100	21800 22000 40000	
NAST 02.03.98	94/#1 CTD-29	19°59.98'N 65°34.98'E	3187	3172 3178	DOC 58250/DOC	9 5
NAST 02.03.98	94/#2 CTD-30	20°00.02'N 65°34.97'E	3186	3142 3147 3156 3160 3164	DOC DOC DOC DOC DOC	40 35 25 20 14
NAST 03.03.98	97/#1 CTD-31	19°59.99'N 65°35.02'E	3187	50 3078 3123 3154	17950 DOC 54250/DOC 56400	 100 55 25
NAST 03.03.98	97/#2 CTD-32	19°60.00'N 65°34.99'E	3187	10 2680/1 2680/2	18600 47750 57350	 500/1 500/2
NAST 03.03.98	97/#3 CTD-33	20°00.01'N 65°34.96'E	3190	2183 2681 2930	DOC DOC DOC	1000 500 250
NAST 04.03.98	102 CTD-34	20°00.02'N 65°35.10'E	3187	20 40 59 198 696	16000 18800 27450 37800 47300	

#: Fluorescence maximum

Sediment and pore water

Sediment and pore water were sampled from ten cores taken by multiple corer at WAST, WAST-T, SAST, EAST, CAST, NAST, between WAST + SAST (ZW IV), between SAST and EAST (ZW V), between EAST + CAST (ZW VI) and between WAST + NAST (ZW VII) (Tab. 5).

The cores were subsampled for sediment and pore water. The multicorer supernatant was filtered and sampled as bottom water. Sediment was subsampled at selected intervals (Tab. 6). Pore water for the analysis of dissolved organic compounds was centrifuged from the sediment subsamples at a temperature of 2°C at 2000 rpm for 20 minutes. Subsequently, the supernatant pore water was removed with syringes and filtered through glass microfibre filters (GF/F, 0.7 µm, pre-combusted at 450°C). The pore water was filled in 10 ml glass ampoules (pre-combusted at 500°C), the ampoules were sealed under nitrogen and deep frozen (-17°C to -23°C).

Tab. 5: Sediment and pore water sampling

Station	Station No.	MC	Position	Date	Water depth (m)	Core length (cm)
WAST-P	7/#4	03	16°13.078'N 60°15.995'E	03.02.98	4041	20
WAST-T	19/#9	11	16°10.502'N 59°45.956'E	06.02.98	1917	14
ZW IV	26	13	14°27.155'N 61°39.213'E	09.02.98	4113	10
SAST	34/#1	15	10°01.998'N 64°59.992'E	11.02.98	4423	30
ZW V	46	20	12°50.521'N 66°48.024'E	15.02.98	4137	25
EAST	49/#2	22	15°35.005'N 68°33.987'E	16.02.98	3855	10
ZW VI	56	26	15°02.579'N 66°42.759'E	19.02.98	3915	30
CAST	62/#2	28	14°25.009'N 64°34.004'E	20.02.98	3954	10
ZW VII	88/#1	37	17°44.999'N 65°44.967'E	01.03.98	3419	7.5
NAST	95/#4	41	19°59.948'N 65°35.011'E	03.03.98	3187	25

The sediment samples were dried at 60°C for 6-20 days and stored in glass vials. The sampling was done at 11°C, the filtration at 24°C.

Tab. 6: Sampling intervals of sediment and pore water

Sampling interval
Bottom water
0-0.5 cm
0.5-1 cm
1-1.5 cm
1.5-2 cm
2-2.5 cm
2.5-3 cm
3-4 cm
4-5 cm
6.5-7.5 cm
9-10 cm
14-15 cm
19-20 cm
24-25 cm
29-30 cm

Sediment samples will be analyzed for organic carbon, nitrogen, carbonate, biogenic opal, lithogenic material, amino acids, hexosamines, carbohydrates and stable carbon and nitrogen isotopes. Pore water samples are being analyzed for dissolved organic carbon, dissolved combined and dissolved free amino acids, hexosamines and carbohydrates.

Recovery attempt of a long-term sediment trap mooring in the Southern Arabian Sea

An attempt was made to recover a long-term sediment trap mooring which had been deployed at SAST during M33/1 in 1995. Futile attempts were made to recover it during cruises SO118 and SO119. The mooring consists of one sediment trap at a water depth of 2974 m below surface (1437 m above ground), one release (Benthos; Codes 1D, 1B), 24 floats (Benthos), one top float with radio and flash light, 1420 m of wire rope. The water depth is 4411 m.
The mooring position (10°02.92'N 65°02.28'E) was encircled at slow speed keeping a horizontal distance of 0.5 nm. A MARISCOPE-Hydrophone-fish which was towed behind the ship was used to send commands. The intensity of the answers to single pings were checked in order to find the best position for sending the release command. However, these intensities were very week and the system could not be released. However, from slant ranges measured, the mooring or part of it appeared to be at the original location. Due to lack of time no further attempts of recovery were made.

5.4 Benthic resuspension, bioturbation and biorrigation

*Barbara Springer# and Robert Turnewitsch**
 # BIGSET, Fachbereich Biologie, Universität Rostock
** GEOMAR Forschungszentrum für Marine Geowissenschaften, Universität Kiel*

Research programme

The principal aims of BIGSET subproject 2 were to quantify several particle-associated processes in the bottom nepheloid layer (BNL) and in the upper layers of the sediment and to investigate their mutual coupling. The diffusional and bioirrigational transports of pore water are another objective. The processes in this zone form an essential link between processes in the upper water column and processes below the bioturbated zone of the sediment (e.g. GRAF, 1989). They are of great importance for early diagenetic changes of settling and settled particles before being buried.

BACON & RUTGERS VAN DER LOEFF (1989) showed that particle-associated processes in the BNL are very dynamic and estimated the mean residence time of 25 days for resuspended particles in the BNL of the HEBBLE site (NE Atlantic). In order to characterize the particles in the BNL water samples were taken with a CTD/rosette and the bottom water sampler (BWS). Water samples were filtered and analyzed for total suspended matter (TSM), particulate organic carbon (POC), particulate nitrogen, bacterial abundance and cell sizes, particulate carbonate, and silicate. A particle camera, mounted on the BWS, registered *in situ* particle size classes, abundances, and current velocities. Particulate and dissolved ^{234}Th in samples from the rosette water sampler were used to calculate the residence time of resuspended particles in the BNL according to the model applied by BACON & RUTGERS VAN DER LOEFF (1989). As auxiliary parameter fluxes of particulate ^{234}Th into sediment traps deployed approximately 500 m above bottom (mab) were measured (co-operation with subproject 4). All main BIGSET sites were sampled for these parameters. These data will yield an estimate of the POC degradation in the near-bottom water column.

Sediments cores were sampled for the determination of the natural radionuclide ^{234}Th. The profiles of this radionuclide provide information on the ^{234}Th inventory and on the intensity of bioturbation if a steady state can be assumed. All ^{234}Th data (from sediment, BNL and sediment traps) combined with the other particle-associated data will give an insight to processes on time scales of a few weeks.

In situ incubations with bromide tracer were carried out in the benthic chambers of the GEOMAR lander in order to quantify bioirrigation rates subproject 5 participated in these experiments by injecting fluorescing microspheres and glass beads of several size-classes into a lander chamber. These particles serve as tracers for bioturbational activity of foraminifera.

The bioirrigation and bioturbation rates will become part of the diagenetic model developed in subproject 7.

Station works

Investigations of the bottom nepheloid layer

DEGENS (1989) emphasizes that boundaries in general often are zones of enhanced activity and crucial for the determination of features of the adjacent compartments. Located above the seafloor, one of the major ocean boundaries, the bottom nepheloid layer (BNL) is a layer of elevated turbidity due to increased concentration of suspended matter, observed as an increase in light scattering near the seafloor in many parts of the world ocean (BACON & RUTGERS VAN DER LOEFF, 1989). According to BACON & RUTGERS VAN DER LOEFF (1989) local or nearby resuspension of surficial sediment accounts for this observation. Bioturbational processes span timescales much shorter and space scales much longer than sedimentational ones. Bioturbation can move old particles from deeper sediment layers back to the sediment surface where they can be resuspended again. Therefore, a sedimentary particle can cycle many times in the resuspension loop before being finally buried for geological timescales below the zone of bioturbation. Thus, there is the possibility for diagenetic processes to affect the characteristics of particles before being buried.

To obtain information on this link between upper water column and sediment water and sediment trap samples (in co-operation with subproject 4) have been taken for the determination of parameters characterizing the particles in the BNL (cf. Research Programmes). Measurements in the BNL have been done in order to learn more about the particle dynamics in the BNL. A principal aim is the determination of the mean residence time of resuspended particles.

All BIGSET main stations were sampled at least once with the BWS and the CTD/rosette (Tab. 1). Particulate ^{234}Th was also measured in samples from four short-time sediment trap moorings in co-operation with subproject 4.

3-6 litres of water from the BWS (normally from 12, 20, 35 and 65 cm above bottom) and from the CTD/rosette were filtered on pre-weighed GF/F filters (previous heat treatment for 12 h at 500°C) for determination of TPM according to LENZ (1971). Chlorophyll *a* and phaeopigments were also determined fluorometrically with a TURNER fluorometer according to SHUMAN & LORENZEN (1975). Blank filters for both methods have been measured. Additional filters will be measured for pigments with the HPLC method (in co-operation with SP 3). For bacterial abundance and cell size determination 100 ml-samples of water preserved with buffered formalin were taken. At GEOMAR they will be stained with DAPI and analysed with an

epifluorescence microscope and an image analysis system modified after THOMSEN (1991). While sampling near-bottom water with the BWS the programmed particle camera (a camcorder with a close up lens in a pressure housing) mounted on the BWS filmed aggregates (about 20 minutes per deployment). The videotapes of the particle camera will also be analysed with the image analysis system for amount, size classes, and velocity of aggregates.

For the measurement of dissolved and particulate ^{234}Th 30 litres of water were sampled at each depth with 3 x 10-liter bottles of a CTD/rosette. For details see RUTGERS VAN DER LOEFF & MOORE (in press).

The samples were drawn into PE containers and filtered immediately. 142 mm diameter Nucleopore™ polycarbonate filters with a porediameter of 0,4 µm were used to filter the particulate matter in a pressure filtration device (pressure up to 400 mbar). The filters were folded in a reproducible way while wetted, dried, wrapped in Mylar™ foil and directly counted in a beta counter ("Risø low-level gasflow betacounter"). The volume of filtered water (generally about 28 litres) was determined with volumetric flasks and graduated cylinders. Blank filters were measured.

To 20 litres of filtrate 6 drops of concentrated ammonia, 250 µl of saturated $KMnO_4$ and 100 µl of concentrated $MnCl_2$ were added to form a MnO_2 precipitate that encloses thorium. The particles have to grow for at least eight hours to achieve an almost 100% extraction efficiency. The MnO_2 precipitate was then filtered on 142 mm diameter Nucleopore™ polycarbonate filters with a porediameter of 1,0 µm in the pressure filtration device. The filters were dried, folded in a reproducible way, wrapped in Mylar™ foil and directly counted in the betacounter on board. Again the volume of filtered water was determined with volumetric flasks and graduated cylinders. In the new filtrate another precipitate was formed and processed like the first one in order to determine the remaining activity in the first filtrate.

The filters have to be counted several times during the weeks following the first measurement to check whether the activity decreases with the half-life of ^{234}Th. Furthermore, a standard filter has to be counted to determine the self-absorption of the filters.

Tab.1: Station numbers, sampling dates and sampling positions of BWS (lower part of the table) and CTD deployments (upper part of the table) for SP 2.

WAST				WAST-				SAST			
Stat.-	Device	Date	Positio	Stat.-	Device	Date	Positio	Stat.-	Device	Date	Positio
1#1	CTD-01	02.Feb	16°13.	19#5	CTD-05	06.Feb	16°10.	34#4	CTD-09	11.Feb	10°01.
			60°15.				59°46.'				65°00.
1#2	CTD-02	02.Feb	16°13.					36#5	CTD-10	13.Feb	10°02.
			60°15.								65°00.'
13#1	CTD-03	04.Feb	16°12.					40#6	CTD-11	14.Feb	10°02.
			60°15.								65°00.'
23#1	CTD-06	07.Feb	16°12.					40#7	CTD-12	14.Feb	10°01.
			60°15.								64°59.
82#1	CTD-25	26.Feb	16°12.								
			60°15.								
86#1	CTD26	27.Feb	16°13.								
			60°15.								
86#2	CTD-27	27.Feb	16°13.								
			60°16.								
9#1	BWS-	03.Feb	16°12.	19#3	BWS-	06.Feb	16°10.	34#5	BWS-	11.Feb	10°02.
			60°15.				59°45.				64°59.
16#3	BWS-	05.Feb	16°12.					38#1	BWS	13.Feb	10°02.
			60°15.								65°00.
23#3	BWS-	8.Feb	16°13.					40#5	BWS	13.Feb	10°02.
			60°16.								64°59.
CAST				NAST				EAST			
Stat.-	Device	Date	Positio	Stat.-	Device	Date	Positio	Stat.-	Device	Date	Positio
62#4	CTD-20	20.Feb	14°24.	94#1	CTD-29	02.Mar	19°59.	49#5	CTD-15	16.Feb	15°34.
			64°34.				65°34.				68°34.
62#5	CTD-21	20.Feb	14°25.	94#2	CTD-30	02.Mar	20°00.	49#11	CTD-16	17.Feb	15°24.
			64°33.				65°34.				68°33.
68#5	CTD-22	23.Feb	14°25.	97#1	CTD-31	03.Mar	19°59.	52	CTD-17	18.Feb	15°35.
			64°34.				65°35.				68°34.
68#6	CTD-23	23.Feb	14°25.	97#3	CTD-33	03.Mar	20°00.	55	CTD-18	18.Feb	15°35.
			64°34.				65°34.				68°33.
62#3	BWS-	20.Feb	14°24.	95#1	BWS-	03.Mar	20°00.	49#4	BWS-	16.Feb	15°34.
			64°33.				65°35.				68°34.
68#4	BWS-	22.Feb	14°25.	97#4	BWS-	03.Mar	19°59.				
			64°33.				65°34.				

Tab.2: Multiple corer sampling stations, dates and coordinates.

station	station no.	sampling date	multiple corer no.	latitude	longitude
WAST	9#2	3./4.2.98	MC-4	16°13.00'N	60°16.00'E
SAST	38#3	12.02.94	MC-19	10°02.00'N	65°00.00'E
EAST	52#2	18.02.98	MC-25	15°35.00'N	68°34.00'E
CAST	68#2	22.02.98	MC-32	14°24.99'N	64°34.03'E
NAST	97#5	03.03.94	MC-42	19°59.98'N	65°35.66'E

Results and conclusions

Most analyses of samples taken with the BWS and deep CTD/rosettes are still in progress. ^{234}Thorium data from previous cruises (SO118 and cruise 229 of RRS DISCOVERY in the Northeast Atlantic) indicate that especially in the first 200 mab there might be profile features on a spatial scale of a few meters. Therefore, high-resolution profiles of TSM, POC, particulate nitrogen, dissolved and particulate ^{234}Th have been measured at all BIGSET main stations up to 1000 mab. In contrast to the profiles from SO118 dissolved ^{234}Th shows no or only a slight activity decrease towards the bottom (Fig. 1). An exception is NAST with a clear decrease below 500 mab. Since the activity of dissolved ^{234}Th is much higher than the activity of particulate ^{234}Th the former determines the profile of total ^{234}Th. These results suggest that at NAST there is radioactive disequilibrium between ^{234}Th and its parent ^{238}U. Therefore NAST is the only station with evidence for a resuspension event. All stations show an increase in particulate ^{234}Th activity towards the seafloor (Fig. 2). Most profiles have some common features: At 250-500 mab particulate ^{234}Th is in a minimum, below this zone activity increases and below 4-25 mab activity of particulate ^{234}Th is almost constant or slightly decreases (Fig. 2). A phenomenon indicated in some profiles SO118 and clearly visible in profiles from the NE-Atlantic (49°00'N, 16°30'W) was detected at NAST: a minimum of dissolved ^{234}Th and a corresponding maximum of particulate ^{234}Th (Figs.1 and 2). The other parameters measured in the BNL on this cruise will furthermore validate this phenomenon. Despite the obvious need for more information two basic profile shapes can be distinguished: (1) exponential increase of particulate ^{234}Th towards the seafloor or an increase with a minimum at 250-500 mab in-between and almost constant activity below 4-25 mab; (2) exponential increase of particulate ^{234}Th towards the seafloor or an increase with a minimum at 250-500 mab in-between and a peak at 10-50 mab. Particulate ^{234}Th data show regional differences: Activities increased at almost all depths in the following station ranking: SAST < EAST < CAST < WAST < NAST. A similar ranking was observed at SO118 (Fig. 2). For WAST a short time series for the ^{234}Th flux was determined (Fig.3a). During the first three weeks of February very low particulate ^{234}Th fluxes (30-40 dpm/m^{2}d) were measured at 561 mab. During the last week of February the flux increased by a

factor of two. Fluxes at EAST and CAST are slightly higher than at WAST during the second half of February at 538mab (approx. 100 dpm/m-d). In the first week of March the particulate ^{234}Th fluxes at NAST were much higher at 500-1000 mab than at the other stations in the weeks before. No significant differences were found between the trap at 538 mab and at 1067 mab (Fig. 3a). Being close to the flux at NAST and WAST during end of March/beginning of April 97 (Fig. 3b).

^{234}Thorium as tracer for bioturbation

Since the biogeochemical processes in the BNL and in the sediment are closely coupled (RUTGERS VAN DER LOEFF & BOUDREAU, 1997). Another principal topic of the cruise was to achieve a broad understanding of the near-bottom boundary layer sedimentary mixing. The mixing intensity can be estimated through profiles of the natural radiotracer ^{234}Th (for mixing on timescales of up to 100 days) assuming a steady state situation for this nuclide (e.g. SMITH ET AL., 1993). Sediment samples for the measurement of ^{234}Th were taken with a multiple corer (10 cm core diameter). At all main stations WAST, SAST, EAST, CAST and NAST (Tab. 2). The fluff layer and/or sediment horizons 0-1 mm, 1-2 mm, 2-3 mm, 3-4 mm, 4-5 mm, 9-10 mm, 14-15 mm, 19-20 and 29-30 mm were analyzed according to RUTGERS VAN DER LOEFF & MOORE (in press, see above).

In situ experiments on bioirrigation and bioturbation

In addition to natural radiotracers, artificial tracers can be used to quantify bioturbation rates. For this cruise an *in situ* experiment with fluorescing microspheres and glass beads of different size classes was designed in co-operation with subproject 5. The microspheres and beads are inert particles simulating a pulse-type input of particulate matter on the sediment surface. In contrast to the assumption for natural radiotracers a non-steady state situation is created. The microspheres and beads were injected into incubation chambers of the GEOMAR chamber lander. The chambers were also used for quantify bioirrigation rates. Bromide was used as an inert tracer for the transport of pore water (MARTIN & BANTA, 1992; SAYLES & MARTIN, 1995). After an incubation of 3-4 days the bromide profile in the sediment yields information on biogenically increased transport of porewater in comparison to solely diffusive transport. *In situ* experiments were carried out at WAST (FFR 2), EAST (FFR 4) and NAST (FFR 7) in co-operation with subproject 1. A 50 cm^3- syringe was filled with bromide solution and injected into the benthic chamber obtaining a final concentration 15 times the natural in the chamber representing a good compromise to keep the final concentration high enough to maintain an almost constant value in the overlying water, on the other hand the concentration is low enough to prevent the system from

being dominated by diffusion during incubation. The volume of the overlying water was measured after recovery of the lander and if possible sampled at the beginning of the experiment after injection of the bromide solution. At FFR 4, the overlying water was sampled in the course of the experiment to check whether there was a change in bromide concentration. The sediment was sampled with small piston corers (50 cm^3 each) down to a depth of 5 cm. An untreated lander was sampled to determine the natural bromide background for the sediment porewater. The sediment cores were cut into 0,5 cm slices, sealed in tubular foil, and stored frozen. The porewater will be separated by centrifugation and filtered (0,45 µm). Bromide and chloride will be determined ionchromatographically at GEOMAR.
The analyses are still in progress.

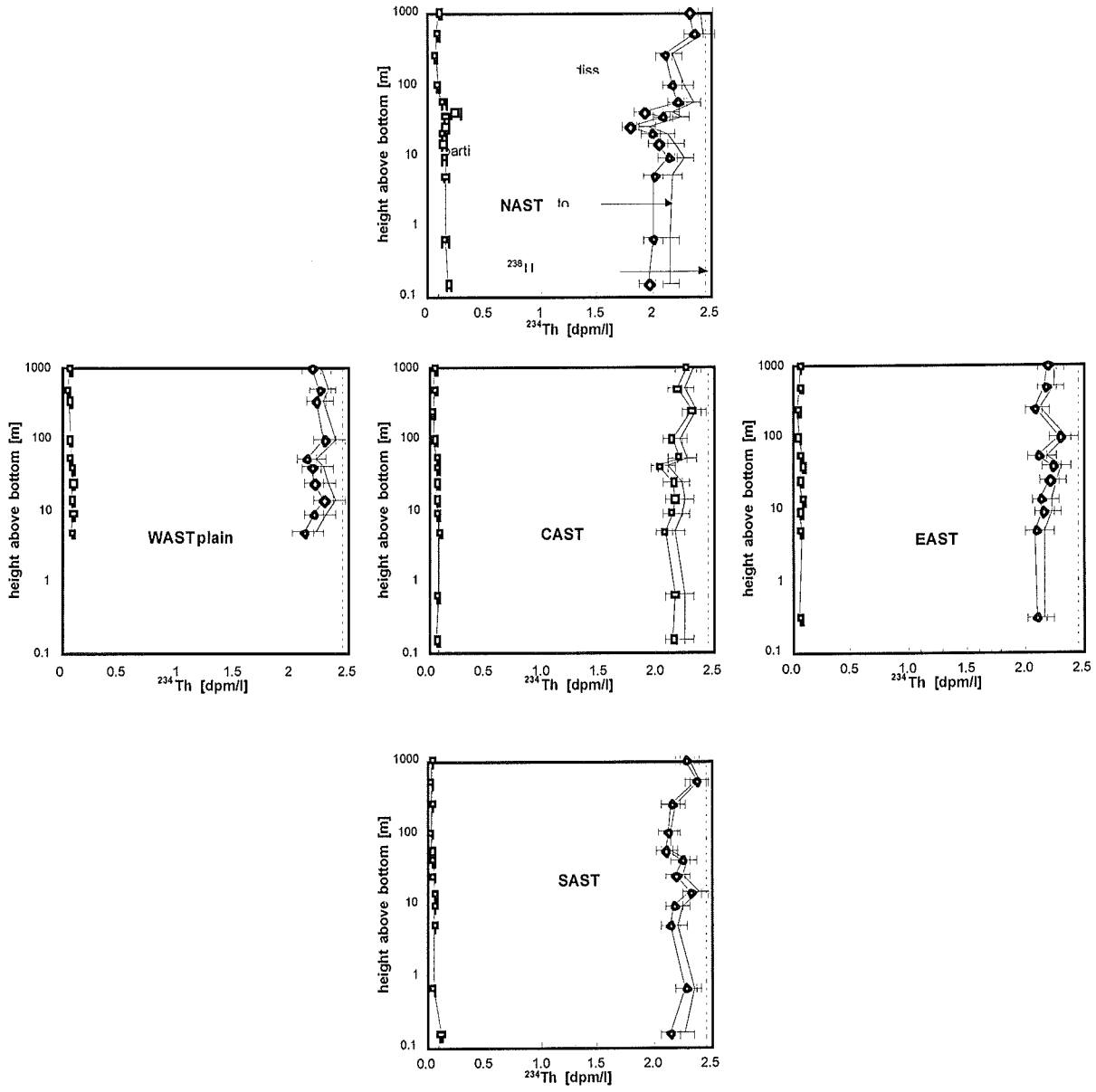

Fig. 1: Profiles of particulate, dissolved and total ^{234}Th and ^{238}U at the BIGSET main stations WAST, NAST, CAST, EAST and SAST

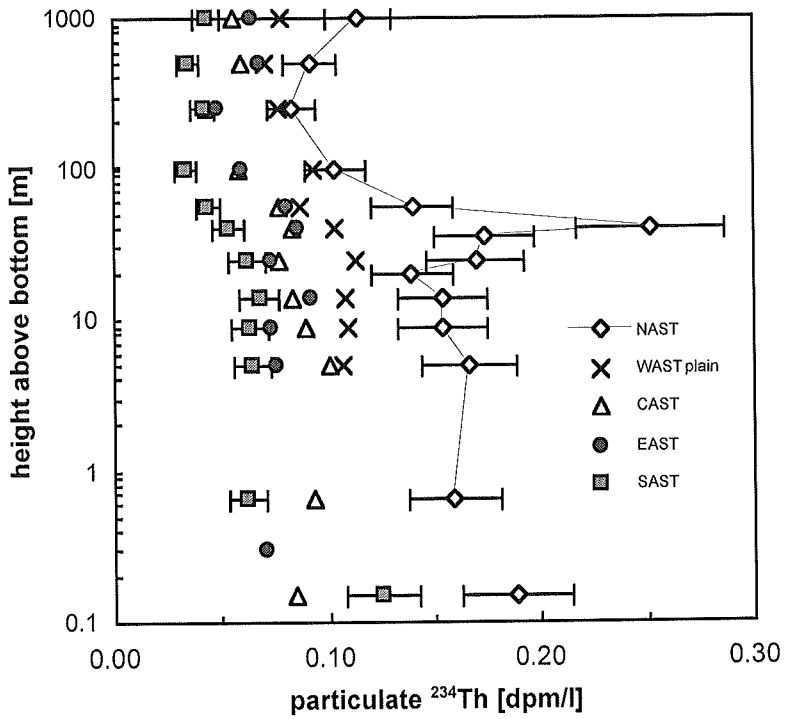

Fig. 2: Profiles of particulate ^{234}Th at the BIGSET main stations NAST, WAST, CAST, EAST and SAST. Error bars indicate the method's error of ±13% and are shown for SAST and NAST.

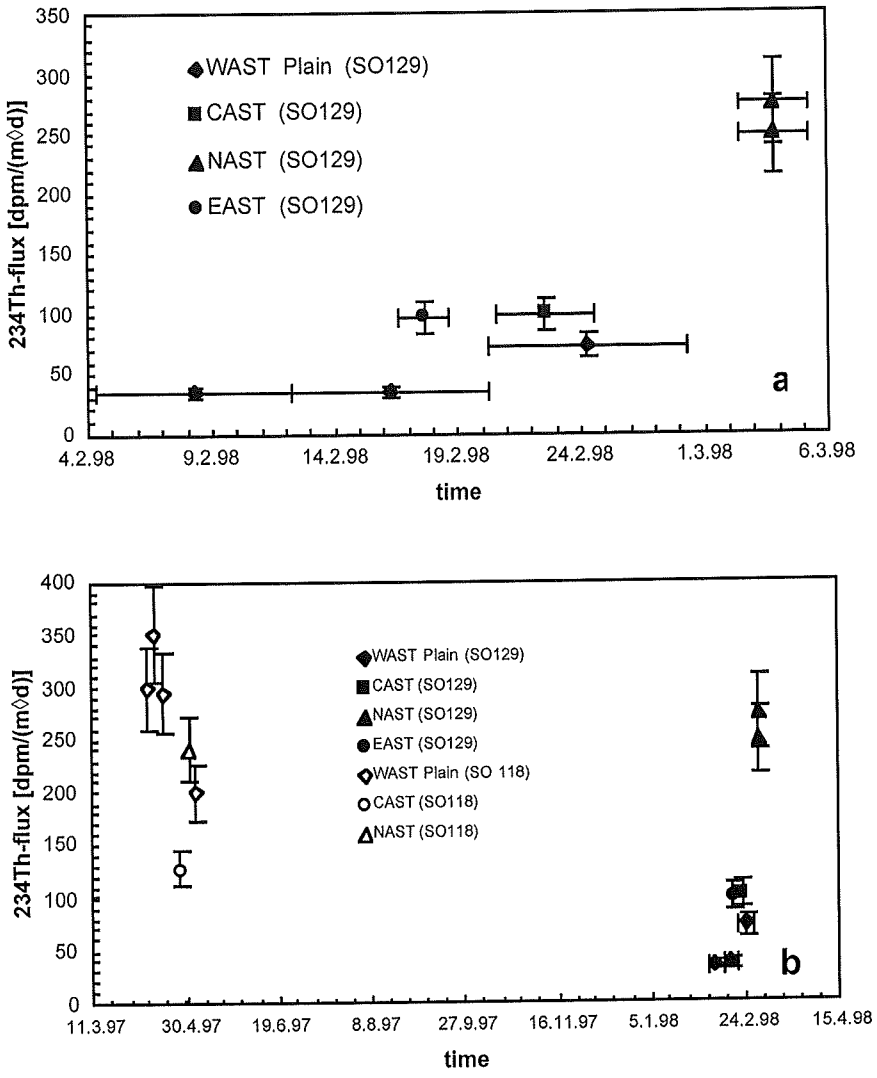

Fig. 3a,b: Particulate ^{234}Th fluxes in short term trap moorings.

(a) Fluxes determined during SO129.

(b) Fluxes determined during SO118 and SO129.

Vertical error bars denote the ±13% method's error. Horizontal bars denote the duration of sample collection. Except for WAST (SO129) the horizontal bars have been omitted in Fig. 3(b) since they have approximately the size of the symbols.

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5.5 Particle flux in the benthic boundary layer, benthic foraminiferal habitats and early diagenetic processes in deep-sea environments

Frank Kurbjeweit and Katharina Bayer
BIGSET, Institut für Geologie und Paläontologie, Universität Tübingen

Research programme

Objectives of subproject 5 are studies on deep-sea benthic foraminifera at the six stations WAST-T, WAST, SAST, CAST, EAST and NAST in order to get more information on the ecology and biotic processes in respect to the environmental constraints (biogeochemistry and related processes). More detailed information on the ecology and biology of deep-sea benthic foraminifera will help to quantify and model the energy and matter cycling within the benthic boundary layer. In this respect, it is of major importance to record the spatial and temporal variability of this energy and matter cycling. The investigations are conducted as part of field studies to document important system components in oceanographic regions, which underlie episodic sedimentation events (monsoonal system in the Arabian Sea vs. spring blooms in the Northeast Atlantic). On SO129 we focused on species composition and their distribution, on the biomass, food web structure, habitat preferences, growth, reproduction, bioturbation, new production of organic material and pore water chemistry to investigate the foraminiferal contribution to the BBL carbon cycle and related processes. The processing of samples from METEOR cruises M31/3, M33/1 and SO118 indicated a clear gradient in the foraminiferal biomass (C_{org}) and abundance as well as faunal composition and diversity from north to south and from west to east (C_{org}: WAST > WAST-T > NAST > CAST > EAST >SAST). This is referred to different trophic conditions. At WAST-T and WAST the estimated foraminiferal biomass (C_{org}) was about 0.15-0.42 gcm^{-2} within the upper 5 cm of the sediment and thus 5-30 times greater than at stations SAST and EAST. During the previous cruise SO118 large allogromiids dominated the surface sediments at WAST-T with up to 1.2 gcm^{-2}. Furthermore, different vertical distribution patterns in the sediment depending on oxygen, carbon content, nutrients, chlorophyll, organic matter flux and water depth were observed. High abundance, biomass and turnover of benthic foraminifera is related to sedimentation rate of organic matter. Therefore, our investigations are carried out at different seasons. On SO129 we focused on species composition and their distribution, on the biomass, food web structure, habitat preferences, growth, reproduction, bioturbation, benthic new production of organic material and pore water chemistry to investigate the foraminiferal contribution to the deep-sea carbon cycle and related processes. The knowledge about grazing of benthic foraminifera in the deep-sea is rather limited (TURLEY et al. 1993; LINKE et al. 1995; HEMLEBEN & KITAZATO 1995). Fresh sedimented material from the euphotic zone (phytodetritus) is

used by most foraminifera. However, we do not know how much of these food items are ingested on which time scales and how much organic material is produced in terms of biomass for sustaining their microhabitats (e.g. cysts) and waste product release. Presently we also have only a limited knowledge how important the meiofauna is in terms of bioturbation and bioirrigation (HEMLEBEN & KITAZATO 1995; GROß in prep.). Most authors (i.e. MAHAUT & GRAF 1987, WHEATCROFT et al. 1994) suggest that mainly macrofauna is responsible for bioturbation, but in many deep-sea areas meiofauna is dominant in terms of abundance and biomass. Thus, it is feasible that benthic foraminifera exceeding often more than 50% of the eukariotic biomass (GOODAY 1994) play an important role also in bioturbation and bioirrigation. In this respect, we need quantitative data from *in situ* and laboratory experiments with benthic forminifera to model the energy budget in deep-sea sediments. In addition to natural radiotracers, artificial tracers can be used to quantify ingestion and bioturbation (SHERR & SHERR, 1993). For that reason, fluorescently labelled microbeads and bacteria, freeze dried *Chlorella* as well as micro glassbeads were used.

Abundance and composition of benthic foraminifera

At all main and four intermediate stations multicorer (MC) samples were taken (Tab. 1). In addition, foraminiferal tests and pore water were sampled to determine stable isotopes (^{13}C and ^{18}O). Maxicorer (MAC) samples were used to run experiments under *semi in situ* conditions related to bioturbation and grazing of benthic foraminifera.

Tab. 1: Main and intermediate stations at which multi- (MC) and maxicorer (MAC) were retrieved for faunal analysis and experiments.

Station	Date	St.	MC	MAC	Longitude	Latitude	Depth
WAST	03.02.98	8	3	1	16°13,08	60°16,00	4041
WAST	04.02.98	11		2	16°13,27	60°16,08	4040
WAST-T	06.02.98	19	9	3/4	16°10,46	59°46,00	1915
WAST-T	07.02.98	19		5/6	16°10,46	59°46,00	1915
WS	09.02.98	26	13		14°27,16	61°39,21	4109
SAST	11.02.98	32	14	7	10°02,00	65°00,00	4427
SAST	12.02.98	37	17	8	10°01,99	64°59,99	4424
SE	15.02.98	46	20		12°50,20	66°48,03	4139
EAST	16.02.98	48	21		15°35,00	68°34,00	3845
EAST	16.02.98	49	22	9/10	15°35,00	68°34,00	3845
EC	19.02.98	56	26		15°02,94	66°42,76	3917
EC	19.02.98	56	26		15°02,94	66°42,76	3917
CAST	20.02.98	62	27	11	14°25,00	64°34,00	3956
CAST	21.02.98	64	31	12	14°25,03	64°33,99	3956
CAST	24.02.98	71		13	14°25,03	64°34,02	3954
WAST	26.02.98	79	34		16°12,95	60°15,98	4046
WAST-T	26.02.98	80	35	14	16°10,50	59°46,00	1915
NC	01.03.98	88	37		17°45,00	65°44,97	3419
NAST	02.03.98	92	38		20°00,00	65°35,01	3187
NAST	03.03.98	95	40	15/16	20°00,02	65°35,02	3187

Immediately after arriving on deck, whole MAC cores for experiments were transferred to either the cool room (3-7°C) or a water bath (1.8-3.7°C). Subsamples for cultures (only at WAST-T) of the upper 2 cm of sediment and the bottom water of MC cores were transferred into 250 ml DURAN flasks. These were kept under *semi in situ* conditions (4°C and darkness). The samples were regularly inspected every day for foraminifera and their tracks in the sediment. From MC casts at each station, one core was used for faunal analysis of the foraminiferal assemblage. These cores were photographed to document the original fabrics before they were sliced in half centimetre intervals for the top two centimetres and thereafter in one centimetre slices. In general, the slices of the upper 10 cm were stained with a solution of ethanol and Rose Bengal (2 g/l) to distinguish between living and dead specimens. Routinely two replicates were taken. The sediment of a second MC core was used for transmission electron microscopy (TEM) of foraminiferal cytoplasma to trace ingested food particles. For that purpose the upper 2 cm of the sediment were sieved over a 125 µm-screen and washed with filtered seawater. Subsequently, the living foraminifera were picked under the stereo microscope, fixed and stained according to standard procedures. From a third core benthic foraminifera and pore water as well as water from the bottom nepheloid layer (BNL) were acquired for ^{13}C and ^{18}O analysis to record microhabitat processes. The pore water was obtained by extracting it from cores sliced in centimetre intervals down to 14 cm by an Argon flow for twenty minutes (3 atm). All samples were poisoned with $HgCl_2$ to stop bacterial growth and sequestration of CO_2. Special attention was paid to keep transfer times as short as possible and to avoid contamination by atmospheric CO_2 during compression. The sediment of a fourth core was used for HPLC analysis by dividing the core into two halves. One half was sampled with a small piston corer of 1.2 cm cross diameter. The second half was sieved over a 125 µm gauze and washed with filtered seawater. Subsequently, the living foraminifera were picked under the stereo microscope and frozen at -30°C for further determination of ingested phytoplankton remains and pigments.

Preliminary results

Daily inspections of a culture from WAST-T in an aquarium indicated due to tracks in the sediment that foraminifera survived the decompression from 1916 m depth, but no specimen were directly observed during the six-week cruise.

The following preliminary abundances were obtained from TEM prepared specimens for the upper 2 cm of the sediment (Tab. 2). They may not be used for comparison of abundance!

Tab. 2: Species of benthic foraminifera >125 µm in the upper 2 cm of the sediment sorted for TEM analysis in order of occurrence at the main stations during SO129.

Station	Species	Number of species
WAST	*Hormosina globulifera*	6
	Cribrostomides subglobosum	5
	Uvigerina peregrina	5
	Cyclammina trullisata	2
	Chilostomella oolina	2
	Fursenkoina mexicana	2
	Hormosina nodulosus	1
	Epistominella exigua	1
	Reophax dentaliniformis	1
	Psammosphaera parva	1
	Ammobaculites agglutinans	1
WAST-T	*Allogromiids*	5
SAST	*Cribrostomides subglobosum*	18
	Sandschaler spp.	7
	Cyclammina trullisata	5
	Glomospira charoides	5
	Lagenammina difflugiformis	4
	Reophax spp.	3
	Epistominella exigua	3
SAST	*Ammobaculites agglutinans*	2
	Trochammina spp.	2
	Fursenkoina mexicana	1
	Uvigerina peregrina	1
	Rhizammina algaeformis	1
	Hormosina globulifera	1
	Qiunqueloculina weaveri	1
	Anomalina sp.	1
EAST	*Bulimina sp.*	5
	Fursenkoina mexicana	3
	Lagenammina difflugiformis	3
	Epistominella exigua	2
	Rhizammina algaeformis	2
	Reophax dentaliniformis	1
	Cribrostomides subglobosum	1
	Sandschaler spp.	1
CAST	*Cribrostomides subglobosum*	7
	Hormosina globulifera	2
	Hormosina nodulosa	2
	Epistominella exigua	2
	Sandschaler spp.	2
	Reophax dentaliniformis	1

Cribrostomides subglobosum, Lagenammina difflugiformis, Hormosina spp. and *Reophax* spp. were recorded from almost all stations in rather high numbers independent from water depth and particle flux. Calcareous species like *Epistominella exigua* belong to the epifauna and were also abundant at most stations. In contrast to MC-samples from M33/1 at the end of the SW monsoon and SO118 at the end of the NW monsoon, they seem to play a minor role during this monsoonal phase. Infaunal species such as *Uvigerina peregrina* occurred exclusively at the eutrophic station WAST in significant numbers. At WAST-T large

Allogromiids (0.2 to 0.8 cm in length) dominated the phytodetritus rich surface layer during with only up to 270 individuals per m^2 equivalent to 0.25 gcm^{-2} and 0.046 gnm^{-2} in the surface sediments (Tab. 3). At least two different morphotypes (spherical and oval) could be distinguished. It appears that Allogromids respond quickly to phytodetritus fluxes from the euphotic zone and harvest it by scavenging. In laboratory experiments with *Tinogullmia riemanni*, a related allogromiid species from the North Atlantic, ingestion rates of bacteria sized fluorescently labelled microbeads (FLM) reached up to 4000 equivalent to about 5.8% of their body carbon. This experiment suggests that their large counterparts in the Indian Ocean represent an important component in the benthic carbon turnover.

Tab. 3: Length and width of allogromiid foraminifera from the sediment surface at WAST-T and calculated carbon (9.77x + 89.53 = y; r^2 = 0.69) and nitrogen (1.81x + 15.75 = y; r^2 = 0.67) contents from measured individuals.

Individual	Length (mm)	Width (mm)	C (µg)	N (µg)
1	7.42	5.17	1544	285
2	6.00	4.17	857	158
3	5.75	4.33	823	152
4	7.08	4.75	1309	242
5	7.92	6.00	2014	373
6	6.00	4.50	919	169
7	2.42	2.33	159	29
8	7.08	4.75	1309	242
9	6.25	4.58	1006	186
10	6.92	5.17	1354	250
11*	3.08	3.08	240	44
12	6.75	5.17	1294	239
13	4.08	2.92	338	62
14	4.33	3.42	418	77
14	6.67	4.75	1170	216
16*	1.67	1.67	113	20
17	5.67	4.25	788	145
18	6.25	4.58	1006	186
	5.63	4.20	926	171

* spherical allogromiids

First results of the abundance, distribution and diversity of benthic foraminifera at station SAST indicate lower numbers of foraminifera per sediment volume during the NE monsoon (February) than during SW intermonsoon (October; Tab. 4a). In addition the average living depth (ALD) within the sediment is deeper during the SW intermonsoon than during the NE monsoon. Furthermore, the diversity in most depth horizons is significantly greater during the SW intermonsoon than during the NE monsoon (Tab. 4b). If this trend is comparable with the other stations in the Arabian Sea, it has to be examined in detail.

Tab. 4a: Abundance and distribution of benthic foraminifera at station SAST in October (SW intermonsoon) and February (NE monsoon) in the upper 5 cm of the sediment.

	SAST - SW intermonsoon M33/1 - October 95				SAST - NE monsoon SO129 - February 98			
sediment depth (cm)	>30 µm n/10cm³	>63 µm n/10cm³	>125 µm n/10cm³	Σ n/10cm³	>30 µm n/10cm³	>63 µm n/10cm³	>125 µm n/10cm³	Σ n/10cm³
0.0-0.5	2	8	1	11	-	7	4	11
0.5-1.0	1	10	10	21	-	9	2	11
1.0-2.0	0.4	5	2	7.4	-	3	1	4
2.0-3.0	-	1	1	2	-	2	-	2
3.0-4.0	-	0.3	0.3	0.6	-	-	-	-
4.0-5.0	-	-	1	1	-	-	0.3	0.3

Tab. 4b: Diversity (Shannon-Wiener-Index) of benthic foraminifera at station SAST in October (SW Intermonsoon; average living depth (ALD)= 1.1 cm) and February (NE Monsoon; ALD = 0.8 cm) in the upper 5cm of the sediment.

	SAST - SW intermonsoon M33/1 - October 95				SAST - NE monsoon SO129 - February 98			
sediment depth (cm)	>30 µm divers. H (S)	>63 µm divers. H (S)	>125 µm divers. H (S)	Σ divers. H (S)	>30 µm divers. H (S)	>63 µm divers. H (S)	>125 µm divers. H (S)	Σ divers. H (S)
0.0-0.5	1.61	1.91	0.69	2.42	-	1.87	1.32	1.93
0.5-1.0	0.69	2.16	2.18	2.84	1.39	1.94	1.49	2.03
1.0-2.0	1.10	2.09	1.83	2.69	-	1.23	0	1.49
2.0-3.0	-	2.20	0	1.79	-	1.10	-	1.10
3.0-4.0	-	0	-	0	-	-	-	-
4.0-5.0	-	-	-	-	-	-	0	-

Grazing and bioturbation experiments

Material and methods

Three different kinds of experiments were performed in MAC cores using living specimens at all main stations:

- 1. Long-term grazing experiments in MAC cores for about 7-10 days under *semi in situ* conditions (1.8-3.7°C, darkness or light, 1 atm) with fluorescent microbeads and/or bacteria in a dilution series to investigate the grazing potential of benthic foramininfera.
- 2. Short-term experiments in MAC cores as time series for about 24 hours with fluorescent microbeads and/or bacteria in a time series to investigate the speed of grazing.
- 3. Coupled grazing and bioturbation experiments lasting for about 24 to 72 hours under in situ conditions (2-4°C, darkness, different pressures depending on depth of station) in the lander system with micro glassbeads and *Chlorella* to investigate the grazing and bioturbation potential of benthic foramininfera.

Small piston corers were used for subsampling the upper few cm in benthic chambers to investigate the distribution of micro glassbeads in the sediment by means of x-ray analysis and/or SEM analysis. The samples were subsequently wet sieved over a 125 µm screen and picked under a stereo microscope (ZEISS Stemi 2000). The foraminifera were examined with an epifluorescence microscope (LEITZ Axioplan) for attached fluorescently labelled microbeads (FLM) and/or bacteria (FLB) and their test diameter were measured. Subsequently the tests were crushed to determine the total numbers of FLM and/or FLB. For the FLB the carbon content was determined by using the conversion factor 30 x 10^{-12} gC_{org} per cell (LOCHTE and BOETIUS pers. comm.). Estimated biomasses converted into organic carbon content were calculated by applying the equations by ALTENBACH (1985) for various calcareous and agglutinated species.

Preliminary results

MAC cores (=liner) were retrieved in good conditions only at few stations, since the maxicorer either failed due to problems in gaining sufficient sediment or problems during the handling procedure of the liners on board (i.e. rendering of the sediment). Preliminary results from short-term incubations indicate that benthic foraminifera ingest and displace glas microbeads and fluorescently labelled microspheres. Quantification depending on concentration and incubation time is still necessary and will be done in the forthcoming weeks.

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5.6 Benthic carbon remineralisation and community structure

Ursula Witte, Axel Cremer, Felix Janssen and Tina Treude
BIGSET, GEOMAR Forschungszentrum, Universität Kiel

Research objectives

During cruise SO129 work focussed mainly on *in situ* -experiments and -measurements. For this purpose, three free-vehicle vehicles were operated: the GEOMAR chamber lander (FFR), the free-fall observation system (FFB) and a free vehicle trap system (FFF). The lander operations were very successful: in total, we conducted 19 deployments with a deployment time of 40,9 days.

The aim of benthic studies were: to study solute exchange processes at the sediment/water interface and to assess the role of the larger size classes within the benthic community (for information on smaller size classes see chapter 5.2 and 5.8). Special effort was made to gather information on the benthic scavenger community in order to test the hypothesis that differing trophic conditions are mirrored in both composition and abundance of this community. We were able to gather an extensive set of data and samples that will be analysed within the framework of two MSc thesis during 1998.

To supplement the *in situ* investigations with samples for taxonomic purposes as well as analyses of faunal abundance and biomass, macrofauna and megafauna were sampled using box corer, maxicorer, Agassiz trawl, and OFOS.

Results

Benthic carbon remineralisation

Benthic carbon remineralisation was measured *in situ* using the GEOMAR chamber lander. During SO129, it was successfully deployed seven times usually carrying three chambers each equipped with a syringe water sampler. Total bottom time was 365 hours, the duration of the measurements varied between 36-98 hours. Earlier investigations following the SW monsoon (M33/1) had demonstrated very high benthic remineralisation activity in most parts of the deep Arabian Sea except our southernmost station SAST. Remineralisation was particularly high at WAST, a ranking according to this parameter was WAST > EAST > CAST > SAST (WITTE & PFANNKUCHE, in prep). Following the NE monsoon, however, a somewhat different picture arises (Fig. 1): again, activities were high for deep-sea environments. This time, however, remineralisation rates at WAST did not exceed those at CAST and EAST. Instead, highest values were reached at NAST and a clear north-south gradient is visible, rendering a ranking NAST > WAST, CAST, EAST > SAST. These findings are in agreement with the fact that the effects of the NE monsoon are most pronounced in the Northern Arabian Sea.

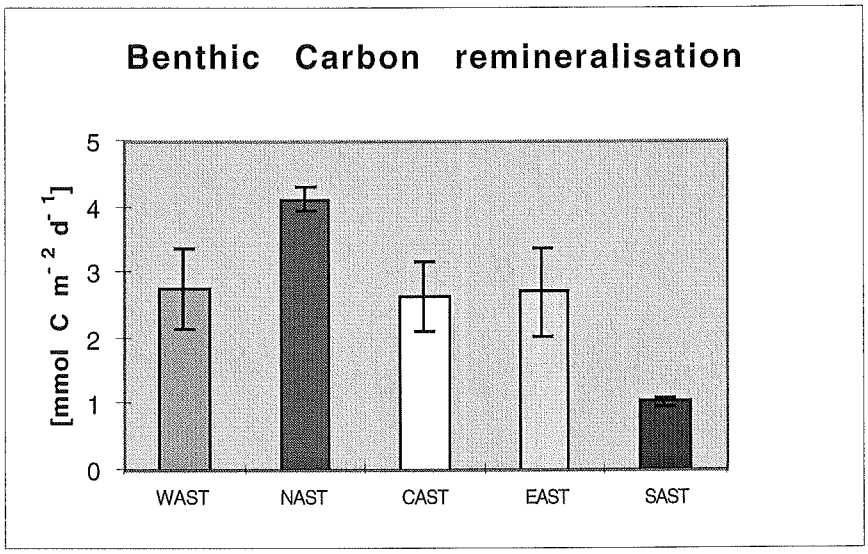

Fig. 1: Benthic carbon remineralisation rates at the five main stations (SO129)

The benthic scavenger community

Investigations on the benthic scavenger community were performed to address the following topics:

- Which species are appearing at a fish carcass offered as bait, i.e. which species comprise the community?
- How are scavenger populations structured and how important are the predominant species in terms of abundance and biomass?
- Which meal sizes do the main scavengers attain?
- Is scavenging obligatory or just an additional feeding habit?
- Are scavengers parts of the 'background megafaunal community'?

To address these questions, the following equipment was applied: free-vehicle camera system (FFB), free-vehicle trap system (FFF), towed camera sled equipped with both still- and video cameras (OFOS) and Agassiz trawl (AT).

Free-vehicle camera system (FFB)

The system was used to monitor the response of benthic megafauna to large food falls. It consisted of a vertically oriented time lapse stereo camera system (BENTHOS 372 cameras) mounted on a GEOMAR lander frame. The photographs covered approx. 0.7 m^2 of the sea floor and were taken at pre-set intervals. As bait, a tuna carcass was placed in the centre of the photographed area. At the end of the deployments a net was released above the bait in order to catch the scavengers present. The FFB was moored five times, at WAST (2 x), SAST, CAST and NAST. Deployments were made for periods between 1.5 and 5 days with bait weighing 2 to 5 kg. Altogether 2500 stereo pairs of slides were taken covering more than 200 hours with time intervals between 0.6 and 10 min. Four main taxa were attracted to

the bait at each location: astacid shrimp (*Plesiopennaeus armatus*), lysianassid amphipods (*Eurythenes* spp.), macrourid fish (*Coryphaenoides* spp.), and zoarcid fish (*Pachycara* sp.). In addition, anomuran crabs appeared in large numbers at NAST and to a lesser extent at SAST. Most other animals observed did not seem to feed on bait. The main taxa appeared at the bait in a recurrent chronological order: astacid shrimp reached the carcass within 20 to 70 min followed closely by lysianassid amphipods appearing after 1 - 3.5 h. Subsequently, after 5 h at the latest the first macrourid fish showed up. Lysianassids as well as macrourids disappeared when the bait was consumed for the most part. At this time zoarcids and anomurans entered the scene in considerable numbers. Individuals of both taxa stayed on or near the remains of the bait until the end of the deployments and were thus caught with the net. The net also caught smaller amphipods invisible on the photographs, which were obviously also involved in the consumption of bait.
Analysis of gut contents revealed that the zoarcids had fed on both small amphipods and tuna meat, indicating that the observed community includes scavengers as well as their predators. Although stations resembled each other to some extent in terms of faunal composition and succession, some striking differences could be observed: At CAST and NAST lysianassids consumed most of the bait. Up two 40 individuals were present simultaneously consuming the bait of approx. 3 kg within one day. At SAST on the other hand, an average of one lysianassid /10 slides could be observed. Here, macrourids were responsible for the main consumption of bait: up to five individuals fed simultaneously for periods of several hours. On average 2 ind./ slide were counted, significantly exceeding the number of macrourids at CAST and NAST. The station at WAST occupies a special position. Here, consumption was not clearly dominated by any of the taxa and much slower. The mean feeding rate at WAST for the community as a whole was app. 1000 g tuna meat per day as compared to 2500 - 5000 g/d at the other locations. A detailed quantitative analysis of the photographic material will be carried out in the near future. In addition, work will focus on two subjects. First, size determinations of scavengers on stereo slide pairs will be combined with length-weight relations determined from individuals caught (FFF, AT, net) in order to obtain biomass data. Second, the slides will be assembled to form a quick-motion picture in order to perceive patterns of movement and feeding behaviour. Of particular interest are information on the sustenance time at bait of individuals of the different taxa, as these data will allow calculating the total number, biomass and feeding rates of the specimens attracted. Furthermore, it will then be possible to estimate maximum distances of attraction to bait as well as scavenger abundances at the different locations (SAINTE-MARIE & HARGRAVE 1987).

Free-vehicle trap system (FFF)

On WAST-T, WAST, SAST, CAST and NAST the community of deep-sea scavengers was sampled with a free-fall trap system (see Tab.1). Basically, it consisted of two net cages, each with a funnel entrance 30 cm above ground. In addition four pairs of amphipod traps (PVC-tube, 10 cm in diameter) were fixed in 30, 50, 70 and 90 cm above ground on one side of the fish cages. To catch life amhipods, a thermoinsulated trap (isotrap) was fixed on the other side of the fish trap. The isotrap was insulated with a cube of syntactic foam. By activation of the acoustic release system, a thermoinsulated lid closed the isotrap watertight. The entrance was 64 cm above ground. In addition, the isotrap was also used on EAST and WAST incorporated into the free-fall respirometer (FFR). In this case, the entrance was 124 cm above ground. Tuna meat was used as bait (head, tail, meat, and intestines) as well as a red snapper (head and tail). In one of the fish traps and one of each pair of amphidod trap as well as in the isotrap the bait was not accessible to scavengers. The catch of the fish and the non-insulated amphipod traps will be used to identify species photographed by the FFB. A comparison of stomach contents between scavengers caught in bait-accessible versus non-accessible traps will reveal information about their feeding behaviour i.e. quantitiy of ingestion. Stomachs of both fish and decapod crustaceans were sampled for analyses of lipid- and glycogen-contents.

Tab.1: Trap deployments during SO129

investigation area	station number	gear	bottom time
WAST	12#2	FFF 1	27
WAST-T	18	FFF 2	24
SAST	29	FFF 3	31
SAST	37	FFF 4	58
EAST	48	FFR 4 +isotrap	43
CAST	60	FFF 5	42
CAST	67	FFF 6	49
WAST	85	FFR 6 +isotrap	33
NAST	101	FFF 7	57

Fish traps

The catch of the fish trap was very low. On WAST the chambers stayed empty, on WAST-T and SAST two macrourids were caught. Therefore, an additional funnel entrance was mounted at the bottom of one of the chambers in 22 cm above ground at CAST, which improved catch results considerably. During the second deployment at CAST, experiments on bait preference were made (tuna, red snapper, squid prepared with luminophore tracers). Stomach contents will be

analysed at GEOMAR. Beside fish, amphipods were caught at every station (probably *Eurythenes* spp.). At NAST, both traps caught zoarcids, anomurid decapods and one extremely large specimen of *Eurythenes* (ca. 12 cm), a few small amphipods (ca. 2 cm) and one unidentified fish species

Uninsulated amphipod traps

At each station, except NAST, amphipods were caught, whereby the bottom-near traps caught more individuals than those more distant from the bottom, which could be linked to the benthic life style of some species. The catch of no amphipod on NAST corresponds with the result of the FFB net catch.

Insulated amphipod trap

In 5 of 9 employments the isotrap caught life specimens (see Tab. 2). The temperature inside the trap upon retrieval was between 1,3 and 2,3°C, i.e. close to *in situ* temperatures of 1,7°C (CTD-data). *Eurythenes* survived the transport to the surface without detectable decompression problems, whereas the unidentified small species were mostly found dead. This result correlates with observations of GEORGE (1979) who showed that *Eurythenes* can tolerate large pressure changes and attributed this to the vertical migrations capacity by this species.

Tab. 2: Life amphipods caught by isotrap during SO 129

investigation area	WAST	WAST-T	SAST	CAST	WAST
gear	FFF1	FFF2	FFF3	FFF6	FFR 6 + ISO
depth	4044m	1907m	4422m	3956m	4044m
alive amphipods	11	2	1	1	3

In vitro respiration, excretion and digestion efficency of deep-sea amphipods

Shipboard investigations on the energy budget of life amphipods from isotrap catches were carried out. The animals were kept in a dark basin at 0,9-1,7°C. The amphipods were allowed to feed for 24h on bait mixed with fluorescing latex beads and were then incubated in closed bottles with filtred deep-sea water at a temperature of 0,9°C. After the incubation the oxygen and ammonium content of the incubation water were determined, and samples for DOC and C/N analysis as well as for the enumeration of defeacated latex beads were taken (see Tab. 3).

Tab.3: Oxygen consumption and ammonium excretion of deep-sea amphipods determined *in vitro.*

amphipod /	body length	A 5 1,22 cm	A 6+7 0,53/ 0,65 cm	A 9 1,63 cm	A10 1,53 cm	A11 3,65 cm
O_2-consumption (µl/h)	1.incubation (65,5h)	3,5	2,1	10,8	-	-
	2.incubation (57,5h)	2,5	2,3	9,6	-	-
	3.incubation (30,5h)	-	-	-	9,1	90,2
	4.incubation (37,5h)	3,4	2,4	7,2	5,3	64,0
NH_4^+- excretion (10^{-2}µmol /h)	1.incubation (65,5h)	4,13	2,46	4,17	-	-
	2.incubation (57,5h)	2,03	0,47	1,60	-	-
	3.incubation (30,5h)	-	-	-	4,00	56,3
	4.incubation (37,5h)	3,09	1,78	1,66	6,41	15,5
origin		SAST	WAST-T	CAST	WAST	WAST
depth (m)		4422	1907	3954	4044	4044
duration of keeping (d)		21	26	9	6	6

As expected, oxygen consumption and ammonium excretion of larger individuals was higher than of smaller ones. During maintenance no symptoms of decompression problems could be detected. The animals usually stayed in a coiled-up resting position unless the basin was moved or food was introduced, then they started to swim actively.

Megafauna and biogenic structures (OFOS and Agassiz trawl)

The OFOS was employed for the following objectives: to describe the composition and abundance of the background megafaunal community (in combination with AT samples) and to supply stereo photographic images of the sea floor in order to characterize the shape, size, abundance and dispersion patterns of biogenic structures like mounds, funnels, crawling traces etc. For the latter purpose, appr. 200 photographs each were randomly taken at CAST, WAST and NAST from 1.50 m above the sea floor. For megafaunal countings the system was deployed successfully at EAST and NAST, taking appr. 500 pictures each at 2.50 m above bottom. All photographs will be analysed at GEOMAR. A 3 m wide Agassiz trawl was used to collect benthic megafauna for determination of both species

composition and biomass of selected individuals. The trawl was towed at stations WAST, SAST, CAST and NAST. Towing speed was appr. 1 kn, bottom times varied between 30 and 60 min. The catch was fixed in borax buffered formalin. Dominant taxa caught were: ophiurids (WAST), porifera and bivalves (CAST), and bivalves (NAST). The following taxa were caught in smaller numbers or as single individuals: astacid shrimp (SAST, CAST, NAST), macrourid fish (WAST), asteroids (SAST, NAST), holothuroids (CAST, NAST), ophiurids (SAST, CAST, NAST), as yet unidentified fish (WAST Plain, SAST, CAST, NAST), the cephalopod *Vampyroteuthis infernalis* (NAST) and scaphopoda (CAST, NAST) Some of the samples included individuals of yet undetermined taxa.

Makrofauna

To analyse the standing stock, structure and distribution of the macrofaunal community, sediment cores were taken with either box corer or maxicorer and sieved with 500 µm to 1 cm (WAST: 20 cm) from sediment horizons (0-1; 1-5; 5-10 cm). Samples were fixed in buffered formalin and will be sorted at GEOMAR.

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5.7 Biogenic sediment compounds

Olaf Pfannkuche, Anja Kähler and Eva Phillip
BIGSET, GEOMAR Forschungszentrum, Kiel

Introduction

Biogenic sediment compounds are applied as proxies for a variety of biological parameters such as input of phytodetritus into the sediment, benthic biomass and benthic activity. As the analyses are based on relatively small volumes of sediment (1 cm^3 respectively 3.4 cm^3 sediment volume per analysis) the measurements mainly provide information on the small size classes of the benthic size spectrum which include meiobenthos (size class 500-30 µm), nanobenthos (size class 30-2 µm) and bacteria (size class ≥2 µm). In comparison to macrofauna biomass the biomass of the small benthic size classes clearly dominates total benthic biomass in the deep sea (PFANNKUCHE 1993, PFANNKUCHE & SOLTWEDEL 1998). The predominance of small organisms in various deep-sea habitats was also stressed by GOODAY *et al.* (1992), who reported that 50% or more of the eukariotic biomass belonged to the foraminiferans, whereas LOCHTE (1992) found that about 80-90% of total benthic biomass in the outer Western European Basin was formed by bacteria. Bacteria and protozoans can multiply in hours and can also activate resting spores; they therefore represent the most reactive potential of benthic communities. Thus, it is the small size spectrum of benthic organisms that can respond very quickly to any pertubations, e.g. sedimentation pulses of particulate organic matter (POM). BOETIUS & LOCHTE (1994, 1996) could demonstrate the short times of response by deep-sea bacteria to POM input. Deep-sea bacteria increased the production of specific exoenzymes, which is the primary step of breakdown of polymeric compounds, within several days. This process necessitates a step-up of metabolic activity. Such a metabolic reaction could be shown by rising ATP levels in deep-sea benthic foraminifera following food supply (LINKE 1992) and by the increase in ATP concentrations in sediment samples less than nine days after deposition of faecal pellets at a bathyal site (GRAF 1989). If a POM pulse is strong enough it can also result in an increase of small size scale biomass. Any short term changes of benthic activity and biomass will therefore be mirrored by the small biota that can be addressed by the measurement of specific biogenic compounds.

Sediment sampling and analysis

Sediment samples with a multiple corer (BARNETT et al. 1984) were taken at all benthos stations (see Tab. 1). At each main station (NAST, WAST, CAST, EAST. SAST) a minimum of three multiple corer hauls was subsampled and analysed. Randomly selected multiple corer tubes were subsampled with small piston corers of 1.1 cm or 3,46 cm cross diameter. Three replicates for each parameter were

taken from an individual multiple corer cast. Sediment samples were analysed in 0.5 cm intervals for the sediment layer 0-2 cm and in 1 cm intervals down to 10 cm depth followed by 2 cm intervals to a maximum of 30 cm depth. Samples for the following sediment analyses were taken (measurements marked with an asterisk were carried out in the ship's laboratory) all other determination will be carried out at GEOMAR (Tab. 1).

Tab. 1: Sediment analyses performed during SO129

Biomass
- adenylates (ATP+ADP+AMP)
- DNA
Metabolic activity
- electron transport system activity (ETS, respirative potential)*
- ATP
- hydrolysis rates of fluorescein diacetate (activity of bacterial exoenzymes)*
Plant pigments
- chlorophyll-a and pheopigments (fluorimetric)*
- pigments (HPLC)
other measurements
- proteins*
- C_{org}, N_{org}
- water content
- grain size

Preliminary Results

Chloroplastic pigments

Concentrations of sediment-bound pigments were measured to obtain general information of the sedimentation patterns and distribution of plankton-derived phytodetritus from the euphotic zone. Chloroplastic pigments are operationally defined as chloroplastic pigment equivalents (CPE) representing the sum of chlorophyll *a* and pheopigments. Fig. 1 shows integrated CPE values from the top two centimetres of the sediment from cruise SO129 in comparison to previous cruises. This sediment horizon has been chosen as any short-term changes are likely to occur in this uppermost sediment layer. CPE content at WAST showed the highest values demonstrating the regionally exceptional position of this station. Phytodetrital sedimentation at NAST was second highest followed by CAST, EAST and SAST. CPE content at NAST was lower at SO129 than in April 1997 (SO118). During our investigations at NAST, we encountered an ongoing phytoplankton bloom with diatoms predominating the net phytoplankton. Although some sedimentation must have taken place already, as indicated by the relatively high CPE values, the full pulse should occur on the sea floor after the decline of the bloom. This is indicated by the higher late April values measured during the SO118.

At all other stations CPE values from SO129 were higher than the values recorded from SO118. However, a comparison of all data from WAST (SO129/February, M31/March and SO118/April) seems to point at a substantial interannual variability by a factor of two. A comparison between the spring (SO118, SO129) and autumn values (M33) indicates the importance of the NE monsoon for the particle flux. At NAST, the NE monsoon even seems to generate even larger CPE fluxes than the SW monsoon. At all other stations fluxes between the two periods did not differ significantly.

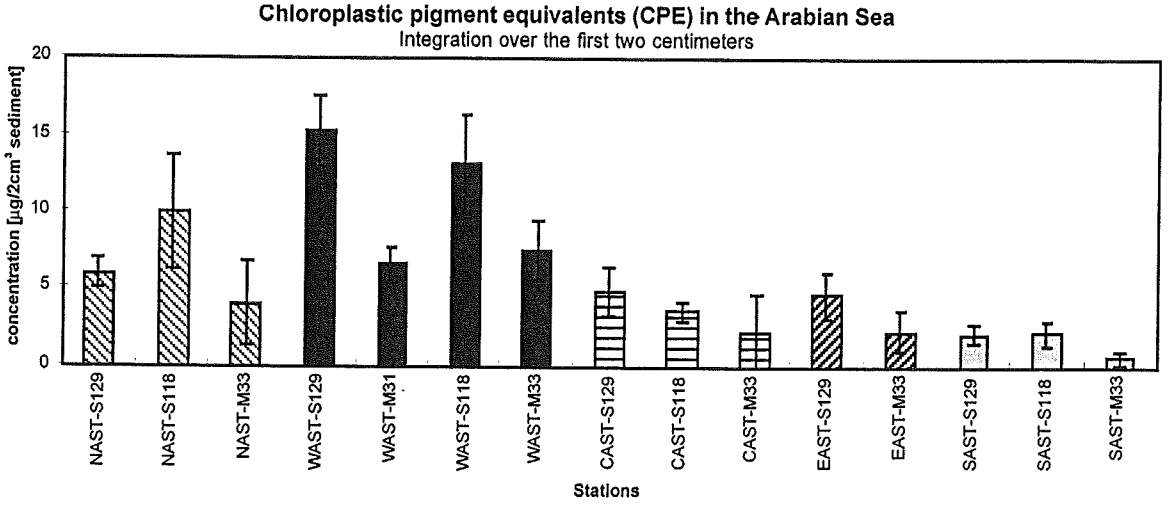

Fig. 1: CPE contents for centimetres 0-2 of the sediment column. Data from SO129 in comparison to data from April 1997 (SO118) October 1995 (M33) and March 1995 (WAST only, M31).

Hydrolytic activity

Bacterial exoenzymatic activity was measured as hydrolytic activity with the fluorigenic substrate (Fluorescein-diacetate, FDA). FDA is cleaved unspecifically by several different hydrolytic enzymes, particularly esterases. This parameter is used as an indicator of changes of general hydrolytic activity. As the substrate is added to the sediment slurry in saturating concentrations, previously determined by concentration experiments, the maximal hydrolytic potential is determined by this measurement. Figure 2 shows the hydrolytic activity from the top two centimetres of the sediment at all stations of cruise SO129 in comparison to results obtained from all other previous cruises.

In contrast to CPE, no significant differences in hydrolytic activity could be found between the station (Fig. 2). The relatively high values for CAST and SAST imply the relative predominance of bacterial processes at the lower level of the trophic gradient between WAST, CAST and SAST. A phenomenon that has been

demonstrated before e.g. at continental margin transects which generally represent a trophic gradient. PFANNKUCHE & SOLTWEDEL (1998) reported for the western European continental margin that the proportion of smaller organisms grew and that bacteria became more important with decreasing trophic conditions.
At all stations FDA hydrolysis rates measured at SO129 were somewhat lower than at SO118 although significant differences were found only at station NAST where the sedimentation of POM was still in progress.

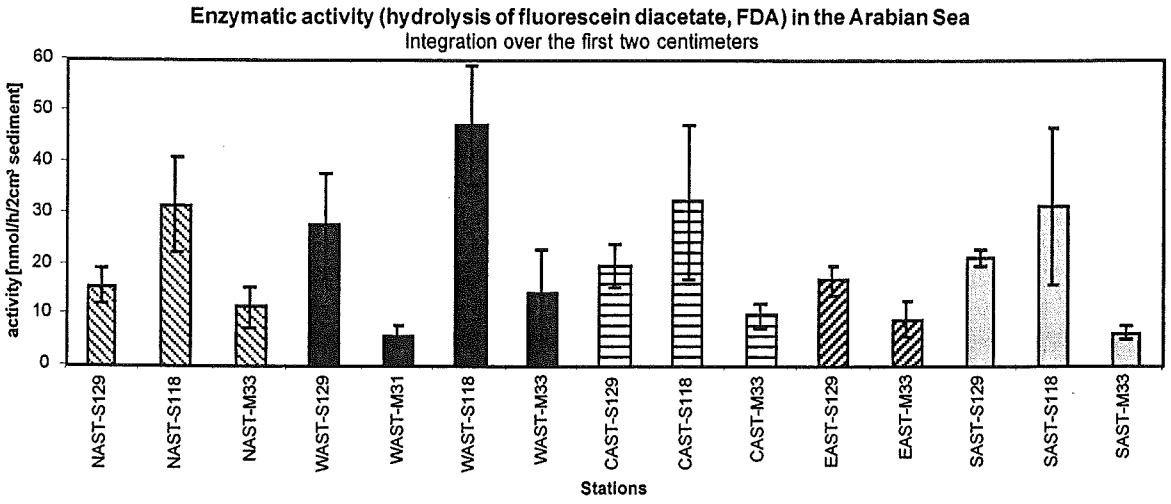

Fig. 2: FDA turnover for centimetres 0-2 of the sediment column. Data from SO129 in comparison to data from April 1997 (SO118), October 1995 (M33) and March 1995 (WAST only, M31).

Potential respiratory activity (ETSA)

The process of enhancement of exoenzyme production necessitates a step up in metabolic activity such as ATP production or electron-transport-system activity (ETSA). In consequence ETSA at the different stations (Fig. 3) corresponded regionally to the hydrolytic activity. Values of SO129 were again lower than at SO118.

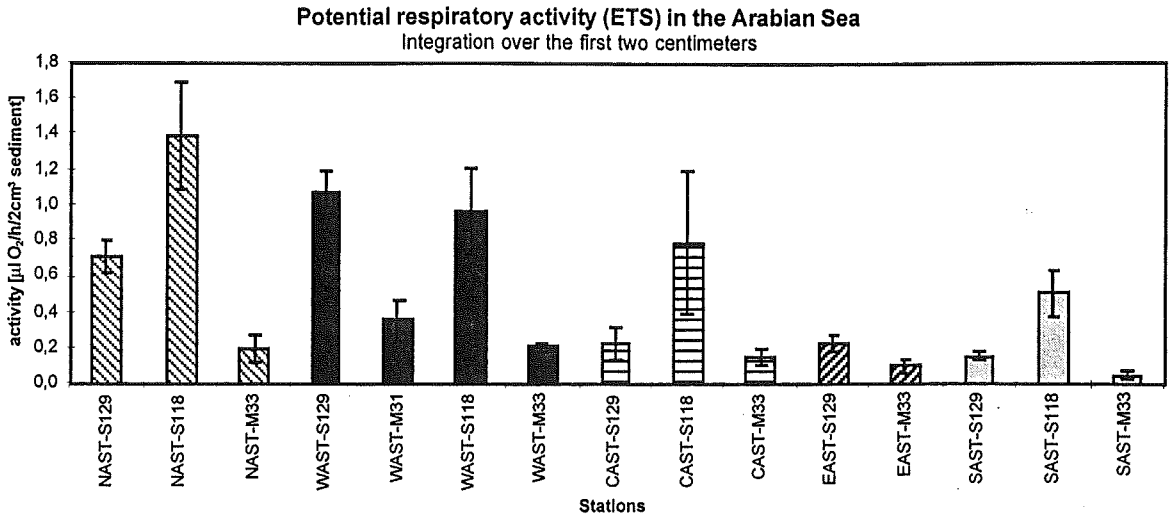

Fig. 3: Electron-transport-system activity for centimetres 0-2 of the sediment column. Data from SO129 in comparison to data from April 1997 (SO118), October 1995 (M33) and March 1995 (WAST only, M31).

Conclusions

The measurements of biogenic sediment compounds pointed at all stations at a benthic reaction to the sedimentation of labile particulate organic matter following the plankton bloom of the NE monsoon. Pigment concentrations in the sediment indicate a recent pulse of phytodetrital input. In contrast to the situation at SO118 benthic reaction mirrored by the above activity proxies (enzymatic activity, electron-transport-system activity) seemed to be still in progress. This holds especially for station NAST. The results from WAST underline the interannual variability of benthic activity.

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5.8 Microbial processes of early diagenesis

Antje Boetius, Karin Lochte and Doris Setzkorn
BIGSET, Institut für Ostseeforschung Warnemünde

Research programme

Primary production in the euphotic zone and degradation processes in the deep water column determine the flux of particulate organic matter (POM) to the ocean floor. Furthermore, the modification of these particles in different water depths is an important factor regarding the quality and quantity of POM reaching the deep-sea floor. The key aspect of early diagenesis of organic matter (OM) in the deep-sea benthic boundary layer (BBL) are microbial processes, since they determine the velocity of the turnover of OM as well as the chemical gradients in the sediment column (DEMING & BAROSS 1993). The first step in the utilization of POM is the extracellular hydrolysis of polymeric compounds, since only products with small molecular weight can pass through bacterial cell pores. In the deep sea, the greatest part of the organic carbon is respired by the bacteria (>70%) and a smaller fraction of the organic C and N is utilized for growth (ROWE & DEMING 1985). Additionally, some of the hydrolyzed molecules may escape from uptake by the bacteria and enter the DOC pool. However, only few investigations were carried out yet to quantify microbial processes in the BBL (LOCHTE & TURLEY 1988, LOCHTE 1992, VETTER & DEMING 1994, BOETIUS & LOCHTE 1994, 1996).

The subproject "Microbial processes of early diagenesis" aims at the quantification of bacterial degradation of sinking particles and deposited OM as well as the investigation of the key factors regulating microbial activity in the BBL. Field sampling and experimental studies are carried out during cruises in the Arabian Sea and the NE Atlantic and include measurements of microbial biomass and growth, enzymatic degradation, respiration and incorporation rates of OM as well as grazing rates. The results will be used to identify regional and seasonal variability of microbial processes in the Arabian Sea. Further, they will be compared to the data on POC flux and remineralisation rates obtained by the geochemical investigations to improve the understanding of the processes of early diagenesis in the deep-sea. Heterotrophic bacteria associated with sinking and resuspended particles degrade POM to dissolved organic matter (DOM) by extracellular enzymes (SMITH et al. 1992), some of which is assimilated or respired by the bacteria in the bottom water. Investigations of microbial processes in the bottom water of the deep sea are scarce (ALLDREDGE & YOUNGBLUTH 1985, TURLEY 1993), mainly due to problems with sampling. The majority of the degradation rates used in deep-sea studies were derived indirectly from the decrease with depth of particulate organic carbon (POC) captured in sediment traps and from the bacterial activity in mid-water depths (CHO & AZAM 1988, SIMON et al. 1990). However, bacterial activity and biomass in the BBL

might be increased compared to the mid-water column due to resuspension of particles or other factors enhancing microbial processes (RITZRAU et al. 1997). In the upper centimeters of sediment, the distribution pattern of bacteria and of hydrolytic enzymes provide indirect evidence for the level of OM input (DEMING & BAROSS 1993). One of the first reactions to a short-term increase in the supply of OM are changes in the production rates and the enzymatic activity adapting to the new food availability (BOETIUS & LOCHTE 1994). In addition to determination of standing stocks and activity of bacteria in the BBL, degradation of OM is studied in shipboard experiments. Concentration and composition of added OM, oxygen content and pressure can be changed in the experiments allowing an assessment of the effects of these external parameters on degradation rates and modes (BOETIUS & LOCHTE 1996). These data will be compared to OM flux rates from sediment traps and to benthic respiration rates determined *in situ*.

Methodology

Extracellular enzyme activities (EEA), rates of secondary production (BSP) and respiration ($^{14}CO_2$, $^{35}SO_4$), microbial biomass (BB, PL) and availability of specific organic compounds were measured on water and sediment samples collected during during 27 deployments of rosette (CTD/ro) and bottom water samplers (BWS) and 38 deployments of the multiple corer (MC) in the Arabian Sea (Tab. 1). Hydrolytic activities of the enzymes α-, β-glucosidase, chitobiase, esterase, lipase, peptidase, phosphatase, sulfatase were measured on board using fluorescence-labeled MUF-substrates (BOETIUS 1995). For the determination of microbial biomass, bacterial numbers, cell volumes and phospholipid concentrations are measured in the home laboratory as well as availability of various organic compounds. Total microbial biomass can be estimated from measurements of phospholipid concentrations in the sediments (FINDLAY & DOBBS 1993). Bacterial biomass is measured by epifluorescence microscopy (MEYER-REIL 1968) and grazing rates are determined according to SHERR and SHERR (1993). Bacterial production rates are estimated by measuring the incorporation of ^{3}H-labeled thymidine and leucine into into DNA and bacterial protein, respectively (KEMP 1994). Bacterial respiration is measured by incubating ^{14}C-labeled organic substrates (single dissolved substrates as well as particulate algal material) and assaying the amount of $^{14}CO_2$ released (LOCHTE 1992). Sulfate reduction rates were measured incubating ^{35}S-labeled sulfate according to FOSSING and JØRGENSEN (1989).

Tab. 1: List of stations for sediment and water sampling. For abbreviations see text.

station	deployment	depth	parameter
WAST	MC-1/SO129	sediment profiles (0-30 cm)	PL,BB
	MC-2/SO129	"	EEA, POC degradation exp.
	MC-3/SO129	"	35-SO4
	MC-4/SO129	"	PL,BB
	MC-5/SO129	"	EEA,BSP,14-CO2,FLB, chitin degradation exp.
	MC-6/SO129	"	PL,EEA
	MC-7/SO129	"	EEA,35-SO4,14-CO2
	MC-34/SO129	"	PL,BB,EEA
	MC-36/SO129	"	EEA,BSP,14-CO_2, (all substrates)
	CTD-3/SO129	5,9,14,25,40,55 m a.b.	EEA, BB, BSP
	CTD-7/SO129	5, 25 Fmax, 50, 250 m	Chl a
	CTD-25/SO129	5, 50 Fmax, 250 m	Chl a
	CTD-26/SO129	5,9,14,25 m a.b.	EEA, BB, BSP
	BWS-1/SO129	10,60 cm a.b.	EEA, BB, BSP
	BWS-4/SO129	10,60 cm a.b.	EEA, BB, BSP
WAST-T	MC-8/SO129	sediment profiles (0-30 cm)	PL,BB,EEA
	MC-9/SO129	"	35-SO4
	MC-10/SO129	"	PL,EEA,BSP
	MC-11/SO129	"	PL, EEA
	MC-12/SO129	"	EEA
	MC-35/SO129	"	EEA, BB
	CTD-5/SO129	5,9,14,25,40,55,100,250 m a.b.	EEA, BB, BSP
	BWS-3/SO129	10,60 cm a.b.	EEA, BB, BSP
SAST	MC-14/SO129	sediment profiles (0-30 cm)	EEA
	MC-15/SO129	"	PL,BB,EEA
	MC-16/SO129	"	EEA,POC degradation exp.
	MC-17/SO129	"	PL,EEA
	MC-18/SO129	"	PL,BSP,14-CO_2, (all substrates),FLB, chitin degradation exp.
	MC-19/SO129	"	EEA,BSP + FLB
	CTD-8/SO129	5,50, 75 Fmax, 250 m	Chl a
	CTD-9/SO129	5,9 m a.b.	EEA, BB, BSP
	CTD-10/SO129	14,25 m a.b.	EEA, BB, BSP
	BWS-5/SO129	10,60 cm a.b.	EEA, BB, BSP
	BWS-6/SO129	10,60 cm a.b.	EEA, BB, BSP

Tab. 1: *continued*

station	deployment	depth	parameter
EAST	MC-21/SO129	sediment profiles (0-30 cm)	PL,BB,EEA
	MC-22/SO129	"	EEA
	MC-23/SO129	"	PL,BB,EEA,14-CO2
	MC-24/SO129	"	EEA,BSP,35-SO4, fluff exp.
	MC-25/SO129	"	PL,EEA,35-SO4
	CTD-14/SO129	5,50 Fmax, 250 m	Chl a
	CTD-15/SO129	5,9 m a.b.	EEA, BB, BSP
	CTD-16/SO129	14,25 m a.b.	EEA, BB, BSP
	BWS-7/SO129	10,60 cm a.b.	EEA, BB, BSP
CAST	MC-27/SO129	sediment profiles (0-30 cm)	PL,BB,EEA
	MC-28/SO129	"	EEA,BSP
	MC-29/SO129	"	35-SO4
	MC-30/SO129	"	PL,EEA
	MC-31/SO129	"	EEA
	MC-32/SO129	"	PL,BB,14-CO2 (all substrates),FLB
	MC-33/SO129	"	EEA
	CTD-19/SO129	5,50 Fmax, 250 m	Chl a
	CTD-20/SO129	5,9 m a.b.	EEA, BB, BSP
	CTD-21/SO129	14,25 m a.b.	EEA, BB, BSP
	BWS-8/SO129	10,60 cm a.b.	EEA, BB, BSP
	BWS-9/SO129	10,60 cm a.b.	EEA, BB, BSP
NAST	MC-38/SO129	sediment profiles (0-30 cm)	PL,EEA
	MC-39/SO129	"	EEA,35-SO4
	MC-40/SO129	"	PL,BB,EEA
	MC-41/SO129	"	EEA,BSP
	MC-42/SO129	"	PL,EEA
	CTD-28/SO129	5,30 Fmax,50,250 m	Chl a
	CTD-29/SO129	5,9 m a.b.	EEA, BB, BSP
	CTD-30/SO129	14,25 m a.b.	EEA, BB, BSP
	BWS-10/SO129	10,60 cm a.b.	EEA, BB, BSP
	BWS-11/SO129	10,60 cm a.b.	EEA, BB, BSP

Preliminary results and conclusions

Chlorophyll fluorescence in the euphotic zone

A profile for chlorophyll fluorescence (Chl a) in the euphotic zone was recorded at each station with a fluorometer attached to the CTD/rosette water sampler. Chlorophyll samples were collected for calibration of the fluorometer and will be processed in the home laboratory. At WAST Chl a was relatively high in the surface waters during the first sampling interval (03.02.-08.02.98), the maximum in fluorescence (Fmax) was recorded at 30 m water depth. Later during the cruise (26.-27.02.98) Chl a was substantially reduced, indicating that nutrients were already depleted in the surface waters. At SAST, EAST and CAST Chl a was already very low at our arrival at the stations but a distinct subsurface maximum was detected at 40-75 m depth just above the thermocline. Highest Chl a was recorded at station NAST at 0-50 m. Accordingly, a diatom bloom was visually observed during our sampling from 01.03.-05.03.1998.

Microbial activities in the bottom waters

Hydrolysis rates were highly variable in the bottom waters ranging from 0.004 µM/h for the glycosidases (α-, β-glucosidase, chitobiase), 0-0.14 µM/h for amino-peptidase and 0.7-3.2 µM/h for esterase. At WAST hydrolysis rates of the glycosidases reached relatively high values in the sediment contact water at 10-60 cm above bottom (a.b.). This may be due to increased sediment resuspension at this site e.g. compared to SAST (Fig. 1). Combining all stations, a general increase in bacterial enzyme activities and production rates in the sediment contact water (0.1-0.6 m) was detected compared to the water layer above (5-25 m a.b.) (Fig. 2). Samples for bacterial biomass, particle concentrations, POC and chlorophyll (see report of SP-2) will be analysed in the home laboratory to check whether microbial activity in the BBL is related to these parameters.

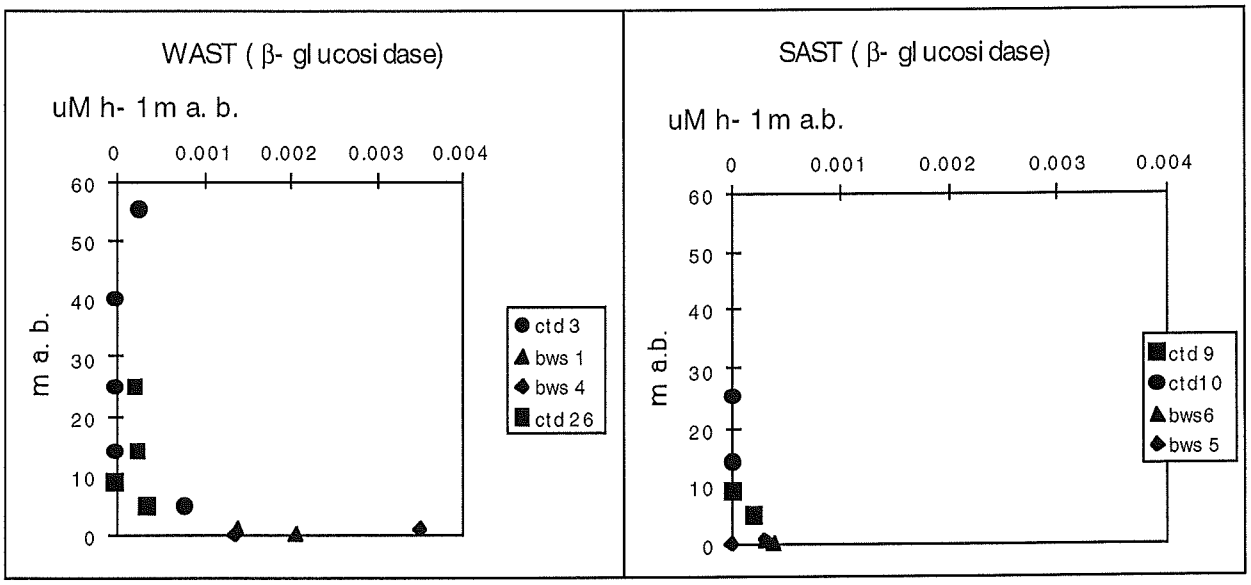

Fig. 1: Activity of extracellular enzymes in the BBL. Each data point represents the result of a time course experiment incubating water from the rosette (CTD) or bottom water sampler (BWS)

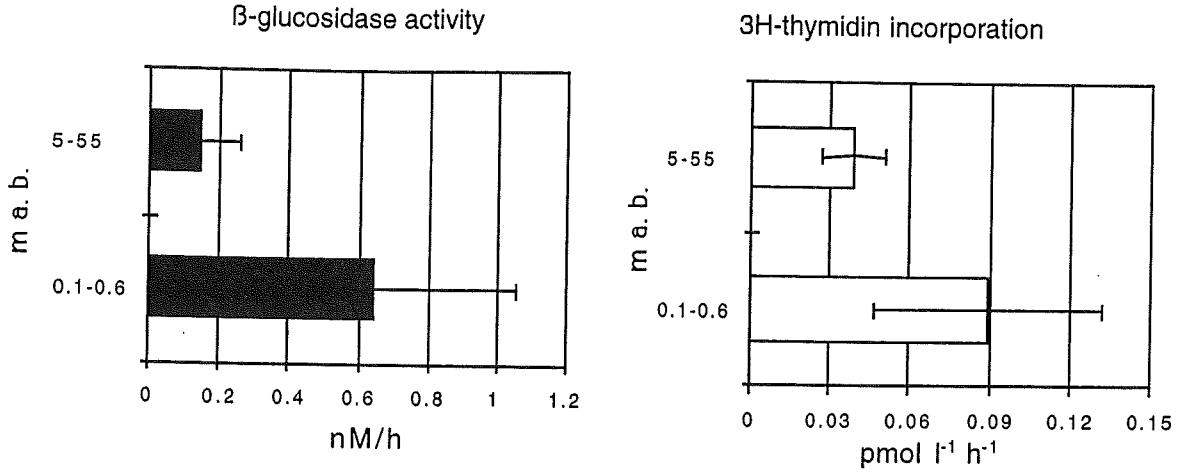

Fig. 2: Comparison of microbial extracellular enzyme activities and incorporation rates in two different water layers in the BBL. Error bars are 95% confidence levels.

Microbial activities in the sediments

In deep-sea sediments, bacterial enzymes are the primary agents of the early diagenesis of organic matter (OM). Most extracellular enzymes are produced when respective substrates become available (substrate induction), others are constantly produced but repressed in the presence of readily available nutrients. A comparison of the average activity potentials of β-glucosidase, one of the enzymes involved in the degradation of polysaccharides, at the stations WAST and SAST shows that microbial activities were higher at WAST and also more variable seasonally (or interannually) than at the oligotrophic station SAST (Fig. 3). Activity potentials at NAST and CAST were similar and about one third lower than at WAST, consistent with the differences in the average annual particle fluxes at these stations (HAAKE et al. 1993). For all enzymes, the lowest activities were generally recorded at SAST. The activity potentials of all eight enzymes measured in the sediments of the Arabian Sea stations WAST and WAST-T, SAST, CAST, EAST and NAST during February 1998 were generally lower than in April 1997 (SO118) and similar to the activities recorded after the SW monsoon in October 1995.

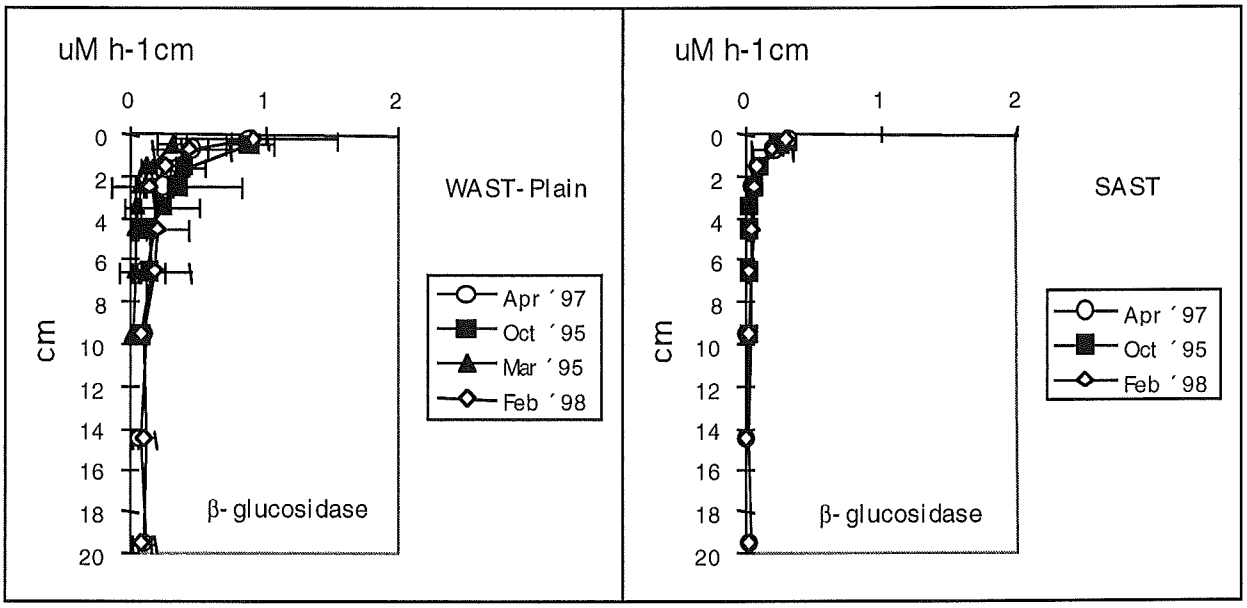

Fig. 3: β-glucosidase activity (μM h^{-1}) in sediments of the Arabian Sea. Error bars indicate 95% confidence level of the average of 3-7 multiple corer.

Microbial production and respiration rates in the sediments

Highest rates of incorporation of ^{3}H-thymidine were detected at station WAST, declining strongly with sediment depth after a subsurface peak at 1-2 cm (Fig. 4). At atmospheric pressure, thymidine incorporation was markedly decreased in the upper sediment layers, indicating the presence of barophilic populations. Thymidine incorporation can be converted to bacterial secondary production, amounting to about 4 mg C m^{-2} d^{-1} at WAST.

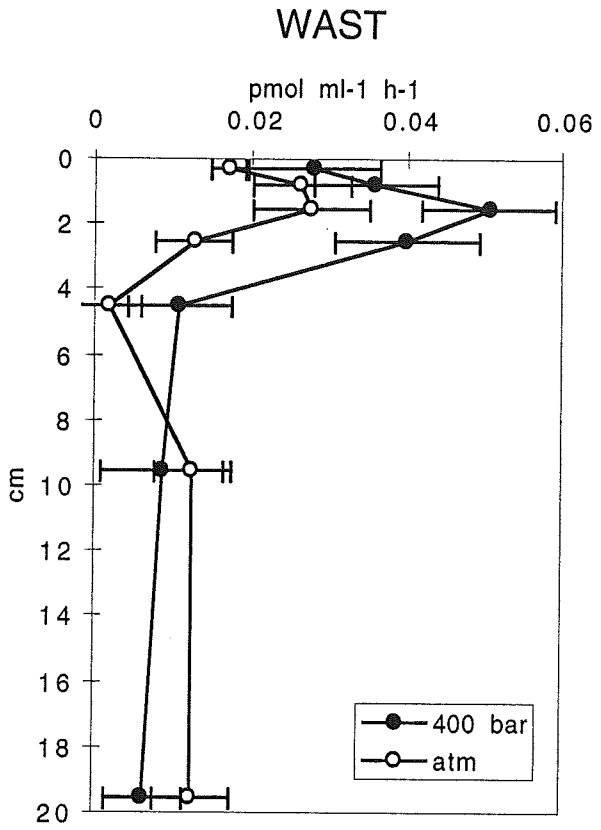

Fig. 4: ^{3}H-thymidine incorporation rates measured under *in situ* and atmospheric pressure. Error bars are 95% confidence levels.

Microbial respiration rates were relatively high at all stations in the Arabian Sea compared to the station BIOTRANS in the NE Atlantic (LOCHTE 1992). Highest $^{14}CO_2$ release from the algal material was measured in the surface sediments of station WAST and lowest rates were detected at station EAST (Fig. 5). An experiment was carried out at station CAST to test whether the respiration rates are related quantitatively to the input of POM. The natural variation of the POC flux at station CAST is around 20-60 nmol C ml^{-1} d^{-1} (calculated from HAAKE et al. 1992). Within a range of different concentrations from 0.5-50 nmol C ml^{-1} of algal carbon added, the respiration rates increased linearly (R^2=0.9953, n=10). Microbial assemblages respired around 12% of the carbon added to the surface sediments of station CAST within one day. Another set of experiments showed that the particulate algal material was turned over nearly as fast as the additions of ^{14}C-labeled free aminoacids or glucose, indicating that enzymatic hydrolysis of such fresh POM might not be rate limiting in the oxygenated surface sediments.

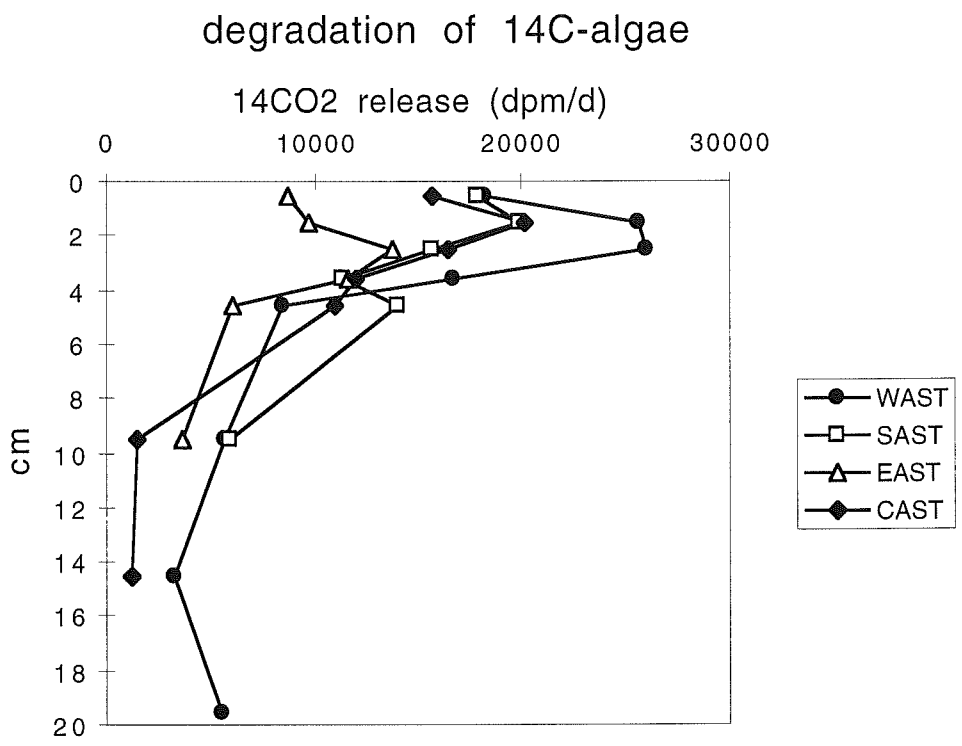

Fig. 5: Microbial respiration in the sediments of the Arabian Sea. Time course experiments under *in situ* pressure and temperature were carried out at each station. Trace amounts of ^{14}C-labeled algae were added to the sediments and the released CO_2 was captured and radioassayed.

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5.9 Geochemistry of deep-sea sediments

Dirk Rickert, Sibylle Grandel and Angela Lunau
BIGSET, GEOMAR Forschungszentrum, Universität Kiel

Research programme

One of the main objectives was to study the turnover processes of organic matter, biogenic opal, calcium carbonate and nutrients in surface sediments of the deep Arabian Sea. Therefore pore waters were sampled from MC cores taken at ten stations in the Arabian Sea in order to investigate the complex interplay of aerobic and anaerobic degradation of organic matter and local and non-local transport processes.

The main aim of our work is to get data sets which would allow to model transport and degradation as well as redox and dissolution reactions in sediments with high C_{org} inputs. These data sets will facilitate a comprehensive modeling of benthic turnover rates and fluxes. With samples taken from multicorer (MC), CTD water sampler and bottom-water sampler (BWS) the vertical distribution of nitrate, phosphate, silicic acid, ammonia, pH, alkalinity, aluminium and iron in the sediments and in the water column was determined. Another aspect which is important for the interpretation of benthic processes are the redox conditions in the sediment and at the sediment water interface. Therefore laboratory oxygen measurements were carried out and in addition an oxygen profiler was used to get *in situ* oxygen profiles. This data will provide more information about possible differences between field and laboratory oxygen measurements affected by the sampling procedures.

Moreover different kinds of laboratory experiments were performed with sediments from the main stations (WAST, SAST, EAST, CAST, NAST) in order to quantify organic matter degradation and the dissolution kinetics of biogenic silica (opal). The incubation experiments are designed to study the bioavailabilty of organic matter and to investigate the impact of oxic and anoxic conditions on the preservation or degradation of organic matter in surface sediments of the Arabian Sea. The processes controlling preservation and recycling of particulate biogenic silica in superficial sediments must be understood before using biogenic silica as a proxy in paleo-oceanographic studies, and in order to compute mass balances for silica. Finally to assess the role of aluminium as a kinetic inhibitor (Van Cappellen and Qiu, 1997 a) for the dissolution of biogenic silica dissolved Al was determined in pore waters of sediments and compared with Si profiles. Kinetic experiments are conducted in the home laboratory using a stirred flow-through reactor technique to determine silica solubilities under a variety of dissolved Al concentrations.

The distribution of dissolved aluminium in open ocean waters is probably controlled by the solution of aluminium from athmospherically derived particles and bottom

sediments balanced against scavenging by siliceous shells of dead organisms or active biological uptake in surface waters by diatom frustules (MORAN AND MOORE, 1992; VAN BEUSEKOM, J. E. E., 1990). Vertical profiles of dissolved aluminium (Al) at the five main stations were determined. The natural fluorescence measured during the aluminium analysis was used as an indication of dissolved organic carbon (DOC, see CADÉE AND LAANE, 1983). Sediment samples taken with the multicorer and water samples taken with the CTD and bottom-water sampler were analyzed on board to get the amount and vertical distribution of anorganic nutrients, pH, alkalinity, oxygen, aluminium and iron.
The measured data will be used as initial and boundary parameters for the transport reaction model C. CANDI to calculate distributions and fluxes of biogenic substances in the studied surface sediments (LUFF et al., 1998). Other parameters such as water and sediment depth, rain rate of biogenic matter to the seafloor, concentration of dissolved and solid phase compounds are collected to describe the whole system and to study the triggered processes.

Station works and preliminary results

Temporal changes in the sedimentation of biogenic matter are ubiquitous in the deep-sea environment. The SO129 cruise was set at the end of the NE monsoon, to investigate the reaction of the benthic system to the expected sedimentation events. In addition to the investigation of seasonally, or better said sedimentation pulse controlled fluctuations, the regional aspect was of research interest. Therefore, we took multicorer samples at intermediate stations to get a better spatial distribution and nutrient data set for a planned date interpretation with GIS (Geographical Information System).

Methodology

Surface sediments taken with a multicorer were brought into the cold room immediately after recovery. They were sampled and processed within 3-4 hours at *in situ* temperature. Pore water samples were obtained using two different techniques: For nutrient analyses wet sediment segments were extracted using a squeezer pressurized by argon and samples were filtered on line through 0.4 µm cellulose acetate filters; for Al analysis pore water was obtained by centrifugation of sectioned cores and subsequently passed through 0.45-µm membrane filters to avoid contamination from the squeezer.
The following dephts intervals were taken and analyzed (cm):
0-0.5, 0.5-1, 1-2, 2-3, 3-4, 4-5, 5-6, 6-7, 7-8, 8-9, 9-10, 10-13, 13-16, 16-19. HCl acidification was avoided to prevent a decrease in silica concentrations which may be caused by precipitation reactions during sample storage. All sampling and

reaction vessels for Al analysis were cleaned overnight with hot detergent (Extran, Merck), rinsed thoroughly with ultrapure water and soaked with 1% suprapure HCl.
The pore waters and the overlying bottom waters as well as the water samples from CTD/ro and BWS were analyzed on board for dissolved nitrite, nitrate, ammonia and phosphate using an auto-analyzer and standard methods after GRASSHOFF et al. (1983). Replicate measurements resulted in relative standard deviations of 10%. Dissolved phosphate and silicic acid was analyzed using standard colorimetric techniques on a convential two beam photometer in fresh pore water subsamples and water samples taken with the BWS or CTD/ro water samplers. Dissolved aluminium was analyzed on board with the lumogallion method (HYDES and LISS, 1976) using slight modifications to essentially remove interferences primarily from dissolved organic matter and iron, which are present at high and variable concentrations in marine pore waters (MACKIN and ALLER, 1984). The method based upon the formation and measurement of the fluorescent Al-Lumogallion complex at pH 5. The emission and excitation wavelengths (465 and 555 nm, resp.) used for the determination of the natural fluorescence were the same as used for the Al analysis.
To avoid any kind of contamination by settling of dust particles in open bottles or on pipette tips, most manipulations were carried out inside a clean bench. The small pore water samples available necessitated a 10 times dilution. Al data and the details of the analytical method can be requested from the authors.
For the measurement of the amount of iron in the sediments 1-2 g wet surface sediment was mixed with 30-50 ml of 1N HCl. The resulting sediment suspensions were shaken over a period of 24-36 h at a temperature of 2-8°C. Subsequently the solids were separated by centrifugation and the dissolved phase was analyzed for ferrous iron and total iron using the ferrozine procedure (GRASHOFF et al., 1983). With this procedure the reactive iron that takes part in the rapid redox reactions is extracted and determined (WALLMANN et al., 1983).
A pH-glass electrode (METTLER) and a pH-ISFET electrode (SENTRON) were used for pH measurements. Both electrodes were calibrated with standards made up in seawater matrix (DICKSON, 1993), for pH determination, temperature and electrode potential were registered and used to calculate the pH values. The resulting pH values give the total concentration of protons present as H^+ and HSO_4^- (MILLERO, 1995). pH measurements with the ISFET electrode directly in the sediment itself and in the pore water samples showed a difference of the pH values less than 3%.
Total alkalinity (TA) was determined by measuring the potential of a pH probe after a one-step addition of HCl. A volume of 0,3 to 0,5 ml of 0,01 N HCl was added to 1 ml pore water sample until a pH value of 3,0-3,52 was reached. The electrode

was calibrated with two pH buffers (3,00 and 3,52) prepared in artificial seawater. The alkalinity of the artificial seawater was determined by GRAN titration and considered in the buffer preparation (STUMM AND MORGAN, 1996). To control the quality and reproducibility of the method, IAPSO seawater standard was titrated in addition to every pore-water sample measurement, the values were constant over the six week cruise with an error less than 5%.

On board the measurements of the oxygen profiles were carried out in the cold room within one hour after sampling of the multicores. Self-made glass electrodes of the Clark-type (REVSBECH, 1989) were assembled on a motor-driven micromanipulator, which was descended into the sediment in 0,1 to 0,5 mm steps.

The *in situ* profiles were taken with an oxygen profiler (SEABED Systems BV) mounted into a frame, which was driven on a wire down to the seafloor. Due to technical problems with the device we got only one *in situ* profile at the station WAST-T. The oxygen content is calculated via an external calibration of the electrodes. The electrode currents of several seawater samples with different temperatures and oxygen contents are correlated to the measured oxygen amount of the seawater with the WINKLER titration method (GRASSHOFF et al, 1983). Parallel measurements (n=5) of seawater samples showed a standard deviation of 1 %.

A complete list of the analyzed multicorer and water samples is given in Tab. 1.

Laboratory investigations were made to study the bioavailabilty of organic matter via an extraction experiment (KEIL et al., 1994).

Degradation experiments with sediment-seawater suspensions (ratio 1:1) were made to study the processes of biodegradation under oxic and anoxic conditions during an incubation time of 2 weeks while the samples were shaken under a temperature of 2-4 °C. Subsamples were taken after 0,1,2,3,5, and 9 days. Their amount of anorganic nutrients and the microbiological activity (via dimethylsulfoxid reduction after ALEF AND KLEINER, 1989) will be measured.

Preliminary results

Pore-water geochemistry

First results compared to the results of SO118 show that the saisonal differences of the benthic activities are lower than expected. Therefore it is likely that the seasonal influences on the benthic system concerning biogeochemical reactions and degradation processes of organic matter are of lesser impact (Fig. 1). On the other hand the differences between the main stations are very significant, with WAST as the most productive station, followed by CAST and NAST and with lowest activities at SAST and EAST.

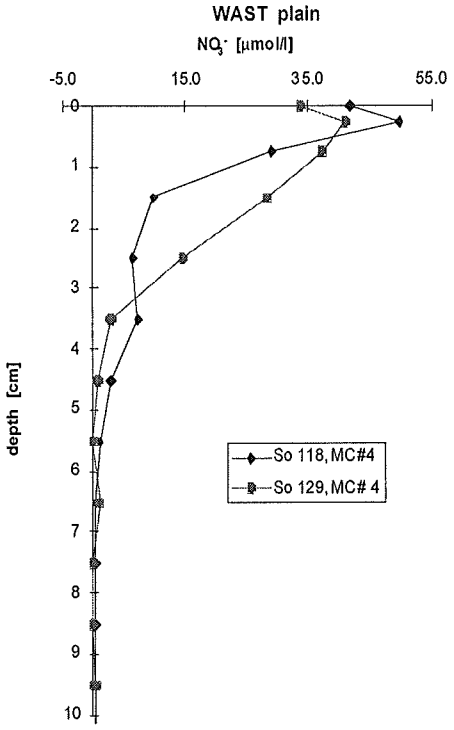


Fig. 1: Nitrate profiles of the station WAST, measured during SO118 and SO129.

Fig. 1 shows two nitrate profiles measured at WAST from SO118 (April 1997) and SO129. In both profiles the nitrate content reaches zero at a depth between 5 and 6 cm. In the profile from SO118 the nitrate content at the sediment-water interface is higher and decreases faster in the upper 2 cm of the sediment. This indicates that the benthic system was more active in April 1997 than in Feb. 1998. We therefore assume that the sedimentation pulse of the NE monsoon has not reached the seafloor yet.

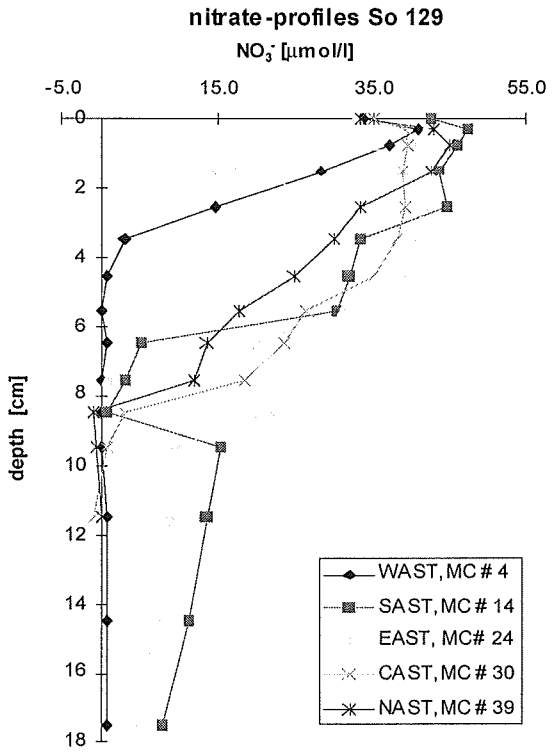
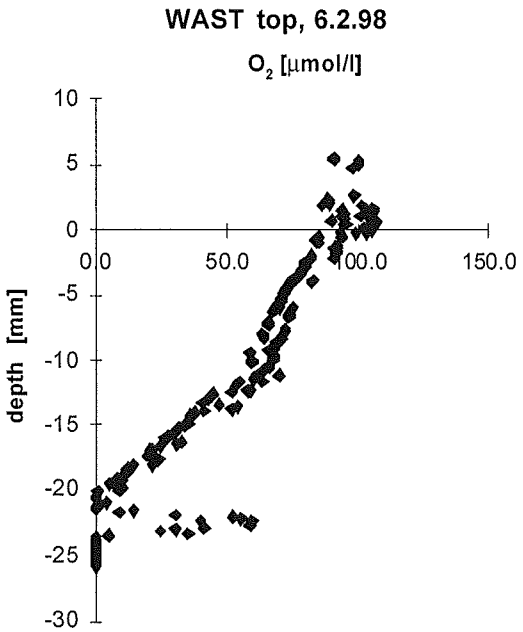


Fig. 2: Nitrate profiles of the five main stations WAST, SAST, EAST, CAST, and NAST measured during SO129

Comparing the nitrate profiles of the five main stations measured during SO129, (Fig.2) shows that at WAST nitrate already decreases to zero at a depth of 4-5 cm, while at NAST a depth penetration of 8 cm occured, followed by CAST with 10 cm. At SAST and EAST the nitrate penetration depth is not reached until a depth of 18 cm. The shallow profile reflects the high biogeochemical activity at WAST compared to the other stations, which is also underlined by the biological parameters. Except of SAST the nitrate concentration at the sediment-water interface lies around 35 µmol/l at all stations.

The *in situ* oxygen profile (Fig. 3) measured at station WAST, shows an oxygen penetration depth at 2,5 cm. Nitrate (Fig. 4) reaches zero at a sediment depth of around 3 cm, which correponds very well to the *in situ* oxygen profile. The oxygen profiles measured in the laboratory during this and the last cruise showed a penetration depth between 5-7 mm, which clearly indicates and emphasizes the need of *in situ* measurements, especially in an area influenced by high temperature changes (GLUD et al., 1994).



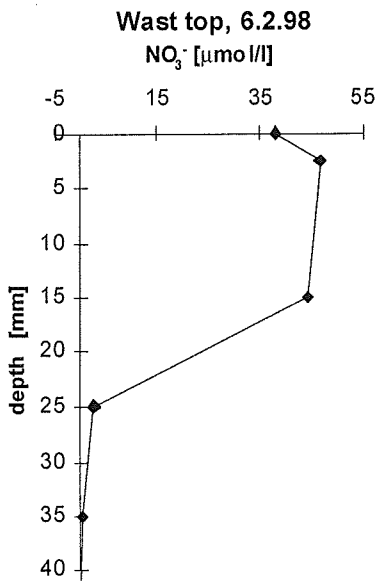


Fig.3: *in situ* oxygen profile WAST-T

Fig.4: nitrate profile WAST-T

Measurements of the iron and incubation experiment samples are in progress.

Pore water silica and aluminium measurements, opal dissolution experiments

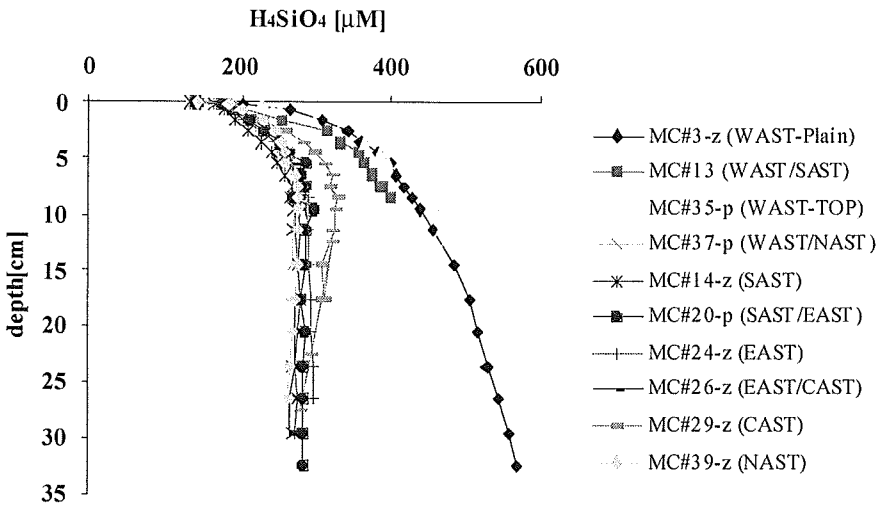


Fig. 5: Dissolved silica as a function of depth in cores of all stations from SO129. Obviously asymptotic silica concentrations (about 500 µM) from WAST, WAST-T and WAST/NAST differ from the other stations.

The solubility values of biogenic silica derived from asymptotic pore water concentrations are highly variable from one site to another as shown in the pore water profiles (Fig. 5). Pore water silica concentrations increase as a consequence of different dissolution behaviour of biogenic silica (opal) or other siliceous phases from bottom water values of about 140 µM to asymptotic values of about 550 µM (WAST), 500 µM (WAST) or 300 µM (NAST, CAST, EAST, SAST and intermediate stations). In general, the apparent solubilities of the silica phases are lower than the values expected for biogenic silica (HURD, 1973).

Regional differences

Pore water profiles alone cannot provide the answer whether the asymptotic Si values are the result of the biomineralization process of silica in surface waters or whether they are the product of early diagenetic reactions, e. g. the association of dissolved Al with biogenic silica at the water-sediment interface (e. g. VAN CAPPELLEN ET QIU, 1997a). Independent determinations of the solubility and dissolution kinetics of the biogenic silica under a variety of variables (temperature, pH, degree of undersaturation, cation concentrations in the pore fluid, opal/detrital content in the solid phase) are required in order to interpret the dissolved silica profiles measured in sediments. Batch experiments performed on board ship are the first step to combine pore water silica and aluminium measurements and laboratory-based

solubility plus rate data from the same sediments. First results show a decrease in reactivity and solubility with increasing depth.

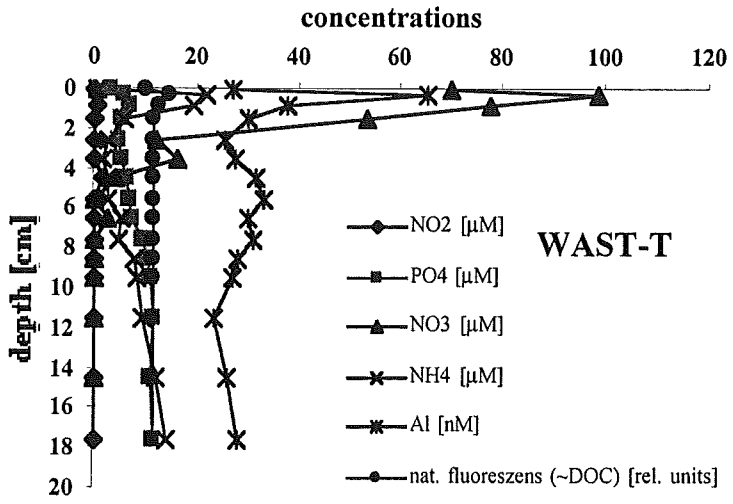


Fig. 6: Dissolved nitrite, nitrate, phosphate, ammonia, aluminium and natural fluorescence from WAST-T station (MC#35). Nutrient maxima observed in the first centimeter correlate well with the observed maximum in Al and DOC concentrations suggesting a common underlying process.

Pore water aluminium concentrations are considerably higher than in the overlying waters (4-10 nM) and reach maxima below the sediment-water interface (30-70 nM) that correlate well with observed maxima in the natural fluorescence (DOC2), nitrate, phosphate and ammonia. Figure 6 illustrates the observed maxima beneath the surface exemplary for WAST (MC#35) in profiles of nutrients as well as of dissolved Al and DOC. The significant maximum within the first centimetre indicates substantial communities of microbial decomposing organisms. Their excretions probably cause the high ammonia values. The organic matter mineralisation results in increasing nitrate concentrations. The similarity between the observed curves suggests a common underlying process, possibly related to adsorption-desorption reactions of aluminium-DOC complexes and the destruction of such complexes through mineralization processes with the release of aluminium. While dissolved Si concentrations increase continuously with depth, the profiles of dissolved Al in Fig. 7 (MC#35, WAST) show a sharp decrease below the sediment-water interface towards a mean of about 30 nM. Similar trends were observed for all stations.

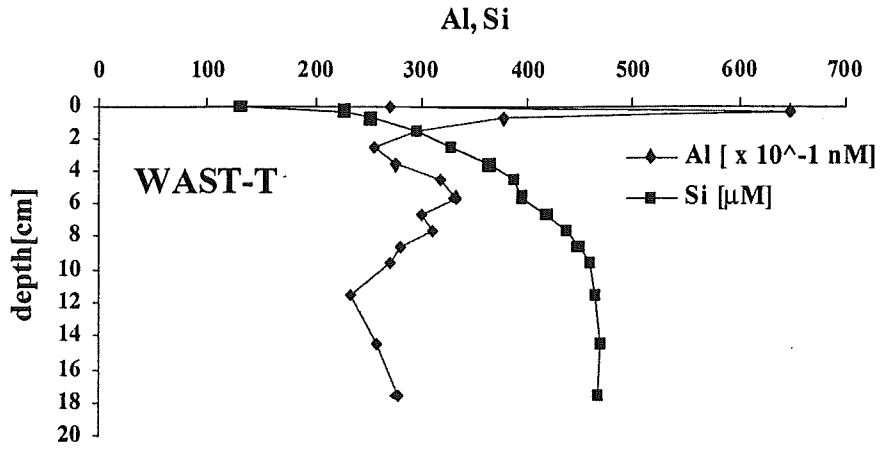


Fig.7: Pore water silica and aluminium orofiles at WAST-T station (MC#35). While silica increases with depth Al data show a marked decrease below the surface maximum towards a mean value of 30 nM.

VAN CAPPELLEN ET QIU (1997a) observed lower solubilities in the top sections than in the deeper ones for three cores from the Antarctic Ocean. Their explanation for the observation is centered around the pore water aluminium levels. The association of Al with biogenic silica right below the sediment-water interface where relatively high levels of pore water Al are observed leads to a marked decrease in the solubility and reactivity of the biogenic silica. Upon further burial, the silica surfaces experience decreasing levels of dissolved Al resulting in an increase in solubility. Our observations do not follow their interpretation. The apparent asymptotic Si concentrations show no clear inverse relationship with the Al/Si ratios of the pore waters at the same depth. In contrary observed Al data below the surface maximum are fairly constant throughout the cores whereas aparent asymptotic silica concentrations vary from 270 to 550 µM.

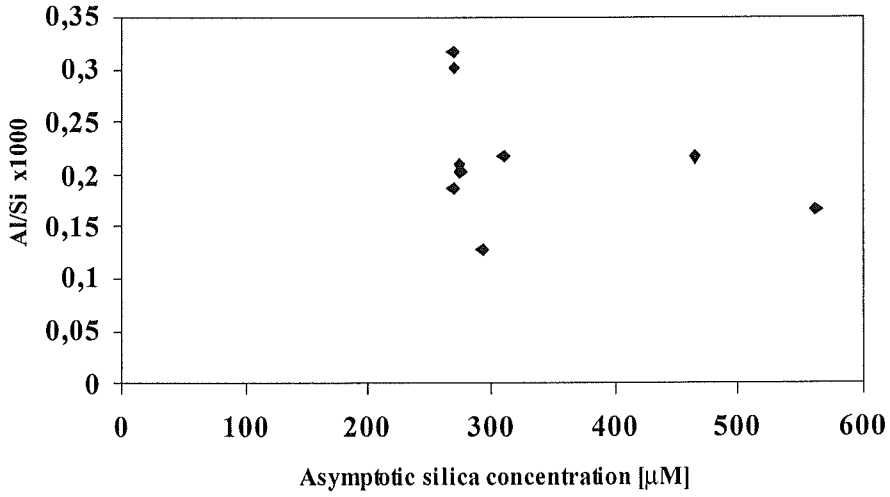


Fig. 8: Relationship between the atomic ratios of aluminium and silica in the pore water summarized from all stations measured at depth exceeding 10 cm and the (pseudo) asymptotic silicic acid concentration. The observations show no clear relationship.

The variable asymptotic pore water silicic acid levels found in the cores of the Arabian Sea cannot be explained solely by a diagenetic interaction between biogenic silica and soluble aluminium. A stirred flow-through reactor technique will be used in the home laboratory to determine silica solubilities under different degrees of undersaturation with respect to silicic acid, various Al concentrations in solution or detrital content in the sediment.

Tab. 1: List of sampled stations during SO129

Stat.-No.	Device	Date	Analyses
WAST			
1#1	CTD # 1	2.2.98	Nutrients, Si, Al
1#2	CTD # 2	2.2.98	Nutrients, Si, Al
13#1	CTD # 3	4.2.98	Nutrients, Si, Al
13#3	CTD # 4	4.2.98	Nutrients, Si, Al
82#1	CTD # 25	26.2.98	Nutrients, Si, Al
86#1	CTD # 26	27.2.98	Nutrients, Si, Al
86#2	CTD # 27	27.2.98	Nutrients, Si, Al
7#4	MC # 3	3.2.98	Nutrients, Si, Al, Alk., pH
9#2	MC # 4	4.2.98	Nutrients, Si, Al, Fe
82#2	MC # 36	26./27.2.98	Nutrients, Si, Alk., pH
9#1	BWS # 1	3.2.98	Nutrients, Si
16#3	BWS # 2	5.2.98	Nutrients, Si
WAST - T			
19#5	CTD # 5	6.2.98	Nutrients, Si
23#1	CTD # 6	7.2.98	Nutrients, Si
23#4	CTD # 7	8.2.98	Nutrients, Si
19#4	MC # 9	6.2.98	Nutrients, Si, Alk., pH
80#2	MC # 35	26.2.98	Nutrients, Si, Alk., pH
19#6	BWS # 3	6.2.98	Nutrients, Si
23#3	BWS # 4	8.2.98	Nutrients, Si
SAST - WAST			
26	MC # 13	9.2.98	Nutrients, Si
SAST			
27	CTD # 8	10.2.98	Nutrients, Si
34#4	CTD # 9	11.2.98	Nutrients, Si
36#5	CTD # 10	13.2.98	Nutrients, Si
40#6	CTD # 11	14.2.98	Nutrients, Si
40#7	CTD # 12	14.2.98	Nutrients, Si
45#2	CTD # 13	14.2.98	Nutrients, Si
32	MC # 14	11.2.98	Nutrients, Si, Alk., pH, Fe
38#3	MC # 19	13.2.98	Nutrients, Si, Alk., pH
38#1	BWS # 6	13.2.98	Nutrients, Si
40#5	BWS # 7	13.2.98	Nutrients, Si
SAST - EAST			
46	MC # 20	15.2.98	Nutrients, Si

Tab. 1: *continued*

EAST			
Stat.-No.	Device	Date	Analyses
49#3	CTD # 14	16.2.98	Nutrients, Si
49#5	CTD # 15	16.2.98	Nutrients, Si
49#11	CTD # 16	17.2.98	Nutrients, Si
52	CTD # 17	18.2.98	Nutrients, Si
55	CTD # 18	18.2.98	Nutrients, Si
49#1	MC # 21	16.2.98	Nutrients, Si, Alk., pH, Laborversuch
49#9	MC # 24	17.2.98	Nutrients, Si, Alk., pH, Fe
49#4	BWS # 8	16.2.98	Nutrients, Si
EAST - CAST			
56	MC # 26	19.2.98	Nutrients, Si
CAST			
57#1	CTD # 19	19.2.98	Nutrients, Si
62#4	CTD # 20	20.2.98	Nutrients, Si
62#5	CTD # 21	20.2.98	Nutrients, Si
68#5	CTD # 22	22./23.2.98	Nutrients, Si
68#6	CTD # 23	23.2.98	Nutrients, Si
71#2	CTD # 24	24.2.98	Nutrients, Si
62#7	MC # 29	21.2.98	Si, Fe
64#2	MC # 30	21.2.98	Nutrients, Si, Alk., pH, Fe
64#3	MC # 31	21.2.98	Nutrients, Si
62#3	BWS # 9	20.2.98	Nutrients, Si
68#4	BWS # 10	22.2.98	Nutrients, Si
WAST - NAST			
88#1	MC # 37	1.3.98	Nutrients, Si, Alk., pH
NAST			
89#1	CTD # 28	2.3.98	Nutrients, Si
94#1	CTD # 29	2.3.98	Nutrients, Si
94#2	CTD # 30	2.3.98	Nutrients, Si
97#1	CTD # 31	3.3.98	Nutrients, Si
97#2	CTD # 32	3.3.98	Nutrients, Si
97#3	CTD # 33	3.3.98	Nutrients, Si
102#1	CTD # 34	4.3.98	Nutrients, Si
93#1	MC # 39	2.3.98	Nutrients, Si, Alk., pH, Fe
97#5	MC # 42	4.3.98	
95#1	BWS # 11	3.3.98	Nutrients, Si
97#4	BWS # 12	3.3.98	Nutrients, Si

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5.10 Interaction between seasonal benthic reaction rates, particle flux and trace element distribution in deep-sea sediments

Lars Dittert
BIGSET, Fachbereich Geologie, Universität Bremen

Research programme

SHANKAR et al. (1987) showed that during the Holocene four factors are very important for the elemental distribution in the solid phase in the Arabian Sea: (1) the hydrothermal activity along the Carlsberg Ridge, (2) the spatially variable input of terrigenious matter, (3) authigenic precipitates and (4) the distribution of biological matter. The regional distribution of organic material and the input of aeolian transported particles in the Arabian Sea is strongly influenced by the seasonal monsoon system (SIROCKO 1991). Hence the input of trace elements may vary within these regional and temporal patterns.

Organic material, which is deposited in the sediment, is decomposed by biological activity. During this degradation the geochemical conditions change and composition of the sediment can be modified. Depending on parameters such as pH and Eh, minerals disolve or precipitate at the same time as adsorption/desorption are shifting. Consequently, release and fixation rates possibly vary in time in deep-sea sediments due to saisonal variations of input materials.

If there are known coherences between short-term processes (seasonality) in the water and the precipitation or disolution of elements in deep-sea sediment, we can possibly connect the chemical parameters with meteorological and biological effects. Depending on the preservation of such a „proxi-parameter" signal in the sediment, it may be used as a paleo-indicator for environmental conditions in geological history.

Station works and preliminary results

Solid phase investigations of the sediments from multicorer cores from WAST-T and WAST recovered on cruise SO118 on RV SONNE have shown different, but characteristic vertical distributions of cadmium, copper and lead. In the case of these two adjacent stations the variation of pore water concentrations in the upper 10 cm of the sediments is obvious, whereas below this depth the concentrations remain on a constant level. It is yet unclear, if the patterns represent early diagenetic processes or a primary sedimentary signal. It is near at hand that the trace metals underlie early diagenesis in the upper part of the sediment and that their concentrations at lower depths are smoothed by these processes. To answer this question, trace metal concentrations of the pore water must be investigated. Pore water analysis provides the possibility to decide whether an element is

precipitated or disolved. To enclose reaction horizons most exactly, it is nessesary to sample the pore water at high resolution.
Two different pore water sampling methods were applied: pressure filtration in a glovebox under argon atmosphere and diffusive gradient in thin films technique (DGT). This method for trace component analysis was developed at Lancaster University (GB) and is based on a perspex sampler, which contains two layers of an acrylamide gel film (DAVISON and ZHANG 1994, ZHANG 1995). Disolved cations diffuse through a gel („diffusive gel"), that is in contact with the pore water to a gel film („resin gel"), containing a cation-exchange resin (CHELEX 100). Fluxes of trace elements can be directly measured from the sediment by knowing the sampling conditions like gel film thicknesses, temperature and sampling time. If releasing rates of trace metals from the solid phase to the pore water are fast enough these fluxes can be interpretated as concentrations. This technique has the advantage of analysing trace contents in very high resolutions up to submillimetre (DAVISON et al. 1997).

Methodology and description of the work carried out

On cruise SO129 six multicorer cores were taken for solid phase and pore water analysis and three cores for pore water sampling applying the gel sampler method. Additionally, water samples were taken from a bottom-water sampler and from a CTD/rosette. Sampling locations were WAST-T (MUC-12, BWS-3), WAST (MUC-04, BWS-1), SAST (MUC-14, BWS-5), CAST (MUC-29, BWS-9, CTD-20) and NAST (MUC-39, MUC-41, BWS-11, CTD-29).
In order to prevent a warming of the sediments on board all multicorer cores were transferred into a cooling room immediately after recovery and maintained at a temperature of 4 to 9°C. Pore water squeezing was processed within a few hours. Samples of the associated bottom water were taken for further analysis. The remaining bottom water was carefully removed from the multicorer tube by means of a siphon in order to avoid destruction of the sediment surface. During subsequent slicing of the cores for pressure filtration in a glovebox with argon atmosphere, pH and Eh measurements were performed with a minimum resolution depth of 0.5 cm. For pressure filtration teflon squeezers were used. The squeezers were operated with argon at a pressure gradually increasing up to 5 bar. The pore water was retrieved through 0.2 µm cellulose acetate membrane filters, which were treated in argon bubbled water before using. Depending on the porosity and compressibility of the sediments, the amount of pore water recovered ranged between about 5 and 35 ml. The remaining sediment was stored after squeezing in PE foil for further analysis. Eh and pH were determined by means of electrodes before the sediment structure was disturbed by sampling.

The pore water of three multicorer cores (WAST-T, WAST and NAST) was sampled by DGT. The perspex sampler had the overall dimensions of 15 x 5 x 0.5 cm with a 1 cm wide and 10 cm long window open to the sediment. Each probe contained two DGT systems, consisting of a 0.4 mm thick resin gel film behind an 0.4 mm thick diffusive gel film, which was covered by a 0.45 µm membrane filter. For sampling preparation they were put into a 0,01M $NaNO_3$ solution. The samplers were deoxygenated in the solution by argon bubbling for at least 24h. For sampling they were immediately put into the sediment after recovery of the multicorer cores in that way, that the bottom-water/sediment boundary was 1 cm below the top of the sampling window. The probes have been in the sediment for 20:13h, 24:00h and 25:49h. The incubating temperature was noticed from time to time. Unfortunately, the temperature in the cooling lab was not constant and varied during the sampling time up to 2.8°C. After the experiment the probes were retrieved and cleaned carefully with MQ water. They were laid on a cleaned teflon plate to avoid contamination. The DGT systems were cut out of the window with a teflon-coated scalpel. The filter and the diffusive gel were carefully pealed off the resin gel, which was then cut into pieces of 0.5 cm resolution. Each resin gel stripe was put into a cleaned 1.5 ml Eppendorf vial and eluated with 100 µl of 1M HNO_3 (s.p.). The samples were stored in a freezer.

Water samples from a bottom-water sampler (BWS-1, -3, -5, -9 and -11) were taken at two depths: 10 and 60 cm above the sediment surface. Water of a depth of 5m above the sediment was sampled from a CTD/rosette on CAST and NAST (CTD-20 and -29). Water of each depth was collected in 100ml scintillation vials, which were cleaned before using with MQ water and HNO_3 and rinsed with a few ml of the sampled water. They were filtered through 0.45 µm cellulose acetate filters. Subsequently all seawater and pore water samples were acidified with HNO_3 (s.p.) down to a pH value of <2 and frozen until further treatment at Bremen University.

Results

Only pH and Eh have been meassured on board. This is due to the complex and difficult methods for sample processing (HF-$HClO_4$-HNO_3-digestion of solid phase samples and extraction of pore water). The samples were conservated for further preparation in the home lab.

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5.11 Primary and secondary elemental signals in deep-sea sediments

Holger Schale
BIGSET, Institut für Chemie und Biologie des Meeres, Universität Oldenburg

Research programme

The project focusses on the distribution of major elements, trace metals, and the sulfur isotopic composition of sediments and pore waters from the Arabian Sea and the NW Atlantic. The major goals of our high resolution inorganic geochemical studies are:

- to detect ocean-wide chemical signals at different locations in the Arabian Sea which reflect climatic variation
- to test the usefulness of „paleoproxies" regarding source provenance of terrigenous matter and paleoproductivity
- to investigate early diagenetic reactions at the sediment-seawater interface and element redistribution processes at the boundaries of pelagic turbidite sections.

Methodology

A list of samples and treatments is given in Tables 1 and 2. A hot digestion for the release of acid volatile sulfide (AVS) and cold chromous chloride digestion for pyritic sulfur was carried out as described by ALLEN *and* PARKES [1995]. For sulfur isotope analysis by Cirm-MS a minimum amount of 20 µg sulfur is required [BÖTTCHER *et al.*, in press]. Owing to the low reduced sulfur content the sample volume for each digestion had to be increased to approx. 20 cm^3. Samples were digested at intervals of 2 cm. Sediments were immediately stored frozen and processed within a few days after sampling, as recommended by LASORSA *and* CASAS [1996].

Filtered and acidified (2% HNO_3) pore-waters from station EAST and sediment samples were stored permanently frozen. 1 ml of a 15% $BaCl_2$ solution was added to a 1 ml pore-water subsample from each depth-interval for $BaSO_4$ precipitation to allow sulfur isotopic analysis of pore water sulfate.

At water depths of 5, 55, and 500 m above the bottom (mab) particulate material was collected by filtration of a water volume of up to 30 l through 0.4 µm polycarbonate membranes. The same water-depths were chosen for the analysis of organic compounds using glass-filters (SP2 and SP4). After washing with demineralized water the filters were dried at approx. 50°C. Table 2 provides sampling information for the water-samples.

Preliminary results

AVS and pyritic sulfur

At stations WAST-T and SAST neither AVS nor pyritic sulfur precipitated during sample digestion. Significant amounts of AVS were found at stations NAST and CAST and pyritic sulfur at WAST and EAST. WAST represents the most extraordinary location not only regarding pyritic sulfur but also with respect to other parameters (such as nutrients, organic composition, biomass, see results of associated SP's). More information on the redox conditions (bacterial sulfate reduction) at the different sites will be obtained from the sulfur-isotopic composition of the porewaters and solids, which will be carried out at the ICBM.

Particulate material in near-bottom water

Table 3 shows the particulate matter content in seawater at three near-bottom depths and from the upper OMZ. The highest amount of material in the near-bottom water were found 5 m above sea-floor (except for station WAST and SAST). The highest concentrations (average of near-bottom samples) were found at station WAST followed by NAST and the remaining stations (Tab. 3). The chemical composition of the particulate matter will be determined by ICP-MS/OES at the ICBM after digestion of filter and sample with mineral acids.

Tab.1: Multicorer sampling information

Multicorer	MC-02	MC-09	MC-14
Station	WAST	WAST-T	SAST
Date	03.02.1998	06.02.1998	11.02.1998
Posititon	16°13'0 N	16°10'5 N	10°02'0 N
	60°16'0 E	59°46'0 E	65°00'0 E
Depth	4045 m	1915 m	4427 m
Corelength	34 cm	18 cm	30 cm
Number of cores	1	1	1
Digestion*	+	+	+

Multicorer	MC-22	MC-29	MC-34	MC-39
Station	EAST	CAST	WAST	NAST
Date	16.02.1998	21.02.1998	26.02.1998	02.03.1998
Posititon	15°35'0 N	14°25'0 N	16°13'0 N	20°00'0 N
	68°34'0 E	64°34'0 E	60°16'0 E	65°35'0 E
Depth	3849 m	3954 m	4046 m	3187 m
Corelength	14 cm	34 cm	30 cm	30 cm
Number of cores	4	2	2	1
Digestion*	+	+	+	+
Slices ** 0.5-2 cm/porewater	+	-	-	-
Slices at 2 mm scale	+	-	+	-
Complete core frozen	+	+	-	-

* Digestion of acid volatile sulfur species (AVS) and pyritic sulfur

** Sampling intervals 0-5 cm, 0.5 cm; 5-10 cm, 1 cm; remianing 2 cm

Tab. 2: Sampling information for water samples

CTD-No.	Station	Date	Postition	Water Depth	Sampling Depth	Sampling Volume (l)	>0.4µm (mg)
CTD-01	WAST	02.02.1998	16°13'1 N, 60^16'0 E	4044	500 masf*	49.38	3.90
CTD-03	WAST	04.02.1998	16^13'0 N, 60^16'0 E	4046	5 masf*	55.23	3.29
CTD-06	WAST	08.02.1998	16°13'0 N, 60°15'9 E	4042	55 masf*	54.09	2.43
CTD-07	WAST	08.02.1998	16°13'0 N, 60°16'0 E	4046	250 mwd**	55.43	1.72
CTD-08	SAST	10.02.1998	10°02'1 N, 64°59'9 E	4426	250 mwd	58.42	1.92
CTD-09	SAST	11.02.1998	10°01'9 N, 65°00'0 E	4425	5 masf	58.42	2.27
CTD-11	SAST	14.02.1998	10°02'0 N, 65°00'0 E	4423	55 masf	57.58	2.69
CTD-12	SAST	14.02.1998	10°02'0 N, 65°00'0 E	4424	500 masf	58.65	1.63
CTD-15	EAST	17.02.1998	15°35'0 N, 68°24'0 E	3848	5 masf	58.00	2.41
CTD-17	EAST	18.02.1998	15°35'0 N, 68°34'0 E	3848	500 masf	58.01	1.63
CTD-18	EAST	18.02.1998	15°35'0 N, 68°34'0 E	3850	55 masf	55.50	1.99
CTD-19	CAST	19.02.1998	14°25'3 N, 64°37'8 E	3949	250 mwd	37.75	2.15
CTD-20	CAST	20.02.1998	14°25'0 N, 64°34'0 E	3950	5masf	58.47	2.40
CTD-22	CAST	22.02.1998	14°25'0 N, 64°34'0 E	3949	500 masf	57.40	2.09
CTD-23	CAST	23.02.1998	14°25'0 N, 64°34'0 E	3958	55 masf	58.40	1.71
CTD-28	NAST	02.03.1998	19°59'5 N, 65°34'6 E	3188	250 mwd	36.80	2.81
CTD-29	NAST	02.03.1998	20°00'0 N, 65°35'0 E	3187	5 masf	50.00	2.41
CTD-32	NAST	03.03.1998	20°00'0 N, 65°35'0 E	3187	500 masf	56.90	2.59
CTD-33	NAST	03.03.1998	20°00'0 N, 65°35'0 E	3190	55 masf	57.50	2.29

* above sea floor **meter water-depth

Tab. 3: Particulate matter concentration in seawater from different stations and depths

	WAST >0.4µm (mg/l)	SAST >0.4µm (mg/l)	EAST >0.4µm (mg/l)	CAST >0.4µm (mg/l)	NAST >0.4µm (mg/l)
5 masf	0.060	0.039	0.042	0.041	0.048
55 masf	0.045	0.047	0.036	0.029	0.040
500 masf	0.079	0.028	0.028	0.036	0.046
average (5, 55, 500 masf)	0.061	0.038	0.035	0.036	0.045
250 mwd	0.031	0.033		0.057	0.076

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Acknowledgements

Cruise SONNE 129 was financed by the Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie (BMBF, Project No. 03 G 0129 A) and by BMBF grant No. 03 F 0177 A (BIGSET), which are part of their deep-sea iniative. Project review and administration was handled by the Forschungszentrum Jülich GmbH, Projektträger BEO. We thank these institutions and their staff for their support. Cruise SONNE 129 was a very successful expedition with nearly all of the projected research programmes fulfilled. This excellent result was made possible by the good cooperation and proficient technical assistance by Captain Kalthoff and his crew, which we gratefully acknowledge.

6. List of Stations

Abbreviations:

AN: Apstein net
AT: Agassiz-trawl
MAC: maxicorer
MC: multiple corer
MOC: MOCNESS
FFR: free-fall chamber lander
FFB: free-vehicle camera system
FFF: free-vehicle trap system
SF: sediment trap
OPI: oxygen profiler
OFOS: ocean floor observation system
BWS: bottom water sampler
CTD: CTD/rosette
KG: boxgrab

Station No.	Date	Time (UTC)	Device	Area	Latitude °N	Longitude °E	Depth (m)	Wire Length (m)
1#1	02.02.1998	11.58	CTD-01	WAST	16°13.07'N	60°15.90'E	4044	3999
1#2	02.02.1998	15.15	CTD-02	WAST	16°13.11'N	60°19.99'E	4046	4048
2#1	02.02.1998	18.05	MOCNESS-01	WAST	16°13.00'N	60°16.00'E	4051	4051
3	02.02.1998	23.45	MC-01	WAST	16°13.04'N	60°16.16'E	4046	4043
4	03.02.1998	3.10	FFR-01	WAST	16°13.98'N	60°16.04'E	4042	
5	03.02.1998		SF-01	WAST	16°14.65'N	60°17.06'E	4043	
6	03.02.1998	7.31	FFF-01	WAST	16°14.55'N	60°15.05'E	4044	
7#1	03.02.1998	9.54	MAC-01	WAST	16°13.00'N	60°16.00'E	4044	4054
7#2	03.02.1998	15.33	MC-02	WAST	16°13.00'N	60°16.00'E	4045	4055
7#3			AN-01	WAST	16°12.97'N	60°15.97'E		
7#4	03.02.1998	14.17	MC-03	WAST	16°13.00'N	60°16.00'E	4045	4056
8	03.02.1998	17.08	FFB-01	WAST	16°15.45'N	60°16.02'E	4044	
9#1	03.02.1998	20.46	BWS-01	WAST	16°12.90'N	60°15.90'E	4047	4073
9#2	03.02.1998	23.07	MC-04	WAST	16°13.00'N	60°16.00'E	4045	4056
9#3	04.02.1998	1.47	MC-05	WAST	16°13.00'N	60°16.00'E	4047	4053
9#4	04.02.1998	4.47	MC-06	WAST	16°13.00'N	60°16.00'E	4044	4049
10#1	04.02.1998	8.11	AN-02	WAST	16°14.10'N	60°16.00'E		200
10#2	04.02.1998	8.11	FFR-01	WAST	16°14.10'N	60°16.00'E	FFR	
11	04.02.1998	10.21	MAC-02	WAST	16°13.00'N	60°16.00'E	4040	4040
12#1	04.02.1998	13.42	AN-03	WAST	16°14.70'N	60°15.70'E		100
12#2	04.02.1998	13.42	FFF-01	WAST	16°14.09'N	60°15.70'E	FFF	
13#1	04.02.1998	15.32	CTD-03	WAST	16°12.90'N	60°15.90'E	4044	4045
13#2	04.02.1998	18.58	OPI-01	WAST	16°13.09'N	60°16.00'E	4044	4071
13#3	04.02.1998	23.00	CTD-04	WAST	16°12.98'N	60°15.93'E	4048	2500
14	05.02.1998	1.08	FFR-02	WAST	16°14.00'N	60°16.00'E		
15	05.02.1998	3.09	MOCNESS-02	WAST	16°14.00'N	60°16.00'E	4045	3290
16#1	05.02.1998	8.20	MC-07	WAST	16°13.00'N	60°16.00'E	4046	4052

Station No.	Date	Time (UTC)	Device	Area	Latitude °N	Longitude °E	Depth (m)	Wire Length (m)
16#2	05.02.1998	11.16	AN-04	WAST	16°13.10'N	60°16.00'E		100
16#3	05.02.1998	13.42	BWS-02	WAST	16°12.99'N	60°15.99'E	4043	4060
16#4	05.02.1998	13.42	AN-05	WAST	16°12.99'N	60°15.99'E		
17	05.02.1998	15.59	MOCNESS-03	WAST	16°13.00'N	60°16.00'E	4049	5984
18	06.02.1998	3.30	FFF-02	WAST- T	16°12.13'N	59°45.96'E	1907	
19#1	06.02.1998	5.00	MAC-03	WAST- T	16°10.50'N	59°46.00'E	1917	1921
19#2	06.02.1998	6.54	MC-08	WAST- T	16°10.50'N	59°46.00'E	1916	1922
19#3	06.02.1998	9.08	MAC-04	WAST- T	16°10.50'N	59°46.00'E	1915	1920
19#4	06.02.1998	10.58	MC-09	WAST- T	16°10.50'N	59°46.00'E	1915	1930
19#5	06.02.1998	12.39	CTD-05	WAST- T	16°10.50'N	59°46.00'E	1916	1912
19#6	06.02.1998	16.03	BWS-03	WAST- T	16°10.50'N	59°46.00'E	1917	1929
19#7	06.02.1998	17.20	MC-10	WAST- T	16°10.50'N	59°46.00'E	1917	1923
19#8	06.02.1998	20.30	OPI-02	WAST- T	16°10.50'N	59°46.00'E	1918	1921
19#9	06.02.1998	22.39	MC-11	WAST- T	16°10.50'N	59°46.00'E	1917	1930
19#10	07.02.1998	0.24	MC-12	WAST- T	16°10.50'N	59°46.00'E	1917	1930
19#11	07.02.1998	2.42	MAC-05	WAST- T	16°10.50'N	59°46.00'E	1916	1919
19#12	07.02.1998	4.32	MAC-06	WAST- T	16°10.50'N	59°46.00'E	1916	1921
20#1	07.02.1998	6.30	FFF-02	WAST- T	16°12.18'N	59°45.89'E	1908	
21#1	07.02.1998	10.45	FFR-02	WAST	16°14.00'N	60°16.00'E	4044	
21#2	07.02.1998	13.00	AN-06	WAST	16°14.00'N	60°16.00'E	4044	
22	07.02.1998	12.30	MOCNESS-04	WAST	16°15.00'N	60°16.00'E	4041	5876
23#1	07.02.1998	21.53	CTD-06	WAST	16°13.00'N	60°15.87'E	4042	4042
23#2	08.02.1998	4.14	OPI-03	WAST	16°13.00'N	60°15.89'E	4045	4079
23#3	08.02.1998	9.00	BWS-04	WAST	16°13.00'N	60°16.00'E	4042	4064
23#4	08.02.1998	11.45	CTD-07	WAST	16°13.00'N	60°15.95'E	4046	250
24	08.02.1998	12.45	FFB-01/-SO129	WAST	16°15.00'N	60°16.00'E	4044	
25	08.02.1998	14.55	AT-01	WAST	16°15.00'N	60°16.00'E	4040	6300

Station No.	Date	Time (UTC)	Device	Area	Latitude °N	Longitude °E	Depth (m)	Wire Length (m)
26	09.02.1998	8.07	MC-13	WS	14°27.07'N	61°39.23'E	4109	4120
27	10.02.1998	16.41	CTD-08	SAST	10°02.03'N	65°59.92'E	4426	249
28	10.02.1998	21.30	SF	SAST	10°00.99'N	65°00.19'E	4424	
29	10.02.1998	21.00	FFF-03	SAST	10°01.47'N	65°00.98'E	4422	
30	10.02.1998	22.50	FFB-02	SAST	10°01.50'N	64°59.00'E	4426	
31	11.02.1998		FFR-03	SAST	10°00.90'N	65°59.90'E	4426	
32	11.02.1998	1.38	MC-14	SAST	10°02.00'N	65°00.02'E	4427	4438
33	11.02.1998	4.55	SF-02	SAST	10°04.00'N	65°00.02'E	4425	
34#1	11.02.1998	6.50	MC-15	SAST	10°02.00'N	65°00.00'E	4425	4430
34#2	11.02.1998	11.07	MC-16	SAST	10°02.00'N	65°00.00'E	4425	4436
34#3	11.02.1998	14.00	OFOS-01	SAST	10°01.98'N	64°59.90'E		
34#4	11.02.1998	15.30	CTD-09	SAST	10°01.98'N	65°00.01'E	4425	4426
34#5	11.02.1998	19.38	BWS-05	SAST	10°02.01'N	64°59.90'E	4427	4445
34#6	12.02.1998	0.29	OPI-04	SAST	10°01.99'N	64°59.99'E	4423	4454
34#7	12.02.1998	4.43	MAC-07	SAST	10°02.00'N	65°00.00'E	4423	4429
35#1	12.02.1998	6.18	FFF-03	SAST	10°01.71'N	65°00.72'E	4421	
35#2	12.02.1998	8.30	AN-06	SAST	10°01.70'N	65°00.70'E	4421	
36	12.02.1998		OFOS-02	SAST	10°02.20'N	64°59.99'E	4426	34
36#2	12.02.1998	11.10	MC-17	SAST	10°02.00'N	65°00.00'E	4424	4334
36#3	12.02.1998	14.15	MC-18	SAST	10°02.00'N	65°00.00'E	4425	4430
36#4	12.02.1998	18.00	AT-02	SAST	09°59.06'N	65°02.27'E	4423	6300
36#5	12.02.1998	23.10	CTD-10	SAST	10°02.03'N	65°00.04'E	4423	4417
37	13.02.1998	1.25	FFF-04	SAST	10°01.49'N	65°00.96'E	4424	
38#1	13.02.1998	5.59	BWS-06	SAST	10°02.02'N	65°00.02'E	4424	4440
38#2	13.02.1998	9.55	MAC-08	SAST	10°02.02'N	65°00.00'E	4425	4426
38#3	13.02.1998	12.52	MC-19	SAST	10°02.00'N	65°00.00'E	4424	4431
40	13.02.1998	14.24	OFOS-03	SAST	10°02.00'N	64°59.99'E	4424	2890

Station No.	Date	Time (UTC)	Device	Area	Latitude °N	Longitude °E	Depth (m)	Wire Length (m)
40#5	13.02.1998	18.57	BWS-07	SAST	10°02.00'N	64°59.99'E	4425	4444
40#6	13.02.1998	22.26	CTD-11	SAST	10°02.00'N	64°59.99'E	4423	4375
40#7	14.02.1998	3.20	CTD-12	SAST	10°01.98'N	64°59.99'E	4425	3926
41	14.02.1998	11.45	SF	SAST	10°02.95'N	65°02.28'E		
42	14.02.1998	12.23	FFR-03	SAST	10°01.99'N	65°00.00'E	4425	
43	14.02.1998	10.25	SF-02	SAST	10°03.96'N	64°59.87'E	4425	
44	14.02.1998	12.18	FFB-02	SAST	10°03.95'N	64°59.99'E	4425	
45	14.02.1998	14.45	FFF-04	SAST	10°01.56'N	65°00.83'E	4425	
45#2	14.02.1998	17.00	CTD-13	SAST	10°01.70'N	65°00.86'E	4422	2500
46	15.02.1998	13.22	MC-20	SE	12°50.52'N	66°48.02'E	4139	4135
47	16.02.1998	9.00	SF-03	EAST	15°34.52'N	68°32.97'E	3856	
48	16.02.1998	9.55	FFR-04	EAST	15°35.50'N	68°33.27'E		
49#1	16.02.1998	11.54	MC-21	EAST	15°35.00'N	68°33.99'E	3845	3846
49#2	16.02.1998	14.26	MC-22	EAST	15°34.52'N	68°32.97'E	3849	3847
49#3	16.02.1998	15.34	CTD-14	EAST	15°34.96'N	68°34.01'E	3848	
49#4	16.02.1998	21.44	CTD-15	EAST	15°34.99'N	68°34.00'E	3848	3840
49#5	16.02.1998	22.21	BWS-08	EAST	15°34.97'N	68°34.00'E	3848	3858
49#6	16.02.1998	23.35	FFB	EAST	15°34.52'N	68°32.97'E	3848	max.3770
49#7	17.02.1998	4.32	MAC-09	EAST	15°34.99'N	68°33.96'E	3845	3848
49#8	17.02.1998	7.07	MC-23	EAST	15°35.00'N	68°34.01'E	3850	3849
49#9	17.02.1998	9.41	MC-24	EAST	15°34.99'N	68°34.02'E	3848	3843
49#10	17.02.1998	12.16	MAC-10	EAST	15°35.03'N	68°34.03'E	3848	3845
49#11	17.02.1998	18.26	CTD-16	EAST	15°34.99'N	68°33.97'E	3848	3841
50	17.02.1998	18.35	OFOS-04	EAST	15°35.30'N	68°32.90'E	3844	3848
51	17.02.1998	23.57	Hydrosweep	EAST	15°36.00'N	68°33.00'E	3845	
52	18.02.1998	4.05	CTD-17	EAST	15°35.01'N	68°34.01'E	3847	3357
52#2	18.02.1998	6.32	MC-25	EAST	15°35.00'N	68°34.00'E	3845	3837

Station No.	Date	Time (UTC)	Device	Area	Latitude °N	Longitude °E	Depth (m)	Wire Length (m)
53	18.02.1998	11.15	AN-07	EAST	15°34.23'N	68°33.35'E	3854	
54	18.02.1998	10.56	SF-03	EAST	15°34.23'N	68°33.35'E	3854	
55	18.02.1998	12.55	CTD-18	EAST	15°35.04'N	68°33.93'E	3850	
56	19.02.1998	4.17	MC-26	EC	15°02.49'N	66°42.76'E	3917	
57#1	19.02.1998	18.18	CTD-19	CAST	14°37.80'N	64°37.00'E	3949	250
57#2	19.02.1998	20.36	MOCNESS-05	CAST	14°25.00'N	64°41.00'E	3938	2929
58	20.02.1998	0.11	FFR-05	CAST	14°24.00'N	64°33.00'E	3958	
59	20.02.1998	0.42	FFB-03	CAST	14°24.01'N	64°33.96'E	3961	
60	20.02.1998	1.13	FFF-05	CAST	14°25.03'N	64°33.99'E	3956	
61	20.02.1998	3.30	SF-04	CAST	14°26.11'N	64°34.03'E	3955	
62#1	20.02.1998	5.12	MC-27	CAST	14°25.02'N	64°34.04'E	3956	3954
62#2	20.02.1998	7.46	MC-28	CAST	14°25.01'N	64°34.00'E	3954	3954
62#3	20.02.1998	11.13	BWS-09	CAST	14°24.99'N	64°33.99'E	3955	3968
62#4	20.02.1998	13.40	CTD-20	CAST	14°24.99'N	64°34.00'E	3950	
62#5	20.02.1998	17.57	CTD-21	CAST	14°25.02'N	64°33.97'E	3956	3951
62#6	20.02.1998	21.42	OPI-05	CAST	14°25.01'N	64°33.99'E	3954	3977
62#7	21.02.1998	1.30	MC-29	CAST	14°24.99'N	64°33.99'E	3954	3954
62#8	21.02.1998	3.54	MAC-11	CAST	14°25.00'N	64°33.98'E	3954	3959
63	21.02.1998	9.23	MOCNESS-06	CAST	14°25.00'N	64°34.00'E	3956	
64#1	21.02.1998	11.53	KG-01	CAST	14°25.00'N	64°33.99'E	3961	
64#2	21.02.1998	14.17	MC-30	CAST	14°25.01'N	64°34.07'E	3956	3956
64#3	21.02.1998	16.54	MC-31	CAST	14°24.98'N	64°33.99'E	3963	3955
64#4	21.02.1998	19.49	OFOS-05	CAST	14°25.00'N	64°33.90'E	3942	
65	21.02.1998	21.54	FFF-05	CAST	14°25.24'N	64°32.85'E	3958/	
66	22.02.1998	2.29	MOCNESS-07	CAST	14°25.00'N	64°33.00'E	3962	6333
67	22.02.1998	9.59	FFF-06	CAST	14°25.00'N	64°35.00'E	3954	
68#1	22.02.1998	11.51	KG-02	CAST	14°24.99'N	64°33.99'E	3955	3958

Station No.	Date	Time (UTC)	Device	Area	Latitude °N	Longitude °E	Depth (m)	Wire Length (m)
68#2	22.02.1998	14.16	MC-32	CAST	14°24.99'N	64°34.03'E	3957	3953
68#3	22.02.1998	16.48	MC-33	CAST	14°24.99'N	64°34.01'E	3955	3948
68#4	22.02.1998	20.04	BWS-10	CAST	14°25.00'N	64°33.99'E	3955	3969
68#5	22.02.1998	23.35	CTD-22	CAST	14°25.02'N	64°34.05'E	3949	3470
68#6	23.02.1998	2.32	CTD-23	CAST	14°24.97'N	64°34.02'E	3958	3954
68#7	23.02.1998	5.24	MAC-12	CAST	14°24.99'N	64°33.97'E	3958	3951
68#8	23.02.1998	8.05	OFOS-06	CAST	14°25.10'N	64°33.90'E	3953	3960
70	23.02.1998	21.00	MOCNESS-08	CAST	14°28.68'N	64°39.61'E	3923	6545
71#1	24.02.1998	4.41	MAC-13	CAST	14°25.03'N	64°34.02'E	3954	3952
71#2	24.02.1998	6.04	CTD-24	CAST	14°24.97'N	64°33.96'E	3958	
71#3	24.02.1998	9.15	AN-08	CAST	14°24.98'N	64°33.96'E	3958	
73	24.02.1998	10.02	FFB-03	CAST	14°24.01'N	64°34.00'E	3960/	
74	24.02.1998	12.22	SF-04	CAST	14°25.85'N	64°33.89'E	3954/	
75	24.02.1998	14.00	FFF-06	CAST	14°24.96'N	64°34.73'E	3957/	
76	24.01.1904	18.43	MOCNESS-09	CAST	14°25.00'N	64°35.00'E	3937	6163
77	25.02.1998	23.51	FFR-06	WAST	16°13.50'N	60°16.50'E	4040	
78	26.02.1998	0.15	FFB-04	WAST	16°13.50'N	60°16.00'E	4040	
79	26.02.1998	1.58	MC-34	WAST	16°12.99'N	60°15.97'E	4046	4040
80	26.02.1998	6.50	AN-09	WAST-T	16°10.48'N	59°45.95'E	1917	
80#1	26.02.1998	7.14	OPI-06	WAST-T	16°10.48'N	59°45.56'E	1915	1928
80#2	26.02.1998	9.32	MC-35	WAST-T	16°10.56'N	59°45.99'E	1913	1922
80#3	26.02.1998	9.50	AN-10	WAST-T	16°10.50'N	59°45.96'E	1917	
80#4	26.02.1998	10.57	MAC-14	WAST-T	16°10.50'N	59°45.97'E	1914	1917
81	26.02.1998	15.55	MOCNESS-10	WAST	16°12.08'N	59°51.65'E	4016	6525
82#1	26.02.1998	21.45	CTD-25	WAST	16°12.96'N	60°15.99'E	4042	249
82#2	26.02.1998	23.20	MC-36	WAST	16°12.96'N	60°16.05'E	4045	4040
82#3	27.02.1998	1.59	KG-03	WAST	16°12.97'N	60°16.00'E	4042	4045

Station No.	Date	Time (UTC)	Device	Area	Latitude °N	Longitude °E	Depth (m)	Wire Length (m)
82#4	27.02.1998	4.26	KG-04	WAST	16°12.97'N	60°15.97'E	4043	
83	27.02.1998	7.14	MOCNESS-11	WAST	16°12.78'N	60°16.37'E	4044	2774
84	27.02.1998	10.17	FFB-04	WAST	16°13.50'N	60°16.00'E	4040/	
85	27.02.1998	13.20	FFR-06	WAST	16°12.96'N	60°16.05'E	4040/	
86#1	27.02.1998	14.45	CTD-26	WAST	16°13.38'N	60°16.47'E	4044	4044
86#2	27.02.1998	17.51	CTD-27	WAST	16°13.32'N	60°16.49'E	4045	4048
86#3	27.02.1998	21.17	OFOS-07	WAST	16°13.50'N	60°16.80'E	4046	
86#4	01.03.1998	4.30	OFOS-07	WAST	16°13.30'N	60°17.20'E	4039	
87	28.02.1998	3.02	SF-01	WAST	16°14.42'N	60°16.99'E	4040/	
88#1	01.03.1998	12.09	MC-37	NC	17°44.99'N	65°44.97'E	3422	3412
88#2	01.03.1998	12.30	AN-11	NC	17°44.99'N	65°44.97'E		
89#1	02.03.1998	1.31	CTD-28	NAST	19°59.46'N	65°34.58'E	3188	250
89#2	02.03.1998	2.00	FFB-05	NAST	19°59.46'N	65°34.58'E	3188	
90	02.03.1998	2.30	FFF-07	NAST	19°59.50'N	65°34.99'E	3185	
91	02.03.1998	3.55	SF-05	NAST	19°59.95'N	65°35.61'E	3185	
92	02.03.1998	5.29	MC-38	NAST	20°00.00'N	65°35.00'E	3188	3186
93#1	02.03.1998	7.33	MC-39	NAST	19°59.99'N	65°34.99'E	3187	3189
93#2	02.03.1998	8.30	AN-12	NAST	20°00.00'N	65°35.00'E		
94	02.03.1998	8.30	FFR-07	NAST	19°59.99'N	65°34.50'E	3189	
94#1	02.03.1998	10.30	CTD-29	NAST	20°00.00'N	65°35.00'E	3187	3190
94#2	02.03.1998	12.30	CTD-30	NAST	20°00.00'N	65°35.11'E	3186	3190
94#3	02.03.1998	13.00	AN-12	NAST	19°59.46'N	65°35.11'E		
94#4	02.03.1998	15.45	OFOS-08	NAST	20°00.00'N	65°35.00'E	3186	
95#1	03.08.1998	0.07	BWS-11	NAST	20°00.00'N	65°35.00'E	3186	3201
95#2	03.03.1998	3.04	MAC-15	NAST	20°00.00'N	65°35.00'E	3187	3185
95#3	03.03.1998	5.21	MC-40	NAST	20°00.00'N	65°35.00'E	3187	3190
95#4	03.03.1998	7.30	MC-41	NAST	20°00.00'N	65°35.00'E	3188	3191

Station No.	Date	Time (UTC)	Device	Area	Latitude °N	Longitude °E	Depth (m)	Wire Length (m)
96	03.03.1998	8.50	AT-04	NAST	19°56.46'N	65°35.04'E	3188	4800
97#1	03.03.1998	14.45	CTD-31	NAST	19°59.98'N	65°35.02'E	3187	3188
97#2	03.03.1998	17.10	CTD-32	NAST	20°00.00'N	65°35.00'E	3187	2692
97#3	03.03.1998	18.35	CTD-33	NAST	20°00.40'N	65°35.02'E	3190	3187
97#4	03.03.1998	22.53	BWS-12	NAST	19°59.99'N	65°34.99'E	3187	3199
97#5	04.03.1998	1.44	MC-42	NAST	20°00.00'N	65°35.04'E	3188	3185
97#6	04.03.1998	3.45	MAC-16	NAST	19°59.98'N	65°35.03'E	3186	3188
98	04.03.1998	5.07	MOCNESS-12	NAST	20°00.00'N	65°34.50'E	3186	
99	04.03.1998	11.32	FFR-07	NAST	20°00.00'N	65°35.00'E	3186	
100	04.03.1998	13.20	FFB-05	NAST	19°59.98'N	65°35.03'E	3188	
101	04.03.1998	14.10	FFF-07	NAST	19°59.98'N	65°35.03'E	3187	
102#1	04.03.1998	16.53	CTD-34	NAST	20°00.00'N	65°35.05'E	3187	2500
102#2	04.03.1998	19.10	OFOS-09	NAST	20°00.00'N	65°34.09'E	3186	3184
103#1	04.03.1998	23.02	KG-05	NAST	19°59.98'N	65°35.00'E	3186	3185
103#2	05.03.1998	1.09	KG-06	NAST	20°00.00'N	65°35.00'E	3186	3184
104	05.03.1998	2.18	SF-05	NAST	19°59.97'N	65°35.67'E	3185	

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