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UBBC	Fachbereich Biologie/Chemie Abt. Meereschemie, Abt. Marine Mikrobiologie Universität Bremen, FRG
IfM	Institut für Meereskunde Universität Kiel, FRG
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DWD	Deutsche Wetterdienst Seewetteramt Hamburg, FRG

2. Research Program

Marine Geology

a. Paleoceanography

In order to reconstruct Late Quaternary surface and deep-water circulation in the western equatorial Atlantic sediments were planned to be retrieved on two transects perpendicular to the continental shelf and margin off northern Brasil, and east of the Amazon Fan. Additionally, the eastern Caribbean continental margin off Barbados shall be sampled for sediments, presumably containing only low amounts of terrigenous material. Sediment recovery will be carried out with a multicorer and a large box corer for surface samples and with a gravity corer for longer sediment cores at water depths mainly between 1000 and 4500 m. The combination of sample transects east and west of the Amazon Fan should enable the study of changes in intensity of the North Brazil Current (NBC), particularly east and west of the North Equatorial Countercurrent (NECC) retroflection located at about 49°W/5°N under modern conditions. Moreover, the sediments will allow the estimation of fluxes of terrestrial and marine material outside the direct influence of the Amazon discharge on the northeastern Brazilian margin and will be used to study changes in the westward transport of Amazon river load to the Caribbean region.

b. Amazon shelf sediments

The Amazon shelf is characterized by a modern submarine delta where recent bathymetric contouring revealed interesting features not yet fully investigated. A proposed track line with Parasound and HYDROSWEEP should cover an area with foreset beds. Furthermore, at the outer Amazon shelf, carbonate sedimentation should occur containing ooliths which shall be sampled and which are probably related to the development of the Amazon forest.

Particle flux and stable isotopes

Seasonal particle sedimentation shall be monitored over several years in the western equatorial Atlantic. For this purpose, three moorings with multi-sample sediment traps were installed on a SW-NE-transect during Meteor cruise 29/3. These moorings were planned to be recovered and redeployed. Our objective is to receive information about productivity and export flux in the equatorial upwelling area as well as further south in the more oligotrophic gyre (northern Brazil Basin) on a longer-term basis.

The particles collected will be investigated for species composition of planktonic organisms and their stable isotope composition as well as for the composition of organic matter and terrigenous components. The aim is to identify seasonal variations which play an important role for the formation and interpretation of sediments. The results provide a basis for the reconstruction of paleocurrents and productivity conditions in the South Atlantic from sediment cores. To recieve more information about the amount, size and type of particels suspended in the water column or sinking through it, a high-resolution particle camera will be used preferentially at the sediment trap mooring sites.

The stable isotopes of particulate matter from the water column and from the surface sediments will also be studied in relation to organic matter degradation processes. Samples from the water column (casts/net plankton) and from the surface sediments (multicorer) will be taken. The results of this study will be compared to data derived from the Baltic Sea to draw more general conclusions concerning the alteration of the nitrogen isotope signature.

Geophysics

During the cruise the shipboard echosounder systems HYDROSWEEP and PARASOUND will continuously record the bathymetry and sediment structures of the ocean floor. According to the results of these echosounder surveys geologic sampling sites can be more efficiently selected. Because of the rough and partly very steep morphology of the sediment surface at the continental slopes, the two acoustic shipboard systems are of great importance for the choise of suitable sample locations. At all stations the PARASOUND system will be tested with various frequences for the further development of the interpretation of the data obtained by the acoustic system. The comparison of the measurements to echogramms simulated by several relevant physical properties will be conductive for the comprehensions of the PARASOUND data.

Geochemistry

The sampling of the sediments deposited under the North Brasil Current (NBC) are linked to the working areas of the Special Research Project 261 further to the east (Equatorial Atlantic). Sampling strategy will allow us to document the depositional regimes influenced by different water masses and their variability through time as well as by sediment materials derived from the continent and shelf. Analyses of surface samples recovered with large box corers and multicorers together with sediment sequences from gravity cores should result in a detailed picture of both the recent sedimentary environments and former glacial/interglacial fluctuations. At selected stations supplementary core material will be recovered for geochemical analyses.

Micropaleontology

a. Paleobiology (Dinoflagellates)

The regional distribution of the species assemblages in the surface water, as well as the relation of living and empty cysts through the water column and in the sediment will be determined. As a primary producer, this important phytoplankton group yields valuable informations concerning the current systems in the South Atlantic. The distribution of the ultrastructure types within the associations of calcareous cysts shall be related to environment factors (temperature, salinity, light), which will allow the interpretation of fossil associations. The study of the variations of the associations which should change between glacial and interglacial periods is of special importance in this context. Sediment material will be sampled, and plankton will be extracted by filtration of water samples from various depths (Niskin bottles), and isolation of living individuals. Apart from sediment samples, plankton samples from the surface water will be taken daily by the ship's membrane pump.

b. Coccolithophore communities:

There is little known about the recent distribution of one of the most important groups of pelagic carbonate-producing organisms. During Leg M34/3 and M34/4, horizontal and vertical sampling profiles will be collected to investigate the composition of the coccolithophorid communities in the water column. Surface water samples will be collected regularly during cruise time with the sea water pump to receive a continuous plankton profile. To record the vertical composition of the coccolithophorid communities in the upper 200 m of the water column, samples will be taken with Niskin bottles attached to the multinet.

Trace element cycling

The vertical transport of trace elements from the mixed layer until their burial in the sediments will be investigated in cooperation with the sediment trap program. Several productivity regions typical for the western and the equatorial Atlantic will be studied. In addition to the mostly fast sinking particles in the traps, suspended material will be sampled at the mooring stations during M34/4 by in-situ-pumps and GoFlo-bottles. The comparison of the trace element composition in both kinds of particles from the water column with those of the sediments and their relation to the vertical distribution of dissolved trace elements in the water column are expected to provide important clues to transport and sorption mechanisms as well as to the general geochemical behaviour of these elements in the ocean. Part of the particulate material collected by the in-situ pumps will be provided for microbiological studies (AG U. Fischer, Microbiology). Particles will be studied with respect to microbiological colonization by bacteria.

Oceanography

A region of special interest in the global circulation is the western tropical Atlantic, where water exchange across the equator takes place. For the upper ocean, the major flow is from the South Atlantic to the North Atlantic by the North Brazil Current located just off the Brazilian shelf. Still unresolved is the question how the water transfer towards the Caribbean occurs. Shipboard ADCP-measurements are planned to investigate transports and water mass distributions as well as the continuation of the North Brazil Current toward the Caribbean. Several shipboard ADCP-sections complemented by hydrographic CTD-measurements are planned for sections crossing the North Brazil Current. On four earlier METEOR cruises, direct current observations of the North Brazil Current were carried out off the northeastern tip of Brazil and near the equator for different seasons. During M34-4, sections are planned near the northeastern tip of Brazil but also further northwest to investigate the strength of the North Brazil Current and the flow toward the Caribbean.

3. Narrative of the Cruise

RV METEOR departed from Recife, Brazil, on Tuesday, March 19, 1996 at 16:00 local time with a delay of about 8 hours due to the late arrival of some of the scientific and ship's equipment. In addition to two meteorolgists, 28 scientist were on board. Most of them were from the Geoscience Department of the University of Bremen. Other groups were from the Marine Chemistry and the Marine Microbiology Department of the University of Bremen, from the „Institut für Ostseeforschung" at Warnemünde and the „Institut für Meereskunde" at Kiel. Two marine geologists from the Universidade Federal Fluminense, Niteroi, Rio de Janeiro, were also on board, as was one observer from Brazil.

After leaving the 12 sm zone, we began with ADCP-profiling and a first CTD-profile (5 stations) to study water mass distribution and transport in the North Brazil Current. We further started with PARASOUND- and HYDROSWEEP-profiling to obtain information about ocean floor topography and the acoustic character of the sediment. Lateron, plankton material was taken from the ship's membrane pump to measure chlorophyll, study dinoflagellate and coccolithophore communities and perform microbial studies. On March 21, we could recover the first sediment trap mooring (WA6) deployed in August 1994 with two traps and one current meter; all instruments had worked perfectly. The two complete series of trap samples showed low seasonality and low fluxes in the oligotrophic gyre of the Brazil Basin. At this site, we further carried out water sampling with in-situ pumps, GoFlo- and Niskin water bottles and a mulitnet. After the deployment of a mooring with a similar configuration as WA6, we used the multicorer to obtain surface sediments.

After terminating this station, we continued our cruise track 260 sm to the northeast and reached the second sediment trap mooring site WA7 on March 23. We recovered the array completely and obtained two more complete series of samples recording particle flux over the last 19 months. As expected, particle fluxes at this site located between the oligotrophic gyre and the equatorial upwelling, were significantly higher than at the WA6 site. Lateron, we carried out an intensive water column sampling program using similar equipment as at the first mooring site. In addition, we used a high-resolution particle camera in the profiling mode. In the early morning of March 24, we redeployed the mooring in a similar configuration and proceeded 270 sm to the third mooring site located close to the equator. We reached this location on March 25, and commenced with a sampling programe of the water column. On early March 26, we recovered the mooring WA8 completely and redeployed it shortly afterwards. After sampling the sediment surface with the multicorer, we continued our cruise to the southwest to start with the first geological profile A, located off the coast of northern Brazil between Fortaleza and Natal. We reached the starting point of transect A on Friday, March, 29. According to PARASOUND and HYDROSWEEP, coring sites between 3100 m and about 830 m were chosen along the NE-SW transect A; suitable sites were difficult to find due to widely extended slumping structures and rough bottom topography with channel systems at the continental margin. The shallowest site at 830 m corresponded to a coring site chosen by the JOPS expedition (core 3129) conducted with „RV VIKTOR HENSEN" in early 1995. We then proceeded to the beginning of the second NE-SW transect B located about 150 miles further to the west. Before commencing this profile, we cored another site in 770 m water depth (JOPS, core 3104). Along a transect B, we sampled three sites with multicorer and gravity corer between 2200 and 3100 m water depth.

On early monday of April 1, we terminated transect B and continued our track to the north, beginning an ADCP-profile which followed the equator to the Amazon delta. On late Wednesday, April 3, we started geophysical profiling with PARASOUND and HYDROSWEEP and coring in the Amazon delta. The main objectives of this cooperative research with the Universidade Federal Fluminense, Niteroi, Rio de Janeiro, were to understand the sedimentation pattern in the delta foreset and its relationship to sea level fluctuations, as well as the study of the presence of Amazon ooliths. In the southern part of the delta, we observed sand waves crossed by erosion channels as well as fine-grained foreset sediments. We obtained one core with fine-grained, gas-containing foreset sediments from 35 m water depth; another core was retrieved from 70 m water depth. Surprisingly, the core catcher contained consolidated sandy beach rocks obviously uncovered by recent sediments. According to our geophysical profiling, it appears as if large areas of the delta are characterized by zero deposition. On April 5, we obtained two cores from 45 m water depth with clayey sediments containing high amounts of gas, presumably methane. The sediment surface was covered by many oysters; we concluded that recent sedimentation had to be very low. On early April 6, we cored two sites in 100 and 130 m water depths in the northern part of the delta. Using a box corer, we recovered carbonate-bearing quarz sands, probably containing some ooids. At the deeper site, we retrieved clayey material containing carbonate particles; parts of the sediment were already consolidated by organisms and iron oxides/hydroxides (hard grounds).

We finished our coring and profiling program on the Amazon shelf and continued our track to the NE; underway, we continued with ADCP- and CTD-measurements. On early Sunday, April 7, we arrived at ODP site 940 which is located slightly east of the glacial Amazon channel. We retrieved sediments with the multicorer and gravity corer from the eastern overbanking sediments; lateron, we routinely sampled the water column with pumps, Niskin-and GoFlo-bottles. Lastly, we lowered the particle camera and the multinet. After about 24 hours, we terminated this station and continued with a detailed PARASOUND and HYDROSWEEP-profiling crossing the ODP sites 934, 935 and 936. On Monday 8, we started our transect 640 sm to the west to the next ADCP-CTD-profile, located off Guyana which we reached on Wednesday 10. There, we sampled 7 CTD-stations from the continental rise to the deep sea; at two sites, we used the particle camera in conjunction with the CTD. On late Thursday, April 11, the investigations off Guyana were finished and we commenced with the geological profile C off Barbados and continued our oceanographic studies. We used PARASOUND and HYDROSWEEP on a 200 sm SE-NW transect to investigate the bathymetry and sediment structure on the continental margin off Barbados and searched for suitable core locations. Particularly between 1500 and about 2000 m water depths, core locations were rather easy to find; we obtained gravity cores and multicorer samples from four sites. Finally, we intended to find a deeper site at the continental rise off Barbados and we obtained a core from 2467 m water depth. On Sunday morning, April 14, we finished our station work. We arrived in Bridgetown, Barbados, on early Monday April 15.

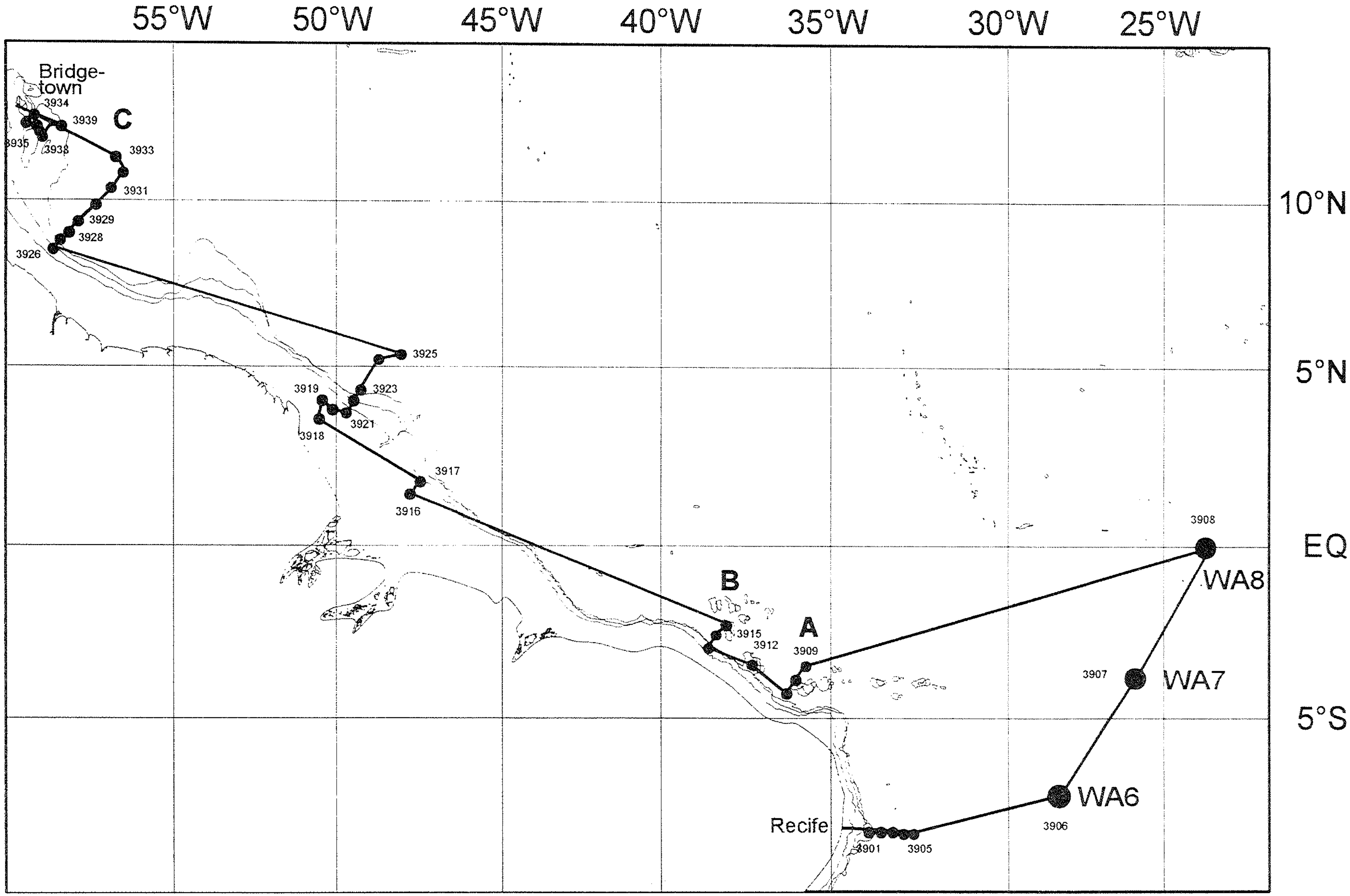


Fig. 1. Cruise track during M34/4. Mooring sites with sediment traps are indicated as black dots. A detailed map of the Amazon area is shown in chapter 4.11.4.

4. Preliminary results

4.1. Shipboard ADCP-Measurements and CTD-O_2-Transparency Probe

(U. Garternicht, B. Baschek)

4.1.1. Methods

A vessel-mounted acoustic Doppler current profiler (VM-ADCP) has been used to measure open ocean currents in the western tropical Atlantic. The good performance of the ADCP and the associated Ashtech-GPS lead to an almost complete data set with a vertical resolution of 8 m, beginning at 21 m depth, and a horizontal resolution of about 1.5 km.

33 CTD/O_2-profiles (with a conductivity-temperature-depth sonde plus oxygen sensor and transmissiometer) were taken with a self-contained SBE 19 sonde at a sampling rate of 1-2 samples/dbar. At about half of the stations, the CTD was attached to the wire 50 m above a bottom reaching multicorer. Profiles with CTD were only down to 1000–1200 m water depth. The CTD/O_2-sensors have been calibrated prior to the cruise by the manufacturer. The calibration coefficients from this calibration have been used to process the down-cast data on board shortly after reading them out of the memory of the CTD. A new oxygen sensor has been installed in place of one damaged during the preceeding cruise. Comparison with chemically analyzed water samples (Winkler titration) show the values of the new oxygen sensor as being to low (approx. 0.4 ± 0.4 ml/l). There were too few analyzed samples to perform another calibration. At some of stations the down-cast profiles of beam attenuation measured with the transmissiometer show a broad peak over several 100 m centered around 400–500 m, which had no equivalent in the upcast profiles. In such cases, the upcast profile of beam attenuation coefficient was taken.

The ships data recording system (DVS) has collected hull temperature and salinity, shipsdrift, depth and meteorological data. A linear correction scheme from Autosal-analyzed surface water samples was used to calibrate salinity values (courtesy of M. Vanicek and W. Zenk, M34/3).

4.1.2. Preliminary Scientific Results

In the upper western tropical Atlantic warm water of the South Atlantic crosses the equator to the north within the North Brazil Current (NBC), compensating much of the southward flow of North Atlantic Deep Water (NADW) confined to depth below 1200 m. The NBUC and the South Equatorial Current (SEC) have been shown to feed the NBC in its source region located at the northeastern tip of Brazil (Schott et al., 1994). These three currents have been crossed during the cruise, the latter several times.

Figure 2 shows the geostrophic velocities of the NBUC (relative to the deepest available CTD-data at about 1150 m) as derived from the hydrographic section at 8°S. The current core was very close to the shelf and was not covered by this survey. The geostrophic transport of the NBUC was about 25 Sv (1 Sv=10^6 m^3s^{-1}) to the north, whereas the additional wind-driven Ekman transport to the south was negligible. The horizontal current fields along the cruise track can be seen in Figure 3 as measured by the ADCP. In the upper 300 m the NBC transported about 18 Sv along the South American coast to the northwest. Maximum velocities wee above 1 m/s in 100 m depth. Between 36° and 38°W, an anticyclonic recirculation cell was found to flank the NBC to the south below 75 m depth. The CTD/ADCP-transect at roughly 5°N exhibited northwestward flow off the South American shelf west of 48°W. The upper-layer velocity field along the equator was dominated by the Equatorial Undercurrent (EUC) with eastward velocities up to 80 cm/s. The section along the equator (Fig. 4) marks the source region of the EUC which was between 42°–43°W. The depth of its current core rapidly decreased to the east; it was 250 m at 43°W, 100 m at 38°W and 50 m at 24°W.

The two sections offshore of Guayana and Barbados have been completed successfully. They have not been processed during the cruise due to the ending of the survey in Barbados. It is intended to combine these direct ADCP and indirect geostrophic current measurements with water mass characteristics from the CTD/O_2 to find the pathways along which warm waters of the South Atlantic flow into the Caribbean Sea.

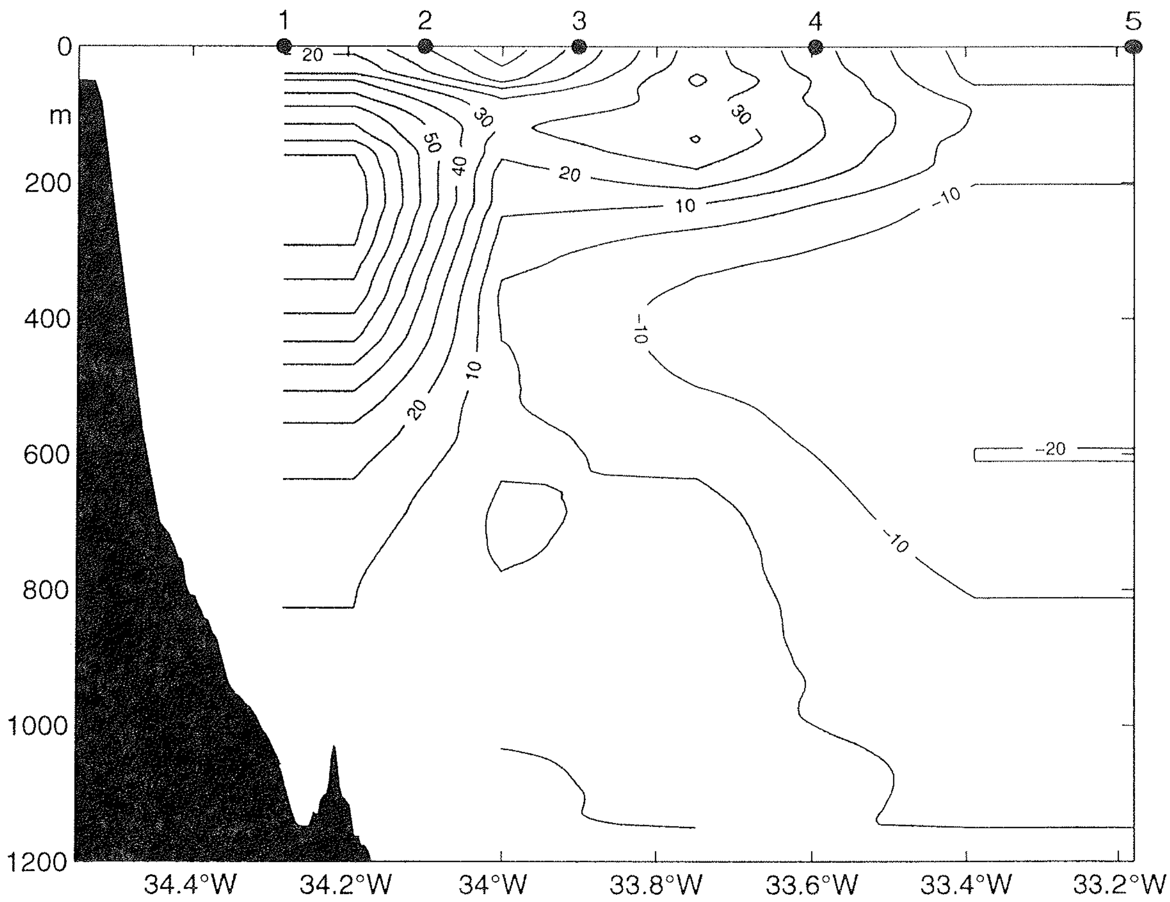


Fig. 2. Geostrophic velocities of the NBUC from a hydrographic section at 8°S. The reference level is about 1150 m. Northward velocities are shaded and the contour interval is 10 cm s^{-1}.

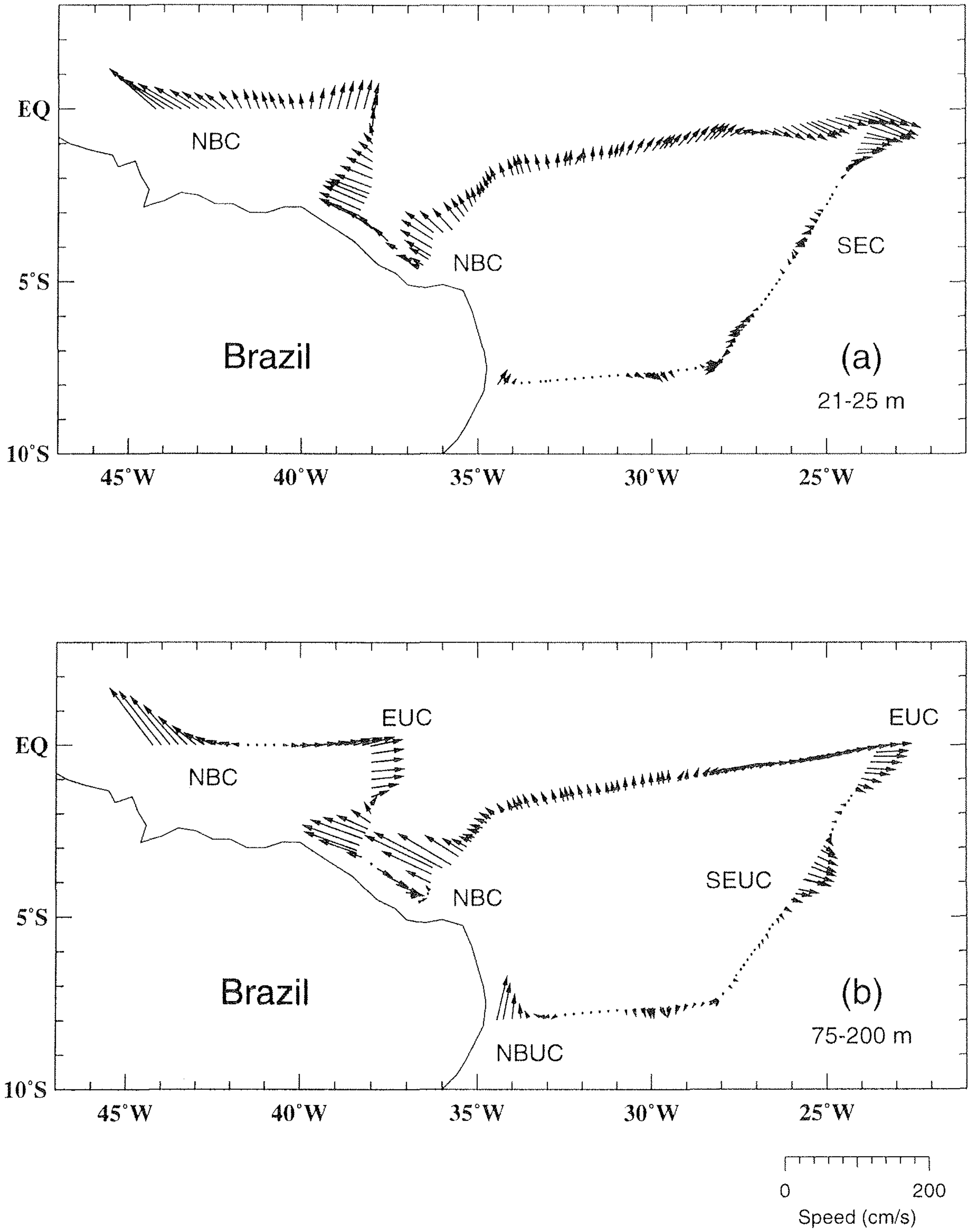


Fig. 3. The horizontal current field along the cruise track as derived from VM-ADCP (a) within the surface layer (21-25 m) and (b) within the subsurface layer at 75-200 m depth.

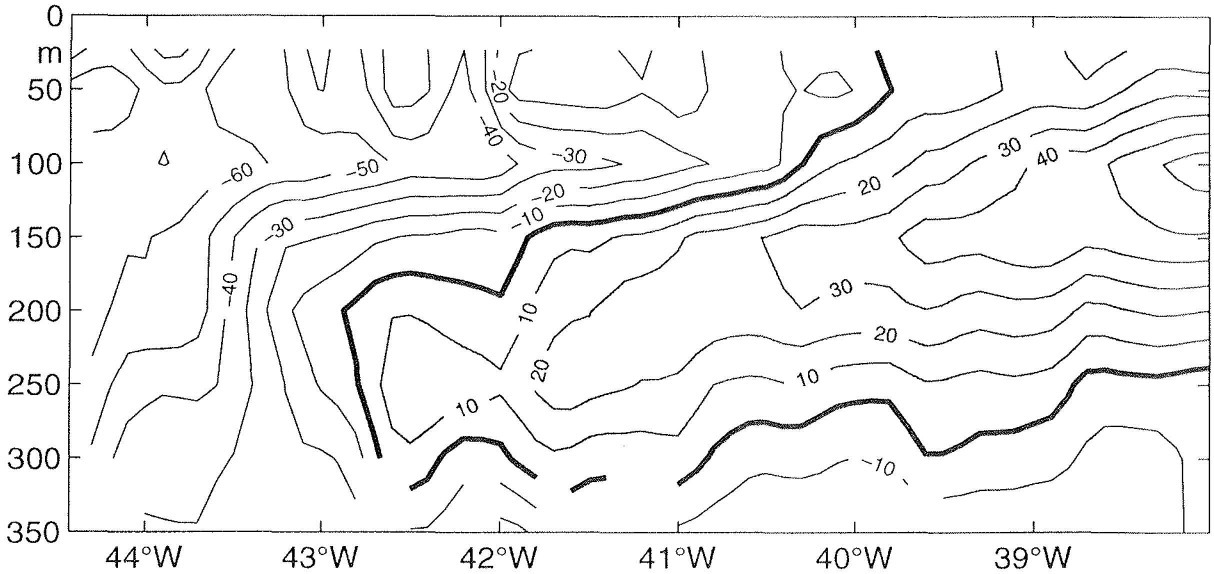


Fig. 4. Zonal velocities from the VM-ADCP-section along the equator at the source region of the EUC. The EUC's eastward velocities are shaded. The contour interval is 10 cm s^{-1}.

4.2. Marine Chemistry

(A. Deeken, H. Dierssen)

A major key for understanding the biogeochemical cycling of chemical elements in the ocean are particle-water interaction processes. The main objectives during this cruise were to increase our knowledge about the control of trace element distribution in the water column which interact with biogenic and abiotic particles and to investigate how particle sedimentation in a high productivity region effects the vertical trace element distribution. The sampling strategy was to collect water samples, samples of suspended particulate material (SPM) and subsamples from three sites with multi-sample sediment traps; the latter were deployed on a SW-NE-transect during METEOR cruise 29/3 (see Fig. 1).

4.2.1. Water Sampling

At all three stations where sediment traps were recovered/redeployed (Fig. 1) and one station from the Amazon Fan, 12 GoFlo-bottles from GENERAL OCEANICS were taken to analyze the vertical distribution of trace elements in the water column. To minimize contamination, GoFlo-bottles with pressure valves were employed, enabling the bottles to remain closed while passing through the surface layer. At a depth of 10-15 m, these bottles will open. For lowering through the water column, the GoFlo-water-sampler and the in-situ pumps were attached to a metal-free and non-greased KEVLAR® wire. All samples from the water column were collected rigorously applying clean sampling techniques to avoid contamination. A laboratory container proved to be a valuable facility for this purpose. All manipulations after subsampling were performed under a clean bench in the lab-container. A total of 48 water samples were collected for nutrients, oxygen and trace element analysis. Part of the collected water samples were provided for other studies (AG Wefer (GeoB), AG Lochte (IOW) and AG U. Fischer (UBBC)). The nutrients phosphate and nitrate were kindly analyzed by AG Schulz with an air-segmented Autoanalyser. Silicate was analyzed according to a standard photometric procedure. Immediately after collecting, oxygen content was determined by conventional Winkler titration. The resulting values show a similar depth profile than the oxygen sensor of the CTD-sonde. The absolute values, however, deviate somewhat from each other (see chapter 4.1).

The only trace element which was determined on board was Al, which was determined spectrophotometrically (fluorescence) with lumogallione (after Hydes and Liss, 1976). The data quality control will be carried out onshore. All other trace elements (primarily Cd, Co, Cr, Cu, Mn, Ni and Pb) will be analyzed onshore with anodic stripping voltammetry (ASV) or graphite furnance atomic absorption spectrometry (GF-AAS). After the water samples for trace elements were filtered through a polycarbonate filter (0,4 µm pore size, NUCLEPORE) in a plastic container, they were acidified with subboiled HNO_3 for storage.

4.2.2. In-situ Filtration of Suspended Particles

At the same stations where sediment traps were recovered/redeployed and one station from the Amazon Fan, suspended particulate material (SPM) was filtered using in-situ pumps at different depths (stations GeoB 3906 (100 m, 400 m, 700 m and 1200 m), GeoB 3907 (100 m, 400 m, 700 m, 1200 m, 2000 m, 3000 m, 4000 m and 5000 m), GeoB 3908 (100 m, 400 m, 700 m and 1200 m) and GeoB 3925 (100 m, 400 m, 700 m and 1200 m)) (Table 1).

The filtered suspended particulate material is supposed to consist of slowly sinking biogenic and terrestrial detritus exhibiting a large surface area for sorptive processes. Due to the low concentration of SPM, larger volumes of sea water have to be filtered, if trace elements are to be analyzed in SPM. Between 300 l and 600 l sea water from depths down to 5000 m were filtered through acid cleaned polycarbonate filter (∅ 293 mm; 0,4 µm pore size, NUCLEPORE) using an in-situ pump from CHALLENGER. To reduce contamination, a metal-free and non-greased KEVLAR® wire was used and all handling of the filters was performed under a clean bench. From pump deployments, a total of 20 filters was obtained. The filters with the retained particles will be examined for trace elements later in the laboratory in Bremen. Part of the particulate material collected by the in-situ pumps were provided for microbiological studies (AG U. Fischer). Aliquots of the material caught at the three mooring stations with intercepting sediment traps consists of larger, faster sinking particles which incorporated trace elements during their formation and by scavening of SPM; they will be analyzed in Bremen for trace and major components after digestion with nitric and hydrofluoric acid.

Table 1. Location and depth of sampling with the in-situ pumps (*pump failed, **filter teared)

Meteor-No./ GeoB-No.	Date	Location	Water depth (m)	Depth of pump (m)	Pumping time (min)	Pumping volume (l)
70/3906	21.03.96	07°25.6S	5581	100	60	826**
		28°09.2W		400	60	541
				700	60	598**
				1200	60	475
71/3907	23.03.96	03°56.4S	5553	100	60	864**
		25°41.2W		400	60	551
				700	60	482
				1200	60	540
				2000	60	509
				3000	60	571
				4000	60	561
				5000	60	576
72/3908	25.03.96	00°01.3S	3620	100	60	387
		23°28.3W		400	60	533
				700	*	*
				1200	60	545
89/3925	07.04.96	05°08,4N	3150	100	60	307
		47°31,8W		400	60	532
				700	60	535
				1200	60	586

4.3. Plankton Samples

4.3.1. Dinoflagellate Investigations

(A. Freesemann, B. Karwath)

Dinoflagellates are unicellular, biflagellated organisms, representing one of the major groups in the marine phytoplankton. During their life-cycle, dinoflagellates undergo certain stages: a motile vegetative-thecate stage and a resting cyst stage. Dinoflagellates in the motile vegetative-thecate stage usually consist of cellulose, the only exception being the calcareous-walled vegetative-coccoid *Thoracosphaera heimii*. The resting-cyst stage is in most cases organic-walled, but calcareous tests are also known („calcispheres"). During this cruise, phytoplankton samples were collected from surface waters to 100 m depth. They were analysed for the content of living dinoflagellates, especially calcareous resting cysts and the vegetative *Th. heimii*. Of special interest are the interaction between the species associations and the related environmental parameters (temperature, salinity, light). Knowledge of these may allow a better interpretation of fossil assemblages in the sedimentary record.

Surface water was sampled with the ship´s membrane pump three times per day (morning, mid-day, afternoon). The water was passed through a 100 µm mesh-sieve (DIN 4188) to separate the zooplankton. It was then filtered through 5 µm gauze (polycarbonate filters) using a vacuum pump system (Table 2). The samples were scanned for vegetative-thecate dinoflagellates, calcareous cysts and the vegetative-coccoid *Th. heimii*. Individual specimens were isolated and rinsed in polyterene Cell Wells™ with different culture media (f/2 35‰, K 35‰, filtered seawater), attempting to culture calcareous cysts under „on board" conditions using the local day/night cycle and temperatures between 20° and 25°C. Germination experiments and routine culturing of living calcareous cyst producing dinoflagellates will be done at the Laboratory at Bremen for the investigation of productivity, life-cycles, biomineralisation and systematics. The remaining 100 ml of seawater were stored together with the polycarbonate filters in 250 ml NALGENE polycarbonate flasks and fixed with 3-4% Formaldehyde. For transportation, the samples were stored in the dark at 4°C.

In addition, about 10 l of seawater were collected with a Rosette using 30 l Niskin-bottles (Table 3). Samples were taken at depths of about 20, 50 and 100 m. The obtained sea water was treated in the same manner than the samples from the ship's membrane pump. All stored samples and filters will be prepared for Scanning Electron Microscopy (SEM) at the Laboratory for the examination of the composition and regional distribution of dinoflagellate communities in the equatorial South Atlantic.

Motile vegetative-thecate stages have been observed in every sample (calcareaus resting cysts in almost every) except those taken from the Amazon Delta. Here, salinities dropped from 34‰ to 12‰ and even further below. In marine environments, dinoflagellates were abundant to about 20 m depth, becoming rarer towards 100 m. Predominant forms of cacareous dinoflagellates were *„Sphaerodinella" albatrosiana*, *„S." tuberosa* and the vegetative-coccoid *Th. heimii*. The cysts *Orthopithonella granifera* and *Rhabdothorax* sp. were rarely observed. Organic-walled cysts were extremely rare. About 270 specimens of mainly calcareous dinoflagellates and some motile stages have been isolated for cultivation on board for further examination at Bremen University. The cells were scanned at regular intervalls. After a time period of four weeks excystment has been observed in a number of cells, only some resulting in the production of a sufficient number of motile specimens.

Table 2. Surface water samples for dinoflagellate analyses. Sampling with 5 μm vacuum pump filtration.

Sample No.	Time of filtration UTC	Station	Latitude S/N	Longitude W	Water depth (m)	Water temperature (°C)	Salinity (‰)	Volume of filtered water (l)
3/20a	10.30		07°52.9' S	33° 00.2'	3399	28.6	34.52	40
3/20b	16.30		07°47.1' S	31°51.4'	4982	28.9	34.51	40
3/20c	21.30		07°42.4' S	30°54.6'	-	-	34.6	30
3/21a	10.30		07°30.3' S	28°31.2'	5000	28.4	34.44	30
3/21b	16.30	3906	07°25.5' S	28°08.0'	5411	28.9	34.41	30
3/21c	21.30	3906	07°25.9' S	28°08.2'	5280	28.6	34.45	30
3/22a	13.30		07°27.7' S	28°06.9'	4868	28.6	34.48	30
3/22c	21.45		06°18.9' S	27°18.3'	5650	28.8	34.31	13
3/23a	11.40		04°10.6' S	25°47.8'	5376	28.6	34.15	30
3/23b	16.30	3907	03°56.9' S	25°41.0'	5555	29.0	34.24	30
3/24a	11.30		03°54.7' S	25°41.7'	5554	28.6	34.22	30
3/24b	18.00		03°54.7' S	25°32.7'	5558	28.7	34.04	30
3/24c	22.00		03°30.1' S	25°23.4'	5609	28.6	33.93	30
3/25a	11.00		01°11.2' S	24°07.0'	4751	28.6	33.95	30
3/25b	17.00		00°14.6' S	23°35.7'	3780	28.1	34.12	30
3/25c	21.00		00°01.3' S	23°28.1'	3609	28.0	34.07	30
3/26a	11.00		00°00.4' N	23°26.4'	3710	28.0	34.12	30
3/26b	16.30	3908	00°00.4' S	23°25.6'	3690	28.3	34.14	30
3/26c	22.00		00°08.1' S	24°10.3'	2884	28.1	34.08	30
3/27a	11.00		00°34.1' S	26°35.1'	3674	28.4	33.93	30
3/27b	17.00		00°47.8' S	27°52.2'	3755	28.7	34.02	30
3/27c	21.00		00°55.1' S	28°32.8'	4089	28.6	33.87	30
3/28a	12.00		01°25.7' S	31°22.5'	4903	28.5	34.01	30
3/28b	16.30		01°34.4' S	32°10.0'	4679	28.5	34.09	30
3/28c	21.30		01°45.1' S	33°08.5'	4485	28.7	34.26	30
3/29a	13.30		03°21.6' S	35°36.7'	3594	-	34.16	30
3/29b	16.30		03°33.9' S	36°02.5'	3289	28.9	34.33	30
3/29c	20.30	3909	03°32.6' S	36°12.6'	3173	29.0	34.26	30
3/31b	16.30		02°43.3' S	38°13.6'	2465	29.0	34.29	30
3/31c	21.00		02°43.3' S	38°13.7	1010	28.9	34.43	50
4/1a	11.00		01°26.3' S	38°00.0'	4141	28.9	34.37	50
4/1b	16.30		00°34.1' S	27°59.9'	4380	29.1	34.37	50
4/2a	11.00		00°00.0'	41°03.1'	3795	28.1	34.3	50
4/2b	16.30		00°00.0'	42°05.2'	3859	28.5	34.36	50
4/2c	20.15		00°00.0'	42°49.7'	3630	28.4	34.36	50
4/3a	13.00		00°27.2' N	46°22.0'	44.2	28.4	32.78	30
4/3b	16.30		00°34.6' N	46°52.9'	30.9	28.4	30.75	30
4/3c	20.15		00°46.7' N	47°42.7'	42.1	28.2	12.2	3.0
4/4a	10.50		01°54.0' N	48°15.2'	48.1	28.1	29.11	30
4/4b	16.30		02°17.7' N	48°09.6'	75.9	28.3	32.91	30
4/4c	21.00		02°37.1' N	48°43.5'	92.9	28.1	32.13	30
4/5a	10.50		03°11.6' N	49°23.4'	78.8	28.0	30.1	30
4/5b	17.00		03°41.1' N	49°23.4'	50.1	28.1	19.16	3.5
4/5c	20.15		03°42.2' N	50°24.3'	49.3	27.8	19.34	3.0
4/6a	12.00		04°36.0' N	49°42.1'	1937	27.7	33.79	50
4/6c	20.30		05°00.4' N	48°46.4'	2659	27.6	34.20	50
4/7a	12.00		05°08.6' N	47°31.7'	3197	27.5	34.3	50
4/7b	16.00	3925	05°07.9' N	47°30.8'	3167	27.6	34.29	50
4/7c	20.00		05°08.1' N	47°30.5'	3187	27.5	34.29	50
4/10b	17.30		08°22.6' N	58°04.7'	1282	27.4	33.36	50
4/11b	18.00		10°26.6' N	56°50.0'	4089	27.1	-	50
4/12a	12.00		11°54.2' N	57°48.9'	3047	27.2	33.63	40
4/12b	18.00		12°15.8' N	58°20.2'	1955	27.1	33.46	40

Table 3. Water samples for dinoflagellate analyses taken from 30 l Niskin-bottles at about 20, 50, 100 m water depth (filtration with 5 µm polycarbonate filters).

Sample No.	Time UTC	Water depth (m)	Volume of filtered water (l)	Latitude S/N	Longitude W	SST (°C)	Salinity in surface water (‰)
Station 3906							
20 m	18.10	5215	13	07°25.4′ S	28°07.9′	28.8	34.47
50 m			13				
100 m			13				
Station 3907							
20 m	18.45	5555	13	03°55.7′ S	25°40.9′	29.6	34.38
50 m			13				
100 m			13				
Station 3908							
20 m	15.00	4234	13	00°00.2′ S	23°23.8′	28.3	34.12
50 m			13				
100 m			13				
Station 3925							
20 m	18.30	4808	13	05°07.8′ N	47°30.6′	27.6	34.29
50 m			13				
100 m			13				
Station 3932							
20 m	23.30	4239	13	10°59.9′ N	56°30.0′	-	-
50 m			13				
100 m			13				

4.3.2. Coccolithophore Communities

(M. v. Herz, H. Kinkel)

Coccolithophorids are a diverse group of marine phytoplankton belonging to the algal class Prymnesiophyceae. They produce external plates of carbonate, named coccoliths. Coccoliths are a major component in almost all ocean sediments. Their distribution in the sediments is relatively well known, but information on their abundance, ecology and physiology in the surface waters is rare. The water samples taken during that cruise will allow us to better understand the relationship between living communities and the assemblages in the sediments. At 4 stations, water samples of 2 l were taken from the rosette with 6 Niskin bottles (30 l) or from the small Niskin-bottles (1.2 l) attached to the multinet (depths generally at 200 m, 100 m, 75 m, 50 m and 20 m). In addition, 37 surface water samples from about 3.5 m water depth were taken from the vessel's membrane pump system along the cruise (see track plot, Fig. 1), mostly at dawn, high noon, twylight and midnight. Generally, 2 of the water samples were filtered through cellulose nitrate filters (25 m in diameter, 0.45 m pore size) by a vacuum pump immediately. Without washing, rinsing or chemical conservation, the filters were dried at 45°C for at least 24 and then kept permanently dry with silica gel in transparent film to protect them from humidity. The filtered material will be used for studies on distribution and composition of the coccoloithophorid communities with Scanning Electron Microscope (SEM). Species composition and abundances will be determined by identification and counting on measured filter transects.

4.3.3. Chlorophyll-a Measurements

(V. Diekamp. I. Engelbrecht)

For the determination of chlorophyll-a concentrations in the surface waters, 0.5 of seawater was collected 3 times a day from the ship's seawater pump (inlet in about 3.5 m water depth). The water was filtered onto glass fibre filters and frozen to -20°C. Chlorophyll-a measurements by means of photometry will be carried out in the laboratory in Bremen. The chlorophyll-a data should give information on seasonal and regional variability in biomass distribution; satellite-derived chlorophyll-a concentrations may also calibrated against these mesurements. For sampling locations see Table 4.

Table 4. Sampling locations for chlorophyll-a measurements.

No.	Date	Time UTC	location	Water-depth (m)	Salinity (‰)	Water-temp. (C)	Sample-volume (l)
222	20.03.96	11:30	07°52.0S,	4698	34.52	28.7	2x0.5
223			42°48.3W				
224	20.03.96	14:58	07°48.7S,	5035	34.55	29.0	2x0.5
225			32°09.4W				
226	20.03.96	21:16	07°42.7S,	5344	34.59	28.8	2x0.5
227			30°58.1W				
228	21.03.96	11:10	07°29.5S,	5562	34.42	28.4	2x0.5
229			28°22.2W				
230	21.03.96	15:09	07°27.5S,	5052	34.40	28.8	2x0.5
231			28°08.1W				
232	21.03.96	21:57	07°25.8S,	5275	34.46	28.6	2x0.5
233			28°08.1W				
234	22.03.96	11:54	07°27.8S,	4854	34.47	28.5	2x0.5
235			28°06.8W				
236	22.03.96	14:14	07°26.9S,	4878	34.48	28.7	2x0.5
237			28°06.6W				
238	22.03.96	21:11	06°24.1S,	5645	34.30	28.7	2x0.5
239			27°22.0W				
240	23.03.96	11:30	04°12.5S,	5421	34.12	28.6	2x0.5
241			25°49.3W				
242	23.03.96	14:52	03°58.7S,	5554	34.26	28.7	2x0.5
243			25°39.9W				
244	23.03.96	21:51	03°54.8S,	5559	34.26	28.9	2x0.5
245			25°40.4W				
246	24.03.96	11:24	03°54.6S,	5552	34.22	28.6	2x0.5
247			25°41.5W				
248	24.03.96	15:18	03°54.9S,	5558	34.21	28.6	2x0.5
249			25°36.7W				Kreiselp.
250	24.03.96	21:41	03°34.4S,	5327	33.95	28.8	2x0.5
251			25°25.8W				
252	25.03.96	11:29	01°12.8S,	4297	33.97	28.6	2x0.5
253			24°07.9W				
254	25.03.96	14:11	00°48.2S,	3880	34.00	28.9	2x0.5
255			23°54.3W				
256	25.03.96	21:32	00°01.3S,	3624	34.06	28.0	2x0.5
257			23.28.2W				
258	26.03.96	11:22	00°00.5S,	3706	34.12	28.0	2x0.5
259			23°26.5W				
260	26.03.96	14:27	00°00.1S,	3859	34.12	28.3	2x0.5
261			23°24.3W				
262	26.03.96	21:13	00°06.7N,	2910	34.08	28.2	2x0.5
263			24°02.2W				
264	27.03.96	11:35	00°35.0S,	3812	34.01	28.4	2x0.5
265			26°40.4W				
266	27.03.96	14:29	00°40.9S,	3739	34.03	28.6	2x0.5
267			27°13.2W				
268	27.03.96	21:15	00°54.6S,	3877	33.91	28.6	2x0.5
269			28°30.1W				
270	28.03.96	11:47	01°24.2S,	4863	33.83	28.5	2x0.5
271			31°13.4W				
272	28.03.96	14:14	01°29.3S,	4777	34.06	28.4	2x0.5
273			31°41.6W				
274	28.03.96	21:34	01°44.5S,	4494	34.25	28.6	2x0.5
275			33°05.3W				
276	29.03.96	11:12	02°56.3S,	3766	34.13	28.7	2x0.5
277			35°16.1W				
278	29.03.96	14:31	03°26.0S,	3553	34.15	29.0	2x0.5
279			35°40.3W				
280	29.03.96	22:03	03°33.4S,	3160	34.31	29.1	2x0.5
281			36°16.0W				
282	31.03.96	14:14	02°47.5S,	2482	34.27	29.0	2x0.5
283			38°15.5W				

Table 4. continued.

No.	Date	Time UTC	location	Water-depth (m)	Salinity (‰)	Water-temp. (C)	Sample-volume (l)
284	31.03.96	21:39	02°43.2S,	2455	34.43	28.9	2x0.5
285			38°13.8W				
286	01.04.96	11:25	02°56.0S,	3847	34.39	28.4	2x0.5
287			38°00.1W				
288	01.04.96	14:05	02°07.8S,	4289	34.34	29.0	2x0.5
289			38°59.9W				
290	01.04.96	21:19	00°00.5S,	4387	34.38	28.7	2x0.5
291			38°20.6W				
292	02.04.96	11:30	00°00.0 ,	3799	34.34	28.2	2x0.5
293			41°05.1W				
294	02.04.96	14:10	00°00.1S,	3889	34.34	28.3	2x0.5
295			41°36.1W				
296	02.04.96	21:11	00°00.01N,	2754	34.37	28.4	2x0.5
297			43°02.7W				
298	03.04.96	11:11	00°21.1N,	53	32.69	28.3	2x0.5
299			45°56.7W				
300	03.04.96	15:06	00°31.3N,	39	31.85	28.3	2x0.5
301			46°39.0W				
302	03.04.96	20:20	00°45.1N,	44	12.61	28.2	2x0.5
303			47°35.9W				
304	04.04.96	11:26	01°56.8N,	55	30.05	28.0	2x0.5
305			48°12.7W				
306	04.04.96	14:56	02°11.1N,	69	32.99	28.2	2x0.5
307			48°00.1W				
308	04.04.96	21:27	02°39.9N,	87	32.02	28.1	2x0.5
309			48°41.4W				
310	05.04.96	11:20	03°14.0S,	74	29.82	27.9	2x0.5
311			49°27.5W				
312	05.04.96	14:25	03°30.8N,	78	27.30	28.1	2x0.5
313			49°55.6W				
314	05.04.96	21:16	03°46.4N,	55	21.49	28.1	2x0.5
315			50°24.1W				
316	06.04.96	11:34	04°45.9N,	1849	33.76	27.7	2x0.5
317			50.06.6W				
318	06.04.96	15:53	04°46.6N,	2451	34.26	27.7	2x0.5
319			49°17.8W				
320	06.04.96	21:36	05°04.7N,	2836	34.34	27.6	2x0.5
			48°36.7W				
321	07.04.96	11:21	05°08.6N,	3198	34.29	27.4	2x0.5
322			47°317W				
323	07.04.96	14:10	05°08.6N,	3195	34.30	27.5	2x0.5
324			47°31.8W				
325	07.04.96	21:41	05°.08.3N,	3198	34.29	27.5	2x0.5
326			47°30.7W				
327	08:04.96	11:19	05°44.5N,	3651	34.26	27.6	2x0.5
328			47°38.7W				
329	10.04.96	15:33	08°28.5N,	1620	33.53	27.4	2x0.5
330			57°53.9W				
331	10.04.96	22:12	08°39.3N,	2080	33.57	27.4	2x0.5
332			57°54.5W				
333	11.04.96	13:28	09°54.2N,	3677	30.84	27.4	2x0.5
334			57°09.5W				
335	11.04.96	14:59	09°59.3N,	3465	---	27.5	2x0.5
336			57°06.5W				
337	11.04.96	22:39	10°55.3N,	4167	33.39	27.2	2x0.5
338			56°32.8W				
339	12.04.96	12:22	11°51.0N,	3128	33.64	27.3	2x0.5
340			57°44.0W				
341	12.04.96	15:21	12°03.0N,	2334	33.47	27.2	2x0.5
342			58°01.3W				
343	12.04.96	22:13	12°32.3N,	1623	33.28	27.2	2x0.5
344			58°44.3W				

4.3.4. Pumped Plankton Samples

(R. Schneider)

Marine plankton from surface waters was sampled during the whole cruise (Table 5). The shipboard installed sea-water pump was used to filter about 2000 to 6000 l each day, mostly during daylight. The amount of water filtered, depended on the plankton mass caught in the net. The sea-water was pumped through a net with a mesh size of 10 µm. When the water flow was stopped by the material closing the net openings, the plankton was washed into plastic bottles and the sampling was continued with the cleaned net. For each day the wet plankton samples were concentrated into one bottle and frozen at -20°C.

The plankton material will be investigated for the bulk composition of the biogenic detritus in order to determine the ratios between bulk opal, organic carbon and carbonate produced by near surface water plankton communities. In particular, the marine organic material will be investigated in more detail. It is planned to analyse the composition of stable carbon and nitrogen isotopes as well as organic compounds which can be related to specific phytoplankton organisms. This type of data is needed to compare the marine plankton production in the surface waters of different high productivity systems with fluxes of biogenic particles caught in sediment traps and found in the surface sediments beneath high productivity areas.

Table 5. Plankton Pump Samples

Nr.	Date	Start filtration: time (Local)	Position Latitude	Longitude	Salinity (°/oo)	Temp. (°C)	Water-clock	Stop filtration: time (Local)	Position Latitude	Longitude	Salinity (°/oo)	Temp. (°C)	Water-clock	Liters pumped (l)
1	24.04.96	08:05	03°55.4S	25°42.2W	36.39	28.6	509290	19:35	03°25.4S	25°20.8W	36.00	28.7	511947	2659
2	25.03.96	08:05	01°17.1S	24°10.2W	36.05	28.7	511967	21:15	00°01.4S	23°28.2W	36.21	28.0	518397	6430
3	26.03.96	10:00	00°00.7S	23°25.9W	36.21	28.1	518397	19:55	00°10.1S	24°21.7W	36.21	28.2	523375	4978
4	27.03.96	09:45	00°37.3S	26°53.4W	36.12	28.5	523375	20:31	00°59.2S	28°25.7W	35.95	28.5	530202	6827
5	28.03.96	08:00	01°22.7S	31°05.2W	35.95	28.0	530202	18:35	01°44.5S	33°05.1W	36.33	28.6	535877	5675
6	29.03.96	08:05	02°55.6S	35°15.5W	36.01	28.8	535877	20:20	03°41.5S	36°17.1W	36.38	29.0	542020	6143
7	31.03.96	11:20	02°55.2S	38°19.1W	—	28.9	542022	19:30	02°39.4S	38°11.8W	36.48	29.0	546307	4285
8	01.04.96	06:10	01°55.3S	38°00.1W	36.31	28.8	546307	18:50	0°00.02S	38°24.3W	36.44	28.7	552220	5913
9	02.03.96	08:20	0°00.02S	41°38.2W	36.40	28.2	552220	00:51	00°00.1S	44°29.6W	36.44	28.6	560241	8021
10	03.04.96	09:00	00°23.2S	46°05.6W	35.85	28.3	560259	13:40	00°35.8S	46°57.9W	31.36	28.5	562400	2141
11	03.04.96	13:40	00°35.8S	46°57.9W	31.36	28.5	562400	20:20	00°53.9S	48°12.3W	14.10	28.6	565735	3335
12	04.04.96	06:25	01°45.6S	48°22.3W	29.96	28.2	565735	18:45	02°37.3S	48°43.4W	34.44	28.2	571261	5526
13	05.04.96	08:30	03°15.2N	49°29.6W	32.38	27.9	571261	14:00	03°43.6S	50°19.2W	25.19	28.2	573834	2573
14	05.04.96	15:30	03°43.5N	50°20.7W	24.74	28.1	573834	20:35	04°04.3N	50°23.0W	27.29	28.1	575014	1180
15	06.04.96	12:25	04°44.9N	49°21.6W	36.31	27.6	575014	19:45	05°06.1N	48°34.3W	36.41	27.5	578908	3894
16	07.04.96	09:50	05°08.6N	47°31.8W	36.36	27.5	578908	19:55	05°08.2N	47°30.7W	36.36	27.5	583162	4254
17	10.04.96	14:45	08°24.3N	58°03.4W	35.91	27.5	583218	20:45	08°54.7N	57°45.3W	35.76	27.4	586202	2984
18	11.04.96	08:20	09°45.2N	57°14.9W	35.88	27.4	586202	00:15	11°13.9N	56°50.4W	35.63	27.1	594007	7805
19	12.04.96	08:35	11°51.9N	57°14.9W	35.83	27.3	594029	20:00	12°39.8N	58°55.4W	35.55	27.1	599836	5807

Salinity values from ships salinometer were corrected for instrument deviation by $S_{corr}=S_{value} \times 0.8411 + 7.515$

4.3.5. Plankton Sampling using a Multiple Closing Net

(H. Kinkel, M. v. Herz, V. Diekamp, I. Engelbrecht)

Plankton was sampled with a multiple closing net (Fa. HYDROBIOS) with 0.25 m^2 opening and 64 µm mesh size. It was used for vertical hawls at 4 sites (Table 6). Each multinet station comprised three hawls with:

1. depth intervals from 500-300, 300-200, 200-100, 100-50 and 50-0 m.
2. depth intervals from 400-200, 200-100, 100-0, 40-20 and 20-0 m.
3. depth intervals from 250-00, 100-75, 75-50, 50-25 and 25-0 m.

Hawl 1 will be used for studies on planktonic foraminifera, hawl 2 for radiolarian and diatom analyses, and hawl 3 for geochemical and isotopic analyses. The samples containing mostly zooplankton and some phytoplankton were carefully rinsed with seawater into KAUTEX bottles, fixed with mercury chloride for the reduction of bacterial degradation, and stored at 4°C. At all stations, 1.2 l Niskin-bottles were used during the first and the third hawl to obtain water samples from the different water depths for analyses of carbon and oxygen stable isotopes and phytoplankton investigations (see chapter 4.3.).

Table 6. Water samples for $\delta^{13}C$ and $\delta^{18}O$ analyses (multinet- and GoFlo-bottles)

Station GeoB	depth (m)	$\delta^{13}C$ (‰ PDB)	$\delta^{18}O$	corr. depth (m)	Position Latitude Longitude
3906-5(MN)	50	x	x	100	7°26,1S 28°08,3W
	100	x	x	200	
	200	x	x	300	
	300	x	x	500	
	500	x	x	50	
3906-7(MN)	25	x	x	50	7°25,8S 28,08,1W
	50	x	x	75	
	75	x	x	100	
	100	x	x	250	
	250	x	x	25	
3906-8(GF)	700	x	x		7°25,0S 28°07,9W
	1200	x	x		
	2000	x	x		
	3000	x	x		
	4000	x	x		
	5000	x	x		
3907-5(MN)	50	x	x	100	3°55,1S 25°40,1W
	100	x	x	200	
	200	x	x	300	
	300	x	x	500	
	500	x	x	50	
3907-6(MN)	25	x	x	50	3°54,8S 25°40,4W
	50	x	x	75	
	75	x	x	100	
	100	x	x	250	
	250	x	x	25	
3907-10(GF)	700	x	x		3°54,9S 25°36,6W
	1200	x	x		
	2000	x	x		
	3000	x	x		
	3950	x	x		
	4950	x	x		
3908-3(GF)	675	x	x		0°00,2S 23°27,9W
	1150	x	x		
	2000	x	x		
	2500	x	x		
	3000	x	x		
3908-4(MN)	50	x	x		0°00,2S 23^27,9w
	100	x	x		
	200	x	x		
	300	x	x		
	500	x	x		
3908-5(MN)	25	x	x		0°00,24S 23°27,9W
	50	x	x		
	75	x	x		
	100	x	x		
	250	x	x		
3925-1(GF)	650	x	x		5°08,6N 47°31,7W
	1150	x	x		
	2000	x	x		
	2500	x	x		
	3000	x	x		
3925-7(MN)	50	x	x		5°08,3N 47°30,9W
	100	x	x		
3925-8(MN)	200	x	x		
3925-7(MN)	300	x	x		
	500	x	x		
3925-9(MN)	25	x	x		5°08,3N 47°31,4W
	50	x	x		
	75	x	x		
	100	x	x		
	250	x	x		

4.4. Stable Carbon and Nitrogen Isotope Investigations and Experiments (C. Eichner)

In all biological (enzymatic) reactions fractionation of stable N and C isotopes occurs. The resulting isotope values in suspended particulate matter, sedimenting particles and also in sediments are used to infer enviromental conditions during particle formation. The aim of this investigation was to examine the fractionation during degredation of organic matter, especially at the water/sediment boundary layer. There, the influence of nutrient concentrations, oxygen contents or water depth for the fractionation has to be known. For this, in-situ measurements as well as experiments were carried out.

At different stations samples were taken from the water column (Niskin-, Goflo-bottles (AG Balzer), overlying water from the multicorer)) and from the upper sediment layers (multicorer); at other sites, bottom water and surface sediment was taken (multicorer) (see Table 7). Oxygen in the water from different depth was measured by conventional titration (Grasshoff et al., 1983). A defined volume of water from Niskin- or Goflo-bottles was filtered (GF/F-filters), filters were frozen for later measurement of $\delta^{15}N$, $\delta^{13}C$ and C/N-ratios in the particulate fraction and for chlorophyll determination. Nitrite, nitrate and ammonium in the filtrate was determined either by autoanalyser (AG Schulz) or was frozen for later measurement. Unfiltered water has been fixed with formaldehyde (end concentation 0.4%) for later dying with the fluorescent dye DAPI to count bacteria and measure their volume under the fluorescence-microscope and for microscopic identification of particles (algae etc.).

The sediments sampled with the multicorer were cut into 1 cm slices. These were partly frozen (-18°C) for later determination of $\delta^{15}N$, $\delta^{13}C$ and C/N-ratios. 1 cm^3 was fixed with formaldehyde for counting and measuring bacteria (see above). The remaining sediment was centrifugated for pore water recovery. It was frozen for later determination of $\delta^{15}N$ in the dissolved nitrogen fraction.

Aging experiments were carried out with suspended particles from stations 3906 and 3907, and with sediments from station 3908. Water from the euphotic zone (50 m, Niskin-bottle), below the euphotic zone (250 m, Niskin-bottle) and bottom water (multicorer) has been incubated at in-situ temperature for 20 days. Organic matter from both upper layers was concentrated through a 10 mm gaze. At certain intervals, an aliquot was taken for filtration and nutrient measurement. In another experiment, surface water was single-fold, double- and four-fold enriched. Subsamples were taken at certain time intervals and treated as described above.

To investigate the influence of oxygen on the fractionation of C- and N-isotopes in bottom water, another experiment was done. Bottom water from station 3908 was filled into glas bottles and one half was bubbled with argon to get oxygen free water. The rest was shaken every day to keep the samples oxic. At certain time intervals, an oxic and anoxic bottle was subsampled for $\delta^{15}N$, $\delta^{13}C$, C/N-ratios and nutrient measurement and for number and volume of bacteria. The same set of experiments was carried out with sediments. Surface sediment was homogenized, diluted with bottom water and filled into glas bottles. One half was bubbled with argon. After certain intervals, an oxic and an anoxic bottle was subsampled. The sediment was partly preserved with formaldehyde and partly frozen (see below). The overlying water was analysed for nitrite, nitrate and ammonium.

Table 7. Sampling and preparation for stable C- and N-isotope analyses.

Station no.	Position	Water depth (m)	Sampling equipment and depth	Treatment of sample	Measurement
3906	07°27,7'S 28°06,9'W	5581m	Niskin-bottles: 20m, 50m, 100m, 250m Goflo-bottles: 200m, 700m, 1200m, 2000m, 3000m, 4000m, 5000m	O_2 concentration (Winkler) filtration	$\delta^{15}N$, $\delta^{13}C$, C/N, Chl -a NO_3, NO_2, NH_4 in filtered sea water
				fixation with formaldehyde	bacterial number and volume
			multicorer	overlaying water, same as procedure above	see above
				sediment: cutting in 1 cm layers: - deepfreezing	$\delta^{15}N$, $\delta^{13}C$, C/N
				- fixation with formaldehyde	bacterial number and volume
				- centrifugation for porewater	measurement of $\delta^{15}N$ in the dissolved fraction
3907	03°55,8'S 25°40,9'W	5551m	Niskin-bottles: 20m, 50m, 100m, 250m Goflo-bottles: 50m, 100m, 200m, 400m, 700m, 1200m, 3000m, 4000m, 5000m	same as 3906	see above
3908	00°00,5'N 23°26,5'W	3635m	Niskin-bottles: 20m, 50m, 100m, 250m Goflo-bottles: 10m, 25m, 50m, 100m, 150m, 200m, 400m, 670m, 1150m, 2000m, 2500m, 3000m multicorer	same as 3906	see above
3909	03°32,9' S 36°16,2'W	3165m	multicorer	same as 3906	see above
3914	02°43,5'S 38°13,6'W	2472m	multicorer	same as 3906	see above
3915	02° 16,8'S 38° 01,1'W	3256m	multicorer	same as 3906	see above
3916	01° 49,9'N 48°26,9'W		multicorer	same as 3906	see above
3925	05°08,4'N 47°31,8'S	3190m	Niskin-bottles: 20m, 50m, 75m, 100m, 200m, 250m, 400m, 700m, 1200m, 2000m, 3000m multicorer	same as 3906	see above

4.5. Microbial Colonisation of „Marine Snow“

(Imke Miesner)

Rapidly sinking particles in the water column, so called „Marine Snow“, consist of dissolved and colloidal organic matter which aggregates together, i.e. phytoplankton aggregates, fecal pellets and detritus. Bacteria and protozoa seem to play an important role in decomposition of „Marine Snow“; the main decomposition takes place in the mesopelagic zone (Lochte, 1991; Lochte, 1993 and Austin, 1988). During this cruise, samples were taken from different depths as well as material from long-term placed sediment traps (poisoned with $HgCl_2$). Enrichments of the bacteria attached to „Marine Snow“ and the free living bacteria in the surrounding seawater were made by use of different culturing techniques, as well as preparations for light and electron microscopy. In this case, both seasonal and regional differences have to be recorded.

For the sampling of living material different sampling methods were used. At four stations sea water was taken at different depths from 20 to 3000 m with a Niskin-bottle. It was possible to obtain samples with a GoFlo-water sampler and in-situ pumps (AG Balzer) from different depths between 10 to 5000 m. When sampling with the multicorer was carried out, samples from the overlying sea water were taken. As the samples turned out to be poor in containing macroaggregates, about 300 l water from the surface (3.5 m water depth) were taken daily by the ship's membrane pump and passed through a 55 µm gaze from which the aggregates were collected with a sterile pasteur pipette and transferred into sterilized seawater (for detailed list of all samples see Table 8). All samples were transferred directly to sterile vessels. From each water sample and diluted filtrate of the in-situ pumps, 2 ml were transferred immediately into 50% glycerine and stored at -20°C. 10 ml of each sample were fixed with formalin (2% v/v) and stored at 4°C. Preparations for electron microscopy and direct counting by epifluorescence techniques will be done at the laboratory at Bremen University. The remainder of each sample was stored in sterile screw cap tubes at 4°C.

For the determination of aerobic heterotrophic bacteria 200 ml of each Niskin-bottle water sample were filtered through 0,45 µm cellulose acetate filters. The filters were pressed on agar plates containing ASN_{III}-medium with 0.05% yeast extract added. Then the filters were transferred to liquid cultures in ERLENMEYER flasks containing ASN_{III}-medium and 0.05% yeast extract. Streaks on agar plates containing ASN_{III}-medium, 0.05% yeast extract and 1.6% agar were made from a number of samples. The cultures were incubated aerobically under night/day cycle-light conditions at room temperature (20-25°C). Liquid cultures from the GoFlo-water samples were made in ERLENMEYER flasks containing ASN_{III}-medium and 0.05% yeast extract, inoculated with 1 ml sample. The cultures from water depths > 400 m were incubated aerobically in the dark at 4°C. Complementary, various samples were streaked on agar plates with ASN_{III} and 0.05% yeast extract and were incubated under anaerobic conditions in an anaerobic jar under day/night-light conditions at 20-25°C. The filtrates of the in-situ pumps, diluted in sterilized seawater, were used to inoculate agar plates containing ASN_{III}-medium and 0.05% yeast extract. 1 ml of each sample was used for liquid cultures under aerobic conditions in sterile-filtrated seawater. Simplified enrichment cultures for the recovery of autotrophic bacteria (i.e. cyanobacteria, purple/green sulphur bacteria) were tested. Liquid and solid ASN_{III}-medium without yeast extract was used for the enrichment of cyanobacteria. 1mM Na_2S was added to liquid ASN_{III}-medium as an electron donor for the enrichment of sulfur bacteria. The cultures were incubated anaerobically in screw cap bottles. Separate colonies which grew on the agar plates, were picked and streaked on fresh agar plates to obtain pure strains.

All cultures were scanned using light microscopy with phase contrast in regular intervals. The highest abundance was shown by various greenish rod-shaped, motile or nonmotile forms, 0.5-1 x 3-5 µm in size. Cocci, spirilla and budding forms were also observed. In several cultures, filamentous cyanobacteria were observed. The isolated strains showed various types of heterotrophic bacteria. Greenish and reddish colony forming rods, 1 x 5-7 µm in size, able to decompose agar were isolated, as well as various shorter rods which form colourless and yellowish colonies on agar. The isolates are to be examined at the laboratory at Bremen University for further identification and characterization.

The samples taken by the ship's membrane pump included aggregates (< 2 mm), which consisted of phyto- and zooplankton detritus (copepods, algae debris, empty diatoms, etc.). In the area around these aggregates and attached to them, a much greater number of bacteria than in the surrounding seawater appeared, but it seems to be the same or similar bacteria. Preparations for light microscopy were made, the coverslips were sealed with nail varnish. The preparations were stored at 4°C.

Three moorings with two multi-sample sediment traps each were installed during METEOR cruise 29/3. The sediment traps consisted of 20 bottles which sampled over a period of about 4 weeks each. 1 ml of poisoned material was transferred from each bottle to sterile 1.5 ml EPPENDORF caps and stored at 4°C (WA6/upper 1-20, WA6/lower 1-20, WA7/upper 1-20, WA7/lower 1-20, WA8/upper 1-20 and WA8/lower 1-20). Attached bacteria, possible seasonal and regional differences are to be determined using scanning electron microscopy techniques.

Table 8. Water samples for microbiological investigations.

Sample No.[a]	Station	Latitude S/N	Longitude W	Water depth (m)
MP 1	3904	07°53.0′ S	33°00.3′	2,5
MP 2	3906	07°25.6′ S	28°08.0′	2,5
MP 3	3906	07°25.3′ S	28°08.1′	2,5
MP 4	3906	07°27.7′ S	28°06.9′	2,5
MP 5	-	07°47.2′ S	31°51.4′	2,5
MP 6	-	06°15.2′ S	27°15.7′	2,5
MP 7	-	04°10.6′ S	25°47.9′	2,5
MP 8	3907	03°55.8′ S	25°40.9′	2,5
MP 9	-	01°01.5′ S	24°01.6′	2,5
MP 10	-	00°54.8′ S	28°31.2′	2,5
MP 11	-	01°32.5′ S	31°59.2′	2,5
MP 12	-	03°24.7′ S	35°39.2′	2,5
MP 13	-	02°42.7′ S	38°13.2′	2,5
MP 14	-	00°00.0′ S	38°31.0′	2,5
MP 15	-	00°46.7′ S	47°42.8′	2,5
MP 16	-	02°37.1′ N	48°43.6′	2,5
MP 17	-	04°42.7′ N	49°26.4′	2,5
MP 18	3925	05°08.6′ N	47°31.8′	2,5
MP 19	-	09°55.7′ N	57°08.7′	2,5
WS 1	3906-3	07°24.8′ S	28°08.0′	250
WS 2	3906-3	07°24.8′ S	28°08.0′	100
WS 3	3906-3	07°24.8′ S	28°08.0′	50
WS 4	3906-3	07°24.8′ S	28°08.0′	20
WS 5	3907-3	03°55.8′ S	25°41.0′	250
WS 6	3907-3	03°55.8′ S	25°41.0′	100
WS 7	3907-3	03°55.8′ S	25°41.0′	50
WS 8	3907-3	03°55.8′ S	25°41.0′	20
WS 9	3908-8	00°00.4′ S	23°26.4′	250
WS 10	3908-8	00°00.4′ S	23°26.4′	100
WS 11	3908-8	00°00.4′ S	23°26.4′	20
WS 12	3925-6	05°08.3′ N	47°30.7′	3000
WS 13	3925-6	05°08.3′ N	47°30.7′	2000
WS 14	3925-6	05°08.3′ N	47°30.7′	1200

Table 8. contiunued

Sample No.[a]	Station	Latitude S/N	Longitude W	Water depth (m)
WS 15	3925-6	05°08.3′ N	47°30.7′	700
WS 16	3925-6	05°08.3′ N	47°30.7′	400
WS 17	3925-6	05°08.3′ N	47°30.7′	250
WS 18	3925-6	05°08.3′ N	47°30.7′	200
WS 19	3925-6	05°08.3′ N	47°30.7′	100
WS 20	3925-6	05°08.3′ N	47°30.7′	75
WS 21	3925-6	05°08.3′ N	47°30.7′	50
WS 22	3925-6	05°08.3′ N	47°30.7′	20
WS 23	3932-1	11°00.0′ N	56°29.8′	3000
WS 24	3932-1	11°00.0′ N	56°29.8′	400
WS 25	3932-1	11°00.0′ N	56°29.8′	100
WS 26	3932-1	11°00.0′ N	56°29.8′	50
WS 27	3932-1	11°00.0′ N	56°29.8′	20
GF 1	3906-8	07°25.0′ S	28°07.9′	10
GF 2	3906-8	07°25.0′ S	28°07.9′	25
GF 3	3906-8	07°25.0′ S	28°07.9′	50
GF 4	3906-8	07°25.0′ S	28°07.9′	700
GF 5	3906-8	07°25.0′ S	28°07.9′	1200
GF 6	3906-8	07°25.0′ S	28°07.9′	2000
GF 7	3906-8	07°25.0′ S	28°07.9′	3000
GF 8	3906-8	07°25.0′ S	28°07.9′	4000
GF 9	3906-8	07°25.0′ S	28°07.9′	5000
GF 10	3907-10	03°54.9′ S	25°36.6′	10
GF 11	3907-10	03°54.9′ S	25°36.6′	25
GF 12	3907-10	03°54.9′ S	25°36.6′	50
GF 13	3907-10	03°54.9′ S	25°36.6′	100
GF 14	3907-10	03°54.9′ S	25°36.6′	200
GF 15	3907-10	03°54.9′ S	25°36.6′	700
GF 16	3907-10	03°54.9′ S	25°36.6′	1200
GF 17	3907-10	03°54.9′ S	25°36.6′	3000
GF 18	3907-10	03°54.9′ S	25°36.6′	3950
GF 19	3907-10	03°54.9′ S	25°36.6′	4950
GF 20	3908-3	00°02.7′ S	23°27.9′	25
GF 21	3908-3	00°02.7′ S	23°27.9′	50
GF 22	3908-3	00°02.6′ S	23°27.9′	100
GF 23	3908-3	00°02.7′ S	23°27.9′	200
GF 24	3908-3	00°02.7′ S	23°27.9′	400
GF 25	3908-3	00°02.7′ S	23°27.9′	675
GF 26	3908-3	00°02.7′ S	23°27.9′	1150
GF 27	3908-3	00°02.7′ S	23°27.9′	3000
MUC 1	3906-9	07°28.0′ S	28°06.4′	4886
MUC 2[b]	3906-9	07°28.0′ S	28°06.4′	4886
MUC 3	3908-11	00°00.4′ S	23°25.7′	3693
MUC 4	3909-1	03°32.9′ S	36°16.2′	3174
MUC 4[b]	3909-1	03°32.9′ S	36°16.2′	3174
MUC 5	3910-3	04°14.7′ S	36°20.8′	2361
MUC 6	3911-1	04°36.8′ S	36°38.1′	826
MUC 7	3912-2	03°40.0′ S	37°43.1′	772
MUC 8	3913-2	02°53.8′ S	38°18.6′	2289
MUC 9	3915-1	02°16.8′ S	38°00.9′	3127
MUC 10	3916-1	01°41.9′ N	48°26.0′	37
MUC 11	3918-1	03°42.3′ N	50°24.3′	52
MUC 12	3925-2	05°08.6′ N	47°31.8′	3198
ISP 1	3925-5	05°07.9′ N	47°30.4′	100
ISP 2	3925-5	05°07.9′ N	47°30.4′	400
ISP 3	3925-1	05°08.6′ N	47°31.7′	700
ISP 4	3925-1	05°08.6′ N	47°31.7′	1200

Table 8. continued.

Sample No.[a]	Station	Latitude S/N	Longitude W	Water depth (m)
WA 6/upper 1-20	3906-1	07°27.4′ S	28°08.4′	544
WA 6/lower 1-20	3906-1	07°27.4′ S	28°08.4′	4410
WA 7/upper 1-20	3907-1	03°58.6′ S	25°40.6′	854
WA 7/lower 1-20	3907-1	03°58.6′ S	25°40.6′	4630
WA 8/upper 1-20	3908-7	00°00.5′ N	23°26.5′	718
WA 8/lower 1-20	3908-7	00°00.5′ N	23°26.5′	3204

a) abbreviations in Table 8:

MP, membrane pump; WS, Niskin-bottle sampler, GF, GoFlo-water sampler; MUC, multicorer; ISP, In-situ pumps; WA, West Atlantic mooring.

b) sediment sample, uppermost layer.

4.6. In-situ Particle Camera System, PARCA

(V. Ratmeyer)

For measuring the vertical particle concentration, size distribution and aggregate composition in the water column a high-resolution fotographic camera system was used (Ratmeyer and Wefer, 1996). It was designed and improved in consideration of similar systems used by Honjo et al.(1984), Asper (1987) and Lampitt (1985). This method provides in-situ information on the origin and abundance of particles and aggregates („Marine Snow"). In addition to the use of sediment traps, particle flux can be measured even in areas or depths with high lateral transport.

The aim of deployment to different depths between 1000 and 3000 m was to observe the deep-sea particle population and possible lateral advection of particle clouds from the continental shelf towards the open ocean. Abundance profiles were made on two of the mooring stations as well at three different sites close to the continental shelf of Guyana. (Table 9). The pictures show variable particle and plankton concentrations, with maximal concentrations in the upper 100 m. This correlates to previous measurements with particle camera and chlorophyll sensors in the Brazil Basin (Ratmeyer and Wefer, 1996). Various known species of plankton and macroplankton can be identified on the images, including foraminifera, radiolaria, copepods and medusa. Particle and aggregate sizes vary from 80 µm to > 20 cm. Largest aggregates were found on profile 4 (site GeoB 3926-1), above the continental slope off Guyana, with fractal shapes of marine snow and stringers. Also, highest particle concentrations were found at this site. Quantitative analysis of concentration, shape and size of particles will be performed using a PC-based image analysis system.

The ParCa system consists of the following components:

For best optical resolution we used a 70 mm deep-sea camera (model PHOTOSEA 70) with max. 45.7 m film capacity. Two 150 Ws (model PHOTOSEA 1500S/1500SD) strobelights were installed as light sources. The illuminating beam was collimated by a combination of highly refractive fresnel-lenses mounted inside a steelframe at the focal distance in front of the strobes. Camera and light source consisting of two flashlights plus collimator were installed in orthogonal position, thus avoiding backscatter of water molecules and highly hydrated particles. Power source is a 24V/38Ah rechargeable lead battery designed for the use to full ocean depth. Maximum operation depth is 6000 m for the complete system. The system is fixed inside a frame of the dimension 200 x 200 x 120 cm, which is made of 48 mm hot galvanized steel pipe. Pipes mounted close to the probe volume are painted black to avoid backscatter. The complete system weight is approximately 300 kg in air. Camera and the strobe-collimator units can be slided to any position inside the frame for correct justification. The camera was triggered by a computer on deck of the ship. Communication with the ship is performed by two micro-computers inside the ParCa system, allowing different exposure programs to be run during profiling and moored deployment. Pictures were exposed while lowering the system with a speed of 0.3 m s^{-1}. The flash duration of $<$ 1/2.000 second was short enough to get sharp pictures of particles down to a size of 80 μm using Kodak Tri X Pan Film.

Table 9. Deployment data of the ParCa system

Station GeoB	Water depth (m)	Profile depth (m)	Trigger (m)
3907-8	5558	2000	10
3908-2	3609	3000	10
3925-10	3186	1000	5
3926-1	1116	1000	10
3929-1	3195	2000	10

4.7. Particle Collection with Sediment Traps

(G. Ruhland, V. Ratmeyer, G. Fischer)

Table 10 lists deployment and recovery data for all moorings as well as the sampling data of the traps. During cruise M34/4, three moorings were recovered and deployed afterwards at the same position (see Fig. 1). The moorings were located in the oligotrophic northern Brazil Basin and in the higher productive western eqatorial upwelling region. The arrays were equipped each with two multisample traps and one current meter. All moorings are planned to be recovered by RV METEOR (M38/1) in February, 1997.

On March 21th, the mooring WA6 was recovered successfully at a site located in the lower productive subtropical gyre. This mooring array was equipped with two multisample traps in 544 and 4410 m water depth and one current meter in 569 m. All instruments had worked perfectly. Both traps had been programed for a 28 day sampling interval for each bottle starting at August 18th, 1994. The traps provided two complete sample series showing flux maxima in summer and fall with clearly lower fluxes to the deeper waters (Fig. 5a). On March 22th, the mooring array was deployed again as WA9 at the same position. The traps have been scheduled for a 17 day sampling interval starting March 23th, 1996.

The mooring WA7 has been recovered on March 23th. This mooring array was deployed during M29/3 in an area between the oligotrophic site represented by WA6 and the western equatorial upwelling area where WA8 was deployed. Both traps (854 m, 4630 m) worked fine as well as the moored current meter. Fluxes again peaked in late summer (Fig. 5b). On March 24th, the mooring WA10 was redeployed with similar equipment. Additionally, an inclinometer has been installed on the upper trap.

On March 26th, the mooring WA8 was completely recovered. This mooring was located in the western equatorial upwelling area. The two moored traps worked well and provided two sample sets of 20 samples each. Seasonality and absolute fluxes were highest at this site which is located in the more eutrophic equatorial upwelling band;

highest fluxes were observed in spring and summer (Fig. 5c). The current meter did not register data due to a malfunction. At the same day a similar mooring named WA11 was deployed at the same position.

Table 10. Mooring data for recoveries and redeployments.

Mooring	Position	Water depth (m)	Interval	Instr.	Depth (m)	Intervals (no x days)
Mooring recoveries during M34-4:						
BRAZIL BASIN / WESTERN EQUTORIAL ATLANTIC						
WA6	07°28.3'S	4950	18.08.94	S/MT 234	544	20x28
	28°07,4'W		29.02.96	S/MT 234	4410	20x28
				RCM 8 569		
WA7	03°58.0'S	5601	20.08.94	S/MT 230	854	19x28 (+1x26)
	25°39.0'W		29.02.96	S/MT 230	4630	19x28 (+1x26)
				RCM 8 879		
WA8	00°01.4'N	3744	25.08.94	S/MT 230	718	19x28 (+1x21)
	23°27.1'W		29.02.96	S/MT 230	3204	19x28 (+1x21)
				RCM 8 743		
Mooring deployments during M34-4:						
BRAZIL BASIN / WESTERN EQUATORIAL ATLANTIC						
WA9	07°28.0'S	4996	23.03.96	S/MT 234	591	20x17
	28°08.5'W		26.02.97	S/MT 230	4456	20x17
				RCM 8	615	
WA10	03°54.7'S	5555	25.03.96	S/MT 234	800	19x17 (+1x15)
	25°41.0'W		26.02.97	S/MT 234	4585	19x17 (+1x15)
				RCM 8	824	
				S/MT 105	800	
WA11	00°00.1'S	3860	27.03.96	S/MT 230	834	19x17 (+1x13)
	23°24.7'W		26.02.97	S/MT 230	3319	19x17 (+1x13)
				RCM 8	858	

Instruments used:

S/MT 230	= Sediment trap S/MT 230 Aquatec Meerestechnik, Kiel
S/MT 234	= Sediment trap S/MT 234 Aquatec Meerestechnik, Kiel
S/MT 105	= Inclinometer S/MT 105 Aquatec Meerestechnik, Kiel
RCM 8	= current meter Aanderaa, RCM 8

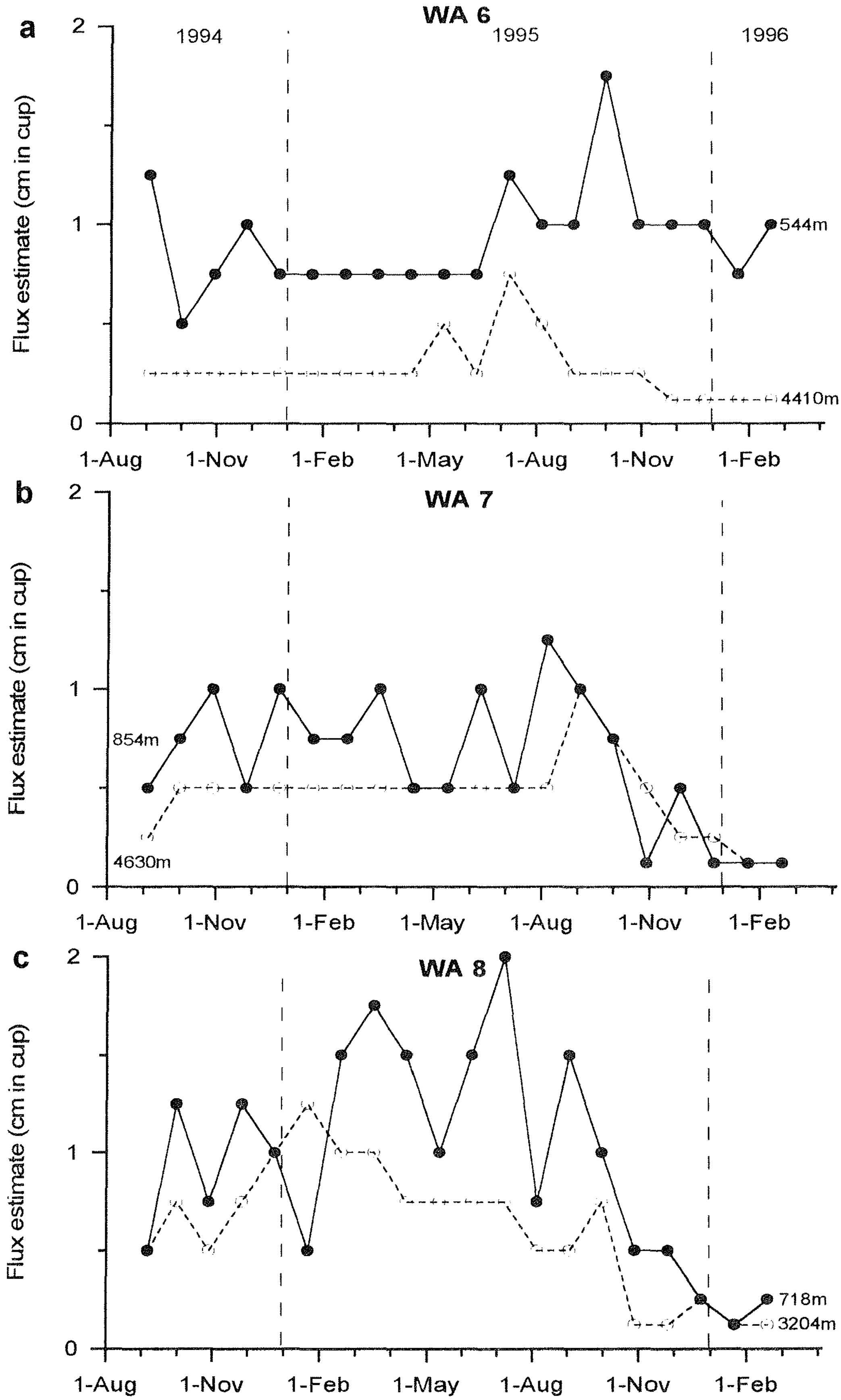


Fig. 5. Flux estimates (cm sediment in trap cup) at the mooring sites WA6 (a), WA7 (b) and WA8 (c). For locations see Fig. 1.

4.8. Marine Geology, Sediment Cores

(R. Schneider, H. Arz, E. Costa, V. Diekamp, I. Engelbrecht, A. Figuereido, M. v. Herz, H. Kinkel, G. Ruhland, B. Schlünz)

During this cruise we used box corer (2x), multicorer (20x) and gravity corer (22x) in order to recover surface and late Quaternary sediments (between 35 and 3300 m) from the continental slope off Northeast Brasil, from the Amazon estuary and fan, and from the Caribbean continental slope off Barbados. The coring locations and related water depths are given in the station list (Table 12, chapter 8). This table also shows the devices used for our program at all stations and the core lengths recovered.

4.8.1. Multicorer and Box Corer Samples

The multicorer is designed to recover undisturbed surface sediment sections and the overlying bottom water. The model used on M34/4 was equipped with 4 small plastic tubes and 8 larger tubes (6 and 10 cm in diameter). At most of the stations 10 to 12 tubes were filled with the uppermost 15 to 35 cm of sediment and the superimposed bottom water (Table 11). Only at station GeoB 3917 the multicorer failed three times due to a hardground (pieces of beachrock recovered with the gravity corer) at the sediment surface. Depending on recovery the tubes were sampled as follows:

- 1 large tube, cut into 1 cm thick slices for the investigations of dinoflagellates,
- 1 large and 1 small tube, cut into 1 cm slices and frozen for organic carbon (TOC) geochemistry and microscopy, respectively,
- 2 large tubes, cut in 1 cm slices for investigation of foraminiferal composition,
- 2 large tubes for pore water analysis, oxygen consumption and mineralogy,
- 1 large tube for nitrogen isotopes on porewater and sedimentary organic carbon,
- 1 small tube, cut in 1 cm slices for paleomagnetic studies,
- 1 small tube for clay mineralogy,
- 1 large and 1 small tube as frozen archive cores,

- 50 ml bottom water samples for stable carbon and oxygen isotopes were taken at all stations, while at selected sites several liters of bottom water were sampled for investigations of bacteria and nitrogen isotopes.

The box corer was used at two stations off the Amazon (GeoB 3919-1 and 3920-1) in order to sample expected oolithes and coarse sands. From the retrieved sediments surface photos were taken. The sediment at Station GeoB 3919-1 was subsampled with 3 multicorer tubes, which afterwards were cutted into 2 cm slices for stratigraphic, mineralogical and geochemical analysis (A. Figuereido). Two extra bulk samples from this box corer were sealed in plastic bags. The box corer from Station GeoB 3920-1, containing a ferromanganese hardground at the sediment surface, was subsampled with four core-liner tubes which will be sampled according to the gravity corer sampling scheme onshore.

Table 11. Multicorer Samples.

Station GeoB	Water depth (m)	Core length (cm)	TOC & Water (ml)	Dino-flagell.	Foram.	Clay miner.	Magn. facies	Archive frozen	N-Isot.	Bottom water, N-Isot. & Bact.	Pore water Chem.
3906-9	4886	30	2, 2x50	1	2	---	---	2	1	x	2
3908-11	3693	16	2, 2x50	1	2	1	1	2	1	x	2
3909-1	3174	34	2, 2x50	1	2	1	1	2	1	x	2
3910-3	2361	32	2, 2x50	1	2	1	1	2	---	x, only 50ml	2
3911-1	826	33	2, 2x50	1	2	1	1	1	---	x, only 50ml	2
3912-2	772	12	2, 2x50	1	2	1	1	2	---	x, only 50ml	---
3913-2	2264	13	2x50	1	2	---	---	1	---	x, only 50ml	---
3914-	2461	25	2, 2x50	1	1	---	---	1	1	x	1
3915-1	3127	34	2, 2x50	1	2	---	1	2	1	x	2
3916-1	37	34	2+C14	1	2	1	1	2	1	x	---
3918-1	52	25	1	1	1	1	1	1	---	x, only 50ml	2
3925-2	3198	25	2, 2x50	1	1	1	1	1	1	x	2
3935-1	1554	37	2, 2x50	1	2	1	1	2	---	---	---
3936-2	1854	35	2, 2x50	1	2	1	1	3	---	---	---
3937-1	1654	32	2, 2x50	1	2	1	1	1	---	---	---
3938-2	1972	33	2, 2x50	1	2	1	1	2	---	---	---
3939-1	2467	31	2, 2x50	1	2	1	1	2	---	---	---

4.8.2. Gravity Cores

4.8.2.1. Sampling

With the gravity corer sediment cores between 4.00 and 8.80 m core length were taken at 22 stations (Table 12, chapter 8). During M34/4 altogether 136 m of sediments were recovered with this device. Before using the coring tools, the liners were marked with a straight line lengthwise, in order to be able to sample the core segments afterwards in the same orientation, in particular for paleomagnetic purposes. When the core was retrieved on deck, the core liners were cut into 1-m segments, closed with caps at both ends and inscribed (Fig. 6).

All cores were cut along-core in two half pieces: one Archive and one Work half. The sediments were described, smear-slide samples were taken from distinctive layers and spectrophotometric measurements were carried out on the Archive half, which was stored in a cool room at +4°C after taking a photo. For color scanning a Minolta CM - 2002 hand-held spectrophotometer was used to measure percent reflectance values of sediment colour at 31 wavelength channels over the visible light range (400-700 nm). The digital reflectance data of the spectrophotometer readings were routinely obtained from the surfaces of split archive halfs immediately after core opening to provide a continous record of the sediment color variation. The surfaces of all core segments were scraped with a knife to expose a fresh, unsmeared surface for measurements at 2 cm intervals. A thin, transparent plastic film (Hostaphan) was used to cover the wet surface of the sediment to protect the photometer from being soiled. Before measuring each core the spectrophotometer was calibrated for white color reflectance by attaching a white calibration cap. The spectrophotometer readings were transfered to a personal computer and a graphic representation for selected wave band reflection (450, 550, and 700 nm) in each core is given in the following section.

From the Work-Half three parallel series of syringe samples (10 ccm) and 1 cm thick half-round samples were taken at a depth interval of 5 cm. These samples were taken for the measurements and determination of physical properties, stable isotopes, foraminiferal and dinoflagellate assemblages, as well as for mineralogy and organic geochemistry. One additional syringe sample series was taken in 20 cm intervals in order to get a first impression about the composition of planktonic foraminifera and changes in sand content for each core, whilst onboard. On selected cores the carbonate content was determined at 5 cm intervals.

Cores obtained for pore water analysis are indicated as geochemistry cores in Table 12 (chapter 8). They were sampled as described in section 4.9. and frozen afterwards.

Inscription:

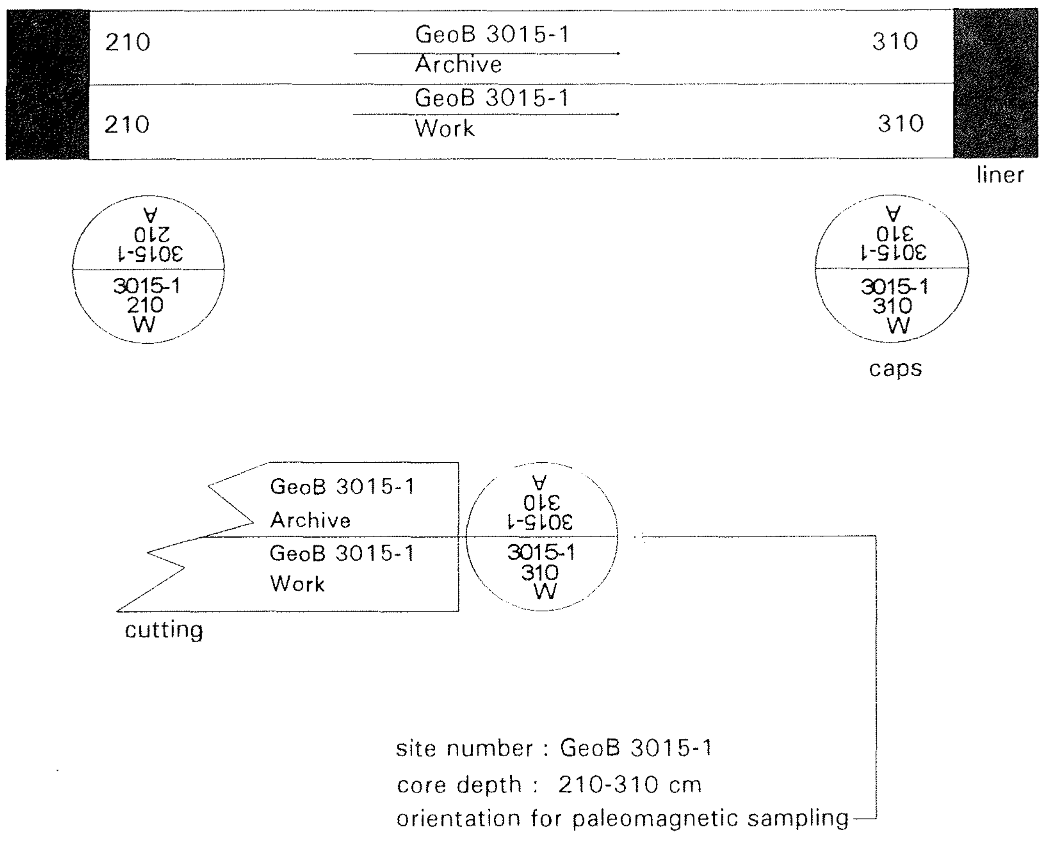


Fig. 6. Scheme of the inscription of gravity core segments.

4.8.2.2. Lithologic Core Summary

(H. Arz, H. Kinkel, B. Schlünz, R. Schneider)

This preliminary lithologic summary of the sediments retrieved with the gravity corer is based on visual description, and colour scanner readings, as well as microscopic inspection of stratigraphy samples and smear slides taken from distinctive sediment horizons. Core descriptions are shown in figures 7 to 16 (legend for stratigraphic columns is shown in Fig. 17), presenting main lithologies, their colour according to the MUNSELL soil colour chart, sedimentary structures, and if already determined the carbonate content. Stratigraphic information was obtained from the foraminiferal assemblages, using the *Globorotalia menardii* and *Pulleniatina obliqueloculata* as biostratigraphic markers according to Ericson and Wollin (1968) and to Damuth (1975), respectively. For correlation colour scanner readings of distinctive wave length bands (450, 550, 700 nm) are also shown. It is likely, that these colour changes result from variations in the sediment composition - particularly the ratio of carbonate or silicate (light and high reflection values) to organic residue and clay mineral (dark or low reflection values) content. The lithological data are primarily based on smear slide analysis. The main purpose was to describe all representative lithologies and special or unique layers of particular interest.

A first measure of sediment grain size variation is provided by the sand content reported in figures for each core (Figs. 18-23). Cores GeoB 3935-2, 3936-1, 3937-2, 3938-1, 3939-2 were not opened onboard and are thus, not included in this summary.

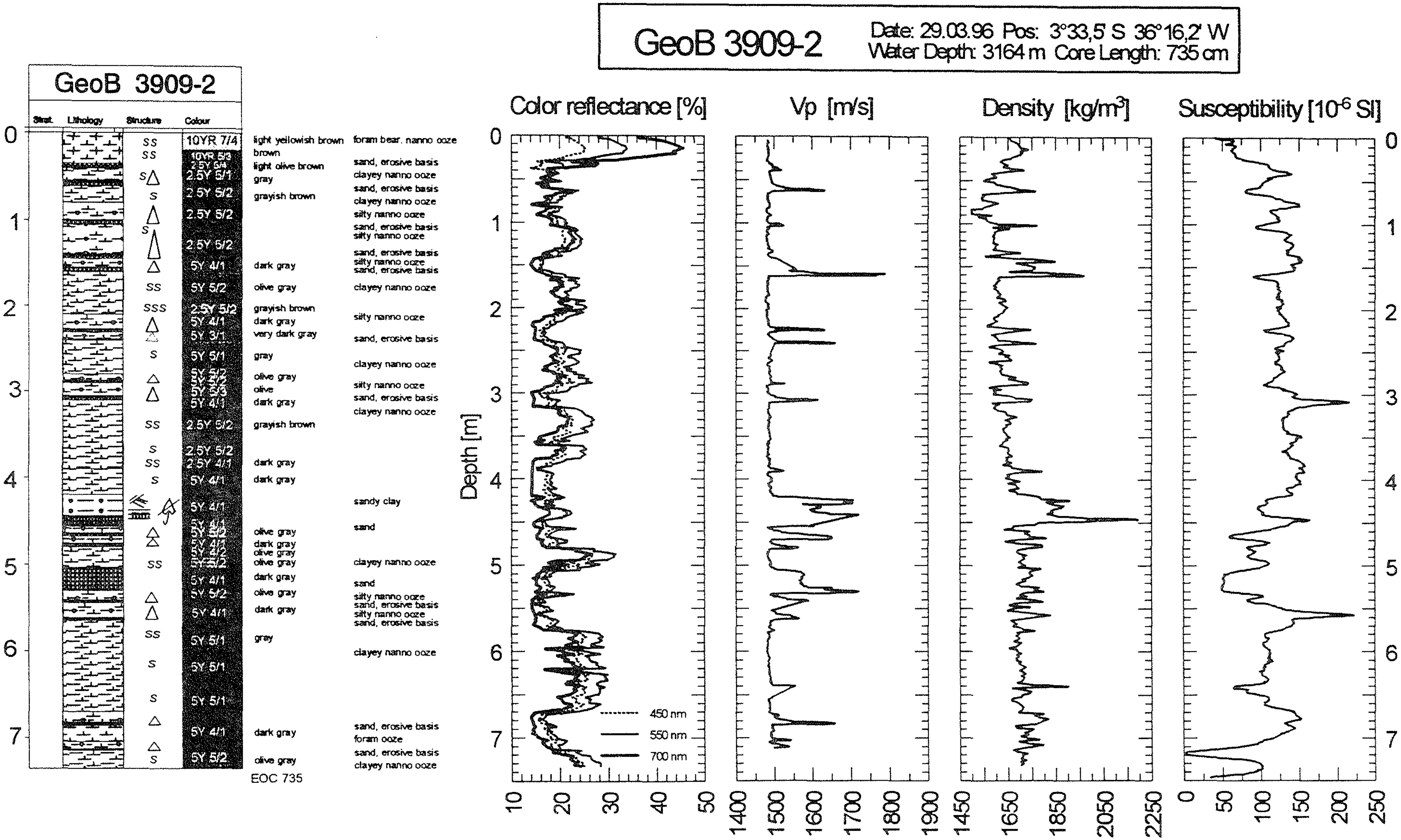


Fig. 7. Sediment descriptions, colour reflectance, and physical properties studies (Vp, density, susceptibility) for the gravity core GeoB 3909-2.

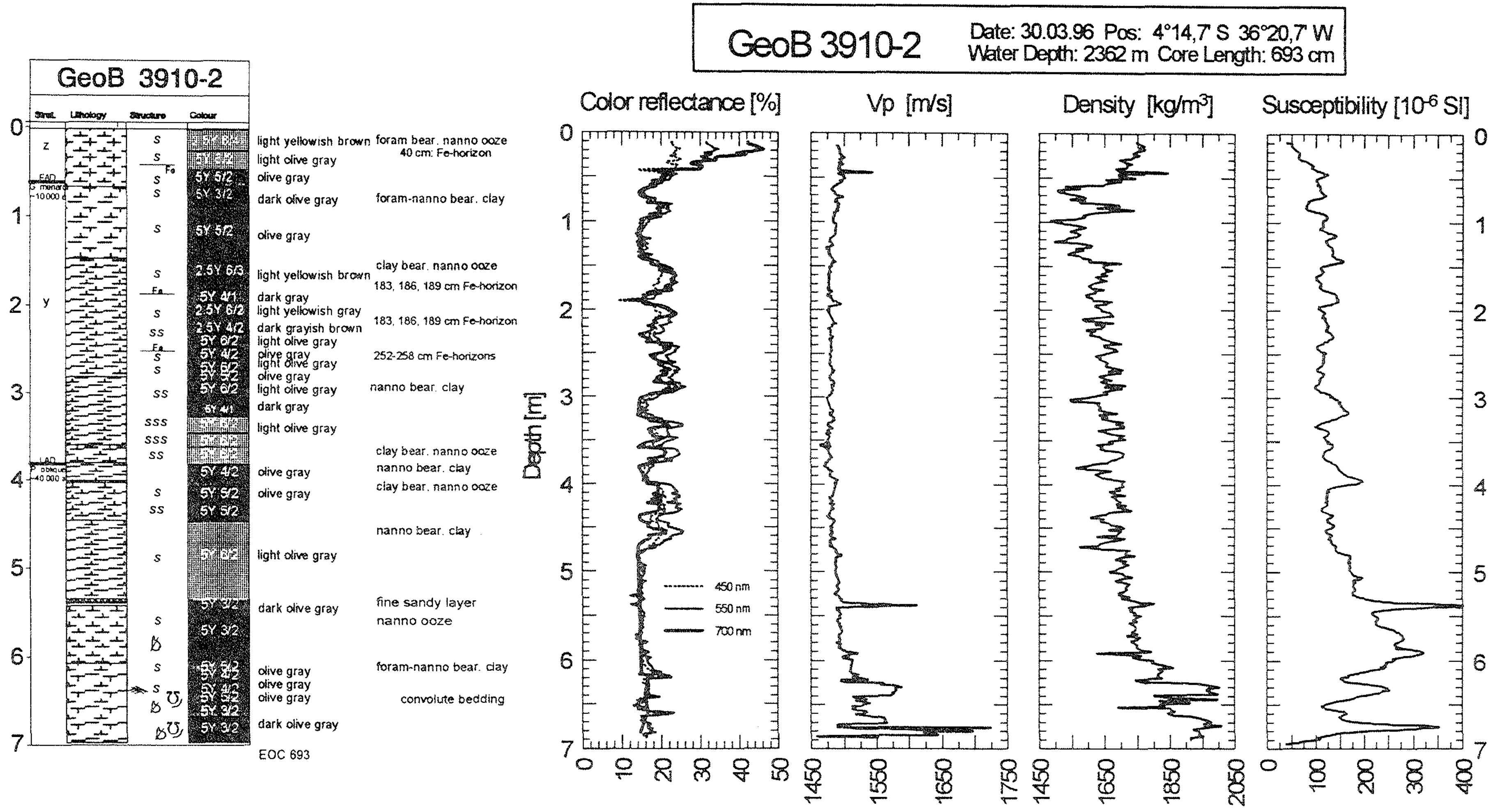


Fig. 8. Sediment descriptions, colour reflectance, and physical properties studies (Vp, density, susceptibility) for the gravity core GeoB 3910-2.

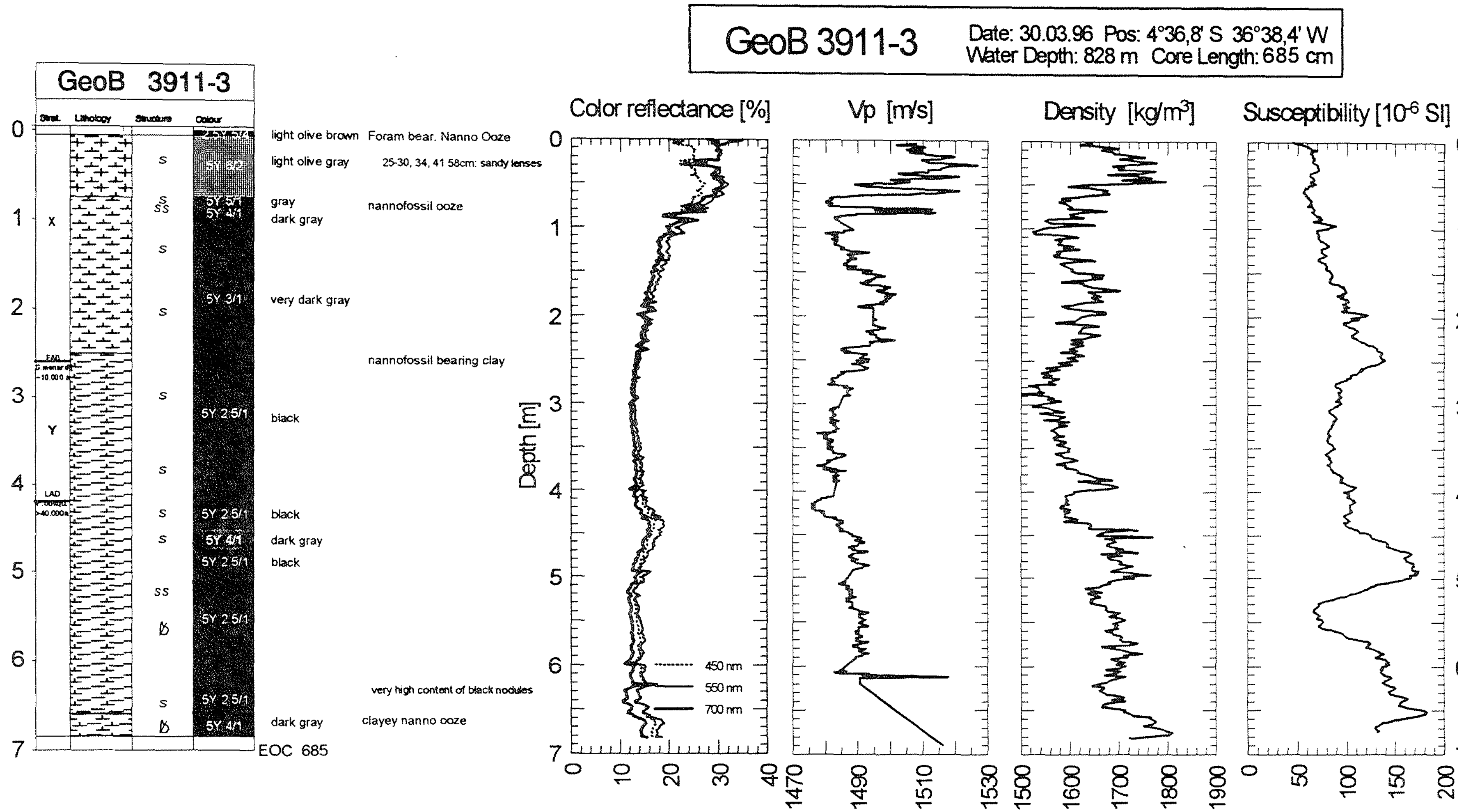


Fig. 9. Sediment descriptions, colour reflectance, and physical properties studies (Vp, density, susceptibility) for the gravity core GeoB 3911-3.

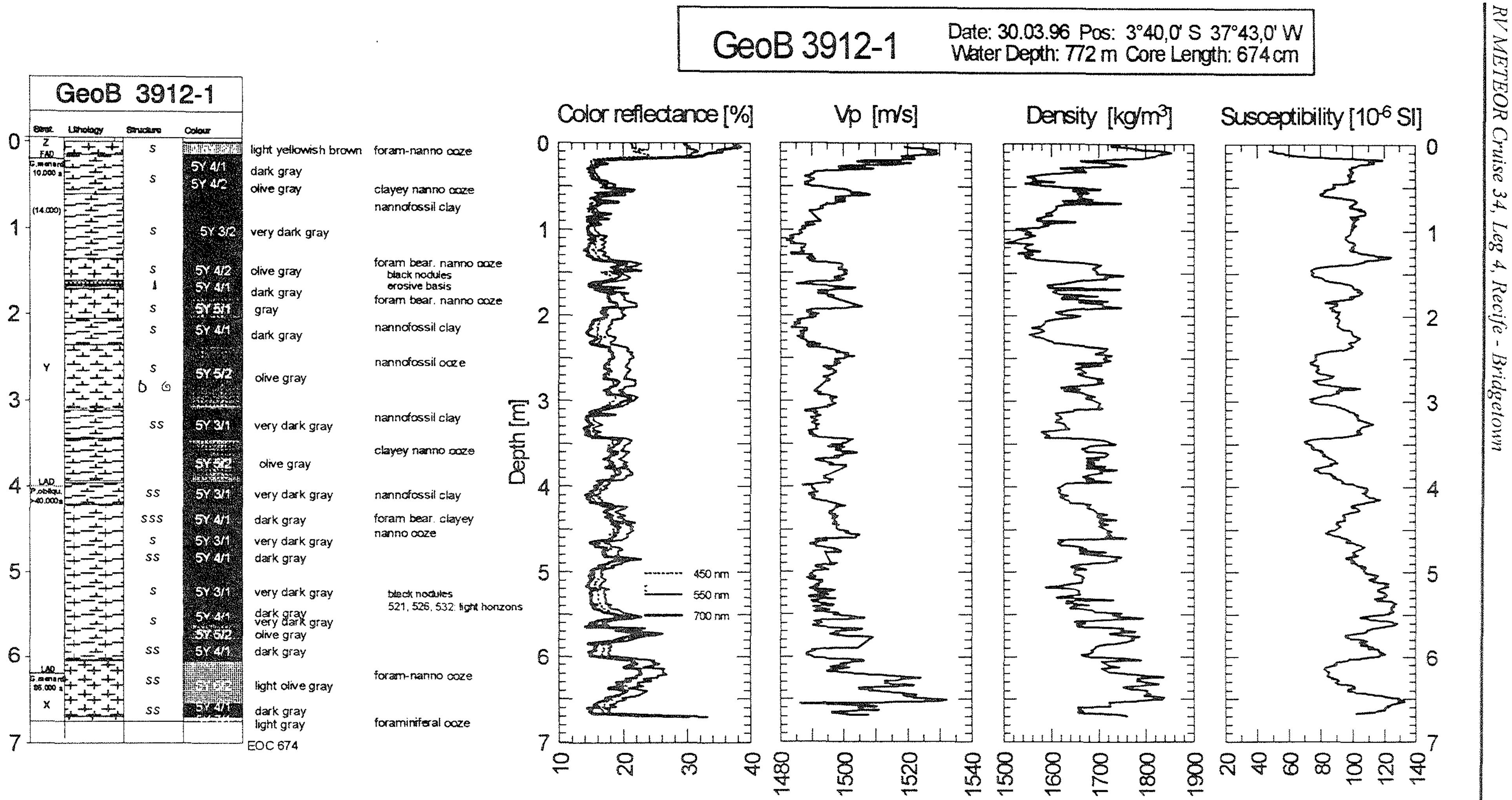


Fig. 10. Sediment descriptions, colour reflectance, and physical properties studies (Vp, density, susceptibility) for the gravity core GeoB 3912-1.

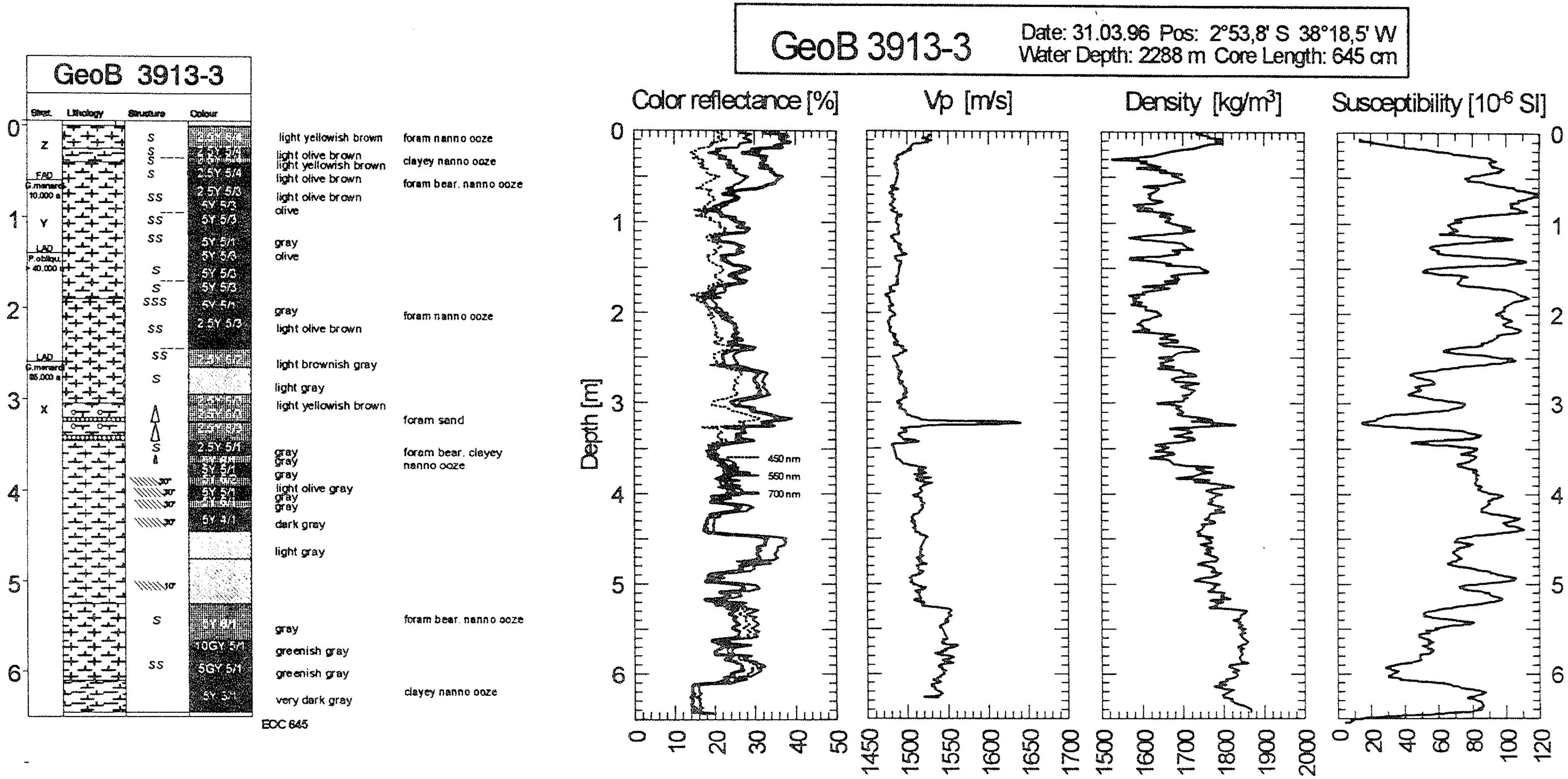


Fig. 11. Sediment descriptions, colour reflectance, and physical properties studies (Vp, density, susceptibility) for the gravity core GeoB 3913-3.

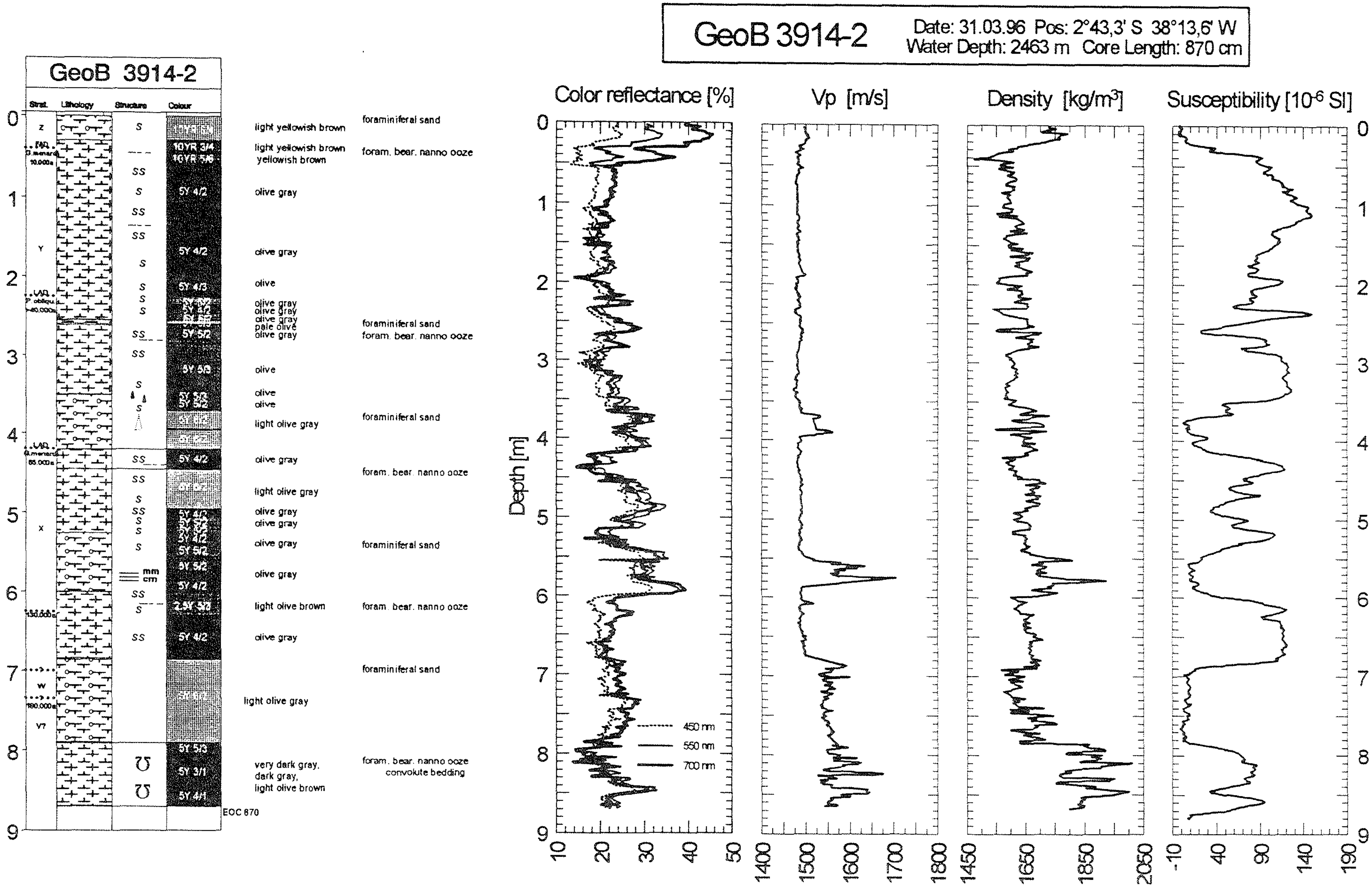


Fig. 12. Sediment descriptions, colour reflectance, and physical properties studies (Vp, density, susceptibility) for the gravity core GeoB 3914-2.

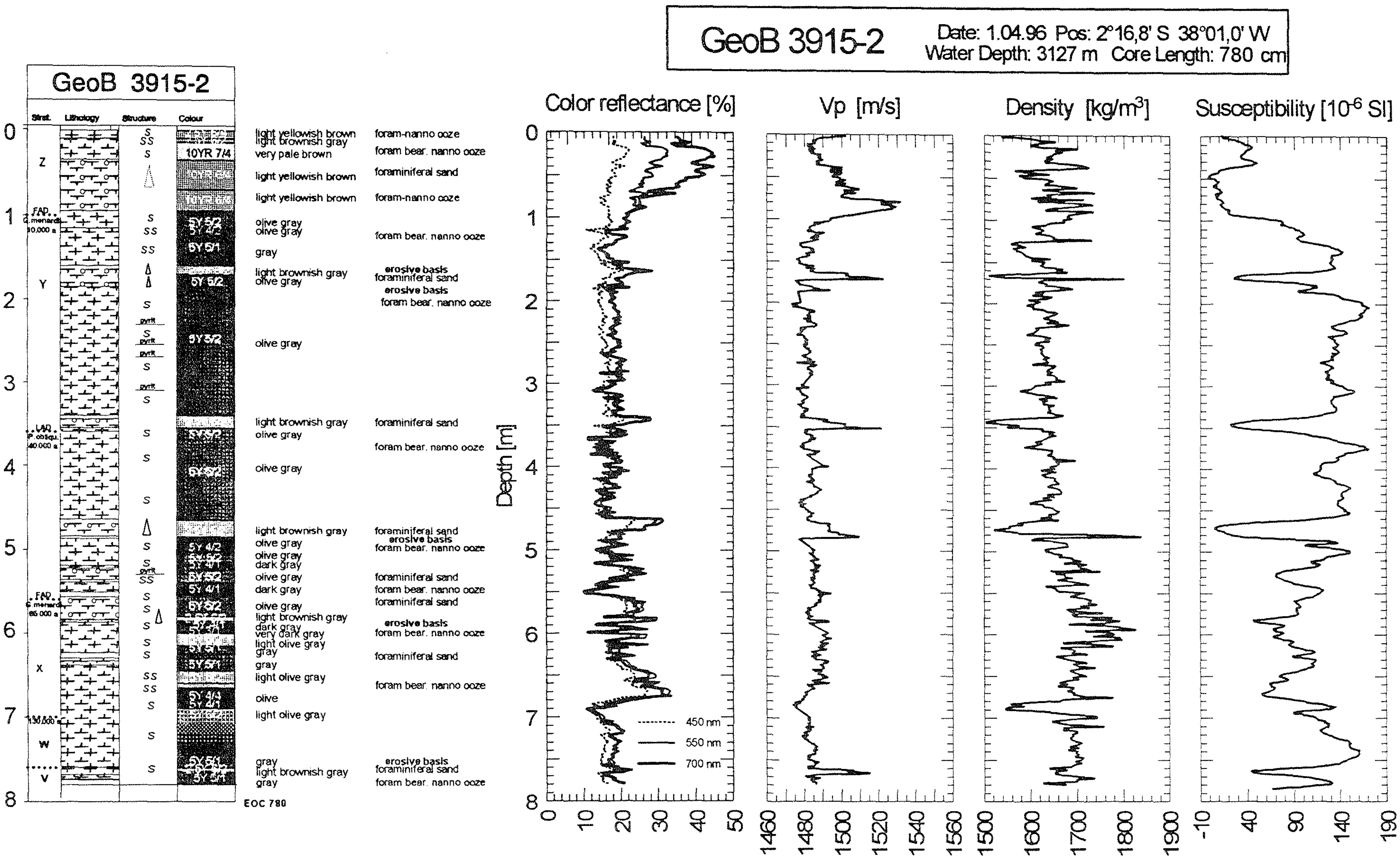


Fig. 13. Sediment descriptions, colour reflectance, and physical properties studies (Vp, density, susceptibility) for the gravity core GeoB 3915-2.

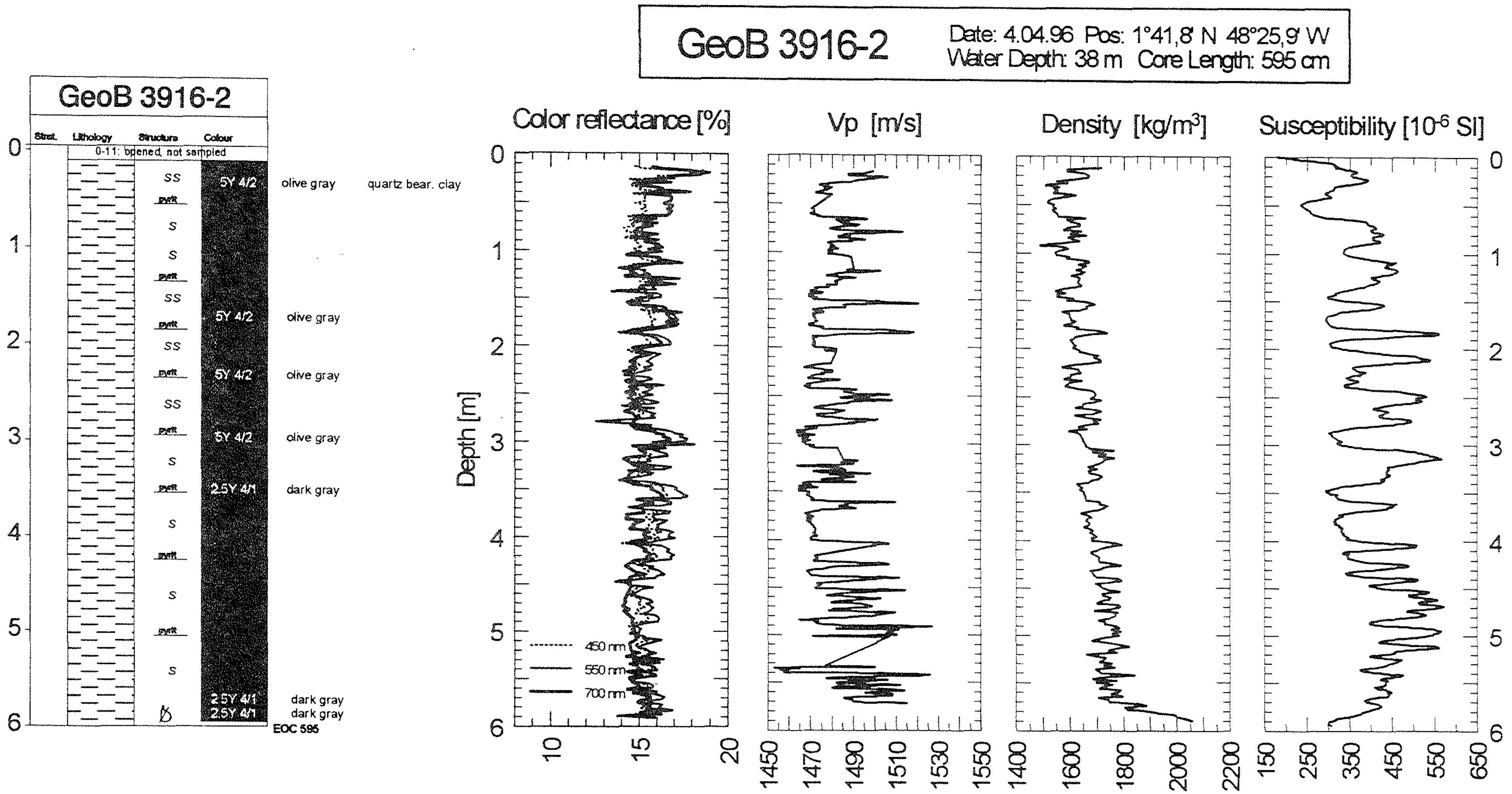


Fig. 14. Sediment descriptions, colour reflectance, and physical properties studies (Vp, density, susceptibility) for the gravity core GeoB 3916-2.

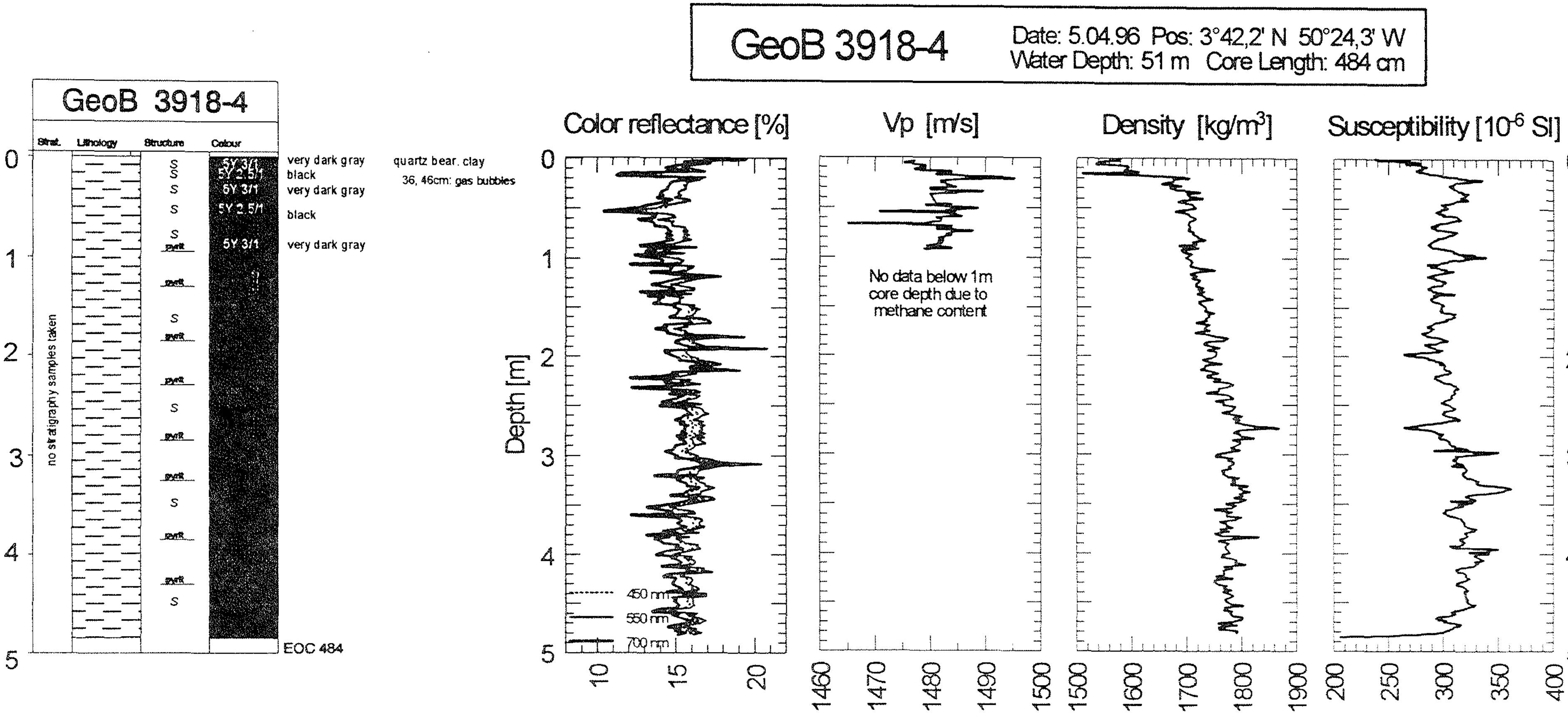


Fig. 15. Sediment descriptions, colour reflectance, and physical properties studies (Vp, density, susceptibility) for the gravity core GeoB 3918-4.

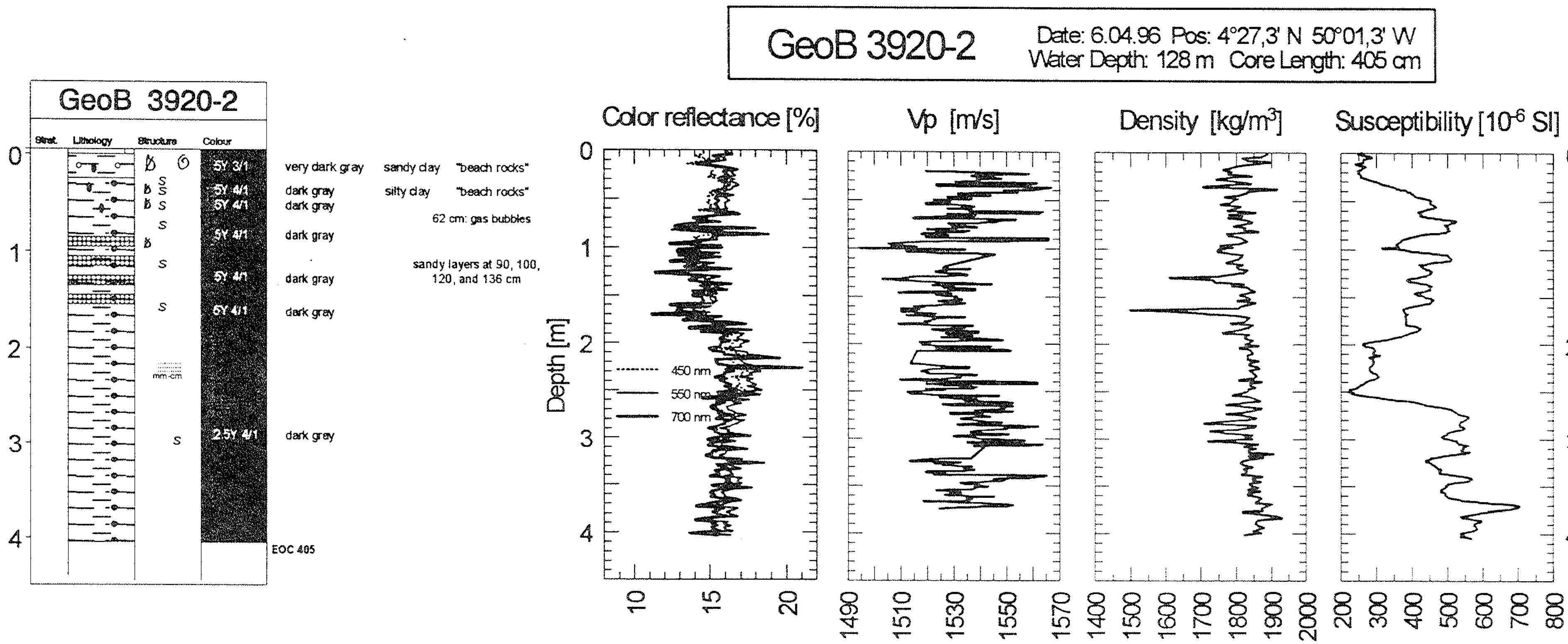


Fig. 16. Sediment descriptions, colour reflectance, and physical properties studies (Vp, density, susceptibility) for the gravity core GeoB 3920-2.

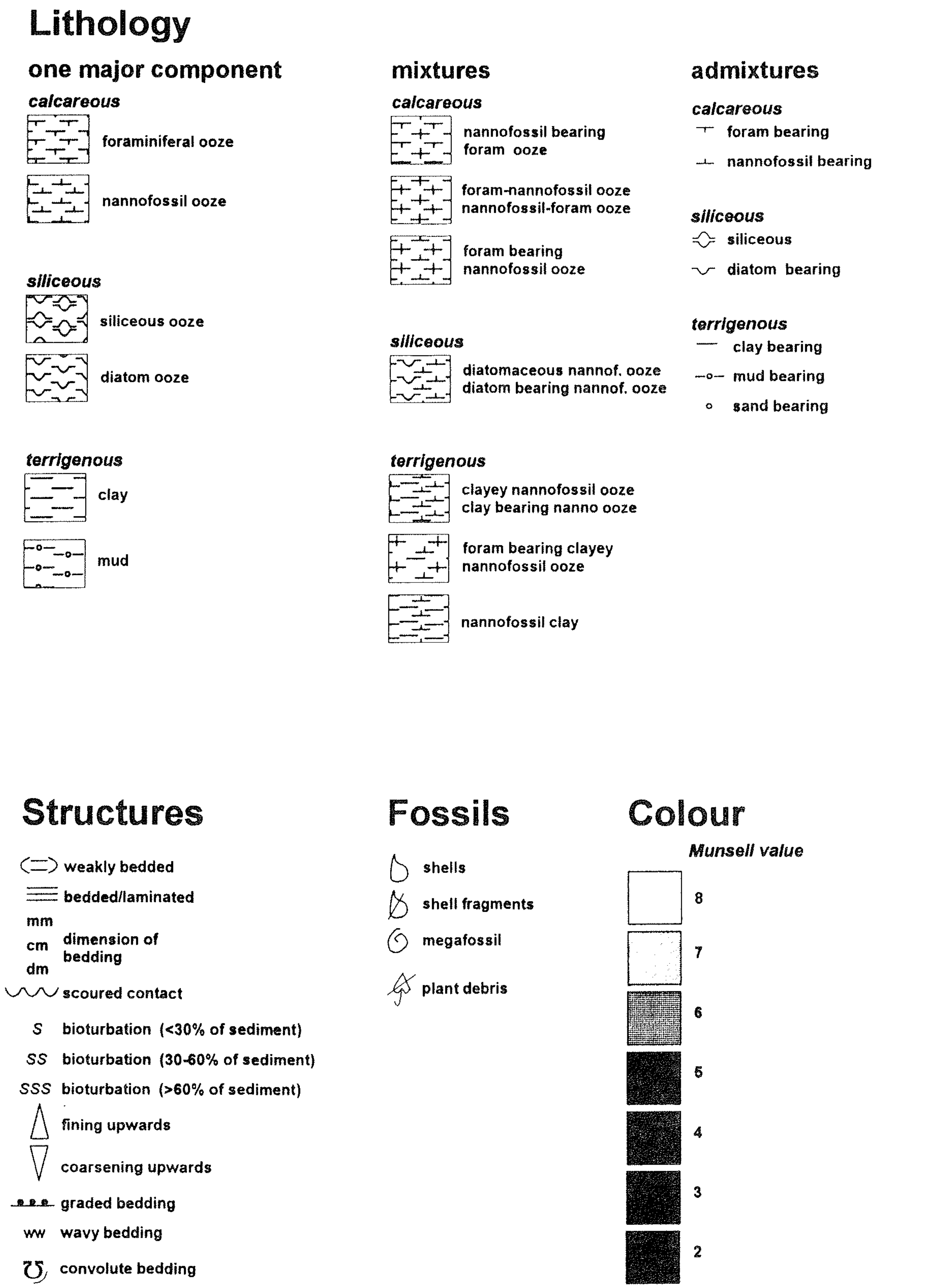


Fig. 17. Legend for stratigraphic columns of Figs. 7-16.

Northeast Brasilian Margin: Profile A

Three gravity cores, core GeoB 3909-2, 3910-2 , and 3911-3 where taken at water depth of 3164, 2362, and 828 m respectively. The average core recovery was about 700 cm (Table 12, chapter 8). According to the smear slide analysis, core GeoB 3909-2 consists predominantely of olive gray to dark gray nannofossil ooze with variable clay content (Fig. 7). Throughout the core erosive turbidity sequences of terrigenous sediments (quartz sands) with an average thickness of 10-20 cm are interbedded. At about 420 cm depth in the core, cross bedded and laminated sandy layers with plant debris occur.

The uppermost 30 cm of core GeoB 3910-2 are composed of yellowish brown coloured foraminiferal nannofossil ooze (Fig. 8). Below, the sediment turns to more grayish coloures consisting of clayey nannofossil ooze. In the upper part of the core several layers rich in Fe-oxyhydroxides (2-3 mm thick) were found. The sediment is sligthly bioturbated, with burrow density reaching a maximum between 3-4 m. The last 50 cm of the core are showing disturbed sediments, which are cross bedded and convoluted. Within this bottom end, shell fragments were observed.

The top 50 cm of the shallowest core GeoB 3911-3 consists, like in GeoB 3910-2, of light brownish foraminiferal nannofossil ooze (Fig. 9). The following two meters are characterized by increasing content of terrigenous silt and clay with the sediment colour turning to almost black. At about 460 cm and at the bottom end of the core layers with slightly increased content of nannofossils occure. The core is overall sligthly bioturbated.

Northeast Brasilian Margin: Profile B

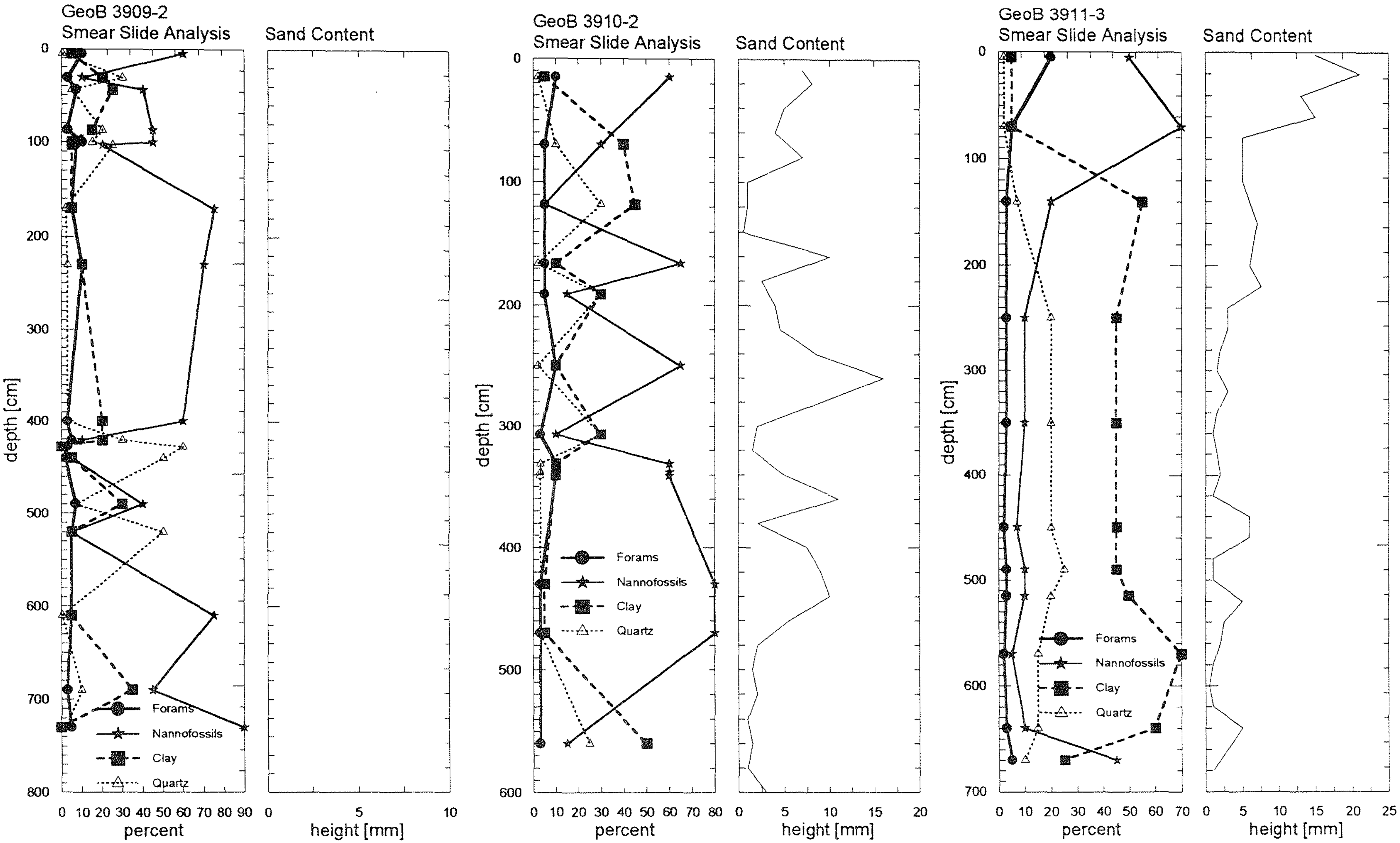
Four gravity cores (GeoB 3915-2, 3914-2, 3913-3, and 3912-1) where taken at water depths of 3127, 2463, 2288, and 772 m, respectively. The core recovery varies between 645 and 870 cm (Table 12, chapter 8). Cores GeoB 3915-2 and 3914-2 in the uppermost part consist of foraminiferal sand (Figs. 12, 13). Similar layers, partly graded, especially in core GeoB 3915-2, were observed over the whole length of the core. In between, olive to olive gray foraminifera bearing nannofossil ooze occur. The lowermost meter of the core GeoB 3914-2 shows convoluted sediments.

In the upper half of core GeoB 3913-3 the sediment is composed predominatly of strongly bioturbated, light olive brown to gray foraminiferal nannofossil ooze (Fig. 11). From 300 to 350 cm two graded beds with foraminiferal sands at the base were observed. Below, down to 525 cm the layers are tilted by 30° and are marked by nannofossil ooze with slightley enhanced clay content. From 525 cm to the end of the core the sediment consists of gray to greenish gray nannofossil ooze with varying content of foraminiferas and clay.

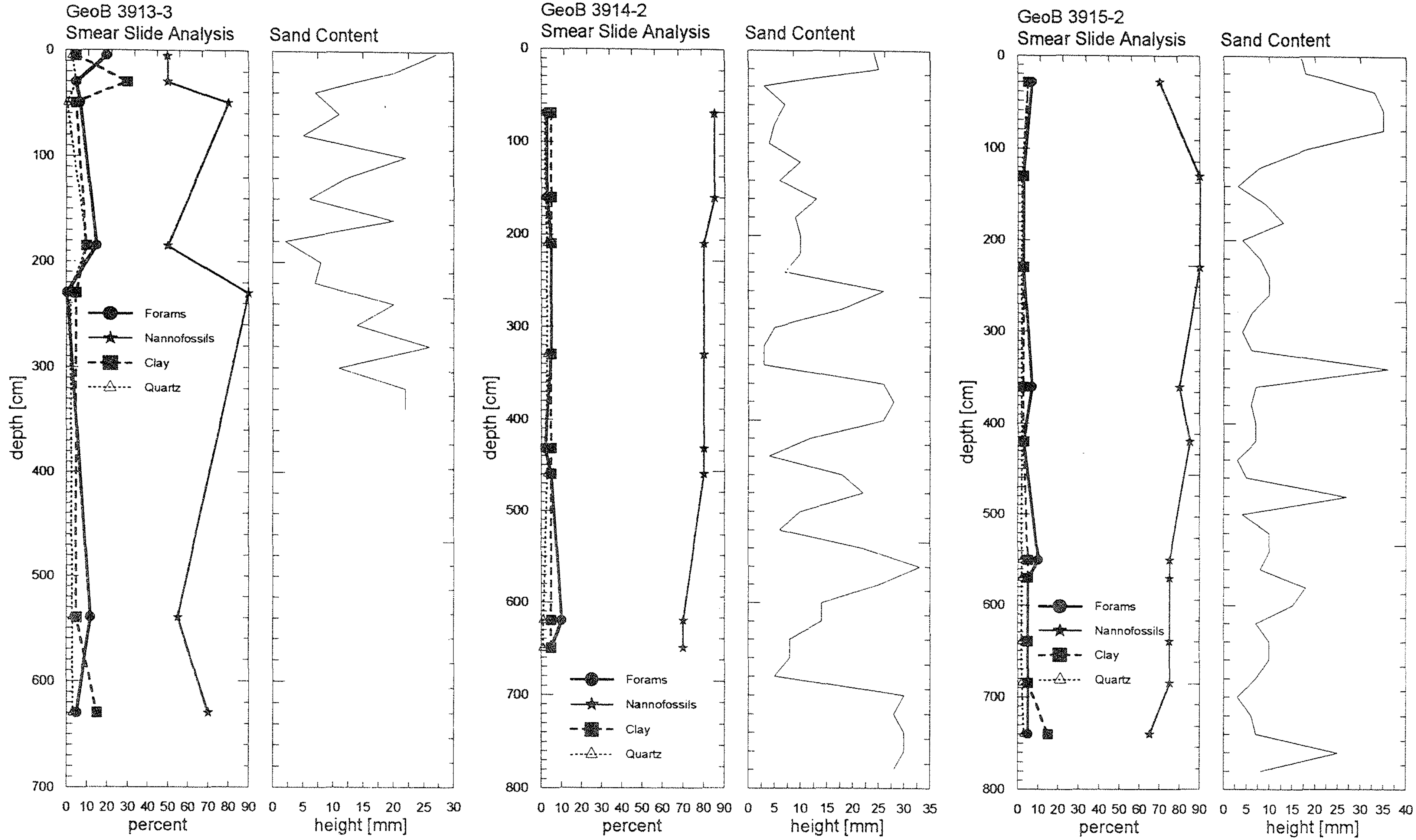
Like in the shallower cores of the profile A, the uppermost part of GeoB 3912-1 consists of yellowish brown foraminiferal nannofossil ooze (Fig. 10). Below, alterating sections of olive gray and very dark gray sediment occur, indicating fluctuations in terrigenous and marine (nannofossils) components. Over the whole core length, and especially the lower part, the sediment is bioturbated.

<u>Amazon shelf</u>

Three gravity cores, core GeoB 3916-2, 3918-4, and 3920-2 where taken at shallow water depths (< 130 m) on the Amazon shelf area. An environmental summary of the Amazon shelf area based on these cores is given in chapter 4.11.4. GeoB 3916-2 and 3918-4 are characterized by olive gray to very dark gray terrigenous clays (Fig. 14, 15). Only small variations in sediment composition are recognized. Remarkable features are black lenses and layers rich in pyrite and organic matter. The uppermost 10 cm of GeoB 3916-2 are enriched in 2-4 cm large oyster shells. Generally, core GeoB 3920-2, retrieved from a water depth of 128 m, consists of dark gray silty clay (Fig. 16). In the uppermost 200 cm sandy layers and lenses are interbedded. The top sediment of the core contains fossil beach rocks up to 10 cm in size. Between 220-264 cm a weak lamination of the sediment occures. According to the preliminary stratigraphic investigations mentioned above, all the cores of profile A and B are probably older then 40 ka. In the cores GeoB 3912-1 and 3913-3 the biostratigraphic *Globorotalia menardii* - zone X was detectet, and an age > 85 ka can be expected (Figs. 10, 11). Cores GeoB 3914-2 and 3915-2, however, are showing an age of more than 180 ka (Zone V) (Figs. 12, 13). Due to frequent turbidity (erosional ?) interbeddings in some of these cores, the preliminary stratigraphic results are to handle with care. For detailed stratigraphic information concerning the cores taken on the Amazon shelf refer to Figueiredo et al. (this volume).



Figs. 18-20. Smear slide results and sand contents for cores 3909-2, 3910-2 and 3911-3.



Figs. 21-23. Smear slide results and sand contents for cores 3913-3 , 3914-2 and 3915-2.

4.8.2.3 Carbonate Records

(H. Kinkel, M. v. Herz)

Carbonate contents were measured on board with a "carbonate-bomb". The $CaCO_3$ content of a sample was ascertained by the measurement of the CO_2 pressure after the treatment with HCl. The absolute error of a single determination is about 1% (Müller and Gastner, 1971). In total, two cores were measured for their carbonate content in 10 cm intervals. The lower parts of both cores were not analyzed, as they obviously show disturbed sedimentation patterns (turbidites, slumping).

Both cores analysed for their carbonate content were retrieved from the northeast Brazilian margin. They are located at water depths above the recent carbonate compensation depth (CCD). Even during glacial shallowing of the CCD, these sites were not affected by carbonate dissolution. Relatively high content of aragonitic pteropods in both cores indicates that the deposition occurred above the aragonite compensation depths (ACD) (Fig. 24). Variations in the carbonate content mainly reflect changes between marine, carbonate-dominated sedimentation during sea-level highstands (interglacials) and terrigenous sedimentation during sea-level lowstands (glacials). These results are confirmed by the preliminary biostratigraphy established on board. The carbonate mainly origins from skeletons of planktonic organisms (foraminiferas, pteropods and coccoliths).

Moderate high carbonate contents (66%) in the uppermost part of the cores (Holocene, Z-Zone, Fig. 24) suggest that there is still a relatively large amount of terrigenous dilution. The input of terrigenous material in core 3910-2 is much higher during glacials, with carbonate-contents dropping close to zero, whereas in core 3913-3 the carbonate content never drops below 15%. Moreover, in core 3910-2 the carbonate content undergoes strong fluctuations during the Y-Zone indicating very instable conditions shifting from terrigenous to marine sedimentation patterns, with several pteropod layers indicated by distinct peaks in the carbonate content record (Fig. 24). This observation is consistent with earlier studies (e.g. Damuth, 1975). In core 3910-2, numerous iron-rich hardgrounds occur, indicating oxidation of organic matter.

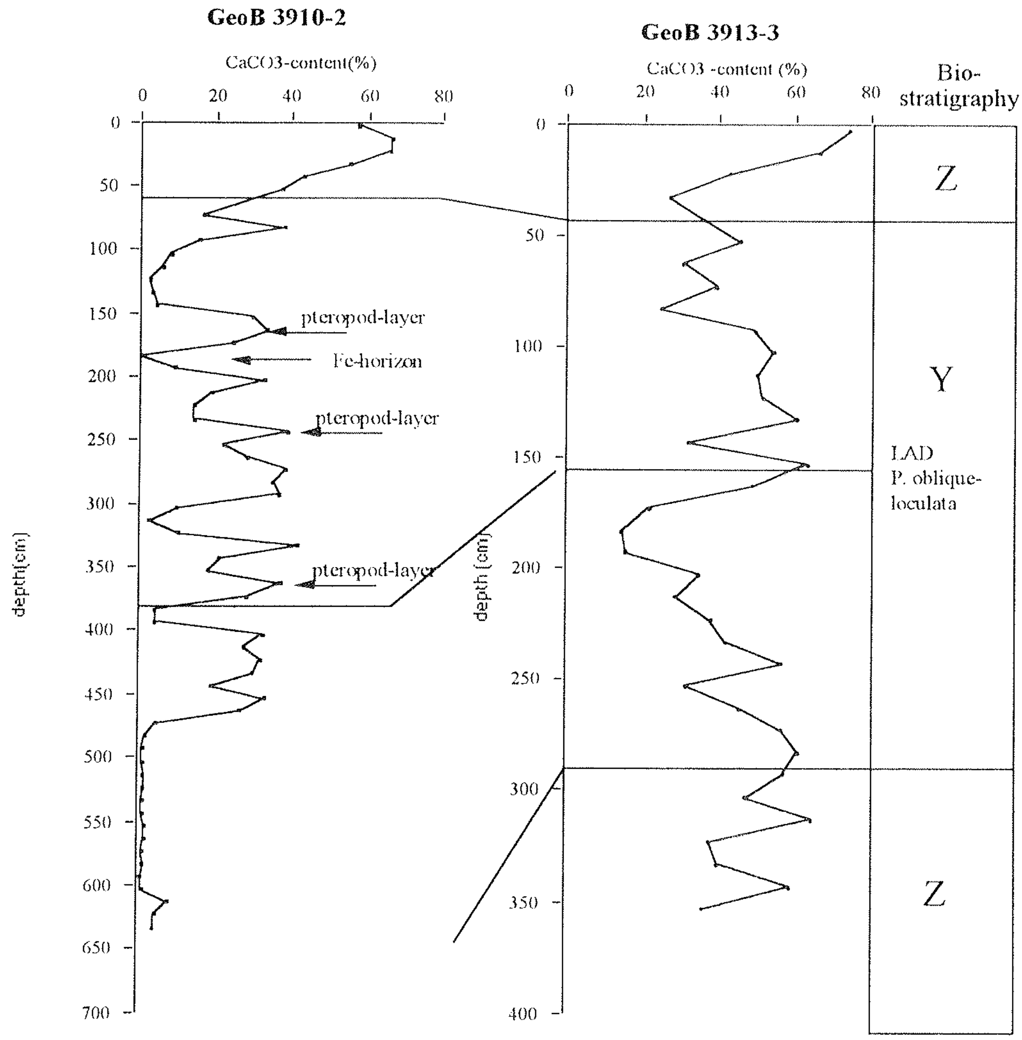


Fig. 24. Carbonate contents (%) and biostratigraphy of the gravity cores GeoB 3910-2 and GeoB 3913-3; pteropod layers are indicated by an arrow. For core location see Fig. 1 and Table 12.

4.9. Pore Water Chemistry

(K. Enneking, S. Kasten, M. Kölling, M. Zabel)

The main objectives of geochemical investigations carried out during this cruise are:

- to study the processes of early diagenetic mineralization of organic matter in marine sediments through determination and quantification of diffusive pore water fluxes. A further aim was to extent the pore water database for sediments from the western equatorial Atlantic Ocean in order to calculate and model the diffusive nutrient fluxes across the sediment/water interface on a regional scale. This will be carried out in detail at the University of Bremen within the framework of the German JGOFS program. Besides the standard sampling and analyses of multicorer samples, incubation experiments were performed on selected multicorer cores. The aim was to determine the differences in pore water concentration profiles between cores sampled immediately after retrieval and those incubated for several days at in-situ temperature. In addition, the variation of nutrient concentrations in the incubated bottom water with time was monitored.

- to examine mineralization processes at a shallow sampling site off the Amazon River mouth which has been studied e.g. by Blair and Aller (1995). In contrast to the hemipelagic sediments from the western Atlantic Ocean which are generally low in reactivity, this sampling location on the Brazilian shelf is characterized by high mineralization rates and therefore allows a comparison with the organic-rich deposits from the eastern South Atlantic mainly focussing on the importance of anaerobic methane oxidation and the sedimentary sulphur cycle. Additional solid phase examinations will be performed at the University of Bremen.

- to recover a sediment core from the Amazon Deep-Sea Fan that shows the typical stratigraphy with terrigenous glacial deposits overlain by Holocene calcareous sediments. It was intended to analyse methane in the deeper core section and to sample the sediment solid phase under argon atmosphere as these data and kind of samples are lacking for the gravity cores taken on the Amazon Fan during a former METEOR cruise in 1991. The main focus in studying these deep-sea fan sediments is to evaluate the potential of climatically induced non-steady-state conditions to modify the sedimentary record. The Amazon Fan experienced such a distinct change in depositional conditions during the Pleistocene/Holocene transition. Detailed solid phase examinations including acid digestion, mineralogical and geophysical studies are to be carried out at the University of Bremen. Although it was originally intended to reoccupy station GeoB 1514 it was finally decided to recover a gravity core at ODP site 940 for cooperation with the Marine Geology group. This location which is close to the active Amazon Channel experienced strong differences in sediment type and accumulation rates between the Last Glacial and the Holocene and was therefore assumed to be suitable for the exmination of non-steady-state early diagenetic processes induced by strong changes in depositional conditions.

4.9.1. 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 4°-6°C. The multicorer cores were processed within a few hours. Two samples of the associated bottom water were taken for oxygen determination and two samples for nutrient analysis. The remaining bottom water was carefully removed from the multicorer tube by means of a siphon in order to avoid destruction of the sediment surface. During subsequent 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. At some stations this second core was stored under in situ temperature within an incubation box for two or three days. Therefore the tubes were captured with 1.8 l-plexiglas cells ("Dittert cells") which are combined with a pumping system to simulate the bottom water current. During the experiments the overlying waters were analysed continously. After incubation the cores were processed like described before.

The gravity cores were cut into 1 m segments on deck. At sampling locations where methane was expected to be present, syringe samples were taken on deck from every cut segment surface. Higher resolution sampling for methane analysis was carried out in the cooling laboratory immediately after storing by sawing 2-4 cm rectangles into the PVC liner. In this way, syringe samples of 5 ml sediment were taken every 10-20 cm and injected into 50 ml septum vials containing 20 ml of a concentrated (1.2 M) NaCl-solution. $HgCl_2$ was added to the solution to prevent additional production of methane by microbial activity. After closing and subsequent shaking methane becomes enriched in the headspace of the vial. 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 20 cm for pressure filtration. Conductivity and temperature were measured on the archive halves. Solid phase samples were taken at same intervals and kept in gas-tight glass bottles under argon atmosphere. 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- and PE-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.

The following parameters were determined on this cruise:
Eh, pH, conductivity (porosity), O_2, NO_3^-, NH_4^+, PO_4^{3-}, alkalinity, Fe^{2+} , SO_4^{2-}, Cl^- and CH_4.

H_2S was not analysed because the sediments in the study area are mainly dominated by iron reduction. The high amounts of dissolved iron result in an immediate precipitation of iron sulphides as soon as any sulphide is produced - in this way preventing the buildup of significant amounts of H_2S in the pore waters. Bottom water O_2 concentrations were analysed in duplicate by Winkler titration. Eh, pH, conductivity and temperature values were determined by means of electrodes before the sediment structure was disturbed by sampling for pressure filtration. Nitrate, ammonium and phosphate were measured photometrically with an autoanalyser using standard methods. Alkalinity was calculated from a volumetric analysis by tritration of 1 ml sample with 0.01 or 0.05 M HCl, respectively. For the analysis of iron subsamples of 1 ml were taken within the glove box and immediately complexed with 50 µl of Ferrospectral and determined photometrically afterwards. SO_4^{2-} and Cl^- were analysed by ion chromatography from pore water diluted 1:20 with deionized water. For the detection of methane 25 µl of the headspace gas was injected into a gas-chromatograph. The concentrations of methane measured have to be related to the sediment porosity. Since corrected porosity data were not available we assumed a uniform porosity of 0.6 in all gravity cores for the calculation of preliminary methane contents. These concentrations will be recalculated with the corrected porosity values at the University of Bremen. The remaining pore water samples were acidified with $HNO_3^-{}_{(suprapure)}$ down to a pH value of 2 for storing and subsequent determination of cations by ICP-AES and AAS. All pore water samples will be maintained at 4°C until further treatment in Bremen.

4.9.2. Shipboard Results

During this cruise a total of 10 stations was examined geochemically including 5 gravity cores and 9 multicorer cores. In addition, multicorer cores from five stations were incubated. The locations of the sampling sites are illustrated in Fig. 25.

Most of the sampling sites examined on this cruise are characterized by low mineralization rates of organic matter. Furthermore the sedimentary sequences of three of the investigated gravity cores (GeoB 3910, 3911, 3914) are disturbed by abundant turbidites. Although being of overall low reactivity, the multicorer cores taken along Profile A on the northeast Brazilian Margin (GeoB 3909, 3910 and 3911) show a characteristic increase in mineralization activity with decreasing water depth. This is demonstrated by the NO_3 pore water concentration profiles illustrated in Fig. 26. For PO_4 the same trend is observed with no concentration gradient detectable within the upper centimeters at the deepest station GeoB 3909 (3174 m). At stations GeoB 3910 and 3911 pore water concentrations indicate a flux of PO_4 across the sediment/water interface. The steepest PO_4 concentration gradient was determined for the shallowest sampling location GeoB 3911 at a water depth of 826 m. Pore water iron and NO_3 at this station show characteristic profiles (Fig. 27a) . Both are consumed at around 13-15 cm sediment depth accompanied by a pronounced shift in redox potential.

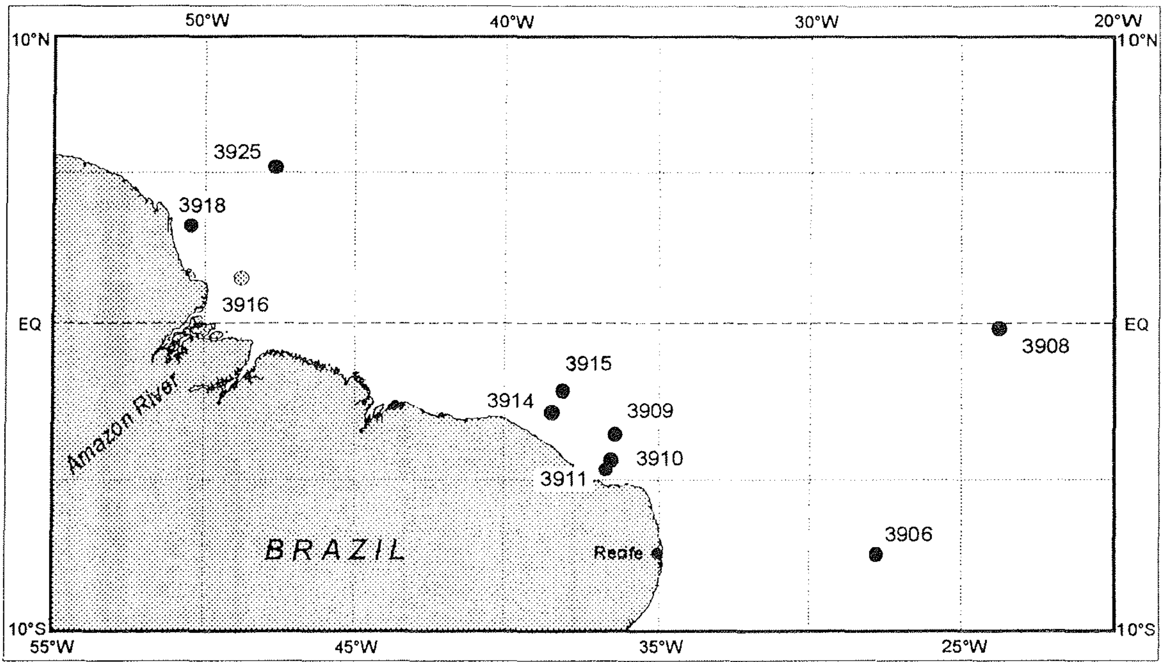


Fig. 25. Stations where geochemical investigations were carried out.

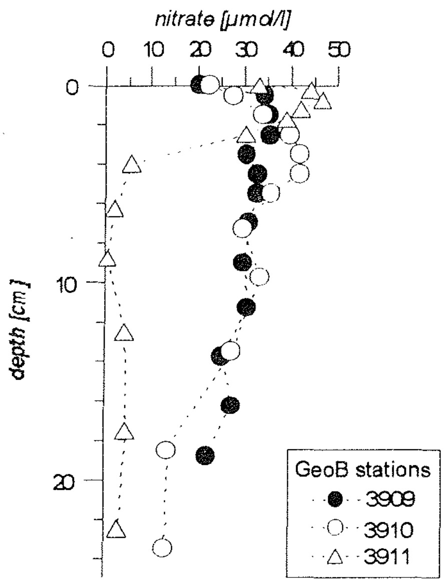


Fig. 26. Nitrate pore water profiles from multicorer sediments sampled on profile A.

Station GeoB 3918 is located on the Amazon River shelf close to the site examined by Blair and Aller (1995) as part of the AmasSeds project (Nittrouer et al., 1991) and has been subject to an erosional event about 5-10 years ago. The pore water profiles for the multicorer core displayed in Fig. 27b illustrate the higher reactivity of the sediments at this location compared to those from site GeoB 3911 (Fig. 27a). The determined concentration profiles for alkalinity, sulphate (Fig. 28) and methane for the gravity core are comparable to those reported by Blair and Aller (1995). They demonstrate that the rate of methane oxidation can be increased when methane-charged buried sediments are reexposed to sulphate-rich seawater by a physical non-steady-state process, such as erosion. The highest methane concentrations detected in this core amount to 4.5 mmol (CH_4)/l (wet sed). The methane contents determined in the samples immediately taken on deck from the cut sediment segments were generally higher than those measured from the higher resolution samples taken subsequently in the cooling laboratory. The methane contents detected in gravity core GeoB 3925-3 below 1 m sediment depth are a tenfold higher than those measured in geology core GeoB 3916-2 below 3 m. The latter core is located directly in front of the Amazon River mouth.

At station GeoB 3925 - which corresponds to ODP-site 940 - the examined multicorer core consists of the characteristic Holocene carbonate ooze and shows a gradual increase in alkalinity and PO_4 with depth. Nitrification is completed at about 1 cm sediment depth from whereon NO_3 concentrations decrease to values around 10 µmol/l at the base of the core in 20 cm depth. At this level iron was detected in pore water. Due to a slight shift in the position of the ship before recovering the gravity core, the multicorer core and gravity core taken at this station do not fit into a sequence. A top pelagic unit is absent in the gravity core and pore water concentration profiles of alkalinity and NH_4 (Fig. 29) indicate that several meters of the upper sedimentary sequence are missing. Furthermore, sulphate reduction is not completed so that, unfortunately, the early diagenetic zone of interest has not been reached in this gravity core.

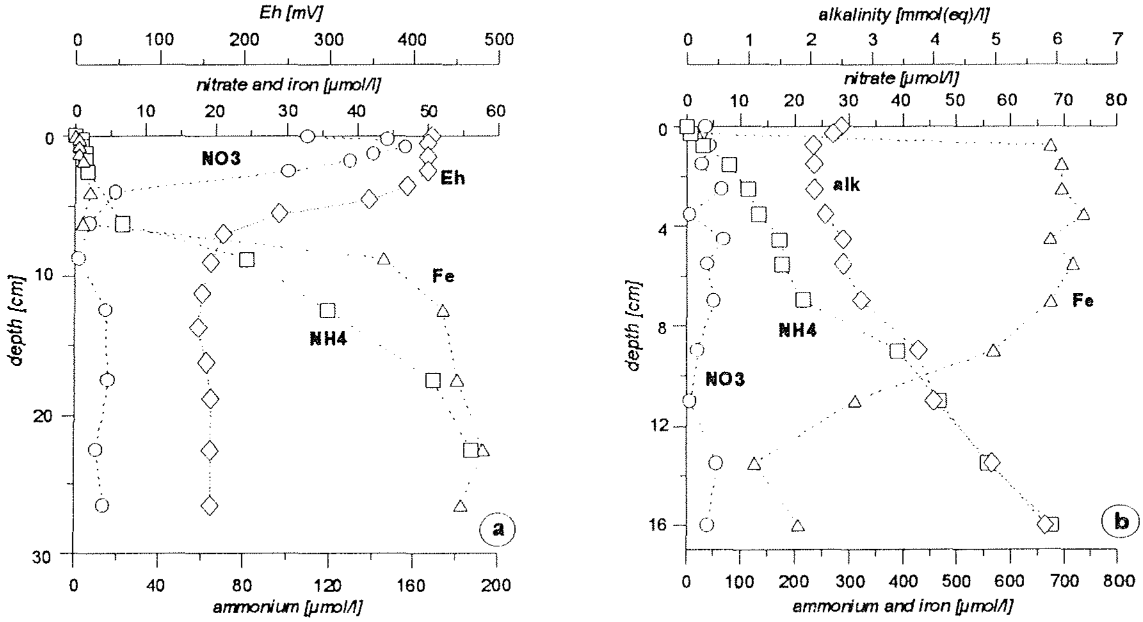


Fig. 27. Pore water profiles from multicorer sediments sampled at GeoB sites 3911 (a) and 3918 (b). While concentrations profiles at station GeoB 3911 show the common sequence, the very high mineralization rates at GeoB 3918 lead to the compression of nitrification and denitrification directly at the sediment surface and the overlying water, respectively.

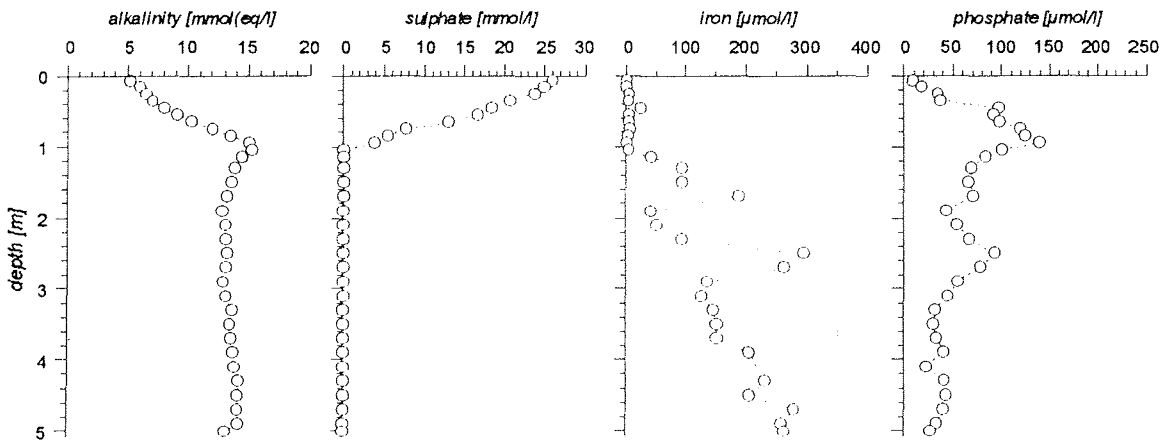


Fig. 28. Pore water concentration profiles at station GeoB 3918. Sulphate reduction is completed at about 1m depth, where the released sulphide precipitates with iron as authigenic iron sulphides. Sulphate reduction seems to be controlled by the anaerobic oxidation of upward diffusing methane.

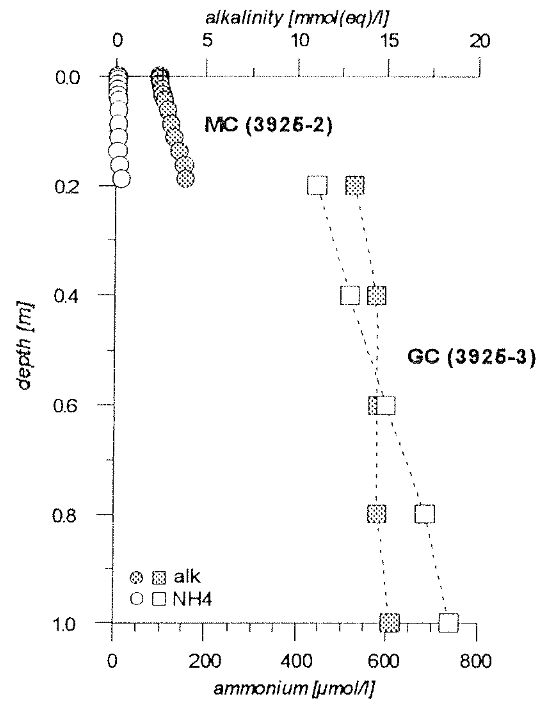


Fig. 29. Pore water concentration profiles from multicorer and gravity core samples at station GeoB 3925. Obviously the top layers of the gravity cores have been eroded.

4. 10. Physical Properties -Studies

(T. Frederichs, F. Schmieder, C. Hübscher, A.Figueiredo, E. Costa)

During METEOR cruise 34/4 the recovered gravity cores were subject to laboratory geophysical studies. A routine shipboard measurement of three physical parameters was carried out on the segmented sediment cores, comprising the determination of:

- the compressional (P-) wave velocity v_p,
- the electric resistivity R_S, and
- the magnetic volume susceptibility κ.

These properties are closely related to the grain size, porosity and lithology of the sediments and provide high-resolution core logs (spacing 1 cm for P-wave velocity and magnetic volume susceptibility, 2 cm for electric resistivity) available prior to all other detailed investigations. In addition, oriented samples for later shore based paleo- and rockmagnetic studies were taken at intervals of 10 cm.

4.10.1. Physical Background and Experimental Techniques

The experimental setup for the shipboard measurements was basically identical to that of previous cruises. Therefore, the descriptions given here are kept brief. For a more detailed treatment of the experimental procedures we refer to Wefer et al. (1991) for R_S and to Schulz et al. (1991) for v_p.

P-wave velocity

The P-wave velocity v_p was derived from digitally processed ultrasonic transmission seismograms, which were recorded perpendicular to the core axis with a fully automated logging system. First arrivals are picked using a cross-correlation algorithm based on the 'zero-offset' signal of the piezoelectric wheel probes. In combination with a measure of the core diameter d the travel time of the first arrivals t lead to a P-wave velocity profile with an accuracy of 1 to 2 m/s.

$$v_p = (d - d_L) / (t - t_0 - t_L)$$

where d_L is the thickness of the liner walls, t_L the travel time through the liner walls and t_0 the 'zero-offset' travel time.

Following Schultheiss and McPhail (1989), a temperature calibration of v_p is effected using the equation

$$v_{20} = v_T + 3 \cdot (20 - T)$$

where v_{20} is the P-wave velocity at 20°C and T the temperature (in °C) of the core segment when logged. Simultaneously, the maximum peak-to-peak amplitudes of the transmission seismograms are evaluated to estimate attenuation variations along the sediment core. P-wave profiles can be used for locating strong as well as fine-scale lithological changes, e.g. turbidite layers or gradual changes in the sand, silt or clay content.

Electric resistivity, porosity and density

The electric sediment resistivity R_S was determined using a handheld sensor with a miniaturized four-electrodes-in-line ('Wenner') configuration (electrode spacing: 4 mm). A rectangular alternating current signal is fed to the sediment about 1 cm below the split core surface by the two outer electrodes. Assuming a homogeneously conducting medium, the potential difference at the inner two electrodes is directly proportional to the sediment resistivity R_S. A newly integrated fast resistance thermometer simultaneously provides data for a temperature correction.

According to the empirical ARCHIE's equation, the ratio of sediment resistivity R_S and pore water resistivity R_W may be approximated by a power function of porosity d

$$R_S/R_W = k \cdot d^{-m}$$

Following a recommendation by Boyce (1968), suitable for seawater saturated, clay-rich sediments, values of 1.30 and 1.45 were used for the constants k and m. The calculated porosity d is subsequently converted to wet bulk density σ_{wet} using the equation (Boyce, 1976)

$$\sigma_{wet} = d \cdot \sigma_f + (1 - d) \cdot \sigma_m$$

with a pore water density σ_f of 1030 kg/m^3 and a matrix density σ_m of 2670 kg/m^3. For the sake of an unbiased uniform treatment of all cores, these empiric coefficients were not adapted to individual sediment lithologies at this stage. Nevertheless, at least relative density changes should be well documented.

Magnetic volume susceptibility

The magnetic volume susceptibility κ is defined by the equations:

$$B = \mu_0 \cdot \mu_r \cdot H = \mu_0 \cdot (1 + \kappa) \cdot H = \mu_0 \cdot H + \mu_0 \cdot \kappa \cdot H = B_0 + M$$

with the magnetic induction B, the absolute/relative permeability $\mu_{0/r}$, the magnetising field H, the magnetic volume susceptibility κ and the volume magnetisation M. As can be seen from the third term, κ is a dimensionless physical quantity. It describes the amount to which a material is magnetised by an external magnetic field.

For marine sediments, the magnetic susceptibility may vary from an absolute minimum value of around $-15 \cdot 10^{-6}$ (diamagnetic minerals such as pure calcite or quartz) to a maximum of some $10.000 \cdot 10^{-6}$ for basaltic debris rich in (titano-) magnetite. In most cases κ is primarily determined by the concentration of ferrimagnetic minerals while paramagnetic minerals such as clays are of minor importance. High magnetic susceptibilities indicate a high lithogenic input/high iron (bio-) mineralisation or low carbonate/opal productivity and vice versa. This relation may serve for the mutual correlation of sedimentary sequences which were deposited under similar global or regional conditions.

The measuring equipment consists of a commercial Bartington M.S.2 susceptibility meter with a 125 mm loop sensor and a non-magnetic core conveyor system. Due to the sensor's size, its sensitive volume covers a core interval of about 8 cm. Consequently, sharp susceptibility changes in the sediment column will appear smoother in the κ core log and, e.g., thin layers such as ashes cannot appropriately be resolved by whole-core susceptibility measurement.

4.10.2. Shipboard Results

Sampling Sites and Recovery

The gravity coring program of cruise 34/4 was performed in two working areas. Profiles A and B were located northeast of Brazil, between 2° and 5° S and 36° and 39° W, respectively (Fig. 1). The cores GeoB 3909-2 to 3915-2 were taken from water depths between 772 and 4061 m. Cores GeoB 3916-2, 3918-4, 3920-2 were recovered on the Amazon shelf, between 1° and 5°N and 48° and 51°W, respectively, in waterdepths of 38, 51 and 128 m.

The core recovery varies between 405 (GeoB 3920-2) and 880 cm (GeoB 3914-2). A total of 10 sediment cores with a cumulative length of 67 m was investigated (upper part of Fig. 30).

General Results

A compilation of the characteristic physical properties of all cores is given in the lower part of Fig. 30. The dots mark the median values of compressional wave velocity, density and magnetic susceptibility for each core, the vertical bars denote their standard deviations. Each diagram is divided into three parts corresponding to profiles A and B and the Amazon shelf.

On the northeast Brazilian Margin (profiles A and B) the average p-wave velocities range from 1489 to 1509 m/s, while mean densities from 1647 to 1724 kg/m^3 were found. The average magnetic susceptibility shows constant values of about $100 \cdot 10^{-6}$ SI on both profiles A and B. Significant higher intensities up to $427 \cdot 10^{-6}$ SI (GeoB 3920-2) were determined in the cores from the Amazon shelf. P-wave velocity and density ranging from 1476 to 1534 m/s and 1677 to 1821 kg/m^3, respectively, differ only slightly from those of the cores of profiles A and B.

Physical property logs for the cores together with the core descriptions are shown in Figs. 7-16 (chapter 4.8.2.2.).

Special Features

Northeast Brazilian Margin (profiles A and B)

In general, there is no obvious core to core correlation based on physical properties, except for the magnetic susceptibility in the upper 340 cm of core GeoB 3914-2 (Fig. 12) which correlates with that of the upper 220 cm of core GeoB 3913-3 (Fig. 11). A preliminary interpretation of these characteristic, probably climatically driven patterns revealed that these core intervals recorded a time period up to oxygen isotope stage 4. Dating of the older sediments is not possible, while in GeoB 3913-3 age may be estimated at least down to 320 cm depth which corresponds to oxygen isotope stage 5.5. These tentative age models are supported by biostratigraphy.

In all cores, except for GeoB 3911-3 (Fig. 9) and GeoB 3912-1 (Fig. 10), turbidites cause distinct maxima in p-wave velocities and density values. In GeoB 3909-2 (Fig. 7) ,these charactistic peaks are associated with minima in the magnetic susceptibility due to foraminiferal sands. The graded bedding of these sediments is reflected particularly in the down-core variations of v_p, for example in 160 cm core depth. In core GeoB 3915-2 (Fig. 13), core depth 170 and 480 cm, layers of pteropod-rich sediments produce maxima in p-wave velocities but minima in density values while the underlaying foraminiferal sands show a typical positive correlation of both parameters. In core GeoB 3910-2 (Fig. 8), p-wave velocity and susceptibility are positively correlated in a layer of fine sandy mica bearing sediments (540 cm core depth).

Amazon shelf

The variations of magnetic susceptibility in core GeoB 3916-2 (Fig. 14), in particular in the lower 250 cm, may correspond to Milankovitch cycles with a characteristic change of frequency at 400 cm core depth. Core GeoB 3918-4 (Fig. 15) is not acoustically measurable below a core depth of about 100 cm due to insufficient signal strength. The reason for this problem seems to be the degassing of methane gas due to preasure release. Gas bubbles in the sediment greatly attenuate sound transmission.

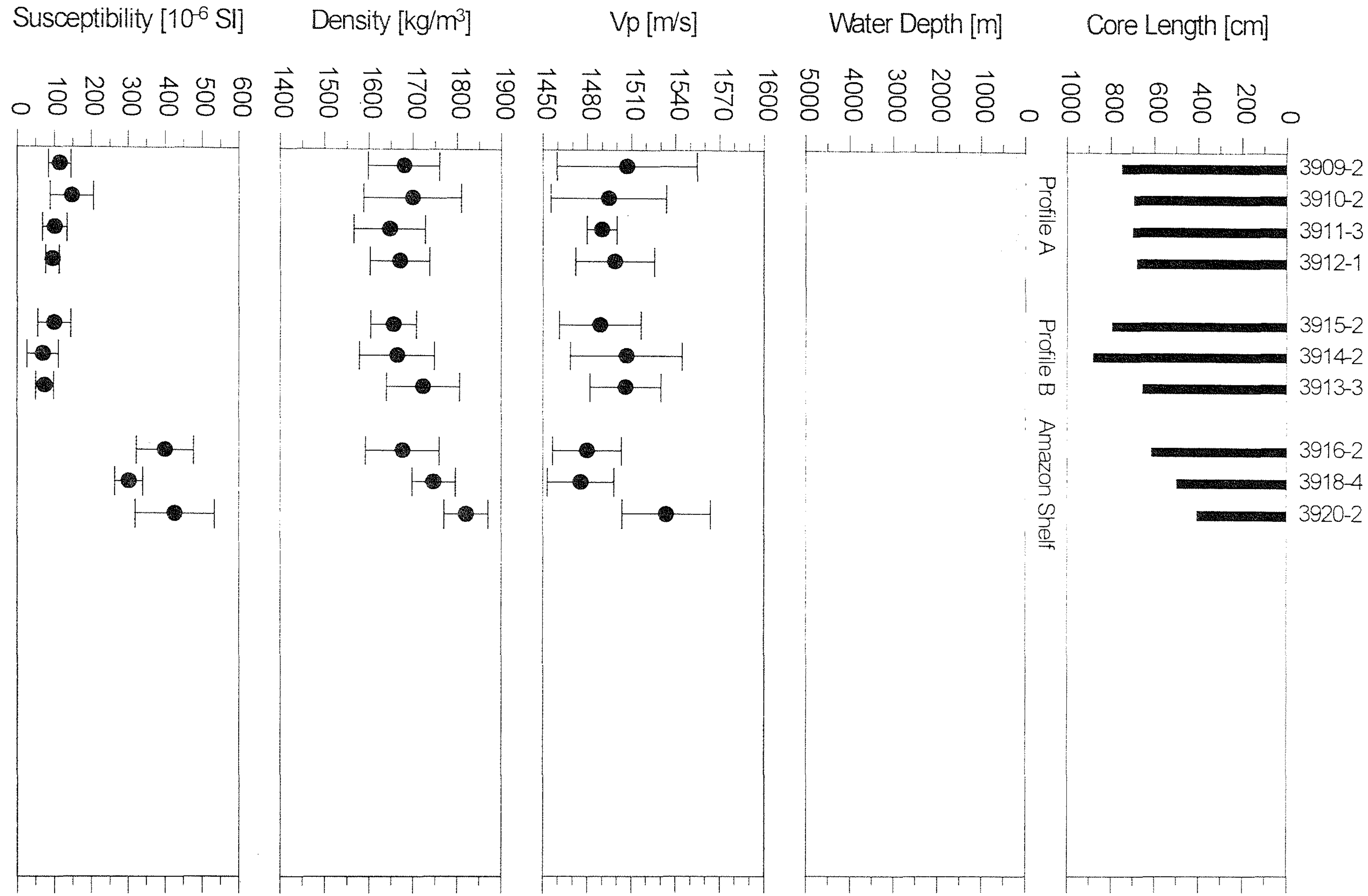


Fig. 30. Mean compressional wave velocity, density and magnetic susceptibility of gravity cores GeoB 3909-2 through 3920-2 compared to water depth and core length. The bars denote the standard deviations.

4. 11. Profiling Hydroacoustic Systems

(C. Hübscher, T. Frederichs, F. Schmieder)

During the entire cruise M34/4 the Hydrographic Multi-Beam Deep-Sea Sweeping Echosounder HYDROSWEEP and the Parametric NBS Deep-Sea Echosounder and Sub-Bottom Profiling System PARASOUND were operated 24 hours a day outside the 12 nm zone of Brazil and the territorial waters of Surinam and French Guayana.

4.11.1. HYDROSWEEP

The general purpose of the HYDROSWEEP system is to survey topographic features of the seafloor. A sector of 90° is covered by a fan of 59 pre-formed beams. Thus, a stripe with the width of twice the water depth is mapped perpendicular to the ship track. A shiprelative bottom map is plotted online. Data are stored on DAT cartridges in a sensor undependent format. Since HYDROSWEEP is not longer a rack mounted system, a workstation is installed directly beside the ParaDigMa PC, enabeling the PARASOUND operator to check the topographic map and cross- and ahead profiles on the HYDROSWEEP screen for optimized PARASOUND control. Beside the production of bathymetric maps HYDROSWEEP data are an important tool for the determination of gravity core and MUC sites. Also, the gained 3D information of the seafloor topography represents an important contribution to the interpretation of the 2D-PARASOUND cross sections.

4.11.2. PARASOUND

The PARASOUND system 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. An optimized succession of generated signals allows the resolution of small horizontal variations. Most of the data reveal no diffraction hyperbolas. The data quality can be compared with stacked and partly migrated MCS data. The ParaDigMa system (Spieß,

1993) converts the analog to digital data and stores them on 9-track tapes or hard disks in a SEG-Y like format. Lateron the data are copied on DAT-cartridges. Therewith, they are available for further processing. The preprocessed analog and digital data are plotted online with the DESO 25 and a HP PaintJet, respectively. Navigation data from the DVS are plotted and stored to disk simultanously.

Besides the usage of the PARASOUND system as a tool for localization of core positions (gravity core, MUC), the main objectives of the PARASOUND survey were

- to image and describe the dominating sedimentation process at the continental slope,
- to study the development and internal structures of channel-levee complexes of the Amazon Deep-Sea Fan,
- to investigate the prograding subaqueous Amazon Delta with its top-, fore- and bottom set,
- to interprete the structural context of the gravity cores.

4.11.3. Selected PARASOUND Data - First Results

The quality of PARASOUND data will be illustrated by four examples in this chapter. Data from the Amazon shelf are presented by Figueiredo et al. (this volume, chapter 4.11.4.). An example from the continental slope off Guyana is shown in Fig. 31. The 24 km long profile strikes perpendicular to the coast and is located at 9.5°N, 57.5°W. The water depth is around 3000 m. The signal penetration reaches 40 m. No or little distinct reflectors can be observed beneath the wavy seafloor, diffuse reflectivity dominates the resolved sediments. Diffuse diffraction hyperbolae contribute to the blurred internal layers. However, no distinct layers can be resolved beneath the plateau at the center of the profile. Therewith it is assumed that disturbed deposited sediments are present. The observed sediment structures are representative for the entire slope between 1900 and 4200 m water depth. The seafloor itself is mainly characterized by sediment waves with a wavelength of around 2 km. The observed reflection characteristic is typical for slumps or contourites and winnowed sediments, respectively. If slumping caused the wavy sediments, changing wavelength and slide plains would have been expected. Therefore, it is more likely that a strong current caused the disturbed layering or a reworking of already deposited sediments. The North Atlantic Depth Water (NADW) forms a strong countour current at the north-west continental slope of South-America (Reid, 1989). The current is reported for water depths between 1800 and 4200 m like it is observed in the data. Therewith, the NADW current is regarded as the causative process for the sediment waves.

Another example for current influenced vs. gravity transported sediments is shown in Fig. 32. The 54 km long profile has been gained in a depth of almost 5000 m close to the Mid-Ocean Ridge, which is located directly in the northeastern prolongation of the profile. Two canyons incise into well layered sediments, which are covered by a 4 m thick semi-transparent layer, presumably consisting of (hemi-)pelagic sediments. The 14 km wide basin in the east is located at the base of a steep slope towards the MOR, its shape is typical of current triggered moats. The origin of the western canyon is less clear. If the sediment block between the canyon represents a sediment slide - internal structures are still seen - the smaller canyon is a slide scarp. The absence of hemipelagic sediments indicates, however, the impact of bottom currents. In this case, both canyons represent erosional channels.

The next section shows a channel-levee complex (CLC) from the Amazon fan. The modern channel has been crossed in a water depth of 3700 m (CLC A, Fig. 33). Sediment waves can be observed at the outer flanks of the levees. East of the active channel, older and abandoned channels have been crossed (CLC B, C, Fig. 33). The eastern levee of CLC B strikes out against the western levee of CLC C as an onlap. All three channels reveal a very high sinuosity, why the meandering channels are crossed several times. e.g., the channel of CLC A itself has been crossed three times.

A typical example for submarine channels outside of fan systems is presented in Fig. 34. An up to 2 km wide mixed depositional-erosional CLC is seen at the western side. The depositional levees exhibit parallel reflectors with no sediment waves at the outer flanks. It is remarkable that no divergent reflectors or inwards thickening of the layers can be observed within the levees. The well layered eastern levees are truncated by a meandering erosional channel. The channel is crossed two times due to the high sinuosity (B, C). No depositions can be observed at the channel shoulders.

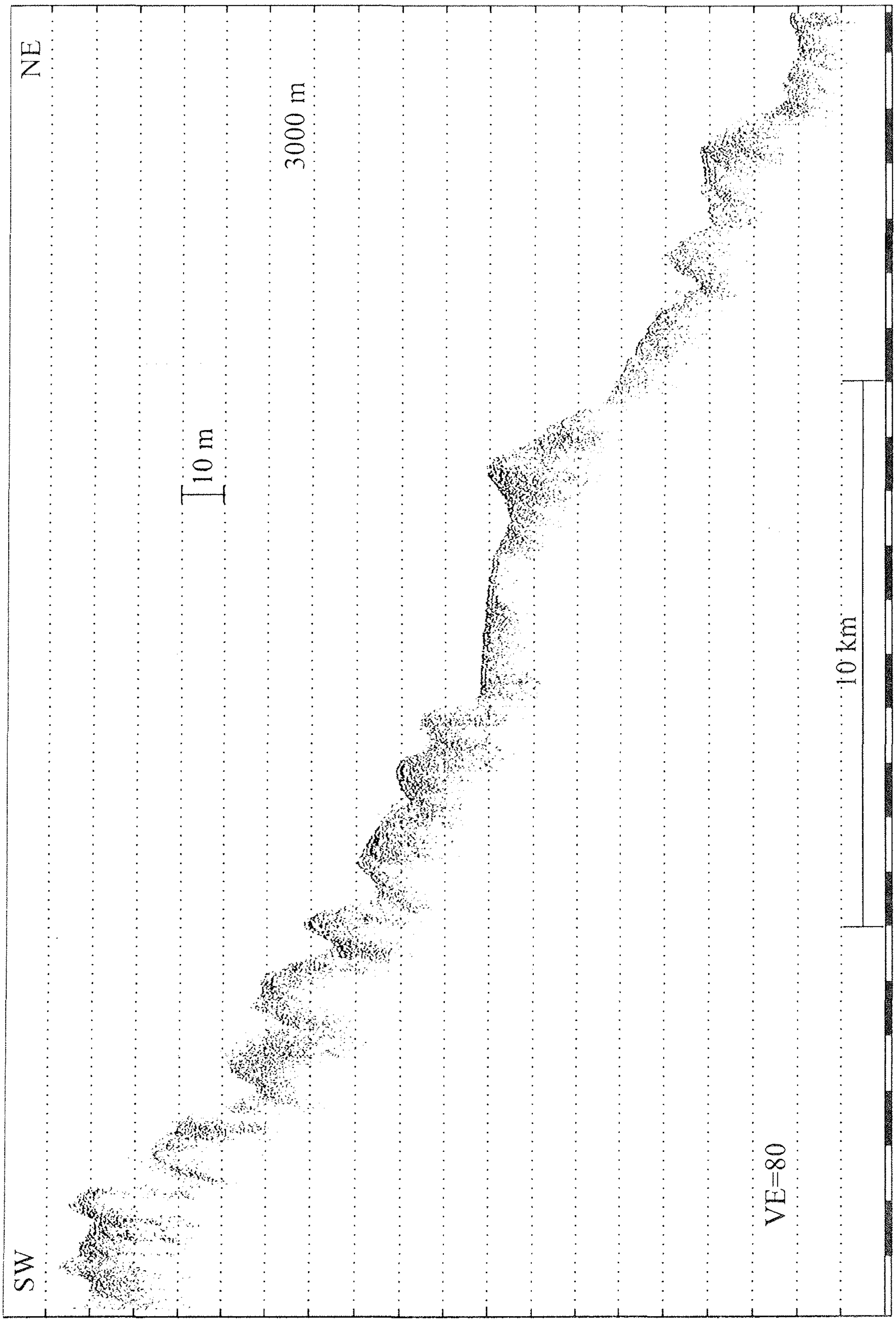


Fig. 31. PARASOUND profile showing diffuse reflecting sediment waves at the continental slope off Guyana, caused by the NADW current.

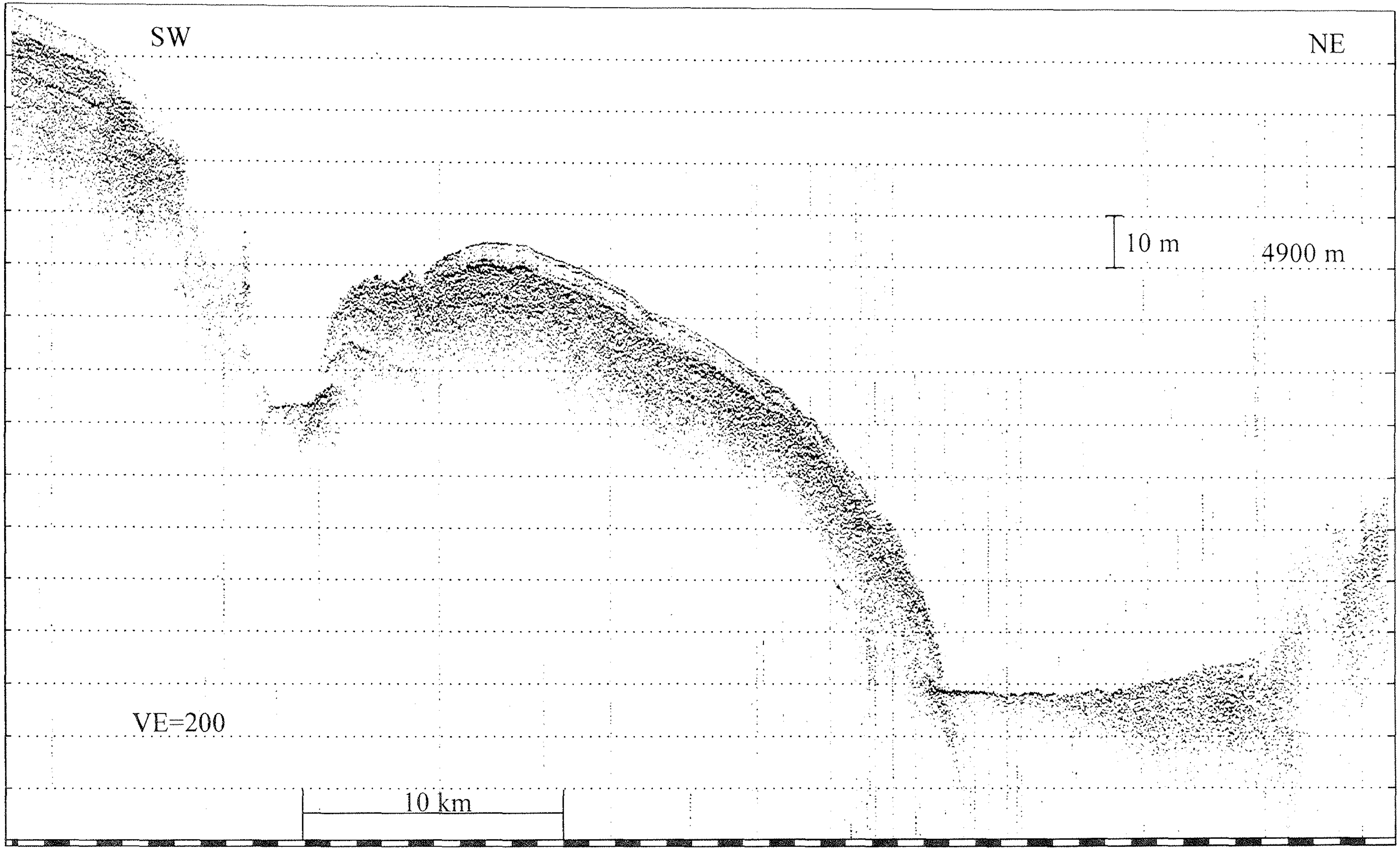


Fig. 32. PARASOUND profile from the western foot of the MOR in the central Atlantic. Two canyons are observed. The western canyon represents a moat, the western canyon a slide scarp or erosive channel.

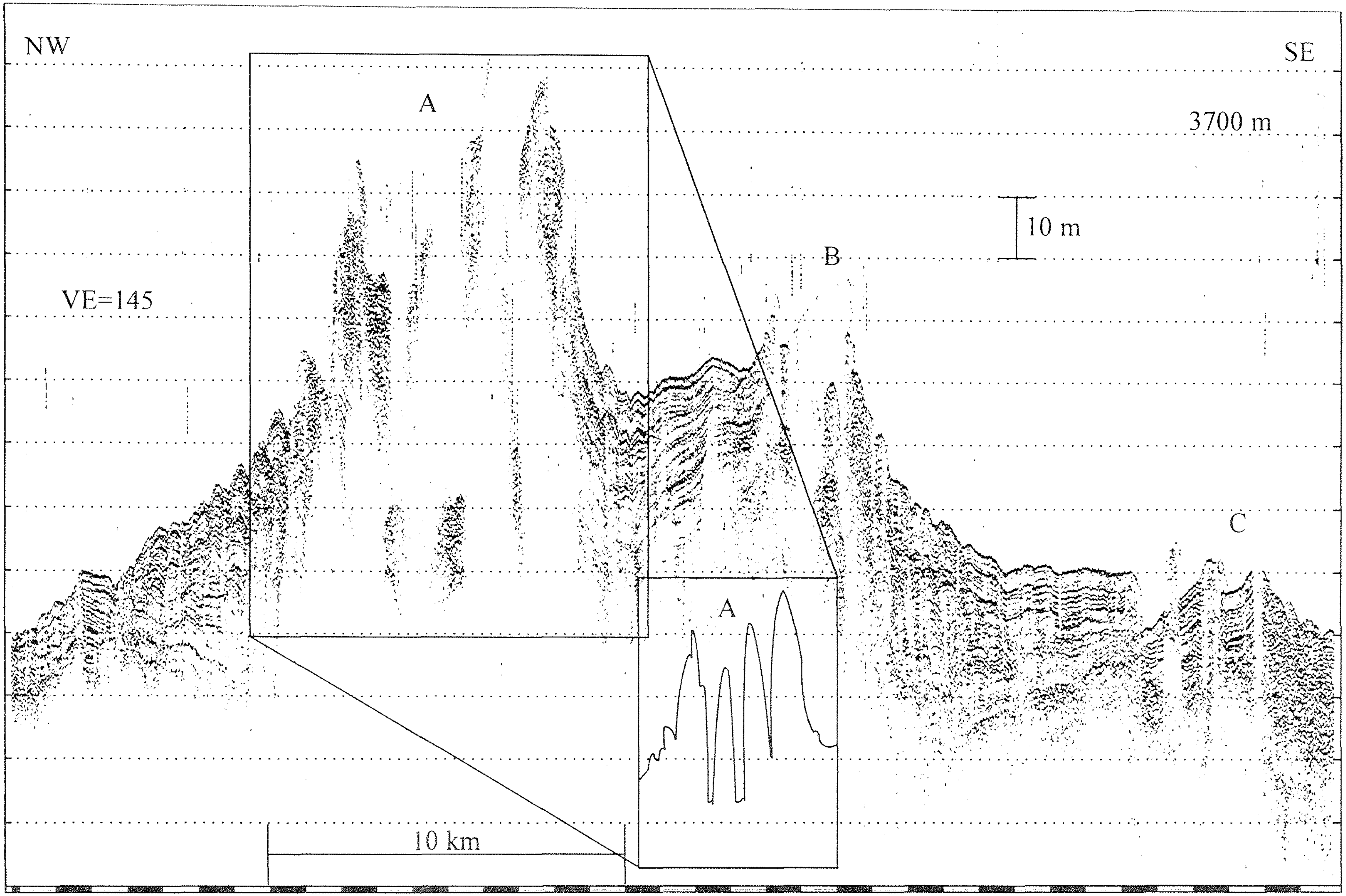


Fig. 33. PARASOUND profile crossing the modern channel-levee complex (CLC A) and older complexes at the lower Amazon Fan. Due to the high sinuosity the meandering channels are crossed more than once.

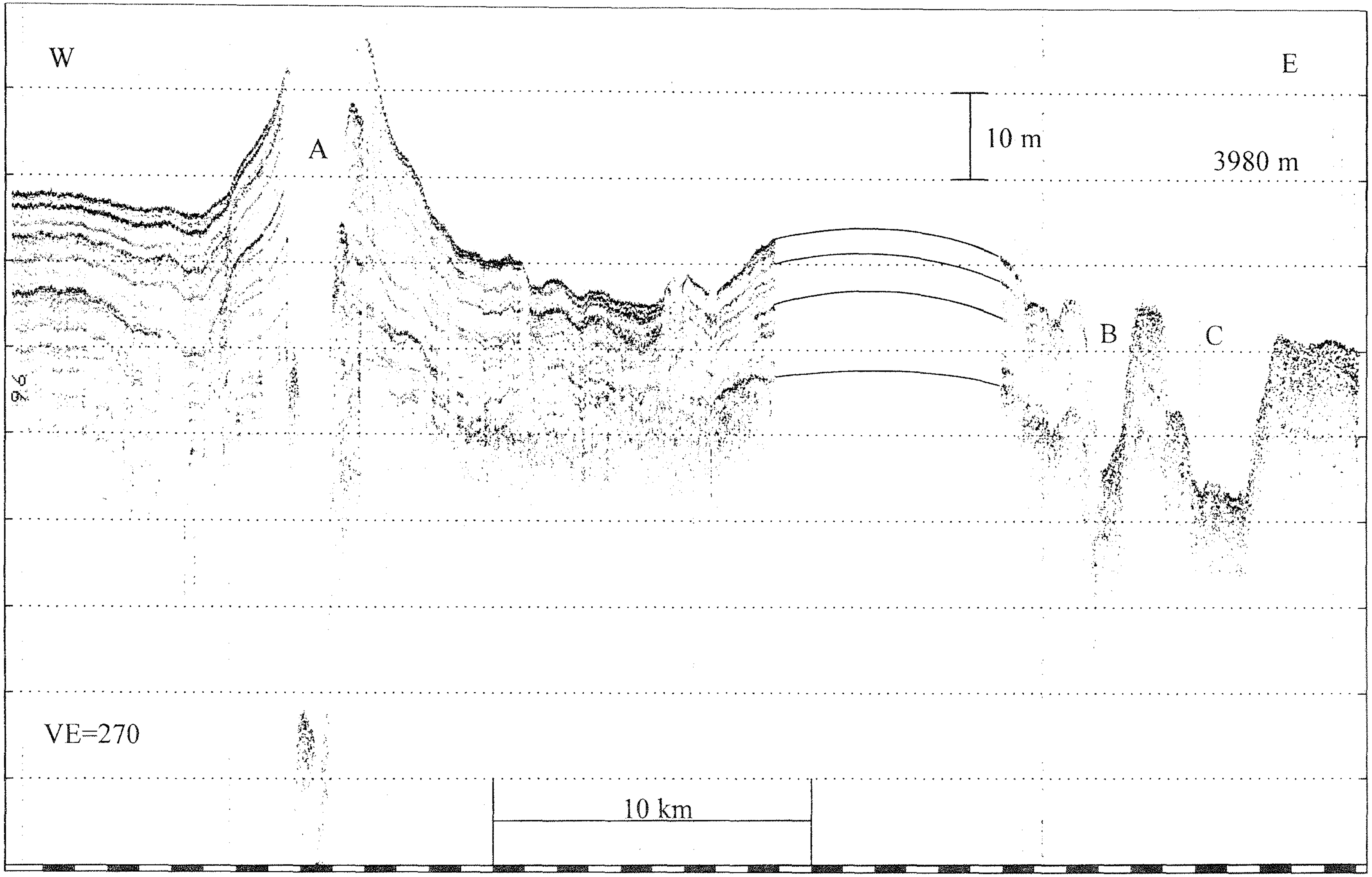


Fig. 34. PARASOUND profile exhibiting a mixed erosional-depositional channel-levee complex (A) with an erosional meandering channel (B, C) in the juxtaposition.

4. 11.4. Amazon Shelf Research

(A.G. Figueiredo, E.A. Costa, C. Hübscher, Th. Frederichs and F. Schmieder)

The Amazon shelf is a scenario for interaction of strong nature forces, including river discharge, the North Brazilian Current (NBC), tide currents and the trade winds. The Amazon river is the largest river in the world and its discharge corresponds to 18% of all rivers going to the oceans (Curtin, 1986). During peak discharge, volume can reach 354,793 $m^3 s^{-1}$ (Figueiredo et al., 1993) and sediment load carried by the river is estimated to be 11-13 x 10^8 ton/yr. (De Meade et al., 1985). As river sediment enters the shelf, it is deposited accordingly to interaction with tide currents, the NBC and the trade winds. As a result of this interactions, the most prominent feature on the shelf is a submarine delta being constructed over relict sands, since last sea-level lowstand (Figueiredo et al., 1972, Figueiredo and Nittrouer, 1995). Together with sediments, it is also included organic matter, which with time generates methane gas and it can be easily detected on the seismic (Figueiredo et al., 1996). Extensive research have been performed in this area by the AMASEDS research group (Nittrouer et al., 1990). However, new seismic techniques and physical property measurements in the cores, performed during METEOR cruise M34/4, are important contribution to further understanding interaction of processes during the last 30 thousand years. Collection of cores for geochemical analysis were also performed (see K. Enneking et al., this volume).

Work in the area involved 486 nautical miles of profiling with PARASOUND and HYDROSWEEP, on 10 profiles, in water depth ranging between 20 and 130 m (see C. Hübscher et al., this volume), 5 stations with collection of 5 gravity cores, 2 multicorers and 2 box corers (see R. Schneider et al., this volume, Fig. 1). Results of PARASOUND and geological data are presented for every profile shown in Fig. 35. On profile 1-2, PARASOUND records show a sand wave field with waves of 4 to 8 m height with none to small echo penetration. On the second half of the profile, with approaching Amazon river mouth, sand waves become covered by muddy sediments from the Amazon delta. Penetration increases up to 12 m and internal reflectors are characterized by a plan-parallel arrangement. The base of the mud unit become undefined and irregular with typical characteristics of gas charged sediments. In this case, since there is no stratigraphic traps, the depth of the gas is controled by the sulphate reduction zone above as stated by Blair and Aller (1995) and reported by K. Enneking et al. (this volume). On profile 2-3, records also have the plan-parallel reflectors and penetration can reach 25 m. Underlying boundary of the records also reflects gas-charged sediments. Profile 3-4 is perpendicular to the delta foreset and is characterized by prograding sigmoidal reflectors over a sand wave field. Sand waves disappear under the foreset, where the gas concentration do not allow for sound penetration. Core GeoB 3916, collected on the foreset, shows several spikes on the p-wave velocity measurements and on the magnetic susceptibility measurements, height frequency peaks at the base, passing to lower frequency peaks at the top (see T. Frederichs et al., this volume). After opening the core, it was possible to correlate the spikes and peaks with groups of fine sand and silt laminations in a muddier core. At the base of the core, well preserved shells were found in a coarse sand sediment. The shells were saved for C-14 dating. The last portion of profile 3-4 is covered by the sand wave field with no sound penetration. Further seaward, bottom drops from 50 to 70 m and the sand waves disappear. At the end of profile 3-4, there was a tentative coring, resulting in a collection of carbonate crusts (GeoB 3917). The strike oriented profile 4-5 presents a gentle undulating bottom with no echo penetration. Profile 5-6 is perpendicular to the foreset and again shows a downlaping of sigmoidal reflectors over an undulating sand bottom (Fig. 36). Profile 6-7 is parallel to the coast next to the "Cabo Norte" area. The bottom is flat with small echo penetration, except for some places with 10 m echo penetration. Profile 7-8 is perpendicular to the foreset, showing the typical progradation of the sigmoids over an undulating sandy bottom. At end of profile there is no echo penetration. Profile 8-9 is characterized at the first third by a gentle undulating bottom with depressions being filled up with seismically transparent mud. The last two thirds, has an irregular surface being covered by muddier sediments. Next to point 9, the irregular surface disappears and a strong reflector can be seen near the surface. Cored at Station GeoB 3918, this reflector prove to be a gas charged mud. In this case the gas is stratigraphycally traped the concentration is higher (see K. Ennecking et al., this volume) and consequently the seismic reflector is strong. One of the cores was specifically collected and sampled for measuring concentration of methane. On profile 9-10, the gas-charged unit disappears and a sub-bottom irregular surface can be traced till half way to point 10. Echo penetration decreases and sediment become more sandier and the ocean bottom have small sand waves over larger undulations. Station GeoB 3919 was done with the objective of collecting relict ooliths, previously described by Milliman and Barreto (1975). At first look, the sample appears to indicate presence of ooliths mixed with carbonate sands. Profile 10-11 has small echo penetration and increasing up to 45 m next to station GeoB 3920. Reflectors are parallel and gentle seaward dipping with erosional surface at sea bottom. Underlying this unit there is an irregular reflector and few meters (500) seaward of this station, a carbonate like platform lies at the shelf break (Fig. 37). This station had also the objective of collecting oolithic sand as indicated in the literature. However, the sediment was mainly mud and only a laboratory analysis could indicate about the presence or not of ooliths.

Major results

These findings are based on an expedite data analysis on board of R/V METEOR and further studies at the laboratories will provide more information to elucidate these findings.

1) PARASOUND system allowed for observation that the submarine delta is migrating over a field of sand waves.

2) On station GeoB 3917, unexpected carbonate crusts were collected.

3) Gas charged sediments can be seen on the PARASOUND records, observed on the p-waves velocity measurements and detected by geochemical methods. Further studies on this topic might lead to estimation of gas concentration using seismic methods.

4) Cores from the active delta foreset (GeoB 3916), presents a peculiar profile of magnetic susceptibility, varying from high frequency peaks at the base to lower frequency at top. Application of this technique to other cores collected in the area, can lead to an alternative dating method.

5) Collection of shells at the base of core GeoB 3916 will serve as a good reference for dating the events above.

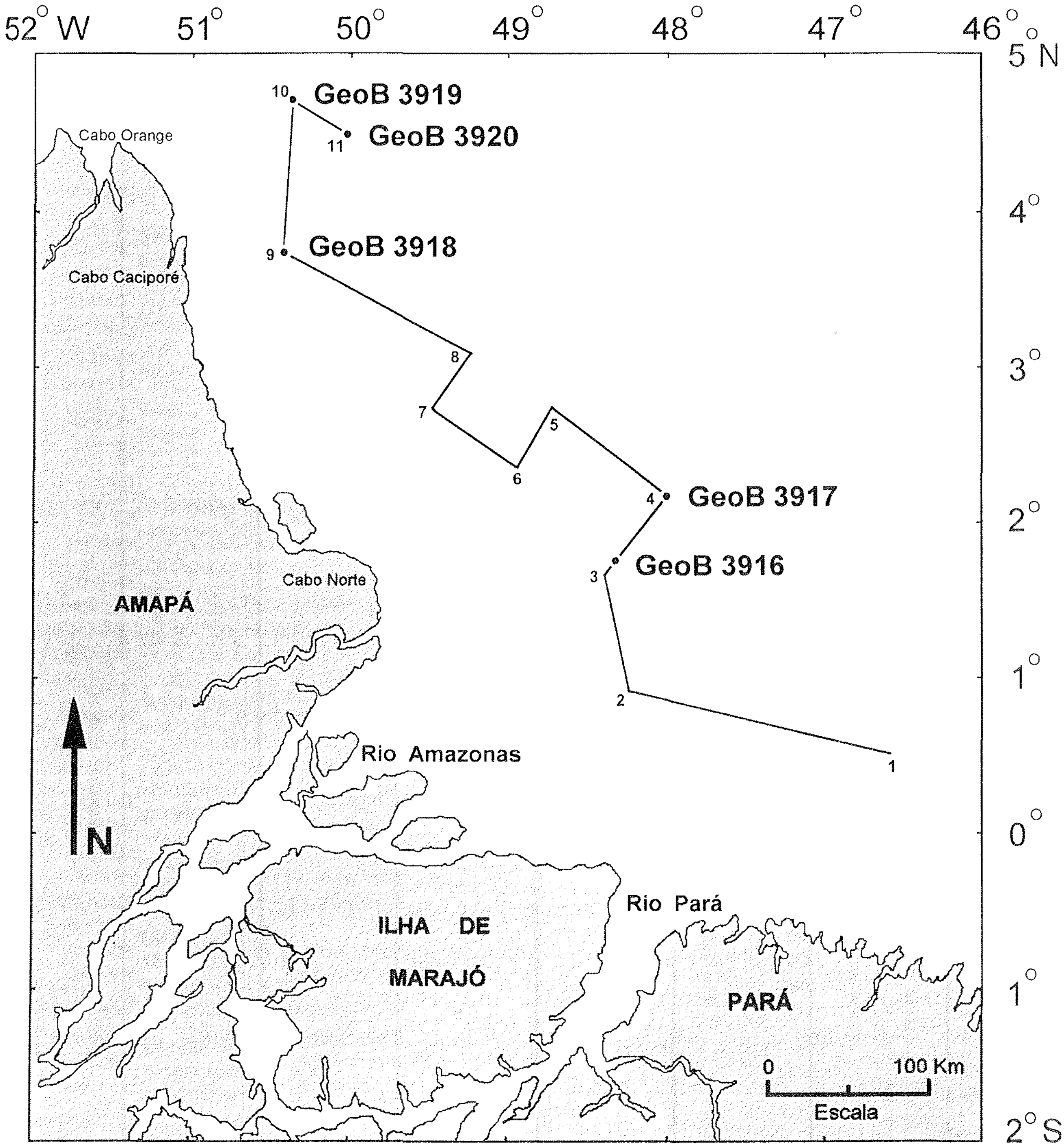


Fig. 35. Amazon shelf research area. Lines indicate location of PARASOUND profiles. GeoB indicates location of geological stations.

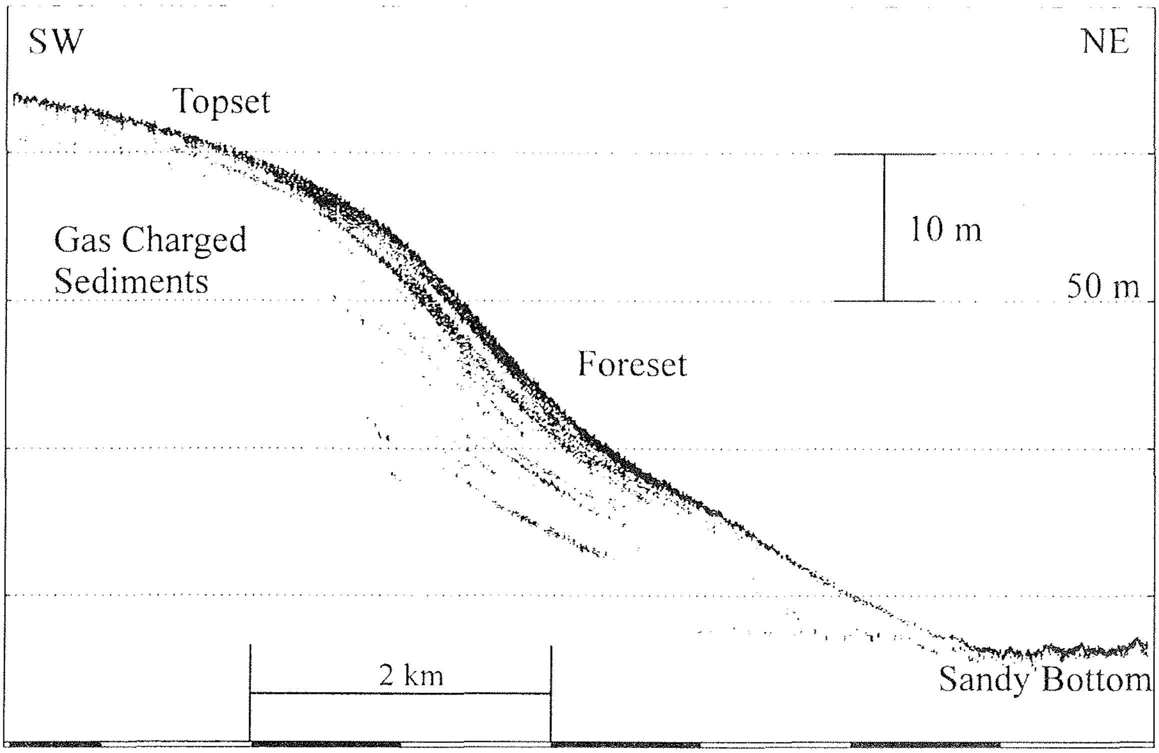


Fig. 36. Foreset beds of the Amazon submarine delta on profile 5-6, migrating over an irregular topography. Gas charged sediments on the right, do not allow for echo penetration.

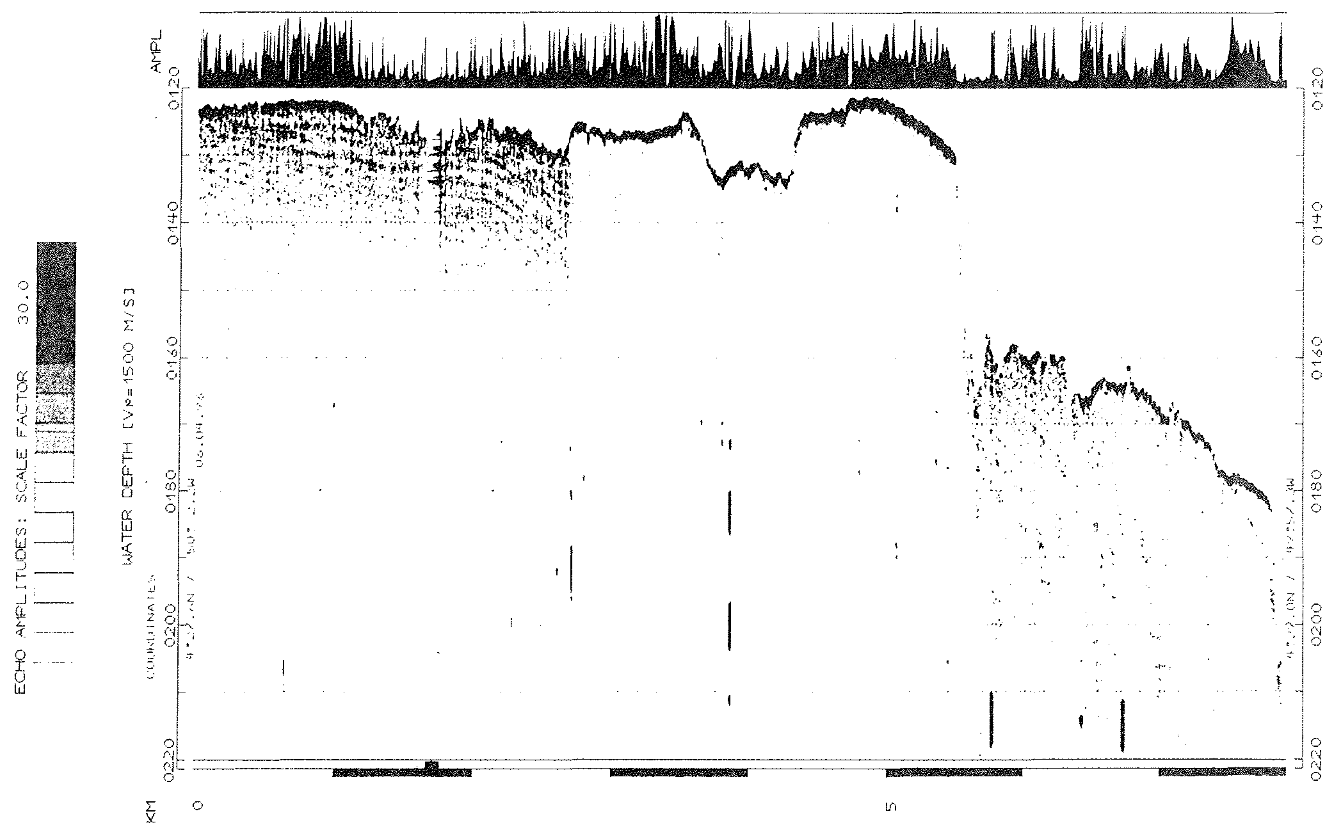


Fig. 37. Carbonate like platform next to station GeoB 3920. On the left, sediments are well layered with erosional surface at the top.

5. Ship's Meteorological Station

(K. Flechsenhaar)

5.1. Cruise Course and Weather

RV METEOR left the port of Recife in the afternoon of Thursday, March 19th, 1996 steered on E'ly courses and started a few hours later with the station works. Also on March 20th and 21st the ship moved slowly to the E and dwelled on March, 22nd for a while at approximately 7.5 S 28 W. Here a mooring system with sediment traps was recovered and a new one was set out. After that METEOR steered N to NE and dwelled on March 23nd/24th at approximately 4°S 26°W and on March 25th/26th at approximately 0°N 23°W to take another two mooring systems with sediment traps on board, put new ones out and get an extensive number of samples.

Then the ship proceeded W to SW and reached on March 29th a position at approximately 4°S 36°W. From now on further station works were done over the coastal shelf of northern Brazil, and the vessel moved , sometimes in sight of the shore, sometimes far out over the deep sea, slowly to NW.

Until to this day the ship operated partly at the edge of a South Atlantic subtropic high and partly within the equatorial low pressure trough. The Intertropical Convergence Zone (ITCZ) varied between 5°S and 5°N, sometimes two ITCZ had been analysed. Accordingly was the weather: Mainly weak to moderate E'ly winds occurred, sometimes the wind was weak and variable. The sky was partly sunny, partly overcast, sometimes a shower came down, which was, due to the tropical temperatures, seen as a welcome refreshing by most of the participants. RV METEOR rolled and pitched smoothly in an E'ly swell of 1 to 1.5 m hight, temporarily the ship was tranquil. The station works had never been disturbed by unfavourable weather conditions.

On April 1st the ship reached the equator at the longitude 38°W and steered now, leaving the spring on starboard and the autumn on her port side, exactly olong the equator to the W, until the region off the Amazonas estuary was reached at approximately 45°W on April 3rd. Here further station works were done, sometimes in shallow water of about 30 m. The weather was influenced by the ITCZ: Sometimes showers with heavy rain, wind partly variable, but mainly E to NE 3 and 4, hight of swell 1 to 2 m.

On April 6th the station works concerning the Amazonas estuary were finished at approximately 5°N 50°W and also the ITCZ was passed through and left behind. From now on the weather was dominated by the NE trade-wind, which blow out of a Northatlantic subtropic high with its axis at about 28°N. So the wind was NE 5 on April 6th, increasing 6 to 7 on April 7th, hight of sea and swell about 3 m.

On April 8th the 200 nautical miles economic zone of French Guiana was reached at the position approximately 6°N 48°W. No research activities in the waters of French Guiana and Surinam were performed. RV METEOR steered now along the coast line W to NW, wind NE 5 or 6, swell 2 to 3 m.

An April 10th, meanwhile in the waters off Guyana, the activities started again at the position approximately 8°N 58°W. A strong NE trade-wind was blowing continuously °and some rolling and pitching was caused by a 2 to 3 m high swell. From April 11th to 14th the ship operated in waters between Guyana and Barbados with high pressure influence, Wind E to NE 3 to 5, sea 1.5 to 2 m, swell between 2 and 3 m. East of the Lesser Antilles a contamination of the air with dust sometimes was observed. Dust originates from the Sahara and is transported via the trade-winds to the Caribbean Sea. In the morning of April 15th METEOR moored under moderate Eīly winds at the quay of the port of Bridgetown, Barbados.

5.2. Activities of the Ship's Weather Watch

a.) Day by day a weather report was compiled and published, so that the shipïs command, chief scientist and participants received a general weather forecast. The necessary charts and data were received from wireless stations (Rio de Janeiro and Bracknell), as satellite pictures (METEOSAT, GOES and NOAA satellites) and by fax

(ECMF forecast charts) or e-mail from Deutscher Wetterdienst, Hamburg and Offenbach.

Special advice or a five days forecast were given in some cases. The forecast of weather conditions and hight of sea and swell based mainly on surface analyses charts of the Central Atlantic Ocean between 40°N and 40°S. These charts, containing surface observations of South American stations and voluntary observing merchant ships, had been drawn by hand every day.

b.) Meteorological parameters have been measured and recorded continuously and were put into the ship's data delivery system. So every participant could retrieve the necessary data into his PC. Sensors and equipment were maintained regularly, some repairs were done.

c.) Every day 8 WMO standard weather observations were practiced and transmitted into the WMO Global Telecommunicating System (GTS). Six of them included eye observations by meteorological staff.

d.) Everyday two rawin sondes were launched with the ASAP-System, determining a vertical profile of pressure, temperature, moisture and wind up to an altitude of 20 to 25 km. The evaluated data (temps) were transmitted into the GTS of WMO.

6. Concluding Remarks

The goals of the cruise M34/4 were almost achieved. Nothing has been lost or damaged. All instruments and measuring systems had worked well. We could recover all sediment trap moorings successfully which were deployed for 19 months during M29/3. We found only small damages due to corrosion. All 6 traps had worked perfectly and we obtained six complete time series from the western tropical Atlantic. The sediment sampling program could be done almost completely, although we enlarged our program on the Amazon shelf. The most interesting cores for paleoceanographic studies seem to come from profile C and probably B. Suitable coring sites were difficult to obtain especially from the Brazilian continental margin.

Acknowledgements

The success of the cruise was only possible because of the excellent teamwork with the ship's crew which was highly competent. The scientific party would like to thank Captain Bruns and the entire crew for the very friendly cooperation and efficient technical assistance.

We also appreciate the most valuable help of the Leitstelle METEOR, Hamburg, in planning and realization of the cruise and in receiving the research permissions for Brazil, Guyana and Barbados.

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8. Station list

Table 12. Station list during M34/4.

GeoB #	Date 1996	Coring device	Time seafloor (UTC)	Latitude	Longitude	Water depth (m)	Sample (XX)	Remarks
Brazil Basin								
3901-1	19.03	CTD	23:12	07°59.2S	34°17.0W	1057	—	Profile depth 980m
3902-1	20.03	CTD	01:18	07°58.5S	34°06.0W	1506	—	Profile depth 1180m
3903-1	20.03	CTD	03:25	07°57.6S	33°54.2W	3560	—	Profile depth 1180m
3904-1	20.03	CTD	05:59	07°55.7S	33°35.8W	4419	—	Profile depth 1180m
3905-1	20.03.	CTD	09:11	07°53.7S	33°10.9W	4290	—	Profile depth 1180m
3906-1	21.03	WA6	12:32	07°28.4S	28°08.5W	5580	2	Release, start recovery
		WA6	15:28	07°27.4S	28°08.4W	4950	traps	Stop recovery, 40 cups with sediment
3906-2		ISP	15:55	07°25.3S	28°08.1W	5394	60 min	Trace metals, 100 and 400m water depth
3906-3		ROS	17:46	07°24.8S	28°08.0W	5467	6x301	2x250m, 1x100m, 2x50m, 1x20m
3906-4		ISP	19:00	07°26.5S	28°07.9W	4895	60 min	Trace metals, 700 and 1200m water depth
3906-5		MN	20:55	07°26.1S	28.08.3W	5300	5 cups	Forams, water isot., 500, 300, 200, 100, 50m
3906-6		MN	21:37	07°25.9S	28°08.2W	5297	5 cups	Radiolaria, 400, 200, 100, 40, 20m
3906-7		MN	22:09	07°25.8S	28°08.1W	5284	5 cups	Corg, water isotopes, 250, 100, 75, 50, 25m
3906-8	22.03	GFW	01:37	07°25.0S	28°07.9W	5441	11x121	Trace metals, Ox, nutrients, 10 to 5000m
3906-9		MUC & CTD	06:46	07°28.0S	28°06.4W	4886	33 cm	Deep sea clay, manganese nodules Profile depth 4776 m
3906-10		WA9	09:07	07°29.1S	28°04.8W	4988	2	start deployment
		WA9	13:08	07°27.5S	28°08.1W	5085	traps	weight over board, stop deployment
3907-1	23.03	WA7	13:07	03°58.7S	25°39.6W	5554	2	Release, start recovery
		WA7	16:08	03°58.6S	25°40.6W		traps	Stop recovery, 40 cups with sediment
3907-2		ISP	16:58	03°56.3S	25°41.3W	5555	60min	Trace metals, 100 and 400m water depth
3907-3		ROS	18:25	03°55.8S	25°41.0W	5552	6x301	2x250m,1x100m, 2x50m, 1x20m
3907-4		ISP	19:23	03°55.2S	25°41.0W	5557	60min	Trace metals, 700 and 1200m water depth
3907-5		MN	21:17	03°55.1S	25°40.1W	5556	5 cups	Forams, water isot., 500, 300, 200, 100, 50m
3907-6		MN	21:56	03°54.8S	25°40.4W	5559	5 cups	Corg, water isotopes, 250, 100, 75, 50, 25m
3907-7	24.03	ISP	00:37	03°54.5S	25°39.8W	5555	60min	Trace metals, 2000 and 3000m water depth
3907-8		ParCa & CTD	06:50	03°53.5S	25°38.6W	5558	Photos	to 2000m waterdepth Profile depth 1980m
3907-9		WA10	09:04	03°54.0S	25°39.0W	5554	2	Start deployment
		WA10	11:08	03°55.4S	25°42.3W	5554	traps	weight over board, stop deployment
3907-10		ISP & GFW	15:30	03°54.9S	25°36.6W	5562	60min 12x121	Trace metals, 4000 and 5000m water depth Trace metals, Ox, nutrients, 10 to 5000m
Equatorial Atlantic								
3908-1	25.03	ISP	19:30	00°01.3S	23°28.2W	3605	60min	Trace metals, 100 and 400m water depth
3908-2		ParCa	23:45	00°01.3S	23°28.2W	3609	Photos	to 3000m water depth, every 10m
3908-3	26.03	ISP & GFW	03:08	00°02.7S	23°27.9W	3542	60min 12x121	Trace metals, 700 and 1200m water depth Trace metals, Ox, nutrients, 10 to 3000m
3908-4		MN	06:18	00°02.6S	23°27.9W	3546	5 cups	Forams, water isot., 500, 300, 200, 100, 50m

GeoB #	Date 1996	Coring device	Time seafloor (UTC)	Latitude	Longitude	Water depth (m)	Sample (XX)	Remarks
continued: Equatorial Atlantic								
3908-5		MN	06:57	00°02.4S	23°27.9W	3554	5 cups	Corg, water isotopes, 250, 100, 75, 50, 25m
3908-6		MN	07:30	00°02.6S	23°27.9W	3550	5 cups	Radiolaria, 400, 200, 100, 40, 20m
3908-7		WA8	08:43	00°00.5N	23°26.5W	3635	2	Release, start recovery
		WA8	11:18	00°00.5N	23°26.5W		traps	Stop recovery, 40 cups with sediments
3908-8		ROS	11:35	00°00.4N	23°26.4W	3707	1x30l	Only 1 sample from 250 m
3908-9		WA11	12:08	00°01.8N	23°26.8W	3722	2	Start deployment
		WA11	13:46	00°00.1S	23°25.9W		traps	Weight over board, stop deployment
3908-10		ROS	14:44	00°00.2S	23°23.9W	4061	6x30l	2x250m,1x100m, 2x50m, 1x20m
3908-11		MUC & CTD	16:27	00°00.4S	23°25.7W	3693	16cm	Clayey carbonate ooze, pale brown Profile depth ≈ 3600 m
Northeast Brazilian Margin: Profile A								
3909-1	29.03.	MUC & CTD	19:10	03°32,9S	36°16.2W	3174	33cm	Clayey carbonate ooze, forams, pterop. at surf. Profile depth ≈ 3100 m
3909-2		GC12	21:31	03°33.5S	36°16.2W	3164	747cm	CC: stiff gray clay, mica, forams
3910-1	30:03	GC12	03:16	04°14.7S	36°20.7W	2364	650cm	Geochem., cc: Sandy mud, gray, mica, forams
3910-2		GC12	05:07	04°14.7S	36°20.7W	2362	694cm	CC: stiff gray clay, mica, forams
3910-3		MUC & CTD	07:17	04°14.7S	36°20.8W	2361	32cm	Carbonate ooze, forams, pteropods at surf. Profile depth ≈ 2300m
3911-1	30:03	MUC & CTD	11:57	04°36.8S	36°38.1W	826	33cm	Carbonate ooze, forams, pteropods at surf. Profile depth ≈ 2300m
3911-2		GC12	12:45	04°36.8S	36°38.2W	825	650cm	Geochemistry, cc: gray clay, forams
3911-3		GC12	13:43	04°36.8S	36°38.4W	828	700cm	CC: gray clay, forams
3912-1	30:03	GC12	22:03	03°40.0S	37°43.0W	772	680cm	CC: light gray carbonate mud, sandy, forams
3912-2		MUC & CTD	11:57	03°40.0S	37°43.1W	772	12cm	Carbonate ooze, forams, pteropods Profile depth ≈ 720m
Northeast Brazilian Margin: Profile B								
3913-1.	31:03	MUC & CTD	08:52	02°53.8S	38°19.0W	2264	---	No bottom contact, strong surface current Profile depth ≈ 2200m
3913-2		MUC	10:53	02°53.8S	38°18.6W	2289	13cm	All big tubes washed out, small t. foram sand
3913-3		GC12	12:32	02°53.8S	38°18.5W	2288	655cm	CC: stiff gray clay clay, forams, pteropods
3914-1	31:03	GC12	16:56	02°43.3S	38°13.6W	2464	820cm	Geochemistry, cc: carbonate mud, gray, forams
3914-1		GC12	18:50	02°43.3S	38°13.6W	2463	880cm	CC: carbonate mud, gray, forams
3914-3		MUC & CTD	20:57	02°43.5S	38°13.7W	2461	25cm	5 big t. washed out, others foram sand, l. brown Profile depth ≈ 2400m

GeoB #	Date 1996	Coring device	Time seafloor (UTC)	Latitude	Longitude	Water depth (m)	Sample (XX)	Remarks
continued: Northeast Brazilian Margin: Profile B								
3915-1	01.04.	MUC & CTD	04:04	02°16.8S	38°00.9W	3127	33cm	Carbonate ooze, sandy, forams, pteropods Profile depth ≈ 3050m
3915-2		GC12	06:06	02°16.8S	38.01.0W	3127	794cm	CC: carbonate ooze, light gray to brown
Amazon Shelf and Fan								
3916-1	04.04	MUC	07:37	01°41.9N	48°26.0W	37	34cm	Terrigenous mud, light brown to gray
3916-2		GC12	08:10	01°41.8N	48°25.9W	38	615cm	CC: terrigenous gray mud, sandy
3917-1	04.04	MUC	14:01	02°11.0N	48°00.0W	68	—	All tubes empty, foraminiferal sand, washed out
3917-2		MUC	14:12	02°11.0N	48°00.0W	68	—	All tubes empty, foraminiferal sand, washed out
3917-3		MUC	14:25	02°11.0N	48°00.0W	68	—	All tubes empty, foraminiferal sand, washed out
3917-4		GC6	14:42	02°11.0N	48°00.0W	68	5cm	Beach rock fragments, foram sand, washed out
3918-1	05.04	MUC	18:26	03°42.3N	50°24.3W	52	25cm	4 big tubes washed out, Clayey mud with moll.
3918-2		GC6	18:50	03°42.3N	50°24.3W	50	525cm	Geochemistry, cc: gray clay
3918-3		GC12	19:24	03°42.3N	50.24.3W	50	—	Tube cracked at 2.50 m
3918-4		GC6	20:30	03°42.2N	50°24.3W	51	498cm	CC: gray clay
3919-1	06.04	BC	04:05	04°35.4N	50°20.9W	97	12cm	Brown sand, benthic forams, carbonate ooliths
3920-1	06.04	BC	07:50	04°27.3N	50°01.4W	130	18cm	Brown mud, Fe-Concretions at the surface
3920-2		GC6	08:20	04°27.3N	50.01.3W	128	405cm	CC: gray mud
3921-1	06.04	CTD	10:06	04°30.5N	49°54.4W	1077		Profile depth ≈ 980m
9322-1	06.04	CTD	12:25	04°35.8N	49°43.1W	1893		Profile depth ≈ 1000m
3923-1	06.04	CTD	16:38	04°47.9N	49°15.4W	2519		Profile depth ≈ 1000m
3924-1	06.04	CTD	22:24	05°05.9N	48°34.2W	2882		Profile depth ≈ 1000m
3925-1.	07.04	ISP & GFW	10:11	05°08.6N	47°31.7W	3199	60min 12x12l	Trace metals, 700 and 1200m water depth Trace metals, Ox, nutrients, 10 to 3000m
3925-2		MUC & CTD	13:56	05°08.6N	47°31.8W	3198	25cm	Carbonate ooze, pteropods, forams Profile depth ≈ 3150m
3925-3		GC12	16:41	05°08.0N	47°30.9W	3170	610cm	Geochemistry, cc: stiff gray mud
3925-4		ROS	18:19	05°08.0N	47°31.0W	3167	6x30l	250, 200, 100, 75, 50, 20m
3925-5		ISP	19:15	05°07.9N	47°30.4W	3171	60min	Trace metals, 100 and 400m water depth
3925-6		ROS	21:42	05°08.3N	47°30.7W	3198	6x30l	2x3000, 2000,1200, 700, 400m
3925-7		MN	23:21	05°08.3N	47°30.9W	3194	5 cups	Forams, water isot., 500, 300, 200, 100, 50m
3925-8	08.04	MN	00:06	05°08.4N	47°31.3W	3192	5 cups	Radiolaria, 400, 200, 100, 40, 20m
3925-9		MN	00:43	05°08.3N	47°31.4W	3183	5 cups	Corg, water isotopes, 250, 100, 75, 50, 25m
3925-10		ParCa	02:00	05°08.6N	47°31.5W	3186	Photos	Profile depth 1000 m

GeoB #	Date 1996	Coring device	Time seafloor (UTC)	Latitude	Longitude	Water depth (m)	Sample (XX)	Remarks
Profile Guyana Margin								
3926-1	10.04	ParCa & CTD	18:01	08°22.6N	58°04.7W	1116	Photos	Profile depth 1000 m, 1 photo every 10m Profile depth ≈ 950m
3927-1	10.04	CTD	21:13	08°35.6N	57°56.9W	1952		Profile depth ≈ 1030m
3928-1	11.04	CTD	02:27	09°02.5N	57°41.0W	2752		Profile depth ≈ 1030m
3929-1	11.04	ParCa & CTD	09:23	09°28.0N	57°25.5W	3195	Photos	Profile depth 2000 m, 1 photo every 10m Profile depth ≈ 1950m
3930-1	11.04	CTD	14:23	09°58.1N	57°07.6W	3453		Profile depth ≈ 1030m
3931-1	11.04	CTD	19:10	10°28.3N	56°49.1W	3881		Profile depth ≈ 1030m
3932-1	12.04	CTD & ROS	00:34	11°00.0N	56°29.8W	4227	6x30l	Profile depth ≈ 2950m 2x3000m (Standard Water Isotopes) 400, 100, 50, 20m, N-Isotopes (POC)
3933-1	12.04	CTD	07:26	11°29.0N	57°11.9W	4249		Profile depth ≈ 1050m
Profile Barbados, Atlantic Caribbean Margin								
3934-1	13.04	CTD	02:59	12°50.1N	59°10.1W	1616		Profile depth ≈ 1050m
3935-1	13.04	MUC & CTD	07:41	12°36.8N	59°23.3W	1554	37cm	Carbonate ooze, light brown to gray Profile depth ≈ 1500m
3935-2		GC12	09:01	12°36.8N	59°23.2W	1558	518cm	CC: gray carbonate ooze, forams, pteropods
3936-1	13.04	GC12	14:02	12°43.1N	59°00.1W	1843	745cm	CC: gray carbonate ooze, forams, pteropods
3936-2		MUC & CTD	15:41	12°43.1N	58°59.9W	1853	35cm	Carbonate ooze, light brown to gray Profile depth ≈ 1800m
3937-1	13.04	MUC & CTD	18:53	12°33.5N	58°45.9W	1638	32cm	Carbonate ooze, light brown to gray Profile depth ≈ 1600m
3937-2		GC12	20:07	12°33.5N	58°45.9W	1652	653cm	CC: gray carbonate ooze, forams, pteropods
3938-1	14.04	GC12	00:32	12°15.5N	58°19.8W	1972	649cm	CC: gray carbonate ooze, forams, pteropods
3938-2		MUC & CTD	02:12	12°15.4N	58°19.8W	1972	33cm	Carbonate ooze, light brown to gray Profile depth ≈ 1920m
3939-1	14.04	MUC & CTD	10:46	12°35.3N	58°05.9W	2466	31cm	Carbonate ooze, light brown to gray Profile depth ≈ 2400m
3939-2		GC12	12:26	12°35.3N	58°05.9W	2467	723cm	CC: gray carbonate ooze, forams, pteropods

Abbreviations used in Table 12:

(xx)	Number of water or plankton samples, pumping time, core length, etc.
BC	Box corer
CTD	Conductivity, Temperatur, Density Sensor, profile depth after wire length
GFW	GoFlow -water samplers
ISP	In-situ Pumps
MUC	Multicorer
ParCa	Particle Camera
ROS	Rosette with 6 Niskin-bottles
GC	Gravity corer, length
WA	Western Atlantic moorings

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