5.5 Leg M45/5a

5.5.1. Underway Geophysics in the North Sea and the Cape Ghir Region

(D. Hebbeln, H. Meggers)

During METEOR Leg M45/5a the shipboard acoustical systems HYDROSWEEP and PARASOUND were used for site investigation in the North Sea and in the Cape Ghir region in order to record continuos high resolution bathymetric and sediment echosounding profiles. The data provided valuable information for chosing suitable coring stations in the investgation areas.

a) Methods

PARASOUND: PARASOUND surveys the uppermost sedimentary layers of the seafloor. Due to the high signal frequency of 4 kHz, the short signal length of two sinoid pulses, and the narrow beam angle of 4.5°, a very high vertical resolution is achieved. Sedimentary layers along the ship track on a scale of less than one meter can be resolved. The PARASOUND data provided information about the physical state of the sea bottom as well as about sediment structures up to a depth of 50 m below sea floor. The penetration of the PARASOUND signal depends on the density of the uppermost sediment layers and the impedance contrasts between these layers and at the sea floor. Thus, the penetration was used as a first hint for the quality of a potential coring location. The digitisation and storage of the echosounding seismograms were conducted with the software package ParaDigMa (SPIESS 1993). This system converts the analogue signal to digital data and stores them on 9-track tapes in a SEG-Y like format, making data available for further post-processing. The pre-processed data are plotted online with a HP colour printer. These plots provided a first impression of variations in sea floor morphology, sediment coverage and sediment patterns along the ship's track. In addition, navigational data are printed and stored on disk simultaneously. Besides using PARASOUND as a tool for localisation of promising core sites, it is possible to image and describe the dominating sedimentation processes and to interpret the structural context of the longer sediment cores.

HYDROSWEEP: The general purpose of HYDROSWEEP is to survey topographic features of the seafloor. A fan of 59 pre-formed beams covers a sector of 90°. Thus, a stripe with the width of twice the water depth is mapped perpendicular to the ship track. Data are stored on magnetic tapes in a sensor independent format. Since a workstation is directly installed beside the ParaDigMa PC, the PARASOUND operator is able to check the topographic map and profiles on the HYDROSWEEP screen simultaneously. Thus, in conjunction with PARASOUND, HYDROSWEEP has shown to be a very efficient aid for the selection of suitable coring stations. The precise knowledge of the local bathymetry is essential to select suitable sites and coring device, and to evaluate the impact of morphology, slope angles and sediment instabilities on the continuity of sedimentation. Also, the detailed 3D information of the seafloor topography represents an important contribution to the interpretation of the 2D PARASOUND cross-sections.

b) First results

Helgoland mud area: The PARASOUND data from the Helgoland mud area are ambiguous, as structures beneath the sea bottom reflector are difficult to interpret. However, internal structures of the mud layer as well as its lower boundary are almost absent. The poor resolution of the PARASOUND data may be due to the bad weather conditions encountered around Helgoland, which also hindered any sediment sampling.

Skagerrak: In the Skagerrak three PARASOUND profiles were recorded on the Danish side of the Danish-Norwegian border perpendicular to the slope of the Skagerrak in water depths of 100 m and 480 m.

Along the upper slope, between 100 m and 250 m water depth, the PARASOUND profiles showed a strong sea bottom reflector with only a few internal structures beneath. In this depth range several steep and asymmetric furrows marked the slope. Below 250 m the sea floor reflector weakened and more internal structures were visible. With increasing depth the PARASOUND profiles revealed layered sediments. Based on these data the three coring stations in the Skagerrak were placed on the deeper ends of the PARASOUND profiles close to the Norwegian border, where, according to the PARASOUND, the most promising sediments were located.

Outer Silver Pit: PARASOUND data recorded along two north-south profiles across the northern slope of the Outer Silver Pit revealed a distinct Holocene base reflector, overlain by up to 25 m of Holocene sediments with clear internal bedding. Further to the south, in the inner part of the Outer Silver Pit, the thickness of the Holocene sediments decreased until the Pleistocene sediment layer outcropped.

Cape Ghir: The most spectacular feature in the Cape Ghir region is the Agadir canyon system, which consists of a large number of smaller canyons of various sizes. The morphology in the Agadir canyon system is generally very steep. Within the canyon system only very few spots could be found where PARASOUND revealed an undisturbed sediment cover. However, immediately to the north and to the south of the canyon system layered sediments became commonplace with penetration depths of up to 30 m. Large undisturbed sediment packages were observed along the very upper part of the continental slope between water depths of 200 m to 500 m (Fig. 63).

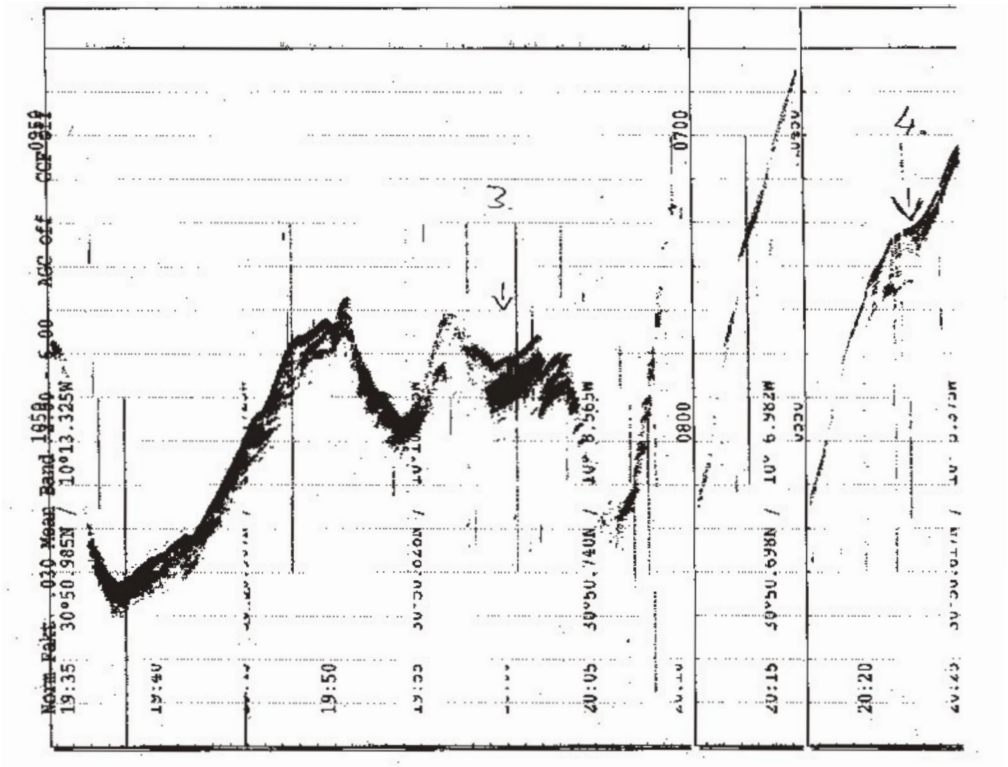


Fig. 63: Digital W-E PARASOUND seismogram section towards the Moroccan coast recorded on the northern profile off Cap Ghir. Changes in the water depth range of Paradigma are indicated. Numbers 3 and 4 mark suitable sites for sediment sampling, whereas sites number 4 is equivalent to core GeoB 6008-1. It is obvious that undisturbed sediment packages could be observed at the very upper part of the continental slope off Cap Ghir.

5.5.2 Sediment Sampling by GeoB

(V. Diekamp, C. Hayn, D. Hebbeln, J. Köster, J. Langer, H. Meggers, S. Nave, S. Neuer, U. Rosiak)

Sediments were recovered by the GeoB group at 4 stations in the North Sea (Fig. 64) and at 7 stations in the Cape Ghir region (Fig. 65). Three of the North Sea sites are located in the Skagerrak, while the fourth site is in the Outer Silver Pit south of the Doggerbank. The other 7 sites are situated in a small area to the west and southwest of Cape Ghir off the coast of Morocco. Surface sediments were recovered with a multicorer (Table 11), while longer sediment sequences were recovered at 11 stations by deploying a 1.5 ton gravity corer with different pipe lengths (Table 12).

a) Methods

Multicore: The main tool for the recovery of undisturbed sediment was the multicorer equipped with 8 tubes of 10 cm and 4 smaller tubes of 5 cm diameter. The multicorer was used at 11 stations (Table 11). The core recovery was generally good, typically 10 to 12 tubes were filled, and cores of very good quality ranging from 13 cm to 43 cm in lengths were recovered. Four of the large tubes were usually sampled in 1 cm slices for analysis of C_{org} (1) and Foraminifera (plantonic and benthic) (3). The overlying bottom water of one of the large tubes was sampled for stable isotopes. The C_{org} samples were frozen immediately after

Tab. 11: Multicorer sampling during M45/5a.

MUC	Depth	Recovery	large tubes								small tubes			
			1/8	2/8	3/8	4/8	5/8	6/8	7/8	8/8	1/4	2/4	3/4	4/4
6001-1	459 m	35 cm	--	--	--	--	--	--	--	--	Ar	--	--	--
6001-2	460 m	42 cm	For.	For.	For.	Corg	Alk	Ar	--	--	Dia	Surf	Ar	Ar
6002-2	428 m	43 cm	For.	For.	For.	Corg	Alk	Dia	--	--	Surf	Ar	Ar	--
6003-1	308 m	36 cm	For.	For.	For.	Corg	Alk	Dia	Ar	--	Surf	Surf	Ar	Ar
6004-1	54 m	25 cm	For.	For.	For.	Corg	Ar	Dia	Surf	Surf	Ar	Ar	--	--
6005-1	1781 m	32 cm	BF	BF	PF	Corg	Ar	Dia	Mag.	--	Ar	--	--	--
6006-2	1282 m	14 cm	BF	BF	PF	Corg	Ar	Dia	Mag	Surf	Surf	Surf	Ar	--
6007-1	899 m	25 cm	BF	BF	Corg	Ar	--	--	--	--	Dia	PF	Ar	Surf
6008-2	355 m	33 cm	BF	BF	PF	Corg	Ar	Dia	Mag	Surf	Surf	Surf	Surf	Ar
6009-1	579 m	24 cm	BF	BF	PF	Corg	Ar	Dia	Mag	Surf	Surf	Surf	Surf	Ar
6010-1	406 m	15 cm	BF	BF	Ar	Corg					Surf	PF	Dia	Ar
6011-2	993 m	13 cm	BF	BF	PF	Corg	Ar	Dia	Mag.	--	Ar	--	--	--

collection at -27°C. Foraminifera samples were stained with a solution of 1g of rose bengal in 1 l ethanol and stored at 4°C. In addition at Cape Ghir, second set of non-stained samples was collected for plankonic foraminiferal (PF) analysis. All the foraminiferal and diatom samples were kept at 4°C. In addition, one tube was sliced for diatom and alkenone analyses, respectively. The diatom samples will be analysed at the IGM in Lisbon, while the alkenone samples will be investigated at the IOW in Warnemünde (North Sea only). Two large and one small cores were frozen as archive material. When available, additional cores were samples only for the uppermost centimeter of the sediment column and one large core was reserved for magnetic studies. Table E1 presents a summary of the multicorer sampling.

Gravity cores: During the work in the North Sea, 4 gravity cores with a total of 21,27 m of sediments were recovered from 4 stations with recoveries varying between 2,04 m and 10,50 m. In addition, 7 cores with a total length of 45,09 m (ranging from 1,57 m and 11,05 m) were recovered in the Cape Ghir region. Due to lack of available time, only the 4 North sea cores (GeoB6001-3, GeoB6002-1, GeoB6003-2, and GeoB6004-3) were opened and sampled on board (Table 12). After separating in two halves, the

Tab. 12: Gravity core sampling during Meteor cruise M45/5a.

GeoB No.	Water depth (m)	Recovery (cm)	A-Serie Corg	B-Serie Isotopes/ Forams	Carbonate Content
6001-3	460	384	77	77	77
6002-1	430	489	98	98	98
6003-2	312	1050	210	210	210
6004-3	53	204	41	41	41
6005-2	1782	1067	Not opened onboard		
6006-1	1275	908	Not opened onboard		
6007-2	900	1105	Not opened onboard		
6008-1	355	542	Not opened onboard		
6009-2	579	253	Not opened onboard		
6010-2	404	157	Not opened onboard		
6011-1	983	477	Not opened onboard		

archive section was described following the ODP nomenclature and sediment colour was determined by comparison with the Munsell soil colour charts. A colour scanner was used to record the colour of the fresh sediments at a 1 cm sampling interval (see spectrophotometry section). All core sections were photographed together with a colour reference card.

On the working halves of the cores, two series of samples with known volume named A- and B-series, were taken with 10 cm^3 syringes every 5 cm, starting at 3 cm below the top of the core. Series A will be analysed for organic geochemistry and physical properties. Series B will be used for foraminiferal and stable isotope analyses. Samples for carbonate were taken every 5 cm starting at 5.5 cm core depth and analysed using the "Müller bomb" (Müller and Gastner, 1971). Table 12 summarises the gravity core sampling.

Sediment analysis: The light reflectance of all opened gravity cores was measured at 31 wavelength channels in the range of visible light (400 - 700 nm). This method (spectrophotometry) is used to determine the colour of the sediment and was carried out with a Minolta CM-2002™ hand-held spectrophotometer previously calibrated with a white calibration standard. The readings were taken immediately after splitting the core. The archive halves of the cores were scraped with a knife to expose a fresh, unsmeared surface for the measurements. The core was then covered with a transparent plastic film to protect the camera and measurements were taken every 1 cm. The reflectance profiles of three wavelengths (400 nm, 550 nm, 700 nm) were chosen since they cover most of the spectrum measured.

Carbonate measurements: Carbonate contents were measured on board using a "carbonate-bomb". The $CaCO_3$ content of a sample was ascertained by the measurement of the CO_2 pressure after the treatment of 1 g of dried sample material with HCl. The absolute error of a single determination is given as about 1% calcium carbonate (Müller and Gastner, 1971). Repeated measurements for samples from

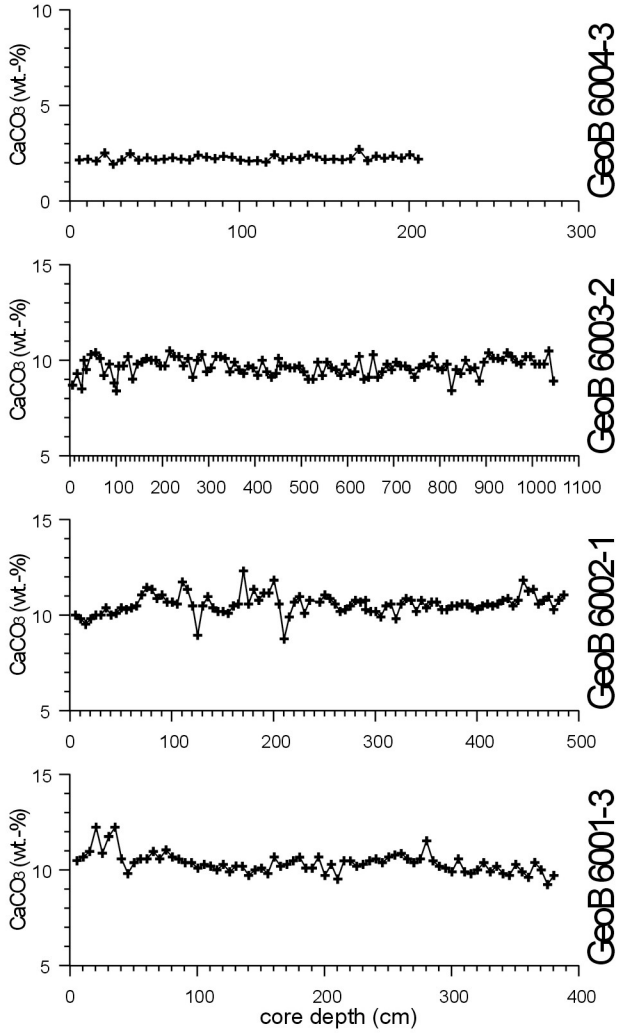


Fig. 64: Carbonate contents in the gravity cores retrieved from the North Sea.

the North Sea cores resulted in a standard deviation of 0.2%. In total, four cores were measured for their carbonate content in 5 cm intervals (core GeoB 6003-2 with a length of 10.5 m was analysed in 10 cm intervals, Fig. 64).

b) First Results

Skagerrak: All three Skagerrak cores (GeoB6001-3, GeoB6002-1, and GeoB6003-2) show a very similar lithology of olive grey silty clays, however, with varying amounts of dark grey to black traces of bioturbation. The most remarkable difference was the appearance of the bioturbation marks. While the black spots occurred in a very small scale pattern (in the mm range) in cores GeoB6001-3 and GeoB6002-1, core GeoB6003-2 had large burrows with diameters up to 2 cm with intact internal structures ("Spreiten") and of all cores, GeoB6003-2 had the most pronounced H_2S-smell.

The carbonate contents of the Skagerrak cores ranged between 8.4 wt.-% and 12.3 wt.-% (Fig. 64). Although the variability was very low, the systematic variations of the carbonate contents through the cores in addition to the good reproducibility of the data (see above) indicated the curves in Fig. 64 as true signals. While the carbonate contents of the two deeper cores GeoB6001-3 and GeoB6002-1 varied almost exactly within the same range (9.2/8.7 wt.-% to 12.3 wt.-%), the range was significantly narrower in the shallowest core GeoB6003-2 (8.4 wt.-% to 10.5 wt.-%). However, distinct variations, which could be used to correlate the cores stratigraphically, could not be observed.

Outer Silver Pit: The core from the Outer Silver Pit (GeoB6004-3) was significantly coarser than the Skagerrak cores and consisted mainly of silty, fine sand. Colour was more brownish grey and olive grey appeared only in few small spots. Again, dark grey to black bioturbation traces were common in mostly small-scale (mm) traces. The carbonate contents of core GeoB6004-3 was very low and ranged between 1.9 wt.-% and 2.7 wt.-% (Fig. 64).

5.5.3. Plankton Sampling

(H. Meggers, V. Diekamp, C. Hayn, D. Hebbeln, J. Köster, J. Langer, S. Nave, S. Neuer, U. Rosiak)

a) Chlorophyll a measurements

Upwelling areas are particularly well suited for a combination of oceanographic, satellite and paleoceanographic observations of related processes, because upwelling produces large gradients of temperature and pigment concentrations at the sea surface, which is also mirrored in underlying sediments. Therefore satellite SST data and chlorophyll-like pigment concentrations are normally used as indicators for upwelling and eastern boundary circulation. Particularly striking for the NW African coast are several giant filaments of cool, pigment-rich waters between 20°N and 31°N between Cape Blanc and Cape Ghir, extending several hundred kilometres offshore (VAN CAMP ET AL., 1991). These filaments are characterized by higher nutrient content, higher productivity, and associated particle loading than ambient water. They transport an "upwelling finger print" into the open oligotrophic ocean. Consequently, filament areas are excellent recorders for the upwelling history and are key-areas for climatic studies relevant on a global scale. One aim of this cruise was therefore to reconstruct the spatial and temporal variability of the Cape Ghir filament by investigating chlorophyll biomass and hydrography on a transect from the oligotrophic subtropical gyre towards the coastal upwelling regime. Sedimentological investigations were carried out in order to decipher the filament history during the last glacial to interglacial cycle (see 5.5.2).

Surface water samples for chlorophyll-a were collected from the ship's sea water pump (inlet in about 3.5 m water depth). More than 100 water samples of 0.5 l were taken in duplicate (Fig. 65). The water was filtered on GF/F glass fibre filters and chlorophyll was extracted during at least 24 hours with 10 ml of 90 % Acetone. Concentrations were measured on board using a Turner 10-AU-Fluorometer.

Surface chlorophyll concentrations increased towards the Moroccan coast off Cape Ghir (Fig. 65), concomitantly with a decrease in temperature. Thus, surface water temperature may be regarded as an indicator of nutrient loading.

A comparison between SeaWIFS observations which were available onboard daily (data were provided by the SeaWIFS Project, NASA/Goddard Space Flight Center), *in-situ* chlorophyll and SST (determined with the ship's thermosalinograph) indicated a well established Cape Ghir filament during the sampling period from October 16 to 19 (Fig. 66). Actual chlorophyll concentrations in the surface and satellite observations agreed very well.

In addition to the surface water analyses, the CTD-profiler SEABIRD SBE 19 was used for water column investigations and was attached 50 m above the multicorer. It was equipped with an oxygen sensor and a SEATECH fluorometer. Only the downcast raw data were used. A total of 6 profiles were taken in the Cape Ghir research area.

Fig. 67 shows 3 CTD-profiles characteristic for the Cape Ghir transects. Stations, which are shown, are GeoB 6005 (1800 m depth), GeoB 6006 (1200 m depth) and GeoB 6007 (900m depth). North Atlantic Deep Water (NADW) and the Mediterranean Outflow Water (MOW) could be observed at STA GeoB 6005, while GeoB 6006 was located in the upper part of the MOW layer, and GeoB 6007 in the North Atlantic

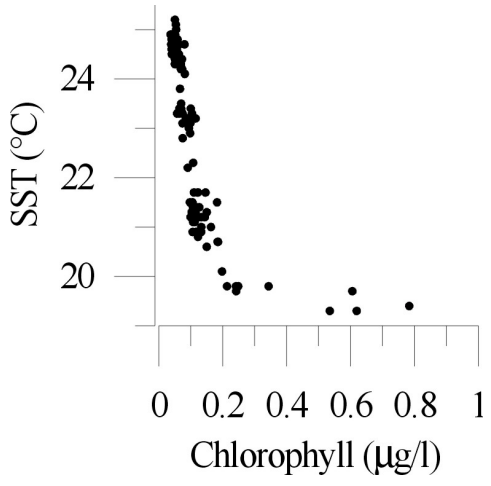
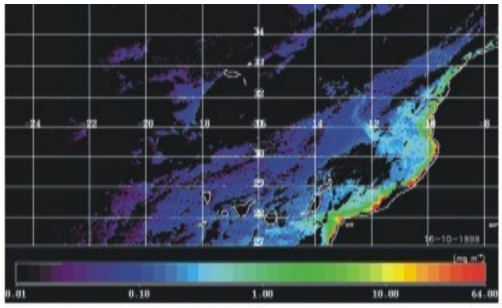
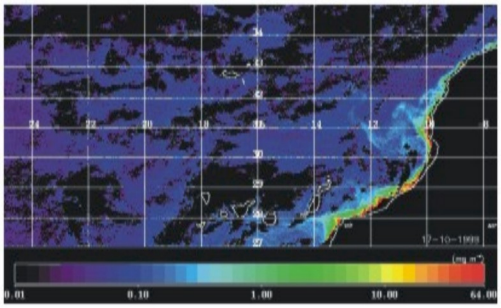


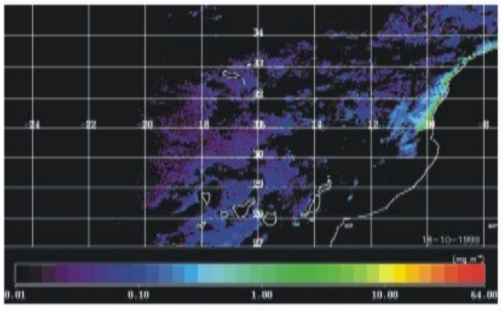
Fig. 65: Relationship between SST and chlorophyll on a transect from the Azores towards the Cape Ghir filament off NW Africa.



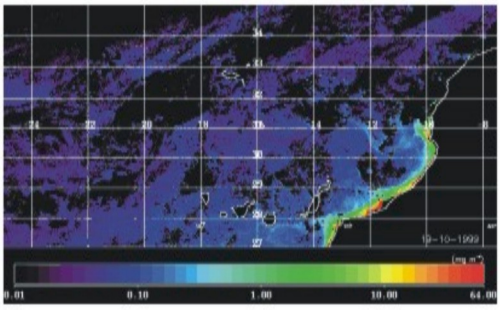
SeaWIFS from 16.10.1999



SeaWIFS from 17.10.1999

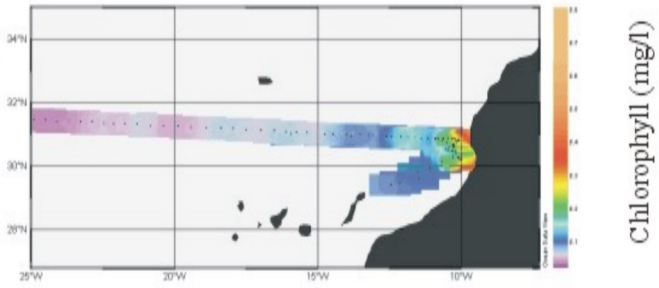


SeaWIFS from 18.10.1999



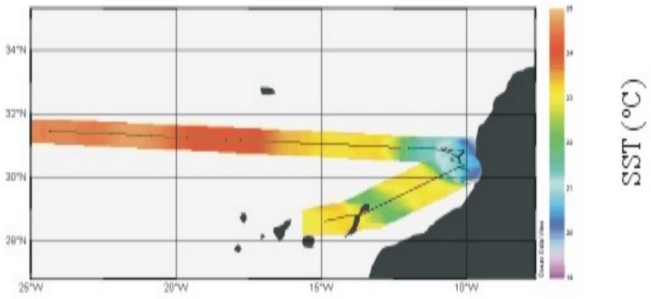
SeaWIFS from 19.10.1999

M 45/5a - Chlorophyll-measurements



15.10. - 19.10.1999

M 45/5a - SST-measurements



15.10. - 20.10.1999

Fig. 66: A comparison between daily SeaWIFS observations and in-situ chlorophyll and SST recorded in the Cape Ghir filament area between 16 and 19 October 1999. Data provided by the SeaWIFS Project, NASA/Goddard Space Flight Center.

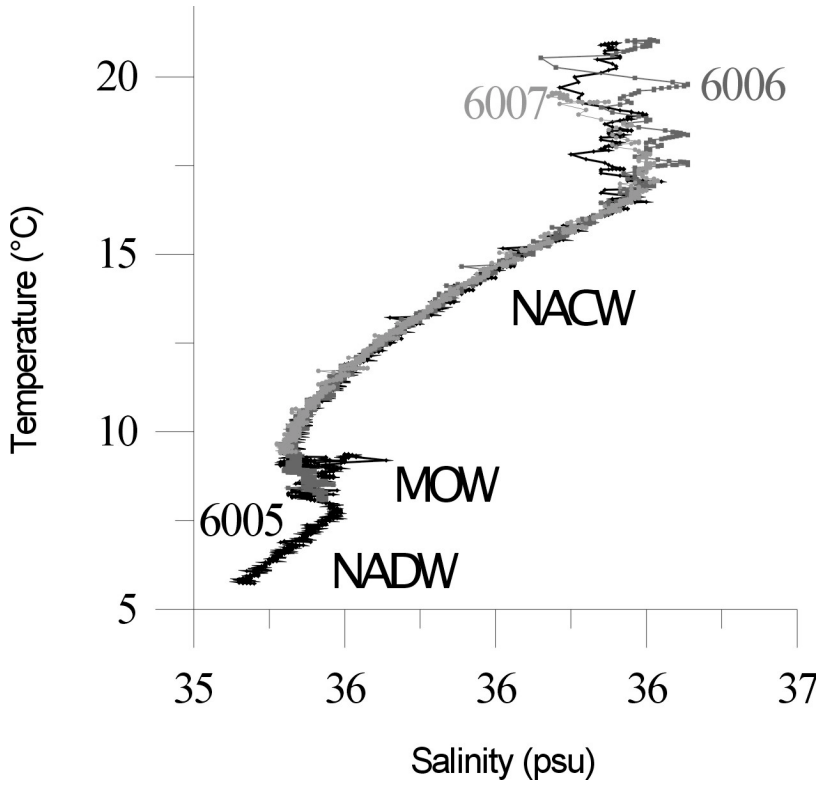


Fig. 67: TS-diagram showing three stations (GeoB 6005, 6006 and 6007) along a W-E transect. The salinity maximum corresponds to the occurrence of Mediterranean Outflow Water (MOW).

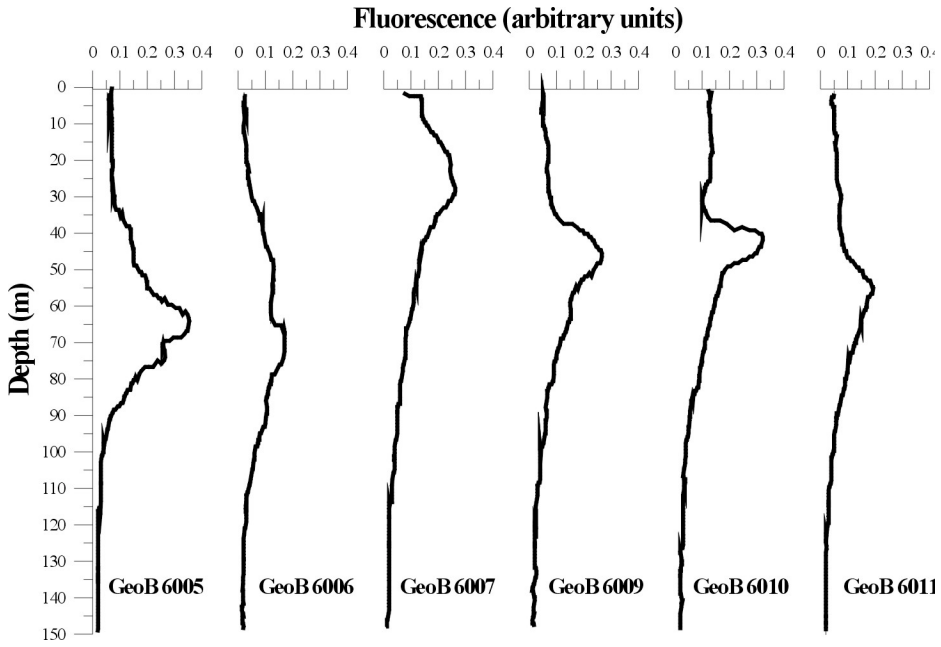


Fig. 68: Fluorescence in arbitrary units (5 step average) in the upper 150 m of the water column on two profiles off Cape Ghir (Sites GeoB 6005, 6006, 6007, 6009, 6010 and 6011).

Central Water (NACW, Fig. 67). Chlorophyll fluorescence (in arbitrary units) profiles as an indicator of chlorophyll concentration showed the position of the deep chlorophyll maximum (DCM) deepening with increasing distance from shore (Fig. 68). The shallowest DCM was found in 25-30 m water depth at STA GeoB 6007. Unfortunately no CTD cast was taken at STA GeoB 6008 (site closest to shore) but this

location showed the highest chlorophyll values suggesting an upwelling-induced phytoplankton bloom with highest chlorophyll in the mixed layer and a non-existent DCM.

b) Planktonic foraminifera

Daily plankton samples were obtained with a handnet (mesh size 70µm) with the ship's emergency pump (inlet located at 3.5 m water depth) to obtain information about the stable isotope composition of living planktonic foraminifera in relationship to regional hydrography. Sampling started after the transfer through the English Channel and stopped north of the Canary Islands. Samples were fixed with mercury-chloride and stored at 4°C.

Planktonic foraminifera larger than 150 µm will be picked from wet samples for shore-based stable isotope analyses. Additionally, we took two 50 ml water samples at the end of each profile for isotope measurements ($\delta^{18}O$, $\delta^{13}C$). The sample for the measurement of $\delta^{13}C$ was also fixed with $HgCl_2$.

Most interesting was the observation of abundant heterotrophic dinoflagellates of the genus *Noctiluca* in the handnet samples, especially north of the Azores. These carnivorous dinoflagellates are typical of the plankton in the North Atlantic in autumn and visible in the dark by their bioluminescence. In contrast, planktonic foraminifera were only of minor importance in the samples, but detailed analysis will follow in Bremen.

5.5.4 Calcareous Plankton and Paleoceanography of the Azores Front-Current System

(R. Schiebel, U. Struck, G. Grimm, H. Hübner and S. Themann)

The distribution of recent and late Quaternary microzooplankton (planktonic foraminifera and pteropods) and nanophytoplankton (coccolithophorids) was studied across the Azores Front-Current System during leg M 45/5a (Fig. 69). At five sites, both water column and sediment samples were analysed to characterise the hydrography of the oceanic front at high resolution by means of its biological components. The resulting patterns may provide clues about paleoceanographic and paleoclimatic conditions of the Azores region and Western Europe. To date, the well-known Azores High-pressure system influences mid and southern European weather in particularly during fall and winter.

The upper water column was sampled for planktonic foraminifers and pteropods with a multinet device (opening 50x50 cm and equipped with 5 cups, 100 µm mesh size). Multinet sampling was conducted at depths between 0 and 100 m (100-80-60-40-20-0 m), and between 0 and 700 m (700-500-300-200-100-0 m). Multinet samples for faunistic analyses were fixed with formalin and buffered to *p*H 8.2. For molecular genetic analysis, live planktonic foraminifers were picked and prepared for DNA extraction and PCR processing. Water samplers (2 liters) were attached to the net frame and released synchronically with the multinets. In addition, water was sampled from approximately 7 meters depth with the shipboard's membrane pump in 4-hour intervals throughout the cruise. Water samples were filtered for coccoliths onto 0.45 µm Millipore filters with a 200 mbar suction. Hydrographic data were recorded from the sea surface to 50 m above the sea floor with a CTD (SEABIRD) and included fluorescence and oxygen sensors attached to the multicorer wire.

Surface sediments were sampled with a multicorer (tube diameter 10 cm) and with a box corer (50x50x60 cm). Surface sediments were cut into 0.5 cm (upper 2 cm) and 1 cm slices (below 2 cm) and fixed with an ethanol / rose bengal solution. In addition, sediment cores were obtained with a 12 meter long piston corer using a tube diameter of 12 cm. To avoid thermodynamic dissolution of calcareous particles, only sediments well above the CCD were sampled (Table 13). North of the Azores, one station was

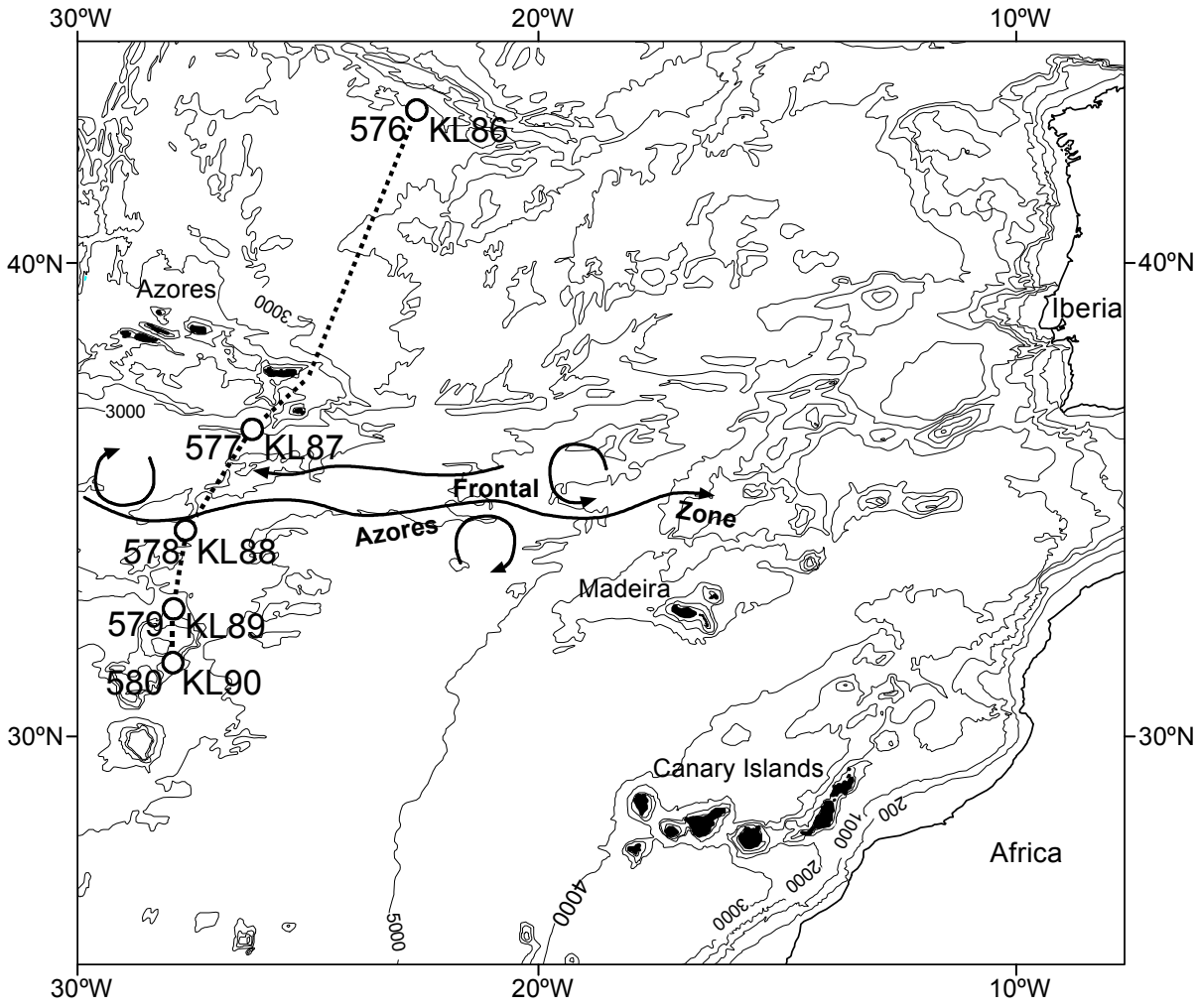


Fig. 69: Bathymetry and location of sites sampled in the Azores region. The sampled transect (hatched line) includes 5 stations (open circles) and crosses the Azores Front-Current System (black arrows). All station were sampled with multinet, multicorer, and piston corer.

sampled (STA 576). This station was located north of the Azores Front and served as a reference for the spatial and temporal development of the fauna and flora at the front. Four locations were sampled south of the Azores Front.

Tab. 13: Position and number of stations across the Azores Front. Multinet (MN), multicorer (MUC), box corer (GKG), and piston corer (KL) samples were numbered according to internal codes used by the working group Hemleben (GPI Tübingen).

Ships #	Date (1999)	Water Depth (m)	Latitude	Longitude	MN	MUC	GKG	KL
576	09.10.	3029	43°22.2'N	22°29.3'W	1392-1393	608		86
577	11.10.	2423	36°33.1'N	25°56.8'W	1394-1396	609	x	87
578	12.10.	2075	34°46.8'N	27°39.8'W	1397-1399	610		88
579	13.10.	3003	32°46.5'N	27°59.4'W	1400-1402	611		89
580	14.10.	3143	31°36.7'N	28°00.9'W	1403-1404	612		90

a) Hydrography

Surface water temperature at the northernmost position was 17.5°C (Fig. 70). The depth of the mixed layer (MLD) was at around 50 m, and the DCM, as deduced from fluorescence data (Fig. 71), was recorded in 40 meters. The hydrographical data thus placed the northern station in the North Atlantic Current (NAC). At the four sites south of the Azores, the depths of the mixed layer were at around 50 m, but surface temperatures steadily increased southward from 23.3 to 24.8°C. Maximum fluorescence was observed at 90 m (STA 577), at 100 m (STA 578 and 579), and at 130 m depth (STA 580; Fig. 71). The depth of the 15°C isotherm south of the Azores (STA 577 and 578) ranged between 185 to 210 m, which, according to the 15°C criterion, places these stations at the northern edge of the Azores Front. At the two southernmost sites, the 15°C isotherm was recorded at 350 m depth, which indicates a position south of the Azores Front.

b) Foraminifera

Live planktonic foraminifers at the northernmost station 576 were most frequent in the upper 40 m, and closely reflected the hydrographic structure of the water column. The most frequently encountered species were *Globigerinoides sacculifer* and *Globigerinoides ruber*. *Globigerina bulloides*, *Globorotalia scitula*, and *Globorotalia truncatulinoides* were present, and several species occurred in small numbers. In total, planktonic foraminifers and pteropods were less frequent than during spring or fall, and reflect a so-called summer fauna, which is also indicated by the high frequency of subtropical taxa like *G. sacculifer* and *G. ruber*. Below 40 m live planktonic foraminifers were rare.

South of the Azores, the faunal composition and abundance of planktonic foraminifera were similar to the northern fauna. In contrast to the north, live planktonic foraminifera were found down to 100 m at the front, corresponding to the depth of the DCM and not the MLD. At the two stations south of the Azores Front (579 and 580), *G. ruber* (pink) was more frequent than in the north (STA. 577 and 578), thus reflecting a different water mass. Below 100 m, live planktonic foraminifera were rare, and only few and small-sized tests were found.

In addition to faunistic analyses of planktonic foraminifers, molecular DNA analysis will be used as an ecological tool in conjunction with the geologic record. The techniques can be applied wherever genetic differentiation may have occurred, and reveal or confirm biogeographic and ecological conditions. A total of 180 single specimens of planktonic foraminifera were collected from the sea surface (0-100 m) for DNA analysis and DNA was extracted from each individual.

Surface sediments were calcareous throughout. Large pteropod shells (*Diacria* sp.) were observed on the sediment surface in high numbers, and *Creseis* shells were present throughout the cores. At the northernmost and at the two southern locations (KL 86, 89, 90), surface sediments consisted of a light clay with silt and fine sand (foraminiferal tests and pteropod tests >0.5 mm). A white chalk (<10% sand), recovered from a core catcher at the northernmost station, reminded us of the chalk cliffs we saw when we passed Dover one week earlier, and is assumed to represent stage 11 according to the black-to-white-reflectivity spectrum (Fig. 72). At the two central stations (STA 577 and 578), and thus contrasting the northern and southern sediment cores, the clay fraction was lacking, and surface sediments consisted of planktonic foraminiferal tests and a few benthic foraminifera and pteropods. Pumice was found in the surface sediment and in the core catcher at the station closest to the Azores Islands. Core catcher contents at stations 578 and 579 were stiff brown clays. At the southernmost station pinkish white clay was recovered containing small amounts of sand.

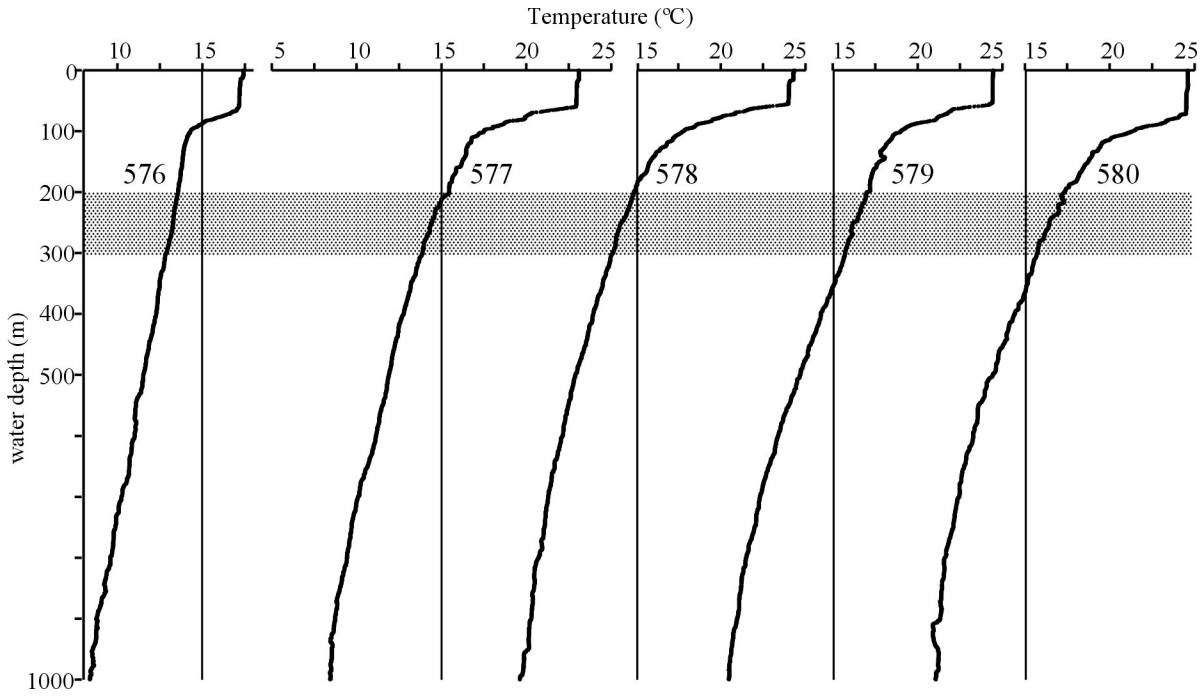


Fig. 70: Temperature profiles (CTD) between stations 576 in the north and 580 in the south. According to the 15°C criterion (shaded area between 200 and 300 m depth), station 576 was located north of the Azores front, stations 577 and 578 at the northern boundary of the front, and stations 579 and 580 south of the front.

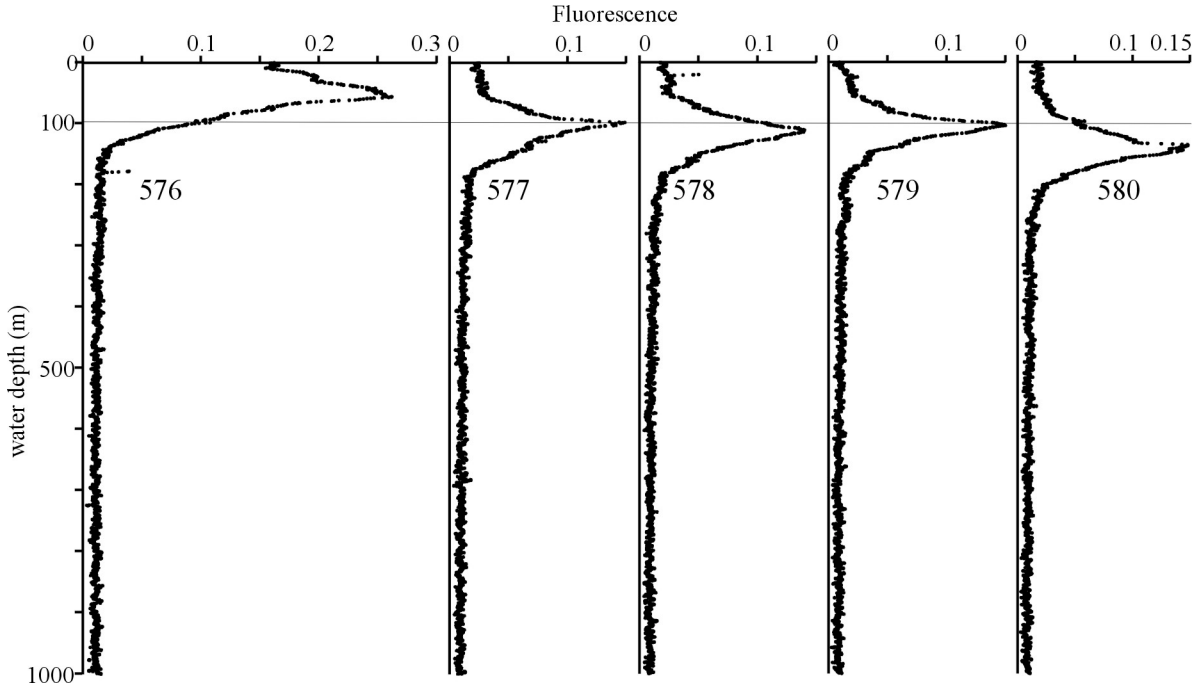


Fig. 71: Fluorescence profiles between STA 576 in the north and STA 580 in the south. Maximum fluorescence was recorded at the northernmost STA 576 at 55 m water depth. South of the Azores at STA 577 to 580 fluorescence was lower, and maximum values were recorded between 100 and 130 m depth.

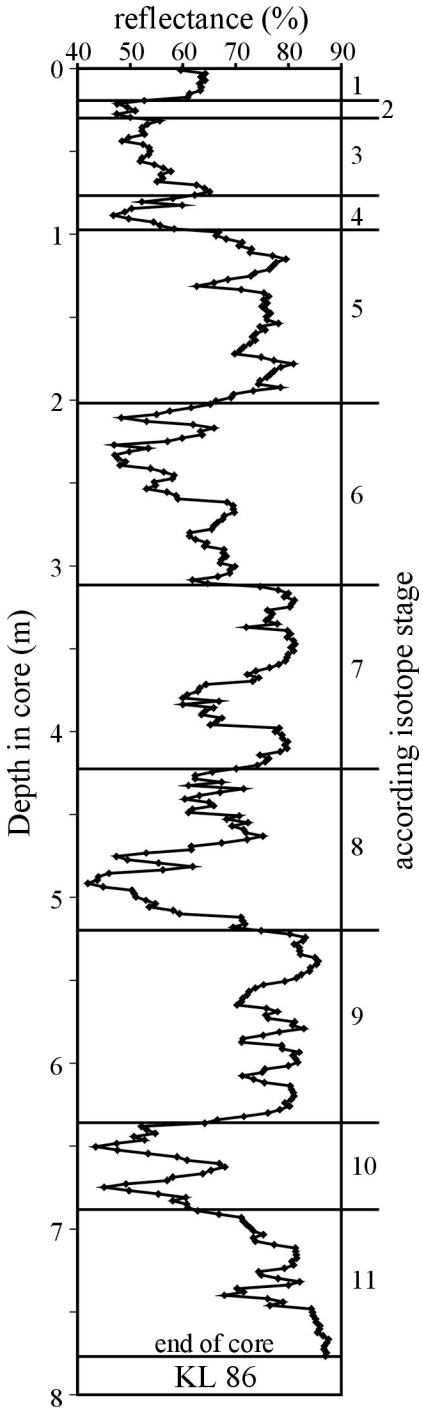


Fig. 72: The black-and-white reflectance (%) of piston core KL 86 (Table 3) can be used as a preliminary stratigraphical tool in comparison with the stable isotopes.