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REPORT AND PRELIMINARY RESULTS OF METEOR CRUISE M 53/1,  
LIMASSOL - LAS PALMAS - MINDELO, 30.03. - 03.05.2002





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## 1. Research objectives

During RV METEOR cruise M53/1, research was carried out in connection with the following projects:

- ANIMATE (“Atlantic Network of Interdisciplinary Moorings and Time series for Europe”)
- DFG-Projects
  - “In-situ measurements and sampling of marine aggregates”
  - “Zooplankton structures and particle flux in the Levantine Sea against the background of the changes in the thermohaline circulation”
- DOLAN (“Operational Data Transmission in the Ocean and Lateral Acoustic Network in the Deep-Sea”)
- ESTOC (“European Station for Time-Series in the Ocean, Canary Islands”)

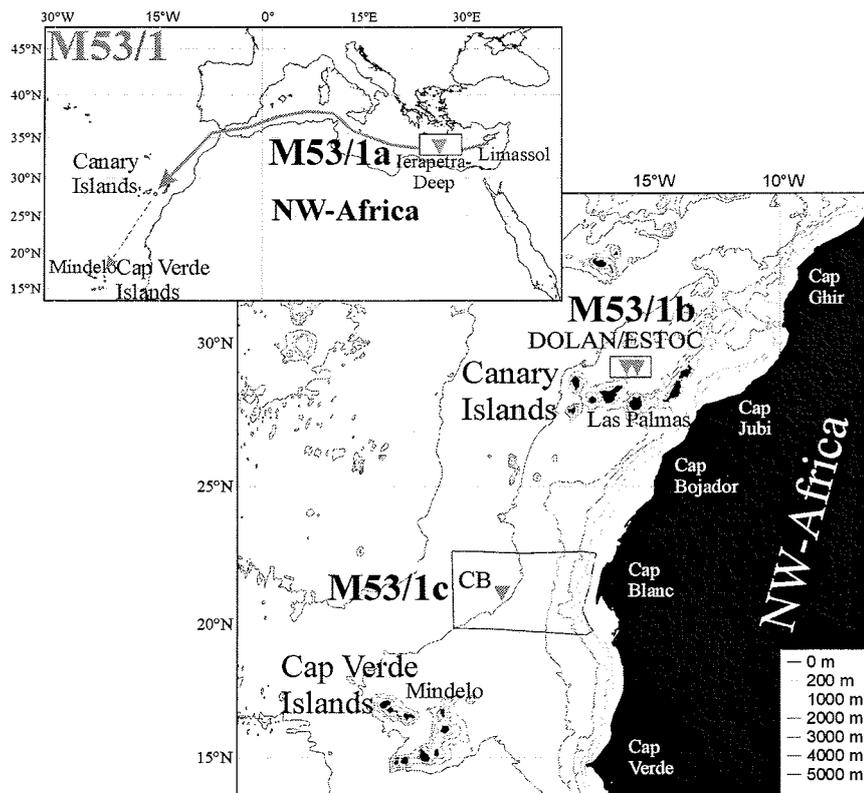


Fig. 1: Working areas during METEOR cruise M53/1 (M53/1a: south of Crete in the Ierapetra-Deep; M53/1b: mainly north of the Canary Islands at ESTOC and DOLAN-moorings; M53/1c: mainly off Cape Blanc and Timirist (Mauritania)).

The main objectives of the first leg of M53/1 were particle flux studies in the Mediterranean Sea and in the NE-Atlantic (Fig. 1). The aim of this study was to determine

and understand the processes controlling the varying fluxes of carbon on short-term, seasonal, inter-annual back to glacial/interglacial time-scales.

For logistical reasons this leg was subdivided into three subparts (Fig. 1). During M53/1a from Limassol to Las Palmas a sediment trap mooring of the University of Hamburg was recovered in the Iapetra-Deep. The aim of this work is to understand the particle flux mechanisms and their relation to the deep-sea biology in the Levantine Sea south of Crete.

M53/1b concentrated on the area north of the Canary Islands. One goal of M53/1b was the monthly sampling work at ESTOC (“European Station for Time-series in the Ocean, Canary Islands”) for April 2002. ESTOC is located 60 nm north (upstream) of Gran Canaria in the eastern boundary flow of the subtropical North Atlantic gyre (at 29°10’N and 15°30’W). The time-series station was initiated in the year 1994 and is co-operated by two Spanish (Instituto Canario de Ciencias Marinas in Telde (Gran Canaria) and Instituto Espanol de Oceanografia in Santa Cruz (Tenerife)) and two German institutes (Department of Oceanography of the University of Kiel and Department of Earth Sciences at the University of Bremen). The main purpose of the station is to build a long-term oceanographic data base to be able to discern seasonal from long-term variability of hydrographic and biogeochemical parameters in this environmentally sensitive region of the Eastern Boundary Current of the North-Atlantic gyre. The region is especially interesting because of episodic dust depositions from the African continent that likely influence productivity and particle formation.

Also on M53/1b the establishment of the operational transmission of datasets at the DOLAN mooring site was performed. In addition to that, mooring-, maintenance works and tests of the technical devices were done within the scope of the BMBF project DOLAN (“Operational Data transmission in the Ocean and lateral acoustic Network in the Deep-Sea”). This gauging station is located 30 nm west of ESTOC and comprises technology for the transmission of data by means of acoustics in the water column via satellite and internet. Closely linked to ESTOC and DOLAN is the EU project ANIMATE (“Atlantic Network of Interdisciplinary Moorings and Time series for Europe”). In the ANIMATE project, moorings were deployed at key sites in the northern Atlantic in order to gain data of CO<sub>2</sub>, nutrients and fluorescence, which will be directly transmitted via satellite to the participating scientific institutes. A significant element in ANIMATE is the technology used in the DOLAN project for the transmission of datasets from the deep-sea. Furthermore, ESTOC is the reference site for the subtropical NE-Atlantic within the ANIMATE project.

The mooring work at ESTOC and DOLAN were accompanied by the deployment of a “Remotely Operated Vehicle” (ROV), which can reach depths up to 1000 m. With aid of this

new and innovative technology, high resolution datasets for the quantitative balancing of particle fluxes through the water column will be obtained. The intention is the measurement, sampling and subsequently analysis of the sinking and suspended material, against the background of the not sufficiently understood processes of the formation of aggregates and their vertical and lateral transport processes in the ocean. For this purpose, a remotely from the ship movements independent and free flying vehicle was deployed. This vehicle was equipped with a new technology for the simultaneous measurement of the in-situ characteristics and selective sampling of single marine aggregates. The obtained datasets will be compared and interpreted with datasets of the size distribution of marine aggregates provided by deep-sea cameras, optical sensors (optical backscatter and fluorescence), CTD profiles and results from particle flux measurements provided by sediment traps. For the immediate comparison of the aggregate- and particle flux data, the grain size distribution of the lithogenic fraction (wind transported dust) in marine aggregates and settling material, will be used as an independent transportation proxy.

During M53/1c sedimentological field work of the Research Center Ocean Margins of the University of Bremen started. The upwelling area off NW-Africa is one of the most important upwelling systems of the world and is influenced by high amounts of Saharan dust, which is transporting nutrients into the ocean. Both processes are of fundamental importance for the particle production in the ocean and influence with the processes biological pump and carbonate pump the global atmospheric CO<sub>2</sub>-budget. Despite the main driving-force for climatic variability is situated in the northern North-Atlantic, the upwelling area off NW-Africa is suitable to reconstruct the past climatic variability, because of high accumulation rates in the sediments and thus a good paleoceanographic resolution. The phenomenon of abrupt climatic change was in the focus of research. Various ice-core studies and paleoceanographic investigations have shown that climatic change in the past often happened abrupt within a few decades. In high resolution sediments of the North Atlantic numerous short-termed climatic changes were described from “Bond-cycles” and “Heinrich-Events” in the Glacial to the Little Ice Age (1300-1870). These abrupt changes in the climatic system, the knowledge and the worrying prospect that global change could also occur very spontaneously within a few decades at present times have brought the paleoceanographic studies more and more in the focus of the public attention. Especially the analyses of highly resolved Holocene marine sediments give the potential to classify historical climatic changes of the last 2000 years like the Little Ice Age or the Medieval Warm Period in the context of the long-term climatic variability of the last 11,500 years. On the basis of the results of previous METEOR

cruises (M37/1, M42/4, M45/5) and the knowledge that the particle flux is higher in the Cape Blanc area due to yearly upwelling in relation to seasonal upwelling in the Canary Islands region, we expect higher sedimentation rates off Cape Blanc and therefore good climatic archives for high-resolution paleoceanographic studies. The POSEIDON cruise POS 272 in April 2001 gave valuable information by first profiling work of Cape Bojador and Cape Blanc and by first sampling of the sediments with multicorer and gravity corer. On the basis of this information work during M53/1c could be done specifically after short surveys with HYDROSWEEP and PARASOUND. Sediments were recovered using a multicorer and a gravity corer with different pipe lengths. These acoustic board systems were used on site as a proven tool to find suitable locations of sampling sites. Suitable locations were sampled with conventional wireline coring techniques (multicorer and gravity corer).

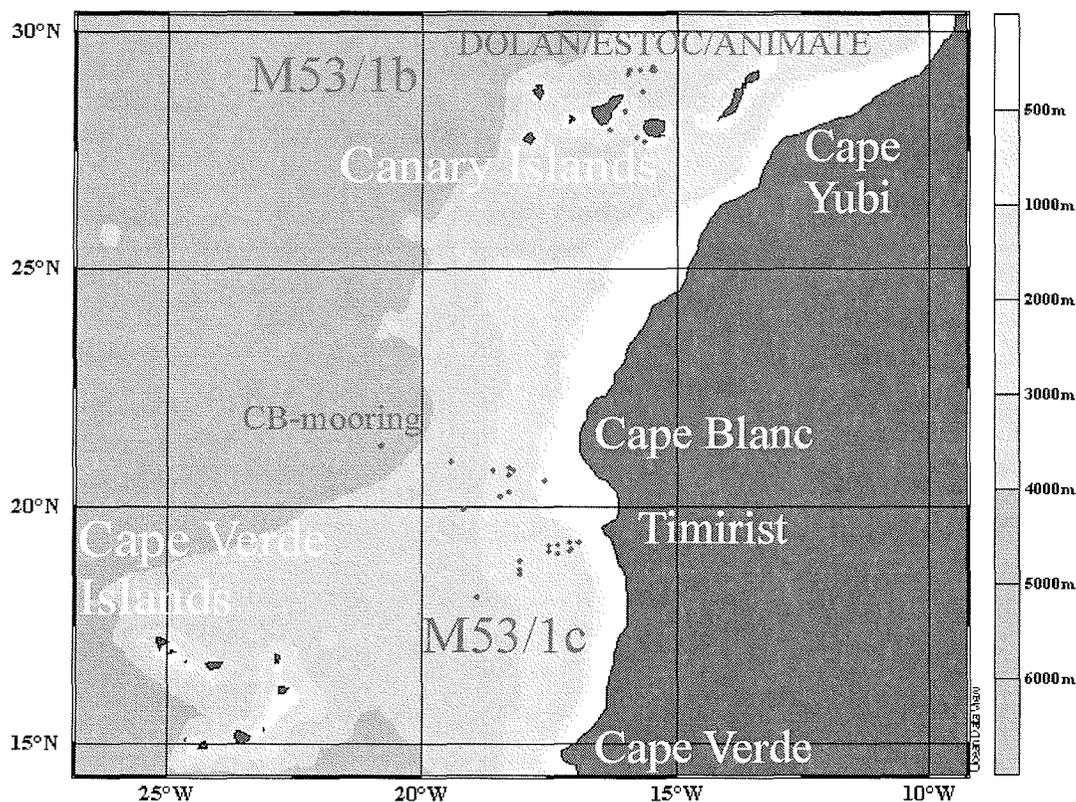


Fig. 2: Stations during METEOR cruise M53/1 b and c.

Also during M53/1c as during M53/1b surveys with a particle camera system and the ROV were carried out to describe and sample the marine aggregates off Cape Blanc and to compare these results with that of the Canary Islands region. SeaWiFS satellite images of the structure of the filament will be transmitted from Bremen in real-time to aid in the investigation of the complex structure of the filament off Cape Blanc.

## 2. Participants

For logistic reasons, the leg M 53/1 was divided in three parts with the following participants and institutions (Tabs.1, 2, 3):

**Part 53/1a: Limassol-Las Palmas, 30.03.2002 - 10.04.2002**

**Part 53/1b: Las Palmas-Las Palmas, 12.04.2002 - 18.04.2002**

**Part 53/1c: Las Palmas-Mindelo, 20.04.2002 - 03.05.2002**

Tab. 1: Participants of METEOR cruise no. 53/1

### Leg M 53/1a

<b>Name</b>	<b>Subject</b>	<b>Institution</b>
Meggers, Helge, Dr. (Chief Scientist)	Sedimentology/Particle Flux	GeoB
Gebhardt, Catalina	Particle Flux	UniHH
Kahl, Gerhard, Dr.	Meteorology	DWD
Truscheit, Thorsten	Meteorology	DWD
Warnken, Carolin	Particle Flux	UniHH

Tab. 1 continued: Participants of METEOR cruise no. 53/1

**Leg M 53/1b**

<b>Name</b>	<b>Subject</b>	<b>Institution</b>
Meggers, Helge, Dr. (Chief Scientist)	Particle Flux	GeoB
Babero-Munoz, Leticia	Marine Chemistry	ULPGC
Barrera, Carlos	Marine Chemistry	ICCM
Bergenthal, Markus	DOLAN/Particle Flux	GeoB
Betancort, Juan	Marine Chemistry	ICCM
Budweg, Harald	Meteorology	DWD
Cardona, Laura	Marine Chemistry	ICCM
Dimmler, Werner	Particle Flux	AWI
Drünert, Frank, Dr.	DOLAN	OHB
Findekle, Antje	Journalist	Spektrum-online
Giani, Dieter, Dr.	Journalist	TV
Hübner, Anneliese, Dr.	Journalist	Weser-Kurier
Kahl, Gerhard, Dr.	Meteorology	DWD
Kläerner, Dietmut, Dr.	Journalist	FAZ/NZZ/Radio
Klar, Steffen	DOLAN	GeoB
Kopiske, Eberhard	DOLAN	GeoB
Koy, Uwe	ANIMATE	IfMK
Löwenberg, Ralf	Ship's logistic	Werum
Meinecke, Gerrit, Dr.	DOLAN/Particle Flux	GeoB
Mews, Klaus	Meteorology	DWD
Moser, Stefan	Journalist	Camera-man
Nowald, Nicolas	ROV	GeoB
Pinck, Andreas	ANIMATE	IfMK
Ratmeyer, Volker, Dr.	DOLAN/Particle Flux	GeoB
Rosiak, Uwe	DOLAN/Particle Flux	GeoB
Ruhland, Götz	DOLAN/Particle Flux	GeoB
Schmidt, Werner	DOLAN/Particle Flux	GeoB
Truscheit, Thorsten	Meteorology	DWD
Villagarcia, Marimar, Dr.	Marine Chemistry	ICCM

Tab. 1 continued: Participants of METEOR cruise no. 53/1

**Leg M 53/1c**

<b>Name</b>	<b>Subject</b>	<b>Institution</b>
Meggers, Helge, Dr. (Chief Scientist)	Marine Geology/Particle Flux	GeoB
Ball Abou Cire	Observer	Mauretania
Barrera, Carlos	Marine Chemistry	ICCM
Bergenthal, Markus	Marine Geology/Particle Flux	GeoB
Cardona, Laura	Marine Chemistry	ICCM
Cianca, Andres	Marine Chemistry	ICCM
Eberwein, Astrid	Marine Geology/Particle Flux	AWI
Freudenthal, Tim, Dr.	Marine Geology/Particle Flux	GeoB
Garming, Johanna	Geophysics	GeoB
Gutt, Julian, Dr.	Particle Flux	AWI
Kasten, Sabine, Dr.	Marine Geochemistry	GeoB
Klar, Steffen	DOLAN	GeoB
Makaoui, Ahmed	Observer	Marocco
Meinecke, Gerrit, Dr.	Marine Geology/Particle Flux	GeoB
Nowald, Nicolas	ROV	GeoB
Plewa, Kerstin	Marine Geochemistry	GeoB
Ratmeyer, Volker, Dr.	Marine Geology/Particle Flux	GeoB
Romero, Oscar, Dr.	Marine Geology/Particle Flux	GeoB
Rosiak, Uwe	Marine Geology/Particle Flux	GeoB
Ruhland, Götz	Marine Geology/Particle Flux	GeoB
Schmidt, Werner	Marine Geology/Particle Flux	GeoB
Scholz, Maike	Marine Geology/Particle Flux	GeoB
Truscheit, Thorsten	Meteorology	DWD
Wülbers, Alexius	Marine Geology/Particle Flux	GeoB

Tab. 2: Participating Institutions

<b>AWI</b>	Alfred-Wegener-Institut für Polar- und Meeresforschung Columbusstr. D-27568 Bremerhaven Germany
<b>DWD</b>	Deutscher Wetterdienst Geschäftsfeld Seeschifffahrt Bernhard-Nocht-Straße 76 D-20359 Hamburg Germany
<b>GeoB</b>	Fachbereich 5 - Geowissenschaften Universität Bremen Klagenfurterstr. D-28359 Bremen Germany
<b>IFMK</b>	Institut für Meereskunde Universität Kiel Düsternbrooker Weg 20 D-24105 Kiel Germany
<b>ICCM</b>	Instituto Canario de Ciencias Marinas Dirección General de Universidades e Investigación Consejería de Educacion E-35200 Telde Canary Islands, Spain
<b>OHB</b>	Raumfahrt + Umwelttechnik OHB-System-GmbH Universitätsallee 27-29 D-28359 Bremen Germany
<b>ULPGC</b>	Universidad de Las Palmas de G. Canaria Edificio de Ciencias Básicas Campus Universitario Tafira E-35017 Las Palmas de Gran Canaria Canary-Islands, Spain

### **3. Research program**

The main purpose of the cruise was the investigation of biogeochemical processes and fluxes on different spatial and temporal scales in relation to water mass circulation. Due to its unique location, the Canary Islands and Cape Verde Islands region occupies a key position with respect to the biogeochemical cycles in the region and is a prime location to study environmental parameters sensitive to climate change.

The purpose is to obtain an integrated view of oceanographic processes in this region both in the present and of the past.

Within the mentioned projects (see above) the following was done:

1. Studying the particle flux by recovering and deploying three sediment trap moorings (MID-II, ESTOC and CB ("Cape Blanc-mooring")). The particulate material collected will be analysed to determine total flux, particulate flux, particulate organic carbon, particulate nitrogen, biogenic opal, carbonate and carbon isotopes of organic matter, and lithogenic material. The trapped material will further be investigated for species composition of the planktonic organisms (pteropods, foraminifera, radiolaria, coccolithophorids, and diatoms), together with the chemical and isotopic compositions of these organisms and the composition of the organic and terrigenous material. Complementary, the ROV and the particle camera system were used to understand processes of the formation of aggregates and their vertical and lateral transport processes in the ocean.

2. Sampling the surface waters to determine the chlorophyll content

3. Studying the amplitudes and rates of longterm environmental variability exemplified by the flux variability of environmental tracers and atmospheric dust through the last glacial-interglacial cycle along transects from the high-productivity coastal zone off Cape Blanc to the oligotrophic central gyre region by taking sediment cores.

Within the framework of the deep-sea device programme DOLAN the following work was carried out:

1. Deployment of a permanent open sea mooring SBU ("Surface Buoy Unit") with surface buoy.

2. Test of the satellite telemetry via OrbComm satellites.

3. Deployment of the MSU ("Multi Sensor Unit") mooring, including the device platform MSD at 3000m depth.

4. Recovery and redeployment of the ESTOC mooring.

## **4. Narrative of the Cruise**

### **4.1 Leg M 53/1a (H. Meggers)**

The final preparations for cruise M53/1a were carried out on RV METEOR in the harbour of Limassol (Cypres) on the 29<sup>th</sup> of March. Two scientists of the University of Hamburg (Institute for Biogeochemistry and Marine Chemistry) and the Chief-Scientist of the University of Bremen (Department of Geosciences) came onboard. Guided ship tours were held in the harbour together with the crew of the METEOR for scientists of the Cyprus Geological Survey and for professors and students of the Ship-Building Technical University of Nicosia. The cruise started due to a high volume of ships traffic in the harbour one day earlier than scheduled on the 30<sup>th</sup> of March in the earlier morning in Limassol, Cypres. METEOR reached the first working station south of Crete on the 1<sup>st</sup> of April in the early morning. The scientific programme started with a first CTD-survey, which was deployed to 3500 m water-depth on the mooring position MID-2 (Mediterranean Ierapetra Depth) in order to obtain the spring hydrographic characteristic of the station. With the first daylight the mooring was recovered (Fig. 1). After some surface water sampling the scientific work during M53/1a was terminated and METEOR took course to the Canary Islands calling Las Palmas harbour in the morning of the 10<sup>th</sup> of April, finishing the first subpart of M53/1.

### **4.2 Leg M53/1b (H. Meggers)**

The vessel preparation including intensive container packing work for cruise M53/1b started on the same day. The scientists of the University of Hamburg disembarked and 18 scientists from the University of Bremen, the Instituto Canario de Ciencias Marinas in Telde (Gran Canaria), the University of Las Palmas, the Alfred-Wegener-Institute in Bremerhaven and the Institute for Oceanography of the University of Kiel embarked. The scientist team was accompanied by five journalists (a TV-journalist including cameraman, two newspaper journalists and a journalist of an on-line scientific medium), who documented the scientific work during M53/1b in the framework of the Year of Geosciences 2002 in Germany. In the evening of the 11<sup>th</sup> of April a reception was held for invited persons from the scientific and politic community (including local journalists) of the Canary Islands onboard. The scientists and crewmembers used the opportunity to present their scientific work to the public.

RV METEOR left Las Palmas on the 12<sup>th</sup> of April in the early morning, taking course to the ESTOC-mooring position (Fig. 2). Underway scientific work started with the deployment

of XBT`s on the way every 10 nautical minutes beginning at 28°10`N. Station work started in the late afternoon with the monthly work (CTD/Rosette casts, deployment of a NOAA-drifter) for April 2002 at the ESTOC time-series station, located 60 nm north of Gran Canaria. The main purpose of this station is to build a long-term oceanographic data base to be able to discern seasonal from long-term variability of hydrographic and biogeochemical parameters. ESTOC is also used as an important reference station for ANIMATE, a EU-project for thermocline measurements of CO<sub>2</sub>- and nutrients at various key-sites in the NE-Atlantic. On the 13<sup>th</sup> of April the sediment trap mooring CI14 was recovered successfully. This mooring contains three sediment traps (20 cup collector), the upper one at least 500 m above the sea floor, the lower one at least 500 m below surface. Sampling periods are two weeks. The particulate material collected will be analysed to determine total flux, particulate flux, particulate organic carbon, particulate nitrogen, biogenic opal, carbonate and carbon isotopes of organic matter, and lithogenic material. The trapped material will further be investigated for species composition of the planktonic organisms (pteropods, foraminifera, radiolaria, coccolithophorids, and diatoms), together with the chemical and isotopic compositions of these organisms and the composition of the organic and terrigenous material.

In the following days testing of deep-sea technology in the framework of DOLAN and use of the CTD/Rosette-system alternate with each other. The deep-sea technology testing included various tests of satellite telemetry via OrbComm– satellite, the programming and interface tests between the under water and satellite communication and tests of the under water communication via the top buoy as a master unit. After this successful testing programme the SBU-mooring (additionally implemented in the mooring chain a nutrient analyser and a fluorometer) was deployed in the morning of the 12<sup>th</sup> of April 30 nm west of ESTOC. In the afternoon of the same day a second mooring with a Multi Sensor Device (MSD) including a sediment trap, a particle camera and a CTD at 3000 m water depth was deployed. After testing the entire data path with SBU and MSD the operational commission of the platforms with measuring and transmission started. In the morning of the 16<sup>th</sup> of April a combined CI15/ANIMATE mooring (including 2 sediment traps, current meters and various Microcat-CTD`s) was deployed near ESTOC. After finishing work north of the Canary Islands METEOR took course southward in the lee of the Canary Islands to get weather condition favourable for an intensive testing of the new “Remotely Operating Vehicle” (ROV). This device can reach depths up to 1000 m and with aid of this new and innovative technology high-resolution datasets for the quantitative balancing of particle fluxes through the water column will be obtained. During M53/1b balance testing and pilot testing were

carried out intensively. The second subpart of M53/1 ended in the morning of the 18<sup>th</sup> of April in Las Palmas.

### **4.3 Leg M53/1c (H. Meggers)**

Since one main focus of the third subpart of M53/1 was the sampling of sediments in the research area off Cape Blanc, the devices for the geology sampling were prepared during port time. Next to this preparation the scientific team and the crew of the METEOR take some time to give guided tours through the ship and its labs for two school classes of the German School in Las Palmas to give an overview of the scientific work in the area.

Part M53/1c started in the early morning of the 20<sup>th</sup> of April. A small group of the scientific group was exchanged in Las Palmas and two observers, one from Mauritania and another from Morocco were welcomed onboard of METEOR. METEOR took course southward between the Canary Islands Gran Canaria and Fuerteventura/Lanzarote to a mooring position 200 nm off Cape Blanc (CB). Underway scientific work started with the deployment of XBT's on the way in a nautical distance of 1° beginning at 27°N.

The structures of the near-surface sediments, which reflect the effects of paleo-oceanographic and paleoclimatic variability in the sedimentation processes, were continuously recorded at high resolution during the entire METEOR Cruise 53/1c with the PARASOUND echo sounder. In addition, a survey of the general morphologic setting was achieved by the swath bathymetry system HYDROSWEEP. Both acoustic board systems were used on site as a proven tool to find suitable locations of sampling sites. These sites were sampled with conventional wire-line coring techniques (multicorer and gravity corer) and subsequently sampled and described. In the early morning of the 22<sup>nd</sup> of April the mooring CB12 was exchanged successfully to CB13. Afterwards METEOR took course eastward towards the Mauritanian coast.

On a first profile west off Cape Blanc sediments were sampled at 6 stations with multicorer and gravity corer in water depths between 3400 and 70 m (Fig. 2). The sedimentological work was accompanied by deployments of the ROV and the particle camera system for documentation, measurements, sampling and subsequently analysis of the sinking and suspended material against the background of the not sufficiently understood processes of the formation of aggregates and their vertical and lateral transport processes in the ocean. In addition to this on several stations the CTD/Rosette –system was used.

The work was continued on a second transect off Cape Blanc on the 26<sup>th</sup> of April with 4 stations from the eutrophic area directly off Cape Blanc to the mesotrophic domain offshore in water-depths from 70 m to 3100 m. This profile was sampled with multicorer and gravity corer as well as with the particle camera system. A third NE-SW profile with 3 stations off Timirist followed to complete the scientific work, which was done during METEOR leg M53/1. This profile started on the 28<sup>th</sup> of April and samples/photographs were taken between 1300 and 3100 m water depth with multicorer, gravity corer, CTD/Rosette and particle camera (Fig. 2).

The objective of sampling transects perpendicular to the coast was to obtain sediment material to reconstruct the history of coastal upwelling and Saharan dust supply during the last glacial/interglacial cycles and to reconstruct the influence of filaments on the particle flux. Initial results indicate that the 5 to 17 m long cores were collected with little disturbance of the recovered material.

During the whole cruise M53/1b and c surface waters were sampled on the way and at various stations using the shipboard membrane pumping system for chlorophyll and CO<sub>2</sub> measurements.

After completion of the work on this last profile in the afternoon of the 1<sup>st</sup> of May, METEOR continued to Mindelo, Cape Verde Islands, arriving in the early morning of the 3<sup>rd</sup> of May, ending the first leg of cruise 53.

## 5. Preliminary Results

### 5.1 M53/1a

#### 5.1.1 Sediment Trap and Suspended Particulate Matter Investigations in the Eastern Mediterranean

(A. C. Gebhardt, C. Warnken)

##### Introduction

When studying the global biogeochemical cycle of elements such as carbon, silica and nitrogen, the transfer of particulate matter from the surface layer through the water column to the sediment-water interface as well as its incorporation into the sediment play a major role. Sediment traps provide a reliable means to sample sinking particulate matter and to calculate flux rates. Sediment trap investigations carried out in numerous regions of the world ocean have contributed to the better understanding of processes and factors controlling the formation, amount and composition of sinking particles (e.g. Honjo, 1996; Ittekkot, 1996). This information is essential for interpretation of the sedimentary record.

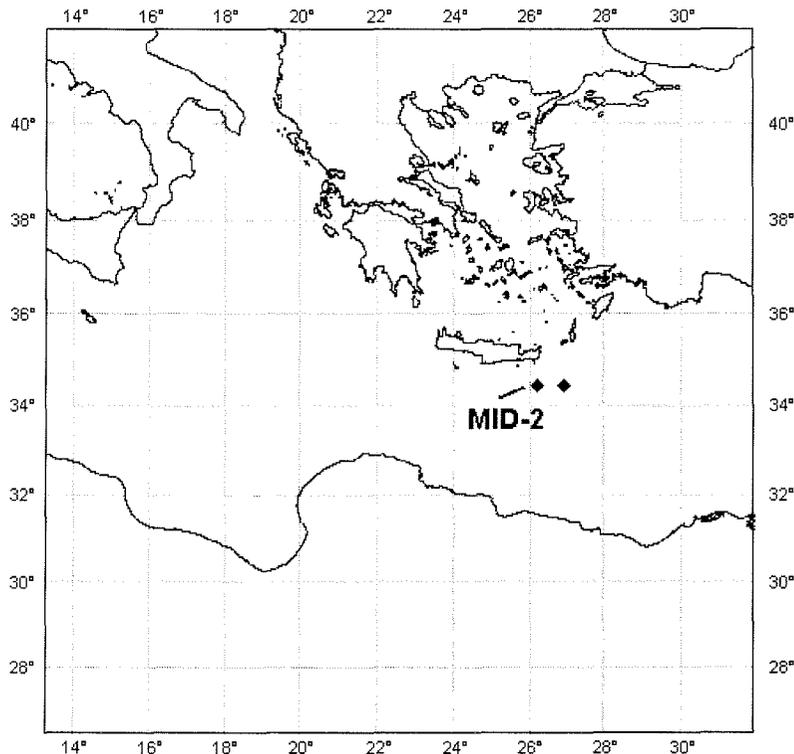


Fig. 3: Positions of sediment trap MID-2

In November 2001, the mooring system MID-2 (Mediterranean Ierapetra Deep) was deployed in the Eastern Mediterranean off Crete in order to prolong the record from MID-1

(deployed in spring 1999, see Pätzold et al., 2000). The major goal of the sediment trap investigation is to record the flux of settling particles in the deep Eastern Mediterranean. Detailed analyzes of bulk composition and organic compounds will provide information on the sources, alteration, transport paths as well as transport processes of the organic matter. Moreover, the sediment trap record will allow to quantify the carbon flux to the deep Eastern Mediterranean.

## Methods

### Sediment Trap

During the M51/2 cruise in October/November 2001 into the Eastern Mediterranean a conical sediment trap mooring was deployed off Crete (34°26.50'N, 26°11.40'E; see Fig. 3) in order to record an semi-annual cycle of the vertical particle flux and its seasonality. The system consisted of two eight-year old PARFLUX MARK 7G-21 and one newly built PARFLUX MARK 78G-21 sediment traps and was deployed at a water depth of 3600 m. The mooring was designed to collect settling particles in water depths of 550 m, 1530 m and 2560 m. The cups were initially filled with filtered sea water fixed with 35 g NaCl and 3.3 g HgCl<sub>2</sub> per litre in order to avoid organic matter decomposition during deployment.

Tab. 3: Recovery scheme for sediment trap MID-2

Cup No.	Start	End	Period	Status
1	05.11.01	12.11.01	7 days	ok
2	12.11.01	19.11.01	7 days	ok
3	19.11.01	26.11.01	7 days	ok
4	26.11.01	03.12.01	7 days	lost
5	03.12.01	10.12.01	7 days	ok
6	10.12.01	17.12.01	7 days	lost
7	17.12.01	24.12.01	7 days	ok
8	24.12.01	31.12.01	7 days	ok
9	31.12.01	07.01.02	7 days	lost
10	07.01.02	14.01.02	7 days	ok
11	14.01.02	21.01.02	7 days	ok
12	21.01.02	28.01.02	7 days	ok
13	28.01.02	04.02.02	7 days	ok
14	04.02.02	11.02.02	7 days	ok
15	11.02.02	18.02.02	7 days	lost
16	08.02.02	25.02.02	7 days	lost
17	25.02.02	04.03.02	7 days	lost
18	04.03.02	11.03.02	7 days	ok
19	11.03.02	18.03.02	7 days	ok
20	18.03.02	25.03.02	7 days	ok
21	25.03.02	01.04.02	7 days	ok

For sediment trap parameters refer to the M51/2 report (Meteor-Berichte, Universität Hamburg, Cruise No. 51, in preparation).

The sediment trap mooring was easily retrieved at the M51/2 station 529 site. Unfortunately, the uppermost and the middle sediment trap – the old MARK 7G-21 traps - turned out not to have rotated at all. Nevertheless, the lowermost new MARK 78G-21 trap had turned to bottle 21 and could be recovered on open hole. Regrettably, the lowermost trap had gotten entangled with the chains and ropes during recovery and 6 of the filtrane cups were lost. Data from the sediment trap timer board could be read and verified the system had turned correctly throughout the investigated time span (see Tab. 3).

The samples were filtered through polycarbonate (0.45  $\mu\text{m}$ ) filters and dried at 40 °C for 72 hours.

### **Suspended Particulate Matter**

Samples of suspended particulate matter were taken from surface water from two stations (one at and one close to the sediment trap site, see Fig. 3). They were filtered through polycarbonate (0.45  $\mu\text{m}$ ) and GF/F (0.7  $\mu\text{m}$ ) filters, respectively. All samples were dried at 40 °C for 72 hours.

### **Ongoing work**

The sediment trap samples as well as the suspended matter samples will be analyzed for opal, organic carbon and nitrogen, carbon and nitrogen isotopes as well as for amino acids. Fluxes for the settling particles will be calculated.

## 5.2 M53/1b

### 5.2.1 Chemical Oceanography

(C. Barrera, J. Betancort, L. Cardona, M. Villagarcia)

#### Objectives and scientific questions

The main area of study for the ICCM oceanography group is located north of the Canary Islands, mainly at 29°N latitude; it is a section that includes the ESTOC station where our group has undergone monthly sampling continuously from 1994. This zone is influenced by the North Atlantic subtropical gyre, which is one of the most significant sources of surface variability of the Atlantic Ocean. The recurrent sampling around the ESTOC environment will help to know what the station represents within the area.

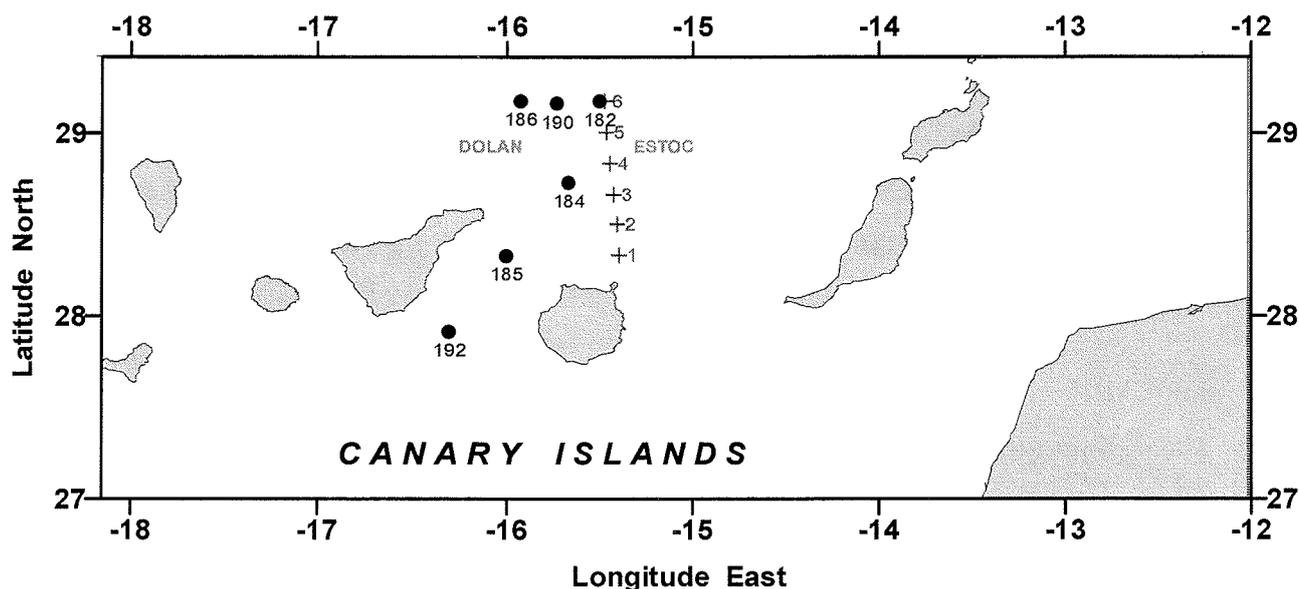


Fig. 4: Position of the CTD stations (dots) and XBT launches (crosses) made by ICCM along Poseidon M53/1b.

The setting of the ANIMATE mooring provides the opportunity to know the physico-chemical parameters of interest, not only monthly but in a daily basis. The smaller scale data sets will allow on one hand to know processes not found by the monthly visit to the station and, on the other hand to check the interannual variability by comparing it with the 8-years data we have from ESTOC. Further, this cruise has permitted to make some stations in the path between Tenerife and Gran Canaria Islands, to test the presence of intermediate waters when coming from the south between the Canary Islands.

The distribution of nutrients, oxygen, chlorophyll and gelbstoff together with the temperature and salinity profiles allow a reasonable approximation to some of the surface phenomena occurring in the area.

## Data

From Las Palmas harbour to the ESTOC station we made a transect of XBT (T7), 6 in total; this is a line customary to the monthly sampling at ESTOC; a NOAA buoy (ID 30314) was deployed at ESTOC after the sampling too. Six stations were made, 3 along longitude 29°N and 3 from this longitude towards the pass between Tenerife and Gran Canaria (Fig. 4). Samples were taken to the bottom (sta. 182, 186, 190 and 192) or to 3000 m (184 and 185). The closing depths chosen for all stations except ESTOC (23 depths in this case due to problems with the rosette, it is customary to have 24) were: 10, 25, 50, 75, 100, 125, 150, 200, 300, 400, 600, 800, 1000, 1100, 1200, 1300, 1500, 1800, 2000, 2500, 2800, 3000 m and bottom.

Tab. 4: List of stations and parameters measured at each station by ICCM. In the salinity column appears in brackets the number of salinity samples taken at the station

Station (Prof.)	Latitude	Longitude	Oxygen	Nut r.	Gelb.	Sal. (#)	Chl "a"
182 (ESTOC 04/02)	29°10.03'N	15°29.90'W	√	√	√	√ (23)	√
184	29°43.98'N	15°39.98'W	√	√	√	√ (2)	√
185	28°20.00'N	16°00.00'W	√	√	√	√ (2)	√
186 (DOLAN)	29°10.88'N	15°55.59'W	√	√	√	√ (2)	√
190	29°09.82'N	15°43.81'W	√	√	√	√ (2)	√
192	27°55.00'N	16°18.07'W	√	√	√	√ (2)	√

Oxygen, nutrients, gelbstoff and chlorophyll "a" was taken at every depth sampled, and salinity samples were taken at two selected depths (except ESTOC) to check for closing of the Niskin bottles (Tab. 4).

Tab. 5: List of stations where XBT were launched by ICCM

XBT #	Date	Latitude	Longitude
D1	12.04.2002	28°20'N	15°22'W
D2	12.04.2002	28°30'N	15°23'W
D3	12.04.2002	28°40'N	15°24'W
D4	12.04.2002	28°50'N	15°25'W
D5	12.04.2002	29°00'N	15°27'W
D6	12.04.2002	29°10'N	15°27'W

Tab. 5 shows the positions of the XBT launches made between Las Palmas and ESTOC.

## **Methods**

**Sampling** Samples were collected immediately after the bottles were on board from each depth. The sampling sequence was as follows:

1.) Oxygen: was taken in glass bottles of about 125 ml of volume which were previously cleaned and washed with HCl acid and was fixed at once; then it was kept for at least six hours according to WOCE regulations and finally it was analysed at the laboratory on board the ship.

2.) Nutrients: were taken in polypropylene bottles which were previously cleaned and washed with HCl acid and were completely dry. Samples were immediately frozen at -20°C, analysing them as soon as possible after arrival at the laboratory. Freezing the samples is a common practice; it does not or only in a non-significant way affects the nitrate + nitrite and the phosphate values (by a slight decrease) and is not noticeable in the silicate values (Kremling and Wenck, 1986; McDonald and McLunghlin, 1982).

3.) Gelbstoff: water was taken in dark glass bottles which were previously cleaned and washed with HCl acid. The samples were analysed within 3 hours of having taken them by spectrofluorometry.

4.) Salinity: samples were taken in dark glass bottles which were previously cleaned and washed with HCl acid. Then, they were kept in boxes to protect them from light till analysis on land.

5.) Chlorophyll: samples of one liter of water were taken. The chlorophyll samples were filtered immediately and the filters were frozen subsequently at -20 °C. Their analyses take place at the ICCM laboratory on land.

All samples were taken using the procedures established in the WOCE Operations Manual, WHP Office Report WHPO 91-1/WOCE Report No.68/91.

## **Analysis**

Dissolved Oxygen: The samples were analysed using the method described in the WOCE Operations Manual, WHP Office Report No. 68/91; the final titration point was detected using a Metrohm 665 Dosimat Oxygen Auto-Titrator Analyser.

Nutrients: The nutrients determination was performed with a segmented continuous-flow autoanalyser, a Skalar® San Plus System (ICCM).

Nitrate+Nitrite: The automated procedure for the determination of nitrate and nitrite is based on the cadmium reduction method; the sample is passed through a column containing granulated copper-cadmium to reduce the nitrate to nitrite (Wood et al.,1967), using ammonium chloride as pH controller and complexer of the cadmium cations formed (Strickland and Parsons, 1972). The optimal column preparation conditions are described by several authors (Nydahl, 1976; Garside, 1993).

Phosphate: Orthophosphate concentration is understood as the concentration of reactive phosphate (Riley and Skirpow, 1975) and according to Koroleff (1983a) is a synonym of “dissolved inorganic phosphate”. The automated procedure for the determination of phosphate is based on the following reaction: ammonium molybdate and potassium antimony tartrate react in an acidic medium with diluted solution of phosphate to form an antimony-phosphomolybdate complex. This complex is reduced to an intensely blue-coloured complex, ascorbic acid. The complex is measured at 880nm. The basic methodology for this anion determination is given by Murphy and Riley (1962); the used methodology is the one adapted by Strickland and Parsons (1972).

Silicate: The determination of the soluble silicon compounds in natural waters is based on the formation of the yellow coloured silicomolybdic acid; the sample is acidified and mixed with an ammonium molybdate solution forming molybdosilicic acid. This acid is reduced with ascorbic acid to a blue dye, which is measured at 810 nm. Oxalic acid is added to avoid phosphate interference. The used method is described in Koroleff (1983b).

Yellow Substance: The values were obtained using the methodology described by Determann et al. (1994, 1996). The samples were measured with a spectrofluorometer SHIMADZU RF-1501 at an excitation wavelength of 341 nm and the intensities taken at emission wavelength between 350 and 500 nm. Gelbstoff fluorescence is derived from the emission spectra and obtained in Raman units.

Phytoplankton pigments: Pigments were measured using fluorimetric analysis, following the methodology described by Welschmeyer (1994). The determination was achieved using a fluorometer TURNER 10-AU-000.

**Salinity:** Samples were measured with a salinometer, model Autosal 8400a, whose measurement range was between 0.005-42 (psu), with an accuracy of  $\pm 0.003$ , according to the manufacturer. It was calibrated following the manufacturer's information and standardizing it with IAPSO Standard Seawater. Salinity values were calculated as practical salinity according to Unesco (1978, 1984).

### **Preliminary Results**

The observation of the diagram T/S from the six stations sampled with CTD shows the well-defined presence of the two nearly-straight segments, which represent the North Atlantic Central Water (NACW) and the North Atlantic Deep Water (NADW) masses respectively (Fig. 5).

Latitudinal stations show great variability in the fringe of intermediate depths, reaching high differences up to 0.5 of salinity for the 8 °C isopycna. This great variability in such short distance is a consequence of the complex distribution of Mediterranean Water (MW) and Antarctic Intermediate Water (AAIW) in this area, being characteristic the south and east components for the AAIW and the north and west ones for the MW (Llinás et al., 2002).

The line with the three stations distributed longitudinally do not show at that sampling time the presence of AAIW (sta. #192) and there is a slight presence of MW in the stations located towards the north (sta. # 184 and 185). From this perspective it seems interesting to try to fix in the future how both water masses transit in the pathway between Gran Canaria and Tenerife Islands to better illustrate the representativity of the ESTOC station within this area.

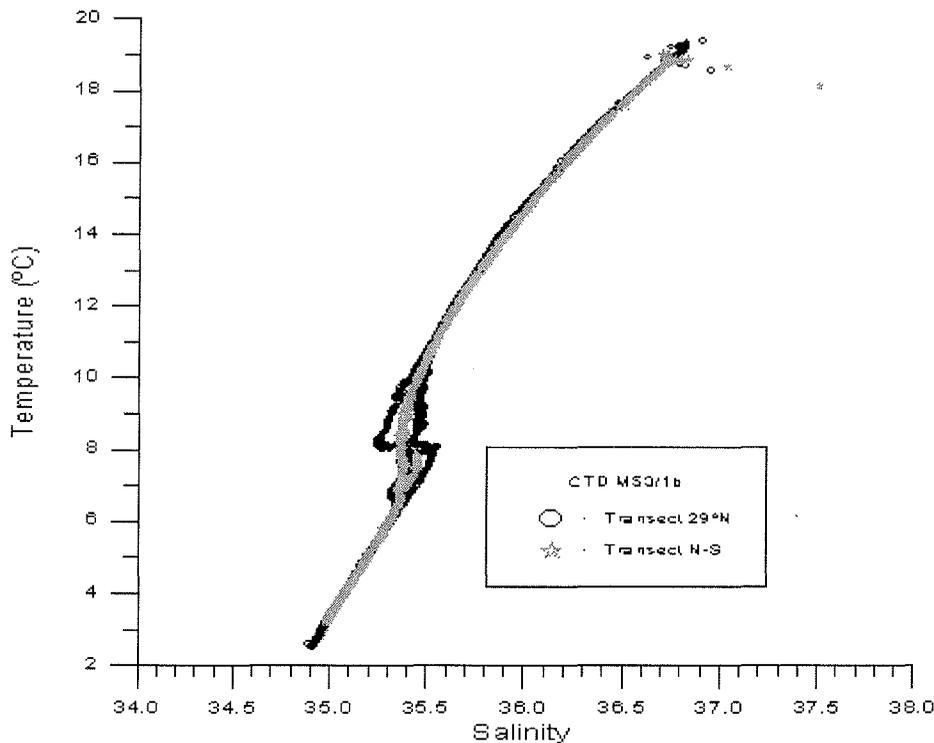


Fig. 5: T/S of the two transects made along the cruise in the ESTOC area

### 5.2.2 Carbon dioxide in sea-water

(L. Babero-Munoz)

In response to increased interest in global climate change and greenhouse warming, measurements of the marine carbon system (i.e. total  $\text{CO}_2$ ,  $\text{TCO}_2$ , titration total alkalinity TA, pH and  $\text{pCO}_2$ ) have been included in several global research programs such as the World Ocean Circulation Experiments (WOCE) and the Joint Global Ocean Flux Study (JGOFS). These programs include time series stations primarily designed to examine temporal variability and the mechanism controlling this variability. The Canary Islands Time series (ESTOC) is visited each month and the surrounding area approximately twice a year. Time series station data provide excellent opportunities to study the temporal variability of the carbon system at a single location over several years, while cruises around the ESTOC station will provide information about spatial variability of the carbon species in the area.

The main objective on this cruise was to study the spatio-temporal variability of the parameters which define the carbonate system in the water column. The parameters to be determined are pH and total alkalinity. Underway continuous  $\text{pCO}_2$  were carried out in the

ESTOC location and vicinity, together with air pCO<sub>2</sub> value (each hour). In addition, water samples for pH and titration alkalinity collected from surface to bottom were analysed on board within four hour of collection with a two-thermostated (25 °C ± 0.1) 200 ml titration cells with ROSS glass pH electrode and Orion double junction Ag, AgCl reference electrodes. The reliability of the titration systems was tested by determining the TA of Certified Reference Material for Oceanic CO<sub>2</sub> measurements (batch 35) provided by Dr. Dickson, Scripps Institution of Oceanography, San Diego. The results of these measurements indicate that high-precision measurements of TA ( $\pm 1.2 \mu\text{mol kg}^{-1}$ ) can be obtained. Photometric pH was determined by a stopped-flow system designed by this group by using a m-cresol purple sea-water solution as dye for the pH determination following the DOE (1994) SOP 6 for the analysis of the carbonate system variables of oceanic sea-water samples. Reproducibility is better than 0.003 pH units.

### **5.2.3 Particle flux studies and deep-sea technology**

#### **5.2.3.1 Mooring work within the projects DOLAN, ESTOC and ANIMATE**

(M. Bergenthal, S. Klar, E. Kopsiske, U. Koy, G. Meinecke, A. Pinck, V. Ratmeyer, G. Ruhland, U. Rosiak)

A main goal during the M53/1b cruise was to establish the operational transmission of datasets at the DOLAN mooring site. In addition to that, mooring-, maintenance work and several tests of the technical devices should be done within the scope of the BMBF project DOLAN (“Operational Data transmission in the Ocean and lateral acoustic Network in the Deep-Sea”). The DOLAN station is located 20 nm west of ESTOC and comprises technology for the transmission of data by means of acoustics in the water column via satellite and internet. Closely linked to ESTOC and DOLAN is the EU project ANIMATE (“Atlantic Network of Interdisciplinary Moorings and Time series for Europe”). In the ANIMATE project, moorings will be deployed at key sites in the northern Atlantic (Porcupine Abyssal Plain, PAP; Central Irminger Sea, CIS and at ESTOC) in order to gain data of CO<sub>2</sub>, nutrients and fluorescence, which will be directly transmitted via satellite to the participating scientific institutes. A significant element in ANIMATE is the technology for the transmission of datasets from the deep-sea used in the DOLAN project. Furthermore, ESTOC is the reference site for the subtropical NE-Atlantic within the ANIMATE project.

In order to reduce the number of permanent mooring sites, it was planned to merge the ANIMATE sensors with the existing DOLAN and ESTOC moorings. For this reason, the MicroCat CTDs and the ADCP should be attached to the ESTOC mooring site. The ANIMATE fluorescence sensor and the Nutrient analyzer should be integrated into the mooring chain below the DOLAN data buoy. The main tasks during the M53-1b cruise were:

1. Deployment of a permanent open sea mooring SBU (“Surface Buoy Unit”) with surface buoy. Measuring of the anchor position of the SBU and integration of the ANIMATE sensors (fluorescence and nutrients)
2. Test of the satellite telemetry via OrbComm satellites. Retrieval of the GPS- and weather data. Programming and test of the interface between underwater- and satellite communication. Test of the underwater communication with the buoy as the master unit.
3. Deployment of the MSU (“Multi Sensor Unit”) mooring, including the device platform MSD at 3000 m depth. Measuring of the anchor position of the MSU and its position in the water above the position of the MSD (“Multi Sensor Device”). Test of the entire data path with SBU and MSU.
4. Recovery of the ESTOC mooring and redeployment of the ESTOC/ANIMATE mooring.

#### Deployment of the SBU

##### *DOLAN data buoy*

The DOLAN data buoy is part of national funded program DOLAN (Data transmission in the Ocean and lateral acoustic Network - BMBF, Germany). The buoy is build of polyurethan foam and has a diameter of 2.4 m by a weight of 1.5 tons (Fig. 6). It is equipped with solar panels in order to provide power for flasher, electronics and to re-charge the build in batteries, which are stored in one of the 4 watertight electronic pockets. In one pocket the complete OrbComm telemetry is installed together with the controlling PC and the acoustic underwater modem. In addition, a short distance radio link (SATEL) is also installed in the buoy in order to communicate with the buoy from the ship nearby. Spare room for additional electronics is still available. A simple and uncalibrated weather station (temperature, speed, direction) is installed on the buoy as scientific sensor. For tracking purposes a complete

independent and battery powered (D-cells) OrbComm telemetry unit was attached to the outer central part of the buoy.

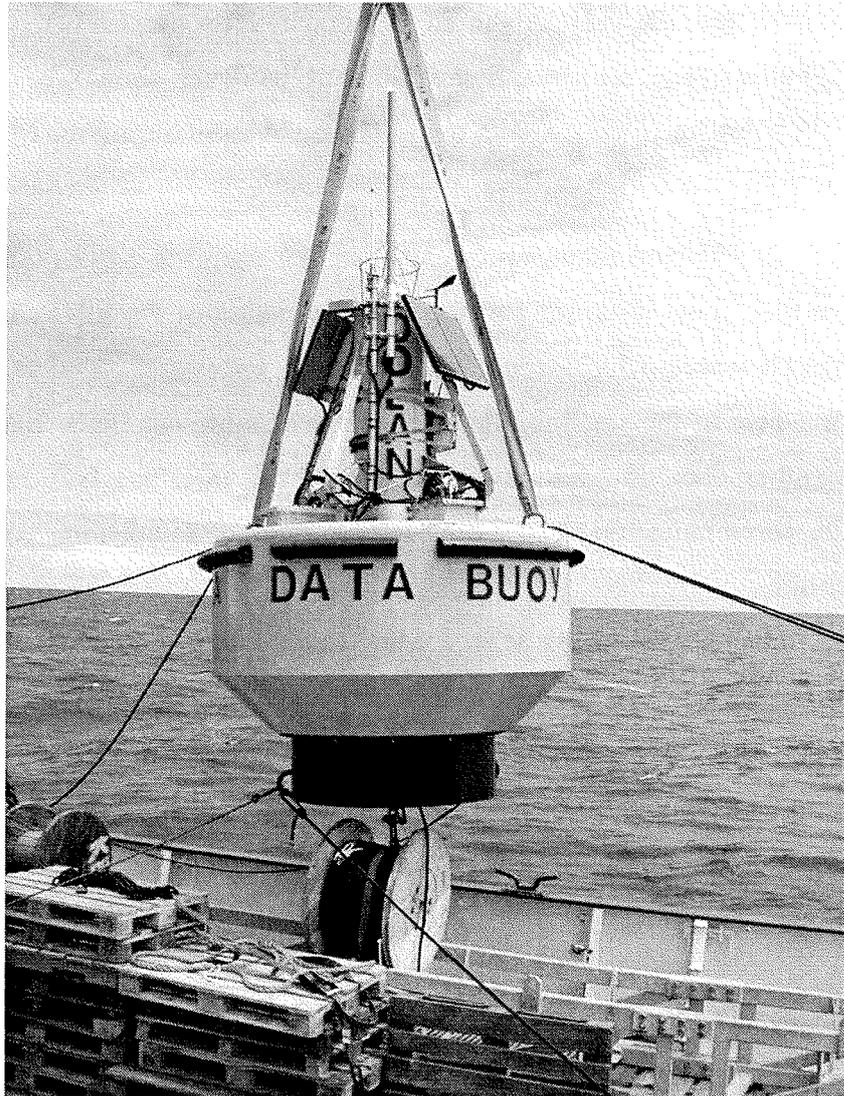


Fig. 6: Dolan surface buoy SBU prior to deployment

#### *Tests prior to deployment*

The OrbComm telemetry system consists of two basic hardware components, a control PC to interface with the attached sensors and the PANASONIC KX-G7100/7101 OrbComm communicator. The control PC *BC10* (digital controller by OHB-Teledata, Bremen, Germany) offers five RS232-Ports, four of these are used as sensor-interface. One RS232 port is used for communication with the PANASONIC and therefore OrbComm. The digital controller is equipped with hardware watchdog, RTC, alarm functions, powersave-mode (to zero microampere external power) and the ability of remote BIOS download. It runs with a power supply from 12 to 24 Volts DC under temperature conditions from -40 °C to +80 °C.

The PANASONIC transceiver is a commercial product and seems to be very robust and easy to use. It runs with power supply from 12 to 24 V and offers 2 digital IO- and 2 analog channels. The serial RS 232 port can be used as the standard interface for scientific application but also for programming of the PANASONIC itself via a terminal program like hyper terminal. The internal software is subdivided into 4 command sets - transmission, tracking, setup and special commands. There is no direct need in general to run the PANASONIC in combination with a control PC - here it is the case due to the demand for additional serial COM ports.

The PANASONIC OrbComm communicator is available in two specification - with (KX-G7101) and without build in GPS receiver (KX-G7100). In the DOLAN/ANIMATE project both types of communicator are still in use - with GPS receiver on the separate tracking unit on the buoy and without GPS as central communication unit on the buoy.

#### *Integration and Test*

In the starting phase of ANIMATE the OrbComm telemetry solely was used at the ESTOC site - more precisely on the DOLAN data buoy. Before installation of the telemetry hardware an intense lab testing has been done in the institute at GeoB Bremen and onboard the RV METEOR. Due to the fact of satellite transmission it's no matter whether the buoys electronic are located in Bremen or at the Canaries. After successful testing the hardware was prepared for integration into the buoy. The central buoy telemetry - internally integrated with the controlling PC into a separate casing - was attached to a steal frame, together with the acoustic underwater modem. This steal frame fits in one of the electronic pockets of the data buoy. Afterwards, the battery pocket and the electronic pocket were completely wired through internal tube-like connections between the 4 pockets. The additional connections from outside like antennas, transducer cable, solar panels and flasher were plugged into the bulkhead connectors located in the pocket lids. Finally, the buoy was completely prepared for deployment.

#### *Deployment of the SBU*

The deployment of the SBU-mooring needs to be operated in two steps. The mooring itself consists of very robust 20 mm polypropylene rope with 3500 m of total length. As the uppermost part, two pieces of 12 mm steel wire (450 m and 50 m) were attached to the mooring line. In order to position the ANIMATE nutrient analyzer at the target depth of 80 m below sea surface, the sensor was clamped between the two steel wires (Fig. 7).

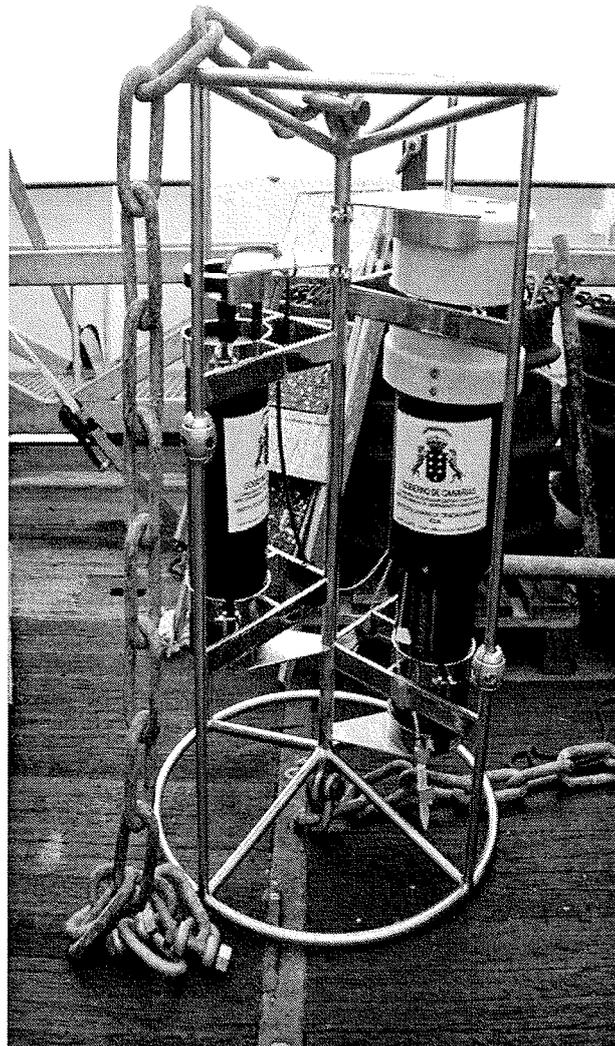
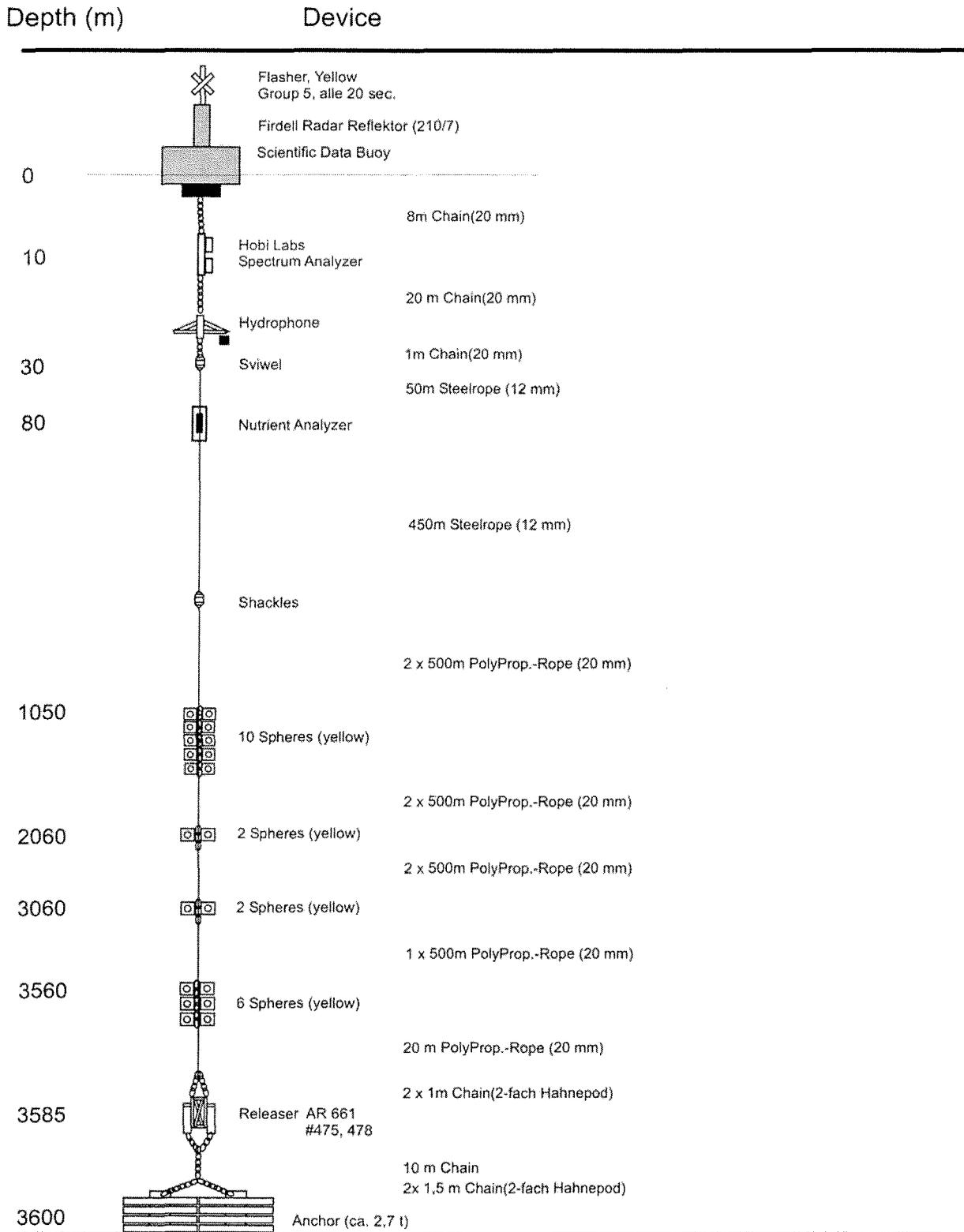


Fig. 7: Nutrient analyzer prior to deployment

The end of the steel wire was prepared with a 5 tons swivel and then connected to 20 m of 22 mm chain. The acoustic transducer and the transducer cable were already integrated in the chain. At the end of the chain 25 glass spheres (dummy buoyancy) were connected. The dummy buoyancy was used in order to prevent the surface buoy of damage during deployment of the complete mooring. Afterwards, the mooring was deployed with a 2.7 tons anchor weight without any problems.

In the second step, the surface buoy itself was prepared onboard the RV METEOR. The dummy buoyancy of the mooring line was recovered and the chain was pulled onboard in order to attach the ANIMATE fluorescence sensor in the target depth of 10 m below sea surface. Afterwards the buoy was clamped to the mooring chain and the transducer cable was connected to the buoys electronic. Finally, the buoy was lowered down to the sea surface and the SBU was completely deployed (Fig. 8).



Mooring: DOLAN SBU (Surface Buoy)

Expedition: M53/1b

Area: Canary Islands, 20nm östlich v. ESTOC Station

Water depth: ca. 3634 m

Deployment date: 15.04.2002

Lat 29°11.15 N  
Long 015°55.35 W



Fig. 8: Mooring design of complete SBU-mooring

### Deployment of the MSD

Several acoustic underwater clients are also part of the DOLAN project. During this RV METEOR cruise the Multi Sensor Device should be deployed as one of these acoustic clients 500 m above the seafloor (Fig. 9). The Multi Sensor Device (MSD) consists of 3 scientific sensors: CTD, Camera and sediment trap (all with its own microcontroller inside). The FSI-CTD is a combination of CTD, acoustic current meter and backscatter sensor. The camera system is a combination of a digital video-camcorder and an image analysis PC. The sediment trap is a special development for the DOMEST/DOLAN project with enhanced sample capacity. These sensors are connected via their serial RS 232 interface to the central BC2 controller, which itself is connected to the acoustic underwater modem and the acoustic transducer. All sensors are integrated into a combination of two coupled sediment trap frames (Fig. 9).

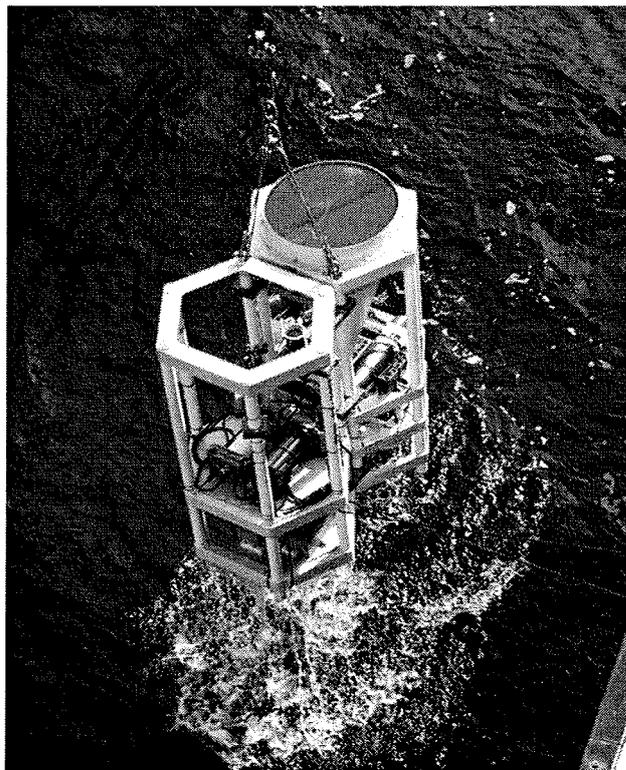


Fig. 9: Multi Sensor Device during deployment

In order to position the MSD mooring into the acoustic beam path of the surface buoys transducer, it was necessary to place the MSD mooring within 0.5 miles distance to the surface buoys deployment position. For this reason, the MSD mooring was placed under weight at the target position (Fig. 10).

Tiefe (m)	Gerät / Seil	(UTC)		Bemerk.
		ins	aus dem	
		Wasser		
				
	20 m Meteorleine (20 mm)			
	Multi Sensor Device			
	500 m Meteorleine (20 mm)			
	4 Kugeln			
	20 m Meteorleine (20 mm)			
	Auslöser AR 661 # 477 # 524			
	10m Kette			
3600	3 Eisenbahnräder			
Verankerung: DOLAN_MSD		Position geplant: 29°10.9'N; 15°55.6'W		

Auslegedatum: 15.04.2002

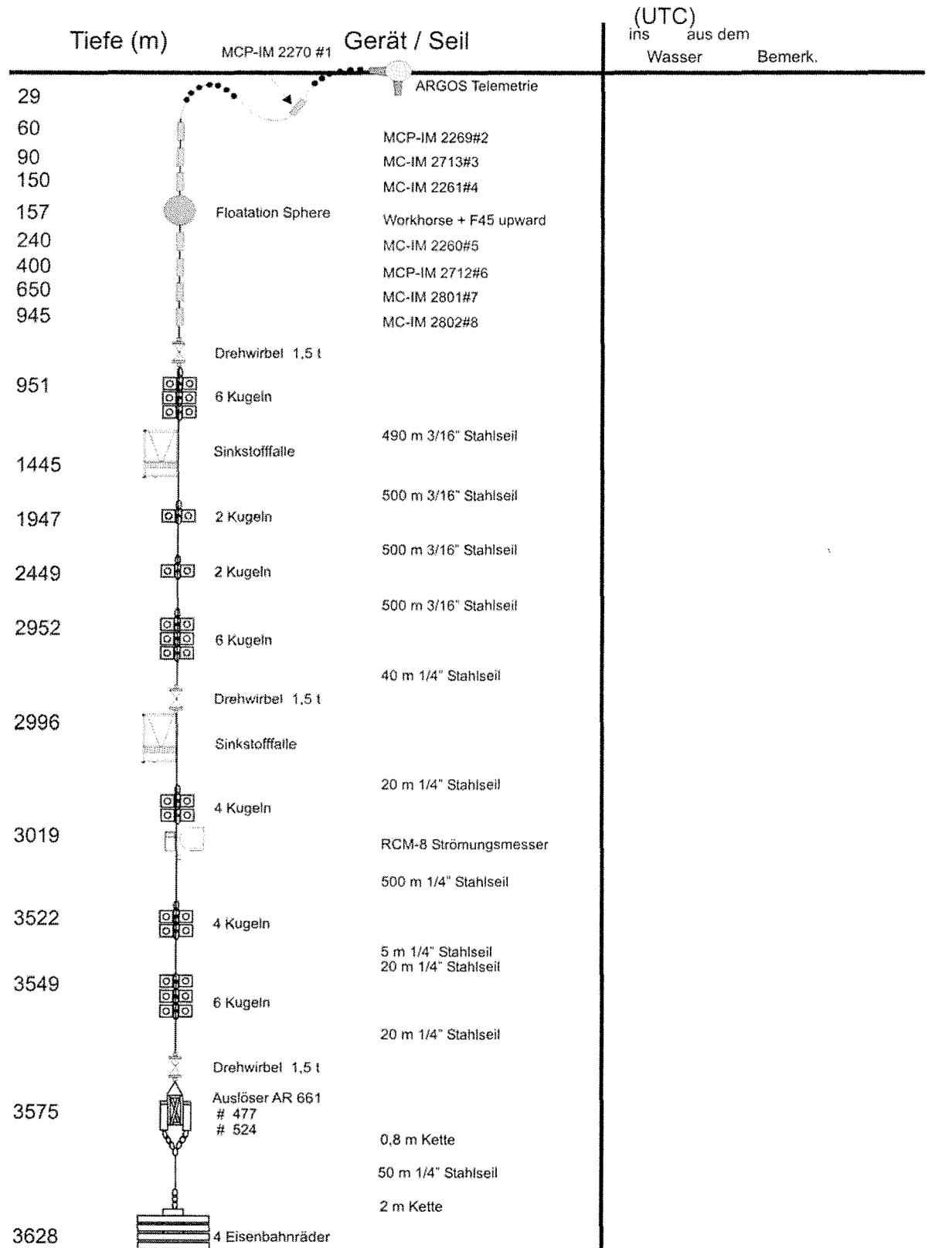
 UNIVERSITÄT BREMEN  
FACHBEREICH GEOWISSENSCHAFTEN

Auslösecodes # 477	I/R	-	5847
	Rel	-	5848
# 524	I/R	-	8A67
	Rel	-	5859

Fig. 10: MSD mooring design

### Deployment of the ESTOC/ANIMATE Mooring

Parallel to the deployment of the nutrient analyzer and the fluorescence sensor inside the SBU mooring it was necessary to implement inductive Microcat CTD and the ARGOS telemetry at the ESTOC site. For this reason the long term ESTOC mooring was redesigned with steel cables instead of polypropylene ropes and the uppermost part of the mooring line was equipped with several. Microcat CTD, an upward looking RDI ADCP and the ARGOS telemetry capsule (Figs. 11, 12, 13). In order to get into contact with the ARGOS satellite it was necessary that the overall mooring length was greater than water depth to ensure the data capsule was at sea surface. All sensors do have the capability to store their data inside but also to transmit their data via the inductive link and the steel cables to the ARGOS data capsule (Fig. 13). As basic part of the ESTOC mooring two sediment traps were also attached to the mooring line. After preparation on deck it was no problem to deploy the complex mooring without any problems.



Verankerung: CI15/ANIMATE

Auslegedatum: 15.04.2002

Wassertiefe: 3628 m

Position geplant: 29°10,75'N; 015°25,67'W



Auslösecodes # 475	I/R	-	5843
	Rel	-	5844
# 478	I/R	-	5850
	Rel	-	5859

Fig. 11: ESTOC/ANIMATE mooring design

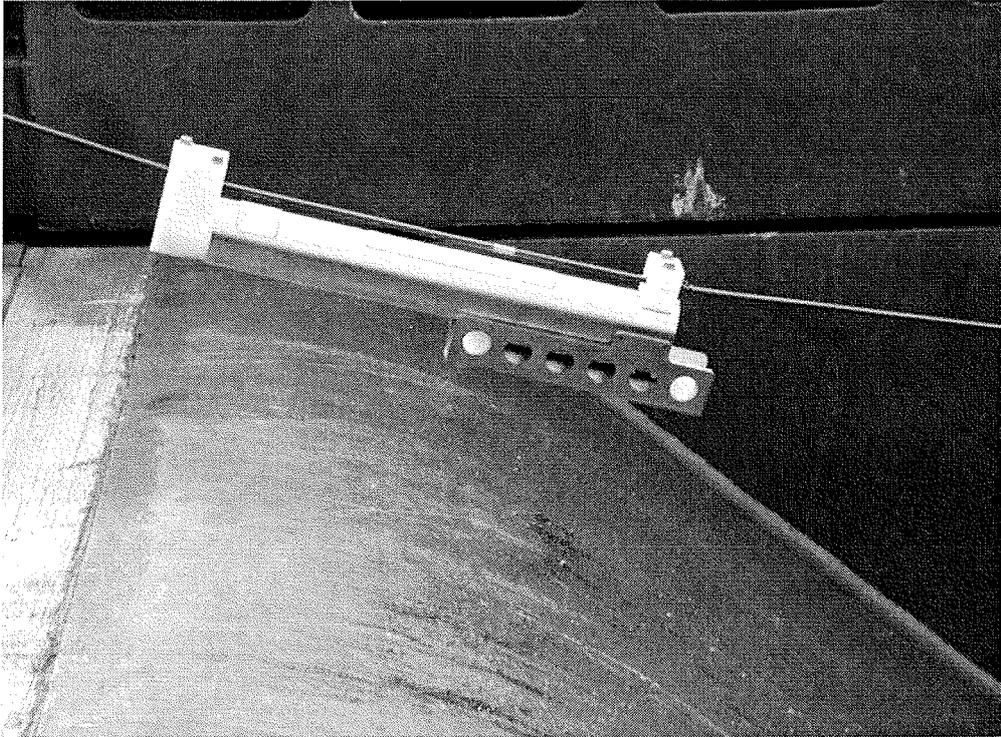


Fig. 12: Microcat CTD connected to the mooring line

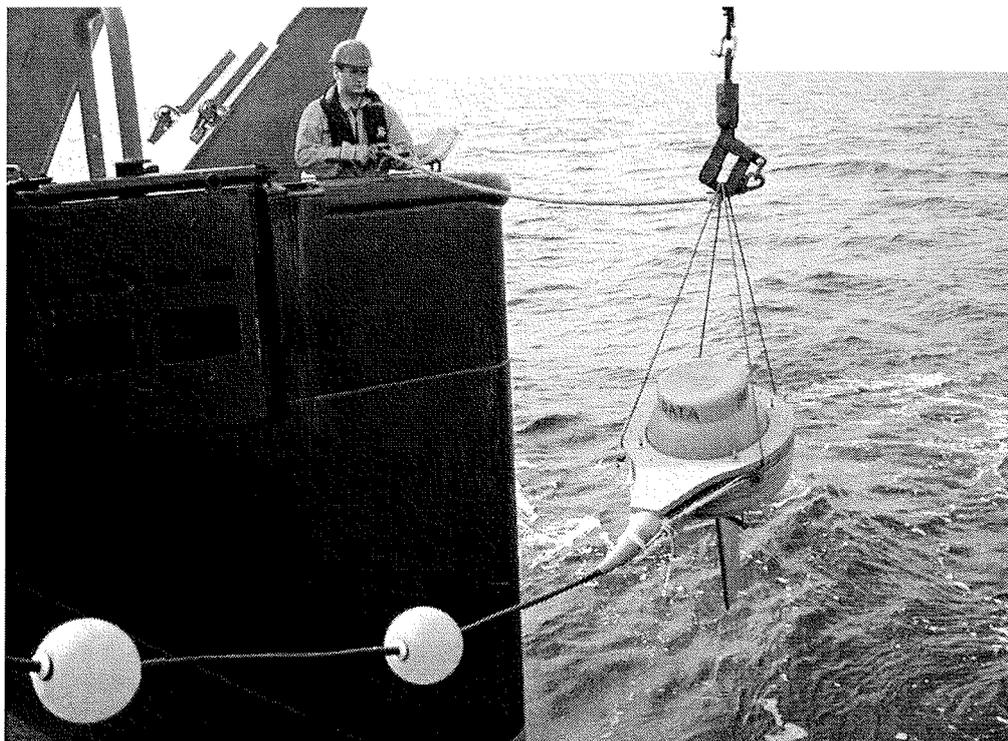


Fig. 13: ARGOS data capsule during deployment

### **5.2.3.2 ROV Operations**

(M. Bergenthal, S. Klar, G. Meinecke, N. Nowald, V. Ratmeyer, G. Ruhland, W. Schmidt)

The METEOR cruise M53-1b and M53-1c were the first open ocean tests for the new Cherokee ROV. In addition to the scientific tasks the ROV should perform the dives were undertaken in order to proof the reliability of the system itself and to train the ROV crew to operate the complete system under field trip conditions. A brief technical overview will be given in the following section. For explanation the complete system is separated into two logical parts, the topside equipment (all components used on the ship) and downside equipment (underwater equipment, the ROV itself).

#### **Topside**

The topside equipment consists of three basic parts, the power distribution unit (PDU), the surface control unit (SCU) and the spooling winch (SW).

#### PDU

The PDU is a galvanic decoupled power transformer which can use input voltages from 380 V to 440 V, three phases. The output voltages of the PDU are 440 V AC and 220 V AC, both necessary to run the ROV. The complete power supply is in a range of 10 to 12 kVA. Due to peak current loads of 30 to 40 A it is necessary to run the PDU on a secure and stable power outlet otherwise the PDU will collapse during ROV diving missions.

#### SCU

The SCU is the central controlling device for the ROV, installed in a 19" flight case rack. It consists of the central controlling PC, operation console, two 9" Panasonic colour screens, one PC with TFT display for the Sonar system, 1 Panasonic SVHS video recorder and an internal video overlay system (Fig. 14). The power supply from the PDU is interconnected with the ROV tether in order to provide the 440 V for the thrusters and the 220 V for the ROV electronics (switched separately). Both voltages are monitored in the SCU and in conjunction with an earth fault detection system one have the ability to perform emergency stops, if necessary. In addition to the power supply, 4 twisted pair copper lines and 4 mono fibres are interconnected from the SCU to the ROV tether. The downside installed sensors like vehicle compass, pressure sensor, altimeter data and also sonar data were transmitted via the copper lines to one of the screens as part of the video overlay system.

These data are permanently visible ones the ROV is powered up and the sonar is switched on. The optic fibres of the tether are used to transmit up to 4 separate Video channels and also four RS 232 (full duplex) and two RS 485 (half duplex) signals between SCU and the ROV. All vehicle functions can be controlled via the operation console. In addition to the thrusters controls (forward, backward; lateral left, lateral right; axial left, axial right; up, down) one can limit the thrusters power consumption, dim the lights, control the pan and tilt unit, run the camera focus and zoom and control auto heading and auto depth. The console itself can be connected to the SCU either directly or via a 30 m remote cable, necessary during deploy and recovery operation of the ROV. If necessary for operations, the ROV manipulator can be controlled by a separate console attached to the main console.

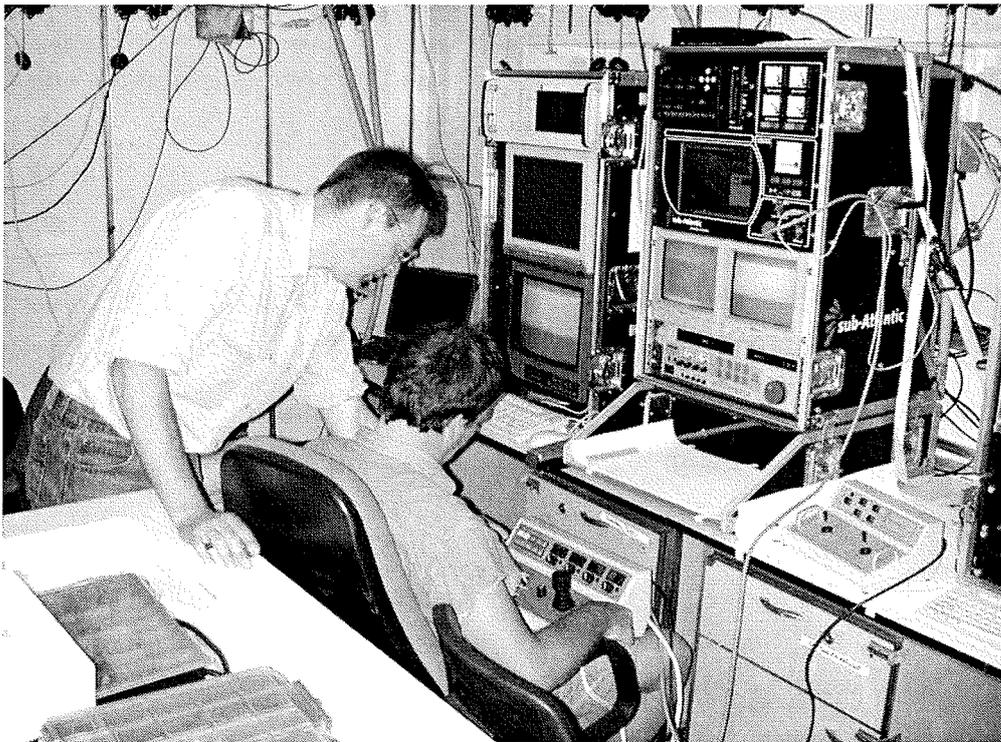


Fig. 14: Surface control unit (SCU, middle) with the additional pilot rack (PR, left) installed onboard the RV METEOR

Beside this SCU rack, two additional 19" racks (pilot rack (PR), stereo cam rack (SR)) are connected to the SCU in order to provide better information for the pilot and for the scientific user of the ROV system. The PR consists of one PC with 15" TFT display with dual head VGA adapter and an attached overlay generator in order to pick up actual ship born data like ships time, ships heading, water depths, GPS data out of the NMEA data stream provided by RV METEOR. These data were merged with the SCU overlay data like ROV heading on a separate 12" Sony Monitor, also installed in the PR rack. Now, the ROV pilot has the

opportunity to see ships heading in relation to ROV heading on one screen (necessary to keep the ROV on the right side of the ship during deploy and recovery).

The SR rack basically consists of one PC with 18” TFT display, frame grabber card and attached overlay generator and has to perform two basic tasks. On one hand, the video signal transmitted in this rack is stored on the Sony DV recorder and can be picked up as a screen shot by the PC frame grabber card (still shots stored as bmp-file on the hard disc). On the other hand, this PC is the control unit for the attached stereo head mounted display (HMD) and the software utility to run the fast proportional stereo cam pan and tilt unit via a joystick interface. One line of this stereo camera system can be transferred to a separately attached 14” Panasonic monitor in order to provide additional video data to the scientific user.

All original video sources (1 pilot cam, 2 pencil cams, 1 spare) and the overlay sources (SCU, Pilot Rack, Stereo Rack) are interconnected via an 8 port Video Cross over Matrix to the video targets (12” Monitor, 14” Monitor, 2 x 9” Monitor, SVHS-Recorder and DV-Recorder, 1 spare). Nearly all combinations of distinct video signals on specific screens or recorders are possible.

## SW

The ROV winch is designed as a simple spooling winch, built of stainless steel with a complete weight of 1.7 tons (winch and tether). It is electric driven by a 440 V AC Motor, controlled by a console box mounted on the winch frame. The winch carries 1000 m Kevlar-reinforced fibre-optical cable (9 copper lines power 440 V, 220 V, 2 times Neutral, 4 twisted pair lines and 4 mono fibres), which is designed as a buoyancy adjusted tether and not as an armoured Umbilical (Fig. 15). The ROV itself can't be lifted with the tether. In the actual configuration a *electric* slip ring (48 connectors) is attached to the winch, means all electric cables pass through the winch axis and are active throughout all operations of the winch. Unfortunately, the fibres need to be connected/disconnected while the winch need to be spooled, means no video data are available from the ROV throughout these operations. The outlet from the slip ring and the 4 optical fibres are interconnected via 30 m of deck cable with the SCU.

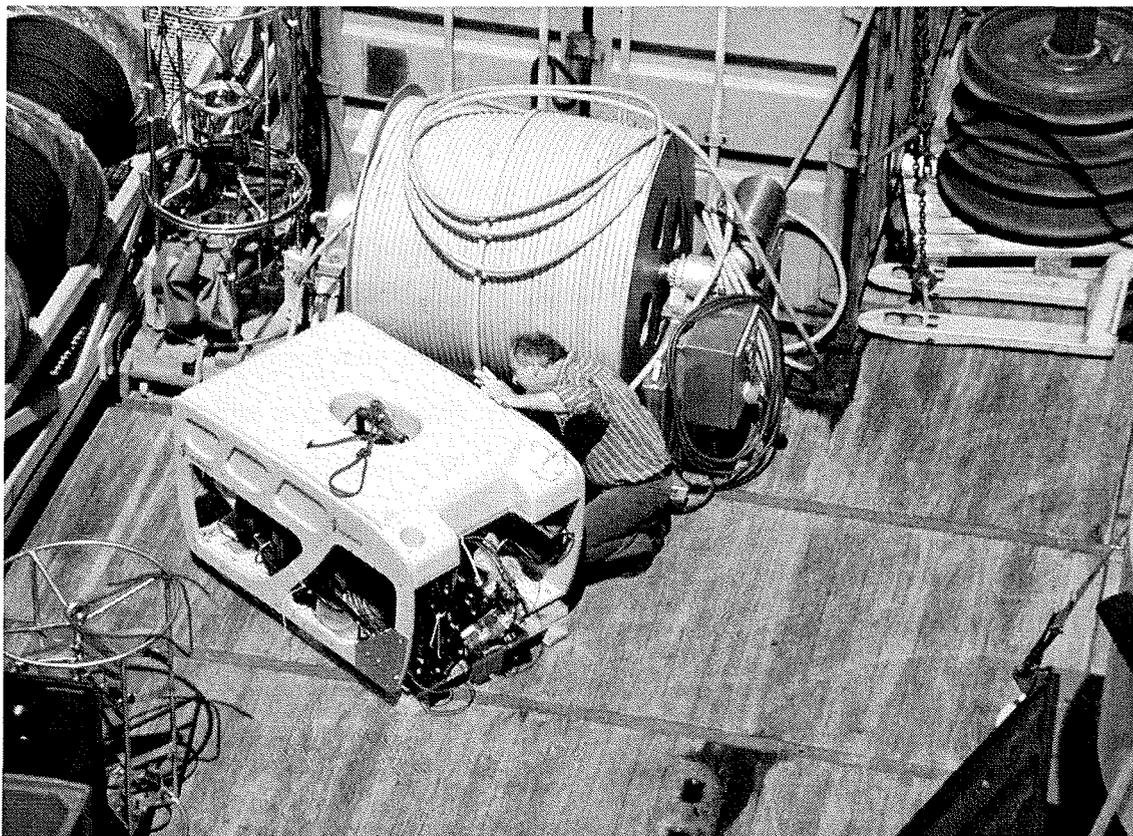


Fig. 15: Spooling winch (SW) with 1000 m of yellow fibre-optic ROV tether and the Cherokee ROV onboard the RV METEOR

### **Downside**

On this cruise the downside equipment consist only of the ROV itself, because no scientific payload needs to be installed of the ROV.

### Cherokee ROV

The Cherokee ROV in the actual configuration is designed as an open frame ROV with the dimensions of  $0.8 \times 0.9 \times 1.5$  m (H×W×L) and a weight of roughly 300 kg. The net payload capacity is in a range of 50 kg. During the actual cruise, the ROV was ballasted with 12 kg of lead. The frame is completely build of polypropylene, a very robust, slightly elastic plastic material which is slightly positive buoyant in seawater.

The buoyancy package is build of syntactic foam pressure tested to 2000 m water depth. All central electronic boards and casings are also adjusted to 2000 m water depth in order to have the chance to upgrade the system to greater depth (a power conversion system needs to be installed). In the actual configuration the system is limited to 1000 m operational depth. The ROV is equipped with 4 reliable AC thrusters, two single head thrusters for forward/backward and axial turns, 1 double head thruster for lateral and one double head thruster for up/down movements. All thrusters are pressure compensated. The central

electronics are placed in 2 pressure resistant aluminium housings. In the front of the ROV the pan and tilt unit (fixed speed) for the pilot camera is installed and the lights ( $3 \times 250$  W) also. A TRITECH TYHOON colour CCD camera with more than 470 TV-lines resolution ( $795 \times 596$  pixels) and 22 times zoom is attached to the pan and tilt as the mayor pilot cam. At the top of the buoyancy block, two additional pencil cameras can be attached to the proportional SCHILLING pan and tilt unit. The  $\varnothing$  17 mm wide angle pencil cameras are build of JAI colour CCD DSP controlled cameras with a resolution of 450 TV lines ( $752 \times 582$  pixels), installed in titanium housings. In addition to the video cameras, a TRITECH dual frequency scanning sonar head (325/675 Hz) is fitted into the buoyancy package, a TRITECH altimeter is located in the bottom part of the frame and the pressure sensor and TCM2 compass is located in one of the electronic pods. At the right side of the ROV a 5 function HYDROLEK manipulator (wrist up/down; arm up/down; arm left, right; jaw rotate lift/right; jaw open/close) is mounted to the frame. The manipulator is controlled by a 6 port valve pack (one spare function) installed at the back of the ROV. To complete the ROV, a small sample box build of stainless steal plates was fitted on the left side in front of the ROV.

### **Deploy and Recovery Operations**

The Cherokee ROV is capable to run as free flying ROV. The tether is buoyantly adjusted but nevertheless it is negative buoyant in seawater. One of the potential risks during deploys and recovery is the free floating tether and the problem of getting the tether into the propeller of the support vessel or to dive the ROV under the ship to the wrong side. Due to the lack of an ultra short base line navigation system, necessary to locate the ROVs position in relation to the ships positions, another simple way of ROV control was used. Before deployment, roughly 100 m of tether were placed on deck of the RV Meteor. Afterwards, the ROV was placed in the ocean at the sea surface and nearly 40 m of tether was spooled out guided by a  $\varnothing$  60 cm sheave, mounted in the A-frame on starboard side (Fig. 16). This sheave is necessary to protect the tether for bending below the minimum radius of the fibre-optic cable.

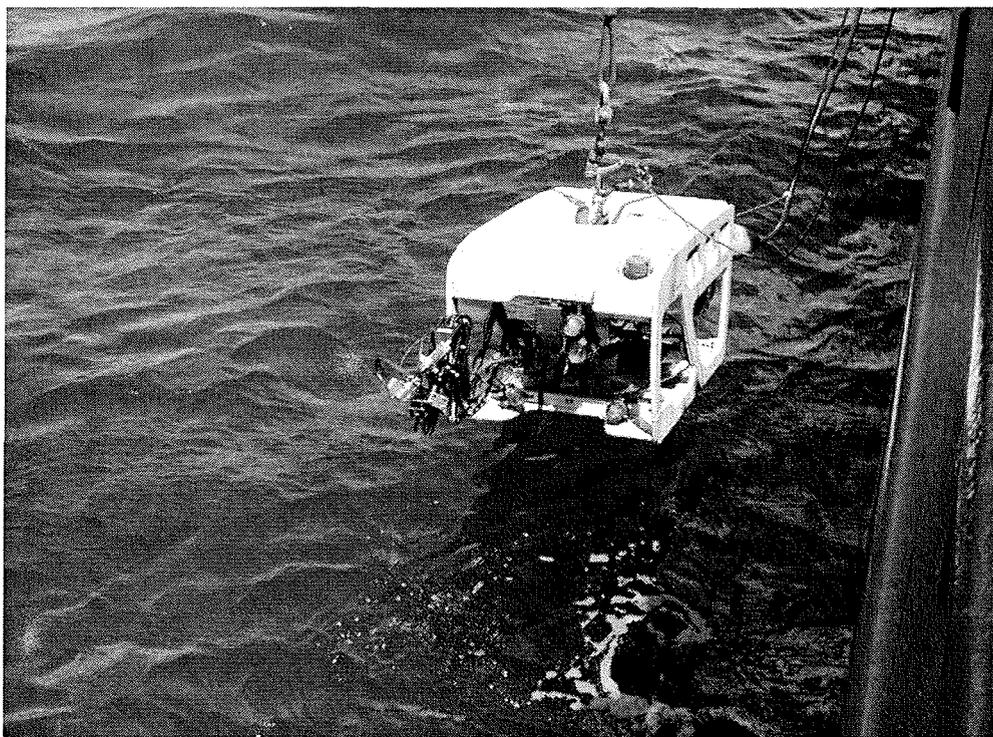


Fig. 16: Cherokee ROV during deployment operation

The 40 m of tether were buoyantly positive balanced due to 4 floatation balls (each with 2.5 kg uplift), clamped equally spaced to the tether. The ROV was driven away in right angle direction from the starboard side of the RV METEOR. Afterwards, a ships wire with a depressor weight was lowered down from the A-frame, 8 m below the ship and than the tether was clamped to the ships wire. Now, in parallel, the ROV and the ships wire both were lowered down farther on and the ROV starts it's descend to the seafloor. The degree of freedom for the ROV was limited to the length of the free floating tether, in this case roughly 40 m around the ships wire. During the ROV operations in the water column, the wire length was adjusted permanently to actual water depth or 10 m less, depending on drag and currents. For the recovery of the ROV, the pilot has to take care that the ROV ascend in right angle direction to the starboard side, roughly 40 m away from of the RV Meteor. At the sea surface, first the depressor weight was recovered while the ROV had to keep the right angle position at starboard side. Afterwards the 40 m of tether, the floatation balls and the ROV itself were recovered.

### **ROV dives**

During the METEOR cruise the Cherokee ROV was used for several test dives. The deploy and recovery operation worked very well and it was easy to bring the vehicle into and out of the water. During these dives a maximum water depth of only 80 m was reached by the

ROV. During all dives the very sensible balance between ships speed, currents and wire length of the depressor weight was clearly visible, due to the lack of a dynamic positioning system on RV METEOR. If one of these three factors was in the wrong setting, it was impossible to go deeper or to stay at a specific position. During the dives the camera signal was stored on the SVHS (with ROV overlay, GPS and ship born data) and in parallel on the DV tape (without any overlay). As standard the pilot camera was recorded.

Only the first test dive south off Gran Canaria was successfully. We were able to locate the ParCa camera system at the water depth of 60 m, which was used as the depressor weight for the ships wire. During this dive we checked the manoeuvrability of the ROV and terminated the test after 1 hour and recovered the vehicle successfully. During the next tests dives, several malfunctions occurred on the ROV. The strongest problems were related to the cable connections in general and specific to the fibre telemetry which obviously is very sensible to mounting and dismounting in the cable connectors at the SCU. Some times the serial communication lines malfunctioned without a specific syntax. After complete dismounting of the electronics, it seems to be clear that small amounts of smear films from the bulkhead connectors which settled down on the tip of the fibres weaken the optical signal more or less completely. In addition, obviously some fibres were interchanged somewhere in the complete tether system (SCU, winch, junction box, electronic pod on the ROV). Due to the lack of an optical fibre checking device, we were unable to locate the concrete problem. Finally we decided that the system was not in the condition to perform dives. We used the remaining time to remove additional components from the ROV and run basic test onboard the RV METEOR.

### 5.3 M53/1c

#### 5.3.1 Chemical Oceanography

(C. Barrera, A. Cianca, L. Cardona)

The area comprised between the Canary Islands and Cape Verde had seldom been studied by the ICCM oceanography group in the last years. This cruise was of great interest to try to elucidate the arrival of AAIW from the south towards the Canary Islands off the African coast. Several cruises to the north and south of the islands have shown the presence of AAIW and there are several theories concerning the arrival paths. The intermediate water masses in the Canary Islands environment show great variation of percentage of MW and AAIW at similar depths, depending on seasonal and geographical parameters.

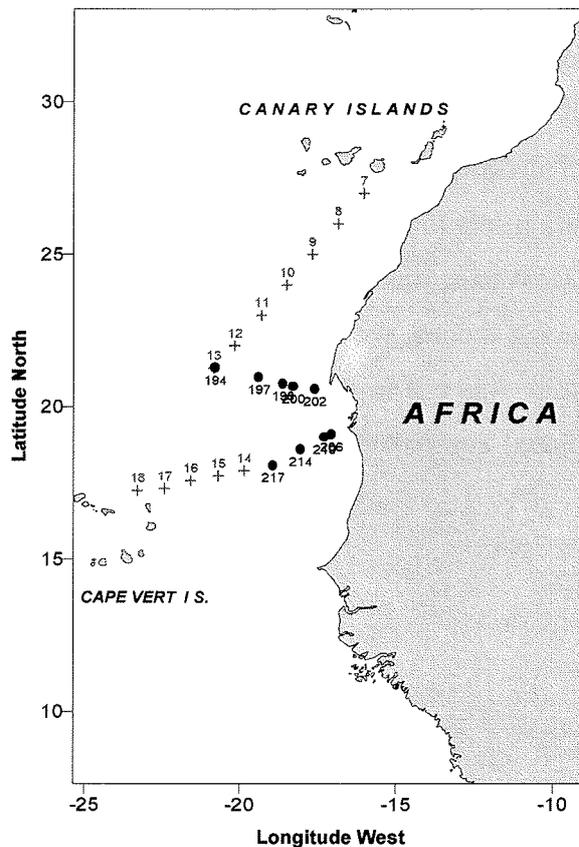


Fig. 17: Position of the CTD stations (dots) and XBT launches (crosses) made by ICCM along Poseidon M53/1c

The surface waters off the African coast at these latitudes are characterised by the upwelling phenomena (through chlorophyll and temperature satellite imagery) and episodes

of Saharan dust outbreaks. For this reason the possibility of measuring chlorophyll "in situ" on a daily basis provided an unvaluable tool to test the primary production models being developed for the Macarronesic (Azores, Madeira, Canaries and Cape Verde) area.

Due to the lack of time there was not possibility of doing rosette and CTD sampling at all the stations needed, therefore XBT's were deployed while the ship kept cruising, which made possible to have a better sampling scheme (Fig. 17). The distribution of nutrients, oxygen, chlorophyll and gelbstoff together with the temperature and salinity profiles allow a reasonable approximation to some of the surface phenomena occurring in the area.

### Data

Every 4 hours of each cruise day surface chlorophyll samples were taken from pumping water. Nine CTD stations were also made along the cruise track, all casts were taken to the bottom. Tab. 6 shows positions and parameters taken.

Tab 6: List of CTD stations and parameters measured by ICCM along M53/1c. The salinity column appears in brackets the number of salinity samples taken at the station

Station (Prof.)	Latitude	Longitude	Oxygen	Nut r.	Gelb.	Sal. (#)	Chl "a"
194	21°15.66'N	20°46.93'W	√	√	√	√ (4)	√
197	20°56.54'N	19°22.98'W	√	√	√	√ (3)	√
198	20°44.96'N	18°34.97'W	√	√	√	√ (3)	√
200	20°39.65'N	18°15.60'W	√	√	√	√ (3)	√
202	20°32.82'N	17°33.56'W	√	√	√	-	√
206	19°05.92'N	17°02.89'W	√	√	√	√ (2)	√
210	19°00.01'N	17°17.02'W	√	√	√	√ (2)	√
214	18°35.45'N	18°02.35'W	√	√	√	√ (2)	√
217	18°05.44'N	18°55.02'W	√	√	√	√ (2)	√

The closing depths chosen for all stations as a general trend were: 10, 25, 50, 75, 100, 125, 150, 200, 300, 400, 600, 800, 1000, 1100, 1200, 1300, 1500, 2000, 2500, 2800 and 3000 m and bottom. Oxygen, nutrients, gelbstoff and chlorophyll "a" was taken at every depth sampled, and salinity samples were taken at 2 or 3 selected depths (except ESTOC) to check for closing of the Niskin bottles (Tab. 6).

Tab. 7: List of XBT stations made by ICCM along M53/1c.

XBT #	Date	Latitude	Longitude
D7	20.04.2002	26°59.97'N	16°06.86'W
D8	20.04.2002	25°59.98'N	16°50.72'W
D9	21.04.2002	25°00.01'N	17°41.37'W
D10	21.04.2002	24°00.00'N	18°31.70'W
D11	21.04.2002	23°00.00'N	19°21.98'W
D12	21.04.2002	21°58.77'N	20°12.06'W
D13	22.04.2002	21°58.77'N	20°12.06'W
D14	01.05.2002	17°54.32'N	19°53.84'W
D15	02.05.2002	17°44.38'N	20°45.74'W
D16	02.05.2002	17°34.65'N	21°36.79'W
D17	02.05.2002	17°34.41'N	21°38.07'W
D18	02.05.2002	17°15.05'N	23°19.57'W

From Las Palmas harbour to Cape Verde (in transit) two transects of XBT (T7) of 7 and 5 probes respectively were also performed at the beginning and end of the cruise (see Tab. 7).

## Preliminary Results

The first XBT section clearly shows the north- south latitudinal gradient in the surface waters, ranging from values of 19 °C in the Canary Islands waters to values of 21 °C at Cape Blanc latitude (Fig. 18a).

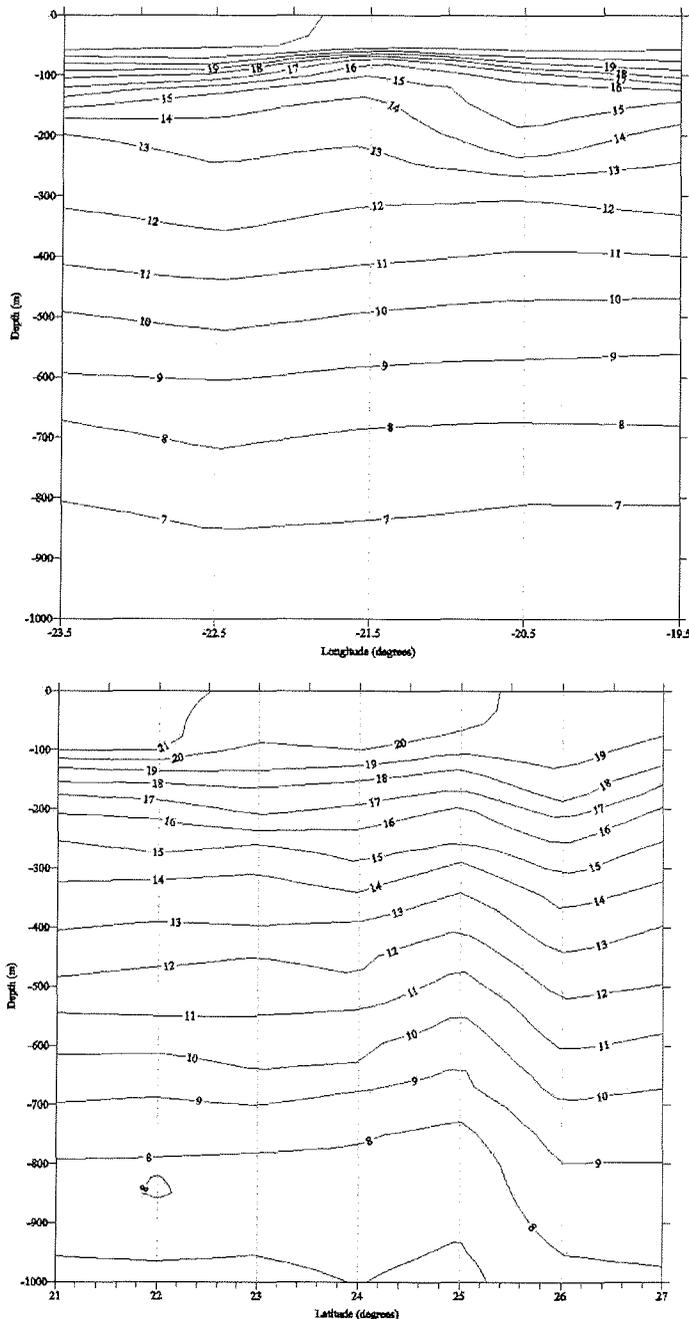


Fig 18 (a ,b): Plots of temperature from XBT's in both transects of the cruise

At the depth range corresponding to the central intermediate waters it clearly appears the contact front between the North Atlantic Central Water (NACW) and the South Atlantic Central Water (SACW) as a step towards colder waters in the transit from north to south.

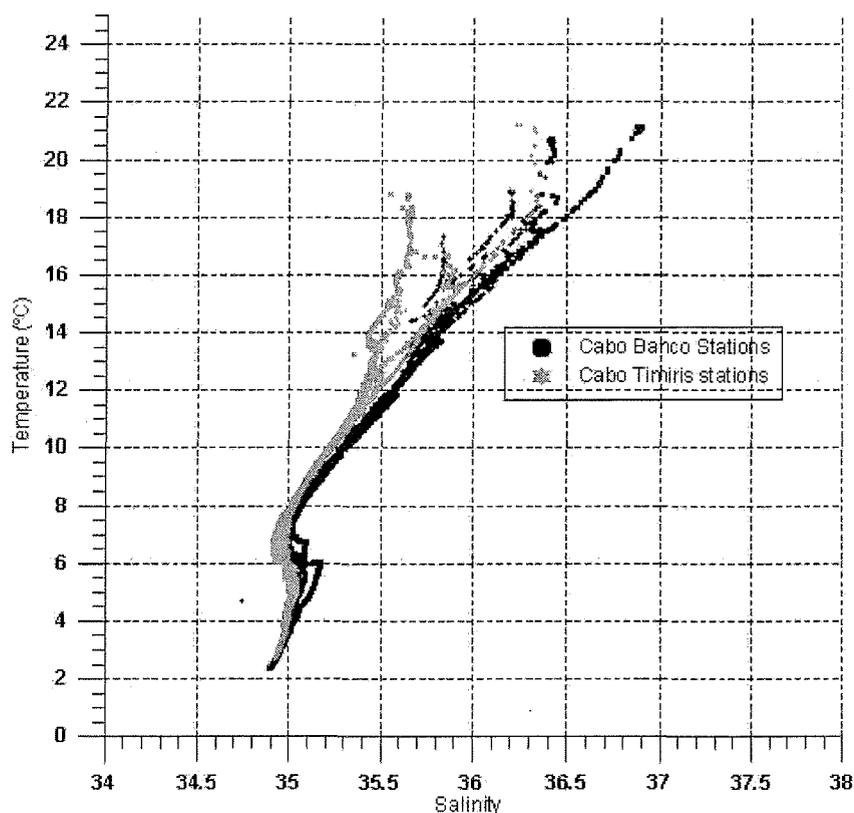


Fig. 19: Diagram T/S showing all the CTD stations sampled along the cruise

The T/S diagrams of the stations sampled with the CTD in the Cape Blanc area ratify the prevalence of the SACW but with certain influence of waters from the north in the section comprising stations #194 to #202 (Fig. 19). This northern influence gets reflected in the sign of MW encountered at deeper depths.

The southernmost XBT section depicts very well the generic coastal cooling produced by the upwelling of the area, and the possibility of the presence of subsurface waters coming from the south below the thermocline centered at XBT station # 15 (Fig. 18b).

The south section made with CTD are clearly defined by waters characteristic from the south, both at intermediate and deep depths. It is worth noticing the diminishment of the salinity in the surface and subsurface waters, corroborating its origin.

The oxygen concentrations are coherent with the appearance of the oxygen minimum core described in the literature (Metcalf, 1969; Sarmiento, 1985; Fukumori et al., 1991; Kawase and; Speer, 1993) located in this area. This is a consequence of the high consumption produced to oxidize the great amounts of organic matter generated at this upwelling core (Fig. 20). In concordance with this first approximation we found out that the oxygen concentration decreases with the proximity to the coastal core, coincident with the decrease in depth.

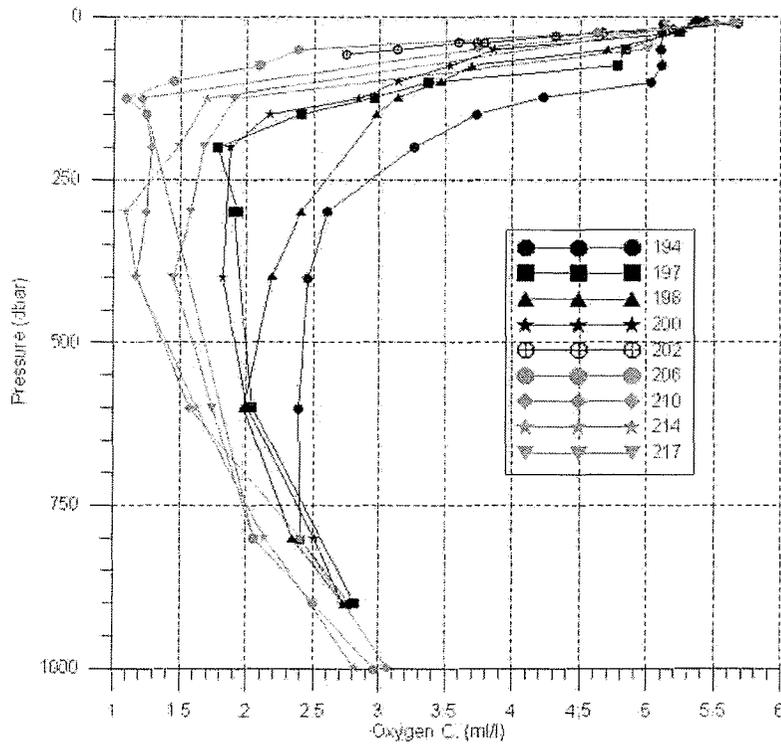


Fig. 20: Vertical profiles (to 1000m) of the oxygen at the CTD stations sampled during the cruise

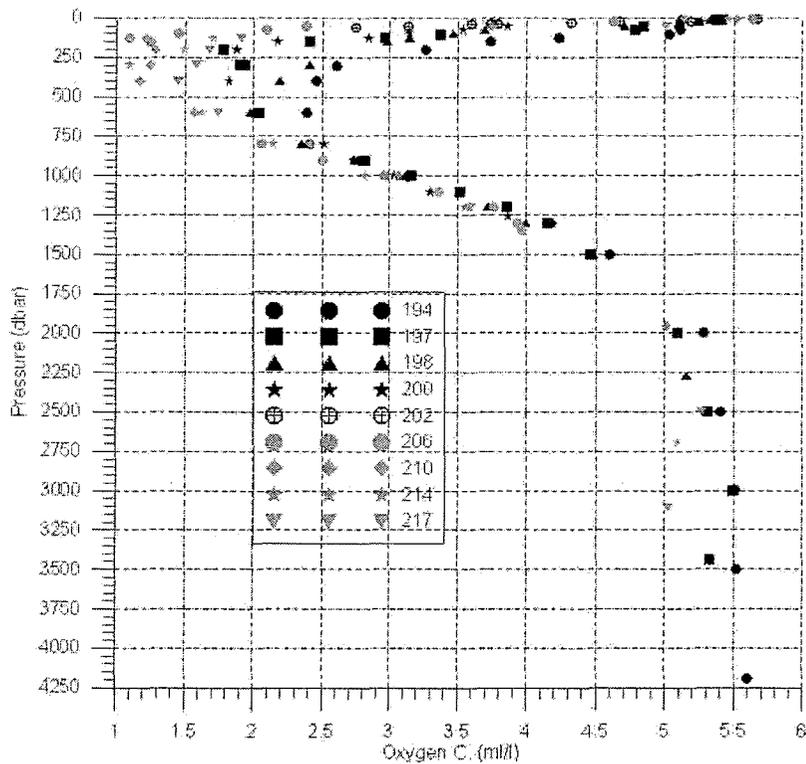


Fig. 21: Vertical values (to the deepest sampled point) of oxygen at the stations sampled along cruise M53/1c

The minimum oxygen value that corresponds to the AAIW does not appear well signalled in the vertical distributions of oxygen (Fig. 21), maybe as a consequence of the subsurface minimum values being masked. The vertical profile of station #194 shows this

fact, since it appears an almost constant value around 2.5 ml/l at depths between 300 and 800 m.

### 5.3.2 Particle flux measurements with moored particle traps

(M. Bergenthal, G. Meinecke, V. Ratmeyer, G. Ruhland, U. Rosiak)

Particle flux measurements off Cape Blanc were carried out since spring of 1988 and show seasonal and short-term variability due to varying productivity and hydrographic conditions.

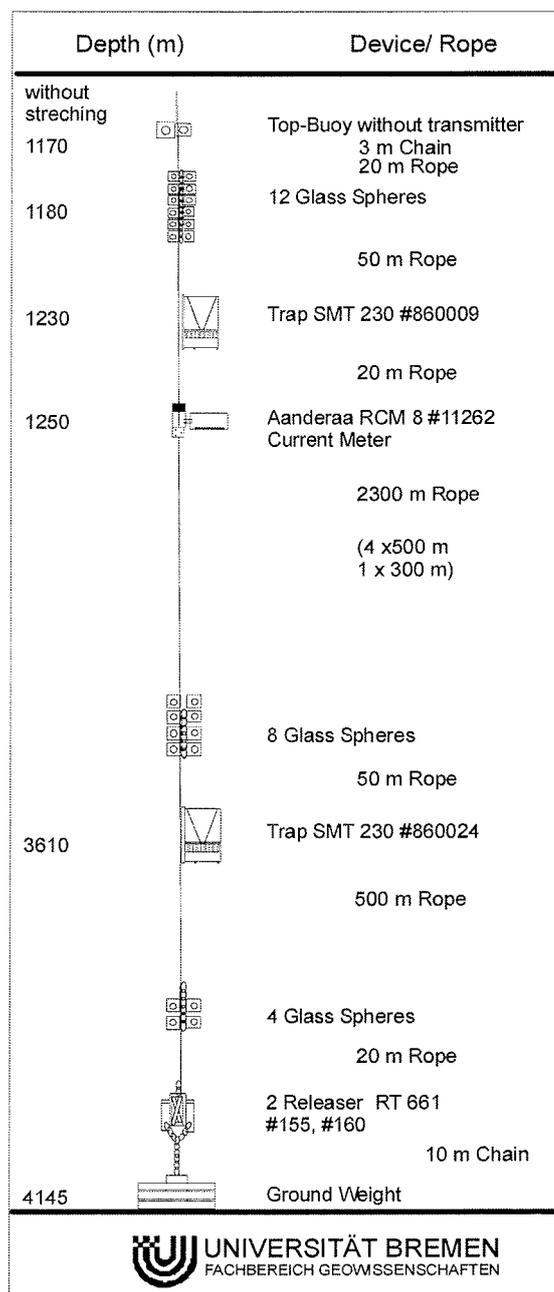


Fig. 22: Mooring design of sediment trap mooring CB13 off Cape Blanc

During METEOR cruise M53/1c the mooring CB was exchanged. The CB12 sediment trap mooring was recovered on April. 22, 2002. It carried two traps and 2 current meters. All instruments functioned properly with the exception of the upper trap that did not turn. The mooring was re-deployed on April. 22, with the same devices as the recovered one (CB 13, see Fig. 22). CB 13 will be exchanged in May 2003 on RV METEOR cruise M 58/2.

### **5.3.3 Deep-Sea Particle Camera System ParCa**

#### **Introduction**

Most studies and calculations on export rates of particulate matter in the ocean are based upon data obtained with sediment traps. Measurements of the in-situ distribution and characteristics of marine snow, like size or shape, are not possible with this technique. Therefore, estimations about the efficiency and processes influencing the vertical and frequently discussed lateral transport, are difficult.

Non destructive, optical methods like the deep-sea camera system ParCa (Ratmeyer and Wefer, 1996) are best suited for the quantification of the in-situ distribution and transport processes of particulate matter in the ocean. The system was designed and improved in consideration of similar systems used by Honjo et al. (1984) or Asper (1987).

#### **Scientific goals**

To continue studies of previous cruises in different regions of the NW African upwelling system, the aim of the deployment of the ParCa system was to obtain high resolution datasets of the vertical distribution of particulate matter on short temporal and spatial scales. This is necessary, because results from previous cruises and satellite data show, that the upwelling region off Cape Blanc is highly dynamic and that the particle distribution changes within hours and differs distinctly even within short distances (i.e. <10 km).

Another focus is laid on studies of transport processes and transport directions of marine particles. Apart from the predominantly vertical sinking direction of particulate matter, the lateral shift of material from the upper slope towards the open ocean, plays an important role with respect to mass transportation of particulate matter. ParCa profiles could detect these lateral advected clouds directly in the water column, so statements about their origin, intensity and influence on particle transport might be possible.

Therefore, the focus of ParCa profiling stations was put on a station matrix south of Cape Blanc, off Timerist. 9 vertical profiles, in 3 profile sequences were taken within 3 days (Fig. 23). A detailed ParCa station list is given in Tab. 8.

Non-destructive, optical techniques provide valuable information about the in-situ shape of particle aggregates. ParCa images will be used, to investigate on particle aggregation and disaggregation processes. Especially the role of large aggregates and their contribution to the vertical flux, is subject of intense studies. The images might be able to tell, in which specific depths particle aggregation takes place and if aggregates are changing in shape and size while sinking through the water column.

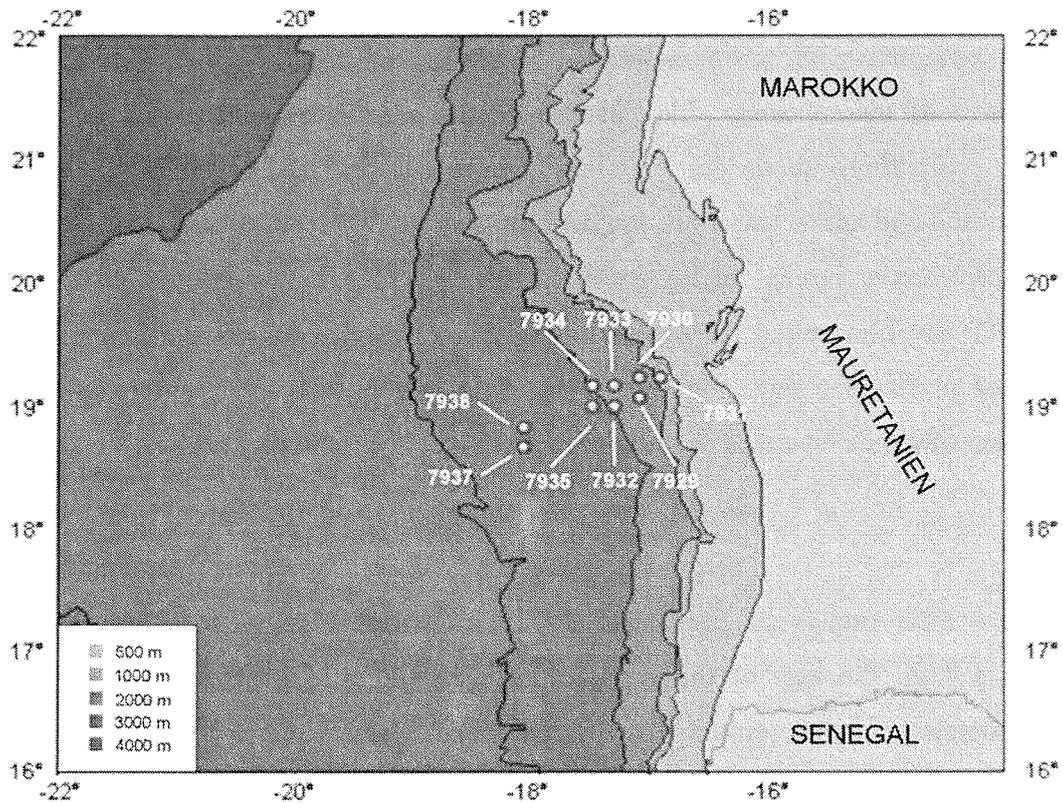


Fig. 23: ParCa station matrix off Timerist

Tab.8: ParCa station list

Station	Date	Lon.	Lat.	Profilingdepth (m)	Waterdepth (m)
7929	29.04.02	19°04.1N	17°04.0W	1425	1425
7930	29.04.02	19°14.1N	17°04.0W	1150	1464
7931	29.04.02	19°14.1N	16°54.1W	424	442
7932	29.04.02	19°00.0N	17°17.0W	1925	1953
7933	30.04.02	19°10.5N	17°17.2W	1925	1950
7934	30.04.02	19°10.3N	17°27.25W	1920	1950
7935	30.04.02	19°04.0N	17°27.5W	1943	2117
7937	01.05.02	18°40.1N	18°02.5W	2600	2667
7938	01.05.02	18°50.1N	18°50.5W	2550	2606

## Methods

ParCa consists of a digital NIKON COOLPIX 995 camera with a picture resolution of 3.34 MPixels. 320 single frames can be stored on a 512 Mbyte memorychip at a pictures resolution of 2048x1536 pixels. A strobe, mounted perpendicular to the camera, provides a collimated light beam of 12 cm width and illuminates a total volume of 0.033 m<sup>3</sup>. Power Source is a 24V/38 Ah rechargeable lead battery designed for the use to full ocean depth. ParCa can operate in depths up to 6000m. All devices are mounted in a 200 kg galvanised frame.

Communication with the ship is done by a microcontroller and adapted software. An additionally installed SeaBird PDIM telemetry provides full control of the entire system, via the ships coaxial wire. ParCa was triggered by the CTD's depth sensor and pictures were exposed while lowering the system with a speed of 0.3 m/sec at each 10 m of depth.

With aid of digital image analysis, parameters like particle concentration, grain size and orientation in the water column can be extracted (Fig. 24).



Fig. 24: ParCa image from site GeoB 7932 (28 m water-depth) showing small particulates and large aggregates (Stringers)

### First results

A particle concentration versus depth plot of the profile GeoB 7931 (424 m) is shown below (Fig. 25). The curve starts with a typical particle maximum of more than 400 particles per litre in the first 40 m. The maximum in the very ocean surface is typical for high productivity areas and due to the increased production of phyto- and zooplanktonic growth. In the midwater column, there is a slight increase in the particle concentration with depth and a midwater maximum is found at 320 m. This midwater peak is possibly created by a lateral advected cloud from the upper slope. The horizontal shift of material seems to play an important role in the Cape Blanc region and might be found and tracked in the remaining profiles also. High abundances of particulate matter above the sea-floor are typical for a concentration profile. Bottom near currents raise particulate matter from the ocean bottom, causing a steady particle maximum.

Further work on the ParCa profiles will be done at the laboratories of the University of Bremen.

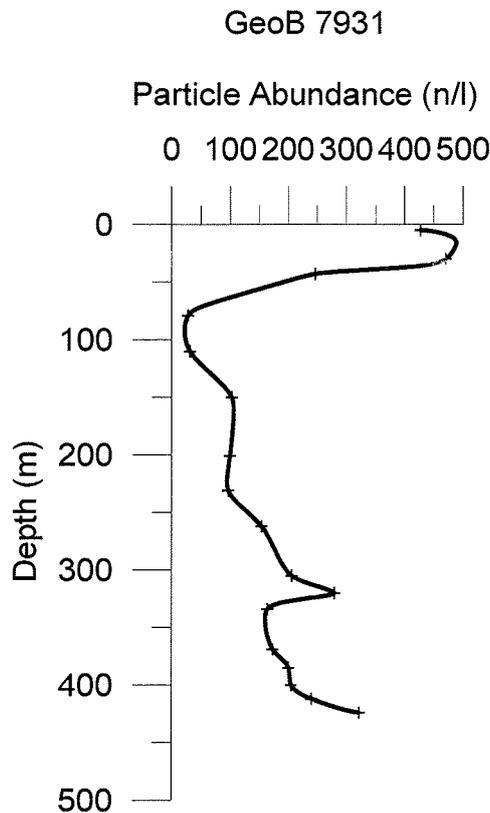


Fig. 25: Particle concentration profile at site GeoB 7931

### **5.3.4 Underway geophysics**

(Shipboard PARASOUND Watchers)

During METEOR Leg M 53/1c the shipboard acoustical systems HYDROSWEEP and PARASOUND were used for site investigation off Cape Blanc in order to record continuous high resolution bathymetric and sediment echosounding profiles. The data provided valuable information for choosing suitable coring stations in the investigation areas.

#### **PARASOUND**

PARASOUND surveys the uppermost sedimentary layers of the seafloor. Due to the high signal frequency of 4 kHz, the short signal length of two sinoid pulses, and the narrow beam angle of 4.5°, a very high vertical resolution is achieved. Sedimentary layers along the ship track on a scale of less than one meter can be resolved. The PARASOUND data provided information about the physical state of the sea bottom as well as about sediment structures up to a depth of 50 m below sea floor. The penetration of the PARASOUND signal depends on the density of the uppermost sediment layers and the impedance contrasts between these layers and at the sea floor. Thus, the penetration was used as a first hint for the quality of a potential coring location. The digitisation and storage of the echosounding seismograms were conducted with the software package ParaDigMa (Spieß 1993). The pre-processed data are plotted online with a HP colour printer. These plots provided a first impression of variations in sea floor morphology, sediment coverage and sediment patterns along the ship's track. In addition, navigational data are printed and stored on disk simultaneously. Besides using PARASOUND as a tool for localisation of promising core sites, it is possible to image and describe the dominating sedimentation processes and to interpret the structural context of the longer sediment cores.

#### **HYDROSWEEP**

The general purpose of HYDROSWEEP is to survey topographic features of the seafloor. A fan of 59 pre-formed beams covers a sector of 90°. Thus, a stripe with the width of twice the water depth is mapped perpendicular to the ship track. Data are stored on magnetic tapes in a sensor independent format. Since a workstation is directly installed beside the ParaDigMa PC, the PARASOUND operator is able to check the topographic map and profiles on the HYDROSWEEP screen simultaneously. Thus, in conjunction with PARASOUND, HYDROSWEEP has shown to be a very efficient aid for the selection of suitable coring stations. The precise knowledge of the local bathymetry is essential to select suitable sites and coring device, and

to evaluate the impact of morphology, slope angles and sediment instabilities on the continuity of sedimentation. Also, the detailed 3D information of the seafloor topography represents an important contribution to the interpretation of the 2D PARASOUND cross-sections.

During cruise METEOR M53/1c, different profiles of sediment cores were taken. These coring locations were exclusively found by the aid of the PARASOUND and HYDROSWEEP systems. The quality of PARASOUND data for sediment sampling will be illustrated with 1 example from a zonal profile along 19°00'N, where the sampling location GeoB 7928 is situated (Fig. 26).

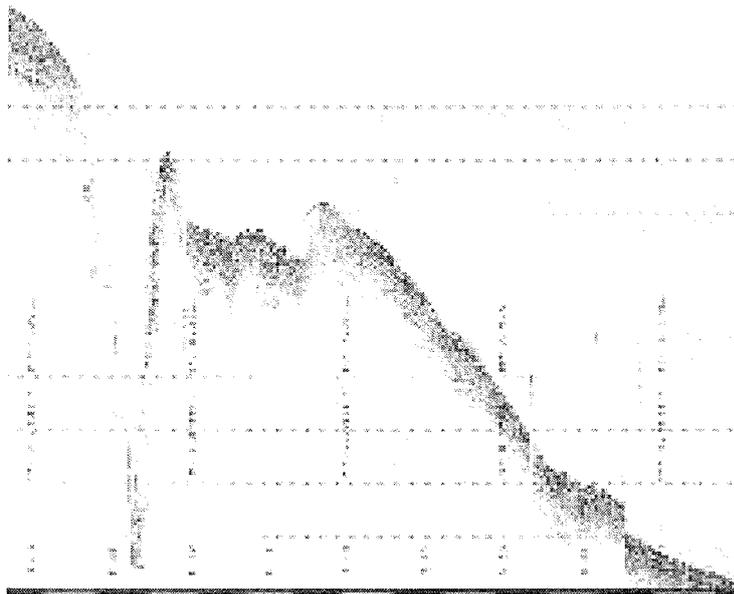


Fig. 26: Digital PARASOUND seismogram section recorded off Timirist between 19°07.29N 17°03.69W and 19°04.09N 17°09.71W, where GeoB station 7928 is situated

Usually, signal penetration was only 20 m in the off-shore site, and about 40 m closer to the coast where the upwelling and the filaments are located.

### **5.3.5 Sediment Sampling**

(A. Eberwein, O. Romero, B. Abou Cire, M. Bergenthal, T. Freudenthal, J. Garming, A. Makaoui, H. Meggers, U. Rosiak, M. Scholz, A. Wülbers)

Sediments were recovered at 12 stations on two profiles west of Cape Blanc and a profile west of Timirist. Surface sediments were generally recovered with a multicorer. A gravity corer with different pipe lengths and a weight of 1.5 tons on top was used at 11 stations to be able to recover deeper sediment sequences (Fig. 2).

#### **5.3.5.1 Sediment surface sampling with multicorer**

##### **Multicorer**

The tool for the recovery of undisturbed sediment surfaces and the overlying bottom water was the multicorer equipped with 8 tubes of 10 cm and 4 smaller tubes of 5 cm in diameter. The multicorer was used at 10 stations (Tab. 9). The core recovery was exclusively good, typically 10 to 12 tubes were filled, and cores of very good quality reaching 32 cm of sediment were recovered from station GeoB 7919 to station GeoB 7936.

At each multicorer station, the overlying bottom water of one of the large tubes was sampled for stable isotope measurements at Bremen. Mostly 4 of the large tubes and 1 of the smaller tubes were usually sampled in 1 cm slices for analysis of  $C_{org}$ , benthic and planktic foraminifera, diatoms and geophysics. The  $C_{org}$  samples were frozen immediately after collection at  $-27^{\circ}C$ . Benthic foraminifera samples were stained with a solution of 1g of rose bengal in 1 l ethanol. A second set of non-stained samples was also collected for planktic foraminiferal and diatom analysis. All this samples were kept at  $4^{\circ}C$ . Mostly one large and/or one small core were frozen as archive material. In addition, surface sediment samples for two purposes. Firstly, surface samples were taken for DNA-analyses of benthic foraminifera. The 0- 1 cm level of one tube was sampled and wet-sieved over a 63 micron sieve immediately after recovery. The remaining fraction was frozen. 1 to 2 surface samples (0-1 cm) were taken for dinoflagellate analyses. Samples were stored in bottles and kept at  $-27^{\circ}C$ .

Tab. 9: Multicorer sampling, METEOR cruise 53/1c

A. Large tubes

GeoB No.	Depth (m)	Recovery (cm)	C <sub>org</sub>	Archive	Geo-chem.	Mar. Chem.	Benthic Forams	DNA	Dinofl.
7919-2	3429	30	1	2	2	-	2	surf	-
7920-3	2278	30	1	1	-	-	2	surf	3 surf
7922-3	1289	23	1	1	-	-	2	surf	2 surf
7923-1	1516	26	1	1	-	1	2	surf	2 surf
7924-3	73	24	1	2	-	-	2	surf	2 surf
7926-3	2501	25	1	2	-	-	2	surf	2 surf
7927-1	3128	29	1	2	-	-	2	surf	2 surf
7928-3	1348	23	1	2+surf	-	1	2	surf	-
7932-2	1964	32	1	3+surf	-	-	2	surf	-
7936-2	2680	32	1	1	-	-	2	1	surf.

Tab. 9 continued: Multicorer sampling, METEOR cruise 53/1c

B. Small tubes

GeoB No.	Depth (m)	Recovery (cm)	Archive	PF	Geo physics.	Diatoms	Dinofl.
7919-2	3429	30	1	1	-	1	1
7920-3	2278	30	-	1	1	1	-
7922-3	1289	23	1	1	1	1	-
7923-1	1516	26	1	1	1	1	-
7924-3	73	24	1	1	1	1	-
7926-3	2501	25	1	1	1	1	-
7927-1	3128	29	1	1	1	1	-
7928-3	1348	23	1	1	1	1	-
7932-2	1964	32	1	1	1	1	-
7936-2	2680	32	1	1	1	1	-

### 5.3.5.2 Sediment sampling with gravity corer

14 gravity cores, in a total of 145 m of sediments were recovered from 11 stations with recoveries which vary between 2.27 m and 16.89 m.

11 cores were opened, described and sampled on board (Tab. 10, Figs. 27-36). After splitting, the archive section was described following the ODP nomenclature and sediment colour was determined by comparison with the MUNSEL soil colour charts. A colour scanner was used to record the colour of the fresh sediments at the 5 cm sampling interval (see spectrophotometry section). All core sections were photographed together with a colour reference card.

Tab. 10: Gravity core sampling, METEOR cruise 53/1c

GeoB No.	Water depth (m)	Recovery (cm)	A-serie Corg	B-Serie Isotopes/ Forams	Geo-physics	Geo-chem.	Smearslides
7919-3	3419	1127	225	225	-	-	8
7919-5	3420	1458	-	-	-	X	-
7920-2	2278	1622	324	324	-	-	21
7921-1	1912	1689	337	337	-	-	15
7922-2	1285	552	110	110	-	-	9
7925-1	1908	1014	202	202	-	-	10
7926-2	2500	1330	266	266	-	-	17
7927-2	3116	818	163	163	-	-	22
7928-1	1350	840	-	-	-	X	-
7928-2	1352	870	174	174	-	-	25
7932-3	1964	835	167	167	-	-	17
7936-1	2670	227	45	45	-	-	22

On the working half of the split cores, two series of known volume samples, A and B were taken with 10 cm<sup>3</sup> syringes every 5 cm, starting at 3 cm below the top of the core. Series A will be analyzed for organic geochemistry and physical properties. Series B will be used for foraminiferal and stable isotope analyses. In addition, Tab. 10 summarizes the gravity core sampling.

### **5.3.5.3 First shipboard results**

#### **Core description and smear slide analysis**

The core description, carried out on the archive half of all gravity core segments, serves to summarize the most important sediment features. The major objective of macroscopic core description is the identification of sediment structures, such as unconformities, discontinuities, turbidites and bioturbation. Core descriptions followed the ODP nomenclature (Fig. 27 for legend). The visible colour classification, determined by comparison with the MUNSEL soil colour chart are supplemented with more detail by Minolta CM 2002TM hand-held spectrophotometer measurements, every 2 cm on the work half. Reflectance profiles are also presented right-hand to the core-description diagrams (Figs. 28-36).

The lithologic observation is supported by smear slide analysis. In each core segment at least one sample was taken depending on the heterogeneity of the sediment and the occurrence of conspicuous lithologies. In some cases, the position of smear slides was determined by changes in colour. For smear slides sediment was taken using a toothpick. The sample was placed on a clean glass microscope slide and smeared with water. Smear slides were prepared using NORLAND OPTICAL ADHESIVE as a mounting medium and dried with UV light for at least one hour. The samples were investigated using an OLYMPUS light microscope at 400 and 1000 X. The sediment composition was described also according to the ODP nomenclature. A total of 175 smear slides were analyzed.

During the cruise M53/1c, 14 sediment cores were retrieved from water depths ranging from 1285 to 3421 m (Tab. 10). Core stations are located along 1 transect from almost west to east, and two transects from northeast to southwest. Core recovery was generally very good, resulting in core lengths between 2.27 m and 16.89 m. 9 cores were opened and described on board, while 5 remain to be opened.

#### **Transect 1**

In the northernmost part of the working area, seven gravity cores were retrieved along a transect between ca. 19°-18°W, 20°45'N off Cape Blanc. Water depths range from 1285 to 3419 m. Recovery was very good, resulting in two cores longer than 16 m length. Three cores were not opened on board. The two shallower cores (GeoB 7923-2 and GeoB 7921-1) are more homogeneous in colour and lithology than the two deeper cores. GeoB 7923-2 mostly consists of olive-coloured sediment, while colour in GeoB 7912-1 varies from olive to olive grey, and is mainly composed by foraminifera and coccolithophores. Both cores contain

megafossils in the range of 1 to 5 cm diameter and a few intercalated coarser grained sections. The two deeper, more pelagic cores are characterized by olive to olive grey and light olive grey sediments. While GeoB 7919-3 is predominantly composed by coccolithophores, the microfossil composition of GeoB 7920-2 shows a larger variety.

### **Transect 2**

Gravity cores GeoB 7925-1, GeoB 7926-2 and GeoB 7927-2 were gained at a NE-SW transect at ca. 20° N, between ca. 18° and 19°W. At all cores colour predominantly varies from olive to olive grey and light olive grey ooze with different lithologic structure, marked by clayey and quartz bearing parts. Turbidites occur in each core, which interrupt the continuous sediment sequence, with features such as fining up- and downwards and erosional contact at their base. The last two cores are characterized by one to three laminated sections within the centimeter-scale. GeoB 7925-1 sediment is mainly carbonaceous, with foraminifera as main component, accompanied by coccolithophores. GeoB 7926-1 shows a strong alternation of all biogenic components, with diatoms mostly as main contributors. Coccolithoporids and foraminifera alternate in GeoB 7927-2.

### **Transect 3**

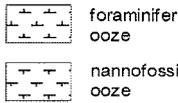
The second NE-SW transect south off Cape Blanc comprises three gravity cores: GeoB 7928-2, GeoB 7932-3 and GeoB 7936-1. The coring sites are located at approximately 20° N, between 18° W and 19° W. The last core was considered unworthy to be opened on board, because the corer's pipe was bended. Except a thin turbidite in core GeoB 7932-3, both cores show a continuous sedimentation. The topmost centimeter of GeoB 7928-2 shows a yellowish brown colour, while sediment, predominantly olive, mostly consist of coccolithophorids and foraminifera with some diatom oozes intercalated. GeoB 7932-3 is characterized by olive and olive grey ooze with strongly varying lithology. The dominant microfossil content is richly composed of coccolithophorids, foraminifera and diatoms. Clayey and quartz bearing sections intercalate.

## Legend for stratigraphic columns

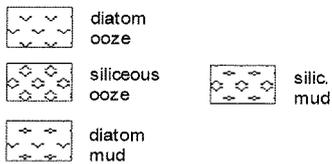
### Lithology

#### one major component

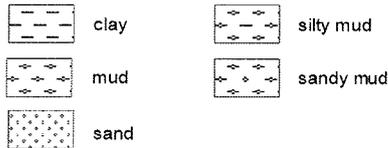
##### calcareous



##### siliceous

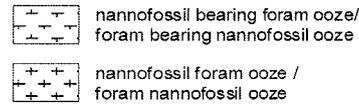


##### terrigenous

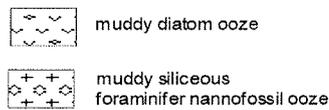


#### mixtures

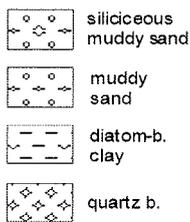
##### calcareous



##### siliceous

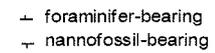


##### terrigenous

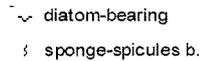


#### admixtures

##### calcareous



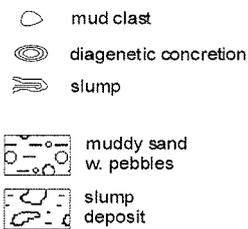
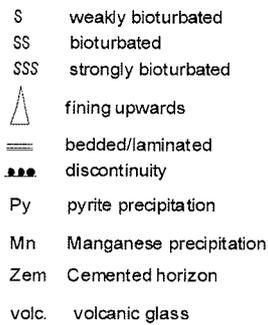
##### siliceous



##### terrigenous



### Structures



### Fossils



### Color

#### Munsell value

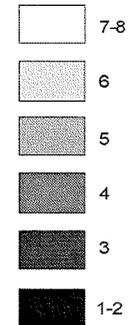


Fig. 27: Legend for core descriptions in Figs. 28-36

GeoB 7919-3 Date: 23.04.02 Pos: 20°56,30'N 19°23,27'W  
 Water Depth: 3419 m Core Length: 1127 cm

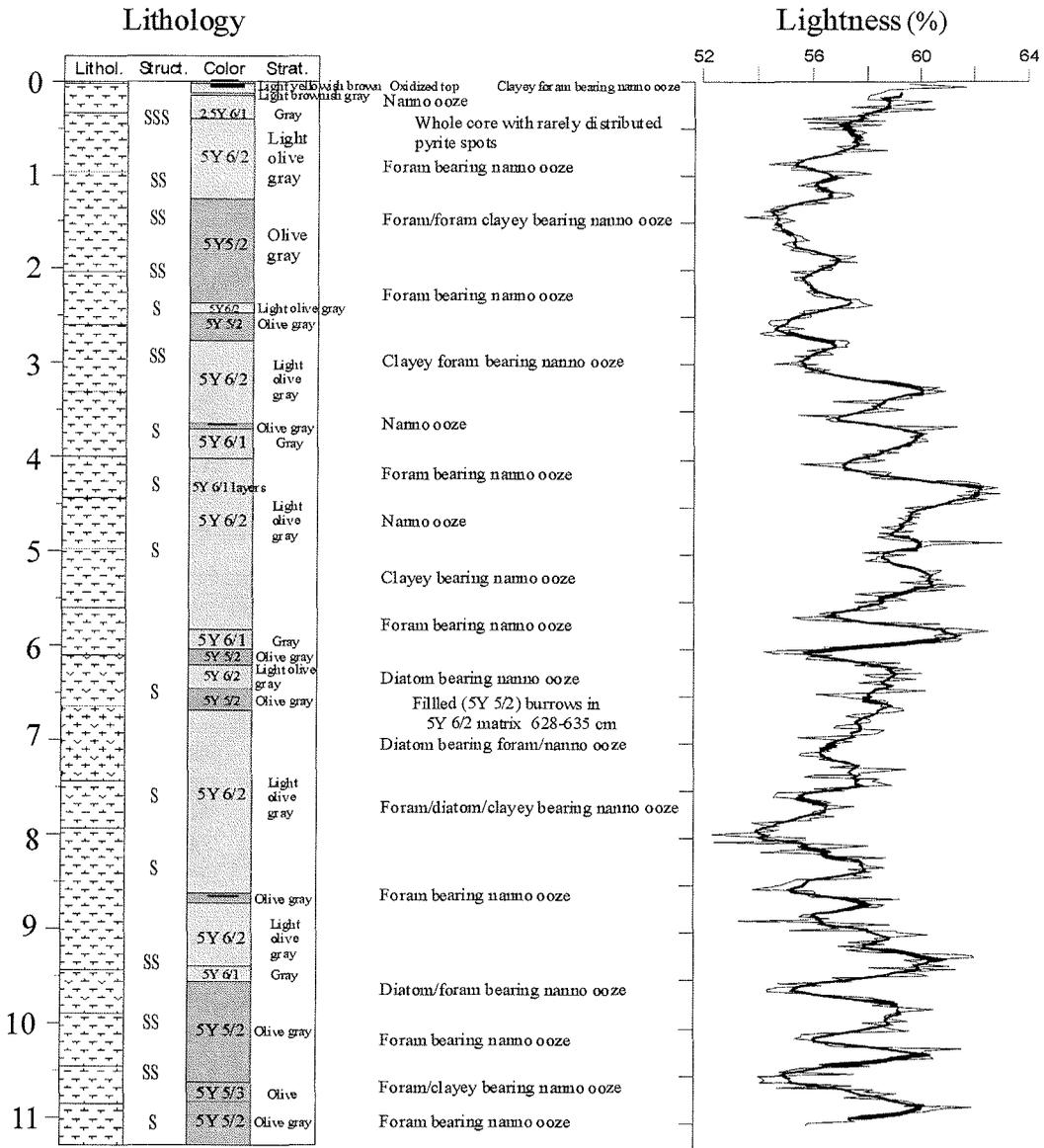


Fig. 28: Sediment descriptions, lightness, and smear slide analysis for the gravity core GeoB 7919-3

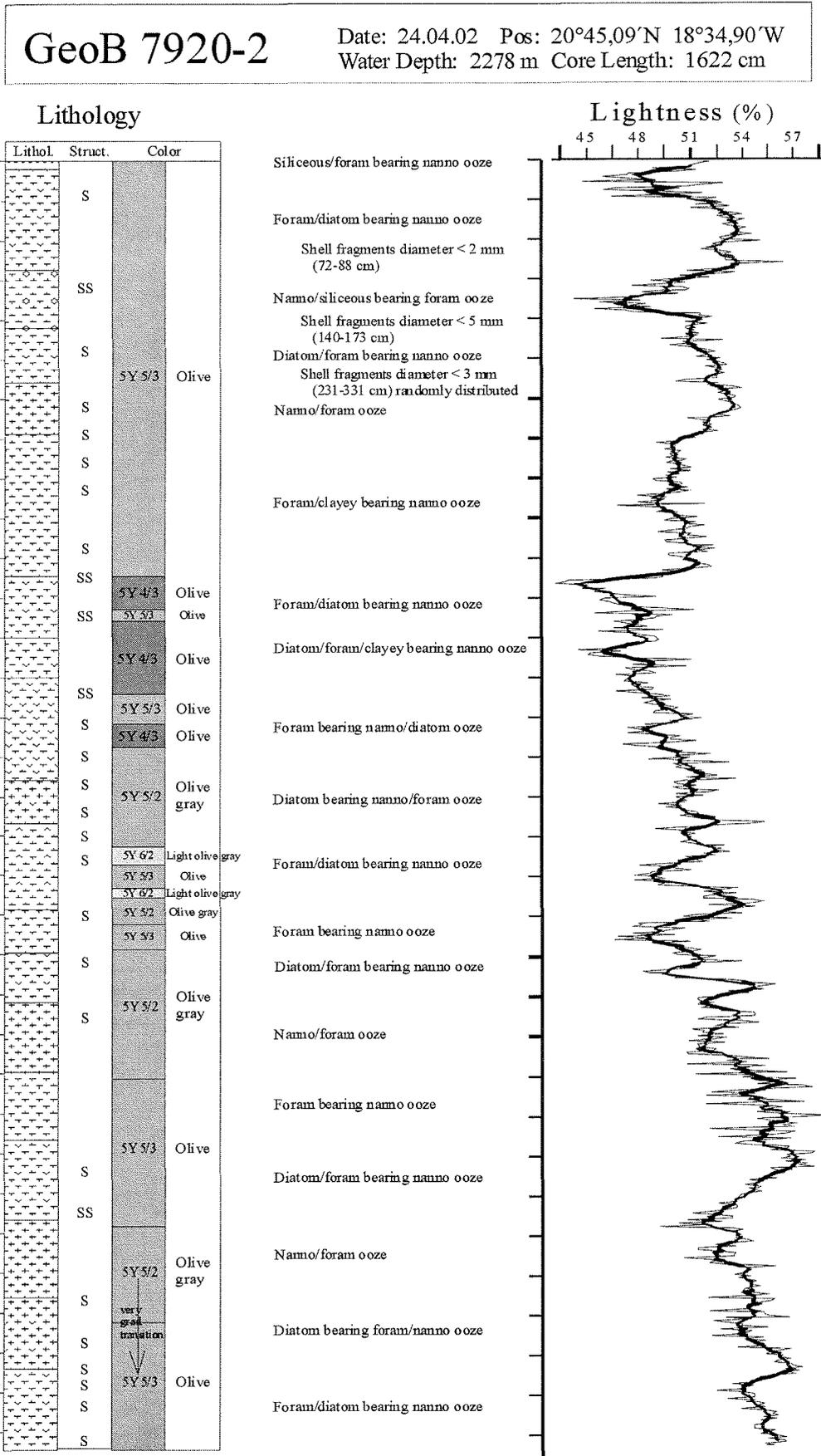


Fig. 29: Sediment descriptions, lightness, and smear slide analysis for the gravity core GeoB 7920-2

GeoB 7921-1      Date: 25.04.02    Pos: 20°48,33'N 18°15,55'W  
 Water Depth: 1912 m    Core Length: 1689 cm

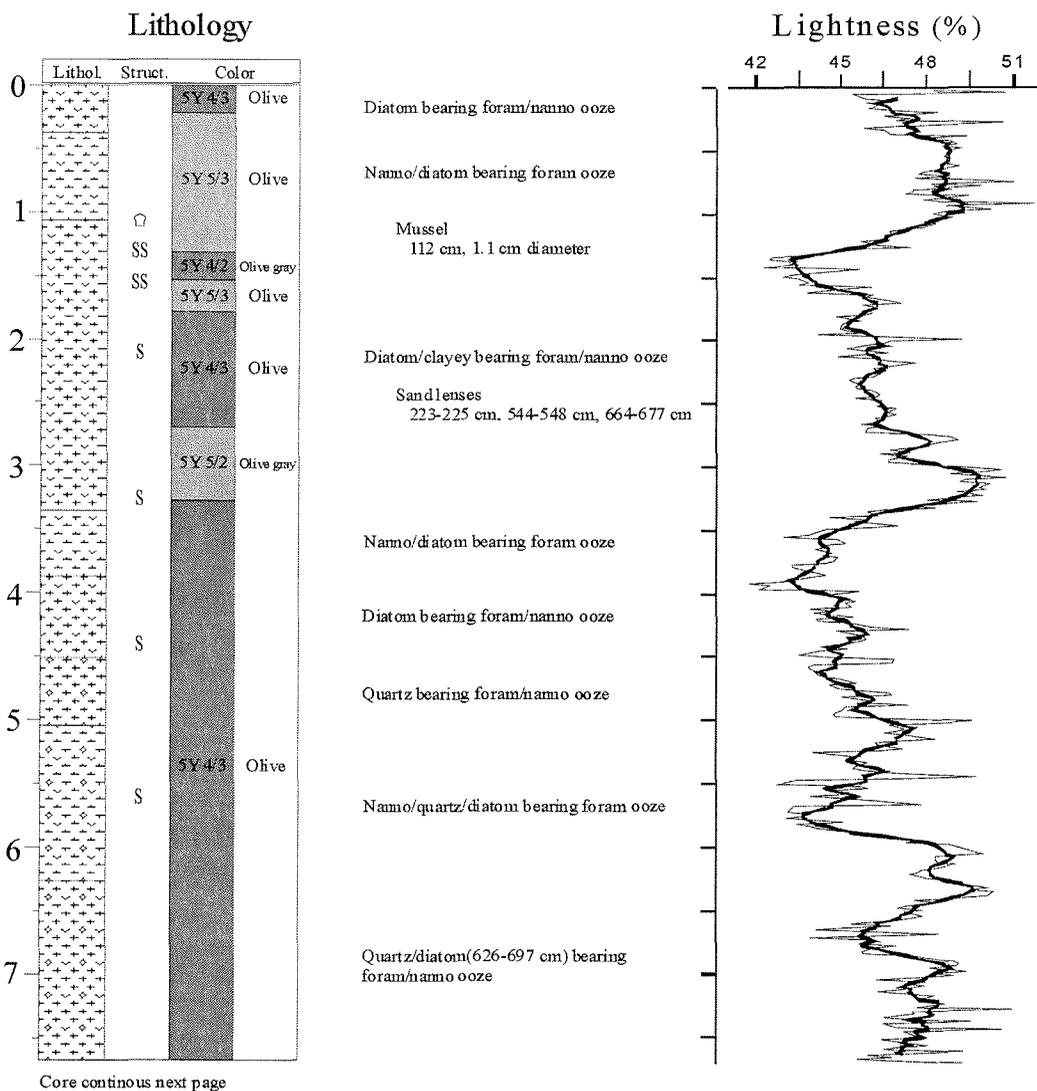


Fig. 30: Sediment descriptions, lightness, and smear slide analysis for the gravity core GeoB 7921-1

GeoB 7923-2 Date: 26.04.02 Pos: 20°44,39'N 18°10,69'W  
 Water Depth: 1516 m Core Length: 976 cm

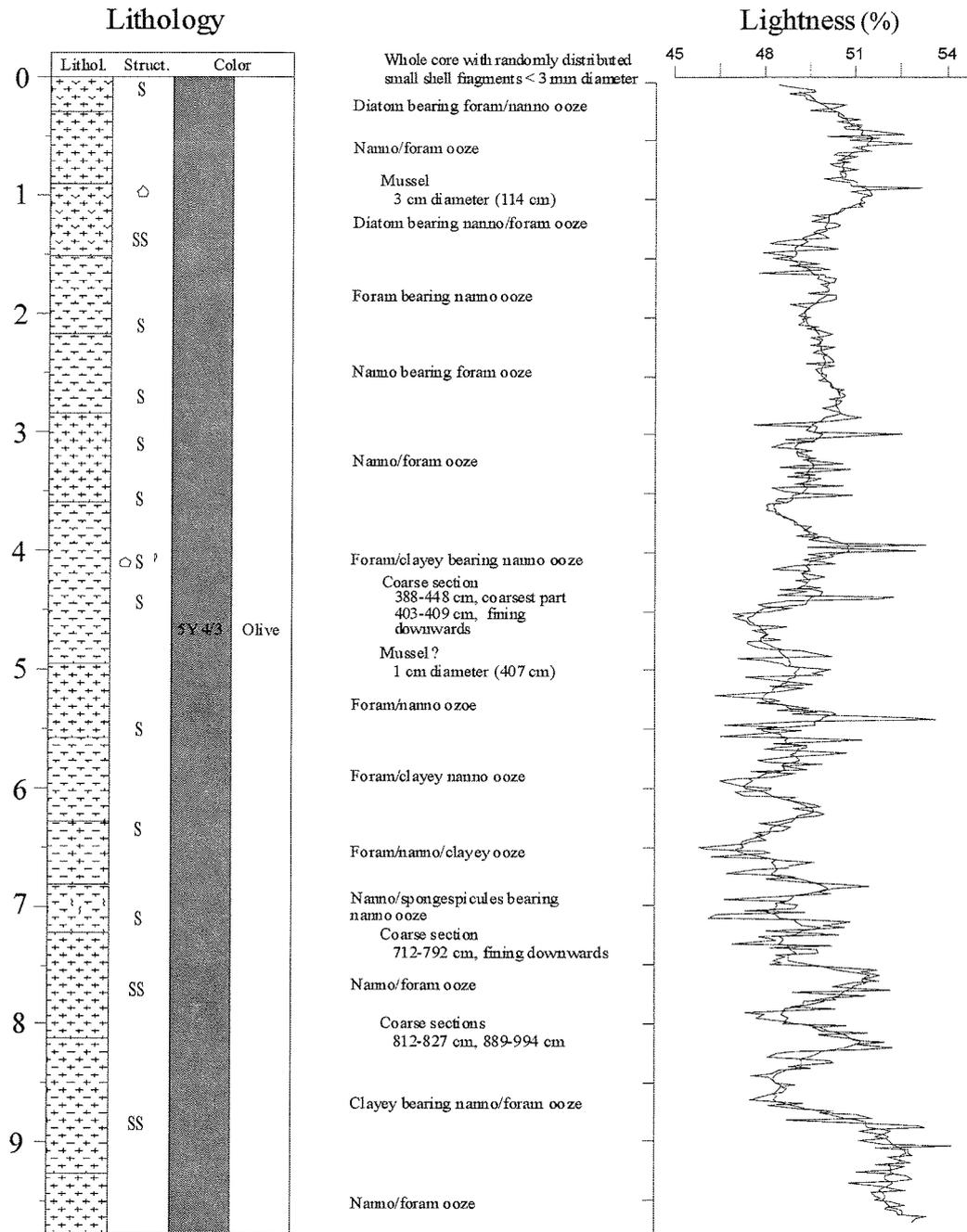


Fig. 31: Sediment descriptions, lightness, and smear slide analysis for the gravity core GeoB 7923-2

# GeoB 7925-1

Date: 26.04.02 Pos: 20°17,48'N 18°15,69'W  
 Water Depth: 2278 m Core Length: 1014 cm

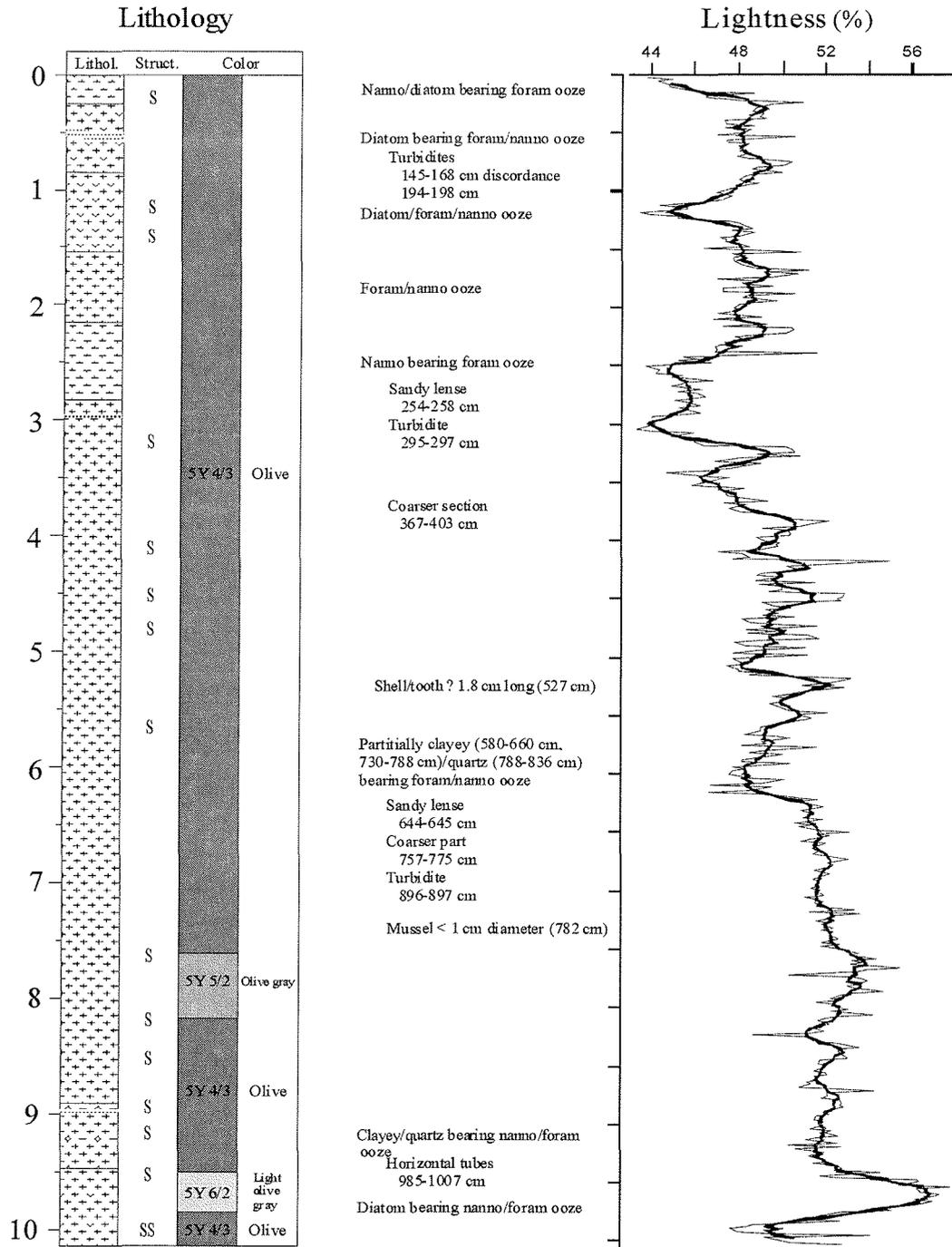


Fig. 32: Sediment descriptions, lightness, and smear slide analysis for the gravity core GeoB 7925-1

# GeoB 7926-1

Date: 27.04.02 Pos: 20°12,79'N 18°27,14'W  
 Water Depth: 2500 m Core Length: 1330 cm

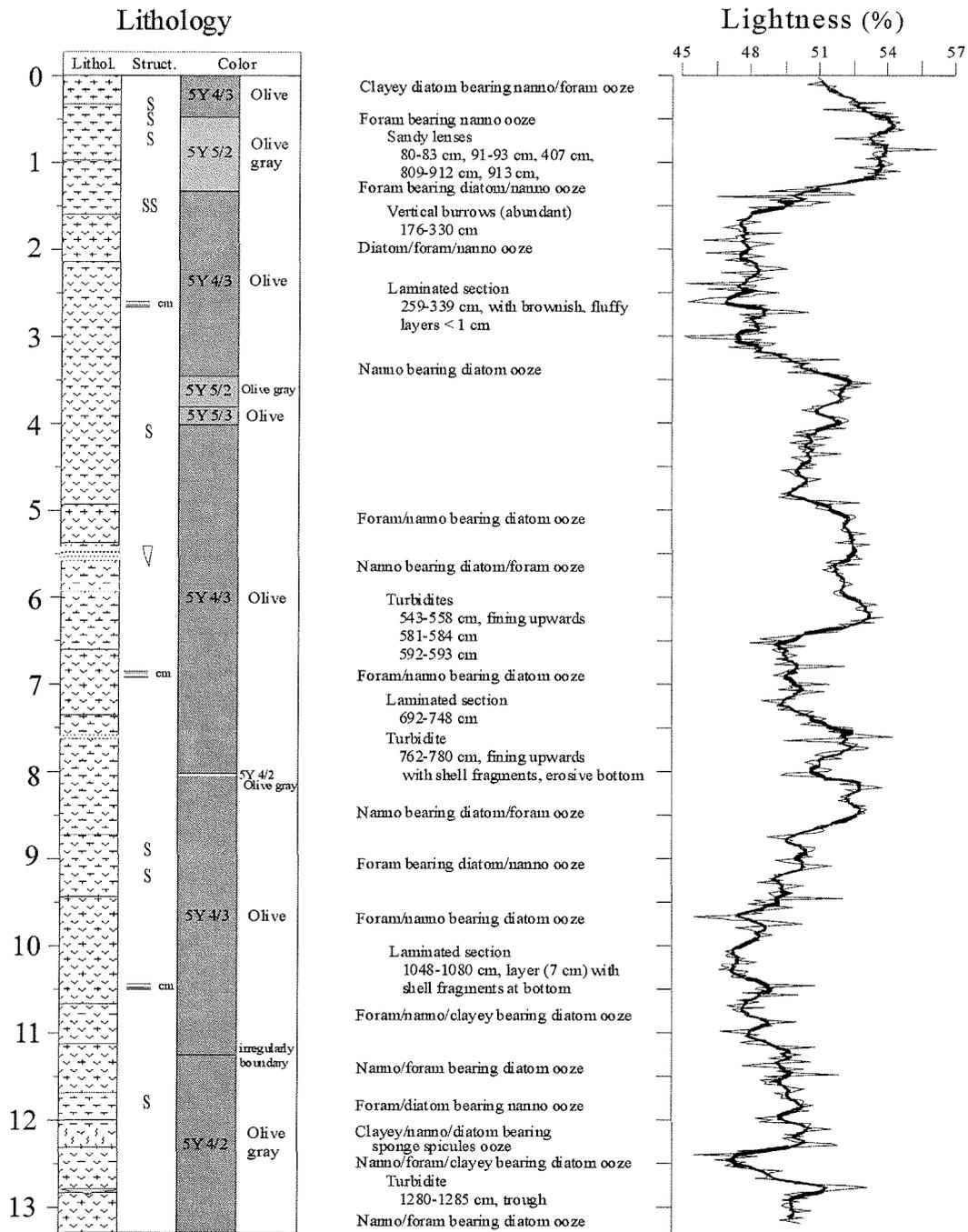


Fig. 33: Sediment descriptions, lightness, and smear slide analysis for the gravity core GeoB 7926-1

GeoB 7927-2 Date: 27.04.02 Pos: 19°56,19'N 19°09,10'W  
 Water Depth: 3116 m Core Length: 818 cm

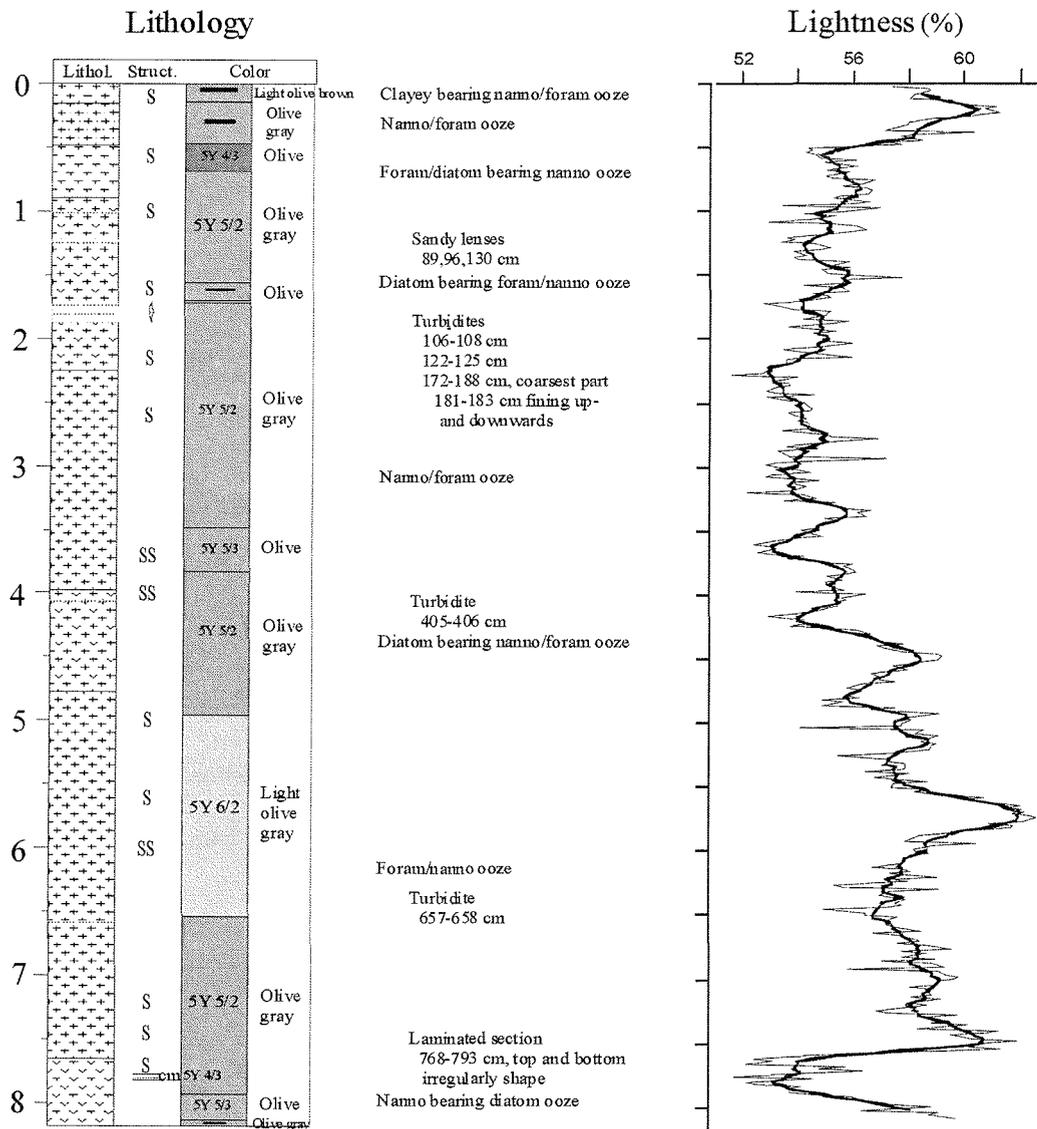


Fig. 34: Sediment descriptions, lightness, and smear slide analysis for the gravity core GeoB 7927-2

GeoB 7928-2 Date: 28.04.02 Pos: 19°05,98'N 17°02,88'W  
 Water Depth: 1352 m Core Length: 870 cm

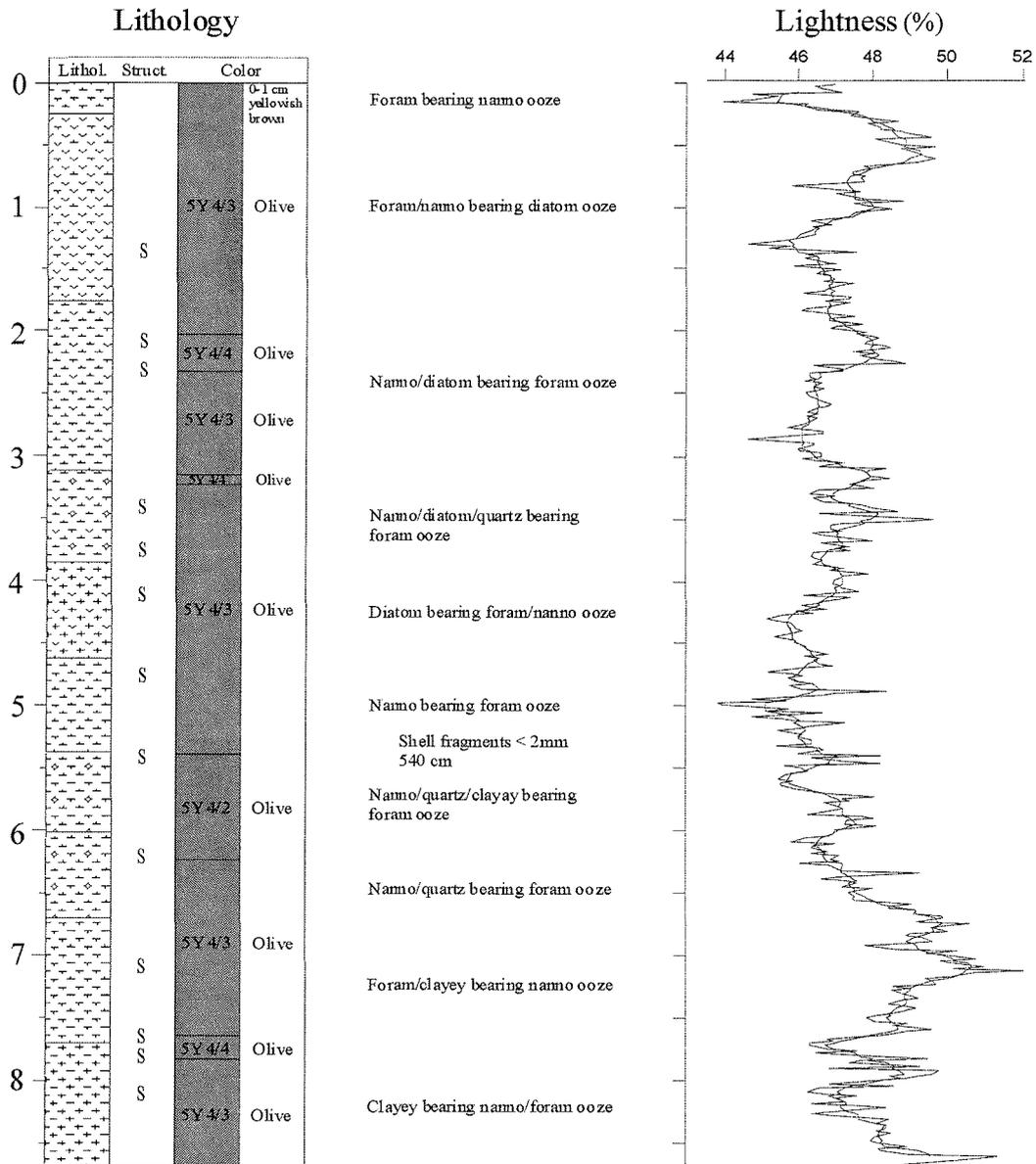


Fig. 35: Sediment descriptions, lightness, and smear slide analysis for the gravity core GeoB 7928-2

GeoB 7932-3 Date: 29.04.02 Pos: 19°00,09'N 17°16,89'W  
 Water Depth: 1964 m Core Length: 835 cm

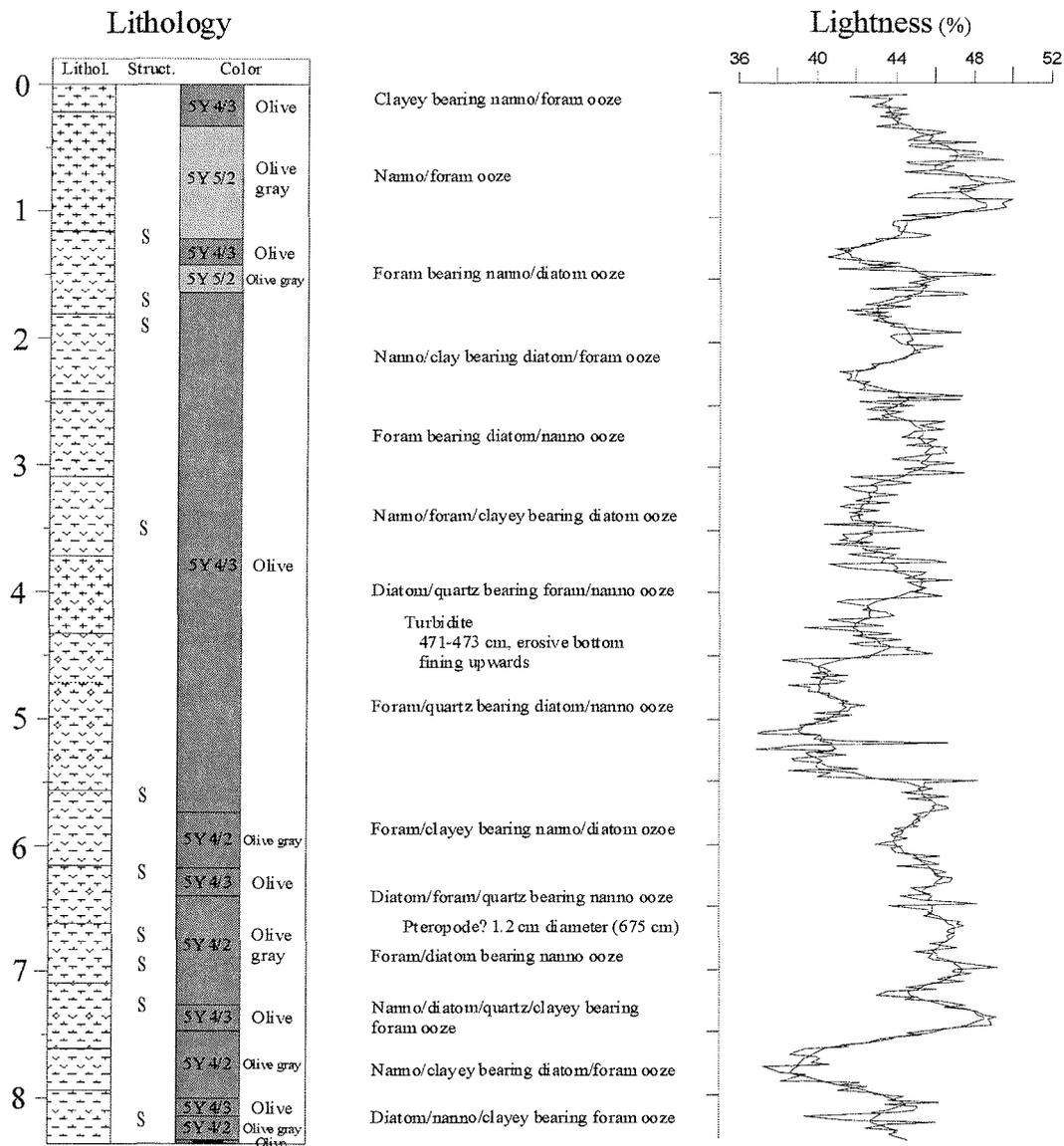


Fig. 36: Sediment descriptions, lightness, and smear slide analysis for the gravity core GeoB 7932-3

### **5.3.6 Geochemistry**

(Sabine Kasten, Kerstin Plewa)

#### **Introduction**

The main focus of geochemical investigations carried out during this cruise was a detailed sampling and analysis of the solid phase of selected sediment cores from the Canary Islands/Cape Verde Islands area. The aim was to reveal whether and how the distribution of various elements and/or minerals in the sedimentary solid phase can be used to reconstruct changes in terrigenous input, in productivity and in the extent of diagenetic overprint.

A second emphasis was put on the high-resolution examination along glacial/interglacial transitions as well as across active and fossil iron redox boundaries in sediments of the study area. Previous studies have demonstrated that the Fe redox boundary is and was often associated with glacial terminations and is/was frequently fixed within this depth interval for a considerable length of time (Funk et al., *subm.*). As a consequence of the sustained localization and/or the downward progression of redox boundaries and reaction fronts, a distinct diagenetic overprint of the primary composition within these transitional sediment intervals occurs – including post-depositional oxidation of organic carbon, dissolution of minerals as well as formation of distinct secondary element and mineral enrichments (e.g., Moreno et al., 2002; Freudenthal et al., *subm.*; Kasten et al., *subm.*). The conditions which trigger such nonsteady-state diagenetic episodes are assumed to be the pronounced differences in sedimentation rate, organic carbon input and oxygen content of bottom waters encountered during the transition from glacials to interglacials. The objective of these high-resolution studies is to identify which factors control the extent of diagenetic overprint in transitional sediment intervals. Furthermore, we intend to reveal which of the secondary element enrichments produced are preserved in the sedimentary record on further burial and can thus serve as valuable indicators for changes in organic carbon burial.

In addition to sampling and storage of the sediments for subsequent solid-phase analyses at the University of Bremen we extracted and analysed the pore water immediately on board in order to characterize the current geochemical environment of the sediments and to identify the depth position of the modern Fe(II)/Fe(III) redox boundary. During this cruise 1 multicorer core (GeoB 7919-2) and 2 gravity cores (GeoB 7919-5 and GeoB 7928-1) were processed.

## **Methods**

To prevent a warming of the sediments on board all cores were transferred into a cooling room immediately after recovery and maintained at a temperature of about 4 °C. The multicorer core was processed directly after recovery. Two samples of the supernatant bottom water were taken and filtered for subsequent analyses. The remaining bottom water was carefully removed from the multicorer tube by means of a siphon to avoid destruction of the sediment surface. During subsequent cutting of the core into slices for pressure filtration, pH and Eh measurements were performed with a minimum resolution depth of 0.5 cm. Conductivity and temperature were measured on a second, parallel core to calculate sediment density and porosity.

The gravity cores were cut into 1 m segments on deck. Within a few days after recovery, gravity cores were cut lengthwise into two halves and processed. On the working halves pH and Eh were determined and sediment samples were taken every 25 cm for pressure filtration. Conductivity and temperature were measured on the archive halves. Solid phase samples were taken at 10 cm intervals and kept in gas-tight glass bottles under argon atmosphere for sequential extractions and mineralogical investigations. The storage temperature for all sediments was -20°C to avoid dissimilatory oxidation.

All work done on opened cores was carried out in a glove box under argon atmosphere. 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. Depending on the porosity and compressibility of the sediments, the amount of pore water recovered ranged between 5 and 20 ml.

## **Pore water analyses**

Pore water analyses of the following parameters were carried out during this cruise: Eh, pH, temperature, conductivity (porosity), alkalinity, ammonium, and iron.

Eh, pH, conductivity and temperature were determined with electrodes before the sediment structure was disturbed by sampling for pressure filtration. Ammonium was measured photometrically with an autoanalyser using a standard method. Alkalinity was calculated from a volumetric analysis by titration of 1 ml sample with 0.01 or 0.05 M HCl, respectively. For the analysis of dissolved iron (Fe<sup>2+</sup>) sub-samples of 1 ml were taken within the glove box and immediately complexed with 50 µl of “Ferrospectral“ and afterwards determined photometrically.

For further analyses at the University of Bremen, aliquots of the remaining pore water samples were either frozen (for analyses of  $\text{PO}_4$  and  $\text{NO}_3$ ) or acidified with  $\text{HNO}_3^-$  (suprapure) for the determination of cations (Ca, Mg, Sr, K, Ba, S, Mn, Si, B) by ICP-AES and AAS. Sub-samples for sulfate and chloride determinations were diluted 1:20 and stored for analysis by ion chromatography (HPLC).

A complete overview of sampling procedures and analytical techniques used on board and in the laboratories at the University of Bremen is available on <http://www.uni-bremen.geochemie.de>.

### Shipboard Results

Site GeoB 7919 is located off Cape Blanc at a water depth of 3420 m. At this location a visible colour change from brown to grey/green was observed a few tenths of centimeters below the sediment surface. While this colour change was not reached by the penetration depth of the multicorer (c.f., Fig. 37), dissolved iron was detected below a depth of 0.8 m in the gravity core (Fig. 38).

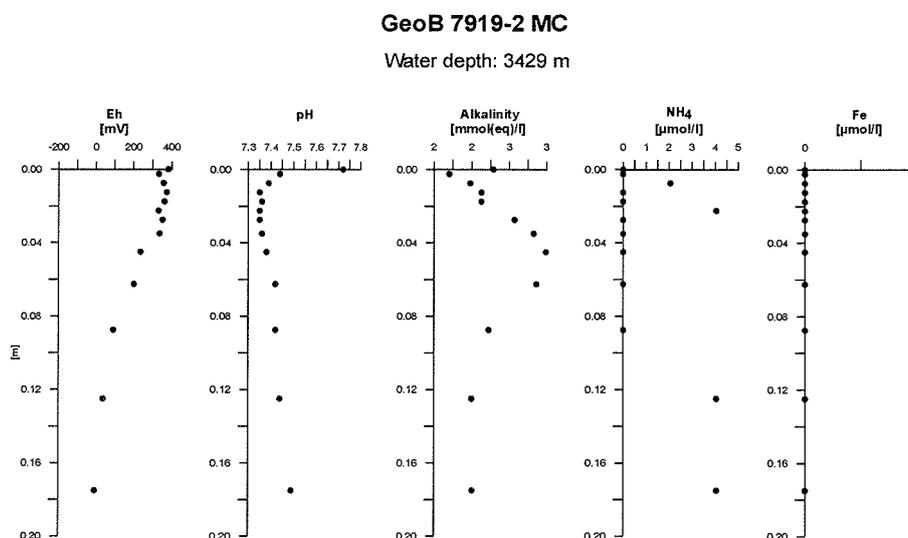


Fig 37: Pore water concentration profiles of Eh, pH, alkalinity, ammonium and iron for multicorer core GeoB 7919-2

This finding is evidence that the active/modern Fe redox boundary is located in the sediment section between 0.5 and 0.8 m depth. Elevated amounts of Fe of up to about 3  $\mu\text{mol/l}$  are found in the depth interval between 0.8 and 8.0 m which could be due to higher rates of iron reduction occurring within this sediment section or a removal of  $\text{Fe}^{2+}$  from pore water due to the formation of authigenic iron minerals in the sediments below 8.0 m. Except for the uppermost meter of the sediment, alkalinity and ammonium show a parallel and linear

increase with depth pointing to a deeper source of these two components (Fig. 38). The subsurface change in the alkalinity gradient is likely to result from the precipitation of calcite as a consequence of the increase in pH at this depth.

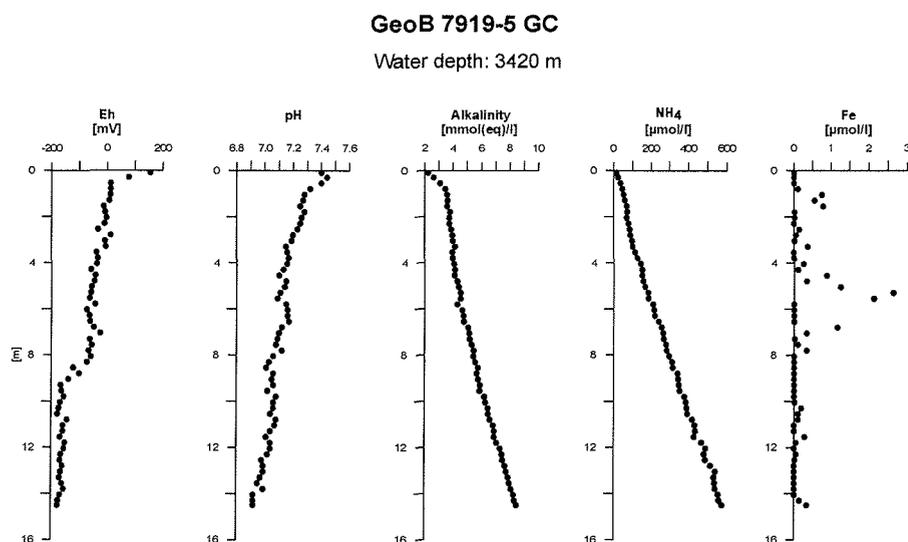


Fig. 38: Pore water concentration profiles of Eh, pH, alkalinity, ammonium and iron for gravity core GeoB 7919-5

Gravity core GeoB 7928-1 (Fig. 39) was recovered from a water depth of 1350 m off Timirist. This site was chosen because Vörösmarty et al. (2000) postulated that a large river system was active in this area during the early Holocene. Solid phase analyses which are to be performed at the University of Bremen will reveal whether significant changes in the amount and/or composition of terrigenous material within this core do support this hypothesis. With respect to the pore water data obtained on board an active iron redox boundary could neither be identified from a visible colour change nor from the occurrence of dissolved iron in pore water (c.f., Fig. 39). Free hydrogen sulfide was detected by smell below a sediment depth of about 7.5 m. Possibly sulfate reduction does not only take place within or below the lower part of the core but occurs over a broad depth range of the sediments sampled. Hydrogen sulfide generated by this process would then promote the precipitation of iron sulfides leading to the complete depletion of  $\text{Fe}^{2+}$  in pore water.

Concentration profiles of alkalinity and ammonium both show a prominent kink at a depth of 3 to 3.2 m, slightly below the maximum in pH at 2.3 m (Fig. 39). There are two possible explanations for the distinct change in the alkalinity gradient at this depth. First, it could result from calcite precipitation induced by the increase in pH. Second, the pore water concentration profiles could represent a nonsteady-state situation initiated by an increase in the flux of alkalinity and ammonium from below – most likely from the depth where active

methanogenesis takes place. Maximum concentrations of ammonium found in this gravity core approximately double the contents determined for core GeoB 7919 located off Cape Blanc indicating that site GeoB 7928 is likely to be characterized by higher input of organic carbon and higher mineralization rates.

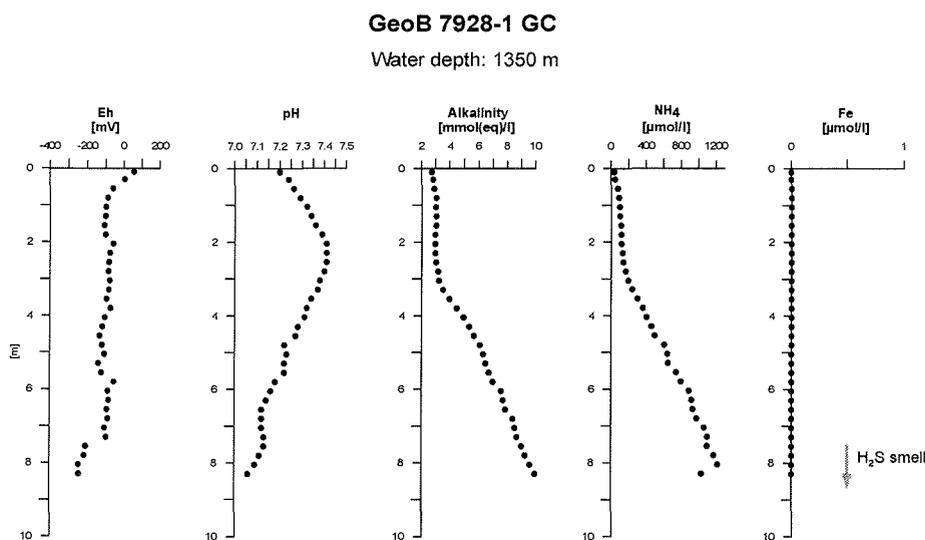


Fig. 39: Pore water concentration profiles of Eh, pH, alkalinity, ammonium and iron for gravity core GeoB 7928-1

The determination of further pore water constituents – particularly of sulfate – as well as the analyses of the solid phase and the computer modelling of the sediment/pore water system will give evidence which of the above discussed explanations hold true for the examined core sites.

## 6. The weather during the cruise M53/1

(G. Kahl, T. Truscheit)

When METEOR left Limassol on March 30<sup>th</sup>, 2002, high pressure influence was prevailing over most of Western and Central Europe, extending east via the Black Sea to the Caucasian Mountains. The only low worth mentioning was of 1005 hPa over Lybia, moving east. Consequently, there were only light easterly winds when the research vessel put out to sea.

During the next day, the low reached the NILE valley, turning north and reaching CYPRUS. Then it turned even west, filling thereby. For the METEOR this meant light to moderate northerly winds when a sounding was recovered at CRETE's south coast.

On April 2<sup>nd</sup>, winds were light and variable as METEOR was passing through a high north of the SYRTE. Meanwhile, a low of about 1004 hPa had developed over the TUNESIAN salt lakes west of the SYRTE and another one with a central pressure of 1000 hPa near IBIZA. Still another low was developed near Sicily so that when the ship stopped shortly before LA VALLETTA, MALTA, southeasterly winds of 6 Bft were prevailing. With that the METEOR left the EASTERN MEDITERRANEAN, where she had been working since October 2001.

The WESTERN MEDITERRANEAN welcomed the ship with westerly storms of 10 Bft for the duration of an hour on April 4<sup>th</sup>, 11 Bft (60 kn) for a 10 minutes-mean and hurricane force gusts of 12 Bft. The synoptic situation in the morning comprised of a gale center 996 hPa just east of the BALEARIC Islands intensifying and moving east into the TYRRHENIAN SEA, central pressure going down to 993 hPa. This intensification was not responsible for the storms, however, for within about two hours a storm center developed in the trough, reaching SARDINIA with a central pressure of 990 hPa. As this low was passed the storms were felt. On April 5<sup>th</sup>, northwesterly gales of 9 Bft subsided to westerly 7 Bft as the METEOR passed the Straits of SARDINIA.

In the meantime an Atlantic low of 995 hPa had arrived just southwest of Ireland. A secondary low 1003 was lying just west of PORTO, Portugal. This secondary low was the one to develop to 993 hPa west of Cabo Sao Vicente by April 7<sup>th</sup> as the METEOR was sailing along the Costa del Sol under light westerly winds. Then the research vessel passed the Straits of Gibraltar, re-entering the Atlantic. From one minute to the next winds backed to the southwest to become pure headwinds, and force was up to 5 Bft. To achieve this, the synoptic situation had developed as follows: the low near Cabo Sao Vicente had moved north and filled somewhat, but had retained its character as the central low. A secondary low which had developed near 40°N 18°W had moved southeast to 35°N 12°W and intensified to 1000 hPa. In this manner moderate to strong southwesterly winds prevailed until the ship called at Las Palmas on April 10<sup>th</sup>, even peaking Southwest 7 Bft up to the very last hours.

During the time the research vessel was in port the advection of cold air that had kept the merry-go-round of lows alive lessened, a low of 997 hPa still lying east of MADEIRA on April 11<sup>th</sup>, but then this remnant, too, filled quickly. When the ship put out to sea again on April 12<sup>th</sup>, northerly winds 4 to 5 Bft prevailed. The wind even abated to Northeast 3 Bft. Starting April 16<sup>th</sup>, however, conditions changed: the northeasterly winds were gradually up 6 Bft because a low over the southern part of Morocco had formed and was intensifying slowly.

METEOR called at Las Palmas again on April 18<sup>th</sup> only to leave port on April 20<sup>th</sup>.

When METEOR left Las Palmas de Cran Canaria on April 20<sup>th</sup>, 2002 southwards, light northeasterly wind was prevailing. From April 22<sup>nd</sup>, for the present it was partly cloudy and from April 23<sup>rd</sup> to April 24<sup>th</sup> it was completely cloudy with some rain. The synoptic situation to this was a low 1008 hPa over Senegal and high pressure 1033 hPa easterly of the Azores Islands.

During the next days and till METEOR called at Port of Sao Vicente, light to moderate, sometimes fresh breeze, northerly winds, on April 30<sup>th</sup> up to near gale (Bft 7), prevailed.

## 7. References

- Asper, V.L., 1987. Measuring the flux and sinking speed of marine snow aggregates. *Deep-Sea Research*, 34, 1-17.
- Determann, S., R. Reuter, P. Wagner and R. Willkomm, 1994. Fluorescent matter in the eastern Atlantic Ocean: Part 1, method of measurement and near-surface distribution. *Deep-Sea Research*, 41, 659-675.
- Determann, S., R. Reuter, R. Willkomm, 1996. Fluorescent matter in the eastern Atlantic Ocean: Part 2, vertical profiles and relation of water masses. *Deep-Sea Research*, 43, 345-360.
- Freudenthal, T., S. Kasten, and H. Meggers, submitted. Glacial trade wind intensity controlled by latitudinal sea surface temperature gradients. Submitted to *Geology*.
- Fukumori, I., F. Martel and C. Wunsch, 1991. The hydrography of the North Atlantic in the early 1980's: an Atlas. *Progress in Oceanography*, 27 (1-2), 1-110.
- Funk, J., T. von Dobeneck, T. Wagner and S. Kasten, submitted. Late Quaternary sedimentation and early diagenesis in the equatorial Atlantic Ocean: Patterns, trends and processes deduced from rock magnetic and geochemical records.- In: G. Wefer, S. Mulitza, V. Ratmeyer (eds.) *The South Atlantic in the Late Quaternary: Reconstruction of Mass Budget and Current Systems*. Springer, Berlin Heidelberg New York.
- Garside, C., 1993. Nitrate reductor efficiency as an error source in seawater analysis. *Marine Chemistry*, 4 (1), 25-30.
- Honjo, S., 1996. Fluxes of particles to the interior of the open oceans. In: V. Ittekkot, P. Schäfer, S. Honjo and P.J. Depetris (eds.), *Particle Flux in the Ocean*. SCOPE, Wiley and Sons, Chichester, pp. 91-154.

- Honjo, S., K.W. Doherty, Y.C. Agrawal and V.L. Asper, 1984. Direct optical assessment of large amorphous aggregates (marine snow) in the deep ocean. *Deep-Sea Research*, 31, 67-76.
- Ittekkot, V., 1996. Particle flux in the ocean: Introduction. In: V. Ittekkot, P. Schäfer, S. Honjo and P.J. Depetris (eds.), *Particle Flux in the Ocean*. SCOPE, Wiley and Sons, Chichester, pp. 1-6.
- Käse, R.H., J.F. Price, P.L. Richardson and W. Zenk., 1986. A quasi- synoptic survey of the thermocline circulation and the water mass distribution within the Canary Basin. *Journal of Geophysical Research*, 91, 9739- 9797.
- Kasten, S., M. Zabel, V. Heuer, and C. Hensen, submitted. Nonsteady-state diagenesis and its documentation and preservation in marine sediment/pore water systems. In: *The South Atlantic in the Late Quaternary: Reconstruction of Mass Budget and Current Systems*. G. Wefer, S. Mulitza and V. Ratmeyer (eds.). Springer, Berlin Heidelberg New York.
- Kawase, M. and J.L. Sarmiento, 1985. Nutrients in the Atlantic thermocline. *Journal of Geophysical Research*, 90, 8961- 8979.
- Koroleff, F., 1983a. Determination of dissolved inorganic phosphate. In: *Methods of Seawater Analysis*. K. Grasshoff, A. Ehrhardt and K. Kremling (eds), Verlag Chemie, 126-129.
- Koroleff, F., 1983b. Determination of dissolved inorganic silicate. In: *Methods of Seawater Analysis*. K. Grasshoff, A. Ehrhardt and K. Kremling (eds.), Verlag Chemie, 175-180.
- Kremling, K. and A. Wenck, 1986. On the storage of dissolved inorganic phosphate, nitrate and reactive silicate in Atlantic Ocean water samples. *Meeresforsch*, 31, 69-74.
- Llinás, O., A. Rodríguez de León, G. Siedler and G. Wefer , 1994. The ESTOC Time Series Station Started Operation. *WOCE Newsletter*, 17, Nov. 1994.
- Llinás, O., A. Rodriguez de León, G. Siedler and G. Wefer, 1997. ESTOC Data Report 1994. *Inf. Téc Inst. Canario Cienc. Mar.*, 3, Telde, Gran Canaria.
- Llinás, O., M.J. Rueda, J. Pérez-Marrero, E. Pérez-Martell, R. Santana, M.G. Villagarcía, A. Cianca, J. Godoy and L. Maroto, 2002. Variability of the Antarctic intermediate waters in the Northern Canary Box. *Deep-Sea Research II*, 49, 3441- 3453.
- McDonald, R.W. and F.A. McLaughlin, 1982. The effect of storage by freeing of dissolute inorganic phosphate, nitrate and reactive silicate for samples from coastal and internal water. *Water Research*, 16, 95-104.
- Metcalf, W.G., 1969. Dissolved silicate in the deep North Atlantic. *Deep-Sea Research*, 16, 139- 145.

- Moreno, A., S. Nave, H. Kuhlmann, M. Canals, J. Targarona, T. Freudenthal, and F. Abrantes, F., 2002. Productivity response in the North Canary Basin to climate changes during the last 250 000 yr: a multi-proxy approach. *Earth and Planetary Science Letters*, 196, 147-159.
- Murphy, J. and J.P. Riley, 1962. A modified single solution method for the determination of phosphate in natural waters. *Anal. Chim. Acta*, 27, 31-36.
- Neuer, S. and M. Rueda, 1997. European Time-Series Station in Operation North of the Canary Islands. *U.S. JGOFS Newsletter*, March 1997.
- Nydahl, F., 1976. On the optimum conditions for the reduction of nitrate by cadmium. *Talanta*, 23, 349-357.
- Pätzold, J., Halbach, P. E., Hempel, G. and Weigert, M., 2000. Östliches Mittelmeer – Nördliches Rotes Meer 1999, Cruise No. 44, 22 January – 16 May 1999. *Meteor-Berichte, Universität Hamburg*, 00-3, 240 pp.
- Ratmeyer, V. and G. Wefer, 1996. A high resolution camera system (ParCa) for imaging particles in the ocean. System design and results from profiles and a three-month deployment. *Journal of Marine Research*, 54, 589-603.
- Riley, J.P. & J.P. Skirrow, 1975. The Micronutrient Element. *Chemical Oceanography*, 2, 245-297.
- Spear, K.G., 1993. The deep silica tongue in the North Atlantic. *Deep-Sea Research*, 40 (5), 925-936.
- Strickland, J.D.H & Parsons, 1972. A practical handbook of seawater analysis. *Fisheries Research Board of Canada*, 167 pp.
- UNESCO, 1978. *Technical Papers in Marine Science*, 28, 35 pp.
- UNESCO, 1984. La escala de salinidades practicas de 1978 y la ecuacion internacional de estado del agua de mar de 1980. *Documentos tecnicos de la Unesco sobre Ciencias del Mar*, no. 36.
- Vörösmarty, C.J., Fekete, B.M., Meybeck, M. and Lammers, R.B., 2000. Global system of river: Its role in organizing continental land mass and defining land-to-ocean linkages. *Global Biogeochemical Cycles* 14, 599-621.
- Welschmeyer, N.A., 1994. Fluorimetric Analysis of Chlorophyll a in presence of Chlorophyll b and Phaeopigments. *Limnol. Oceanog.* 39 (8), 1985-1992.
- Willenbrink, E., 1982. Wassermassenanalyse im tropischen und subtropischen Nordostatlantik. *Berichte aus dem Institut für Meereskunde Kiel*, 96, 72 pp.

8. Stationlist METEOR 53/1

GeoB #	Ships #	Date	Device	Time	Latitude	Longitude	Water	Recovery	Remarks
		2002		seafloor/ max. wire -length [UTC]			depth [m]		
7901-1	179	01.04.	CTD/ PINGER	01:57	34°26.5'N	26°12.6'E	3510		
7902-1	180	01.04.	MID-2	04:49	34°26.8'N	26°11.4'E	3511		recovery of mooring MID-2, two upper traps failed
7903-1	181	12.04.	CTD/ROS	17:07	29°10.0'N	15°30.0'W	3612	water for traps	CTD/ROS test
7903-2	181	12.04.	CTD/ROS	21:44	29°10.0'N	15°30.0'W	3613		failed, unclear sampling depths
7903-3	181	13.04.	CTD/ROS	01:47	29°10.0'N	15°30.0'W	3615	23 bottles	
7903-4	181	13.04.	CTD	05:49	29°10.0'N	15°30.0'W	3613		Microcats-Calibration
7903-5	181	13.04.	NOAA- Drifter	06:24	29°10.0'N	15°30.0'W			
7904-1	182	13.04.	CI14	07:51	29°13.6'N	15°27.0'W	3603		Recovery of mooring CI14 Lower trap stopped on bottle 4
7905-1	183	13.04.	MSD	15:35	29°13.8'N	15°27.2'W	3610		MSD-testing on wire
7905-2	183	13.04.	MSD	19:34	29°13.9'N	15°27.0'W	3610		MSD-testing on wire
7906-1	184	14.04.	CTD/ROS	01:09	28°44.0'N	15°40.0'W	3595	23 bottles	Sampling down to 3000 m
7907-1	185	14.04.	CTD/ROS	07:14	28°18.0'N	16°00.1'W	2859	24 bottles	Sampling down to the bottom
7908-1	186	14.04.	Test	13:18	29°05.0'N	15°56.0'W	3632		ANIMATE-Telemetry test
7909-1	187	14.04.	CTD/ROS	16:35	29°10.9'N	15°55.6'W	3632	24 bottles	Sampling down to the bottom
7909-2	187	14.04.	MSD		29°10.9'N	15°55.6'W	3632		MSD-testing on wire
7910-1	188	15.04.	SBU	08:17	29°10.6'N	15°55.2'W	3634		Deployment of DOLAN- buoy-mooring
7910-2	188	15.04.	MSD	16:10	29°10.9'N	15°55.6'W	3632		Deployment of MSD-mooring
7911-1	189	15.04.	CTD/ROS	22:18	29°09.8'N	15°43.8'W	3625	24 bottles	Sampling down to bottom
7912-1	190	16.04.	CI15/ANI MATE	08:55	29°10.8'N	15°25.7'W	3613		Deployment of the combined CI15 and ANIMATE mooring
7913-1	191	17.04.	CTD/ROS	03:07	27°55.0'N	16°18.0'W	2521	24 bottles	Sampling down to bottom
7914-1	192	17.04.	ROV	10:35	27°44.8'N	15°46.7'W	90		Balance, drive- and diving test
7914-2	192	17.04.	ROV/Par Ca	12:00	27°44.8'N	15°47.2'W	90		Testing
7915-1	193	17.04.	ROV	17:23	27°40.7'N	15°37.1'W	423		Testing
7916-1	194	22.04.	CTD/ROS	03:22	21°15.8'N	20°47.1'W	4154	23 bottles	Sampling down to bottom
7917-1	195	22.04.	CB12	09:23	21°16.0'N	20°47.2'W	4153		Recovery of CB12 mooring
7918-1	196	22.04.	CB13	13:31	21°16.8'N	20°46.7'W	4144		Deployment of CB13 mooring
7919-1	197	23.04.	CTD/ROS	06:16	20°56.5'N	19°23.4'W	3428	22 bottles	Sampling down to bottom
7919-2	197	23.04.	MUC	09:09	20°56.5'N	19°23.2'W	3429	30 cm	
7919-3	197	23.04.	SL12	11:44	20°56.3'N	19°23.4'W	3419	1127 cm	Core for Marine Geology Group
7919-4	197	23.04.	SL12	14:11	20°56.4'N	19°23.4'W	3421	1175 cm	Overpenetration 1 m
7919-5	197	23.04.	SL18	16:45	20°56.4'N	19°23.4'W	3420	1458 cm	Core for Marine Geochemistry Group
7919-6	197	23.04.	ParCa	19:11	20°56.8'N	19°24.8'W	3455		System failed
7919-7	197	23.04.	ParCa	23:18	20°56.6'N	19°26.6'W	3472		

*RV METEOR Cruise 53, Leg 1, Limassol – Las Palmas – Las Palmas - Mindelo*

GeoB #	Ships #	Date 2002	Device	Time seafloor/ max. wire -length [UTC]	Latitude	Longitude	Water depth [m]	Recovery	Remarks
7920-1	198	24.04.	CTD/ROS	07:01	20°45.0'N	18°35.0'W	2278	19 bottles	Sampling down to bottom
7920-2	198	24.04.	SL18	09:10	20°45.1'N	18°34.9'W	2278	1622 cm	
7920-3	198	24.04.	MUC	11:32	20°45.0'N	18°35.0'W	2278	30 cm	
7920-4	198	24.04.	ROV/Par Ca	13:35	20°45.1'N	18°35.1'W	2285		Testing of device
7920-5	198	24.04.	ParCa	22:48	20°45.2'N	18°34.9'W	2266		
7921-1	199	25.04.	SL18	06:30	20°48.3'N	18°15.6'W	1914	1689 cm	
7921-2	199	25.04.	ParCa	11:43	20°49.3'N	18°14.6'W	1948		
7922-1	200	25.04.	CTD/ROS	14:10	20°39.7'N	18°15.6'W	1265	17 bottles	Sampling down to bottom
7922-2	200	25.04.	SL18	15:36	20°40.0'N	18°15.7'W	1285	552 cm	Core bended
7922-3	200	25.04.	MUC	17:02	20°40.0'N	18°15.7'W	1289	23 cm	
7922-4	200	25.04.	ROV/Par Ca	20:20	20°40.0'N	18°15.7'W	1279		
7922-5	200	25.04.	ParCa	23:10	20°40.0'N	18°15.7'W	1279		
7923-1	201	26.04.	MUC	01:25	20°44.4'N	18°10.7'W	1516	26 cm	
7923-2	201	26.04.	SL12	02:45	20°44.4'N	18°10.7'W	1516	991 cm	
7924-1	202	26.04.	ROV/Par Ca	09:14	20°32.9'N	17°33.5'W	73		
7924-2	202	26.04.	CTD/ROS	12:10	20°32.8'N	17°33.4'W	73		Sampling down to bottom
7924-3	202	26.04.	MUC	12:36	20°32.8'N	17°33.4'W	73	24 cm	
7925-1	203	26.04.	SL18	18:35	20°17.5'N	18°15.7'W	1908	1014 cm	
7925-2	203	26.04.	ParCa	22:30	20°17.5'N	18°15.7'W	1908		
7926-1	204	27.04.	ParCa	03:38	20°12.8'N	18°27.1'W	2500		
7926-2	204	27.04.	SL18	05:21	20°12.8'N	18°27.1'W	2500	1330 cm	
7926-3	204	27.04.	MUC	07:15	20°12.8'N	18°27.1'W	2500	25 cm	
7927-1	205	27.04.	MUC	16:03	19°56.2'N	19°09.1'W	3128	29 cm	
7927-2	205	27.04.	SL12	18:07	19°56.2'N	19°09.1'W	3116	818 cm	
7927-3	205	27.04.	ParCa	00:32	19°56.3'N	19°09.1'W	3118		Test and profile
7928-1	206	28.04.	SL12	17:32	19°06.0'N	17°02.9'W	1350	840 cm	Core for Marine Geochemistry Group
7928-2	206	28.04.	SL12	18:55	19°06.0'N	17°02.9'W	1352	870 cm	Core for Marine Geology Group
7928-3	206	28.04.	MUC	20:03	19°06.0'N	17°02.8'W	1348	23 cm	
7928-4	206	28.04.	CTD/ROS	21:16	19°05.9'N	17°02.9'W	1368	18 bottles	Sampling down to bottom
7929-1	207	29.04.	ParCa	00:19	19°04.1'N	17°04.0'W	1425		
7930-1	208	29.04.	ParCa	03:04	19°14.1'N	17°04.0'W	1464		
7931-1	209	29.04.	ParCa	05:06	19°14.1'N	16°54.1'W	442		
7932-1	210	29.04.	CTD/ROS	12:55	19°00.0'N	17°17.0'W	1956	18 bottles	Sampling down to bottom
7932-2	210	29.04.	MUC	14:39	19°00.1'N	17°17.0'W	1964	32 cm	
7932-3	210	29.04.	SL12	17:21	19°00.0'N	17°17.0'W	1964	835 cm	
7932-4	210	29.04.	ParCa	20:44	19°00.0'N	17°17.0'W	1953		
7933-1	211	30.04.	ParCa	00:50	19°10.5'N	17°17.2'W	1950		
7934-1	212	30.04.	ParCa	04:27	19°10.3'N	17°27.5'W	1950		
7935-1	213	30.04.	ParCa	08:12	19°04.0'N	17°27.5'W	2117		
7936-1	214	30.04.	SL12	14:37	18°35.4'N	18°02.3'W	2690	227 cm	Core bended
7936-2	214	30.04.	MUC	16:29	18°35.5'N	18°02.2'W	2663	32 cm	

GeoB #	Ships #	Date	Device	Time	Latitude	Longitude	Water	Recovery	Remarks
		2002		seafloor/ max. wire -length [UTC]			depth [m]		
7936-3	214	30.04.	CTD/ROS	18:39	18°35.5'N	18°02.4'W	2702	21 bottles	Sampling down to bottom
7937-1	215	01.05.	ParCa	00:25	18°40.1'N	18°02.5'W	2667		
7938-1	216	01.05.	ParCa	05:06	18°50.1'N	18°02.5'W	2606		
7939-1	217	01.05.	CTD/ROS	12:57	18°05.4'N	18°55.0'W	3100	23 bottles	Sampling down to bottom
7940-1	218	01.05.	ParCa	15:47	18°05.4'N	18°55.1'W	3097		

ANIMATE – “Atlantic Network of Interdisciplinary Moorings and Timeseries for Europe” (EU-Project)

CB – Cape Blanc Mooring

CI – Canary Islands Mooring

CTD/ROS – CTD-Rosette-System

MID – Mid-Isopetra Deep mooring

MSD – Multi Sensor Device

MUC – Multicorer

NOAA – National Oceanographic Atmospheric Administration

ParCa – Particle Camera System

ROV – Remotely Operating Vehicle

SBU – Surface Buoy Unit

SL – Gravity Corer

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