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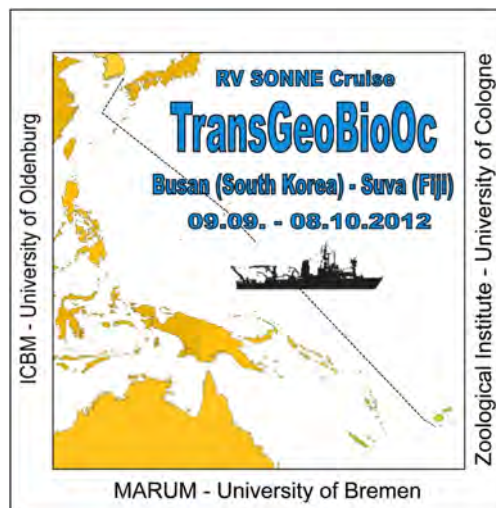
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Mohtadi, M., Arndt, H., Behrens, M., Klann, M., Marschall, J.,  
Meiners, L., Nitsche, F., Pahnke, K., Schönle, A., Steinke, S.

**REPORT AND PRELIMINARY RESULTS OF  
RV SONNE CRUISE SO 223T.**

**TransGeoBioOc.**

**Busan – Suva, 09.09.2012 – 08.10.2012.**



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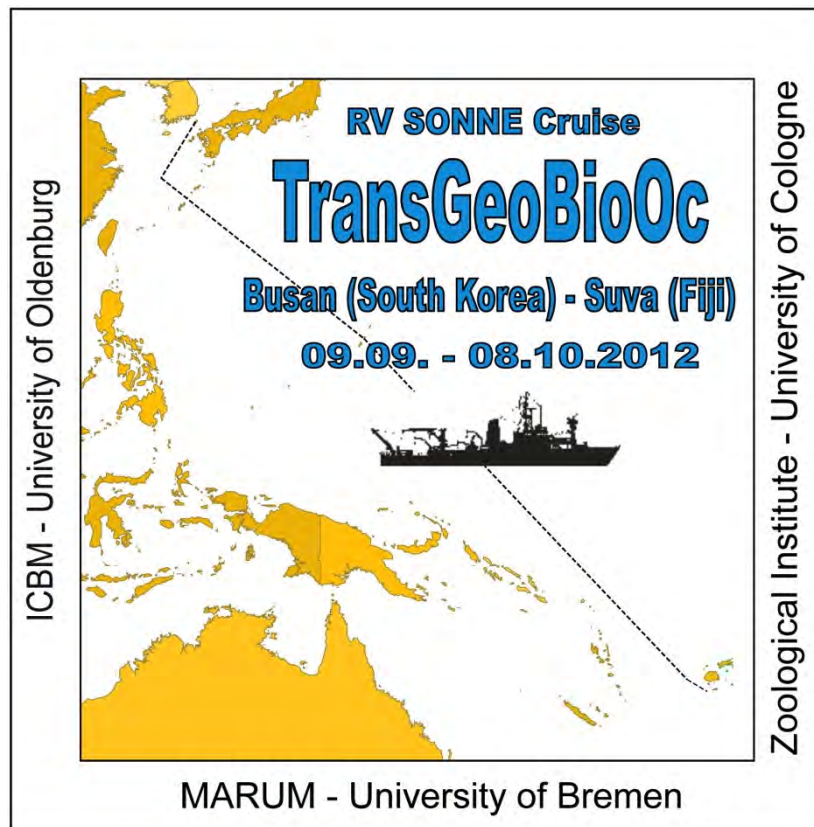
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## Cruise Report

# TransGeoBioOc

## RV SONNE Cruise SO-223T



Busan (09.09.2012) – Suva (08.10.2012)

Mohtadi, M., Arndt, H., Behrens, M., Klann, M., Marschall, J., Meiners, L., Nitsche, F., Pahnke, K., Schönle, A., Steinke, S.



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# 1 Participants

Scientific Party SO-223T

September 9, 2012 – October 8, 2012

Busan (South Korea) – Suva (Fiji)

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Name	Discipline	Institute
Mohtadi, Mahyar	Paleoceanography	MARUM (Chief Scientist)
Arndt, Hartmut	Zoology	UzK
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Pahnke, Katharina	Geochemistry	ICBM
Schönle, Alexandra	Zoology	UzK
Steinke, Stephan	Paleoceanography	MARUM

## Crew list SO-223T

## SO-223T

September 9, 2012 – October 8, 2012

Busan (South Korea) – Suva (Fiji)

---

Name	Rank
Meyer, Oliver	Master
Aden, Nils-Arne	Chief Officer
Goebel, Jens	2. Officer
Hoffsommer, Lars	2. Officer
Raabe, Konrad	Ship's doctor
Rex, Andreas	Chief Engineer
Genschow, Steffen	2. Engineer
Hermesmeyer, Dieter	2. Engineer
Pieper, Carsten	2. Engineer
Beyer, Thomas	Electrician
Leppin, Jörg	Chief Electronic Engineer
Meinecke, Stefan	System Manager
Rosemeyer, Rainer	Fitter
Bolik, Torsten	MPC / Motorman
Ide, Steven	MPC / Motorman
Tiemann, Frank	Chief Cook
Garnitz, André	2. Cook
Pohl, Andreas	Chief Steward
Royo, Luis	2. Steward
Schrapel, Andreas	Boatswain
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Fricke, Ingo	Multi-purpose Rating / A.B.
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Fig. 1.1 Scientific party of the expedition SO-223T

## 2 Research Program

### 2.1 The contribution of submarine volcanic CO<sub>2</sub>-sources to the glacial/interglacial variations in atmospheric CO<sub>2</sub>

To date, the causes of the glacial/interglacial variations in atmospheric CO<sub>2</sub> are still poorly understood. It has been proposed that atmospheric CO<sub>2</sub> was sequestered into an abyssal water mass located in the Pacific during glacials for thousands of years and then ventilated rapidly through intermediate waters that circulated through the Southern Ocean during the last glacial termination (e.g. Broecker and Barker, 2007). In the case of the so-called “deep-water reservoir hypothesis” however, there is no clear evidence that an isolated deep-water reservoir rich in CO<sub>2</sub> was released during the last glacial termination (Broecker, 2009). To date, evidence for a deglacial release of an “old” water mass through intermediate waters (400-600 m) has been found in the eastern tropical Pacific (Marchitto et al., 2007; Stott et al., 2009). However, studies based on sedimentary archives located closer to the Southern Ocean show that an isolated deep-water reservoir rich in CO<sub>2</sub> was not released through intermediate waters in the Southern Ocean (De Pol-Holz et al., 2010, Magana et al., 2010; Rose et al., 2010).

During the past decade submarine surveys conducted along the active volcanic arcs in the Pacific and at hydrothermal vents in the NE and tropical E Pacific have discovered CO<sub>2</sub>-rich fluids venting at intermediate water depths (e.g. Inagaki et al., 2006; Lupton et al., 2006). Estimates of the CO<sub>2</sub> flux at these sites are sparse and the spatial extent of active vents from which there is a separate CO<sub>2</sub> gas or liquid phase venting has only recently come to light. The initial results from these surveys indicate that there are CO<sub>2</sub> fluxes from submarine arc volcanoes along the Pacific trench system in the western Pacific that far exceed that of Mid Ocean Ridge systems and hence, constitute a greater source of carbon to the global carbon budget than was previously thought. Most notably, liquid CO<sub>2</sub> is not only venting from these sites, liquid CO<sub>2</sub> is accumulating within the sediments on the margins of active volcanoes, kept in place by a hydrate caps that regulate the steady-state flux of neutrally buoyant liquid CO<sub>2</sub> from the sediments beneath. To date, liquid CO<sub>2</sub> accumulations have only been observed at sites in the western Pacific. The distribution of sites where liquid CO<sub>2</sub> is documented includes the Okinawa Trough, the volcanoes along the Mariana and the Tonga-Kermadec Arcs.

We are drawn to these recent observations as a means of explaining the enigmatic nature of the glacial/interglacial CO<sub>2</sub> changes. If indeed there is an additional source of CO<sub>2</sub> that contributes to the glacial/interglacial variability in addition to CO<sub>2</sub> dissolved in deep water reservoirs, a strategically important place to test this idea is near the source of that carbon. The back arc of the Mariana system near the Island of Rota is an ideal location to investigate the deglacial signature from intermediate water depths near one of the active volcanic systems. During the SO-223T cruise, it is intended to obtain a suite of cores from sites near the Island of Rota that can yield biogenic carbonate through the last glacial termination to investigate whether there were sources of CO<sub>2</sub> released from the North Pacific volcanic systems that contributed to the distinctive glacial/interglacial CO<sub>2</sub> cycles.

## 2.2 Deep-sea nanofauna diversity in the western Pacific

Although the abyssal seafloor (3000-6000 m depth) represents the most typical common benthic environment on this planet, covering 54 % of the Earth's solid surface, eukaryotic microbial life at abyssal depths is still uncharted territory in eukaryotic microbiology. This is in striking contrast to their importance regarding the material flux in other aquatic ecosystems of the biosphere. Understanding the role of microbial eukaryotic communities in the deep-sea should be essential for understanding global biogeochemical cycles (Azam & Malfatti 2007). Molecular environmental diversity studies have up to now focused on assumed 'hot spots' of activity (e.g., hydrothermal vents, methane seeps) mostly from the bathyal zone. Almost all of these studies were carried out on a local-scale (Edgcomb et al. 2002, 2009, Stoeck et al. 2003).

Abyssal plains have never been considered in a global comparison. Knowledge of diversity and spatial patterns of deep-sea community structure is thus lacking and originates primarily from morphology based studies of foraminiferans (e.g., Gooday 1999) and there are only anecdotal reports for other protists (Hausmann et al. 2002; Arndt et al. 2003; Scheckenbach et al. 2005). Environmental molecular surveys have revolutionized our understanding of microbial diversity, indicating how far we are from understanding microbial diversity in the depth (Lopez-Garcia et al. 2001, 2003, Alexander et al. 2008).

Abyssal plains are among the Earth's flattest and smoothest regions and are covered with muddy soft sediments. They had formerly been assumed to be vast, desert-like contiguous habitats with relatively constant physical and chemical parameters. Recent studies of prokaryotes have shown that even the deepest parts of our Earth are teemed with a large variety of life (Jørgensen & Boetius 2007). The perceived homogeneity of abyssal environments with little environmental variation has led to the assumption that species have broad distribution ranges. This is in fact supported by studies of foraminiferans which, to some extent, have geographic ranges encompassing entire abyssal plains (Gooday et al. 2007, Pawlowski et al. 2007, Pawlowski & Holzman 2008). However, environmental gradients do shape deep-sea community structure, especially those of in benthic environments (Levin et al. 2001). Except for studies by Countway et al. (2007), community driven molecular deep-sea studies of microbial eukaryotes communities in the deep-sea have all been carried out on a local scale. Local-scale studies of benthic deep-sea microbial communities reported differences in the community structures between adjacent sampling sites (Edgcomb et al. 2002, Huber et al. 2007). Knowledge of large-scale patterns of deep-sea community structures is thus missing but necessary to allow the assessment of the forces driving biodiversity and biogeography in the deep.

Recently, we reported on the high phylogenetic diversity of microbial eukaryotic communities of the deep-sea basins of the South-East and West Atlantic and the Mediterranean Sea (Scheckenbach et al. 2010, Shah Salani et al. 2012). An exceptionally high percentage of clones had no close representatives in genetic databases at all. Many clones were affiliated to parasitic species. Furthermore, we could show that environmental gradients clearly shape community structure at the landscape level as differences amongst the Cape Abyssal Plain and the other abyssal plains have revealed. Nevertheless, on a regional scale, local species diversity showed no geographic variation up to our present knowledge. During the SO-223T cruise, it was intended to obtain Multi-Core samples from the undisturbed and populated sediment surface layer from two deep-sea basins of the North-West Pacific. A second aim was to collect sediment surface samples near the Island of Rota to analyze changes in the

nanofauna community along a depth gradient down to the Mariana trench. In continuation of our studies on global distribution mechanisms and patterns of protists we would also like to collect rain samples to study airborne protists potentially reaching the deep sea by sedimentation. In addition, we would like to compare deep-sea nanofauna community structure to that of surface water communities by investigating surface and near bottom water communities.

### **2.3 Neodymium isotope and rare earth element distributions in the western tropical and North Pacific**

Trace elements and their isotopes (TEIs) play important roles in biogeochemical processes in the ocean. Many are important micronutrients, contaminants, or tracers of biogeochemical processes, element fluxes or changes in the ocean today and in the past. Yet, few data exist that would allow for a detailed understanding of TEI distributions and the processes that control them. Neodymium isotope ratios ( $^{143}\text{Nd}/^{144}\text{Nd}$ ; expressed in  $\epsilon_{\text{Nd}}$  notation, the fractional deviation of the  $^{143}\text{Nd}/^{144}\text{Nd}$  in a sample from the value of the bulk silicate Earth in parts per  $10^4$ ) and rare earth element (REE) concentrations are useful tracers for the origin and pathways of water masses, provenance of terrestrial material transported to the ocean (e.g., dust, river load), and element fluxes at continental margins and the seafloor (Frank, 2002; Lacan and Jeandel, 2005). They can therefore provide important information on trace element sources and processes in the ocean.

In the Atlantic, where ocean circulation is vigorous, Nd isotope ratios mirror the water mass structure and pathways well, and models that do not include margin exchange as major process controlling the seawater isotopic composition, reproduce the current Nd isotope distribution (Siddall et al., 2008). This suggests that ocean circulation is a dominant factor in setting the  $\epsilon_{\text{Nd}}$  distribution in the Atlantic. In the Pacific, on the other hand, where full water-column  $\epsilon_{\text{Nd}}$  profiles are scarce (<20; e.g., Lacan and Jeandel, 2001; Amakawa et al., 2004; 2009; Pahnke et al., 2012) and ocean circulation less vigorous, reversible scavenging and margin exchange may contribute to the vertical and spatial Nd isotope distribution (Siddall et al., 2008; Jones et al., 2008).

The TransGeoBioOc transect from Busan to Suva will more than double the available seawater  $\epsilon_{\text{Nd}}$  profiles in the Pacific north of  $15^\circ\text{S}$ , and provide new insight into 1) the  $\epsilon_{\text{Nd}}$  signature of the different water masses in the Pacific (Pacific Deep and Intermediate Water, Antarctic Bottom Water, Antarctic Intermediate Water), 2) the modification of these signatures along the transport pathways of water masses and in the Equatorial Undercurrent (EUC) (through water mass mixing and/or isotopic exchange along continental margins), and 3) the sources and distributions of REEs in the West Pacific.

### **2.4 Oceanic shipboard precipitation validation**

State-of-the-art satellite-derived and reanalysis-based precipitation data still show remarkably large differences in frequency, amount, intensity, variability, and temporal behavior of precipitation over the oceans. The uncertainties are largest for light precipitation within the Intertropical Convergence Zone and for cold season high-latitude precipitation including mix-phase and snowfall. Hence, the International Precipitation Working Group (IPWG) under WMO (World Meteorological Organization) and GPM-GV (Global Precipitation Measurement – Ground Validation – the new satellite based generation of precipitation

measurement from space) is urging that more attention should be paid to the provision of high quality surface validation data in oceanic areas using innovative ship-based instruments. Precipitation studies would greatly benefit from systematic data collection and analysis.

To achieve this goal, the KlimaCampus and Max Planck Institute for Meteorology in Hamburg, Germany, initiated the project “OCEANIC SHIPBOARD PRECIPITATION VALIDATION” within the Excellence Cluster of the University of Hamburg that uses automated shipboard optical disdrometers, called Eigenbrodt ODM470, that are capable of measuring liquid and solid precipitation on moving ships with high accuracy even under high wind speeds and rough sea states. Since the start of the project in 2009, the statistical basis for a conclusive validation has significantly improved with comprehensive data collection of more than 200,000 minutes of precipitation onboard six ships.

Currently three optical disdrometers are permanently mounted onboard the research vessels Polarstern, Akademik Ioffe, and Maria S. Merian and another three instruments are used for individual cruises like the one onboard the RV SONNE during cruise SO-223T.

## 2.5 Maritime aerosol network

MAN (Maritime Aerosol Network) is a program that collects data, which are obtained from the sun photometer Microtops II on ships. The Microtops II measures the direct solar radiation and through the calculation of the aerosol optical depth (AOD) it is possible to draw conclusions about aerosols in the atmosphere. This is an alternative to measurements from islands and can be used as a control for aerosol transport models.

MAN is part of AERONET (Aerosol Robotic Network), a network for long-term continuous aerosol data and accessible through a public domain database of aerosol optical, microphysical and radiative properties for aerosol research and characterization and synergism with other databases. The network was established and is run by NASA and receives its data from many international institutes.

During cruise SO-223T, a sun photometer was used to obtain data for MAN. The data were submitted to the network and are publically accessible under: [http://aeronet.gsfc.nasa.gov/new\\_web/cruises\\_new/Sonne\\_12\\_0.html](http://aeronet.gsfc.nasa.gov/new_web/cruises_new/Sonne_12_0.html)

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### 3 Narrative of the Cruise

#### 09.09.2012, Sunday

In the morning, the scientific crew for the cruise SO-223T boarded the RV SONNE at the port of Busan, South Korea. The main target of this and the following day was to set up the scientific equipment and prepare the laboratories onboard RV SONNE.

#### 10.09.2012, Monday

In the early afternoon, the container (reefer) arrived at the port of Busan and the discharge of the container loaded with scientific equipment started immediately. All the labs could be prepared during this day.

#### 11.09.2012, Tuesday

RV SONNE left the port of Busan at 9 AM heading towards the first station of the cruise in the Northwest Pacific. The vessel reached the first station at 4 PM local time and the first CTD-Rosette water sampler was successfully deployed under perfect weather conditions.

#### 12.09.2012, Wednesday

During this day, two CTD-Rosette water samplers were deployed down to 748 m and 3357 m water depth, respectively. After the successful deployment of the second CTD-Rosette water sampler, we started the sub-bottom profiling with Parasound in order to identify a suitable location for the first Multi-Corer deployment around 25°N, 134°E and at a water depth of about 5000 m.

#### 13.09.-14.09.2012, Thursday-Friday

Station GeoB 17004 located between the Hikoku and the Philippine Basins started in the morning of Tuesday with the CTD-Rosette water sampler followed by a Multi-Corer. All casts were successful and the retrieved material was sampled, labeled and packed immediately after recovery. The retrieved material consisted of dark reddish brown homogenous deep-sea clay.

#### 15.09.2012, Saturday

At station GeoB 17005, another CTD-Rosette water sampler was deployed. Overnight the wind increased significantly with wave heights of up to 4 m as a consequence of the typhoon „Sanba”, which passed close by on its way north to the Korean coast.

#### 16.09.-17.09.2012, Sunday-Monday

The weather and sea conditions prevailed over the course of the day. Wind and sea conditions, however, became much better in the late afternoon of Sunday. We reached our



working area near Rota Island on Monday (17.09.2012). Site survey started immediately and the entire day and night were spent with site surveying.

#### 18.09.-19.09.2012, Tuesday-Wednesday

The entire night of Monday to Tuesday were spent with site surveying. Evaluation of the site survey data revealed several promising sites at different water depths between 1200 and 3000 m for obtaining high-resolution sedimentary archives. Some disappointment arose from the fact that the first retrieved Multi-Corer was empty and the second Multi-Corer retrieved only 19 cm of sediment. The sediments were sandy (foraminiferal ooze with volcanic glass; see description below) at this site, which obviously allowed no deeper penetration of the Multi-Corer. Another Multi-Corer was deployed at a water depth of around 1800 m (station GeoB 17007-1). Similar to the previous station, only sandy sediments were recovered. Maximum recovery was 13 cm. We decided not to deploy a gravity corer due to the sandy nature of the sediment. Instead, we left for the next station (GeoB 17008-1). Although the recovery of the Multi-Corer was with 19 cm slightly higher, again only sandy sediments were cored. The nature of the sediments again prevented deployment of a gravity corer. After finishing this station, we left for station GeoB 17009-1 at 2686 m water depth. Here again a foraminiferal ooze of 17 cm thickness was retrieved. Another Multi-Corer at station (GeoB 17010) was empty. After finishing this station and without any gravity corer deployment, we left our working area near Rota Island rather disappointed and headed towards the Mariana Trench.

#### 20.09.2012, Thursday

The entire day was spent with site surveying in order to identify an appropriate location for a Multi-Corer deployment in a water depth of around 7000 m. The intention was to obtain undisturbed sediment surfaces for biological studies from the Mariana Trench. However, no location for a Multi-Corer deployment was found due to steep morphology of the basin. We left the Mariana Trench for a next CTD-Rosette water sampler deployment.

#### 21.09.2012, Friday

A CTD-Rosette water sampler was deployed in Micronesian waters (station GeoB 17011). Site survey started immediately after the CTD-Rosette water sampler deployment to identify an appropriate site for another Multi-Corer deployment.

#### 22.09.2012, Saturday

The entire day was spent with site surveying in order to identify an appropriate location for a Multi-Corer deployment in a water depth between 5000-6000 m. In the evening, while the site survey was continued, the scientific party and the crew came together to celebrate four birthdays.

#### 23.09.2012, Monday

The evaluation of the site survey data revealed two promising sites at a water depth around 5500 m, which were sampled with the Multi-Corer during the day. At station GeoB 17012, only 2 cm sediment was recovered but sufficient overlying water for biological and rare earth element studies. The sediment sampled at this station is a dark reddish brown (5YR3/3)

homogenous diatom-bearing mud with a minor sand content. The recovery at station GeoB 17013 was lower (~0.5 cm) but again sufficient overlying water was collected. The sediment is dark reddish brown (5YR3/3) homogenous diatom-bearing mud with numerous manganese crusts and nodules (up to 2 cm in diameter). After finishing this station, we left the working area for the next CTD-Rosette water sampler deployment.

#### 24.09.-29.09.2012, Tuesday-Saturday

While steaming further southeast to Suva (Fiji), the water column sampling was continued at stations GeoB 17014, 17015, 17016, 17017 and 17018. All CTD-Rosette water sampler deployments were successful and water for biological, rare earth element and isotopic studies has been sampled.

#### 30.09-01.10.2012, Sunday-Monday

The RV SONNE continued sailing further southeast towards Suva (Fiji).

#### 02.10.-03.10.2012, Tuesday-Wednesday

Today we reached our last scientific station (GeoB 17019) and most of the first day was spent with site surveying in order to identify an appropriate location for a Multi-Corer deployment in a water depth of around 3000 m. After another CTD-Rosette water sampler deployment, sediment and overlying water were sampled with a Multi-Corer. At station GeoB 17019, 32 cm sediment was recovered and sufficient overlying water for biological studies. The sediment sampled at this station is in upper 0-0.04 m a dark brown (7.5YR3/3) foram-nannofossil bearing volcanic ash. Below the ash-layer, the sediment is a strong brown (7.5YR5/6) foram-diatom bearing nannofossil ooze. After finishing the last station of the cruise, the Multi-Corer was demobilized.

#### 04.10.-05.10.2012, Thursday-Friday

During these two days, the reefer was loaded with the first scientific equipment (Multi-Corer, Gravity Corer). The scientific groups started to prepare their equipments for shipping and all the labs were cleaned.

#### 06.10.2012, Saturday

In the afternoon, the RV SONNE reached the port of Suva (Fiji).

#### 07.10.2012, Sunday

On Sunday, the second container could not arrive the pier as scheduled, and the scientific party continued with final preparations for disembarking.

#### 08.10.2012, Monday

The final day of the cruise was spent for loading the second container. The cruise participants disembarked in the afternoon and the expedition SO-223T (TransGeoBioOc) came to an end.

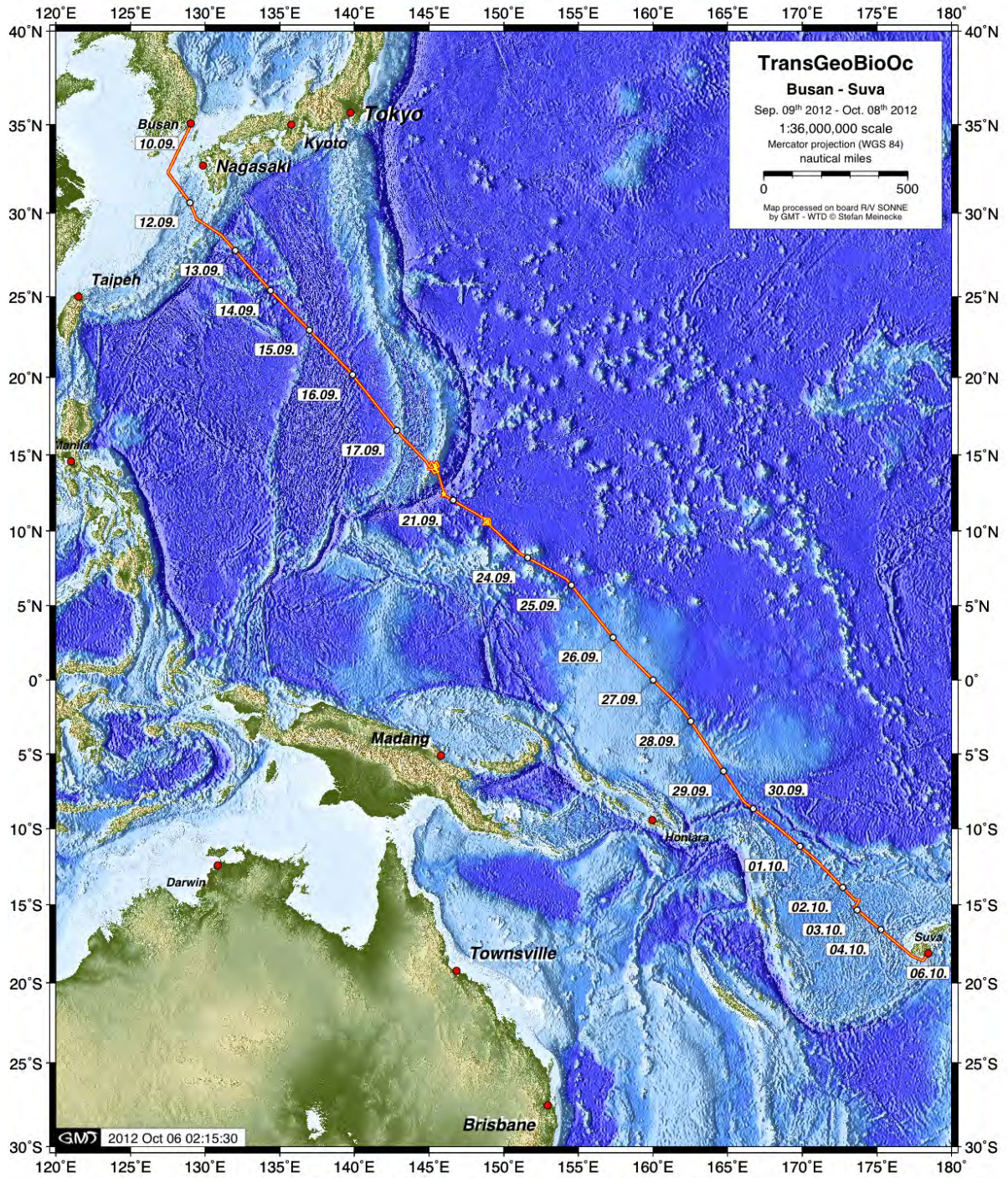


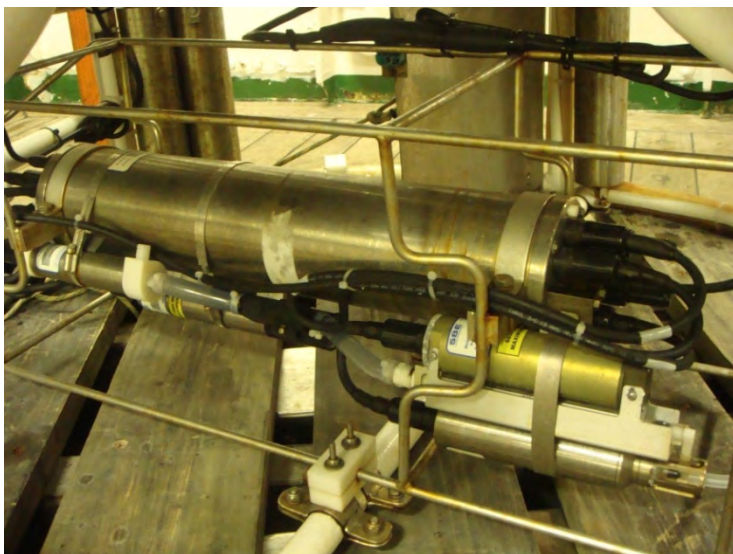
Fig. 3.1 Cruise plot of SO-223T.

## 4 CTD Profiling and Water Sampling

(Pahnke, Behrens, Meiners)

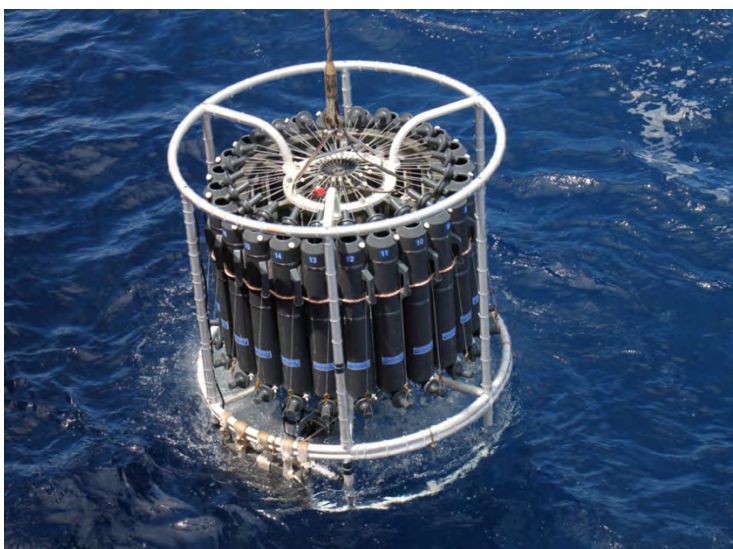
### 4.1 Instrumentation

A Seabird SBE 9plus CTD with sensors for the continuous measurement of conductivity, temperature, pressure and dissolved oxygen was used to obtain data on the physicochemical properties of the water columns (Fig. 4.1). This information was then used to define the sample depths using the CTD Niskin rosette.



**Fig. 4.1** Seabird SBE 9plus CTD with oxygen SBE 43 sensor.

The CTD was deployed with a SBE carousel water sampler (Fig. 4.2), which was equipped with 24 O.T.E. non-metallic free-flushing 10 Liter water sampling Niskin bottles with gray PVC sampler body, latex tubing spring closure, mounting blocks to attach to bottle stand adapter plates, release lanyards, Delrin drain valve and NBR70 (Acrylnitril-Butadien-Kautschuk) O-rings.



**Fig. 4.2** Water sampling rosette with 24 x 10L Niskin bottles.

## 4.2 Water sampling

Depending on the water mass structure und bottom depth at the stations, up to 26 different water depths were sampled per CTD cast (Tab. 4.1). Additionally, surface water was collected using the ship's contamination-free seawater intake (~5 m water depth). Samples were collected for the analysis of Nd isotopes (5-15 L per sample), REE concentrations (250 ml per sample), trace elements (V, U, Tl, Re, Mo, Ba; 60 mL per sample), and nutrients (Si, nitrate, maybe phosphate; 20 mL per sample).

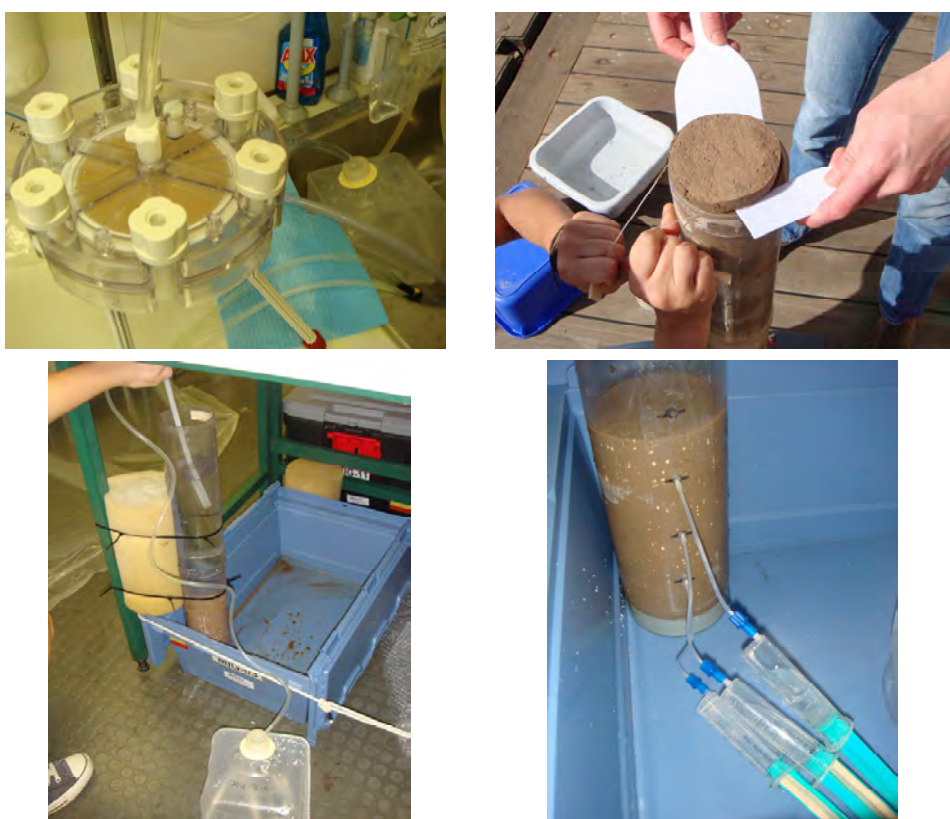
**Tab. 4.1** CTD/Water sampling stations during cruise SO223T.

GeoB No.	Latitude [S]	Longitude [W]	Water Depth [m]	Instrument Depth [m]	Depth sampled [m]	Samples
17001-1	32°19,992'N	127°29,975'E	129	129	129-129-102-53-22	ICBM / UzK
17002-1	30°35,006'N	128°59,990'E	749	748,6	748,6-748,6-696-498-299-249-200-150-100-51-22	ICBM / UzK
17003-1	28°42,980'N	131°05,040'E	3357	3350	3350-3350-1988-1490-993-645-645-496-496-298-250-200-151-101-52-22-22	ICBM / UzK
17004-1	25°22,700'N	134°22,514'E	5339	5276	5276-5276-4977-4479-3980-3483-2985-2487-2000-1501-1004-800-651-303-101-62-22-22	ICBM / UzK
17005-1	20°26,004'N	139°36,977'E	6315	3000	3000-3000-2002-1500-998-751-500-300-201-101-101-61-61-22-22	ICBM / UzK
17011-1	10°37,800'N	148°53,998'E	5667	5574	5574-5574-5001-4502-4502-4002-3000-2502-2002-1500-1001-799-502-370-142-81-21-21	ICBM / UzK
17014-1	6°47,032'N	154°11,979'E	4583	4573	4573-4573-4500-4001-3800-3001-2501-2001-1501-1002-641-502-261-200-121-121-22-22	ICBM / UzK
17015-1	2°00,214'N	157°59,877'E	2695	893	893-602-320-241-200-180-130-130-101-80-80-60-50-40-40-20-20	ICBM / UzK
17016-1	0°0,002'N	160°0,001'E	2837	1003	1003-799-599-501-401-283-283-199-150-150-120-90-70-58-20-20	ICBM / UzK
17017-1	2°0,018'S	162°0,042'E	3162	3082	3082-3082-2998-2000-1004-840-701-701-550-300-200-149-149-119-100-80-41-41	ICBM / UzK
17018-1	8°11,927'S	166°5,016'E	4623	4500	4500-4500-4400-4002-3403-3100-2501-2000-1502-1002-800-720-320-200-150-41-21	ICBM / UzK
17019-1	15°13,021'S	173°31,122'E	2784	2772	2772-2772-2600-1802-1302-1002-800-700-550-410-200-120-41-20-20	ICBM / UzK

### 4.3 Suspended particle and porewater sampling

Suspended particles from 5m water depth were collected upon leaving each station using the ship's contamination-free seawater intake. A volume of 200-500 L of seawater was passed through a Millipore cellulose filter (0.4  $\mu\text{m}$  pore size, 140 mm diameter, 2-3 L/min) that was placed on a Geotech all-PVC/PP filter holder (Fig. 4.3).

From 7 Multi-Corer (MUC) casts, one large tube ( $\varnothing$  10 cm, 60 cm long) each was sampled for the overlying water (1-2.5 L) (Fig. 4.3), porewater (up to 40 ml from every 5 cm) and sediments (Tab. 4.2). The porewater samples were collected using 5 cm-long Rhizons that consist of a porous polymer tube with a typical pore diameter of 0.1  $\mu\text{m}$  that is extended with an apolyvinyl chloride tube (Fig. 4.3). Samples were transferred to acid-cleaned HDPE sample tubes for future analysis of REE concentrations.



**Fig. 4.3** Sampling of suspended particles (top left), sediments (top right), overlying MUC-water (bottom left), and porewater using Rhizons (bottom right).

**Tab. 4.2** Multi-Corer sampling for porewater and overlying water during cruise SO223T.

GeoB No.	Latitude	Longitude	Water Depth [m]	Tubes		Overlying water		Pore-water	Sediment
				∅ 10cm	∅ 5cm	pH 2	C18 cartridge	pH 2	Total (cm)
17004-2	25°22,7'N	134°22,52'E	5339	1		1L		120ml	0-11
17006-2	14°3,7'N	144°3.2'E	1255	1	1	2.3L		120ml	0-15, 0-10
17008-1	14°5,6'N	145°23,16'E	1895	1					0-16
17009-1	13°58,6'N	145°30,72'E	2686	1		2.5L		120ml	0-14
17012-1	10°37,8'N	148°37,8'E	5719	1			2L		
17013-1	10°34,3'N	148°49,0'E	5497	1			2L		
17019-2	15°13,0'S	173°31,1'E	2776	1		1.5L		240ml	0-27

#### 4.4 Sample processing

The water was filtered directly from the Niskin bottles (or the seawater tap in the lab) through AcroPak500 cartridges (0.8/0.2  $\mu\text{m}$  pore size) into acid-cleaned LDPE containers using Teflon-lined Tygon tubing and PP fittings (Fig. 4.4). A laminar flow bench in the wet lab onboard R/V SONNE was extended with plastic sheets to create a semi-clean (low particle) environment for sample processing (acidification, pre-concentration). In order to pre-concentrate the REEs from seawater for Nd isotope analyses, all large-volume samples (5-15 L) were acidified to a pH of 3.5 and passed through Sep-Pak C18 cartridges (Waters Inc.) that were preloaded with a complexing agent (300 mg of phosphoric acid 2-ethylhexyl ester), using a peristaltic pump (20 ml/min) (Fig. 4.4).



**Fig. 4.4** Sampling and filtration of seawater from Niskin bottles (top left) and pre-concentration of REEs (bottom left). Top right and bottom right: 5 L samples and clean-room bubble with pumps.

The REE and trace metal samples were acidified to a pH of 2 and stored at room temperature. The nutrient samples were poisoned with 3.5% mercury chloride and stored at 4°C. All particle filters were folded, placed into plastic sample bags and stored at -32°C.

Porewater samples ( $\leq 40$  ml) for REE analysis were acidified to a pH of 2 and stored in acid-cleaned HDPE tubes.

The MUC-overlying water samples were filtered through an AcroPak500 cartridge (0.8/0.2  $\mu\text{m}$  pore size; GeoB 17004-2, GeoB 17006-2, GeoB 17009-1, GeoB 17019-2), or were passed through a Millipore cellulose filter (0.4  $\mu\text{m}$  pore size, 140 mm diameter, gravity filtration) because of high particle concentrations in the water (GeoB 17012-1, GeoB 17013-1). The overlying water from Stations GeoB 17006-2 and GeoB 17009-1 was clear, while the water from GeoB 17004-2 had high suspended particle concentrations most likely due to disturbance of the sediment surface during recovery of the MUC. At Stations GeoB 17012-1 and GeoB 17013-1, high particle concentrations in the overlying water were most likely caused *in situ* through resuspension of sediment particles at the seafloor, because the cored sediment surface was undisturbed.

MUC sediments were sampled at 1cm intervals using plastic spatulas, placed into plastic sample bags, and stored at 4°C for future analysis of Nd isotopes and REE concentrations in the authigenic Fe-Mn oxide fraction, foraminifera, and/or fish teeth.



## 5 Sub-bottom Profiler, Swath Bathymetry Sounder

(Mohtadi, Arndt, Klann, Nitsche, Steinke)

During the SO-223T cruise, two different echosounders were operated to provide high resolution information on the uppermost 50-100 m of sediment and to gain detailed insight in the local bathymetry. The hull mounted parametric sub-bottom profiler Parasound DS3 (Atlas Hydrographic) works as a narrow beam sediment echosounder, providing primary frequencies of 18 (PHF) and adjustable 18.5 – 24 kHz, thus generating parametric secondary frequencies in the range of 0.5 – 6 kHz (SLF) and 36.5 – 42 kHz (SHF) respectively. The secondary frequencies develop through nonlinear acoustic interaction of the primary waves at high signal amplitudes emitted by a transducer array of 128 transducers on a rectangular plate of approximately 1 m<sup>2</sup> in size. The wave interaction takes place only in the emission cone of the high frequency primary signals which is limited to an aperture angle of only 4° for the Parasound DS3. Therefore the footprint size is only 7% of the water depth and vertical and lateral resolution is significantly improved compared to conventional 3.5 kHz echosounder systems. The Parasound DS3 is an improvement of the former Parasound DS2 (Atlas Elektronik) and is installed on RV SONNE since 2008. The fully digital system provides important features like recording of the 18 kHz primary signal and both secondary frequencies, continuous recording of the whole water column, beam steering, different types of source signals (continuous wave, chirp, barker coded) and signal shaping. However, many of the new features are still in an experimental state. Data is digitized at a sample frequency of 96 kHz to evade aliasing effects for the high secondary frequency. A downmixing algorithm in the frequency domain is used to reduce the amount of data and allow data distribution over Ethernet.

For the standard operation a parametric frequency of 4 kHz and a sinusoidal source wavelet of 1 period were chosen to provide a good relation between signal penetration and vertical resolution. The 18 kHz primary signal and the 40 kHz parametric signal were also recorded permanently. On most lines the system was operated in the quasi-equidistant mode. This mode provides an optimal lateral coverage of the sea floor, since the echosounder calculates an intertwined trigger sequence using the 'unused' travel time of the signal in the water to emit additional pulses in a matter, which generates an equally spaced transmit/receive sequence with at least twice the rate of a standard send-receive-send-sequence. In this mode, usually a depth window of 200-600 m was recorded in all signal frequencies. On selected profiles, for instance in vicinity of coring sites and water sampling sites the system was operated in the single pulse mode, which allow recording of the full water column and therefore provides insight in the particle concentration in the water column, especially for the higher signal frequencies.

The system worked with exceptional stability for the whole cruise period. This stability in conjunction with the automated watch keeping mode allowed a significant reduction of watch keeping times. The data quality is very high.

As the seismic data the Parasound data was loaded into the commercial seismic interpretation system Kingdom Suite (Seismic Micro) and therefore provided a very fast and valuable means to quickly get a first impression of the uppermost 50–80 m of sediments.

Swath bathymetry was carried out along all profiles with the hull mounted Simrad EM120 (Kongsberg). The EM120 operates at a frequency of 12 kHz and provides 191 beams and a maximum swath angle of 128. To calibrate the depth determination algorithms in each survey area a deep CTD station was performed to provide a regional water sound velocity profile. The EM120 worked absolutely reliably throughout the cruise and provided a very high data quality.

## 6 Sediment Sampling

(Mohtadi, Klann, Steinke)

### 6.1 Multi-Corer

The main tool for the sampling of undisturbed surface sediments and overlaying water for biodiversity studies (working group Arndt) was the Multi-Corer (MUC) equipped with six large (diameter of 10 cm) and four smaller (diameter of 6 cm) plastic tubes of 60 cm length. During the SO-223T cruise, 10 Multi-Corers have been deployed (Tab. 6.1). The maximum recovery was 43 cm of undisturbed surface sediment. Different from being outlined in the working plan of the cruise proposal, no gravity corer has been deployed during cruise SO-223T. The composition of sediments around the Island of Rota allowed no gravity coring (see 12.2).



Fig. 6.1 Undisturbed sediment surface in Multi-Corer tubes taken during SO-223T cruise

Table 6.1 Multi-Corer sampling and sub-sampling during R/V SONNE Cruise SO-223T

GeoB No.	Latitude	Longitude	Water Depth [m]	Large tubes (10 cm diameter)						Small tubes (6 cm)				Core length [cm]	
				#1	#2	#3	#4	#5	#6	#1	#2	#3	#4		
17004-2	25°22,700' N	134°22,519' E	5339	Gc	PF	PF	AR	AR	AR	AR	AR	AR	AR	AR	43
17006-1	14°03,717' N	144°58,779' E	1253	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	empty
17006-2	14°03,699' N	144°03,699' E	1259	Gc	PF	PF	AR	AR	AR	AR	AR	AR	Gc	19	
17007-1	14°04,320' N	145°20,592' E	1829	PF	PF	-/-	-/-	-/-	-/-	AR	AR	-/-	-/-	19	
17008-1	14°05,613' N	145°23,191' E	1895	PF	PF	AR	-/-	-/-	-/-	Gc	AR	-/-	-/-	19	
17009-1	13°58,640' N	145°30,719' E	2687	Gc	PF	PF	AR	-/-	-/-	AR	AR	AR	AR	17	
17010-1	14°24,252' N	145°25,420' E	1745	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	empty	
17012-1	10°37,799' N	148°37,800' E	5719	AR	AR	-/-	-/-	-/-	-/-	AR	-/-	-/-	-/-	2	
17013-1	10°34,313' N	148°49,032' E	5497	AR	AR	AR	AR	AR	AR	-/-	-/-	-/-	-/-	0.5	
17019-2	15°13,023' S	173°31,129' E	2776	Gc	PF	PF	AR	AR	-/-	AR	AR	-/-	-/-	32	

PF	Planktic foraminifera	MARUM
Gc	Geochemistry	ICBM
AR	Archive	MARUM

## 6.2 Sub-sampling of the Multi-Corer

Depending on the availability of filled tubes and overlaying water, the following sampling scheme for the Multi-Corer tubes was applied:

- 3 large tubes cut into 1 cm thick slices for planktic foraminiferal investigations (MARUM)
- 2 small tubes cut into 1 cm thick slices for sedimentological analysis (MARUM)
- 1 large tube with small openings for pore water analysis (ICBM)
- 4 small tubes cut into 1 cm thick slices for the archive (MARUM)
- 10 tubes: “fluffy” surface layer for biological studies (UzK)
- 10 tubes: overlaying water for biological studies (UzK)

## 6.3 Sediment classification

The sediment classification largely follows ODP/IODP convention. Lithological names consist of a principal name based on composition, degree of lithification, and/or texture as determined from visual description and microscopic observations. The color of the sediments was determined by comparison with the Munsell soil color chart. Smear slide analyses were applied to evaluate the mineralogy, components (form, size) and the presence of microfossils.

# 7 Counting, Isolation and Cultivation of Protists from Water and Sediment Samples

(Arndt, Nitsche, Schoenle)

## 7.1 Sediment samples

Quantitative benthos samples were collected using the Multi-Corer system (diameter of an individual core either 100 mm or 60 mm). Nearly undisturbed sediment and overlaying water were used for the analysis. With this sampling method, contamination by organisms or cysts from other water layers could be reduced to a minimum. Once on deck, corers were immediately investigated. Samples were taken from the overlaying water as well as from the upper 2 mm sediment layer by means of a sterile syringe. In addition, hard substrates (about 0.2-0.5 cm<sup>3</sup>) were incubated for cultivation. Immediately after sampling, one set of sediment subsamples was filtered on 0.8 µm filters which were transferred to 50% ethanol and stored at 4°C for later molecular biological studies of nanoprotists. Another set of sediment subsamples was fixed with formaldehyde, stained with DAPI (fluorescent dye) and filtered on 0.8 µm membrane filters for later epifluorescence counts of nanofauna.

For additional quantitative estimates, two methods were used: live-counting of untreated samples and cultivation of defined aliquots of the sample (liquid aliquot method = LAM). The direct counts served as an estimate of deep-sea protistan abundance and were carried out within a few minutes after sampling in a miniaturized version of a Sedgewick-Rafter chamber (area about 10 mm x 25 mm, height 0.2 mm) filled by a calibrated micropipette. Inspections and counting of 5-20 µL subsamples of the sediment suspension were done using upright microscopes (Zeiss Axiostar, Zeiss Axioskop 50). The liquid aliquot method served as an estimate of the abundance of cultivable nanoprotists. Subsamples of a few milliliters of the sediment suspension were added into 50 ml tissue culture flasks. In addition, 500 ml aliquots of the overlaying water were incubated in tissue-culture flasks. All cultures were supplied with sterilized quinoa grains. Culture flasks and plates were incubated at 20°C; inspections were carried out using inverted microscopes (Motic, 200-400x magnification) every 3-4 days. The number of culture vessels containing a certain species allowed an estimate of the abundance of cultivable active organisms/cysts. Additional subsamples were fixed for later electron-microscopical preparations or molecular studies.

## 7.2 Plankton samples

For the analysis of molecular diversity of protists in surface waters, water samples from the station GeoB 17004 and GeoB 17011 were filtered and preserved (see above) for later studies at the laboratory of UzK. In addition, water samples from surface and bottom waters were collected and investigated regarding the structure of cultivable protist communities and to isolate unknown species of protists. The procedures followed the protocol of benthic samples (see above). 10  $\mu\text{m}$  net samples were used to enrich potentially occurring acanthoecid choanoflagellates. Subsamples were cultivated; another part was fixed and filtered for later electron-microscopic studies.

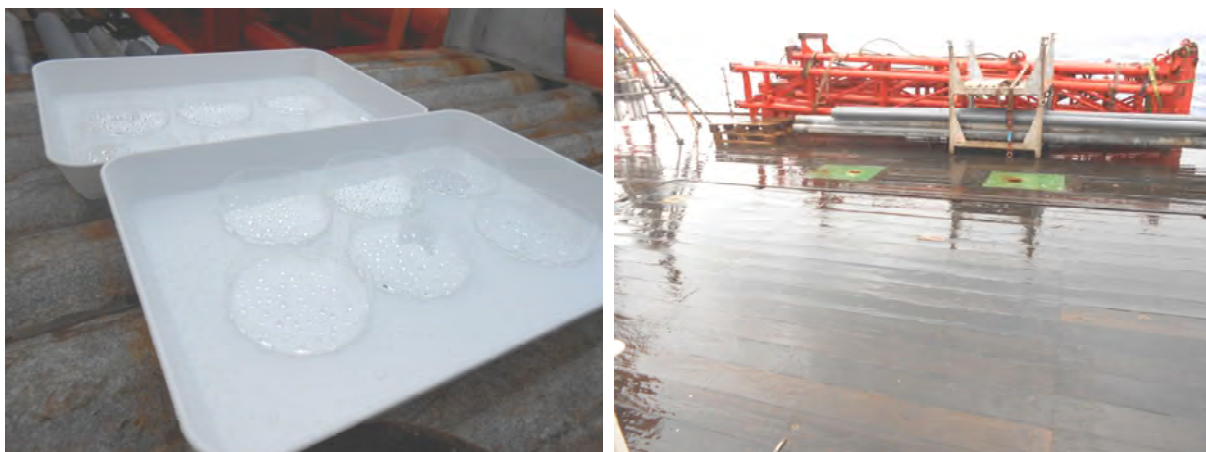


**Fig. 7.1** Collection and preparation of samples from overlaying water and sediment surface of Multi-Core samples for the analysis of deep-sea nanofauna

## 8 Collection and Cultivation of Rainwater

(Arndt, Nitsche, Schoenle)

Rainwater was collected at four dates in the tropical West Pacific. Sterile Petri dishes were exposed in the rain until 10-15 ml per dish was collected. Organic substrate was added and subcultures were transferred to marine and freshwater medium and analyzed every 3 days under an inverted microscope.



**Fig. 8.1** Rainwater collection of protozoan cysts to analyze aeroplankton.

## 9 Experiments on Pressure Tolerance of Deep-sea Protists

(Arndt, Nitsche, Schoenle)

Experiments were carried out onboard to investigate survival and reproduction of nanofauna exposed to various hydrostatic pressures. A pressure generating system was established based on a pneumo-hydraulic pressure intensifier with a transfer of 1:400 atm (Fig. 9.1). Three different pressures were established 150bar, 300 bars and 500 bars. Incubations included either a) deep-sea sediment (GeoB 17004-2) exposed immediately after sampling or b) deep-sea nanofauna cultures isolated during the cruise. Isolates were pre-cultivated in 50 ml tissue culture flasks. Experiments were run for 7 or 4 days at 7°C. Aliquots of sediments or cultures were filled into 200  $\mu$ l PCR tubes. Either 6 or 5 replicates were exposed to the different pressures. Control samples were exposed at the same temperature at 1bar. Several 5-10  $\mu$ l subsamples of each tube were counted under a light microscope and the beginning and at the end of experiments.



**Fig. 9.1** Pressure generating system to expose deep-sea nanofauna at different hydrostatic pressure.

## 10 Sunphotometer Microtops II

(Marschall)

With the handheld sun photometer Microtops II, the direct solar radiation of five different wavelengths was measured (440, 500, 675, 870 and 936 nm). With the data and the exact height of the sun, the aerosol optical depth (AOD) can be calculated.

A handheld GPS is connected to the Microtops II for simultaneous logging of location and time of the measurements. Absolutely clear blue sky in the direction of the sun is needed for the measurements. The photometer has to be orientated towards the sun and the radiation is scanned six to ten times in succession. This series builds one measurement.

The measurements took place on all sunny days when the sun stood at least 15 degrees above the horizon and if possible the measurements were taken every 15 minutes. Measuring days were September 11, 12, 13, 17, 19, 22, 23, 26, 29 and 30 and October 1, 2, 3.

All data was sent to the Maritime Aerosol Network (MAN).



**Fig.10.1** Sun photometer and GPS

## 11 Optical Disdrometer

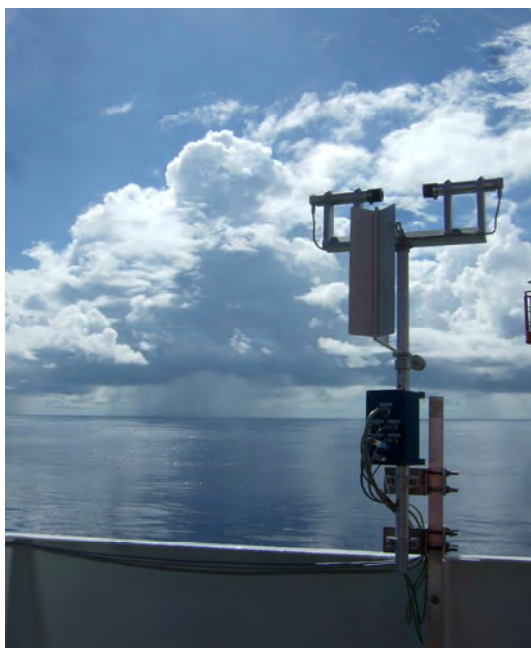
(Marschall)

The optical disdrometer from Eigenbrodt is an electronic instrument for measuring precipitation. An infrared diode illuminates the measurement cylinder. The receiver on the opposite side measures the incoming signal as voltage. With a drop in the measurement cylinder the voltage decreases, and with the difference between the reference voltage and the measured voltage the area of the cross-section of the drop is calculated.

Wind speed is measured with an anemometer and used to calculate the air-volume that streams through the measurement cylinder per unit of time. This information is required for the calculation of the quantity of precipitation.

The measured data was saved on a computer and will be processed in Germany.

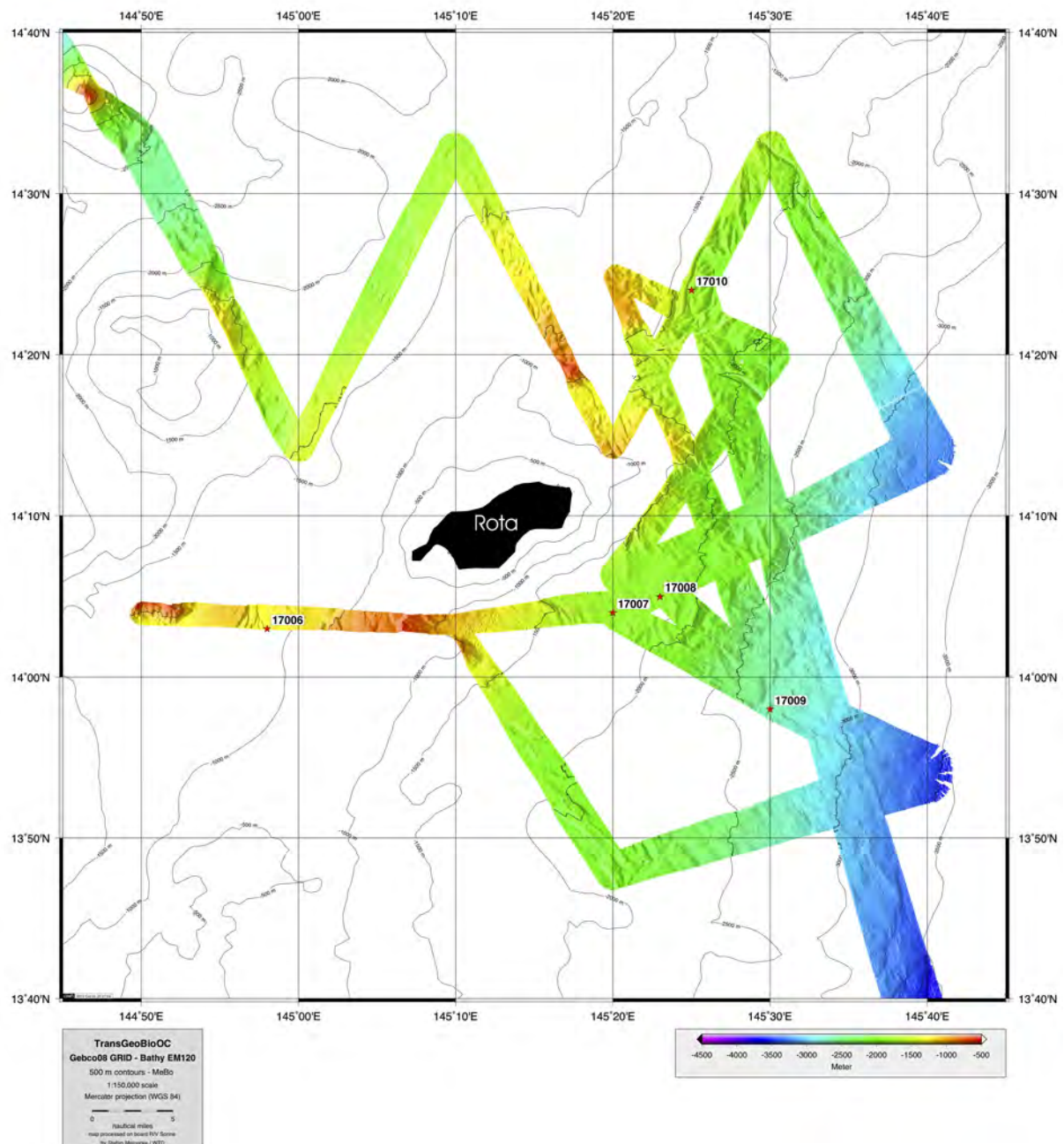
The disdrometer was installed on deck in a standby mode and turned itself on automatically when precipitation occurred and recorded all rain events during the SO-223T cruise.



**Fig.11.1** Optical disdrometer, anemometer and rain sensor installed on deck.

## 12 Shipboard Results

### 12.1 Site survey



**Fig. 12.1** Bathymetry map around Rota Island.

Figure 12.1 shows the stack of the site surveys around Rota Island between 14°40' N and 13°40' N, and 144°50' E and 145°50' E, thereby covering a depth range of approx. 550 to 3500 m. The bathymetry map together with Parasound records along different profiles show a more undulating morphology of the seafloor. Particularly the area north off Rota Island is characterized by the outcrop of steep, high amplitude, and reflection-free seafloor. The irregular rough surface with pinnacles of variable height from few to tens of meters indicated non-deposition or erosion of sediments in this area. In order to access undisturbed sediments at the highest sedimentation rate, GeoB sites 17006 to 17010 were selected from southwestern (GeoB 17006), southeastern (GeoB 17007-09), and northeastern (GeoB



17010) slopes. Parasound profiles indicated an upper well-stratified sedimentation environment around and at these sites (Figs. 12.2 – 12.4), with a signal penetration of up to 40 mbsf for the 4 kHz signal based on a sound velocity of 1500 m/s.

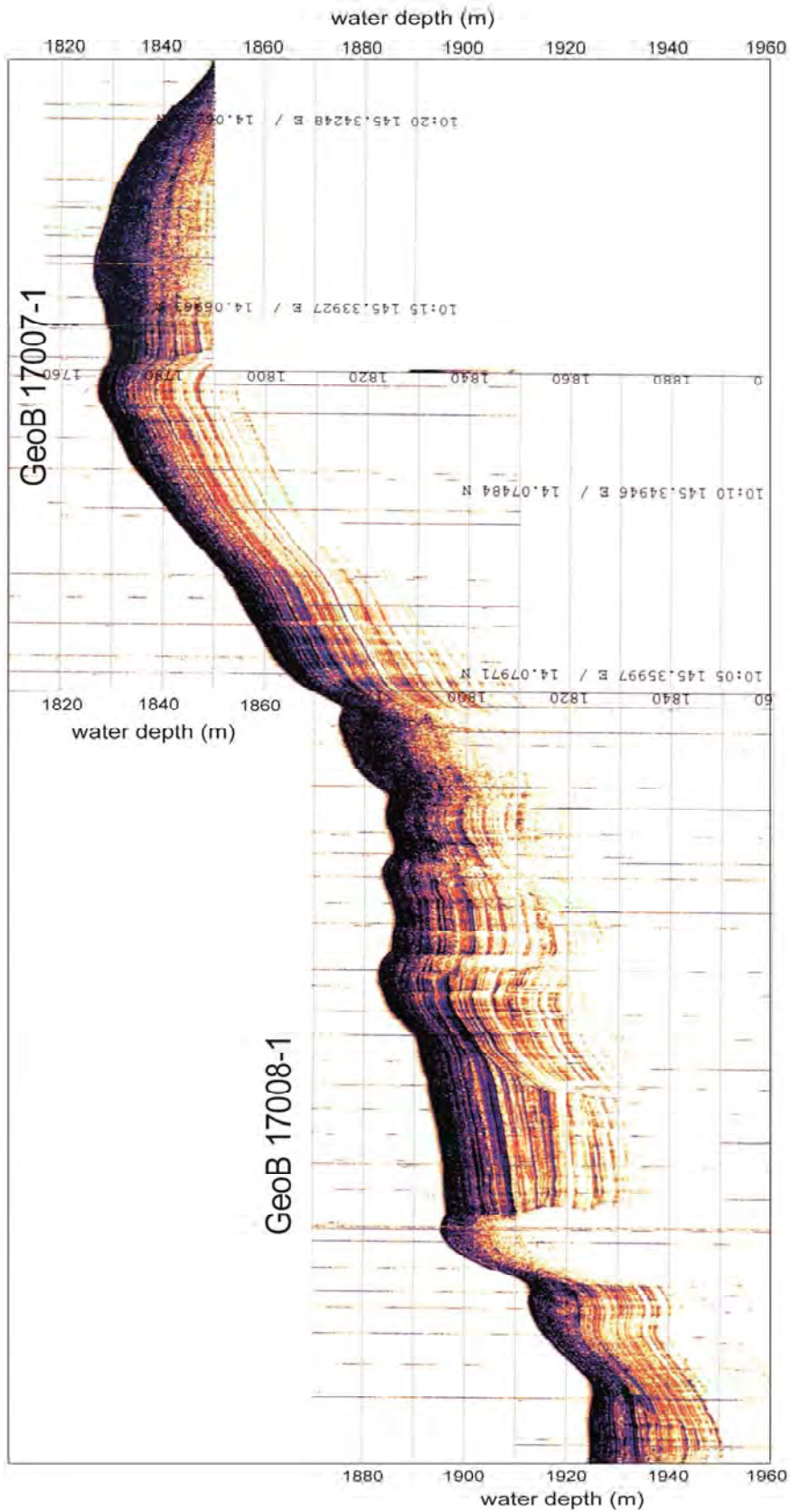
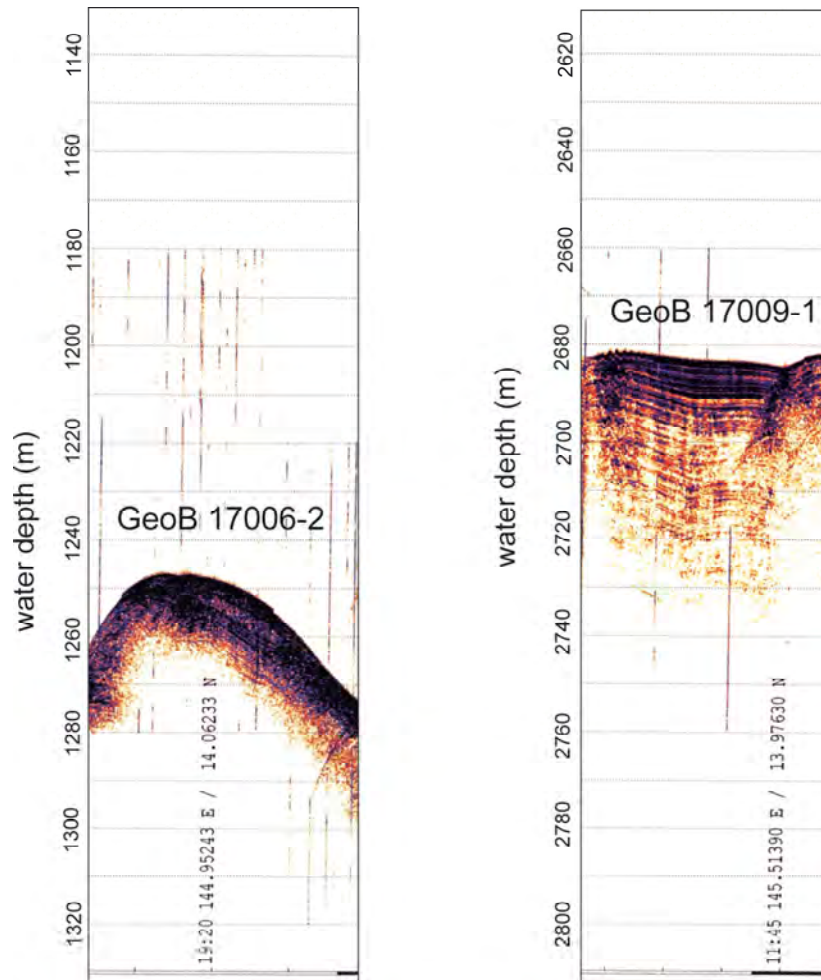


Fig. 12.2 Parasound record showing the GeoB sites 17007-1 and 17008-1 (over approx. 9 km).

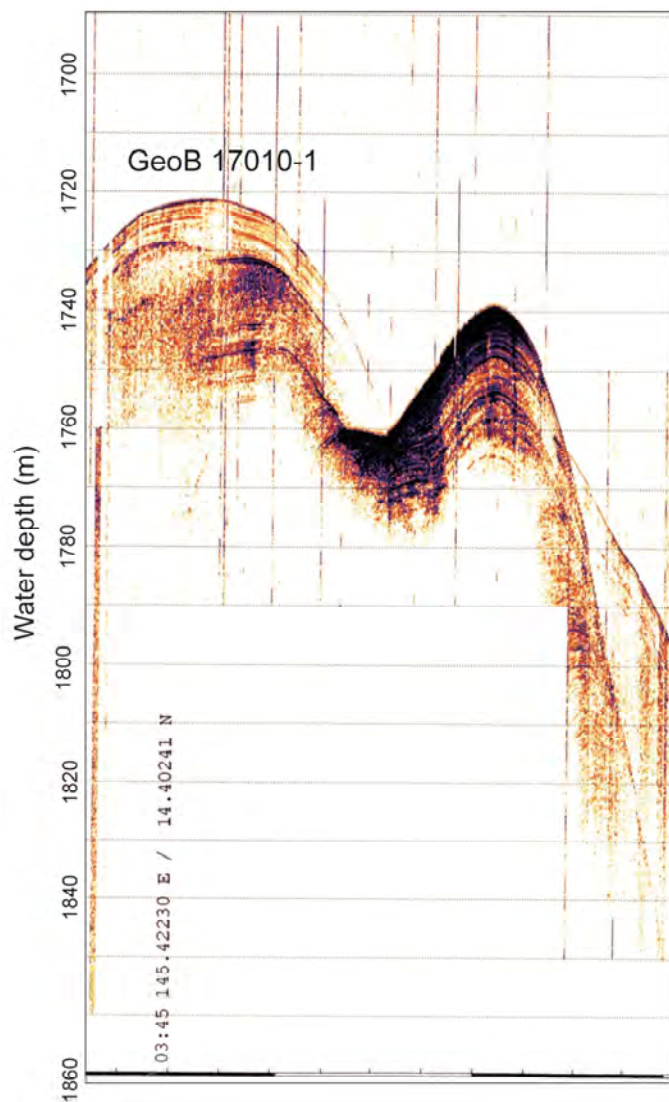


**Fig. 12.3** Parasound record showing the GeoB sites 17006-2 and 17009-1 (over approx. 1.5 km).

The acoustic survey of the near surface sediments at all these stations showed a succession of finely laminated sediments onlap the acoustic basement. However, except for GeoB 17010, the near surface sediments were characterized by rather strong reflectors that turned out to consist of sandy constituents, mainly of planktic foraminifera and volcanic glass. Still, the sediment composition at GeoB site 17010 was nearly identical to the other sites thus indicating either very low sedimentation rates around Rota Island or, rather unlikely, sediment removal over 3000 m of water depth. To this end, we interpret the sedimentary setting in this area being controlled by various factors, among others negligible terrigenous input from the surrounding small Northern Marianna Islands (including Rota), low marine production and hence, low marine snow, and a steep morphology that facilitates the downslope transport of non-consolidated sediments into the trench.

South of the Marianna Trench between 12°55' N and 12°15' N, and 145°45' E and 146°15' E, sediment and bathymetric surveys showed a very steep seafloor ranging between 4500 and 10,300 m (Fig. 12.5). Wherever possible, Parasound records showed a rugged and almost sediment-free basement, again indicating either a non-deposition environment or a complete removal of the sediment cover towards abyssal depths.

Parasound and bathymetric surveys of the other two study areas north of the Okinawa Trench (not shown) and on the Fiji Plateau (Fig. 12.6) revealed nearly identical characteristics of a rugged and undulated seafloor. However, a less steep morphology compared to those around Rota Island and the Southern Marianna Trench allows here for lateral variations in depot centers besides sections of non-deposition or erosion.



**Fig. 12.4** Parasound record showing the GeoB site 17010-1 (over approx. 3 km).

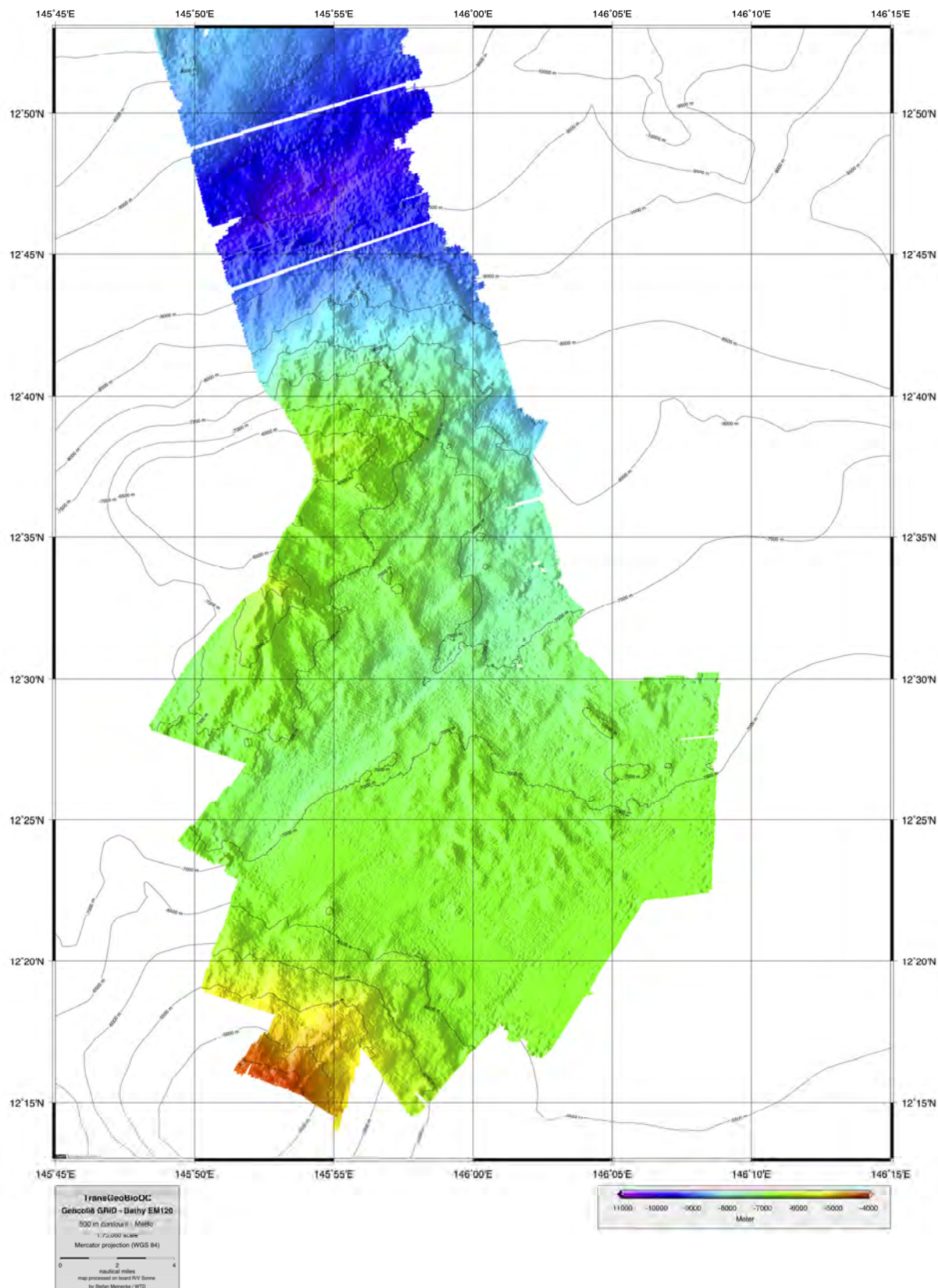


Fig. 12.5 Bathymetry map of the southern Marianna Trench.

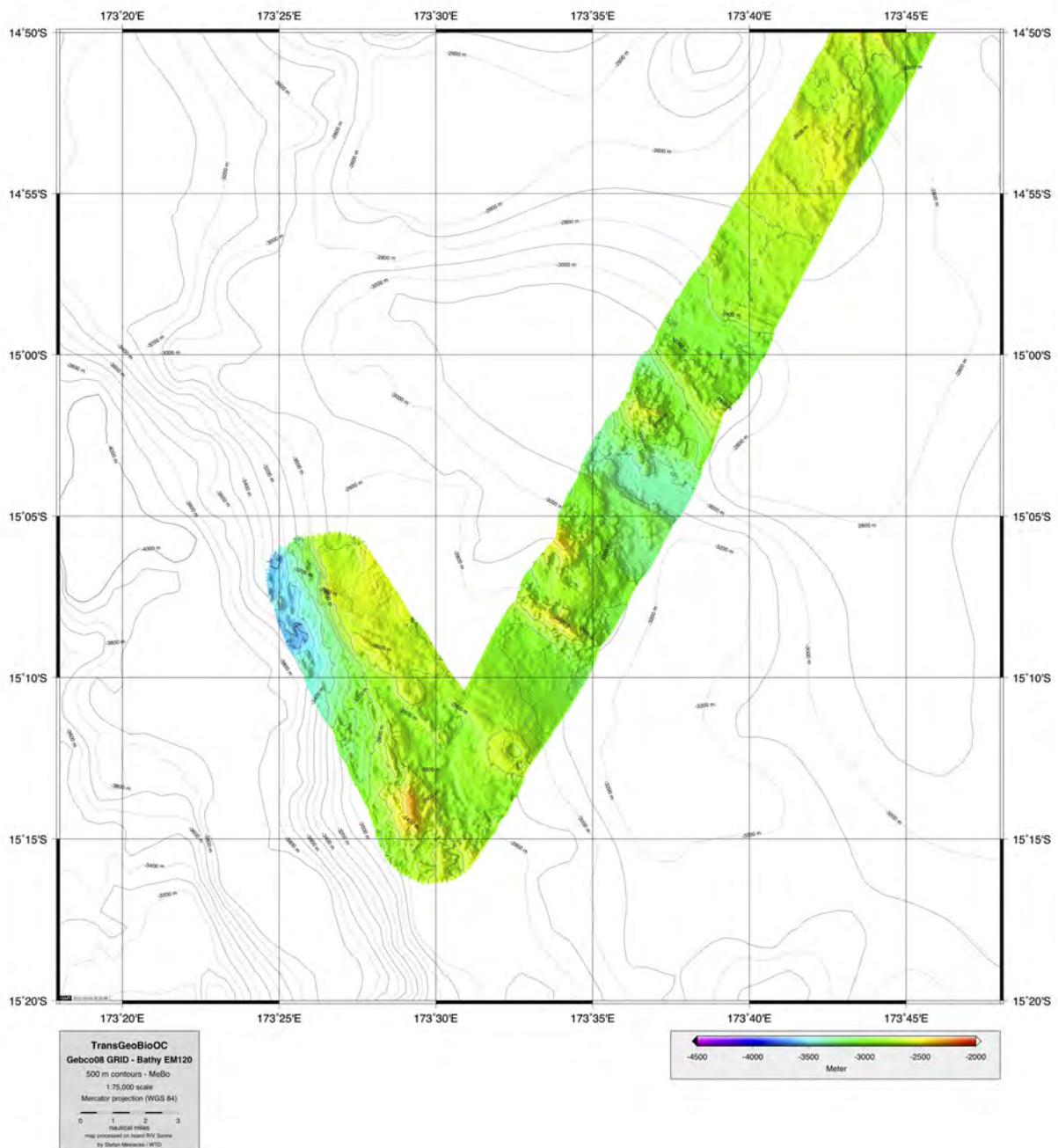


Fig. 12.6 Bathymetry map of the Fiji Plateau.

## 12.2 Sediments

### Station GeoB 17004-2

The Multi-Corer consisted of ~0.06-0.43 m dark reddish brown (5YR3/3) homogenous clay with no planktonic and benthic foraminifera. Diatoms and radiolarians are abundant.

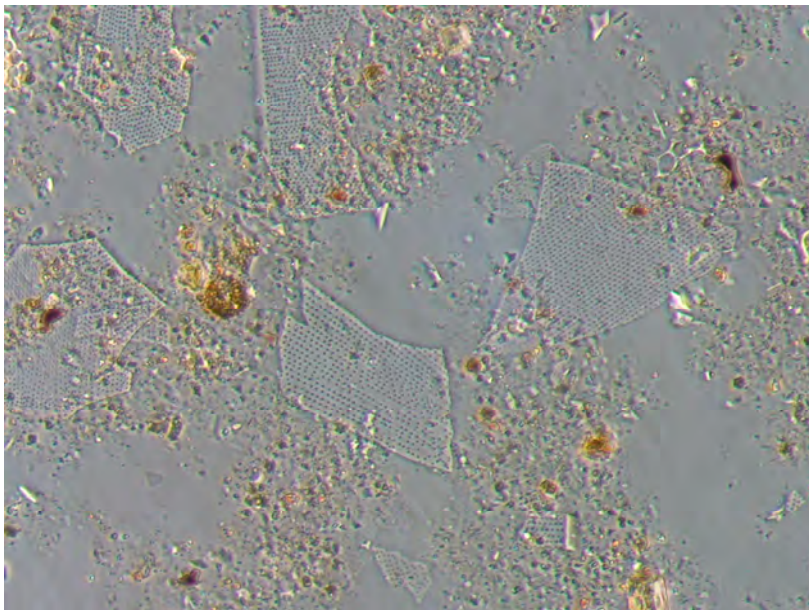
### Stations GeoB 17006-2, 17007-1, 17008-1, 17009-1

The sediment recovered near the Island of Rota is a light yellowish brown (10YR6/4) foraminiferal ooze. The recovery varied between ~0.07-0.19 m. The planktonic foraminiferal assemblage mainly consists of *G. ruber*, *G. sacculifer*, *G. menardii*, *G. conglobatus*, *O.*

*univera*, *G. siphonifera* and *S. dehiscens*. Benthic foraminifera are abundant. Glass shards showing a range of shape from vesicular pumice to glass fragments containing abundant pipe vesicles are very common. Multi-Corers GeoB 17006-1 and GeoB 17010-1 were empty. Due to the composition of the sediments around the Island of Rota, no gravity corers were deployed.

#### Station GeoB 17012-1

At station GeoB 17012-1, only 0.02 m sediment was recovered. The sediment collected at this station is a dark reddish brown (5YR3/3) homogenous diatom-bearing mud with a minor sand content. The sand-sized fraction is composed of manganese nodules. Dark reddish brown clayey clasts have been found at the sediment surface.



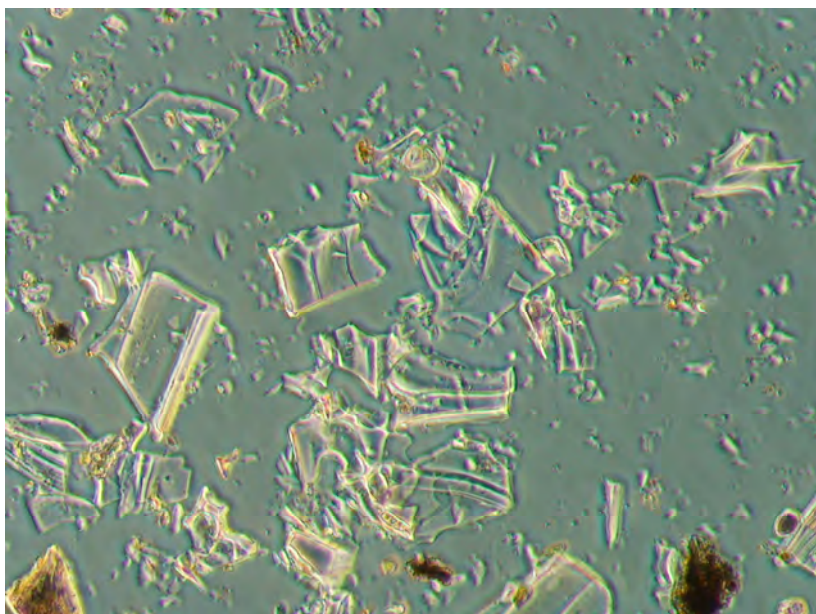
**Fig. 12.7** Diatom-bearing mud recovered at station GeoB 17012-1 (magnification 20)

#### Station GeoB 17013-1

The Multi-Corer (GeoB 17013-1) deployed at this station consisted of ~0.05 m dark reddish brown (5YR3/3) homogenous diatom-bearing mud with numerous manganese crusts and nodules (up to 2 cm in diameter). Other abundant microfossils are radiolarians.

#### Station GeoB 17019-2

At station GeoB 17019-1, 0.32 m sediment was recovered. The upper 0-0.04 m of Multi-Corer (GeoB 17019-1) is a dark brown (7.5YR3/3) foram-nannofossil bearing volcanic ash (0-0.04 m). Below the ash-layer, (0.04-0.32 m), the sediment is a strong brown (7.5YR5/6) foram-diatom bearing nannofossil ooze.



**Fig. 12.8** Foram-nannofossil bearing volcanic ash recovered at station GeoB 17019-2 (magnification 20).

### 12.3 Counting, isolation and cultivation of protists

As a preliminary result, the following genera of cultivable heterotrophic flagellate taxa have been recorded from the North-West Pacific deep-sea basins ( $\geq 5,000$  m depth): *Ancyromonas*, *Bodo*, *Caecitellus*, *Cafeteria*, *Cercomonas*, *Neobodo*, *Percolomonas*, *Pseudobodo*, *Rhynchomonas*, *Salpingoeca* and *Spumella*. We found several species which have to be further studied in detail including some potentially new species. In addition, ciliates could be recorded from different depths.

Preliminary direct counts revealed 1-2 nanoprotists per  $\text{cm}^2$ . The qualitative and quantitative studies complemented to our earlier cultivation based studies of deep-sea sediments in the Southern Atlantic and Mediterranean. Abundance estimates were in the same range as those obtained from the South-Atlantic abyssal plains and they were significantly lower than estimates from Mediterranean deep-sea basins.

Preliminary results of our study may be summarized as follows: A) Abundances determined by direct counts were very low, though comparable with earlier studies of the ultra-oligotrophic Southern Atlantic deep-sea basins. B) Abundance estimates of cultivable species in the two Pacific deep-sea basins were relatively similar to those obtained for the deep-sea basins of the Southern Atlantic (Me 63/2, Me 79/1). C) Even among the cultivable protists new species were recorded indicating that we just begin to understand the nanofauna diversity of the deep sea. D) There seems to exist an enrichment of nanofauna on hard substrates compared to the surrounding soft bottom. The importance of these substrates (during the present cruise, substrates were of volcanic origin) has largely been ignored in the past. Hard substrates seem to form distinct habitats and seem to form some kind of “hot spots” of microbial life in the oligotrophic deep sea. This deserves much more detailed studies in the future. Previous studies showed that morphotypes of protist taxa which we also found during the present cruise consist of a large number of hidden genotypes. To test this hypothesis, clonal cultures of different nanoprotist species from the Pacific deep sea were established onboard and will be transported to Cologne to be characterized by molecular techniques.

In addition to life counts and liquid aliquot cultivation techniques, sediment samples were collected for subsequent molecular biological studies in Cologne (fixed with ethanol). Our aim is to establish a clone library of heterotrophic flagellates from the deep-sea sediments to analyze the genotype diversity independent from the cultivation approach in comparison to our records of cultivable nanoprotists and life counts from the deep sea. We expect new

genotypes that do not appear in surface waters and will probably never appear in cultures. The cultivated strains will serve as a valuable qualitative test for the established clone library. The combination of different methods offers a unique possibility to receive detailed information on nanofauna life in the abyssal plains of the Pacific. In addition, we exposed sediment subsamples to deep-sea pressure conditions immediately after sampling, to check whether specifically deep-sea adapted strains might grow under high pressure. The exposed sediment did not contain enough protists so that quantification of potential growth was not possible. However, we were able to investigate the influence of pressure on single isolates of nanofauna. We tested the effects of pressure incubations on the bicosoecids *Cafeteria*, and *Caecitellus* as well as on *Neobodo* and a small ciliate. Preliminary studies revealed a survival of some of the isolates from different depths up to a pressure of 550 bars.

The sample collected from rain water revealed cysts of marine as well as freshwater protists. The number of cysts was very high and ranged between 0.1 and 0.4 cysts per ml rainwater. The taxonomic diversity of organisms hatching from cysts was very. We observed bicosoecids, chrysoomonads, bodonids, cercozoans and other Rhizaria groups, vahlkampfiid amoebae and lobose amoebae, as well as ciliates.

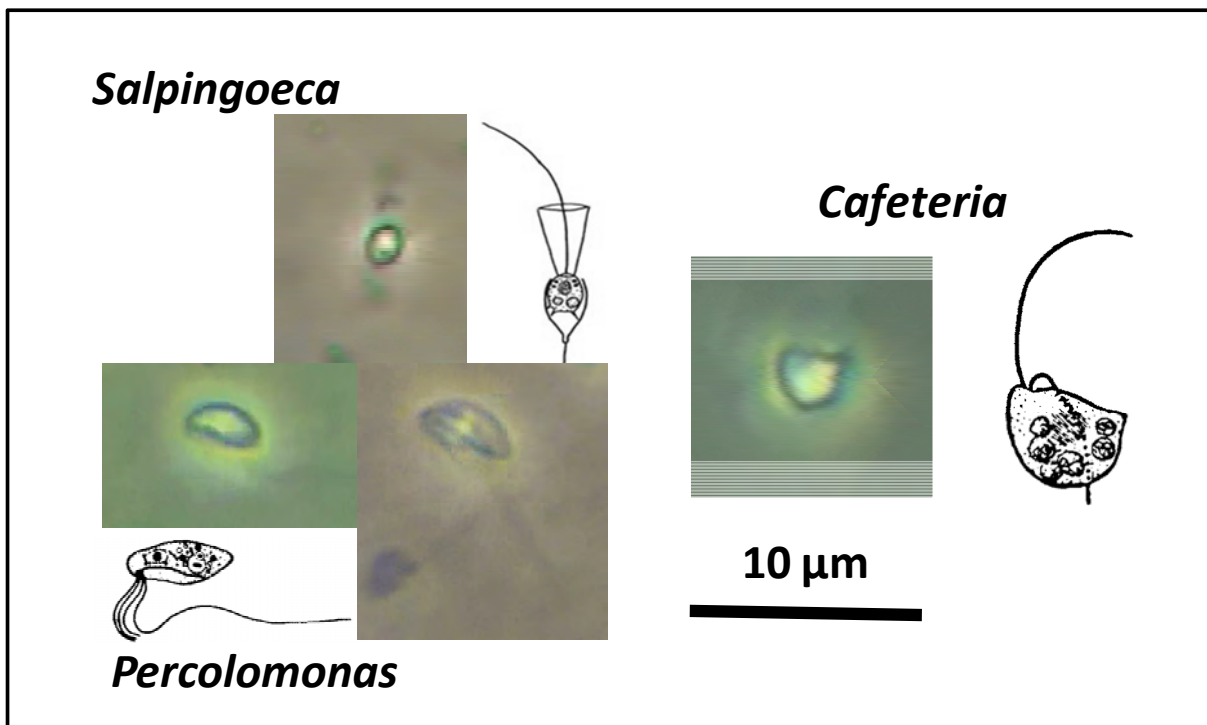
There seems to exist a worldwide exchange between nanoprotozoan populations that includes also deep-sea ecosystems. This feature of nanofauna seems to be extraordinary compared to other deep-sea animals and is connected with their small size, their ability to survive unpleasant conditions (e.g. scarcity of food) in cysts (diameter 2-8  $\mu\text{m}$ ) which can be distributed by water and air, and with their ability to grow as fast as bacteria, when food conditions are temporally or locally enriched (e.g. by sedimented organic debris). Our comparative study of clone libraries from the Atlantic and Pacific will help us to address ideas of global distribution patterns of deep-sea nanofauna.

Our recent molecular findings challenge the idea that abyssal sea floor biodiversity is lower than that of other marine environments (Scheckenbach et al. 2010, op. cit.). The high percentage of novel lineages with no close representatives in genetic databases pointed to unique and rich communities of microbial eukaryotes at the abyssal seafloor, with a potentially high percentage of parasites. According to our cultivations during this cruise, the abyssal seafloor seems to be a contiguous habitat for microbial eukaryotes at least on regional scales. Nevertheless, we found significant differences between different deep-sea basins of the Atlantic demonstrating that ecological parameters should be the decisive factors shaping microbial eukaryote distribution patterns and zonation on large spatial scales at abyssal depths. We have to wait for the result of our molecular studies in our home laboratory in Cologne to check whether this idea is supported by the deep-sea data from the present cruise in the Pacific. The abyssal seafloor may be a mosaic of semi-isolated habitats, shaped and maintained on larger scales by diverse environmental gradients. Investigating the diversity and distribution of natural microbial communities in this largest habitat on Earth's surface is critical to our understanding of global biogeochemical cycles.





**Fig. 12.9** Ciliates (probably scuticociliate) from a depth of 2500 m near Rota during the SO-223T cruise (upper left: cyst; others are trophonts; right: macronucleus stained).



**Fig. 12.10** Heterotrophic nanoflagellates of different genera isolated from depths of 1200, 2500 and 5400 m during the SO-223T cruise.

## 12.4 Hydrography

Water masses in the North and South Pacific can be distinguished by different physicochemical properties especially the salinity and oxygen contents (Figs. 12.11-12.13). At the northern end of our transect in the North Pacific, the upper water column (~200 m) shows salinities of ~34.5 psu and a higher oxygen content (4-4.5 ml/L) than the deeper layers. The intermediate water column in the North Pacific (400-1500 m) has a salinity and oxygen minimum layer (34.1-34.4 psu and 1.2-1.35 ml/L) that shoals towards the equator and carries the characteristics of North Pacific Intermediate Water (NPIW; Talley, 1993; You, 2003). At stations GeoB 17003 to GeoB 17005 in the North Pacific, a salinity minimum is located between 400 and 800 m water depth (Figs. 12.12, 12.13). It reaches its lowest value of 34 psu at stations GeoB 17004 and -5 and is shallowest at station GeoB 17005 (centered at 500 m).

All stations in the North Pacific except stations GeoB 17001 and -2 show an oxygen distribution with a minimum of 1-1.35 ml/L at mid-depth and an increase towards the deeper layers. The oxygen minimum is deepest at the northern stations GeoB 17003 to -5 (centered at 700 to 1000 m water depth) and shallowest at station GeoB 17015 (centered at 200 m water depth). It is absent from the equatorial and South Pacific profiles. The bottom water in the South Pacific is enriched in oxygen relative to overlying deep water and the bottom water in the North Pacific. It reaches highest concentrations of 3.64 ml/L at station GeoB 17011 at 5574 m water depth. The upper boundary of the high-oxygen bottom water shoals from 4000 m at station GeoB 17011 to 3500 m at station GeoB 17018. This high oxygen content as well as the temperature-salinity-density characteristics of this bottom water (Fig. 12.14) are characteristic of Antarctic Bottom Water (AABW) that is formed in the Southern Ocean and transported northward into the Pacific.

The South Pacific stations GeoB 17017 and -18 show a small increase in oxygen concentrations and a decrease in salinity at intermediate water depth (700-900 m). At the southernmost station GeoB 17019 (15°S), the oxygen maximum and salinity minimum at mid-depth become clear features with values of 3.98 ml/L and 34.38 psu, respectively. These properties are characteristic of Antarctic Intermediate Water (AAIW) that is formed in the Southern Ocean and transported within the subtropical South Pacific gyre northward and northwestward into the study area (Reid, 1997).

The equatorial water column is marked in the upper ~200 m by strong salinity variations (Fig. 12.15). A strong salinity maximum of up to 35.9 psu extends from 80 m to ~200 m water depth and marks the depth location of the eastward flowing Equatorial Undercurrent (EUC) that is supplied to a large extent by the New Guinea Coastal Undercurrent (e.g., Tsuchiya et al., 1989).

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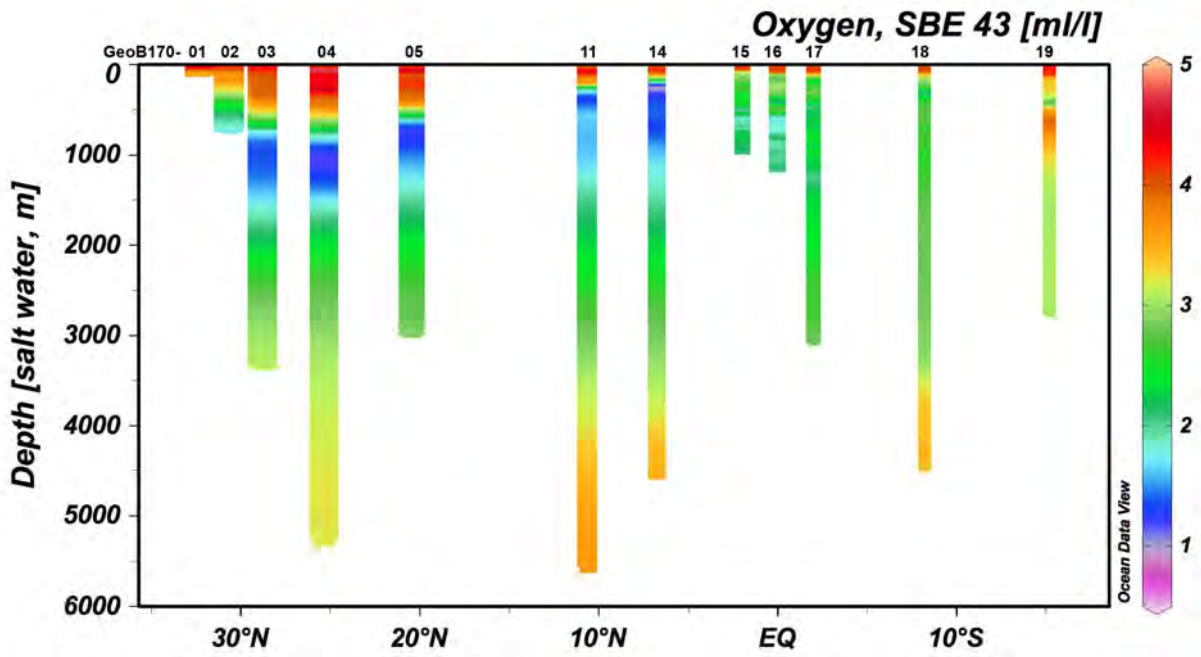


Fig. 12.11 Oxygen concentrations along the cruise track of cruise SO-223T.

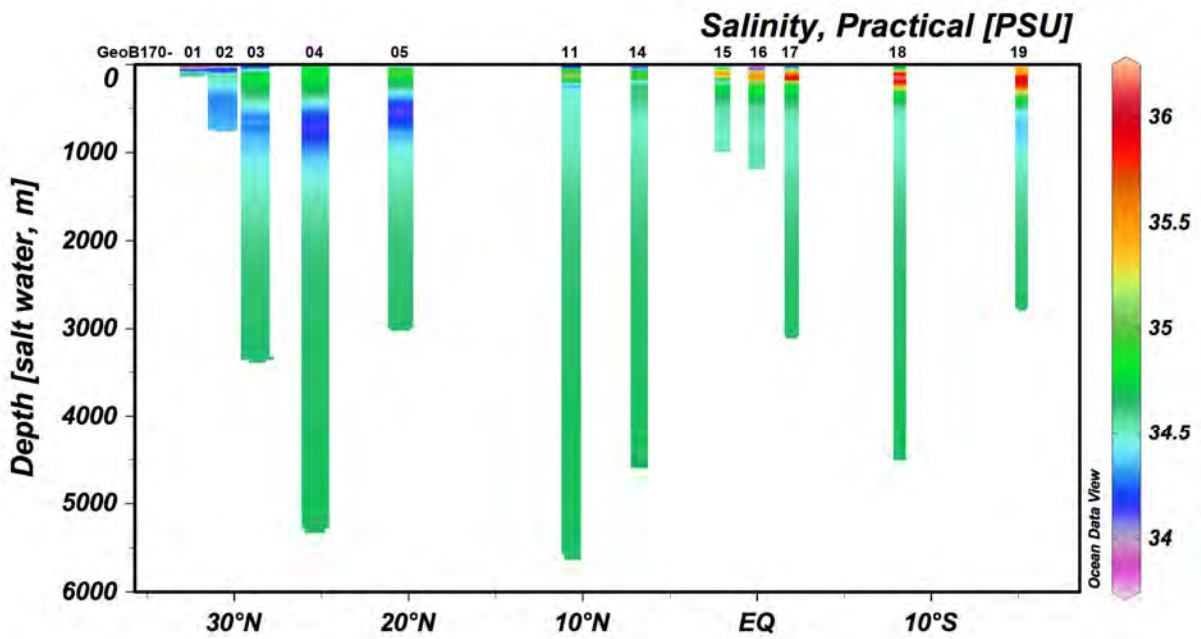


Fig. 12.12 Salinity along the cruise track of cruise SO-223T.

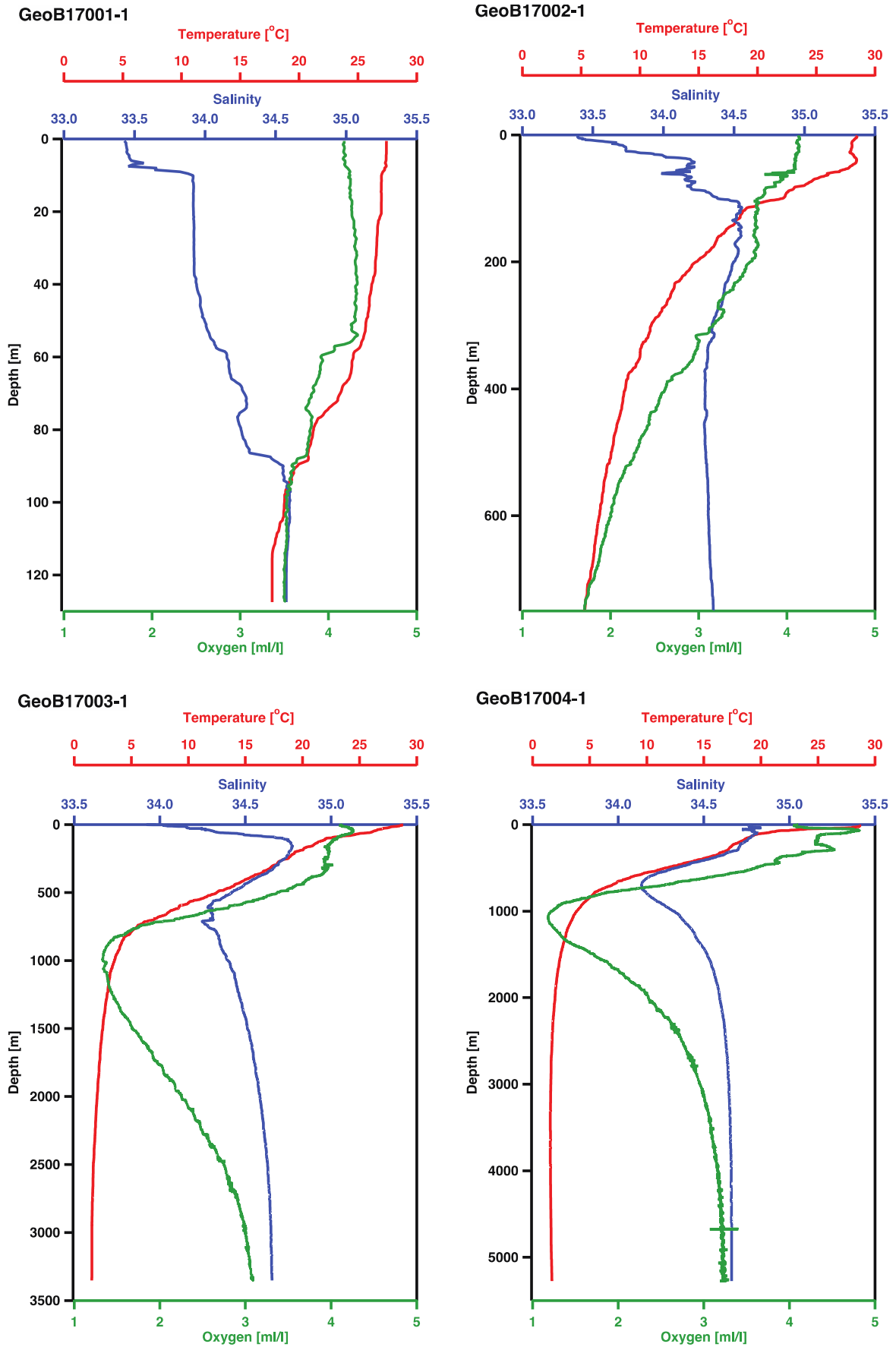


Fig. 12.13 Temperature, salinity, oxygen profiles of CTD stations of cruise SO-223T.

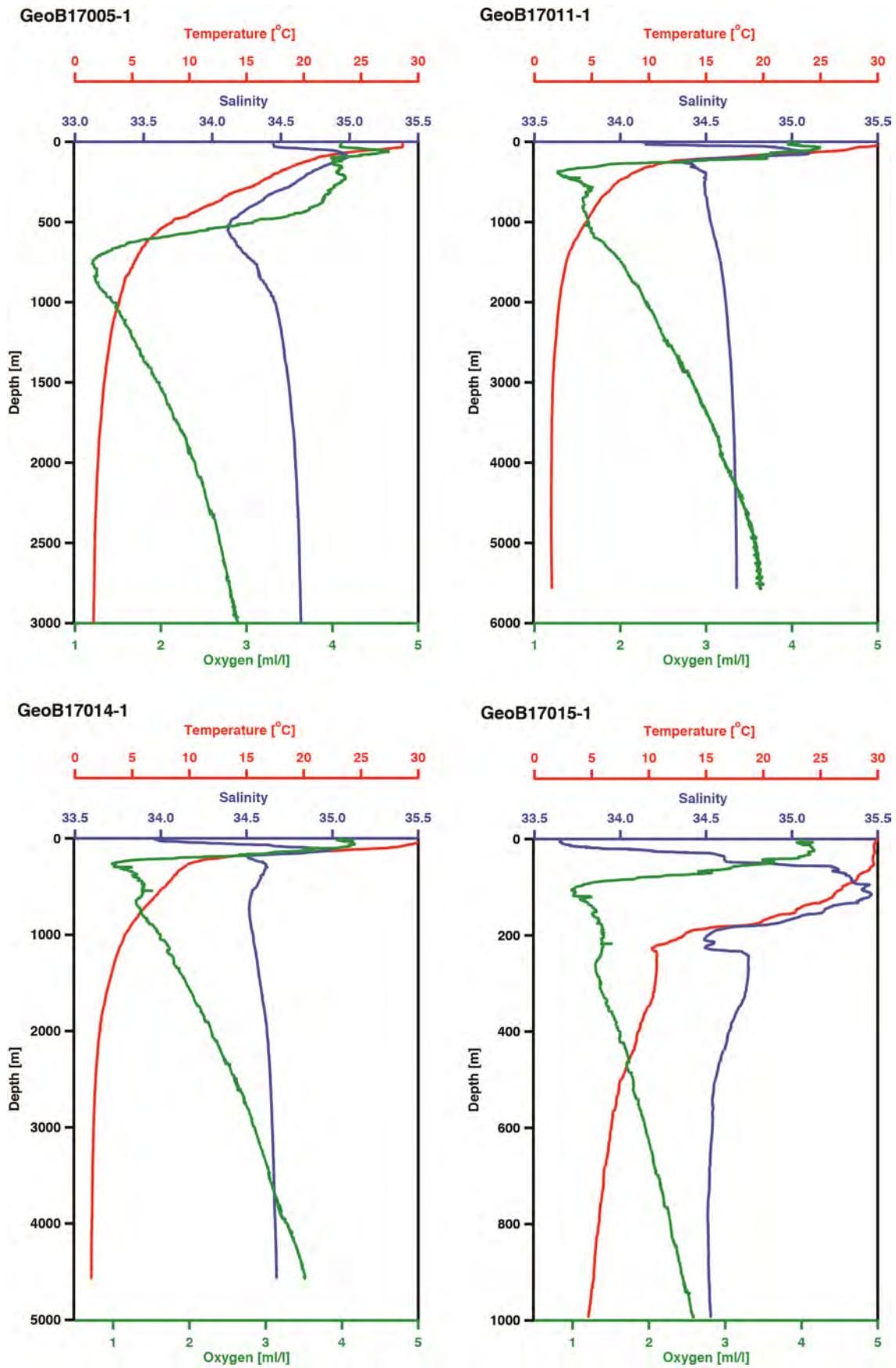


Fig. 12.13 (continued)

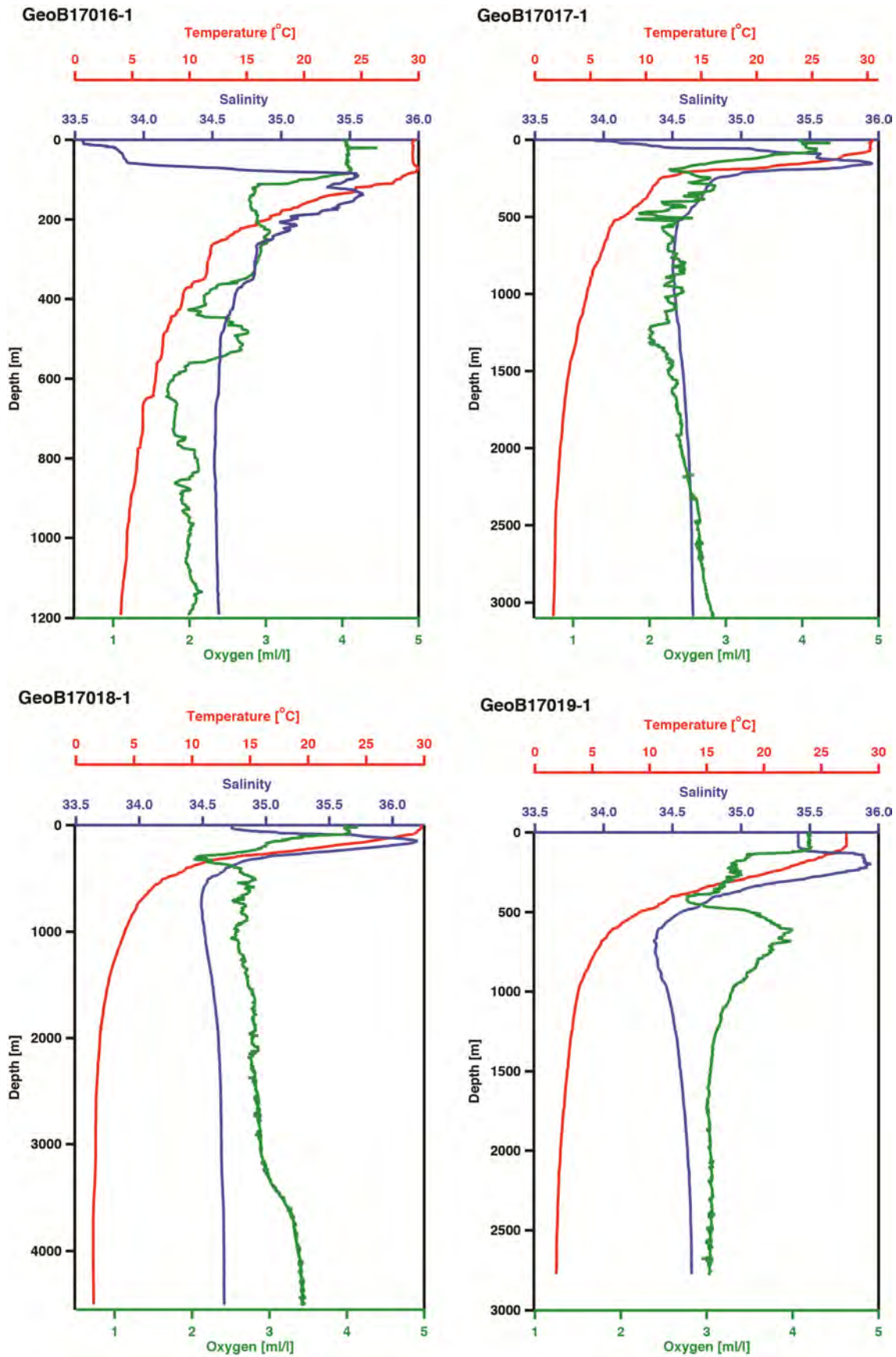
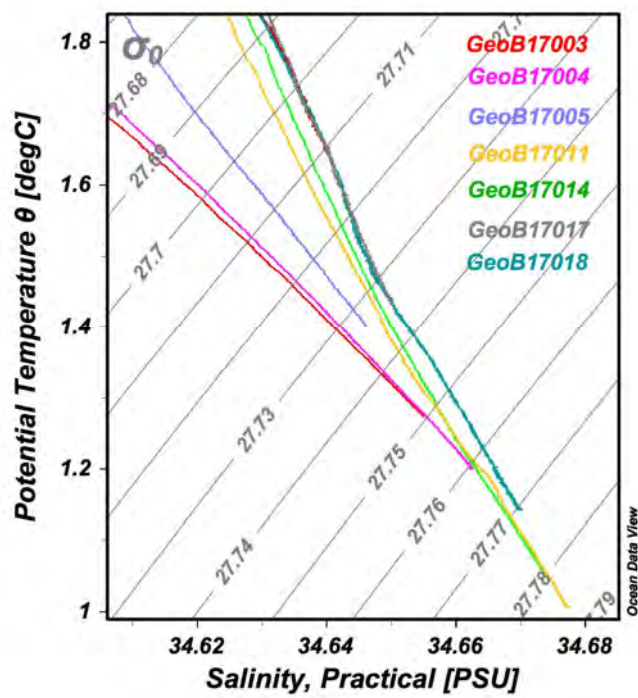
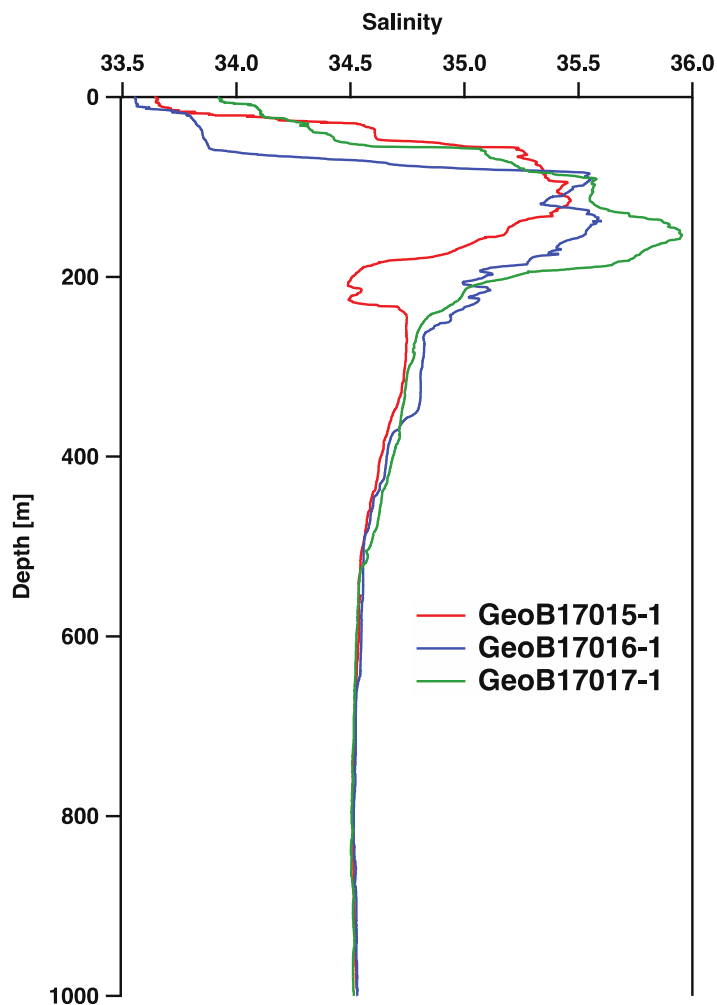


Fig. 12.13 (continued)

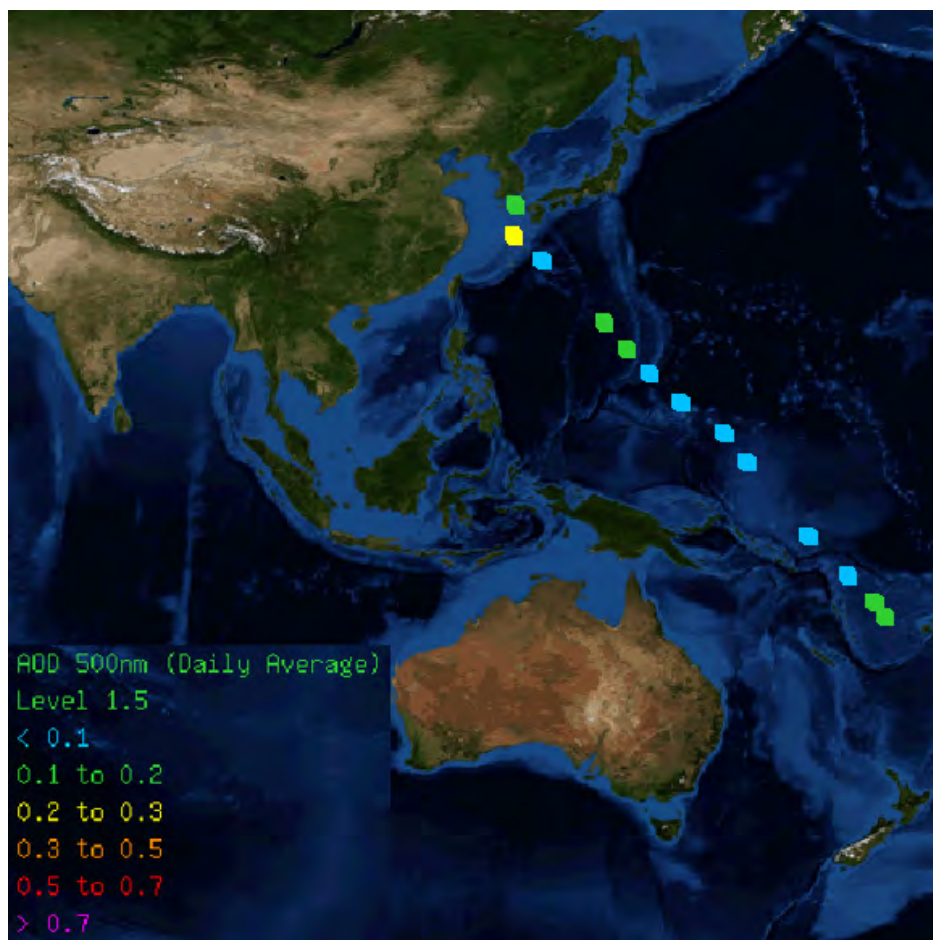


**Fig. 12.14** Temperature-salinity diagram showing deep and bottom waters along the cruise track of cruise SO-223T. Stations GeoB 17011, -14, and -18 reach the densest water with  $\sigma_0 > 27.76$ , that coincide with high oxygen concentrations of  $\geq 3.44$  ml/L (see Fig. 12.3).



**Fig. 12.15** Salinity profiles (psu) near the equator at GeoB 17015 ( $2^\circ\text{N}$ ), GeoB 17016 ( $0^\circ$ ) and GeoB 17017 ( $2^\circ\text{S}$ ).

## 12.5 Aerosol optical depth of 500 nm



**Fig. 12.16** Daily averages of the Aerosol optical depth (AOD) of 500 nm wavelength during the SO-223T cruise



## 13 Station List SO-223T

**CTD** CTD and rosette water sampler

**MUC** Multi-Corer

Station (GeoB)	Gear	Date	UTC	Latitude	Longitude	Water depth (m)	Instrument depth (m)	Remarks
17001-1	CTD	11.09.2012	16:17	32°19,992'N	127°29,975'E	129	129	
17002-1	CTD	12.09.2012	04:16	30°35,006'N	128°59,990'E	749	748,6	
17003-1	CTD	12.09.2012	18:50	28°42,980'N	131°05,040'E	3357	3350	
17004-1	CTD	13.09.2012	21:06	25°22,700'N	134°22,514'E	5339	5276	
17004-2	MUC	14.09.2012	03:00	25°22,700'N	134°22,519'E	5339	bottom	10/10
17005-1	CTD	15.09.2012	22:54	20°26,004'N	139°36,977'E	6315	3000	
17006-1	MUC	18.09.2012	22:28	14°03,717'N	144°58,779'E	1253	bottom	not released
17006-2	MUC	18.09.2012	23:55	14°03,699'N	144°03,699'E	1259	bottom	10/10
17007-1	MUC	19.09.2012	03:54	14°04,320'N	145°20,592'E	1829	bottom	8/10
17008-1	MUC	19.09.2012	06:10	14°05,613'N	145°23,191'E	1895	bottom	5/10
17009-1	MUC	19.09.2012	09:21	13°58,640'N	145°30,719'E	2687	bottom	9/10
17010-1	MUC	19.09.2012	22:38	14°24,252'N	145°25,420'E	1745	bottom	0/10
17011-1	CTD	21.09.2012	20:20	10°37,800'N	148°53,998'E	5667	5574	
17012-1	MUC	23.09.2012	00:29	10°37,799'N	148°37,800'E	5719	bottom	7/10
17013-1	MUC	23.09.2012	06:12	10°34,313'N	148°49,032'E	5497	bottom	6/10
17014-1	CTD	24.09.2012	22:29	6°47,032'N	154°11,979'E	4583	4573	
17015-1	CTD	26.09.2012	09:52	2°00,214'N	157°59,877'E	2695	893	
17016-1	CTD	27.09.2012	01:35	0°0,002'N	160°0,001'E	2837	1003	
17017-1	CTD	27.09.2012	19:20	2°0,018'S	162°0,042'E	3162	3082	
17018-1	CTD	29.09.2012	19:02	8°11,927'S	166°5,016'E	4623	4500	
17019-1	CTD	02.10.2012	21:25	15°13,021'S	173°31,125'E	2784	2772	
17019-2	MUC	03.10.2012	00:12	15°13,023'S	173°31,129'E	2776	bottom	7/10

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