

Cruise Report

RV SONNE Cruise SO219A

Tohoku-Oki Earthquake – Japan Trench

Yokohama-Yokohama
08.03.2012 -06.04.2012

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1. Participants

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Franke, Philipp	ROV	MARUM
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Leg SONNE 219A-2, Yokohama - Yokohama, 24.03.2012 – 06.04.2012

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Kölling, Martin, Dr.	Geochemistry	MARUM
Mai, Hoang Anh	Coring	MARUM

Meyer, Philip	Lab	MARUM
Podszun, Lina	Multibeam	MARUM
Römer, Miriam, Dr.	Multibeam	MARUM
Strasser, Michael, Prof. Dr.	Sedimentology	ETH
Wefer, Gerold, Prof. Dr.	Chief Scientist	MARUM

AIST	National Institute of Advanced Industrial Science and Technology, Japan
AORI	Atmosphere and Ocean Research Institute, University of Tokyo, Japan
ETH	ETH Zürich, Switzerland
Fukada	Fukada Geological Institute, Tokyo, Japan
JAMSTEC	Japan Agency for Marine-Earth Science and Technology, Japan
Kyoto	Kyoto University, Japan
MARUM	Center for Marine Environmental Sciences, University of Bremen, Germany
Tohoku	Tohoku University, Sendai, Japan

2. Research Program

(M. Strasser, G. Wefer)

The 2011 Tohoku-oki earthquake, occurred at 14:46, March 11th JST (05:45 UTC) off the northeastern coast of the Japanese main island. The earthquake, which was determined to be 9.0 on the magnitude scale, with the epicenter located ~70 km east off the Oshika Peninsula of Tohoku and the hypocenter at an underwater depth of ~ 32 km (Japan Meteorological Agency, 2011), was of the largest scale through history. The earthquake is of thrust type, and it released the accumulated strain energy due to subduction of the Pacific plate beneath northeastern Japan (e.g. Sato et al., 2011; Simons et al., 2011). The focal region inferred from the distribution of aftershocks stretches about 500 km long and 200 km wide (Japan Meteorological Agency, 2011). Long-duration ground shaking and in particular large tsunami waves as high as 38.9 m hit a wide range along the northeastern coast of Honshu. More than 15,000 people were killed and more than 4,000 still missing (as of September 30, IOC/UNESCO Bulletin No 29; 2011).

Along-fault slip distribution has been studied by worldwide researchers using different types of data such as (i) seismic waveforms observed by both worldwide and domestic seismic networks (e.g. Chu et al., 2011; Ide et al., 2011; Yoshida et al., 2011), (ii) crustal deformation measures by the GPS (e.g. Iinuma et al., 2011; Ito et al., 2011; Sato et al., 2011), (iii) and tsunami waveforms (Fujii et al., 2011; Maeda et al., 2011) or (iv) combination of above-mentioned approaches (e.g. Lay et al., 2011a, b; Yokota et al., 2011). In fact, this earthquake is quite distinctive in that various co-seismic marine geophysical observations were made for the first time in human's history. Two ocean-bottom tsunami gauges ~40 and ~70 km offshore continued sending real time data of the wave height through the cable until the tsunami washed away the onshore base observatory after its arrival to the coast (Maeda et al., 2011). The source model derived from these offshore tsunami records indicates that a very large slip of up to 58 m occurred off Miyagi (i.e. around 38° to 39° N) and very near the trench (Maeda et al., 2011). Significant co-seismic slip in a confined area near the trench region is further supported by seismic-wave form inversion (e.g. ~ 30 m slip near the trench estimated by Ide et al. (2011) and ~42 m slip estimated by Lay et al. (2011b), and tsunami wave form inversion from coastal tide gauges, seafloor geodesy and ocean bottom pressure measurements (> 40 m slip estimated by Fujii et al. (2011)). Large displacements of more than 20 m near the trench can also be seen in seafloor geodetic observations (Ito et al., 2011; Sato et al., 2011).

First reflection seismic and bathymetric data obtained from rapid-response research cruise KR11-05 (R/V KAIREI) which can be compared to datasets recorded in 1999, indeed confirm significant seafloor displacement and bathymetric changes (Fujiwara et al., 2011). In fact, the toe moved about 50 m towards the southeast and about 7 m along the survey transect. Additionally a submarine landslide is imaged at the frontal prism slope resulting in a head-scarp and deposit on the trench floor ~ 50 m in height and thickness, respectively. New interpretation of comparison between multi-channel seismic data acquired before and after the earthquakes (Kodaira et al., subm), show that coseismic fault rupture reached the seafloor at the trench axis. The positive differential bathymetry in the trench – according to Kodaira et al. (subm) interpretation – can therefore also be explained as a compressional structure due to large co-seismic slip reaching the trench and deforming sediment in the trench. Prior to the 2011 Tohoku-oki earthquake, such large co-seismic slip at the toe had never been expected from available data sets and from commonly accepted

models. Seismicity has been recognized to be highly variable along-strike in the Japan Trench (Nishizawa et al., 1992; Hino et al., 1996; Tanioka et al., 1997; Matsuzawa et al., 2002). Silent, ultra-slow earthquakes, abundant microearthquakes and occasional large-magnitude events with moment magnitude (M_w) 7 to M_w 8 have been reported (Linde et al., 1988; Kawasaki et al., 1995; Heki et al., 1997; Yamanaka and Kikuchi, 2004). The Jogan earthquake of 13 July 869 may be the only documented event to have occurred with a possible magnitude and location similar to that of the 2011 earthquake (Minoura et al., 2001).

Intensive debate is now still ongoing about the nature and geologic implication of the 2011 Tohoku-oki earthquake, in particular also because the source inversion models differ in their details (see differences in estimated maximum slip mentioned above) and the causal mechanism for large shallow slip near the trench remains speculative. Hypothesis postulated so far include (i) the wedge protrusion model due co-seismic slip propagation along the plate-boundary fault all the way to the trench (Fujiwara et al., 2011; Lay et al., 2011a; Kodaira et al., *subm*), (ii) pop-up (uplift) of the other wedge, which is bounded landward by a prominent landward-dipping normal fault system (Tsuji et al., 2011), and (iii) tsunamigenesis by a combination of seafloor deformation due to both co-seismic slip along faults and gravitational collapses along the steep trench landward slopes (Kawamura et al., 2012).

However, a general agreement is shared among scientists that it is owing to the co-seismic seafloor observations that make possible unprecedentedly detailed analyses on earthquake source process and tsunamigenesis. The research cruise by RV Sonne is expected to make very important contribution to further accumulate morphological data and geological records with her state-of-the-art facilities that provide ROV operations, bathymetry mapping, sediment core sampling, and deployment and recovery of ocean-bottom instruments.

The major scientific objectives of this cruise are:

1. Inspection of Observatories with remotely operated vehicle (ROV)
2. Bathymetric mapping with shipboard mounted multibeam system (EM120) measurements of uppermost sediment structure (~50 m) using sub-bottom profiler (PARASOUND)
3. Highly accurate measurement of fault zones and seafloor inspection of a normal fault systems hypothesized to have co-seismically moved during the 2011 earthquake (Tsuji et al., 2011) using an remotely operated vehicle (ROV). Coring small basins overlying the hanging wall block of this landward-dipping normal fault system to document the fault history, and investigating seeps along such fault zone system.
4. Measurements of the deep-sea trench, including identification of slumps, using the multibeam echosounder installed on the ship and the sediment-penetrating Parasound echo-sounding system.
5. Core retrieval from the deep-sea trench in water depths greater than seven kilometers, at the collision zone between the Pacific and North American plates, to test the different hypothesis of large differential bathymetry anomalies (slumps vs. co-seismic rupture to the trench (Fujiwara et al., 2011; Kodaira et al., *subm*).

6. Core retrieval from basin along a transect ranging from shallow water depth (fore arc basin in ~1500 m water depth) to medium (normal fault ponds ~3500 m water depth) to the deep sea trench (~7500 m water depth) in order to investigate the sedimentary fingerprint of the 2011 earthquake and study the deeper sedimentary succession for paleoseismologic studies.
7. To provide the preliminary survey required before drilling by the Japanese drill ship CHIKYU at J-Fast site 3.

Tectonic and geological setting:

The 2011 Tohoku-Oki earthquake occurred on the megathrust where lower Cretaceous (~130 Ma) Pacific ocean crust underthrusts below Japan in a west-northwest direction along the Japan Trench at an average rate of about 8 to 8.5 cm/year (DeMets et al., 2010; Simons et al., 2011). The trench axis between ~ 41°N and ~ 38°N strikes approximately NNE and the general topographic features of the forearc-trench-input system consists (from west to east) of a deep-sea terrace, inner trench slope, midslope terrace, trench lower slope, Japan Trench, and outer trench slope (e.g. Sacks et al., 2000). South of ~ 38°N, the general strike of the trench is deflected more to a NE-SW orientation, which apparently coincides with a change in the morphology of the incoming plate's horst and graben structures and a chain of subducting seamounts, which enters the subduction system at about 36° N (Lallemand et al., 1989; Kobayashi et al., 1998; Tsuru et al., 2002).

Geological and geophysical features of the Japan Trench convergent margin have been studied since 1970s (e.g. von Huene et al., 1982; 1994; Lallemand et al., 1989; Suyehiro and Nishizawa, 1994; Tsuru et al., 2000; 2002; Miura et al., 2005), including Deep Sea Drilling Project (DSDP)/Ocean Drilling Program (ODP) drilling cruises in the area between 41°N and 39°N, during which a total of 10 sites were completed (Legs 56 and 57 (Scientific Party, 1980); Leg 87 (Kagami et al., 1986); Leg 186 (Sacks et al., 2000)). These studies revealed that the bulk of the forearc is composed of Cretaceous accreted strata (based on moderate P-wave velocity and landward-dipping reflectors; e.g. von Huene et al., 1994; Tsuru et al., 2002) discordantly overlain by thick forearc basin fills and thinner slope apron sediments. The forearc basin developed in the deep-sea terrace and trench upper slope, which extends from the northwest coast of Hokkaido more than 600 km to the south and is filled with sediments as much as 5 km thick (Sacks et al., 2000). The sedimentary strata as documented in DSDP/ODP cores in the upper part of the forearc basin and slope apron Neogene-to-Quaternary stratigraphic succession is mainly composed of diatomaceous-hemipelagic mud and volcanic ash (Scientific Party, 1980; Sacks et al., 2000), reflecting the influence of high oceanic productivity, the interplay between the cool Oyashio and warm Tsugaru and Kuroshio currents, and arc volcanism as main sediment source (e.g. Koizumi and Sakamoto, 2003).

ODP Leg 186 in 1999 also installed borehole observatories above the seismogenic zone at Sites 1150 and 1151 (Sacks et al., 2000). The two long term borehole observatories, each consisting of two broadband seismometers, one strain meter and one tilt meter, collected earthquake data over more than 10 year, however, unfortunately, instruments were not recording anymore during the 2011-Tohoku-oki earthquake, as batteries run out before the event (Shinohara pers. com.).

Tectonic history in the convergent margin near the Japan Trench is characterized by tectonic subsidence and erosion: The absence of young accreted strata in the forearc, as well as multichannel

seismic records (e.g. Scientific Party, 1980; Tsuru et al., 2002) attest that most of the sediment entering the trench is subsequently subducted. The Scientific Party (1980) demonstrated progressive subsidence of the seafloor by vertically transient benthic biofacies and lithofacies observed in the forearc basin sediments. The subsidence is associated with subduction erosion of the continental slope and forearc wedge related to the subduction of the Pacific Plate, which also caused the trench to retreat an estimated 50-75 km (e.g. von Huene and Lallemand, 1990). Also, disrupted seafloor topography at the tip of the overriding plate suggests frontal erosion, which is most evident in the wake of a subducting seamount (e.g. Lallemand and Le Pichon, 1987). Furthermore the Neogene-to-Quaternary sediment sequence is cut by several landward-dipping normal faults spaced ~10 to 15 km apart (Nasu et al., 1980; see also Tsuji et al., 2011).

Along the lower forearc slope and within the frontal prism, landward-dipping thrust faults are evidenced in reflection seismic data (e.g. Scientific Party, 1980; Tsuru et al., 2002; Tsuji et al., 2011). They branch from the plate boundary thrust and dissect the wedge to form margin-parallel escarpment structures on their hanging wall blocks. Examples include (1) the Sanriku Escarpment between water depths of 5,600 and 6,400 m in the area between 39°N and 41°N (e.g. Ogawa et al., 1996) and (2) two thrust systems around 38°N interpreted by Tsujii et al. (2011) as (i) a backstop reverse fault (von Huene et al., 1994; Tsuru et al., 2002), and (ii) a branch reverse fault constructing the significant seafloor slope break around 5.2 km depth in this area. Such seafloor escarpment structures related to fault-movements have been documented to often form habitats for dense biological communities, fed by fluid seepage of deeply-sourced fluids (e.g. Henry et al., 1989; Ogawa et al., 1996; Tsuji et al., 2011).

Detailed textural and structural analysis of multibeam bathymetry data by Sasaki (2004) further show evidence for both smaller and larger scale submarine landslide and gravitational slope collapse structures, respectively, which develop along the lower forearc slope and which are often related to above mentioned escarpment structures. Gravitational mass wasting along the forearc slope, overall, is likely related to the tectonic evolution characterized by tectonic subsidence and erosion (Sasaki, 2004; Ogawa, 2011) and as documented for other erosive subduction margins (von Huene et al., 2004; Hühnerbach et al., 2005). Yet, it is hypothesized that large megathrust earthquakes can trigger slope failure initiation, which may bear additional tsunamigenic potential (von Huene et al., 2004; Kawamura et al., 2012). Kawamura et al. (2012) suggest based on seafloor video observation after the earthquake that a prominent area identified as potentially unstable by Sasaki (2004) may have moved to cause submarine landslide. Whether or not the 2011-Tohoku-oki earthquake may have triggered more submarine landslides in areas identified as potentially unstable by Sasaki (2004) remains to be investigated.

3. Narrative of the Cruise

(G. Wefer)

The main group of the scientific party of SONNE-Cruise 219A arrived in Yokohama on March 5th and checked in on the vessel on March 6th. All container handling was done by the crew of SONNE in Yokohama on March 6th and 7th and both days were used to set up the equipment. On March 6th, a press conference was held at the press club located in downtown Tokyo that was attended by about 40 international and local journalists. S. Kodeira from JAMSTEC, K. K. Mochizuki from Tokyo University, and G. Meinecke and G. Wefer from MARUM presented the objectives and plan for the cruise, and then answered questions related to the joint expedition and future cooperation planned between Japanese and German institutions. On March 7th, the German ambassador, Dr. Stranzel, and G. Wefer hosted a reception on the deck of RV SONNE. After a brief greeting by the master of FS SONNE, L. Mallon, Ambassador Dr. Stranzel welcomed the ca. 50 guests and pointed out the importance of international scientific cooperation. This was followed by short speeches by DFG Vice president Ferdi Schüth and G. Wefer. Afterwards the guests had the opportunity to tour the ship and discuss the scientific program of the cruise with the participants.

We left the port of Yokohama on March 8th at 7:45 a.m. local time. The scientific crew included 15 scientists from the DFG Research Center and Cluster of Excellence MARUM 'The Ocean in the Earth System' at Bremen, 3 scientists from JAMSTEC, and one scientist each from Fukada Geological Institute and from Tohoku University. The team was complemented by a two-person movie team from Radio Bremen.

The scientific program began with activation of the hydroacoustic systems of RV SONNE as soon as we reached our main working area (see Fig. 3.1). We were heading toward station JT2, an observatory where we wanted to install a recording system. On the way we mapped with the shipboard-mounted multibeam and the hydroacoustic subbottom profiler (Parasound system) along strike fault systems near locations A1, A2 and A3. Location A1 was identified as an interesting area, characterized by several NNE-SSE trending structures that are related to subsurface fault systems (Sasaki, 2004; Tsuji et al., 2011). These locations are possible sites for coring with the multicorer and gravity corer (for Leg 2). After finishing with the mapping of site A3 we lowered a CTD to a depth of 2000 m to receive an up-to-date sound velocity profile.

On March 10th at 6 a.m. we started preparations for the ROV dive. Due to swells up to 2-3 m high and strong winds (6-7 Bf) we decided at 8:30 not to dive and instead began with mapping profiles. Traveling at a speed of 6 knots we completed line MY101 and half of line 5R101. On March 11th at 6 a.m. we again started preparations on the ROV Quest and lowered it to a depth of about 50 m. Due to strong currents and winds we cancelled the dive and brought MARUM Quest back on deck. As the weather forecast predicted stronger winds and swell until March 13th, we decided to continue mapping profiles (lines MY102/GeoB16405 and GeoB 16406). Due to strong winds and high waves we had to interrupt mapping for about 24 hours.

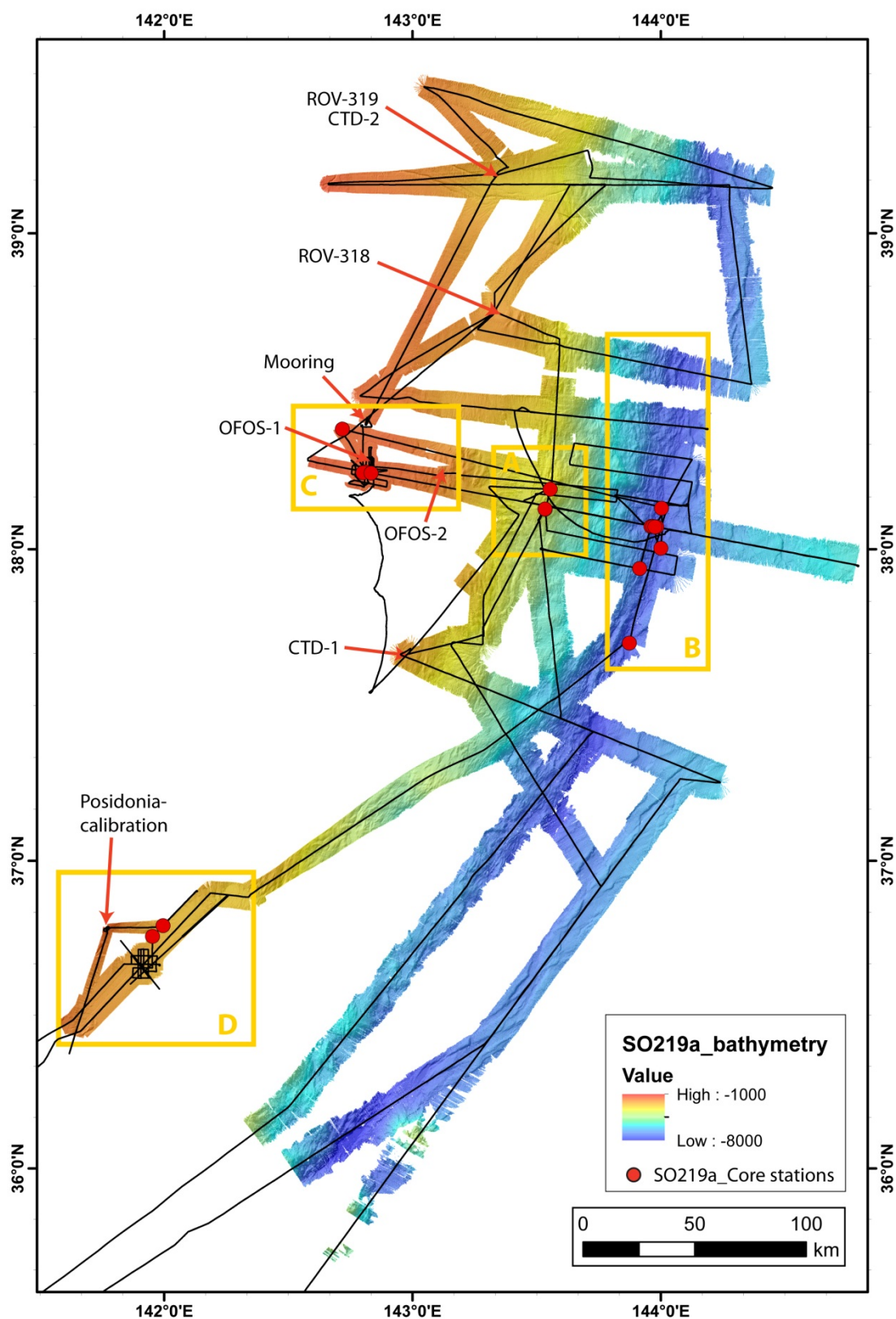


Fig. 3.1: Cruise-track of RV Sonne cruise SO219A. Shown are collected bathymetry data and indicated are the four working areas (A – Normal fault basins, B – Trench Area, C – northern forearc basin, D- southern forearc basin) and stations visited during the cruise.

On March 14th we reached station JT2 at about six in the morning and started preparation of the ROV Quest for diving down to the observatory. At eight we lowered the ROV into the water and dove down to the observatory. Inspection confirmed a displacement of the platform and a bent riser. After inspection, ROV Quest was brought to the surface again. After recovery of the ROV we continued our mapping program on lines GeoB 16404 and KR10-12/GeoB 16410 until March 16th. On that afternoon we sailed to observatory JT1. After diving for 2 ½ hours, the ROV reached the seafloor at a depth of 2696 m. There were no signs of displacement of the ROV platform or bending of the riser. After a survey of about 400 m in an eastward direction, the Quest rose to the surface and was on deck at about 10 p.m.

On Saturday the 17th we deployed an OBP (Ocean Bottom Pressure) sensor and TOBSF (Two Ocean Bottom Seismometer) of Tokyo University in about 1400 m of water near station GJT4. After deployment the positions of the bottom systems were determined. We started a survey mapping in the area around P08. In the night from Saturday to Sunday (17th/18th) we had to position the ship into the wind to wait for better weather conditions. On Monday morning we were able to continue with our mapping program, and during the day and evening we deployed the video sledge OFOS two times for inspection of the sea floor. OFOS is connected to the ship with an electrical and glass-fiber cable, and is equipped with black and white and video cameras. The sledge is towed about two m above the sea floor. Afterwards we mapped line MY104 and on the morning of Tuesday the 20th we started our transit to Yokohama, which we reached on Wednesday the 21st.

On Thursday and Friday equipment was packed, containers were unloaded for transport to Bremen, and two containers with the coring equipment were on-loaded. On Friday at 10 a.m. the participants of the second leg arrived and installed the lab and coring equipment. A smooth continuation of Cruise 219A was guaranteed by five scientists staying onboard for both legs and an intensive exchange of data and ideas during the port call in Yokohama. During the port call about 20 scientists from JAMSTEC und Universities visited the ship. On Saturday the 24th at 7:45 a.m. we left the harbor of Yokohama and started the second leg.

The scientific crew of the second leg included 11 scientists and technicians from MARUM with two scientists each from JAMSTEC, the University of Tokyo, and ETH Zürich, and one scientist from Kyoto University. On the morning of Sunday the 25th we reached our working area and activated the multibeam and Parasound systems. On the way to the first coring station we filled a gap on line MY103 (GeoB 16418) and reached the normal fault area at noon on Sunday the 25th. In a small basin landward of a large normal fault we collected sediment samples using a gravity corer and a multicorer in a water depth of about 3500 m. After taking these cores we moved to the trench area. From Monday the 26th to Wednesday the 27th we alternated between gravity coring and mapping using the sediment penetration beam Parasound and multibeam systems. We recovered six cores between 8 and 9 m long in water depths from 7100 to 7500 meters. Due to the great water depths one coring run took about 7 hours. Immediately after coring, samples were taken for gas measurements and geochemical analyses. Afterwards cores were opened for core description, photography, smear slides, shear strength and magnetic susceptibility measurements. Ikaite, a hydrated carbonate mineral, is common in sediments from the trench area.

The next working areas were small tectonic basins in about 1500 m of water. We mapped some basins with multibeam and Parasound and took relatively short cores of 3 meters. Coarse sand

layers prevented deeper penetration of the core. From the afternoon of Friday the 30th to Sunday morning the 1st of April, we had to stop coring due to strong winds and high waves. Although waves reached heights of 6 m, the RV SONNE was quite stable and we were able to work on our data and samples and met to discuss our results. On Sunday we took a gravity core in a small basin near the normal fault and repeated a profile from east to west on line MY102/GeoB 16405. During the night of Sunday to Monday the 2nd we took a gravity core south of this line in about 7500 m of water depth.

The weather forecast predicted a low-pressure zone with waves up to 9 m high for the night of Tuesday to Wednesday, and to avoid this severe sea state we set a course for the coastal area near the Boso peninsula. From Tuesday noon to Wednesday morning we waited out the wind and afterwards continued our mapping and coring in a forearc basin in the southern part of our working area. On Thursday the 5th we calibrated our Posidonia navigation system and at 5 p.m. finished our work and set a course for the harbor of Yokohama. On Friday the 6th we reached the Yamashita Pier no.3.

During SONNE Cruise 219A, more than 2700 nm of hydroacoustic profiles were collected on the continental margin off Japan. 95 m of gravity cores were recovered and the multicorer was deployed two times. The combined new data set from the two legs will help to document changes in the morphology and sediment distribution as well as displacement of the continental margin caused by the earthquake on March 11th 2011.

4. Methods

4.1 Hydroacoustics

(M. Römer, C. dos Santos Ferreira, Y. Marcon, L. Podzun)

RV SONNE is equipped with a suit of hydroacoustic techniques including the KONGSBERG multibeam echosounder EM120 as well as ATLAS PARASOUND P70 sediment echosounder. These techniques provide images of the sub-seafloor, the seafloor, and the water column above the seafloor. The multibeam systems are routinely used to obtain bathymetry of the seafloor. Seafloor properties such as seabed roughness, sediment density, or seafloor inclination may be obtained using the backscatter information of the beams or sidescan-sonar like images of the seafloor. Slump deposits, shallow gas, or authigenic carbonates at shallow sediment depths may be identified in backscatter maps due to the fact that these features alter the physical properties of the seafloor. PARASOUND has the advantage of providing a composite view of the water column (18 kHz signal) as well as the sub-surface (4 kHz signal). The 4 kHz images provide besides the general subsurface structures of the upper sediment column (up to 150 m below seafloor) also evidence for seep-related features such as gas in sediments leading to signal absorption (blanking) or enhanced reflections due to deposition of gas hydrates and/or carbonates (Nikolovska et al., 2008).

The main intention of using the hydroacoustic systems during SO219A was to obtain bathymetry of profiles crossing the Japan Trench for comparison with data obtained before the earthquake in March 2011 and to obtain subbottom information in the areas where sediment cores have been retrieved. Additionally, finding any indications for seep related features have been of interest.

4.1.1 Bathymetric mapping (with multibeam EM120)

The EM 120 KONGSBERG multibeam echosounder operates at 12 kHz. The transducers have a nominal opening of 2° in along-track direction and also 2° in across track direction. The multibeam echosounder is capable to record up to 191 individual beams across track within a swath of up to 150°. However, due to insufficient data quality in the outer beams, the maximum swath width used during this cruise was between 120/130°. Actual sound velocity profiles were recorded with the CTD (two deployments during SO219A: GeoB 16402 and 16409) and inserted as basis for optimized performance. For the purpose of detailed bathymetry and backscatter mapping in small areas, the swath width was regularly reduced to 90° while for general surveying during transits and running long profiles a swath of 120° or 130° was chosen. Data were recorded in *.all files and processed with software MB-System (Caress and Chayes, 1996) onboard.

4.1.2 Sediment echo sounding (with Parasound)

The ATLAS PARASOUND echosounder uses two high frequencies (primary high frequency PHF and secondary high frequency SHF) of ~18 and ~42 kHz, which can be recorded and used for imaging of gas bubbles in the water column. Non-linear interference of the high frequencies produces a secondary low frequency (SLF) of about 4 kHz. This SLF is used for sub-seafloor imaging. Opening angle of the transducer is ~4°, which corresponds to a footprint size of about 7 % of the water depth. The program PARASTORE is used for storing and displaying echographs. The settings applied in PARASTORE for PHF and SLF displaying are variable and dependent on the actual performance influenced by, e.g., water depth, water and weather conditions. Generally the filtering in the PHF

window has been used to detect possible gas emissions in the water column: Low pass: on, Iteration: 2, High cut: 1. The amplitude scale is also important for this purpose: Clip: between 100 and 500 mV, no Threshold, negative Flanks Suppression or Gain. For SLF subbottom imaging filtering was usually set to: Low pass: on, Iteration: 1, high cut: 6. Amplitude scale with a Clip between 1000 and 23000 mV, no Threshold and Negative Flanks Suppression, but sometimes a Gain: Bottom TVC of 0.1 to 0.25 was chosen to get a deeper bottom penetration. Three file formats are recorded during PARASOUND operations: *.asd files, which can be replayed in PARASOUND contain data of the entire water column as well as the sub-seafloor. PARASTORE also produces *.ps3 and *.sgy-files recorded along with the auxiliary data. The depth range of the *.ps3 files was set identical to those of the online display window. While *.sgy-files were used to be plotted in Kingdom Suite software, *.ps3-files were plotted in the program SENT for interpretation. *.ps3 and *.sgy-files can also be produced by replaying the *.asd files in PARASTORE. For storage mode the option “with phase and carrier” has been selected in the first leg of the cruise, but during the second part it was chosen to use “without phase and carrier” as the produced *.sgy-files can only be implemented into Kingdom Suite when recorded with this setting.

4.2. Remotely Operated Vehicle (ROV) dives

4.2.1 Remotely Operated Vehicle (ROV) “QUEST”

(V. Ratmeyer, H. Buettner, P. Franke, S. Klar, H. A. Mai, W. Schmidt, C. Seiter, M..Zarrouk)

The deepwater ROV (remotely operated vehicle) “QUEST 4000m” used during SO219A aboard RV SONNE, is installed and operated at MARUM, Center for Marine Environmental Sciences at the University of Bremen, Germany. The QUEST ROV is based on a commercially available 4000 m rated deepwater robotic vehicle designed and built by Schilling Robotics, Davis, USA. Since installation at MARUM in May 2003, it was designed as a truly mobile system specially adapted to the requirements of scientific work aboard marine research vessels for worldwide operation. Today, QUEST has a total record of 295 dives during 25 expeditions, including this cruise.

During SO219A, QUEST performed only 2 dives to depths at 2170 and 2677m. QUEST was operated by a team of 8 pilots/technicians on a 12 hour basis. Dive operations included the visual inspection of 2 CORK sites as a preparation for the intended installations of sensores and battery packages. Due to bad weather, these followup operations could not be performed. The vehicle performed well during the 2 established dives.

Close cooperation between ROV team and ships crew on deck and bridge allowed a smooth and professional handling during all deployment and recovery situations. During diving, this cooperation allowed precise positioning and navigation of both ship and ROV, which was essential for accurate sampling and intervention work such as sampling, instrument deployment and cable management with an additional umbilical beacon at depth.

QUEST System description

The total QUEST system weighs about 45 tons (including the vehicle, control van, workshop van, electric winch, 5000-m umbilical, and transportation vans) and can be transported in four standard ISO 20-foot vans. A MacArtney Cormac electric driven storage winch is used to manage up to 5000m of 17.6 mm NSW umbilical cable.

Quest internal equipment and online tooling

The space inside the QUEST 5 toolskid frame allows installation of mission-specific marine science tools and sensors. The initial vehicle setup includes two manipulators (7-function and 5-function), 7 color video cameras, a digital still camera (Insite SCORPIO, 3.3 Mega-Pixel), a light suite (with various high-intensity discharge lights, HMI lights, lasers, and low-power dimmable incandescent lights), a Sea&Sun online CTD, a tool skid with draw-boxes, and an acoustic beacon finder. Total lighting power is almost 3 kW, total additional auxiliary power capacity is 8 kW. In addition, the permanently installed Kongsberg 675kHz Type 1071 forward looking Scanning Sonar head provided acoustic information of bottom morphology and was also used for detection of gas emissions.

Video Setup, HDTV and vertical imaging

Continuous PAL video footage was continuously recorded on two MiniDV tapes with two color-zoom cameras (Insite PEGASUS or DSPL Seacam 6500). In order to gain a fast overview of the dive without the need of watching hours of video, video is frame-grabbed and digitized at 5sec intervals, covering both PAL and HD video material.

For extremely detailed video close up filming, a near-bottom mounted broadcast quality (>1000 TVL) 3CCD HDTV 14 x Zoom video camera was used (Insite Zeus). Spatial Resolution of this camera is 2.2 Mega-Pixel at 59.94 Hz interlaced. Recording was performed on demand onto tapes in broadcast-standard digital Sony HDCAM format, using uncompressed 1.5 Gbit HD-SDI transmission over a dedicated fibre-optic connection. Image display takes place on an HD 46" TFT display screen inside the control van, providing excellent close-up view and covering the full dynamic range of the camera. Distribution of the cameras HDTV video signal was performed through dedicated cabling into the science lab, allowing real-time display on a 26" HD TFT screen at full resolution.

As a standard still image camera, an Insite Scorpio Digital Still camera was used, providing 3.3. Mega-Pixel spatial image resolution and highly corrected underwater optics.

For the task of video mosaicking and vertical downward viewing, a broadcast quality downward looking camera with dedicated corrected underwater optics – Insite ATLAS - was installed for the second time in this functionality on the toolskid in conjunction with one high power HID wide angle flood light. Orientation of light and camera was adjusted in order to gain a large angle between optical axes. Thus, reduced backscatter allowed clear imagery from up to 7 meters above seafloor. A new digital still camera with 14 Mpix resolution was installed aside the ATLAS, but could not be used due to a telemetry failure.

Video distribution was provided by dedicated CAT-5 based VGA transmission hardware, as well as by streaming the main tiled video image over the vessels network.

During SO219A, the following scientific equipment was handled with QUEST:

ROV based tools, installed on vehicle:

- ROV interchangeable draw-box baskets with bio-box
- Sea and Sun CTD real-time probe with turbidity sensor
- acoustic Beacon markers
- Simple "Freddy" knife for manipulator operations

ROV adaptations for instrument deployment and readout:

- serial interfacing and power connections for the data readout and power cabling for use at the CORK sites were provided by JAMSTEC and were successfully tested on deck

4.2.1 Observatories

(K. Kitada, T. Kimura)

4.2.1.1 Objectives

JT1 and JT2 borehole observatory were installed during the ODP Leg 186 in the Sanriku-oki region near the epicenter of the 2011 Tohoku-oki earthquake (Fig. 4.2.1). These observatories have two seismometer, one strainmeter and one tiltmeter in the bottoms of the boreholes to observe earthquake and long-term crustal movement for long-term. We had collected tiltmeter data for over ten years after the installation. However, we recovered data recording unit and battery sphere during JAMSTEC NT10-10 cruise in June 2010. Thus, they are not working after the recovery including after the main shock of the earthquake. In this cruise, we have planned to install recording instruments to monitor crustal movement around the focal region after the earthquake.

ROV operations planned to restart the observatories are as follows: 1) visual inspection of the observatories; 2) install the recorder unit and battery sphere into the observatories; 3) recover initial data to evaluate the conditions of the observatories.

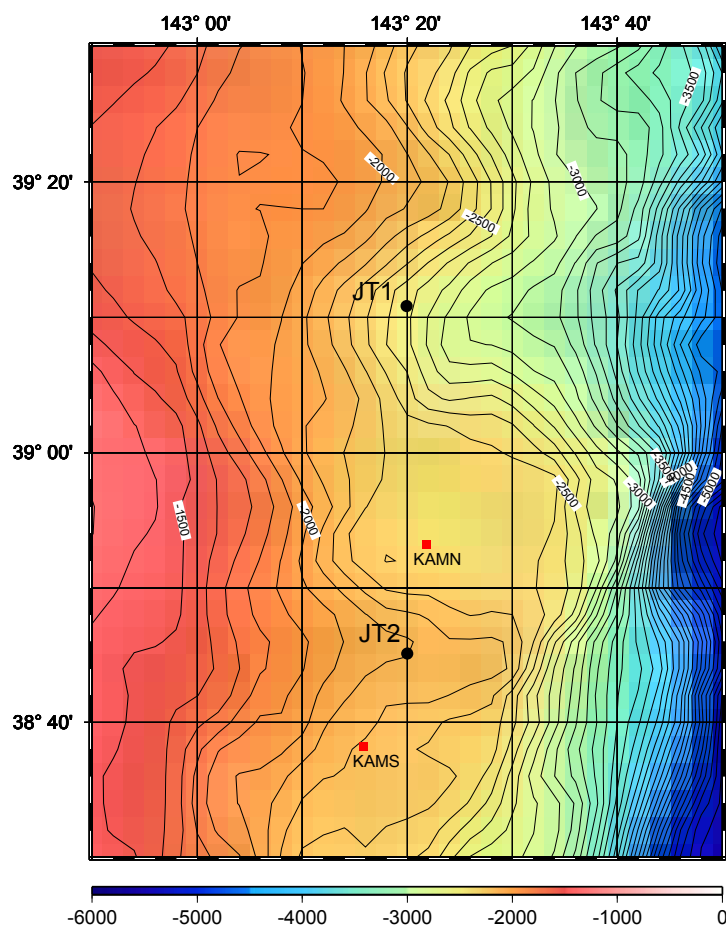


Fig. 4.2.1: Bathymetric map around JT1 and JT2. The location of JT1 and JT2 are shown by black circle and the location of KAMN and KAMS (Sato et al., 2011) are also plotted.

4.2.1.2 Instruments

We prepared some instruments for the JT1 and JT2 observatory to restart tiltmeter data acquisition. Figure 4.2.2 shows the schematic drawing of the connection of the borehole observatory. We prepared the following instruments for this cruise.

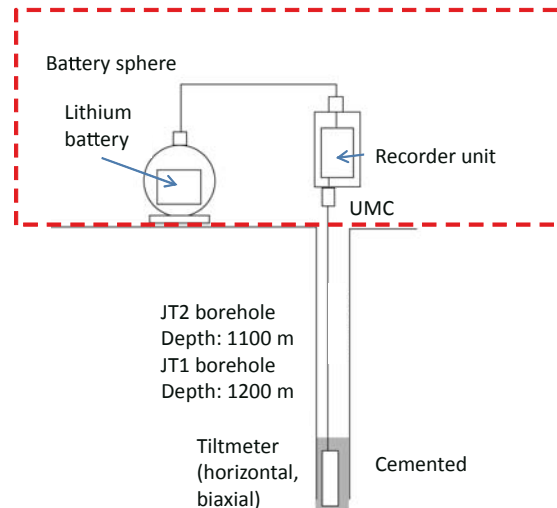


Fig. 4.2.2: Schematic drawing of the borehole observatory. To restart long-term observation, the battery sphere and the recorder unit (surrounded by the dashed line) are need to be installed.

a) Recorder

The recorder unit is prepared for the borehole tiltmeter to collect analog data and to control electrical motors for tiltmeter leveling. The recorder has some printed circuit boards (PCB) including CPU board, AD board and Power supply board in stainless steel pressure vessel. The recorder unit has 12 pin male UMC (Underwater Matable Connector) on the bottom of the pressure vessel for mating the UMC of the borehole tiltmeter and 8 pin male UMC cable for mating the batter sphere as shown in Fig. 4.2.3. AD board has two 24 bit sigma-delta A/D converters for digitizing acquired data. Power supply board has some DC/DC converters and electrical relays to supply DC power to sensors and electrical motors for leveling. CPU board has a CPU chip, flash memories and 32GB SDHC storage media for over 2 years data storage. The recorder has also auto-leveling function to avoid out of range acquisition of tiltmeter.

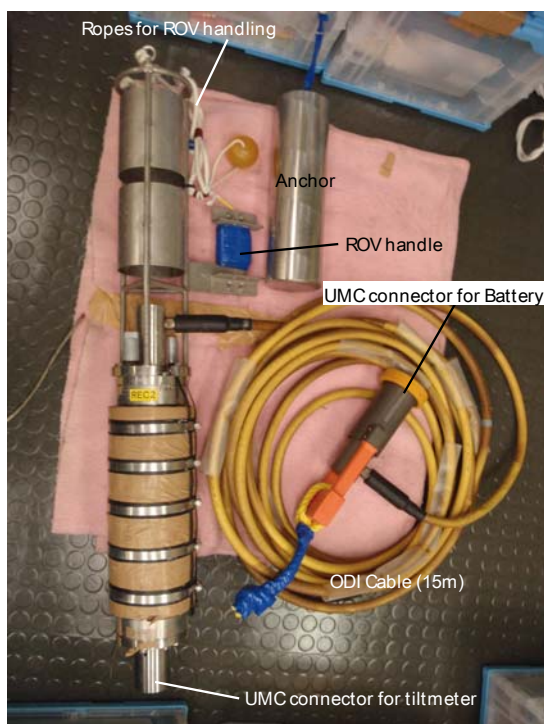


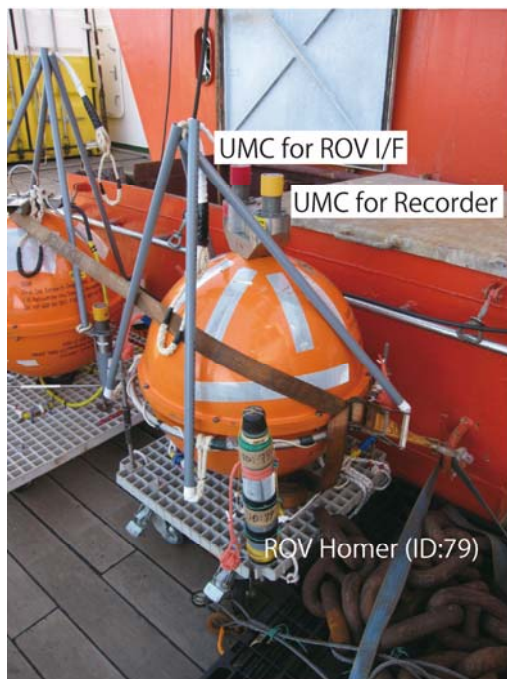
Fig.4.2 3: Photo of tiltmeter data recorder for JT1 and JT2 observatories.

b) Battery sphere

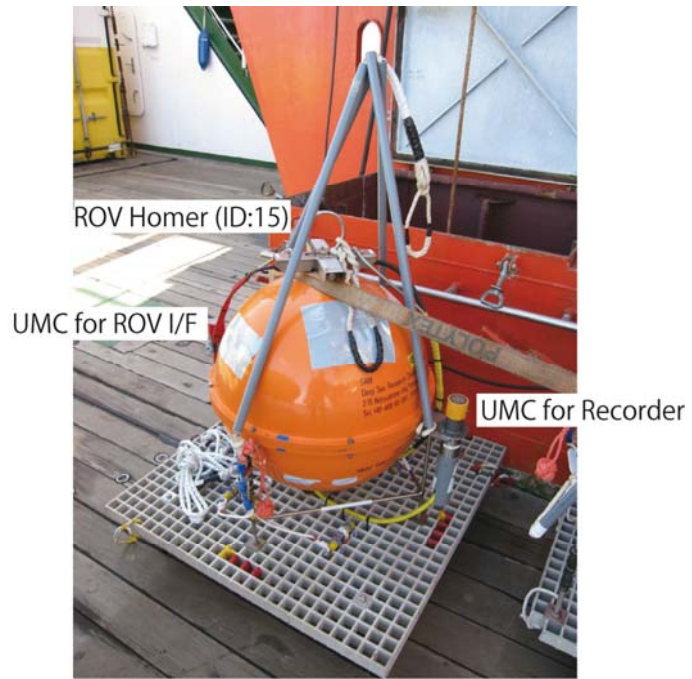
The battery sphere is prepared to supply electrical power to the recorder unit and the borehole tiltmeter. The battery sphere has 38 parallel 27.3V battery packs which consist of 7 series lithium batteries (Electrochem 3B36, 3.9V with 30Ah) in the titanium sphere pressure vessel for continuous observation more than two years. Fig. 4.2 4 shows two types of the battery sphere. These units have entirely same specifications except for their shapes. The battery sphere has two UMC for mating to the recorder unit and the ROV I/F which is 8 pin female and 4 pin male, respectively. Battery units are deployed using mooring system (Fig. 4.2.5) after the visual inspection of the observatories.

c) ROV I/F unit

The ROV I/F unit is prepared for communication between ROV and the borehole instruments. This unit has electrical circuit in titanium pressure vessel. The pressure vessel has one 4 pin male UMC cable for mating the battery sphere and one dry mate connector for mating to the ROV in each side. The function of ROV I/F unit is to isolate UMC pins to avoid electrical corrosion. We prepared a custom-ordered cable for connecting between ROV Quest and our ROV I/F unit for this cruise.



ERI type Battery sphere



JAMSTEC type Battery sphere

Fig. 4.2.4: Photos of Battery instruments for JT1 and JT2 observatories. Two type of the battery sphere (ERI and JAMSTEC types) are shown. ROV HOMER IDs are ID:79 and ID:15, respectively.

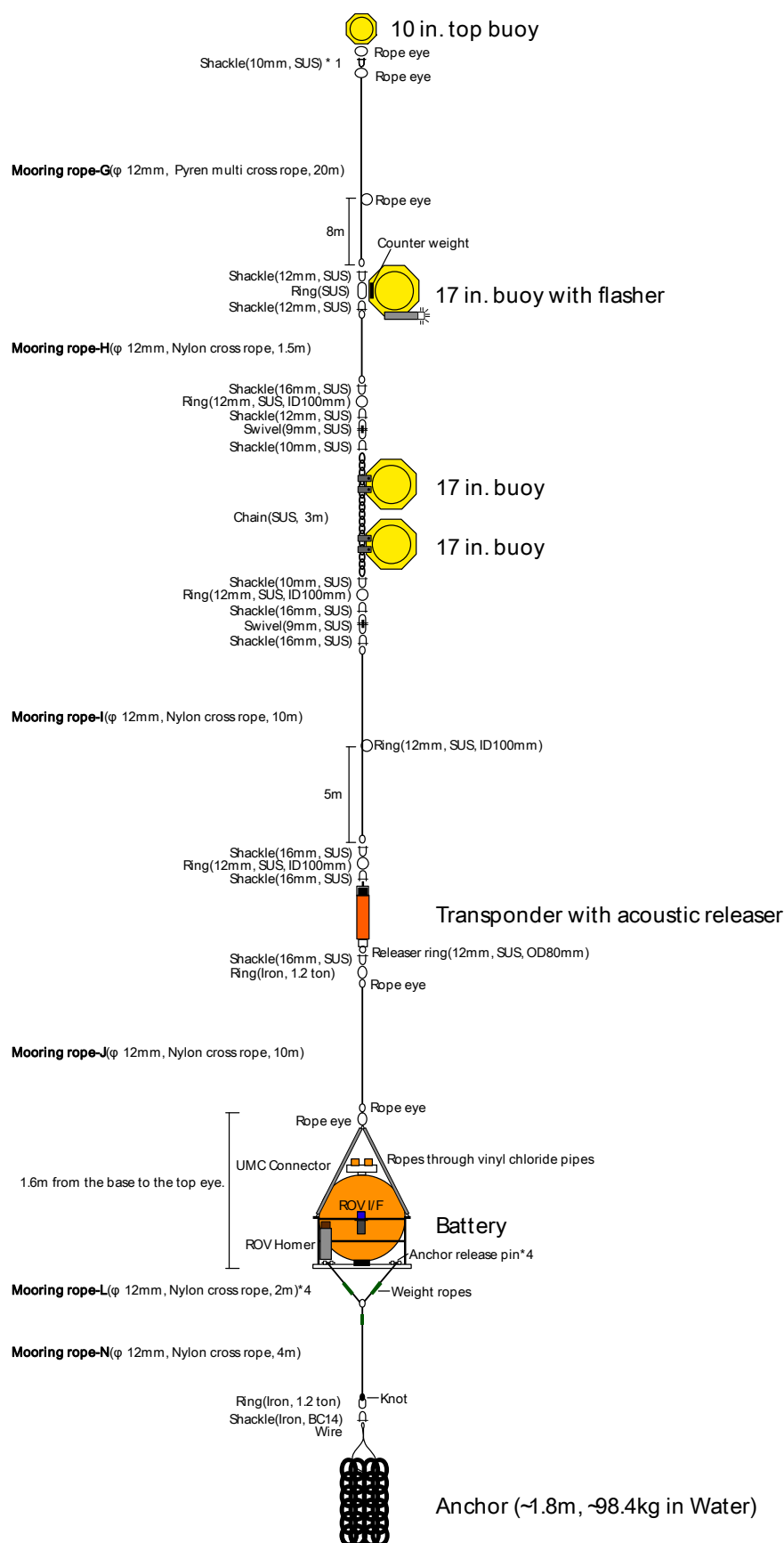


Fig. 4.2.5: Schematic drawing of the mooring system during the SO219A.

4.2.2.3. ROV Quest Dive

a) JT1 OBSERVATORY (ROV Quest Dive #319)

ROV Quest dove to JT1 in the afternoon of 16th March (JST). The vehicle was deployed at 14:10JST and reached to seafloor at 16:39JST. Searching for JT1 was started by using acoustic sonar and JT1 was found at 17:29JST. The JT1 position determined by POSEIDON system of RV SONNE was 39°10.8720'N, 143°19.9401'E. RV SONNE will test POSEIDON positioning system during 2nd leg to determine positing error of USBL system of ROV Quest/RV SONNE. After the inspection, ROV Quest started the topography survey to East and dove to the surface at 19:35JST and was on deck at 22:00JST.

The major results of the visual inspection were as follows (Fig. 4.2.6: 1) No significant displacement of the ROV platform relative to the reentry cone and no riser bending; 2) one UMC connector for CMG sensor (broadband seismometer) was dropped from the attached plate; 3) no problem was found for other UMC connectors and less sediments on the connectors, which was confirmed from the top and side; 4) all the UMC connectors were connected to the borehole sensor cables; 5) ROV platform was stable and Quest landed on for inspection; 6) a part of mud skirt frame under the reentry cone were come out.

b) JT2 OBSERVATORY (ROV Quest Dive #318)

ROV Quest dove to JT2 in the morning of 14th March (JST). The vehicle was deployed at 8:16JST and reached to seafloor at 10:18JST. Searching for JT2 was started by using acoustic sonar and JT2 was found at 11:44JST. The JT2 position of ROV Quest was 38°45.0920'N, 143°20.0190'E. After the inspection, ROV Quest dove to the surface at 12:12JST and on deck at 14:10JST.

The major results of the visual inspection were as follows (Fig. 4.2.7): 1) ROV platform was displaced about 40cm to NW direction relative to the reentry cone; 2) riser was bent (about 5-10 degrees) to NW direction; 3) no problem was found for other UMC connectors and less sediments on the connectors; 4) ROV platform was unstable; 5) a part of mud skirt frame under the reentry cone were come out; 6) the track (hole) under the reentry cone were observed on the side of NW.

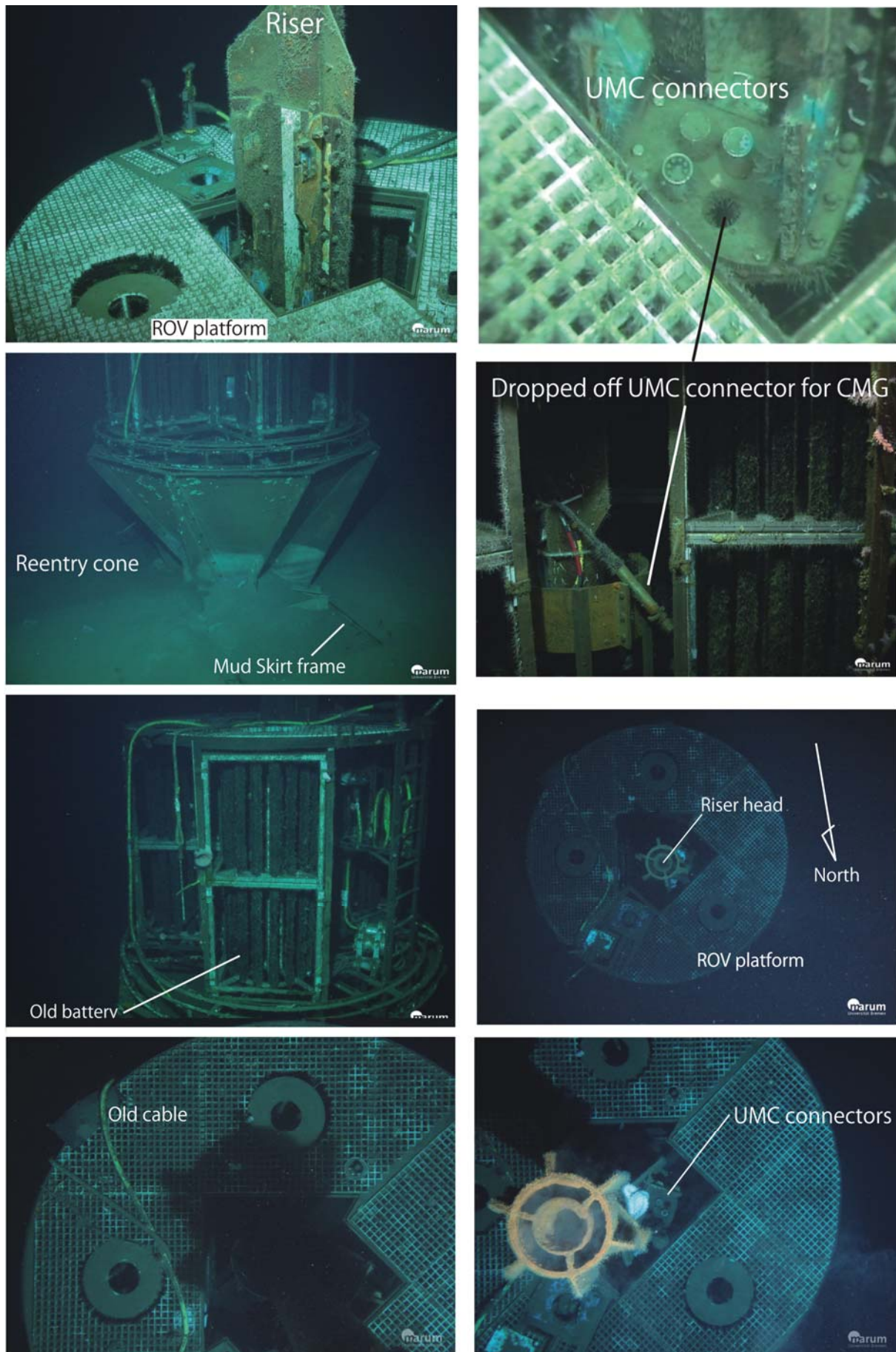


Fig. 4.2.6 JT1 inspection during ROV Quest Dive #319.

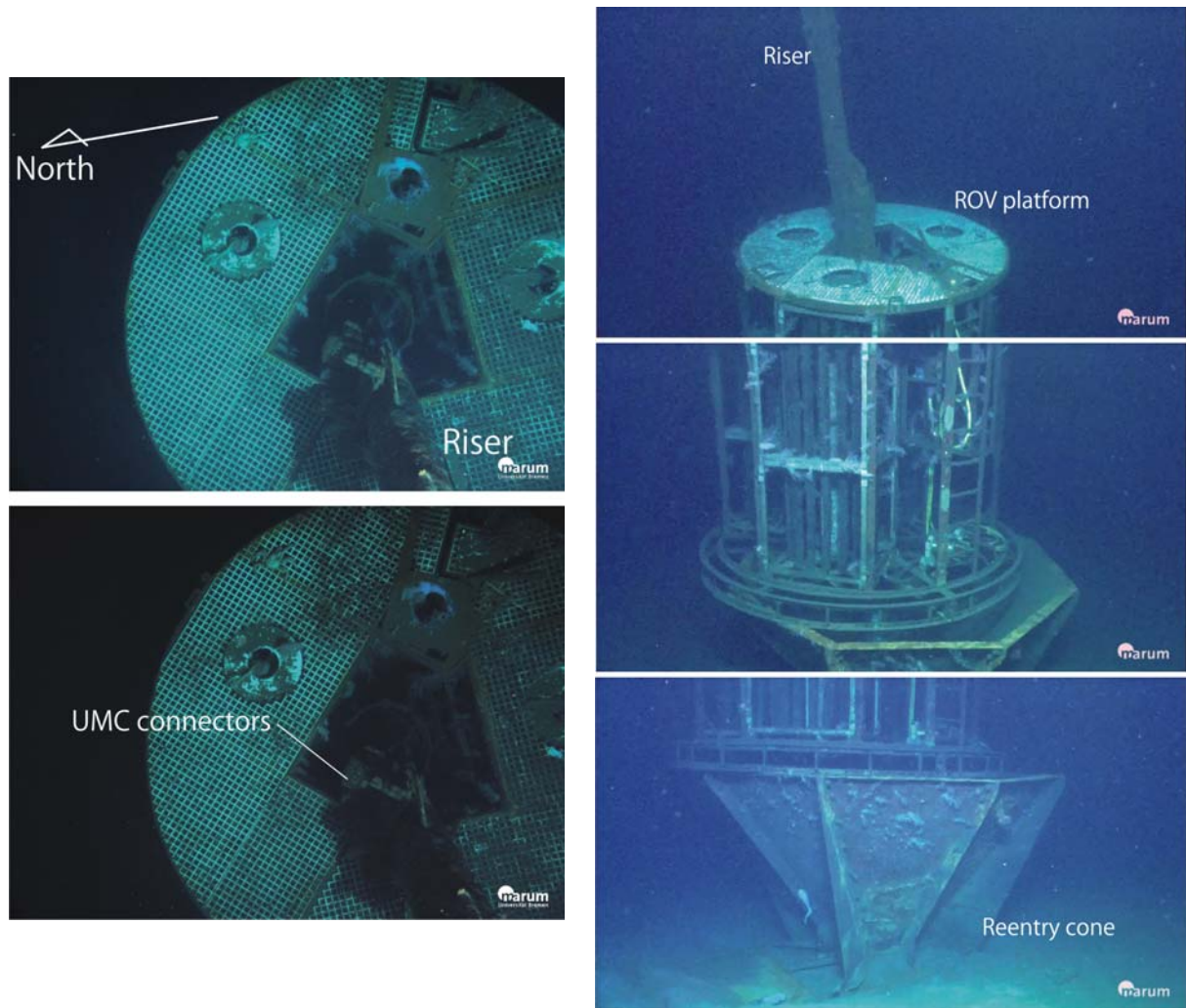


Fig. 4.2.7: **a** (left): JT2 inspection from top during ROV Quest Dive #318. **b** (right): JT2 inspection from side during ROV Quest Dive #318. Top: Riser is bent to NW. Center: ROV platform is shifted to the same direction with the riser bent (NW).

4.3 Ocean Floor Observation System (OFOS) dives

(M. Römer, K. Kawamura)

4.3.1 Ocean Floor Observation System (OFOS)

The OFOS video sled is equipped with the following instruments: two video cameras (color camera and black and white camera, both: Deep Sea Power and Light), a stereo still camera system (Panasonic), and halogen lights (Deep Sea Power and Light), CTD (Seabird), a compass, pitch and roll sensor, and a Benthos altimeter. The sled is towed behind the ship at a speed of about 1 knot (kn). The distance of about 1.5 m to the seafloor is adjusted manually by the winch operator. For this purpose, a ground weight is suspended below the sled on a rope of 2 m in length. Two laser pointers can be used to scale the video image and the still camera images. The laser pointers are parallel and 20 cm apart, while a third one points at an oblique angle. The images were taken manually. The video signal and the images are overlaid with the date and time (UTC). The video signals were digitized in real time and stored as VLC media files.

During SO219A, the OFOS has been deployed twice, both on March 18, 2012 and were conducted in the western part of the working area in relatively shallow water depths of ~1400 m and ~1800 m, respectively.

4.3.2 OFOS dives

OFOS-1: GeoB 16415, Station #18

Purpose: Survey from north to south, crossing over P08 where probably microbial mat may be located (see Fig. 4.3.1 for dive track).

Planned survey:

Start:	38°17.034' N	142°49.918' E	
P08:	38°16.977' N	142°49.918' E	
End:	38°14.569' N	142°49.918' E	
From deck:	18.03.2012 01:24:00 UTC	38°17.03' N	142°49.92' E (Ships position)
At depth:	01:57:30 UTC	38°17.0211' N	142°49.9266' E (OFOS position) 1394 m
From depth:	04:24:00 UTC	38°15.6570' N	142°49.552' E (OFOS position) 1378 m

Protocol:

01:57:30	at the bottom
	typical seafloor, several organisms like brittle stars, sea cucumbers, starfishes, sea urchins, fishes
02:05:00	OFOS crosses P08
02:14:00-16:00	small white spots of about 10 cm in diameter (bacterial mats?; Fig. 4.3.2a)
02:34:00	small white spots by white pebble-sized particles (small clam colony?)
02:40:00	travel distance of about 500 m, still typical seafloor (Fig. 4.3.2b)
02:56:00	whitish structure, thought maybe bacterial mat, but could be as well an accumulation of brittle stars and crinoids. These are aligned mostly E-W direction.
03:03:56	again such a whitish structure
03:06:30	dark patch
03:08:00	again small white spots by the particles
03:09:30	whitish structure again

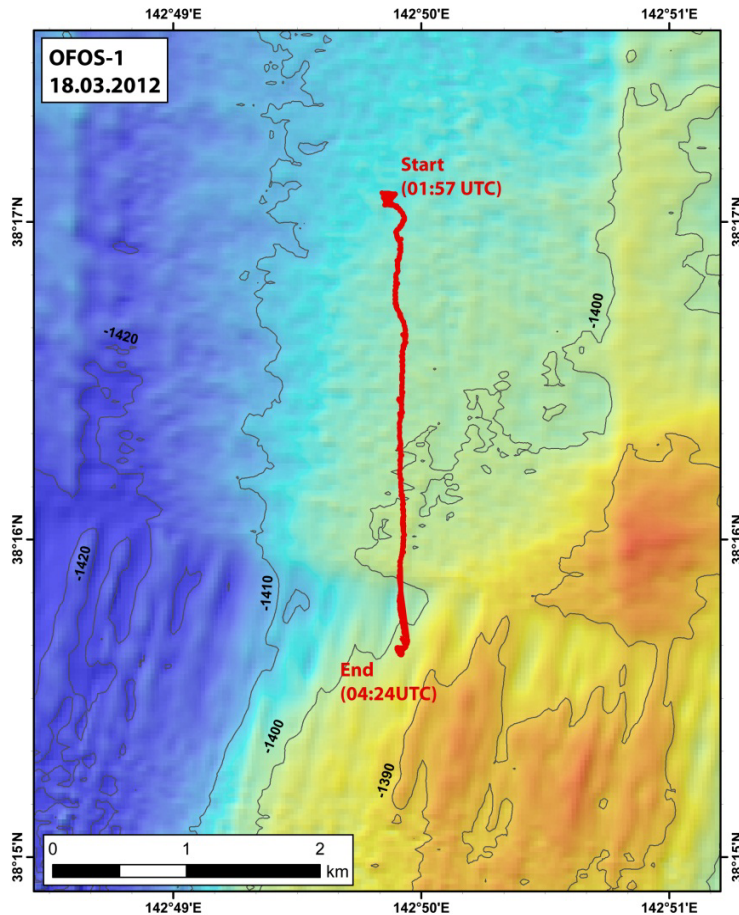


Fig. 4.3.1: Bathymetric map of the area where the first OFOS was deployed (red line).

03:11:20	relatively large white patch, hard to identify due to distance over the bottom
03:18:00	big fish and again whitish structure
03:23:00	whitish structure
03:27:57	whitish structure
03:28:58	whitish structure and also many brittle stars visible close to it
03:31:50	whitish structure
03:39:20	some garbage?
03:46:00	whitish structure
03:47:30	whitish structure, seem to be really an accumulation of brittle stars
03:52:00	blanking relatively shallow below the seafloor (visible in the subbottom profiler)
04:19:40	white points
04:20:00	dark patch (maybe it was only due to tipping the seafloor)
04:23:00	Profile ends, OFOS leaves the seafloor

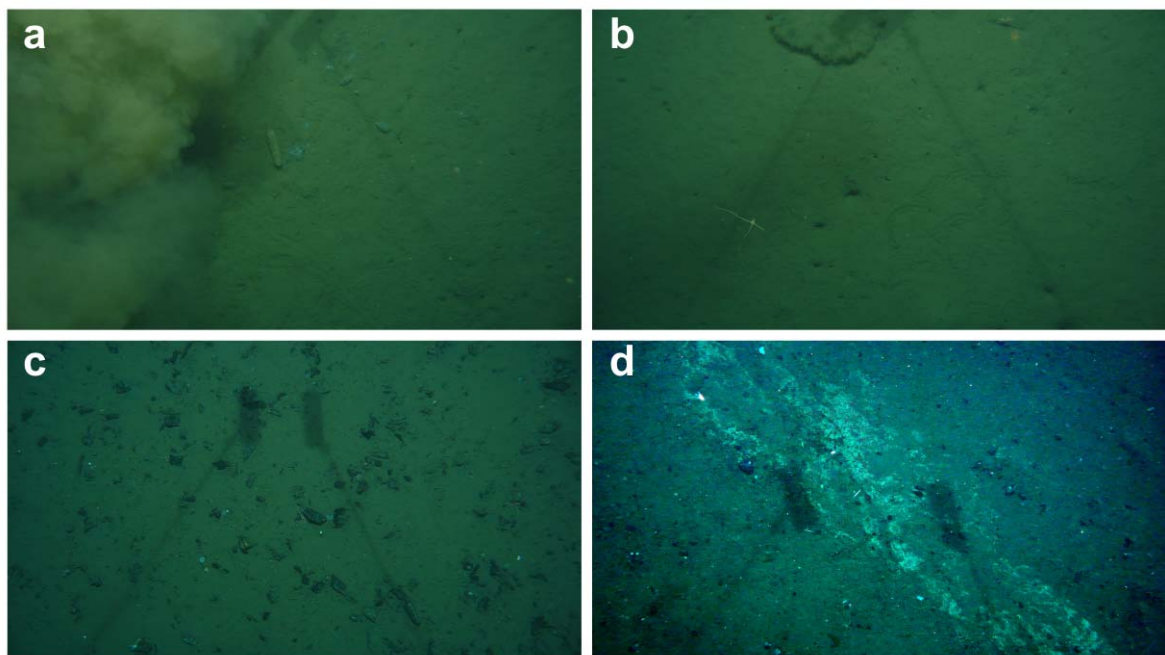


Fig. 4.3.2: Still photographs showing the typical seafloor during OFOS dives #1 (a, b) and #2 (c, d). a) soft sediments with whitish spots (~10 in diameter, bacterial mats?) and a sea cucumber b) soft sediments with a brittle star c) abundant rocks on the seafloor d) outcropping solidified sediments.

OFOS-2

GeoB 16416, Station #19

Purpose: Survey from west to east, approximately 1 km north of line YKDT100 and try to find the described cracks (see Fig. 4.3.3 for dive track).

From deck:	18.03.2012 07:30:00 UTC	38°13.98'N	143°6.66'E (Ship's position)	1800 m
At depth:	08:04:30 UTC	38°14.5090'N	143°06.5559'E (OFOS position)	1793 m
End of record:	11:56:00 UTC	38°14.5551'N	143°09.2959'E (OFOS position)	1942 m
On deck:	14:06:00 UTC	38°14.214'N	143°10.883'E (Ship's position)	2250 m

Protocol:

08:04:30	at the bottom typical seafloor with sea stars, sea cucumber, few brittle stars. Small stones lying on the seafloor, sometimes settles by anemones. Very fine sediments. Sometimes burrows in the sediments caused by endobenthic living organisms.
08:30:00	in the subbottom profile change in the penetration depth
08:32:20	Small white points (shells?)
09:11:22	rocks up to 30 cm in diameter
09:13:04	white patch of about 10 cm in diameter
09:15:09	Piece of wood, 1.5 m in length
09:16:13	huge organism
09:42:00	a rock with anemones and a plastic garbage
09:48:40	Cropout of whitish rock (indication for strong currents?) In the subbottom transparency
10:10:00	Soft sediments again with lot of signs for bioturbation
10:30:00	lots of small stones and rocks at the seafloor (Fig. 4.3.2c) and small white points (shells)
10:34:00	soft sediments with a lot of sea stars
10:50:00	larger rocks, sometimes settled by anemones

10:58:00 a bucket and a spade lying on the seafloor
 10:59:00 more small stones and dark sea stars, and a shovel
 10:01:35 Outcrop of solidified sediment layers with cracks trending north-south, maybe with a small offset (or step by sediment layers). More than at least three cracks with only decimeter to few meter distance to each other (Fig. 4.3.2d)
 11:04:00 already soft sediments again with a lot of small rocks
 11:08:00 no more rocks but sediments seem to be still underlined by the solidified plate
 11:29:00 again small dark rocks
 11:30:00 whitish patches on the seafloor (solidified plate without sediments above)
 11:33:20 hard rocks (solidified sediments or carbonates?) protruding over the soft sediments, building a step in the morphology
 11:37:00 Sediments still seem to be underlined by solidified plate
 11:50:00 Again a lot of brittle stars, the huge ones with up to 30 cm in diameter
 11:59:00 Sediment cover seem to increase in thickness
 12:00:00 A ray passing by
 12:02:00 sediments look more typical again, with bioturbation, holes, small brittle stars
 12:06:20 lot of small rocks again
 12:12:20 Another outcrop of solidified sediments
 12:14:30 a lot of small rocks
 12:20:00 typical seafloor with huge brittle stars? (ten arms)
 13:13:30 huge field of rocks outcropping or accumulated. Blanking in SLF after a steep flank down
 13:20:00 end of dive. Leaving the seafloor

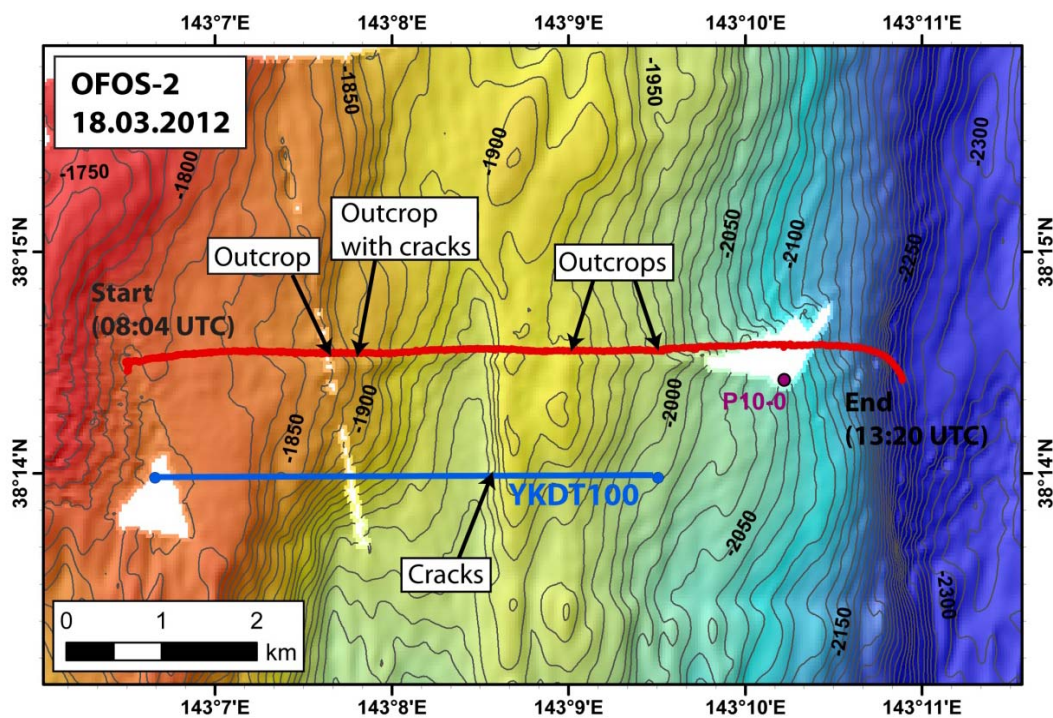


Fig. 4.3.3: The second deployment of the OFOS (red line) was deployed approximately 1 km north of line YKDT100 (blue line), where cracks on the seafloor have been described. Several outcrops and also cracks have been also observed during this dive.

4.4 Deployments - Installation of OBP and TOBSF

(Y. Osada)

Objective

In order to investigate the aftershock seismicity and vertical displacement of the 2011 Tohoku-Oki earthquake, we deployed one OBP (ocean bottom pressure) and one TOBSF (Two Ocean Bottom Seismometer on the FRP mesh) off Miyagi, northern Japan. The deployment site is GJT4 at 100 km away from trench. Kido et al. (2011) reported 15 m of horizontal displacement using GPS-Acoustic observation on this site.

System

TOBSF (Fig. 4.4.1) consists of OBS, Dummy OBS and moored system. OBS and Dummy OBS is free-fall/pop-up type. The moored system was equipped with three glass-spheres, one glass-sphere equipped a beacon and flasher, and acoustic releaser. TOBSF expect for the moored system is out of balance and fall upside down in underwater. Therefore we used the moored system. Dummy OBS was equipped the data logger, compass, batteries, which it was packaged into a glass sphere. OBS with an eigen-frequency of 4.5 Hz is used. The sensor, data logger and batteries are packaged into a glass sphere. It is possible to record continuous data related the vertical and two horizontal components for six months with a sampling rate of 200 Hz. OBP (Fig. 4.4.1) is free-fall/pop-up type equipped with pressure quartz sensor. It is possible to record continuous pressure and temperature data with a sampling of about 10 Hz.



Fig. 4.4.1: Left: Photo of TOBSF. TOBSF consists of OBS, Dummy OBS, and the moored system. Right: Photo of OBP.

Installation of TOBSF and OBP

We deployed one TOBSF and one OBP at GJT4 site on March 17. These instruments were dropped from the deck to the seafloor. Table 1 is the time line of the operation at GJT4. Firstly, we deployed the OBP sunk with a speed of 50-60 m/min. Secondly we deployed the TOBSF sunk with 45 m/min. After the confirmation arrived at seafloor, we recovered the moored system using acoustic system. The rate of climb was estimated 100 m/min. OBP will be recovered by a pop-up system after 1 year. OBS and OBSF will be recovered after six months.

Table 4.4.1: Time line of the operation at GJT4 site.

Time (UTC)	Lat	Lon	
03/16 22:10:50	38-23.989' N	142-49.012' E	Deployed OBP (Depth =1434)
23:54:55	38-23.996' N	142-49.010' E	Deployed TOBSF (Depth =1434)
03/17 00:26			TOBSF on seafloor
00:35:00			Release the moored system
00:51			Received the signal of beacon
01:10			Recovered the moored system on deck
01:35 ~01:45	38-25' N	142-49' E	Measure Travel Time on Point A
02:11 ~02:15	38-23.50' N	142-15' E	Measure Travel Time on Point B
02:42 ~ 02:55	38-23.50' N	142-47.87' E	Measure Travel Time on Point C

Table 4.4.2: The estimation of OBP and TOBSF

Site	Lat	Lon	Depth
OBP	38-24.0582' N	142-48.9743' E	1434
TOBSF	38-24.0852' N	142-48.9615' E	1434

The estimation of position using acoustic triangulation

We estimate the position of instrument using acoustic triangulation. We measured two-way travel times at three points on a circumference with the radius of 1 nautical mile around the location of instrument deployed (Fig. 4.4.3). The difference between the deployment and estimated position is 140 m and 190 m at the direction of NNW on OBP and TOBSF, respectively.

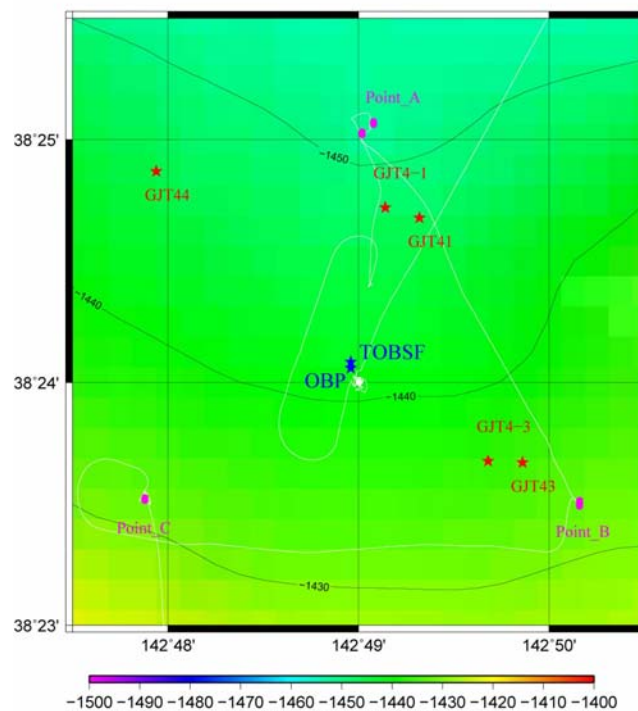


Fig. 4.4.3: The location of OBP and TOBSF. Blue star is TOBSF and OBP. Red star is the precise transducer using GPS-Acoustic observation. Purple circle is the point of acoustic measurement for OBP and TOBSF. White line is the ships-track.

4.5 Sediment Sampling

(G. Wefer, V. Diekamp, D. Dinten, H. Fink, P. Franke, P. Geprägs, K. Ikehara, K. Ishitsuka, K. Kanamatsu, A. Kioka, M. Kölling, H.A. Mai, P. Meyer and M. Strasser)

4.5.1 Gravity corer (GC)

(H. Fink)

A gravity corer with varying pipe length of 6, 9 or 12 m and a weight of 1.5 tons was applied to recover long sediment sequences during RV Sonne cruise *SO219A* (Fig. 4.5.1). Before using the gravity corer, the liners had been marked lengthwise with a straight line in order to retain the orientation of the core. Once on board, the sediment core was cut into 1-m sections and immediately sampled for head space gas (see chapter 4.7). The liners were closed with caps on both ends and labelled according to a standard scheme (Fig. 4.5.2).



Fig. 4.5.1: *Deployment of a gravity corer with a 9 m long pipe on board RV Sonne (Photo V. Diekamp).*

In the following, the core sections were sampled for interstitial water (chapter 4.7) before all cores were split into work- and archive halves. The archive half was used for core description (see chapter 4.5.3 and Appendix) and photography. The working half was analysed for physical properties such as magnetic susceptibility and shear strength (chapter 4.6). After processing, the split cores were put into D-tubes and stored at 4°C.

During RV Sonne cruise *SO219A*, the gravity corer was successfully used at 15 stations (one failed) with sediment recoveries between 1.77 and 11.38 m (Tab. 4.5.1), resulting in total core recovery of 95.17 m. In the normal fault area (A), two gravity cores were recovered, eight cores were collected from the trench area (B) and three were retrieved from the northern forearc basin (C) and two from the southern forearc basin (D), respectively.

All metadata of the gravity cores and samples taken on board, were entered into the GeoB Expedition DIS database.

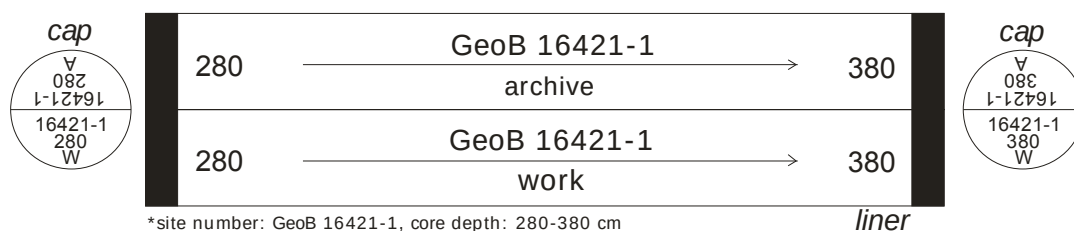


Fig. 4.5.2: *Scheme of the inscription of gravity core segments.*

Table 4.5.1: Metadata of gravity cores collected during RV Sonne cruise SO219A (data are related to time of bottom contact).

Station [GeoB]	Date [ddmmyy]	Working Area	Latitude [N]	Longitude [E]	Water depth [m]	Recovery [cm]
16421-1	25.03.2012	Normal Fault area (A)	38° 07.645'	143° 32.001'	3770	580
16423-1	26.03.2012	JFAST3 (B)	37° 56.301'	143° 54.840'	6936	869
16425-1	26.03.2012	Trench (B)	38° 04.366'	143° 57.615'	7221	864
16426-1	26.03.2012	Trench (B)	38° 04.228'	143° 58.975'	7550	839
16427-1	27.03.2012	Trench (B)	38° 04.363'	143° 58.050'	7412	875
16429-1	27.03.2012	Trench (B)	38° 04.273'	143° 58.572'	7500	607
16431-1	28.03.2012	Trench - S (B)	38° 00.177'	143° 59.981'	7542	940
16433-1	28.03.2012	Trench - N (B)	38° 07.843'	144° 00.135'	7525	926
16435-1	29.03.2012	forearc basin (C)	38° 22.907'	142° 43.006'	1411	197
16437-1	29.03.2012	forearc basin (C)	38° 14.757'	142° 48.600'	1405	227
16438-1	29.03.2012	forearc basin (C)	38° 14.589'	142° 48.029'	1355	-
16439-1	29.03.2012	forearc basin (C)	38° 14.544'	142° 49.988'	1382	177
16442-1	01.04.2012	Normal Fault area (A)	38° 11.467'	143° 33.249'	3468	485
16444-1	01.04.2012	southern Trench area (B)	37° 42.017'	143° 42.377'	7529	1138
16447-1	04.04.2012	Area D	36° 45.319'	141° 57.148'	2386	372
16449-1	05.04.2012	Area D	36° 47.412'	141° 59.675'	2486	421

4.5.2 Multicorer (MUC)

(H. Fink)

A multicorer (MUC) was deployed to recover the sediment-water interface, the undisturbed sediment surface, and the overlying water. The MUC was equipped with six large and four small plastic tubes, each of 60 cm length and 10 and 6 cm in diameter, respectively.

During RV Sonne cruise 219A, the MUC was deployed twice. At station GeoB 16421-2, only 3 tubes were filled with few centimetres of sediment and stored as bulk samples. At station GeoB 16437-2 the MUC was successful (all tubes filled up to 40 cm). One tube was analysed for interstitial water, one tube was stored as archive, 2 tubes were cut into 1-cm slices and finally one tube was split lengthwise and used for visual core description (Appendix).

4.5.3 Sediment description

(M. Strasser, K. Ikehara)

Split gravity cores were photographed and described from a largely sedimentological standpoint. Grain size and composition of sediments were determined visually using a simple hand-lens, a binocular microscope and HCl-testing. Smear slides of dominant lithologies were analyzed under a cross-polarizing microscope in accordance with Rothwell (1989). The size of grains was assessed based on Wentworth's (1922) classification. The color of the material was determined visually using revised standard soil color charts (Oyama and Takehara, 1967). Following on-board detailed core description a composite one-page core log sheet was compiled for each gravity core. It shows the graphical core log and gives information on dominant lithologies, primary sedimentary structures, bioturbation, soft-sediment deformation and sampled interval for further post-cruise analysis (e.g. ash samples), which are indicated by patterns and symbols in the graphic logs. A key to

the full set of patterns and symbols used on the barrel sheets is shown in Appendix (Fig. 9.2.1). The symbols are schematic, but they are placed as close as possible to their proper stratigraphic position on the composite core log. All core descriptions are provided in the Appendix (9.2).

4.6 Physical properties

4.6.1 Magnetic susceptibility

(T. Kanamatsu)

The magnetic susceptibility (MS) of sediment cores was routinely measured using Bartington MS3 apparatus. Pass-through MS measurement on cores was originally planned using a MS loop sensor. But unfortunately a diameter of MS loop sensor prepared by T.K. is smaller than that of a core liner. In this cruise MS measurements were carried out with setting the sensor parallel to split core surface. Although a proper data calibration of this system coordination is not available, onboard MS measurements are expected to figure out sedimentation patterns through their fluctuating patterns. A high resolution MS measurement is planned as a part of MSCL measurement after the cruise in University of Bremen.

MS measurements were done by section by section with blank measurements just before and after measurement of each section to monitor drifting of the sensor. The sensor integrates the response signal over a core interval of about 10 cm. Consequently, sharp susceptibility changes in the sediment column appear smoothed in MS profiles and thin layers may not be resolved appropriately. Other than smoothing effect, MS data for both ends of a section (10 cm) show prominently lower values reflecting the response function than the other interval and a sharp drop.

4.6.2 Undrained Shear strength

(D. Dinten, A. Kioka)

Shipboard undrained shear strength was measured with cone penetrometer tests. The relationship between strength and cone penetration was compared with theoretical predictions and with experimental correlations (Hansbo, 1957; Wood, 1985). Note that the measurement generally underestimates the true in situ undrained peak shear strength, because shipboard measurements naturally take place after disturbance of sediment due to coring and splitting (e.g. Lee et al., 1979). Also, it does not take into account anisotropy effects, as all shear strength measurements were performed in the y-z plane.

Cone Penetrometer test:

A Wykeham-Farrance cone penetrometer was used for a first-order estimate of the sediment stiffness and of the relative downcore trends in undrained shear strength. For the measurement, a metal cone was brought to a point exactly on the split core surface. A manual displacement transducer was then used to measure the distance prior and after the release of the cone (i.e., penetration after free fall of the cone). Precision is about 0.1 mm of displacement. The so measured penetration depth of the falling cone (d) can then be translated into sediment strength using empirical calibration factors “cone factor” (k) derived from systematic comparison of fall-cone tests

and shear strength experiments (see Hansbo, 1957; Wood, 1985; Lu and Bryant, 1997). The undrained shear strength (S_u) is calculated as

$$S_u = kmg / d^2$$

where the cone factor k has been set as $k = 0.85$ for the used 30° cone (Wood, 1985), m is the defined weight of the cone ($m = 80.51$ g) and g is the gravitational acceleration (set constant as $g = 9.81$ m/s² and ignoring variation due to ship motions). Note that we cannot measure the shear strength less than 0.91 kPa owing to the measurement limitation of the used cone penetrometer.

During cruise SO219A, cone penetrometer tests have been performed on all gravity cores. For those cores, 7 to 10 tests have been conducted on each 1m-core-segment, resulting in a vertical resolution ~10 to 15 cm.

4.7 Geochemistry

(M.Kölling, P. Geprägs)

Gas sampling

Sediment samples for gas analytics were taken on the work deck simultaneously to taking off the core catcher and recovering the liner from the gravity corer. 1mL syringes were used to sample 0.5 ml of sediment from the upper end of the core segment immediately after cutting the liner into 1m segments. The sediment sample was transferred to a 4mL glass bottle with a septum cap and a 2mL saturated NaCl brine receiver.

Pore water sampling

The 1 m core segments were transferred to the GeoLab and curated followed by pore water extraction from the closed core within the first three hours after retrieval (before opening and description). Pore waters were sampled using rhizon samplers (Dickens et al, 2007). Before use, rhizons were placed in a beaker with pure water. A standard 3.8 mm diameter drill bit was used to drill a hole in the plastic liner. A spacer on the drill bit prevented it from going into the core material. Core catcher samples were sampled in a bag after they were delivered to the GeoLab from the work deck. If necessary, a 2.5 mm wide stainless steel stick was used to prepare a hole in the sediment. A rhizon sampler was carefully pushed into the sediment and connected to a 20 mL disposable syringe. Vacuum was established by pulling the syringe plunger and keeping it open with a wooden spacer. After a few minutes, the syringes were taken off and the first 0.5 mL of sample was discarded. The vacuum was then reattached and sampling continued until either the syringe was filled or sampling was stopped. The sampling interval was generally 3 cm (0 to 15 cm), 5 cm (15 to 30 cm), 10 cm (30 to 100 cm) 25 cm (100 to 200 cm) and 50 cm below 200 cm. Based on the first results, additional samples were taken from the open working core half to increase the resolution of the data if necessary. The pore water flow was generally good, so that most sample volumes were between 5 and 18 mL after a maximum of three hours.

The syringe was emptied into a 20 mL scintillation vial (Greiner, polypropylene) and stored cool. Sample splits were taken from the master sample. Filtering was not necessary because the

maximum pore width of the rhizons is 0.2 µm. Broken rhizons could easily be detected, as the vacuum can not be maintained when the porous tube is damaged. These rhizons were replaced.

Labelling

The syringes were first hand-labeled with core and sampling depth information, and then the sample was entered into GeoB Expedition DIS. The primary sample label was used for a 20 mL vial (PP, Greiner). Additionally, all samples and all sample splits were labelled with a circled sequential number. This sequential number is useful to quickly label temporary sample containers in the lab and for sorting samples. Samples were collected in the GeoLab and measured for pH, alkalinity and ammonia in the cleanlab (Reinlabor). The results were entered into a worksheet to calculate alkalinities and calibrated ammonia concentrations.

Sample splitting

Five sample splits were taken from the pore water master sample. Where exact amounts were needed adjustable pipettes (Eppendorf 1000 µL, Eppendorf 200 µL) were used to transfer samples from the primary sample vial. Table 4.7.1 shows the sample-split priority sequence.

Table 4.7.1: Sample-split sequences taken from the pore water master sample.

seq	split	Analysis	marker	Amount / type	preserv	Vial
0	gas	Onshore	Blue tape	0.5 mL fresh sediment	2 mL saturated NaCl soln	Twist cap glass 4
1	anions	Onshore	Green tape	0.02 mL PW	1.980 mL pure water -	Eppendorf PE 2
2	Alkalinity / pH	Offshore	none	0.5 mL PW	-	Eppendorf PE1.5
3	NH ₄	Offshore	none	0.5 mL PW	-	Eppendorf PE 2
4	cations	Onshore	yellow tape	1 mL PW	9 mL 0.65% HNO ₃	Scintillation vial PP 20
5	$\delta^{13}\text{C}$ $\delta^{34}\text{S}$ $\delta^{18}\text{O}$ / δD	Onshore	green tape	2 mL PW	No headspace	Crimp glass 1.8
6	S / $\delta^{34}\text{S}$	Onshore	yellow tape	1 mL PW	0.5 mL ZnAc	Twist Cap gl 4
7	Residual of master sample	backup	white tape	1-12 mL PW	-	Scintillation vial PP 20

Pure water

18 MOhm water was generated in the clean lab from the ship's tap water with a Barnstaedt three-stage water purifier. The conductivity of the water was controlled to be <0.05 µS (>18 MOhm) by the built in conductivity detector. Pure water for normal laboratory use was produced in batches of 10 L and stored in a carboy. Pure water for standards and for dilutions of original samples was always prepared freshly.

Sample temperature

In situ temperatures of the sample could not be measured. The water temperatures at the sites were generally around 12°C. Temperatures in the clean lab were very constantly between 22.5 and 24.5 °C. For pH measurement, the temperature compensation was set manually according to an external temperature sensor that reacted to the room temperature. Since pH measurements were performed in 1.5 mL Eppendorf vials, sample temperatures were expected to equilibrate with room temperatures.

pH value

The pH value was measured with a Mettler Toledo InLab 423 microcombination glass electrode with a 3 mm tip connected to a WTW pH 340i pH meter. In 1.5 mL Eppendorf cups, the pH value and the alkalinity were determined from 0.5 mL of sample. A constant reading was achieved by turning the vial around the electrode with a special magnetically driven vial holder rather than stirring the sample with a stir bar. The pH meter was calibrated at least once a day using AppliChem color coded NBS scale pH buffer solutions (pH = 4.00 and 7.00). Slope and offset of the sensor were recorded. Temperatures were monitored with a pt1000 T-sensor next to the sample vial. The instrument shows the pH with a resolution of 0.001 pH units. The measurement has an accuracy of better than ±0.02 pH units.

Alkalinity

Alkalinity was determined by titration with 0.01M, 0.05M or 0.1 M HCl. The equivalence point was detected by titrating 0.5 mL of sample with 0.01M or HCl while controlling the pH value. Titration was stopped at pH < 3.9. The algorithm used to calculate alkalinity accounts for the activity of seawater and dilution by the titration solution so that the results are stable for different endpoint pH values. The measurement has an accuracy of better than 0.2 mmol/L. The algorithm is a corrected version of the algorithm in Grasshoff et al. (1983).

$$Alk \left[mol \cdot L^{-1} \right] = 10^{-pH_{initial}} \cdot f_{H^+_{initial}}^{-1} \cdot V_0^{-1} + c_{HCl} \cdot V_{HCl} \cdot V_0^{-1} - 10^{-pH_{final}} \cdot f_{H^+_{final}}^{-1} \cdot (V_0 + V_{HCl}) \cdot V_0^{-1}$$

pH initial - original pore water pH

pH final - pH at endpoint of titration usually pH 3.95

fH⁺ - activity coefficient of H⁺ for standard seawater this is 0.755

c HCl - concentration of titration solution, usually 0.01 or 0.05 mol/L

vHCl - titration volume depending on Alkalinity of sample

v0 - initial volume of sample usually 0.0005 L (500 µL)

Ammonium

Ammonium was detected using the PTFE tape gas separator technique (modified after Hall and Aller, 1992). With this technique, ammonium is stripped from a 100 µL sample by an alkaline carrier solution (0.2M Na citrate in 10 mM NaOH), passes a 200 mm x 5 mm PTFE membrane area as ammonia(NH₃), and is redissolved as NH₄⁺ in an acidic solution (1 mM HCl). The NH₄⁺ causes a conductivity signal in the acidic carrier that is detected with an Amber Science 1056 conductivity meter with a model 529 temperature-compensated micro flow-through cell. The conductivity signal

was recorded with a Knauer strip-chart recorder, and peak height was analyzed manually. This method is very precise and stable and shows a linear conductivity response for ammonium concentrations between 10 and 1500 μM . The detection limit is 5 μM , and accuracy is better than 2%. Generally, measurements were made with the original sample. If the ammonium concentration was outside the calibrated range (0 to 1.6 mM) the sample was diluted with artificial seawater. Ammonia calibration standards were freshly prepared from a 55.6 mM (1000 ppm) standard solution using artificial seawater as a background.

300–400 μL of sample were taken from the ammonia sample split with a Hamilton 1000 μL precision glass syringe and injected onto a 100 μL loop with a Rheodyne high-pressure liquid chromatography (HPLC) valve. The valve was then opened to the carrier solution stream to start analysis. The Hamilton syringe was rinsed with pure water twice before and after analysis.

Headspace gas sampling

Headspace samples were taken on the work deck when the core liner was cut into 1m segments upon recovery from the gravity corer. Using a cut-off disposable 1 mL syringe, 0.5 mL of fresh sediment were sampled generally from the top of each segment directly after cutting. The sample was immediately transferred into a 4 mL septum twist cap vial containing 2 mL of saturated NaCl brine. The vials were sealed, labelled and stored in a padded box. All headspace samples were labelled with a sequential number. After sediment sampling for gas analysis the core was capped and transferred to the GeoLab for labelling and further processing. The headspace samples were noted in the lab book and entered into the GeoB Expedition DIS.

5. Initial shipboard results

5.1 Sedimentology

(M. Strasser & K. Ikehara)

Detailed descriptions of all cores opened on board are given in the Appendix (9.2). In the following we summarize initial results based on sedimentological and lithostratigraphic observations. We first describe general lithologic characteristic and features for all study areas and then separately describe individual key results for each Study area.

The dominant lithology of sediments cored during SO 219a is a bioturbated diatomaceous hemipelagic mud with various degree of black colour patching and banding intercalated with coarse silt and fine sand layers and volcanic ashes (Fig. 5.1.1a). The siliceous biogenic fraction generally comprises diatoms tests and fragments, silicoflagellates, radiolarian fragments and spines, and sponge spicules (Fig. 5.1.2a). Depending on water depth of core locations (and thus relative depth to the Carbonate Compensation Depth CCD), calcareous biogenic components are also present as a minor component (foraminifera fragments and coccoliths) in cores taken from shallower than ~3770 meter water depth. The detrital fraction of the dominant lithology generally comprises varying fine- to coarse silt-sized volcanic glass shards and pumice, quartz, few feldspar grains and accessory minerals, likely mostly of volcanic origin (see representative smear slide photos in Fig. 5.1.2a). Relatively subtle changes in grain size, relative abundance of diatoms vs. other siliceous biogenic components, as well as changes in the relative abundances of coarser volcanic and detrital fraction occur throughout the cored stratigraphic succession. However, there is rather little macroscopically identifiable compositional variation of the diatomaceous mud throughout the core, which is consistent with observation from nearby ODP cores at Sites 1150 and 1151, where the upper ~200m recovered sedimentary succession has been assigned to a single lithostratigraphic units of Pliocene to Quaternary diatomaceous hemipelagic mud and volcanic ashes (Sacks et al., 2000).

Ash layers typically occur as thin light-coloured discrete layers of maximal 2 cm in thickness, generally showing a sharp base and gradual bioturbated upper boundary (Fig. 5.1.1b). Thinner layers often are more heavily bioturbated and evidence for volcanic ash only occurs as patches of lighter colour, dispersed within the diatomaceous hemipelagic mud. More abundant volcanic glass (bubble wall glass shards and pipe-vesicles and vesicular pumice) and minerals such as green hornblends, however, is clearly observed in smear-slides taken from such intervals (Fig. 5.1.2e). The ashes likely represent deposition from volcanic eruption along the Tohoku arc and will be analysed post-cruise for establishing tephrochronological control of the cores.

The various intercalated coarse silt and sand layers typically show sharp lower and gradual (bioturbated) upper contacts. Parallel and ripple-cross lamination and fining-upward is observed in thicker layers (Fig. 5.1.1c; Fig. 5.1.2b), which partly occur as multiple stacked layers likely representing turbidite sequences of several turbidite pulses associated with one single redeposition event. Fine grained non-bioturbated massive mud, few cm to dm in thickness, occasionally overly such turbidite sequences or occurs as thin intervals without distinct coarser layer at the base. Coarse silt and fine sand layers and massive non-bioturbated mud are interpreted to represent redeposition events and are tentatively hypothesized to reflect remobilization of sediments by earthquake shaking, gravitational transport and deposition of turbidite and density flow, respectively. However, detailed post-cruise sedimentological examination of these layers and intervals is required to further elaborate and test this hypothesis.

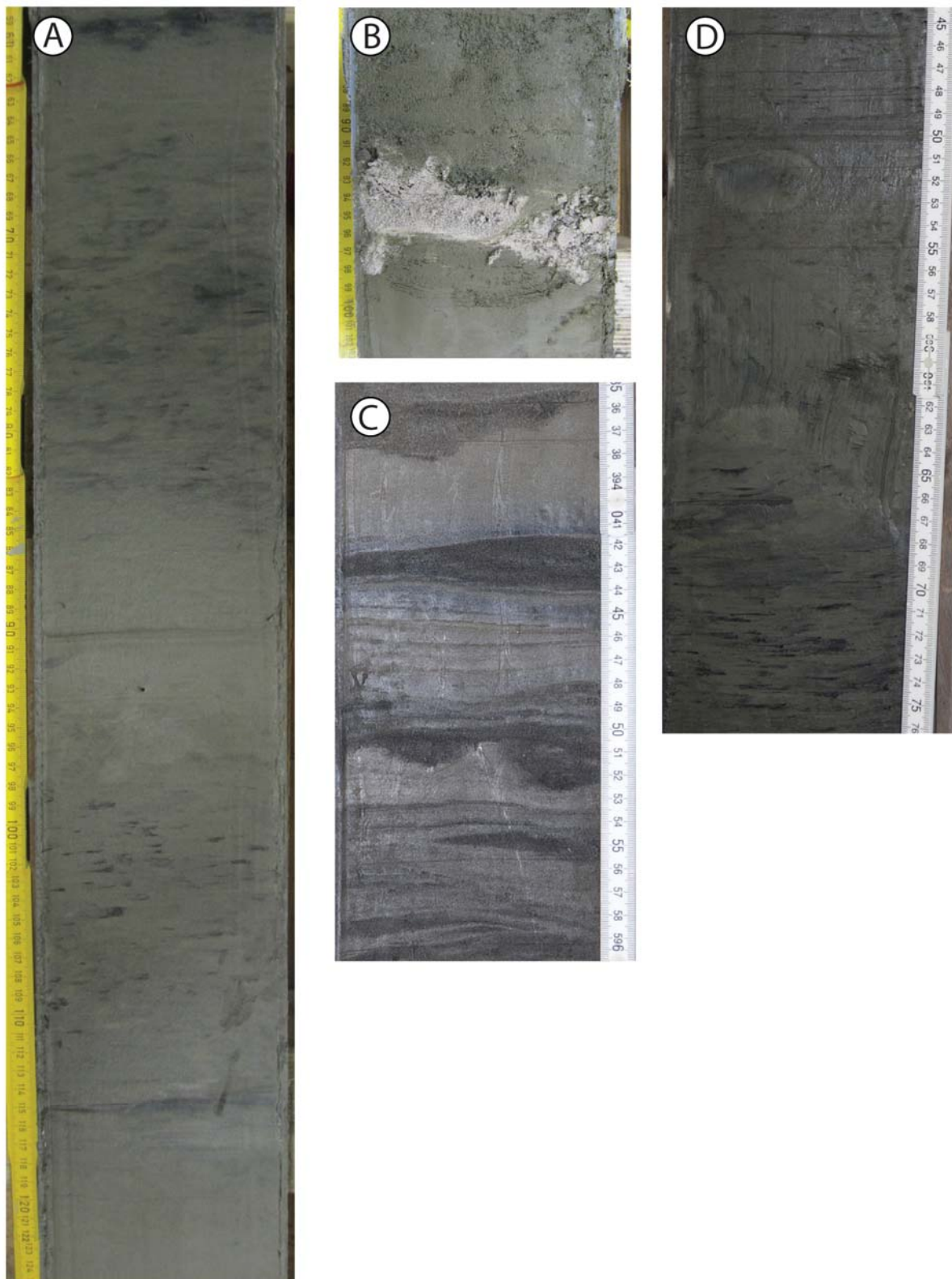


Fig. 5.1.1: Core Photograph showing typical occurrence of dominant and minor lithologies recovered during SO219A: a) GeoB 16444-1, 359-425 cm: general appearance of bioturbated hemipelagic diatomaceous mud with various degree of black colour patching and thin intercalated coarse silt layers (b) GeoB 16442-1, 574 - 599 cm: typical appearance of a vitric volcanic ash layers (c) GeoB 16431-1, 574 - 599 cm: multiple stacked coarse silt and sand layers with parallel and ripple-cross lamination and fining-upwards (d) GeoB 16423-1, 844-876 cm: typical appearance of a mass transport deposit with mud clasts and internal steeply dipping (shear?) surfaces.

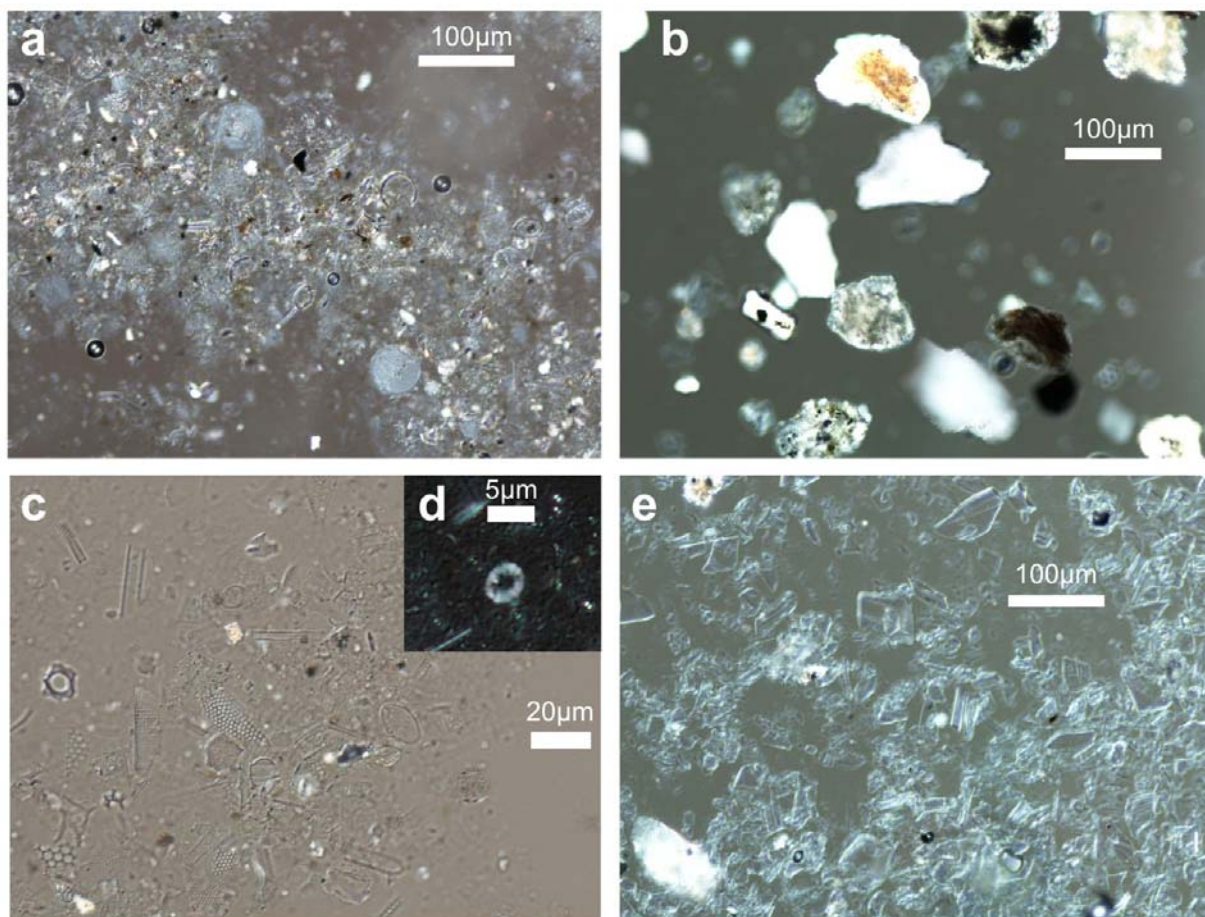


Fig. 5.1.2: Selected representative smear slide image showing typical microscopic characteristic of dominant and minor lithologies recovered during SO219A: a) GeoB 16431-1, 20 cm, typical occurrence of diatomaceous hemipelagic mud; b) GeoB 16431-1, 401 cm, typical occurrence of tubidite sand; c) GeoB 16431-1, 532 cm, coccolith-bearing diatomaceous hemipelagic mud recovered at trench sites more than 7500 meter water depth d) detailed image of a coccolith in the same smear slide shown in c); e) GeoB 16442-1, 295 cm, typical occurrence of vitric ash with bubble wall glass shards and pipe vesicles pumice

Preliminary core-to-core correlation, using prominent turbidite sequences and intercalated ash layers suggests that individual event layers may be correlated over relative large areas ranging from the fore arc basin to the deep Japan Trench. However, stratigraphic correlations need to be established based on reliable age-models, which will be examined in post-cruise work.

Minor lithological characteristics are represented by scattered mm- to cm-scale black specks and black colour banding as well as thicker intervals comprising darker (black) colours. Microscopically, smear slides from such intervals sometimes comprise optically isotropic framboids, which are interpreted as FeS pigments. If abundantly present, these black-coloured specks, stripes and intervals are the most prominent features to be observed upon first core inspection after core splitting, even though they may just represent post-depositional mineralization products. Alternatively, they may reflect various periods of difference in the bottom water oxygenation level, which will be further investigated in post-cruise work.

Additional observation from initial shipboard core description include the occurrence of clear evidence of mass-transport deposits (MTD) in three cores (GeoB 16423-1, GeoB 16426-1 and GeoB 16429-1) from the lower landward trench-slope around 7000 to 7550 water depth. These evidences

for MTD comprise convolute bedding, mixed multi-coloured to chaotic sediments, siltstone gravels and mud clasts floating in diatomaceous mud matrix and mud blocks of various sizes (Fig 5.1.1d).

Initial Results and key observations in the different study areas:

Normal Fault basins (Working Area A):

The two cores recovered from the normal fault basins (cores GeoB 16421-1, GeoB 16442-1, Fig. 5.1.3) are characterized by calcareous biogenic (coccoliths and foraminifera) bearing diatomaceous mud with intercalated coarse silt-fine sand turbidite beds. The core from the upper, northern basin shows more densely spaced and coarser turbidite beds and also contains prominent ash layers, which hopefully may provide age information along with possible foraminifera (isotope and/or ^{14}C) stratigraphy, to be examined in post cruise work. The Multicorer (MUC) at Station GeoB 16421-1 only recovered few cm of the seafloor sediment comprising a polymictic silty fine sand composed of diatoms, radiolarian, spicules, ash shards, pumice, lithic grains, benthic and planktic foraminifera. This layer potentially is a turbidite layer related to the 2011 Tohoku earthquake.

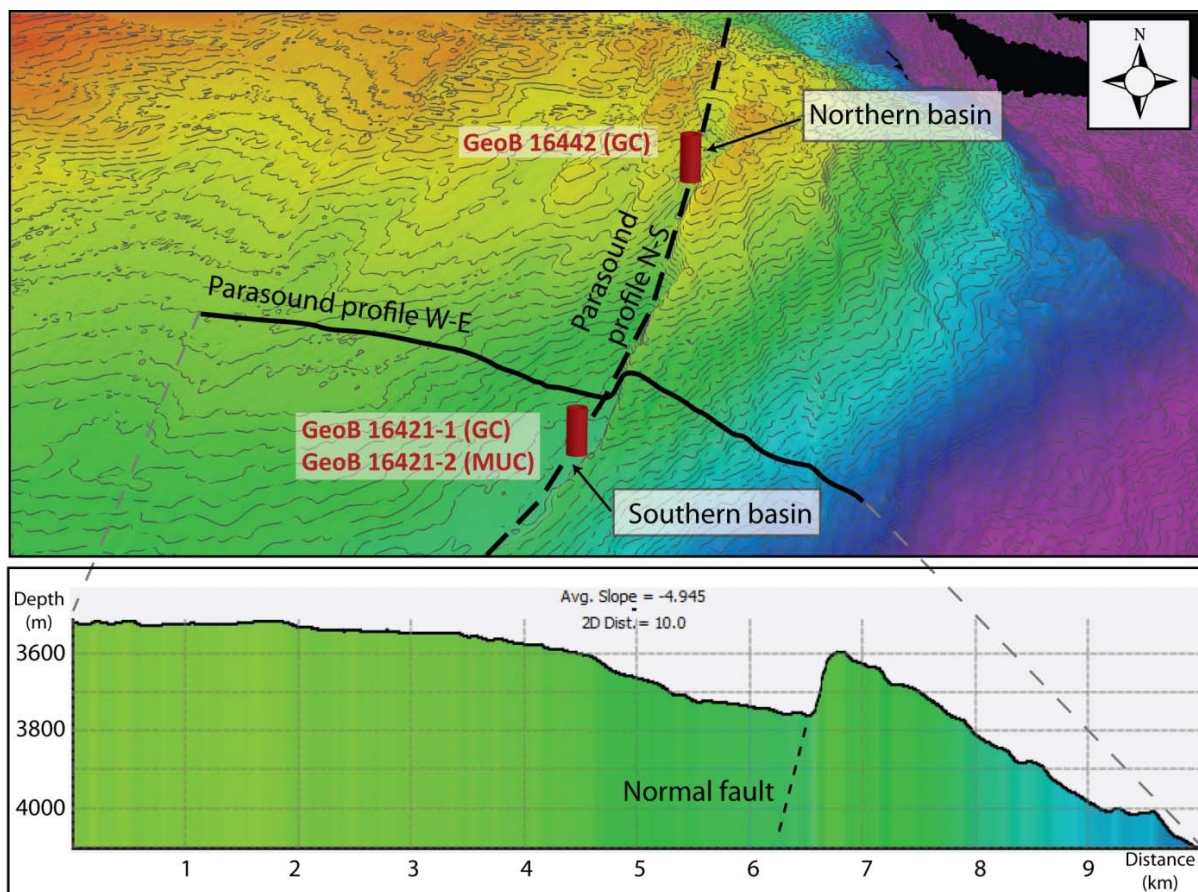


Fig. 5.1.3: 3-D-Fledermaus bathymetry image and profile showing working area A (Normal fault area), indicated are the parasound profiles and coring sites of Gravity corer and Multicorer.

Trench Area (Working Area B):

Three cores were retrieved from the central depression of the more than 7500 meter deep trench floor (cores GeoB 16431-1, GeoB 16433-1, GeoB 16444-1). They represent a trench-parallel coring transect along two independent axial trench basins covering ~65 km in along-strike, north-south direction). These cores are characterized by two or three thick turbidite sequences possibly related to past large earthquakes, and by dark-light color changes possibly reflecting paleo bottom water oxygenation level. At least one prominent ash layer occurs in all cores which will be analyzed post-cruise for tephrochronology/tephrostratigraphy to confirm the tentative core-to-core correlation. A coccolith-bearing interval (Fig. 5.1.2c) occurs in all three cores immediately overlying a prominent turbidite sequence. Redeposition of coccolith-bearing diatomaceous mud from shallower areas (above the CCD) is the most plausible explanation for the occurrence of coccoliths in sediments at water depth > 7500 m. Thus, the massive coccolith-bearing mud is likely associated with the underlying turbidite sequence and may be related to the same event.

A coring transect (cores GeoB 16425-1, GeoB 16426-1, GeoB 16427-1, GeoB 16429-1) perpendicular to the strike of the lower most trench slope was conducted (Fig. 5.1.4) to investigate the large negative displacement identified on differential bathymetry comparing pre- and post Tohoku Earthquake multibeam data (Fujiwara et al., 2011). Cores from the foot of the slope (GeoB 16426-1, and GeoB 16429-1) show clear evidence for recent mass-movements deposition (characteristics of MTD see above), whereas cores from the upper part of the slope show “normal stratigraphy” with some evidence for tilted beds (core GeoB 16427-1). A further MTD was observed below 49 cm core depth in core GeoB 16423-1, which is located on a shallower (6936 m water depth) lower-trench slope segment ~20 km south of the above-mentioned coring transect.

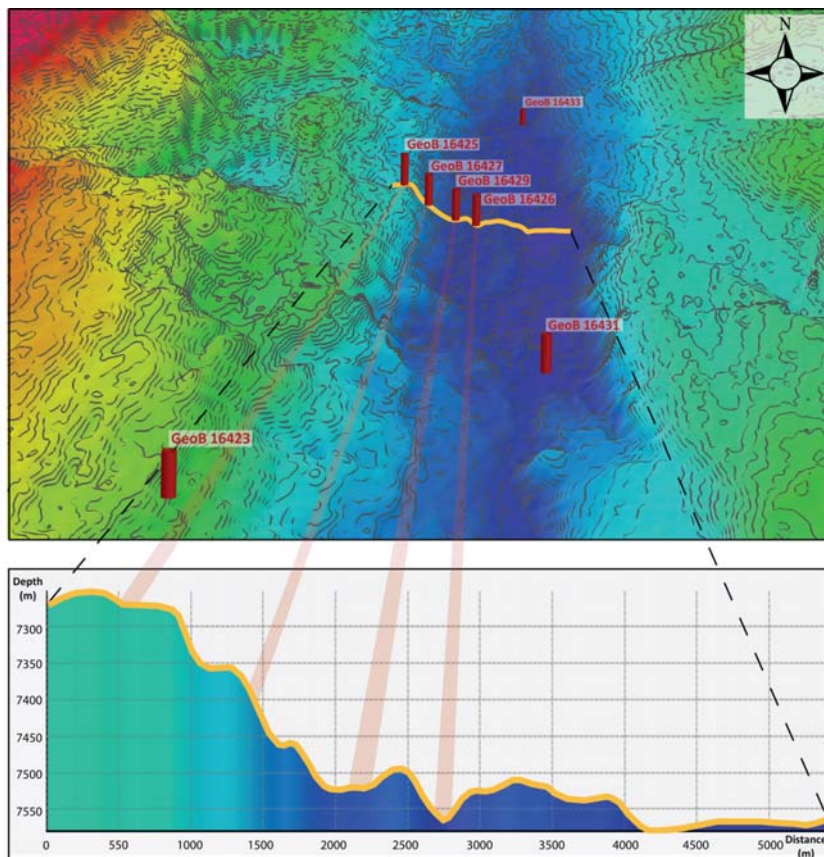


Fig. 5.1.4: 3-D-Fledermaus bathymetry image and profile showing working area B (Trench area), indicated are the parasound profiles and coring sites of the Gravity corer.

Forearc Basins:**Working Area C:**

Cores recovered from the forearc basins in working area C (cores GeoB 16435-1, GeoB 16437-1, GeoB 16437-2, GeoB 16438-1, GeoB 16439-1, see Fig. 5.1.5 and 5.1.6) provided only limited recovery of maximal 2.77 meter (at station GeoB 16337-1). Core GeoB 16438-1 even revealed no recovery, likely due to no-sediment cover and harder substrate outcropping on top of the ridge in the footwall block of the seaward-dipping normal fault investigated in this area.

The recovered forearc basin sediments are characterized by bioturbated diatomaceous hemipelgaic mud with coarser, sometimes gravelly sediments in the lower part. A sandy layer comprising a sharp base and parallel-cross lamination and containing more abundant benthic foraminifera observed in smear slides likely correlates to the 2011 event deposits identified in MUC cores previously obtained during Japanese Cruise KT-11-17 at the same position (Station Nr. 6; Ikehara et al., 2011).

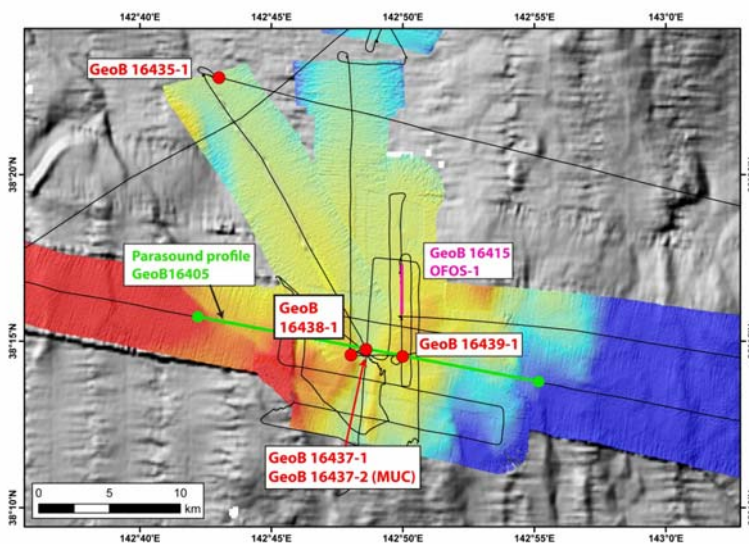


Fig. 5.1.5: Bathymetry map and parasound profile tracks of working area C (northern Forearc basin); indicated are coring sites of the Gravity corer and the Multicorer, and the track of OFOS dive 1 (GeoB 16415).

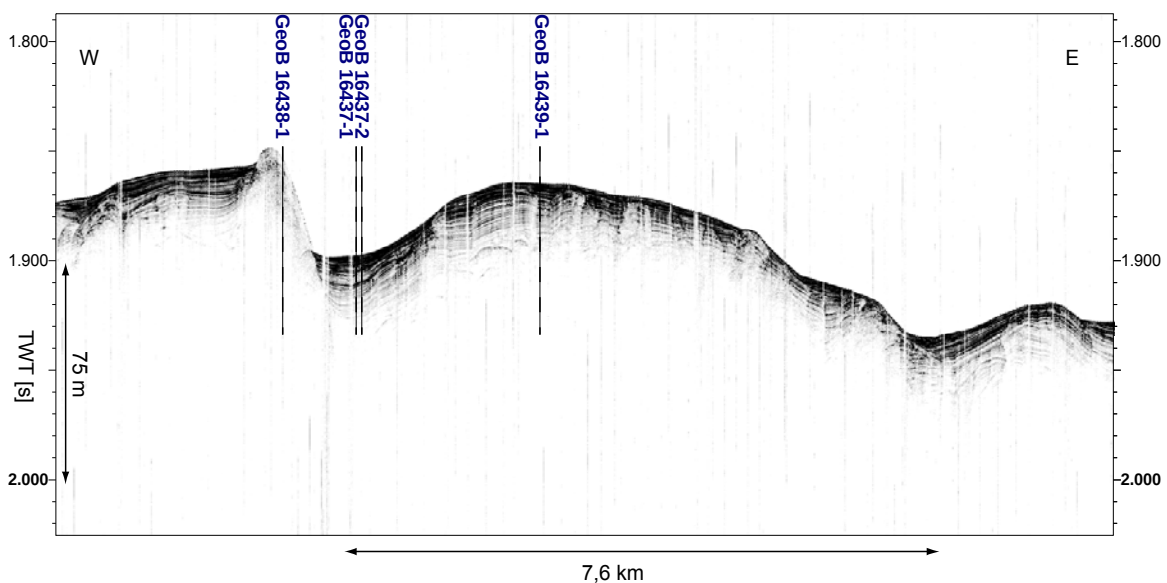


Fig. 5.1.6: Parasound profile GeoB 16405 (W-E) in working area C (northern Forearc basin). Indicated are the coring sites of the gravity corer.

Working area D:

Cores GeoB 16447-1 and GeoB 16449-1 were recovered to characterize the sediments of the fore arc basin surveyed around 36°45' N at ~2500 meter water depth (Fig. 5.1.7). Core recovery was 3.72 and 4.21 meter, respectively. The cored succession comprises grayish olive to olive black, bioturbated diatomaceous hemipelagic mud (coccolith and foraminifera bearing). Only few small dispersed ash patches are recognized in the otherwise relatively homogenous-looking core.

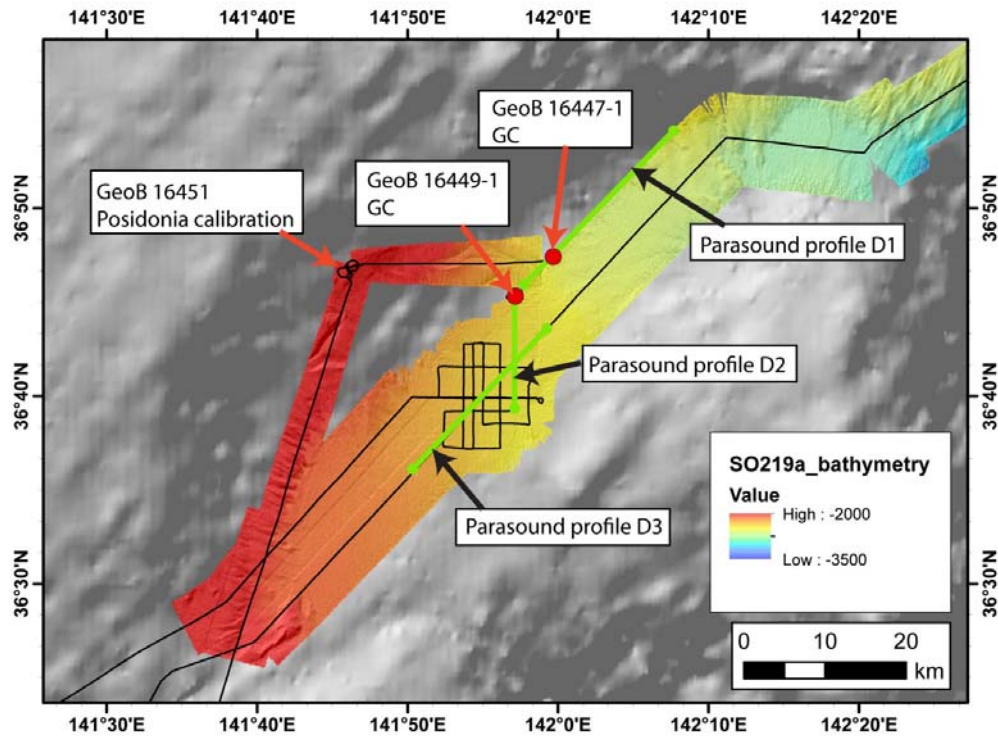


Fig. 5.1.7: Bathymetry map and parasound profile tracks of working area D (southern Forearc basin); indicated are coring sites of the Gravity corer.

5.2 Physical properties

5.2.1 Magnetic susceptibility

(T. Kanamatsu)

Profiles of magnetic susceptibility (MS) for all cores are given in the appendix. Generally MS of SO219A cores are characterized by weak MS in diatomaceous mud, and strong MS in sand layers and occasionally in tephra layers. Sometimes MS profiles show a similar fluctuation trend on basin scale. For example, in the trench basin, a remarkable high MS peak is found in all cores just below the interval of coccoliths-bearing diatomaceous mud. In the normal fault area, an unique MS profile, which consist of two patterns, is recognized in cores. Identification of such patterns in MS profiles is informative guide to understand sedimentation history of the area.

Normal Fault basins (Working Area A):

MS profile from the normal fault area (GeoB 16421-1 and GeoB 16442-1) is characterized by two different fluctuating patterns. One is a sharp fluctuation in the upper interval, and the other is a relatively less fluctuation in the lower interval.

GeoB 16421-1: high magnetic susceptibility peaks are at around 56 cm, 210 cm and 280 cm, which are correlated to silt - fine sand intervals. Below ca. 300 cm a smaller fluctuation is in the MS profile (see Fig. 11.3.1; Appendix). **GeoB 16442-1:** Occasional high peaks between 0 and 240 cm, and a prominent high peak of sand layer around 280 cm are observed. Below ca. 300 cm a smaller fluctuation is in the MS profile (see Fig. 11.3.12; Appendix).

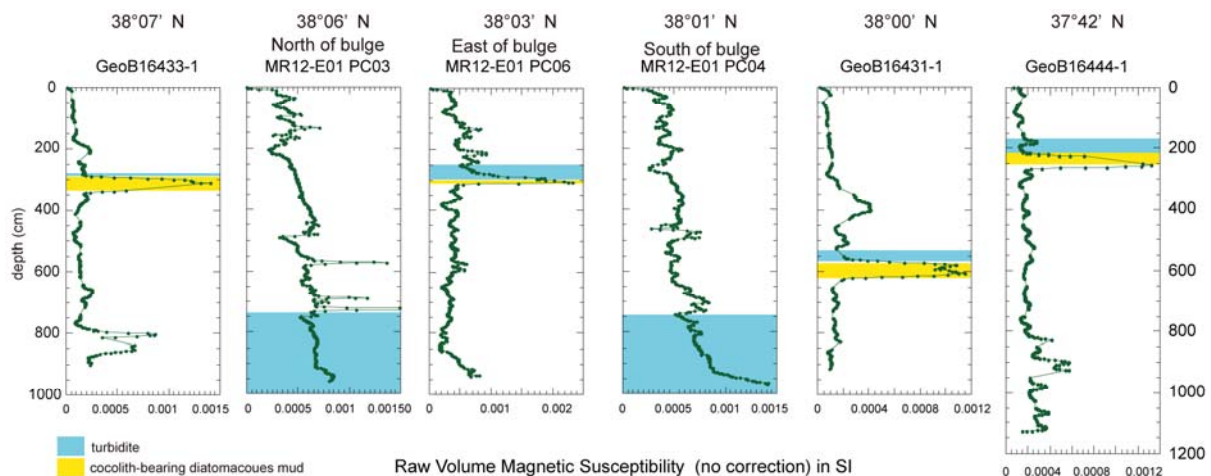


Fig. 5.2.1: Magnetic susceptibility profiles of cores taken from trench basins by SO219A and MR12-E01. Blue shows interval of coccoliths-bearing diatomaceous mud. Yellow show sand layers below coccoliths-bearing diatomaceous mud.

Trench Area (Working Area B):

Three major turbidite intervals are identified in sediment cores, taken from the trench floor (GeoB 16431-1, GeoB 16433-1, GeoB 16444-1). High magnetic susceptibility peaks are identified in those intervals. A prominent high MS in the turbidite interval just below the interval of coccoliths-bearing diatomaceous mud is an unique feature in the profiles. A similar pattern is identified in MS

profiles of cores taken by cruise MR12-E01, JAMSTEC (see Fig. 5.2.1). In cores, taken from the landward slope of the trench (cores GeoB 16423-1, GeoB 16425-1, GeoB 16426-1, GeoB 16427-1, GeoB 16429-1), prominent high magnetic susceptibility are in a black colored tephra layer (GeoB 16426-1), a white tephra layer (GeoB 16425-1), and a sand layer (GeoB 16425-1).

GeoB 16423-1: A relatively strong MS is in the interval between 0 and 257 cm, and a high peak at 70 cm, probably relating to mud clast interbedding. MS increases downward below ca. 430 cm (see Fig. 11.3.2; Appendix). **GeoB 16425-1:** A broad high MS is in the interval of 20-80 cm caused from a frequent sand layer interbedding. High MS are at 200 cm without visible lithological feature, at 410 cm in a tephra layer, and in a sand layer at 440 cm (see Fig. 9.3.3; Appendix). **GeoB 16425-1:** A very high MS at 730 cm is observed in a black ash layer (see Fig. 9.3.3; Appendix). **GeoB 16427-1:** A broad MS peak around 90-10 cm occurred in silt –fine sand layers. A high MS peak is in a tephra layer at 319 cm. Relatively low MS below 700 cm (see Fig. 9.3.5; Appendix). **GeoB 16429-1:** A relatively high MS interval is between 0 and 280 cm (see Fig. 9.3.6; Appendix). **GeoB 16431-1:** A broad peak is in sand layers (turbidite sequence) between 350 and 420 cm. A smaller peak is in 510-520 cm. 550-620: Very high MS is in sand layers (turbidite sequence) below the coccoliths-bearing diatomaceous mud (see Fig. 9.3.7; Appendix). **GeoB 16433-1:** A broad peak is in sand layers (turbidite sequence) between 170-215 cm. A very high MS interval around 280-340 cm is observed in sand layers (turbidite sequence), which are below the coccoliths-bearing diatomaceous mud. A large peak is in sand layers (turbidite sequence) between 770-850 cm (see Fig. 9.3.8; Appendix). **GeoB 16444-1:** A large peak is in sand layers below coccolith bearing clay (turbidite sequence) around 280-340 cm (see Fig. 9.3.13; Appendix).

Forearc Basin (Working Areas C and D):

A frequent MS high value is observed in the interval, which sand layers interbed frequently (GeoB 16437-1, GeoB 16442-1).

GeoB 16435-1: An obvious high MS is in a sand layer in the top of core, and broad MS peaks around in 50 and 150 cm (see Fig. 9.3.9; Appendix). **GeoB 16437-1:** High MS values are in sand layers. Below 180 cm, MS is relatively high (see Fig. 9.3.10; Appendix). **GeoB 16439-1:** Below 80 cm a relatively high MS interval is observed. High MS peak is in a sand layer at 160 cm (see Fig. 9.3.11; Appendix). **GeoB 16442-1:** Between 0 and 300 cm, several MS high peaks are observed. A most prominent peak is in a sand layer at 280-290 cm, which is above a thick white tephra layer (see Fig. 9.3.12; Appendix). **GeoB 16447-1:** A prominent high MS occurs in a sand patch at 275 cm (see Fig. 9.3.14; Appendix). **GeoB 16449-1:** High MS peaks in the top of core and at 253 cm as sandy patch (see Fig. 9.3.15; Appendix).

5.2.2 Undrained shear strength

(D. Dinten & A. Kioka)

In general all cores show clearly an increasing linear shear strength gradient with depth due to the compaction of the overlaying sediments. Variable gradients represent different consolidation stages due to various lithologies, sedimentary regimes, and erosional and/or depositional histories. More coarser grained layers (e.g. sand) and ash layer do not follow the overall trend in the core. Most of the cores show scattering below a certain depth.

Normal Fault basins (Working Area A):

Undrained shear strength values (S_u) derived from the cone penetrometer test in the cores which were taken from the normal fault area range from around 3 kPa and 50 kPa in near seafloor and around 5 m core depth, respectively. These cores show nice linear shear strength gradients with depth in the order of around 10 kPa/m. The measured values in core GeoB 16442-1 show a bigger scatter below 250 cm core depth. Compared to the cores which were taken in the trench basin, the shear strength gradient with depth is much higher (Fig. 5.2.2). The undrained shear strength value for the ash layer at 441 cm in core GeoB 16442-1 goes up to 410 kPa.

Trench Area (Working Area B):

All the cores from the trench area show low shear strength values (S_u). For most of them the shear strength in the shallow subsurface is below the detection limit of the cone penetrometer method and less than 20 kPa in a depth of 3 m. All cores show scattering in the S_u values below 3 m core depth. The scattering was particularly identified in cores GeoB 16423-1, GeoB 16426-1 and GeoB 16429-1. Intervals with higher scatter correlate with mass-transport deposits identified in visual core description (see chapter 5.1). The shear strength gradient with depth in these sediment cores varies from 2 kPa/m to 5 kPa/m. Such low shear strength gradient indicated that the sediment in the trench area is relatively less compacted compared to sediments recovered from the normal fault area or the forearc basin.

Forearc Basin:

Working Area C:

Three cores have been taken from the forearc basin. The higher sand content makes it difficult to get good results in the undrained shear strength, because this fall-cone penetrometer test is not fully applicable for sandy material (Hansbo, 1957). That's why the undrained shear strength values (S_u) are extremely scattered, from close to 10 kPa up to 250 kPa. The big scattering in all cores starts around 60 cm depth. Nevertheless shear strength gradients are distinct for cores GeoB 16435-1 and GeoB 16437-1, where the top is dominated by diatomaceous mud. In this upper interval the calculate shear strength gradient with depth is about 25 kPa/m.

Working Area D:

Two cores were taken from southern forearc basin. Undrained shear strength values (S_u) range from around 2 to 40 kPa. Both cores show a linear shear strength gradient in order of around 13 kPa/m. This gradient is more closer to the normal fault pond than to the more northern upper

for arc basin (Fig. 5.2.2). Below 200 cm core depth the measured values of shear strength show bigger scattering than in the upper part of the cores.

Further post-cruise shore-based laboratory testing will complement the penetrometer test and also will include laboratory shear experiments on discrete samples to reliably calibrate absolute shear strength values from shipboard measurements. This database will eventually reveal the quantitative means for in-depth geotechnical interpretations of consolidation and how it relates to the strength of the sediments, as well as to investigate earthquake-shaking effects on sediment destabilization and deformation.

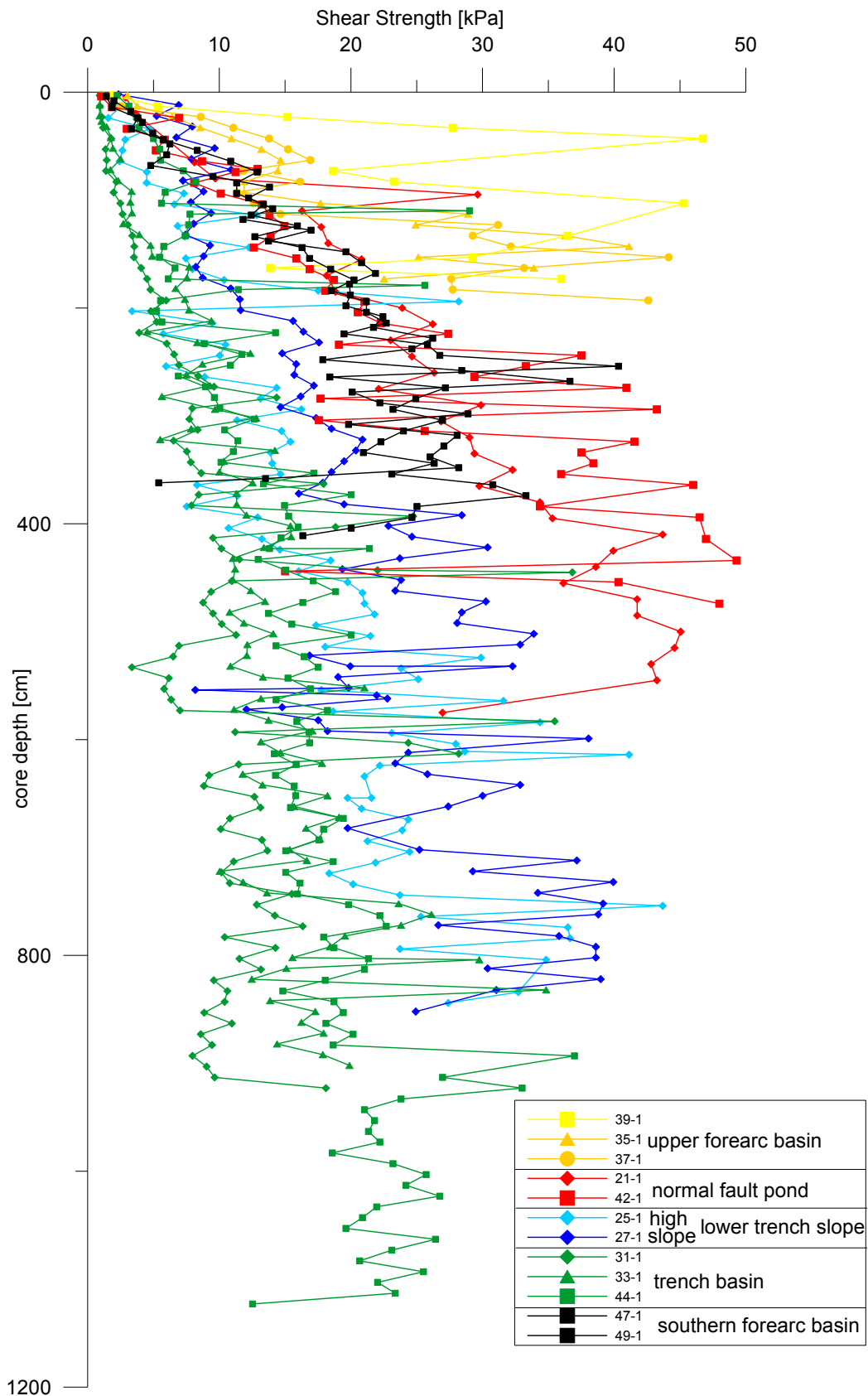


Fig. 5.2.2: Undrained shear strength data derived from gravity cores (GeoB 164xx-x). A trend is observed from the trench basin, which has the lowest shear strength gradient (2 kPa/m – green), over the lower trench slope (5 kPa/m – blue), the normal fault pond (~ 10 kPa/m – red), the southern forearc basin (13 kPa/m – black), to the highest gradient in the upper forearc basin (~ 25 kPa/m – yellow). The shear strength gradient in the southern forearc basin is closer to the one in the normal fault area than to the one in the upper forearc basin. Note that the scattering values of mass transport deposits are removed in this graph for a better visualization of our data.

5.3 Geochemistry Offshore Measurements

(M. Kölling, P. Geprägs)

On SO219A, a total of 361 porewater samples were taken from 11 gravity cores and one multicorer and analysed for pH, alkalinity and ammonia offshore. Alkalinities, and ammonia data indicate high production sediments reaching alkalinities up to 70 mM and ammonia concentrations up to 4mM at depths of 8 to 9 mbsf. Both ammonia concentrations and alkalinities are increasing with depth starting with seawater concentrations at the sediment surface (alkalinity 2.3 mM/L, ammonia 0 mM/L). Most of the cores show non-steady-state profiles of both, ammonia and alkalinities in the upper part: Cores GeoB16427 and GeoB 16444 show a cut profile, where the uppermost porewater values are significantly elevated. The slope of the increase below the surface may be used, to estimate the thickness of the record lost at the top.

Cores GeoB 16426, GeoB 16429, GeoB 16431, and GeoB 16442 show unusual values in the upper part. In these cores, the values slightly increase with depth but decrease significantly to almost seawater concentrations at depths between 0.30 and 1.20 mbsf. Below this minimum, the profile continues with a mostly constant increase with depth, as seen in normal high production sites.

Core GeoB 16425 shows a normally increasing profile in both, ammonia and alkalinities with a very unusual steep negative spike to less than half the expected concentration at a depth of 2 mbsf. The existence of the unusually low concentrations were confirmed by increasing the sampling density around 2 mbsf. These additional samples were taken with rhizons from the work half of the open core.

In most cores some sulfide smell was detected from a certain depth (typically below 2 or 3mbsf), but given the high production rates indicated by the alkalinity data, most sulfide seems to be fixed as iron sulfides that are highly abundant in the cores. Since the source rock for the terrigenous fraction in the recovered sediments is mostly of vulcanoclastic origin, a high abundance of iron minerals is likely and it will keep the formation of sulfide minerals sulfur limited rather than iron limited, keeping the free sulfide concentrations low.

pH-values are in the range of 7.4 to 8.2 which is normal for marine sediments. Single values are significantly higher and might correlate with ash layers in the sedimentary sequences.

Large Authigenic Minerals

In cores GeoB 16423-1 (WD 6936m), GeoB 16425-1 (WD 7221m) and GeoB 16427-1 (WD 7412m) large amber crystals were recovered from depths > 4 mbsf. These crystals were identified as ikaite (Suess et al., 1982), which are known to form as rare authigenic minerals in high production sediments at low temperatures and high pressures. Since ikaite is not stable at room temperature and ambient pressure, they were extracted from the cores, stored under seawater and kept below 4°C.

6. Data and Sample Storage and Availability

All sediment cores and samples are stored in the MARUM core repository. All data produced can be obtained from the respective research groups on request. Data sets which are part of publications will automatically be made publically available on www.pangaea.de.

7. Acknowledgements

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9. Appendix

9.1 Station-List SO219A

9.2 Sediment core description

9.3 Shipboard results on sediment cores (physical properties and geochemistry)

Date	St. No.	Int. No.	Instrument	GeoB St. No.	Location	Time (UTC)				Begin / on seafloor / Bottom contact			End / off seafloor			Recovery / Remarks
						Begin	on seafloor	off seafloor	End	Latitude N	Longitude E	Water depth (m)	Latitude N	Longitude E	Water depth (m)	
08.03.2012		PE-01_1	EM120 and PS	16401-1	Transit to A3-mapping	19:57			7:20				37° 41.344'	143° 9.416'	3270	Bad weather conditions
09.03.2012	1	CTD-1	CTD	16402-1	A3	07:25				37° 41.602'	143° 9.338'	3270	37° 42.126'	143° 9.655'	3270	Down to 2500 m
09.03.2012		PE-01_2	EM120 and PS	16401-2	Transit to A3 start point	10:10			10:47	37° 42.16'	143° 9.74'	3270.1	37° 42.01'	143° 17.00'	3732.9	
09.03.2012	2	PE-01_3	EM120 and PS	16401-3	A3-mapping	10:47			11:17	37° 42.01'	143° 17.00'	3732.9	37° 44.99'	143° 17.00'	3508.7	
09.03.2012		PE-01_4	EM120 and PS	16401-4	Transit to A1-mapping	11:17			13:39	37° 44.99'	143° 17.00'	3508.7	38° 7.92'	143° 32.24'	3782.9	
09.03.2012	3	PE-01_5	EM120 and PS	16401-5	A1-mapping	13:39			14:26	38° 7.92'	143° 32.24'	3782.9	38° 12.77'	143° 33.65'	3439.4	
09.03.2012		PE-01_6	EM120 and PS	16401-6	Transit to A2	14:26			16:40	38° 12.77'	143° 33.65'	3439.4	38° 36.95'	143° 35.49'	3173	
09.03.2012	4	PE-01_7	EM120 and PS	16401-7	A2-mapping	16:40			17:10	38° 36.95'	143° 35.49'	3172.8	38° 39.91'	143° 35.50'	3220	
09.03.2012		PE-01_8	EM120 and PS	16401-8	Transit to JT2	17:10			19:37	38° 39.91'	143° 35.50'	3220.4	38° 44.810'	143° 19.643'	2154	
10.03.2012	5	PE-02_1	EM120 and PS	16403-1	Line MY101	00:00			09:23	38° 44.810'	143° 19.643'	2154	38° 31.428'	143° 21.808'	6290	
10.03.2012		PE-02_2	EM120 and PS	16403-2	Transit to profile in the north	09:23			13:14	38° 31.428'	143° 21.808'	6290	39° 9.05'	144° 16.56'	6940	
10.03.2012	6	PE-03_1	EM120 and PS	16404-1	Northern profile	13:14			18:00	39° 9.05'	144° 16.56'	6940.5	39° 9.09'	143° 38.20'	3567	
10.03.2012		PE-03_2	EM120 and PS	16404-2	Transit to JT2	18:00			20:56	39° 9.09'	143° 38.20'	3567.2				
11.03.2012	7	-	ROV	-	JT2	00:40			01:45	38° 45.166'	143° 19.891'	2187	38°45.174'	143°19.879'	2187	Dive aborted due to bad weather
11.03.2012		PE-03_3	PS	16404-3	Transit to startpoint of line MY102	02:10			06:15	38° 45.18'	143° 19.88'	2215	38° 16.70'	142° 36.07'	1265	EM120 has to be repaired
11.03.2012	8	PE-04-1	EM120 and PS	16405-1	Line MY102 W-E	06:15			00:04	38° 16.70'	142° 36.07'	1265	37° 57.02'	144° 46.98'	5510	
12.03.2012	8	PE-04_2	EM120 and PS	16405-2	Line MY102 - opposite direction	00:15			07:19	37° 57.02'	144° 46.98'	5510				Against the waves, very slow, very bad data quality
13.03.2012	9	PE-05_1	EM120 and PS	16406-1	Middle line W-E	00:57			08:14	38° 22.85'	144° 11.28'	6828.6	38° 22.85'	144° 11.28'	6829	First part with 6 kn, crossing the trench axis with 4 kn
13.03.2012	9	PE-05_2	EM120 and PS	16406-2	Middle line-opposite direction	08:27			17:47	38° 22.85'	144° 11.28'	6828.6	38° 29.12'	142° 47.86'	1481	First part with 8 kn, from 12:37 UTC on with 6 kn
13.03.2012		PE-05_3	EM120 and PS	16406-3	Transit to JT2	17:47			20:45	38° 29.12'	142° 47.86'	1481	38° 45.146'	143° 20.119'	2192	

Date	St. No.	Int. No.	Instrument	GeoB St. No.	Location	Time (UTC)				Begin / on seafloor / Bottom contact			End / off seafloor			Recovery / Remarks
						Begin	on seafloor	off seafloor	End	Latitude N	Longitude E	Water depth (m)	Latitude N	Longitude E	Water depth (m)	
13.03.2012	10	ROV-318	ROV	16407-1	JT2	23:16	01:15	03:12	05:10	38° 45.146'	143° 20.119'	2192	38° 45.031'	143° 19.907'	2192	Observatory found, seems not to be usable anymore
14.03.2012		PE-06_1	EM120 and PS	16408-1	Transit to Line GeoB16404	05:23			08:02	38° 45.031'	143° 19.907'	2192	39° 9.22'	143° 46.29'	4492	
14.03.2012	11	PE-06_2	EM120 and PS	16408-2	Finishing line GeoB16404 to the West	08:02			16:47	39° 9.22'	143° 46.29'	4492	39° 9.14'	142° 40.01'	1270	
14.03.2012		PE-06_3	EM120 and PS	16408-3	Transit to JT1	16:47			20:09	39° 9.14'	142° 40.01'	1272	39° 11.114'	143° 20.196'	2675	
14.03.2012	12	CTD-2	CTD	16409-1	JT1	23:40			01:54	39° 11.114'	143° 20.196'	2675	39° 12.175'	143° 22.126'	2700	Down to 2500m
15.03.2012		PE-07_1	EM120 and PS	16410-1	Transit to line KR10-12	02:18			05:20	39° 12.175'	143° 22.126'	2700	39° 27.31'	143° 4.32'		
15.03.2012	13	PE-07_2	EM120 and PS	16410-2	Profile KR10-12	05:20			16:34	39° 27.31'	143° 4.32'		39° 8.66'	144° 26.74'	6421	PS crashed between 13:45 and 14:34 UTC
15.03.2012		PE-07_3	EM120 and PS	16410-3	Transit back to JT1	16:34			04:01	39° 8.66'	144° 26.74'	6421	39° 10.836'	143° 19.884'	2696	Strong winds and waves led to very bad data quality. in between stop due to weather
16.03.2012	14	ROV-319	ROV	16411-1	JT1	05:15	07:39	10:30		39° 10.836'	143° 19.884'	2696				Found the observatory, seem to be less damaged
16.03.2012		PE-08_1	EM120 and PS	16412-1	Transit to GJT4	13:18			20:58	39° 10.649'	143° 20.171'	2691	38° 24.048'	142° 49.000'	1435	
16.03.2012	15	Mooring	Mooring	16413-1	GJT4	21:00			03:36	38° 24.00'	142° 49.00'	1450	38° 23.309'	142° 47.953'	1437	2 moorings deployed and calibrated successfully
17.03.2012	16	PE-09_1	EM120 and PS	16414-1	GJT4 to P08	03:32			05:33	38° 22.819'	142° 48'	1435	38° 14.63'	142° 49.44'	1385	After the first line S-N ship on stand by due to weather conditions
17.03.2012	17	PE-09_2	EM120 and PS	16414-2	P08	20:50			01:03	38° 14.63'	142° 49.44'	1385	38° 17.18'	142° 50.31'	1391	Continuation of the profile, 2,5 more lines N-S
18.03.2012	18	OFOS-1	OFOS	16415-1	P08	01:25	02:00		05:03	38° 17.065'	142° 49.892'	1400	38° 15.733'	142° 49.872'	1375	
18.03.2012	19	OFOS-2	OFOS	16416-1	close to P10	07:30	08:06	13:25	14:06	38° 13.98'	143° 6.66'	1800	38° 14.214'	143° 10.883'	2250	found cracks on the seafloor
18.03.2012	20	PE-10_1	EM120 and PS	16417-1	A1 area	16:22			00:15	38° 12.752'	143° 30.118'	3344	38° 10.6'	143° 29.985'	3400	Two lines completes W-E
19.03.2012		PE-10_2	EM120 and PS	16417-2	Transit to MY103 (southern line)	00:22				38° 10.6'	143° 29.985'	3400	37° 39.64'	142° 57.42'	2309	

Date	St. No.	Int. No.	Instrument	GeoB St. No.	Location	Time (UTC)				Begin / on seafloor / Bottom contact			End / off seafloor			Recovery / Remarks
						Begin	on seafloor	off seafloor	End	Latitude N	Longitude E	Water depth (m)	Latitude N	Longitude E	Water depth (m)	
19.03.2012	21	PE-11_1	EM120 and PS	16418-1	MY103	07:07			18:01	37° 39.64'	142° 57.42'	2309				
19.03.2012		PE-11_2	EM120 and PS	16418-2	Transit to Yokohama	18:01			6:39				37° 15.39'	144° 13.82'	6094	
24.03.2012		PE-12_1	EM120 and PS	16419-1	Transit to profile GeoB16418	14:40			22:31	36° 6.833'	142° 21.592'	4177	37° 25.132'	143° 43.023'	7795	
24.03.2012	22	PE-12_2	EM120 and PS	16419-2	Trench in GeoB16418	22:31			23:34	37° 25.132'	143° 43.023'	7795	37° 27.784'	143° 35.721'	6775	Filling the bathymetry-gap in profile GeoB16418
24.03.2012		PE-13_1	EM120 and PS	16420-1	Transit to A1	23:34			02:55	37° 27.784'	143° 35.721'	6775	38° 5.917'	143° 30.591'	3800	
25.03.2012	23	PE-13_2	EM120 and PS	16420-2	Southern basin close to A1	02:55			03:45	38° 5.917'	143° 30.591'	3800	38° 8.73'	143° 32.460'	3720	mapping the extension of the southern basin filled with sediments to define a core position
25.03.2012	24	GC-1	GC (9 m)	16421-1	Southern basin close to A1	04:04	05:33		07:06	38° 07.645'	143° 32.001'	3770	38° 7.679'	143° 31.913'	3769	9 m liner, 580 cm recovery
25.03.2012	25	MUC-1	MUC	16421-2	Southern basin close to A1	07:42	09:24		11:46	38° 07.685'	143° 32.015'	3772	38° 7.63'	143° 32.177'	3773	3 of 10 liners with little sediment
25.03.2012	26	PE-14-1	EM120 and PS	16422-1	Transit to profile GeoB16422	11:56			12:25	38° 03.46'	143° 33.19'	3750	38° 03.452'	143° 33.222'	4500	
25.03.2012		PE-14_2	EM120 and PS	16422-2	Profile GeoB 16422	12:26			21:25	38° 03.452'	143° 33.222'	4500	38° 0.165'	143° 31.028'	4390	
25.03.2012		PE-14_3	EM120 and PS	16422-3	Transit to JFAST3	21:25			23:09	38° 0.165'	143° 31.028'	4390	37° 56.326'	143° 54.764'	6895	
26.03.2012	27	GC-2	GC	16423-1	JFAST3	23:29	02:19		05:43	37° 56.301'	143° 54.840'	6936	37° 56.292'	143° 54.850'	6915	12 m liner - 869 cm recovery
26.03.2012		PE-15	EM120 and PS	16424-1	Transit to trench	06:25			07:23	37° 56.292'	143° 54.850'	6915	38° 4.331'	143° 57.638'	7360	
26.03.2012	28	GC-3	GC	16425-1	Trench in GeoB16405	07:27	10:32		14:12	38° 4.366'	143° 57.615'	7221	38° 4.394'	143° 57.613'	7251	12 m liner - 864 cm recovery
26.03.2012	29	GC-4	GC	16426-1	Trench in GeoB16405	15:13	18:55		22:44	38° 4.228'	143° 58.975'	7550	38° 4.833'	143° 57.653'	7273	12 m liner - 839 cm recovery
27.03.2012	30	GC-5	GC	16427-1	Trench in GeoB16405	00:47	04:19		08:06	38° 4.363'	143° 58.050'	7412	38° 4.615'	143° 57.002'	7254	9 m liner - 875 cm recovery
27.03.2012		PE-16_1	EM120 and PS	16428-1	Transit to profile north of GeoB16405	08:50			09:41	38° 5.214'	143° 55.368'	7100	38° 10.318'	143° 49.570'	6370	Good data quality
27.03.2012	31	PE-16_2	EM120 and PS	16428-2	North of GeoB16406	09:41			21:00	38° 10.318'	143° 49.570'	6370	38° 17.063'	144° 7.505'	7150	Good data quality

Date	St. No.	Int. No.	Instrument	GeoB St. No.	Location	Time (UTC)				Begin / on seafloor / Bottom contact			End / off seafloor			Recovery / Remarks
						Begin	on seafloor	off seafloor	End	Latitude N	Longitude E	Water depth (m)	Latitude N	Longitude E	Water depth (m)	
27.03.2012		PE-16_3	EM120 and PS	16428-3	Transit back to coring station	21:00			22:52	38° 17.063'	144° 7.505'	7150	38° 4.677'	143° 58.742'	7500	Good data quality
27.03.2012	32	GC-6	GC	16429-1	Trench in GeoB16405	23:14	02:46		06:45	38° 4.273'	143° 58.572'	7500	38° 3.975'	143° 58.687'	7510	12 m liner - 607 cm recovery
28.03.2012		PE-17	EM120 and PS	16430-1	Trench - S	07:06			07:56	38° 3.880'	143° 58.566'	7510	38° 0.203'	143° 59.967'	7540	Good data quality
28.03.2012	33	GC-7	GC	16431-1	Trench - S	07:58	11:30		15:20	38° 0.177'	143° 59.981'	7542	38° 0.424'	143° 59.631'	7537	12 m liner - 940 cm recovery
28.03.2012		PE-18	EM120 and PS	16432-1	Trench - N	16:05			17:27	38° 0.437'	143° 59.651'	7540	38° 7.826'	144° 0.119'	7530	Bad weather - bad data quality
28.03.2012	34	GC-8	GC	16433-1	Trench - N	21:23	00:53		04:39	38° 7.843'	144° 0.135'	7525	38° 7.717'	144° 0.229'	7535	12 m liner - 926 cm recovery
29.03.2012		PE-19	EM120 and PS	16434-1	Transit to shallow area	05:07			10:04	38° 7.960'	143° 59.993'	7500	38° 22.965	142° 42.879	1420	Speed about 13 kn
29.03.2012	35	GC-9	GC	16435-1	Shallow area (St.6)	10:16	10:47		11:27	38° 22.907'	142° 43.006'	1411	38° 22.864'	142° 42.829'	1409	12m liner - 197cm recovery
29.03.2012		PE-20	EM120 and PS	16436-1	Transit to GC16437	12:11			13:20	38° 22.971'	142° 42.45'	1416	38° 14.799'	142° 48.596'	1406	
29.03.2012	36	GC-10	GC	16437-1	Shallow water area	13:27	13:58		14:35	38° 14.757'	142° 48.600'	1405	38° 14.751'	142° 48.606'	1404	6m liner - 277 cm recovery
29.03.2012	37	MUC-2	MUC	16437-2	Shallow water area	15:12	16:04		16:56	38° 14.758'	142° 48.596'	1405	38° 14.758'	142° 48.597'	1405	40 cm recovery each liner
29.03.2012	38	GC-11	GC	16438-1	Shallow water area	17:25	17:56		18:36	38° 14.589'	142° 48.029'	1355	38° 14.591'	142° 48.028'	1355	6m liner - No recovery
29.03.2012	39	GC-12	GC	16439-1	Shallow water area	19:21	19:57		20:32	38° 14.544'	142° 49.988'	1382	38° 14.455'	142° 49.923'	1384	6m liner - 177 cm recovery
29.03.2012	40	PE-21	EM120 and PS	16440-1	Shallow water area	20:46			04:52	38° 14.334	142° 49.854'	1388	38° 11.953'	142° 50.552'	1420	
31.03.2012	41	PE-22	EM120 and PS	16441-1	Shallow water area	15:32			02:18				38° 11.506'	143° 33.221'	3430	
01.04.2012	41	GC-13	GC	16442-1	Normal fault area (area A)	2:49	04:04		05:25	38° 11.467'	143° 33.249'	3468	38° 11.645'	143° 33.158'	3404	9m liner - 485 cm recovery
01.04.2012		PE-23_1	EM120 and PS	16443-1	Transit to profile trench	5:45			06:23	38° 11.703'	143° 33.257'	3407	38° 09.07'	143° 27.02'	3500	
01.04.2012	42	PE-23_2	EM120 and PS	16443-2	Profile trench	6:23			14:15	38° 09.07'	143° 27.02'	3500	38° 3.036'	144° 7.062'	6852	
01.04.2012	43	GC-14	GC	16444-1	southern trench area	20:59	00:28		04:11	37° 42.017'	143° 42.377'	7529	37° 42.723'	143° 52.398'	7530	12m liner - 1138 cm recovery
02.04.2012		PE-24_1	EM120 and PS	16445-1	Transit to shallow area	04:45			12:02	37° 42.840'	143° 52.470'	7530	36° 52.952'	142° 20.0'	2860	
02.04.2012	44	PE-24_2	EM120 and PS	16445-2	Profile in area D	12:02			18:25	36° 52.952'	142° 20.0'	2860	36° 27.03'	141° 40.0'	1970	

Date	St. No.	Int. No.	Instrument	GeoB St. No.	Location	Time (UTC)				Begin / on seafloor / Bottom contact			End / off seafloor			Recovery / Remarks
						Begin	on seafloor	off seafloor	End	Latitude N	Longitude E	Water depth (m)	Latitude N	Longitude E	Water depth (m)	
04.04.2012	45	PE-25_1	EM120 and PS	16446-1	Transit to Area D	08:12			10:20	36° 27.783'	141° 35.447'	1730	36° 39.930'	141° 50.946'	2260	
04.04.2012	45	PE-25_2	EM120 and PS	16446-2	Mapping Calibration, area D	10:20			12:32	36° 39.930'	141° 50.946'	2260	36° 39.9'	141° 52.2'	2260	
04.04.2012	45	PE-25_3	EM120 and PS	16446-3	Survey in Area D	12:32			21:20	36° 39.9'	141° 52.2'	2260	36° 45.319'	141° 57.148'	2386	
04.04.2012	46	GC-15	GC	16447-1	Area D	21:46	22:15		23:07	36° 45.319'	141° 57.148'	2386	36° 45.250'	141° 57.038'	2386	6m liner - 372 cm recovery
04.04.2012		PE 26	EM120 and PS	16448-1	Area D	23:21			02:35	36° 45.231'	141° 56.868'	2386	36° 47.431'	141° 59.675'	2480	
05.04.2012	47	GC-16	GC	16449-1	Area D	02:38	03:29		04:25	36° 47.412'	141° 59.675'	2486	36° 47.272'	141° 59.521'	2489	6m liner - 421 cm recovery
05.04.2012		PE 27	EM120 and PS	16450-1	Area D	04:40			05:59	36° 47.225'	141° 59.413'	2490	36°46.819'	141°46.112'	1520	
05.04.2012	48		Posidonia	16451-1	Area D	05:59			07:48	36°46.819'	141°46.112'	1520	36°46.650	141°46.114'	1540	
05.04.2012		PE-28	EM120 and PS	16452-1	Area D	08:12			09:59	36°46.120'	141°46.246'	1618	36°25.912'	141°38.326	1870	

Instrument Abbreviations:

CTD Conductivity-Temperature-Depth

EM120 Multibeam Echosounder

GC Gravitycorer

MUC Multicorer

PS Parasound

ROV Remotely Operated Vehicle ROV Quest

Sonne Cruise 219a

Legend for Lithostratigraphy Logs

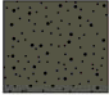
Lithologies		Structures	
	diatomaceous mud (mostly clayey silt)		parallel lamination
	diatomaceous sandy silt / silty sand		ripple (cross-) lamination
	diatomaceous mud mass-transport deposit MTD		cross lamination
	coccoliths-bearing diatomaceous mud (lithology for trench sites)		fining upward
	coarse silt layer		inverse upward
	sand layer		sand patch
	volcanic ash		gravel (stone)
			mud clast
			mud blocks
			convolut / contorted bedding
			mixed / chaotic sediment
	slightly fractured (coring disturbed?)		inclined surfaces (lithological contacts or deformation)
	coring disturbed		syn-sedimentary fault
			ash patch
			Pumice
			shell fragment
			(faint) bioturbation
			Ikait
Coring disturbance		Samples	
		SS	smear slide
		Ash	Ash sample
		plant remain	C14 dating
		★	Ikait

Fig. 9.2.1: Legend for visual core description of sediment cores collected during cruise SO219A.

Sonne Cruise SO 219a

GeoB 16421-1 (GC-9m) Latitude: 38°N 07.645 Longitude: 143°E 32.001
 Waterdepth: 3770 m Recovery: 5.80 m

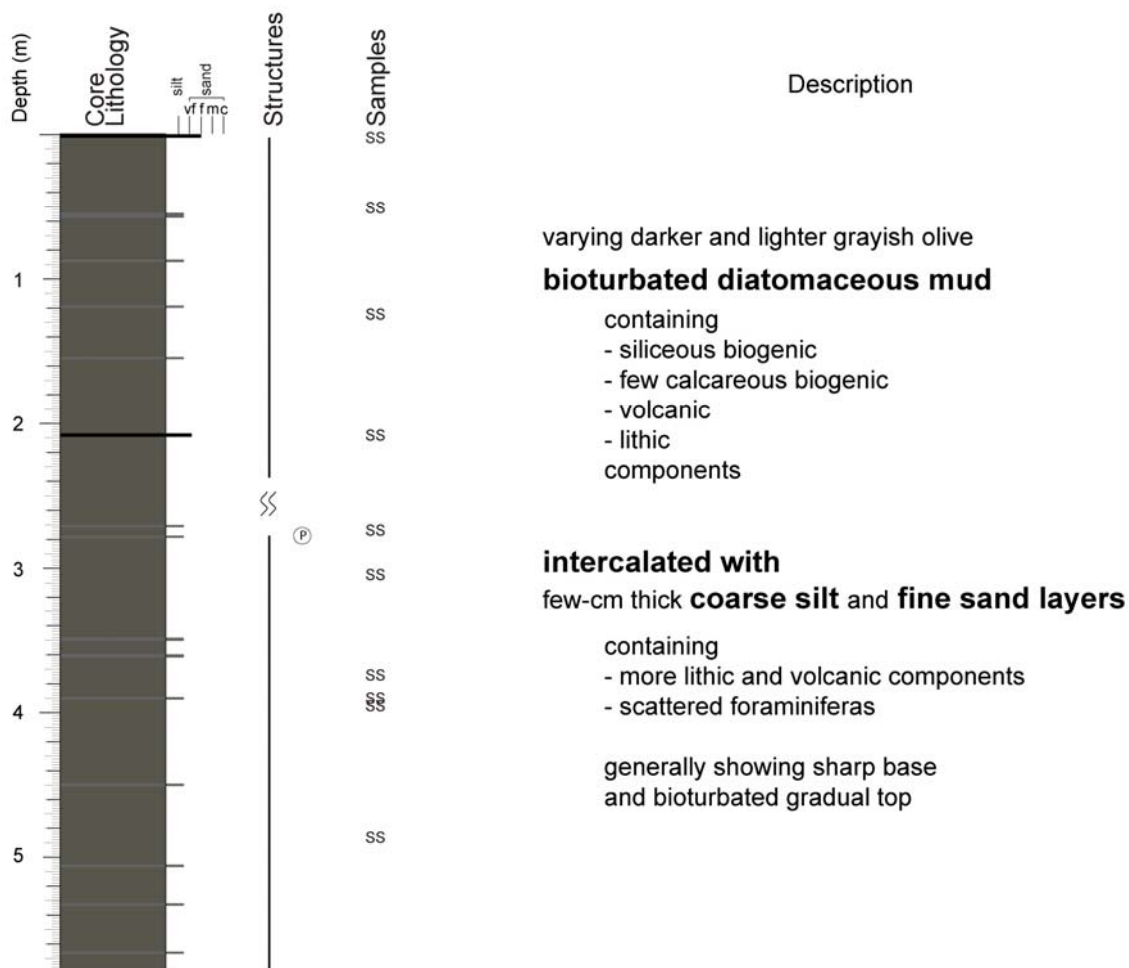


Fig. 9.2.2: Core description of sediment core GeoB 16421-1.

GeoB 16423-1 (GC-12m) Latitude: 37°N 56.501 Longitude: 143°E 54.840
Waterdepth: 6936 m Recovery: 8.69 m

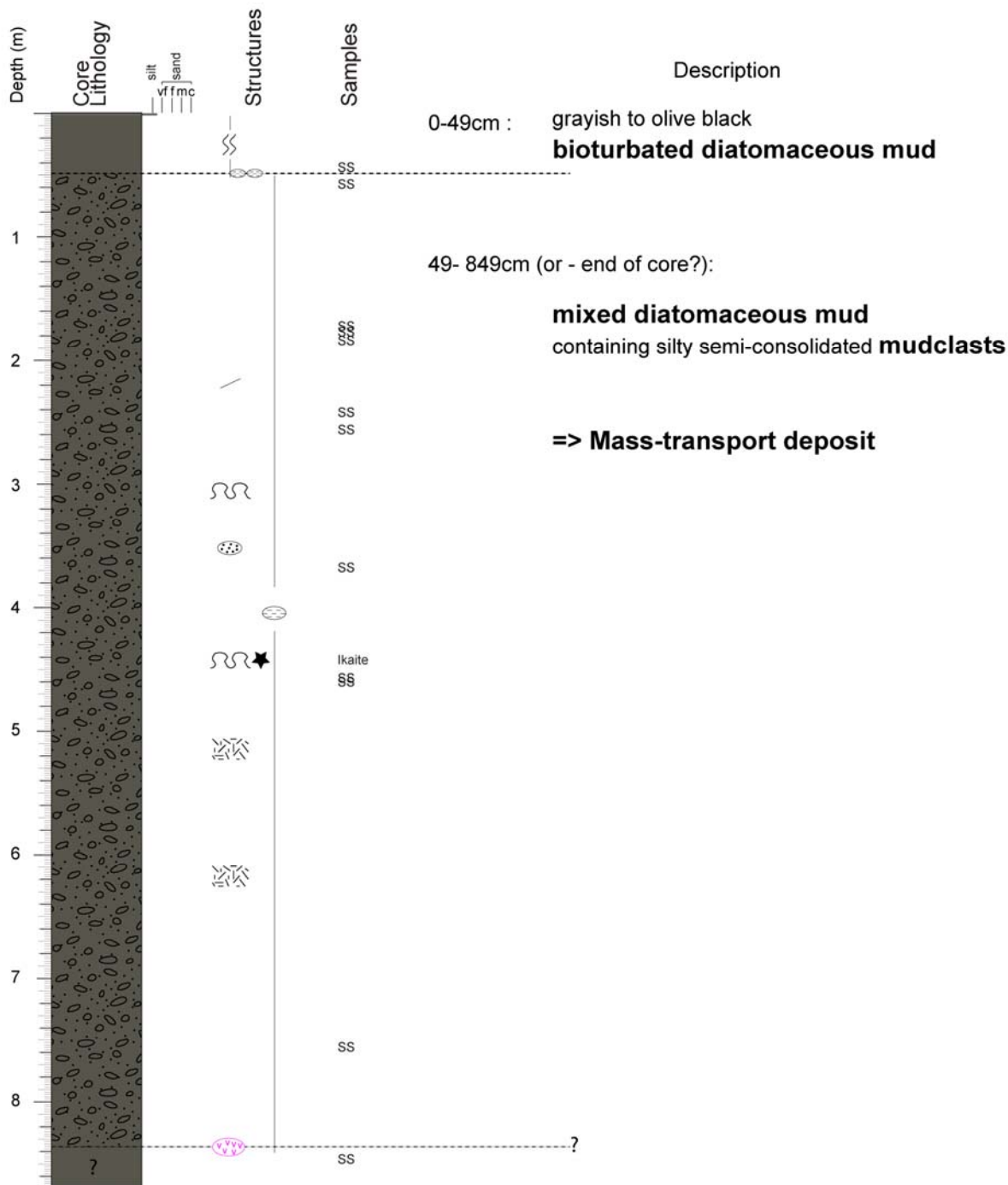


Fig. 9.2.3: Core description of sediment core GeoB 16423-1.

Sonne Cruise SO 219a

GeoB 16425-1 (GC-12m) Latitude: 38°N 4.366 Longitude: 143°E 57.615
 Waterdepth: 7221 m Recovery: 8.64 m

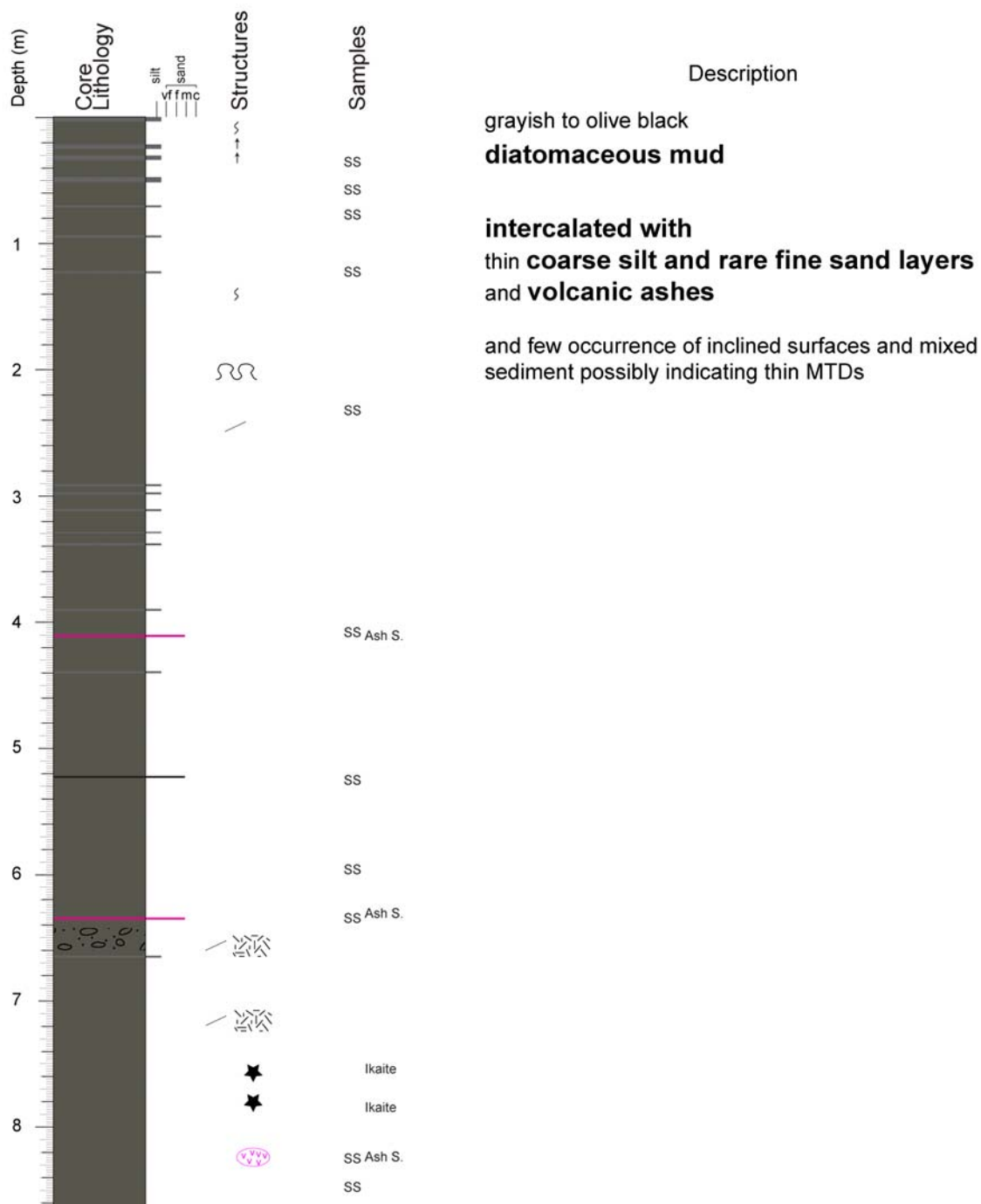


Fig. 9.2.4: Core description of sediment core GeoB 16425-1.

Sonne Cruise SO 219a

GeoB 16426-1 (GC-12m) Latitude: 38°N 4.228 Longitude: 143°E 58.975
Waterdepth: 7550 m Recovery: 8.39 m

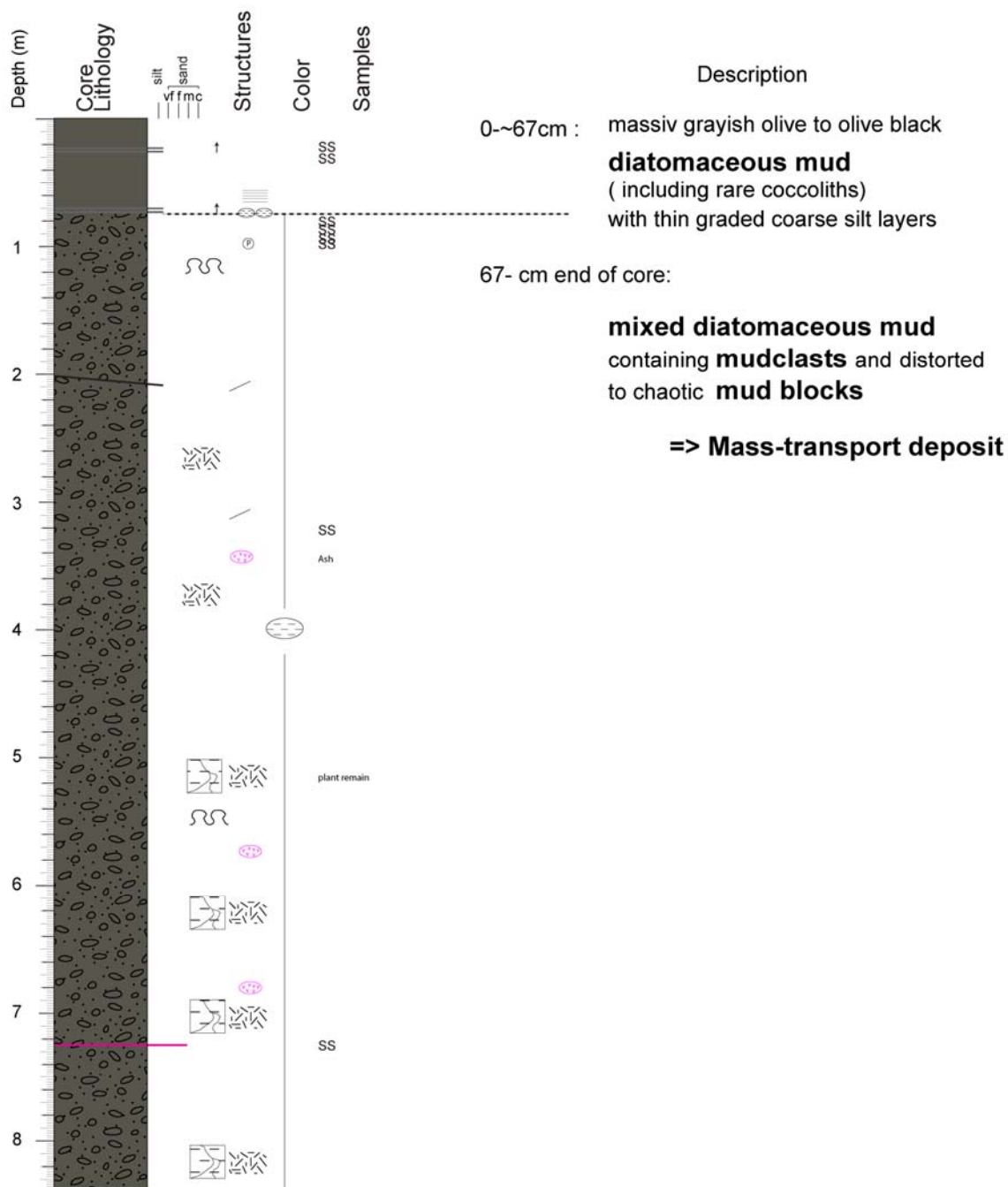


Fig. 9.2.5: Core description of sediment core GeoB 16426-1.

Sonne Cruise SO 219a

GeoB 16427-1 (GC-9m)

Latitude: 38°N 4.363 Longitude: 143°E 58.050

Waterdepth: 7412 m Recovery: 8.75 m

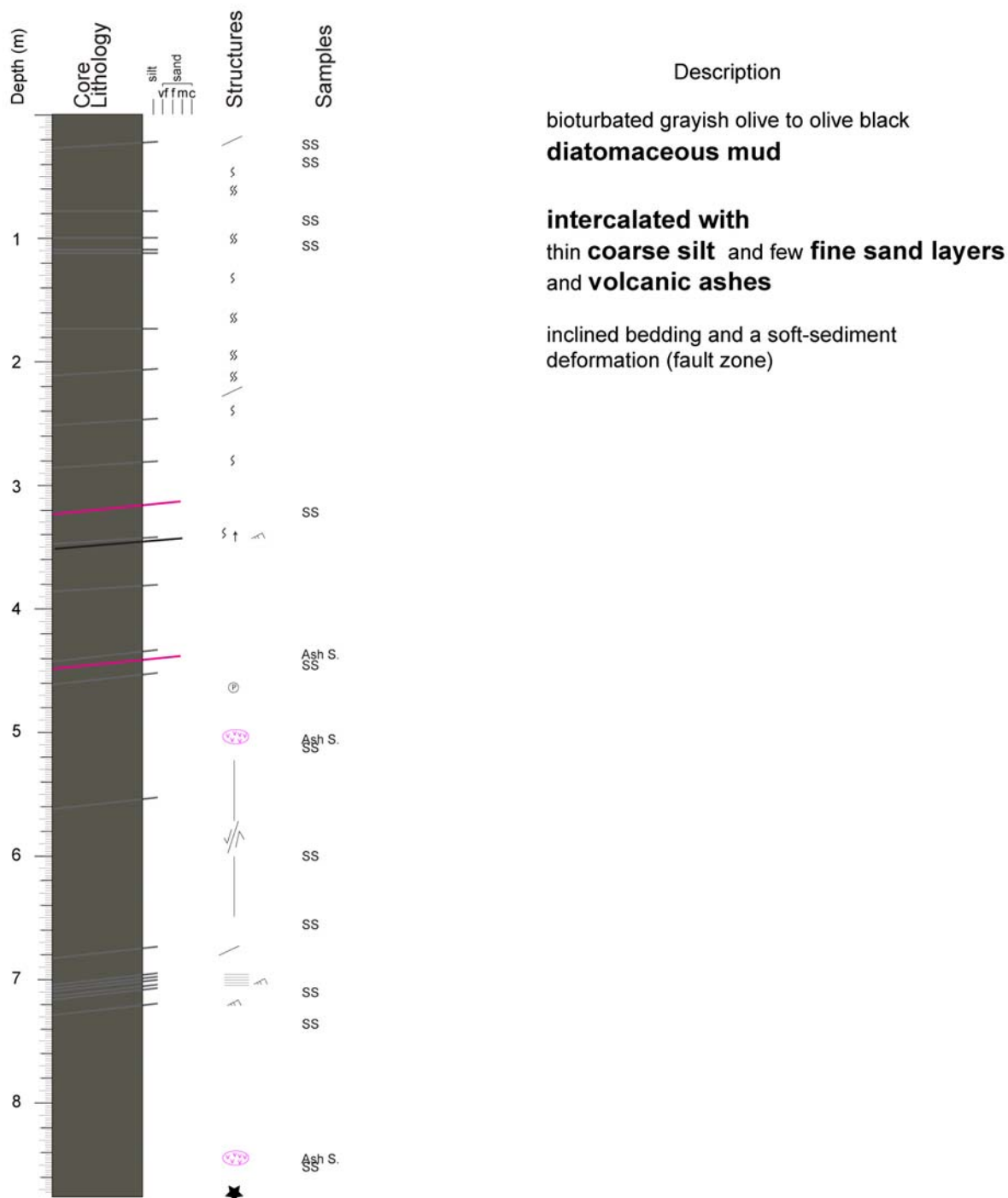


Fig. 9.2.6: Core description of sediment core GeoB 16427-1.

GeoB 16429-1 (GC-12m)

Longitude: 143°E 58.572

Recovery: 6.07 m

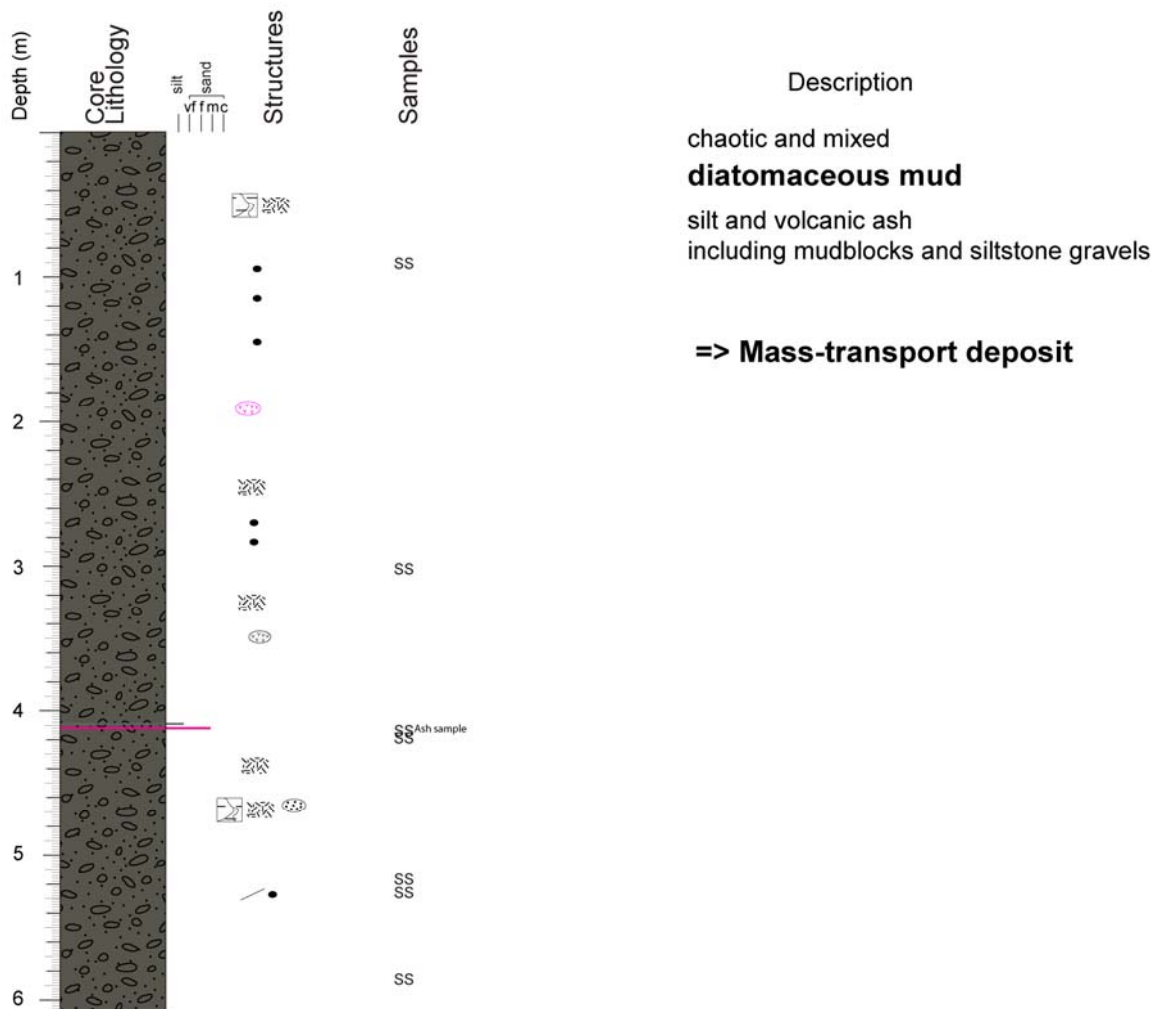


Fig. 9.2.7: Core description of sediment core GeoB 16429-1.

Sonne Cruise SO 219a

Recovery: 9.40 m

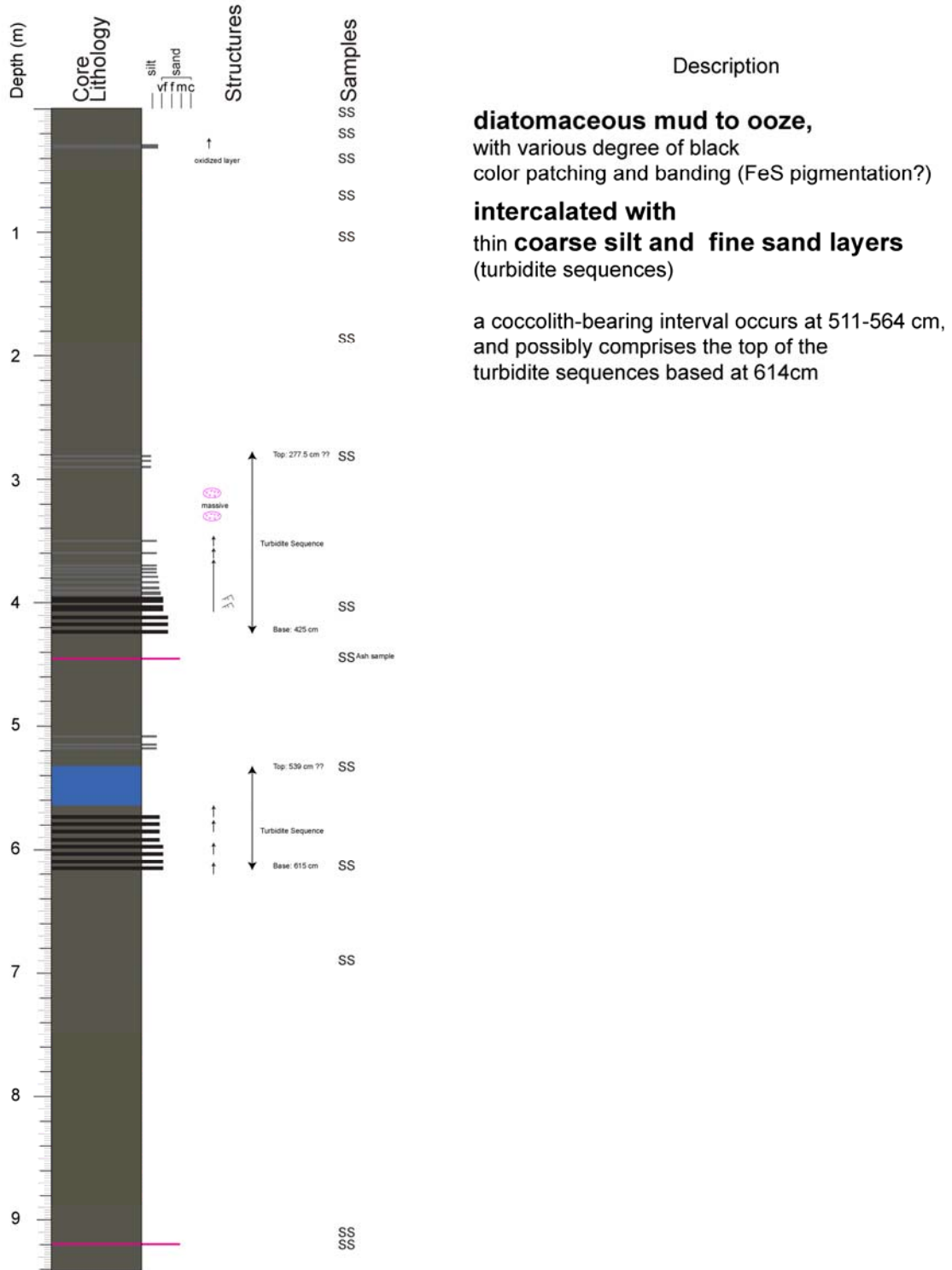


Fig. 9.2.8: Core description of sediment core GeoB 16431-1.

Sonne Cruise SO 219a

GeoB 16435-1 (GC-12m) Latitude: 38°N 22.907 Longitude: 142°E 43.006

Waterdepth: 1411 m Recovery: 1.79 m

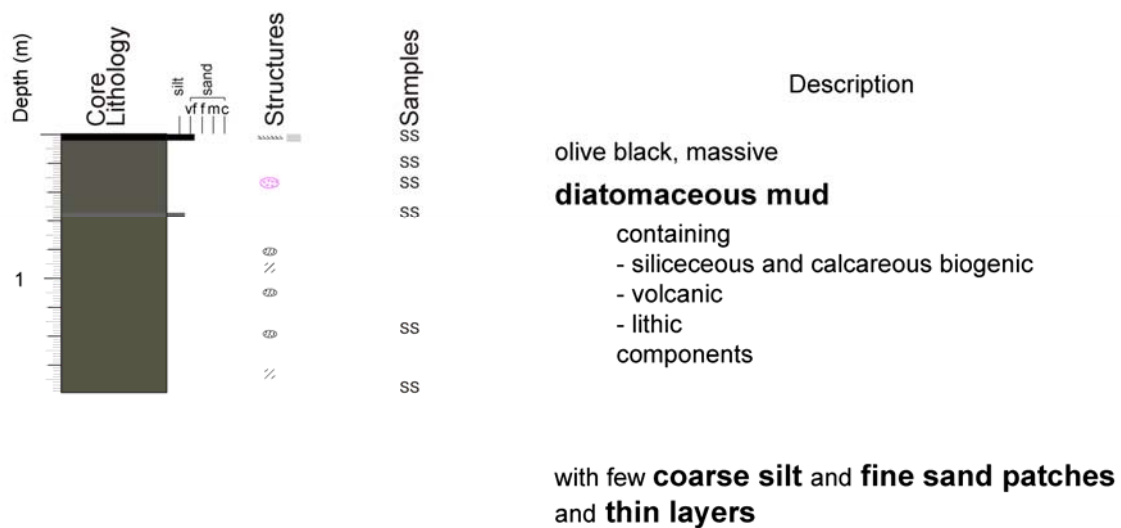


Fig. 9.2.10: Core description of sediment core GeoB 16435-1.

Sonne Cruise SO 219a

GeoB 16437-1 (GC-6m)

Latitude: 38°N 14.757 Longitude: 142°E 48.600

Waterdepth: 1405 m Recovery: 2.77 m

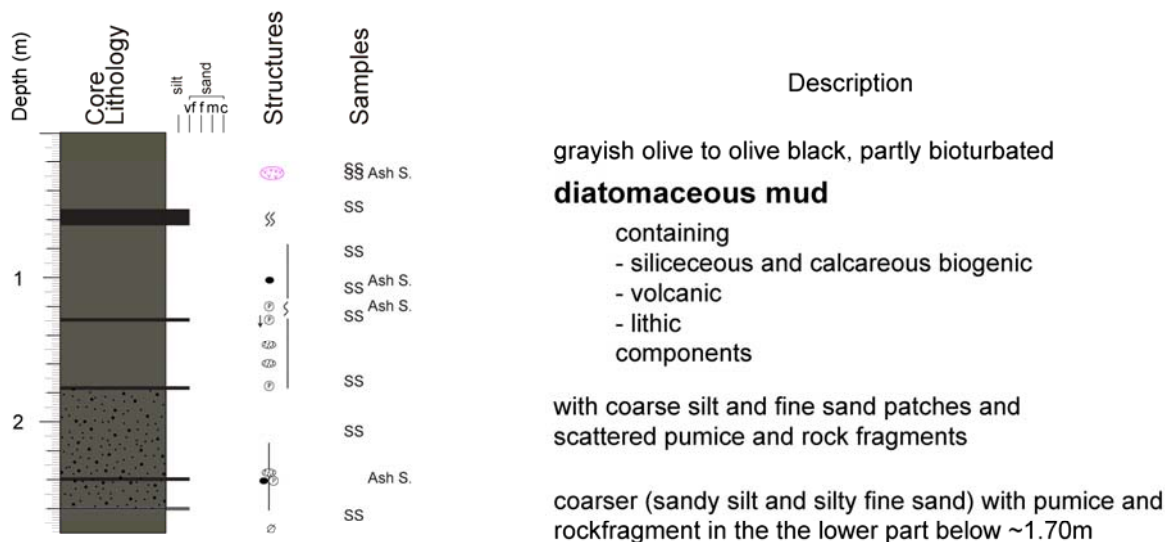


Fig. 9.2.11: Core description of sediment core GeoB 16437-1.

Sonne Cruise SO 219a

GeoB 16437-2 (MUC)

Latitude: 38°N 14.758 Longitude: 142°E 48.596

Waterdepth: 1405 m Recovery: 0.4 m

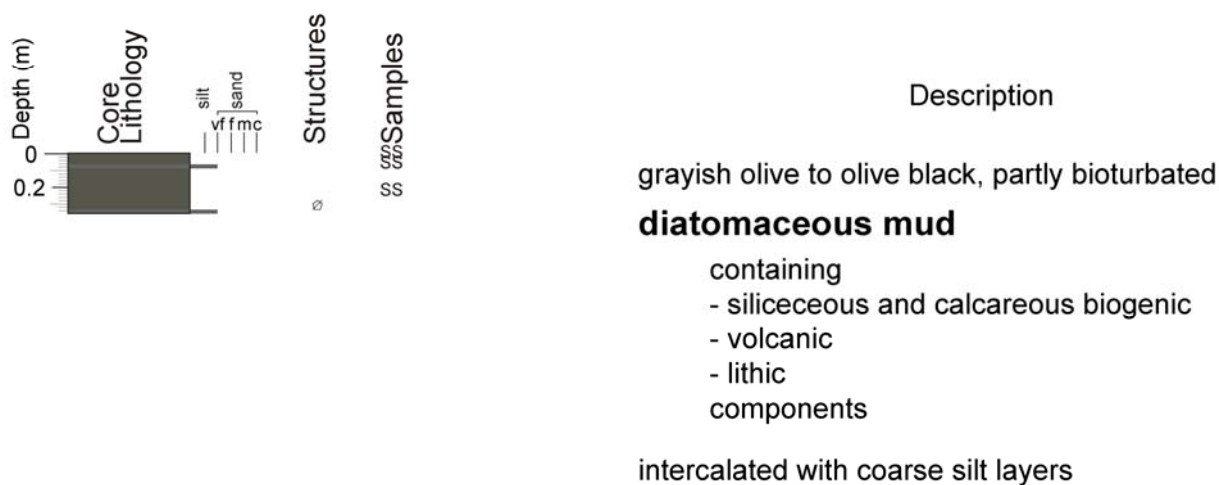


Fig. 9.2.12: Core description of MUC core GeoB 16437-2.

Sonne Cruise SO 219a

GeoB 16439-1 (GC-6m)

Latitude: 38°N 14.544 Longitude: 142°E 49.988

Waterdepth: 1382 m Recovery: 1.77 m

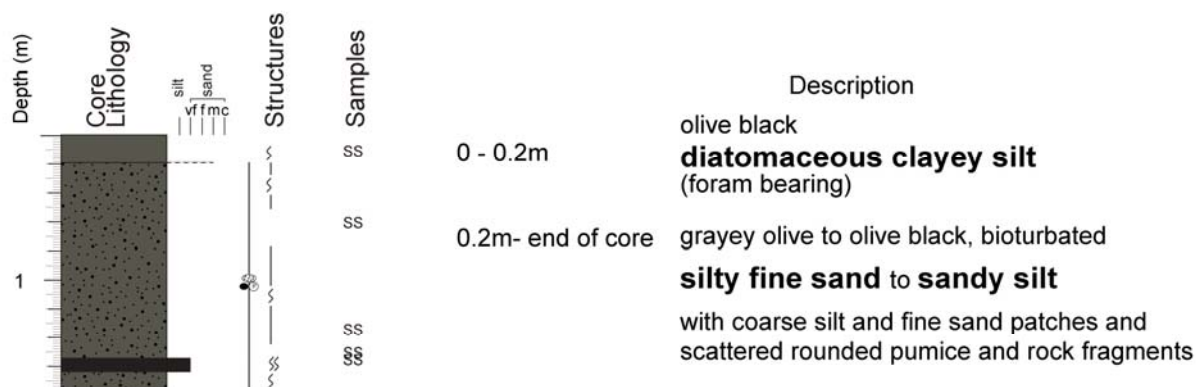


Fig. 9.2.13: Core description of sediment core GeoB 16439-1.

Sonne Cruise SO 219a

GeoB 16442-1 (GC-9m) Latitude: 38°N 11.467 Longitude: 143°E 33.249

Waterdepth: 3468 m Recovery: 4.85 m

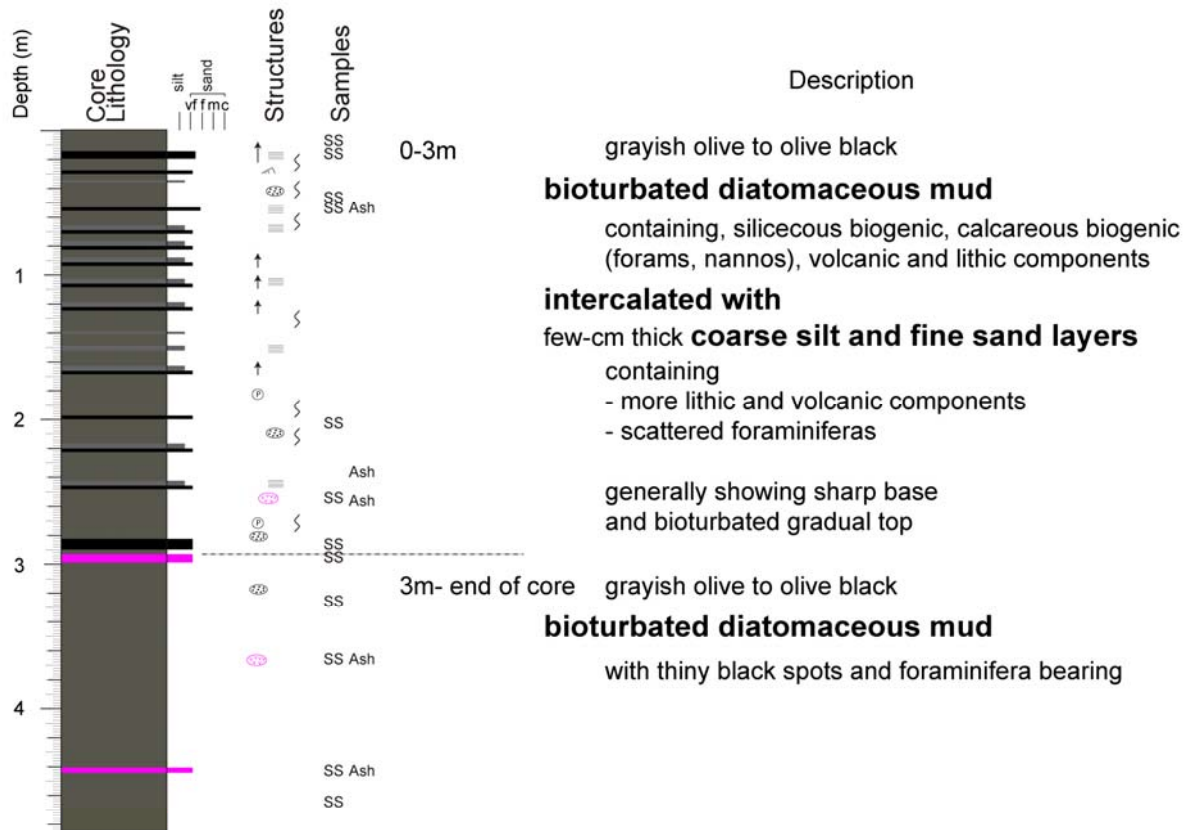


Fig. 9.2.14: Core description of sediment core GeoB 16442-1.

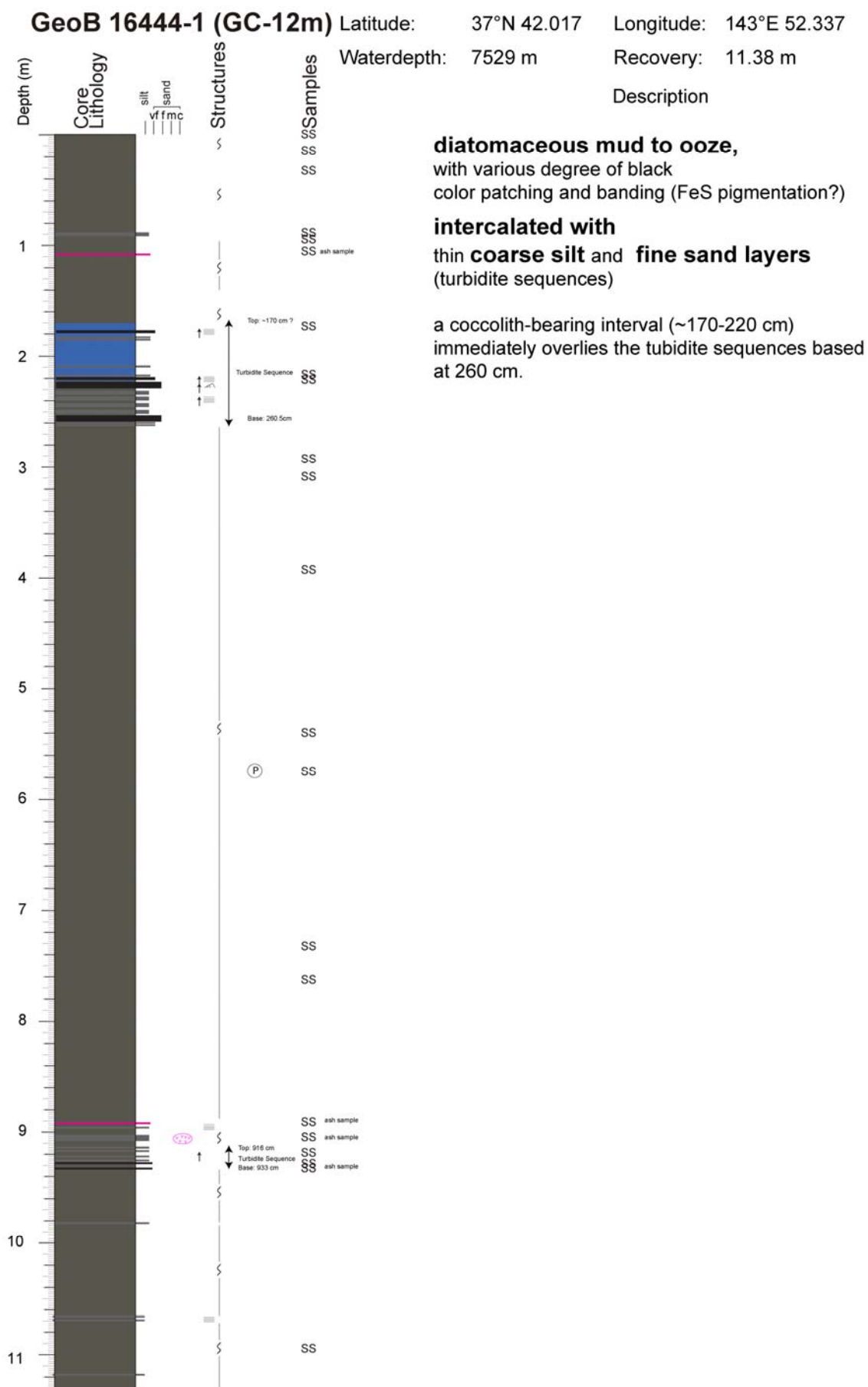


Fig. 9.2.15: Core description of sediment core GeoB 16444-1.

Sonne Cruise SO 219a

GeoB 16447-1 (GC-6m)

Latitude: 36°N 45.319 Longitude: 141°E 57.148

Waterdepth: 2386 m Recovery: 3.72 m

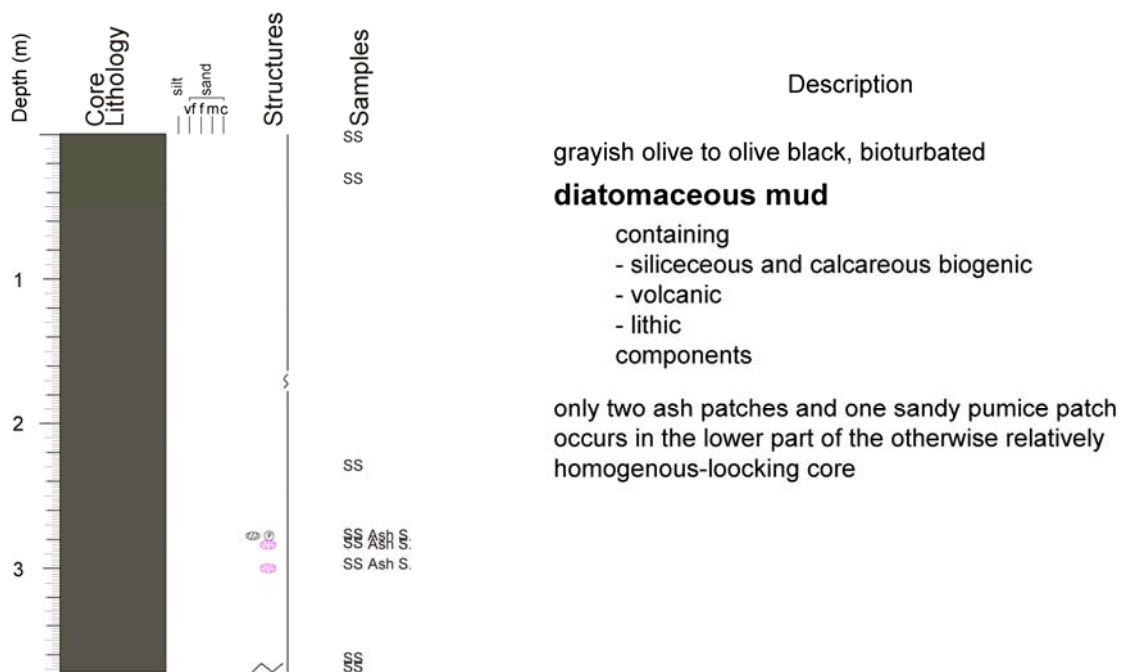


Fig. 9.2.16: Core description of sediment core GeoB 16447-1.

Sonne Cruise SO 219a

GeoB 16449-1 (GC-6m)

Latitude: 36°N 47.412 Longitude: 141°E 59.675

Waterdepth: 2486 m Recovery: 4.21 m

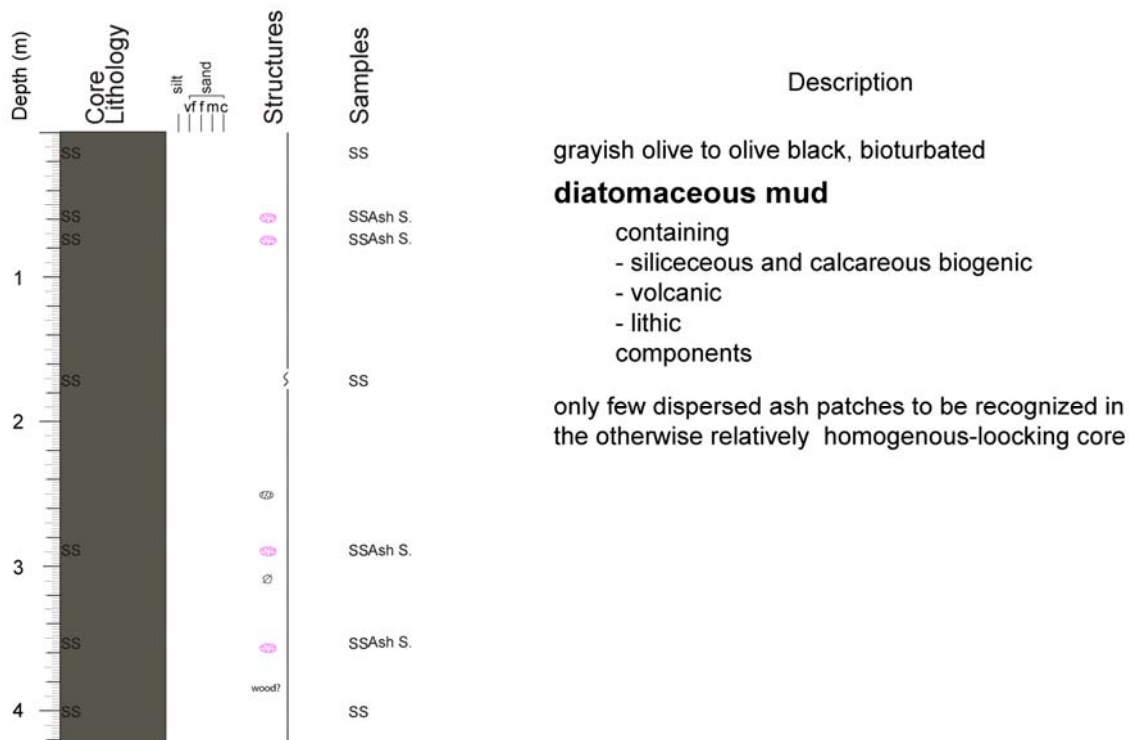


Fig. 9.2.17: Core description of sediment core GeoB 16449-1.

GeoB 16421-1

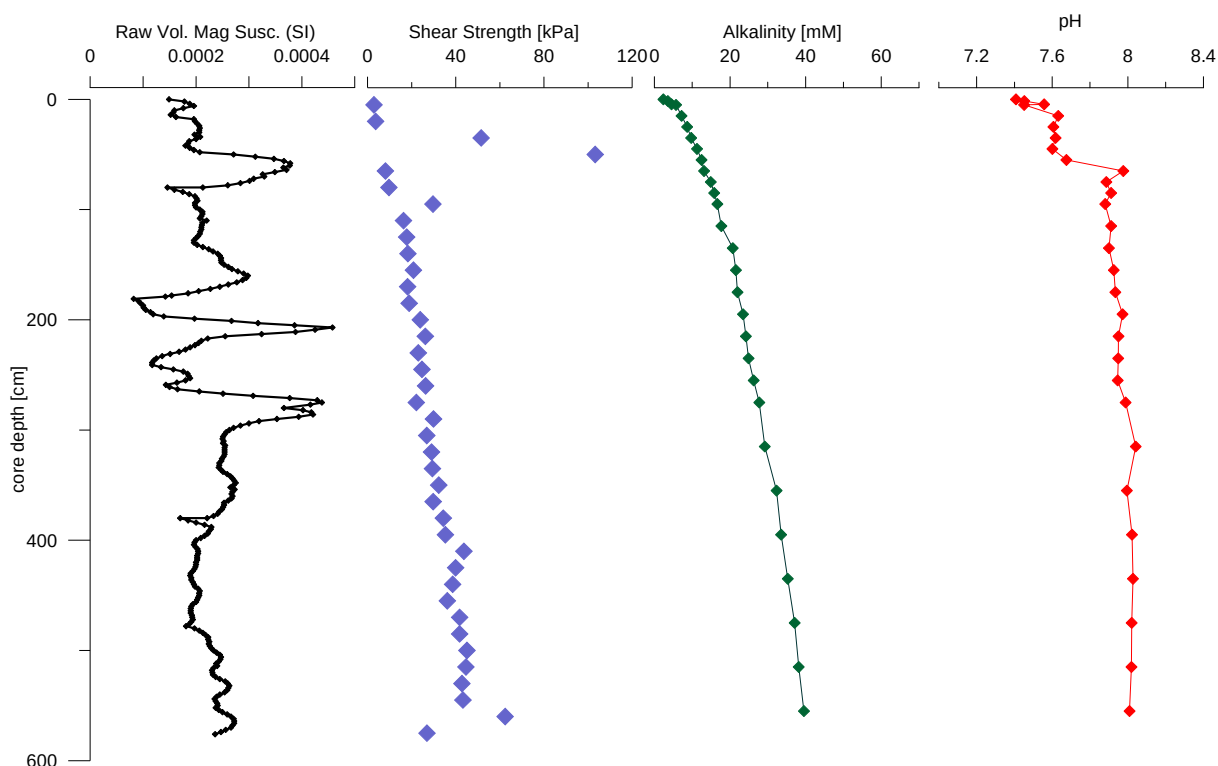


Fig. 9.3.1: Compiled shipboard results of sediment core GeoB 16421-1.

GeoB 16423-1

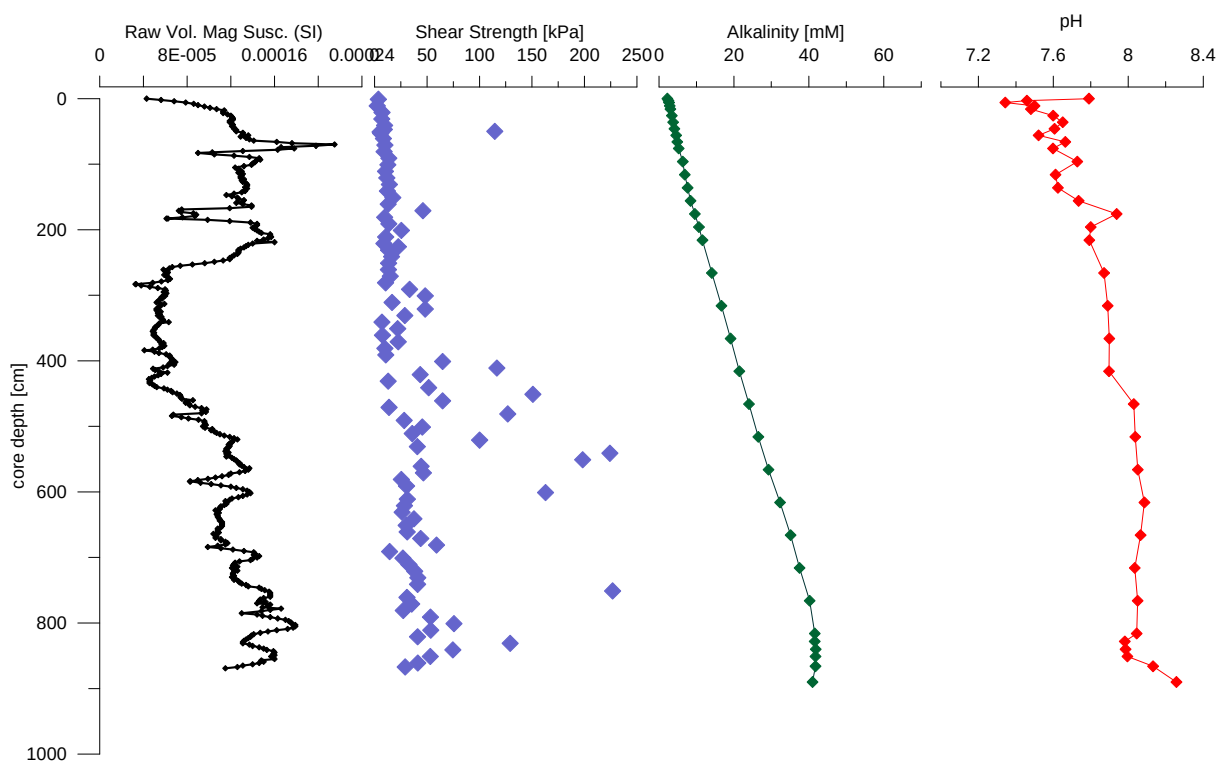


Fig. 9.3.2: Compiled shipboard results of sediment core GeoB 16423-1.

GeoB 16425-1

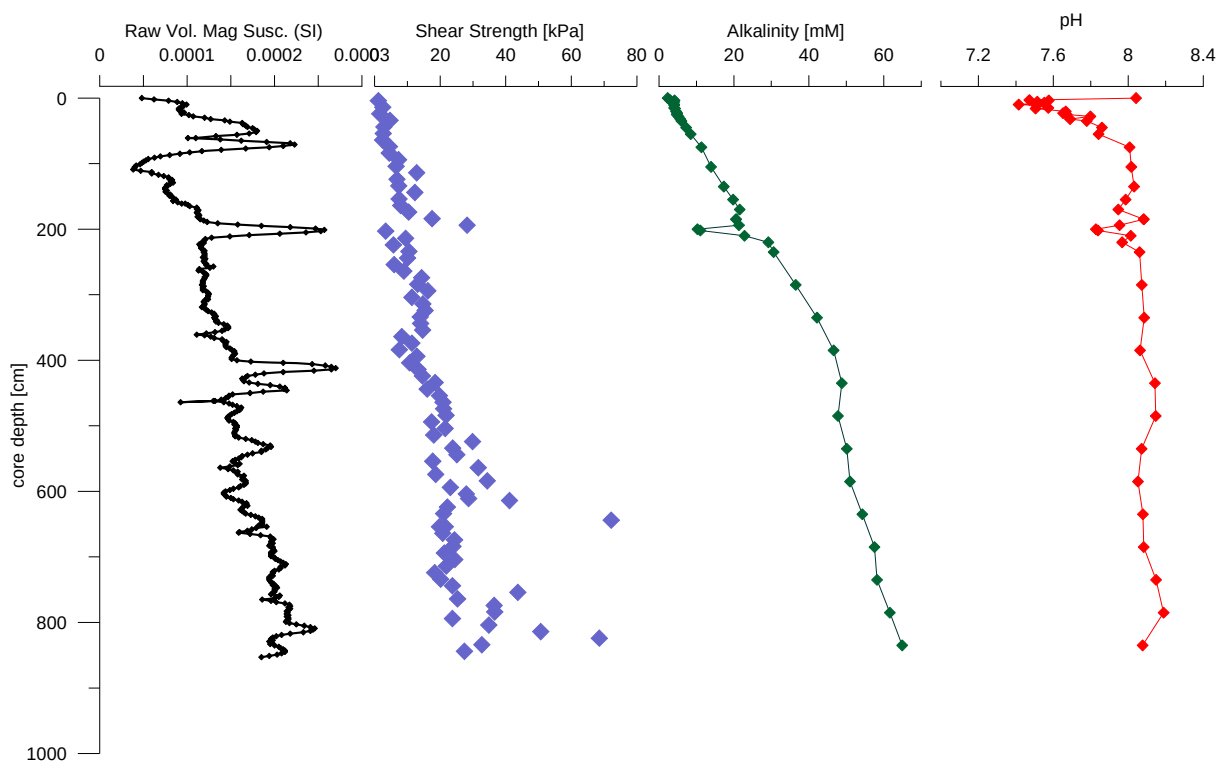


Fig. 9.3.3: Compiled shipboard results of sediment core GeoB 16425-1.

GeoB 16426-1

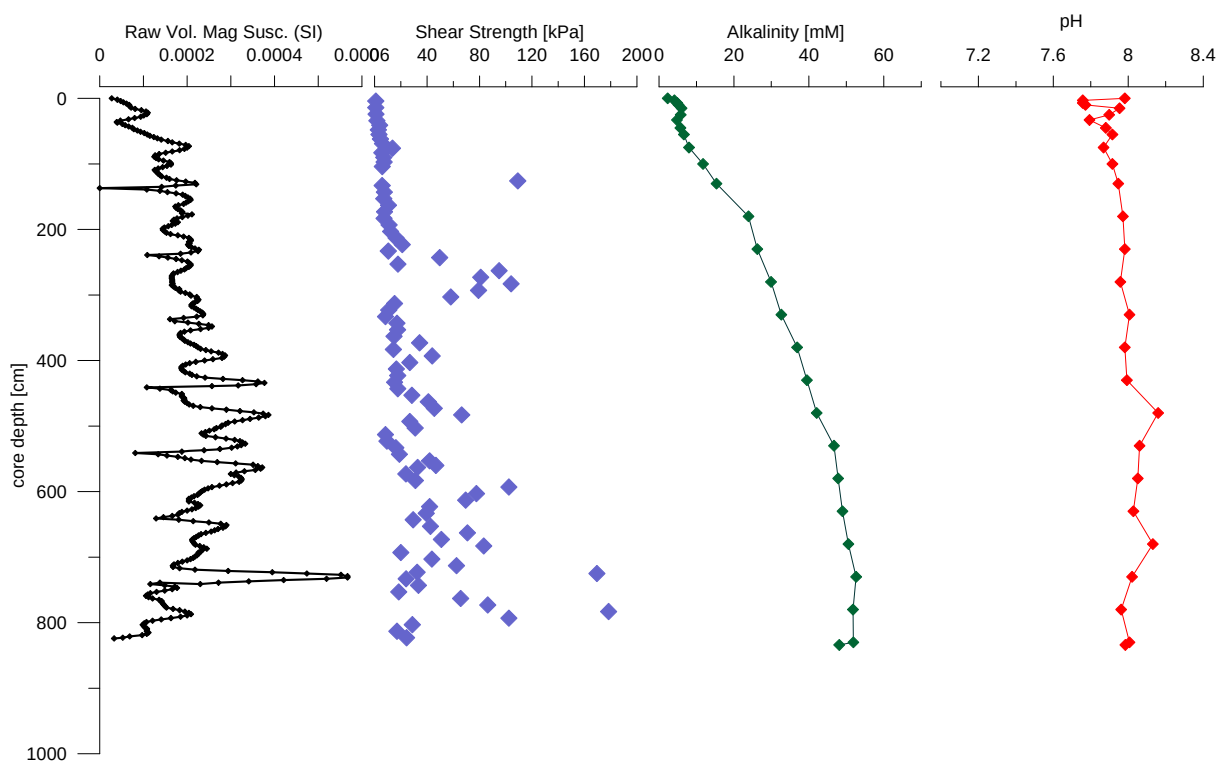


Fig. 9.3.4: Compiled shipboard results of sediment core GeoB 16426-1.

GeoB 16427-1

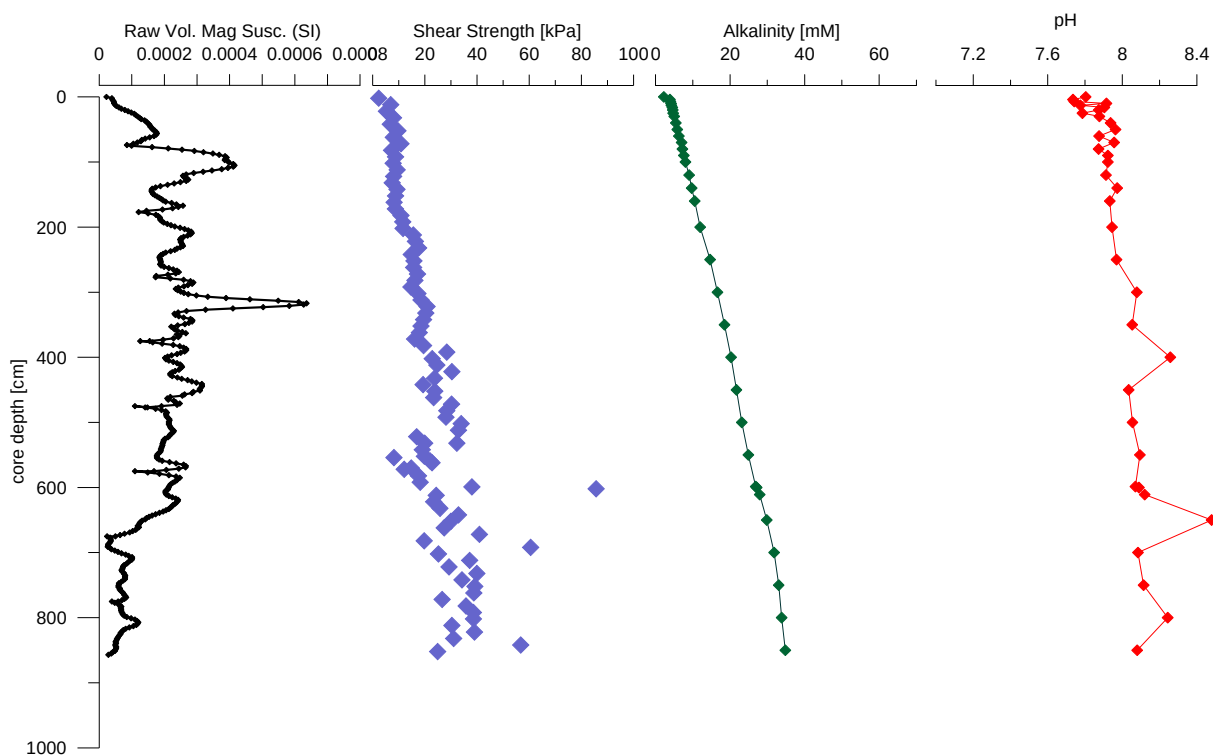


Fig. 9.3.5: Compiled shipboard results of sediment core GeoB 16427-1.

GeoB 16429-1

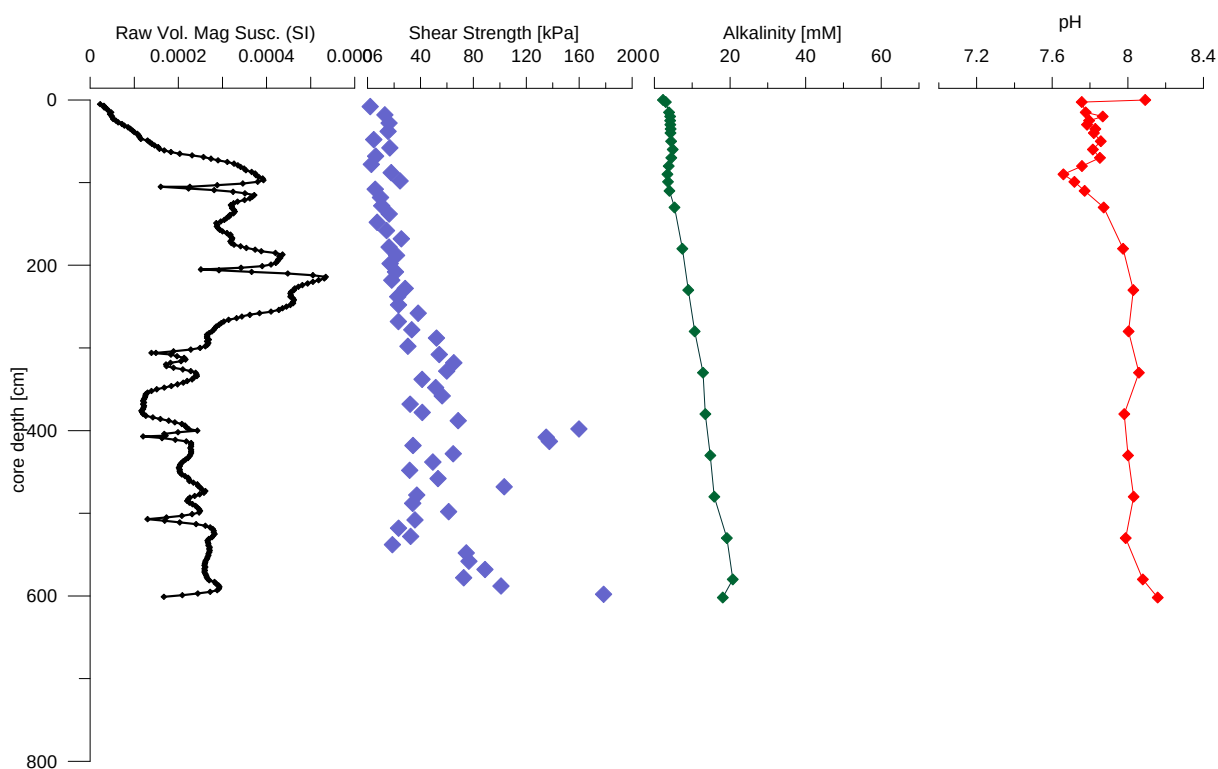


Fig. 9.3.6: Compiled shipboard results of sediment core GeoB 16429-1.

GeoB 16431-1

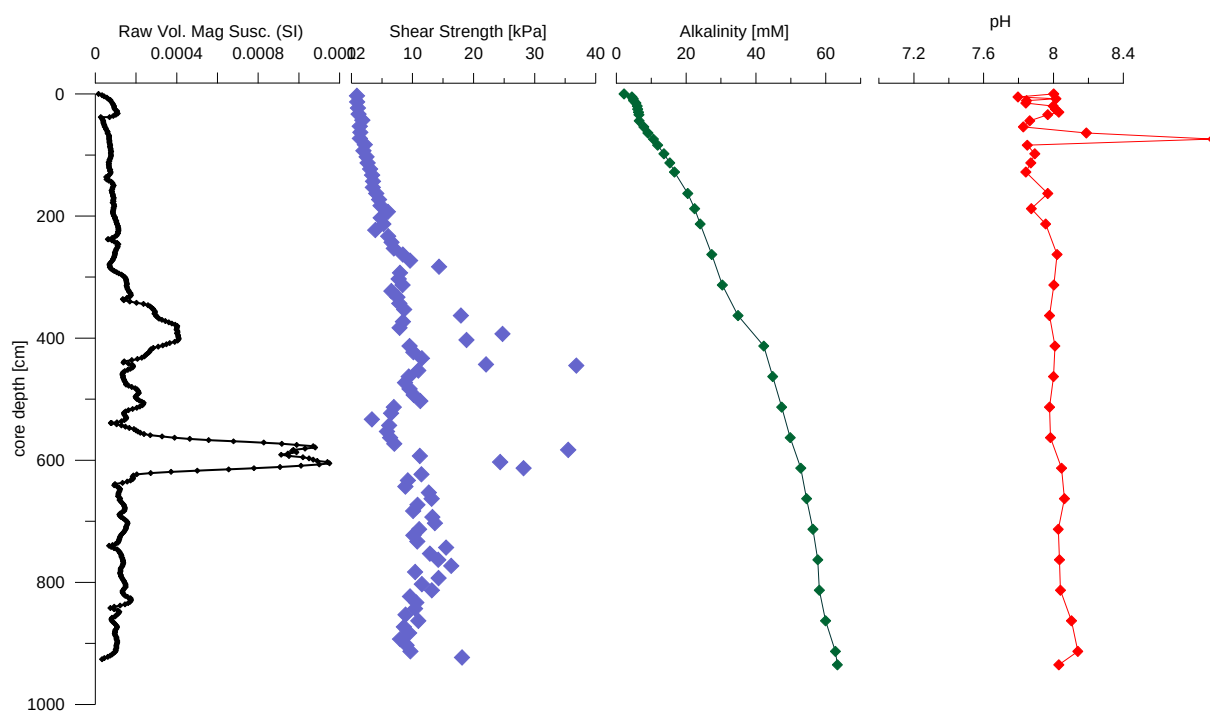


Fig. 9.3.7: Compiled shipboard results of sediment core GeoB 16431-1.

GeoB 16433-1

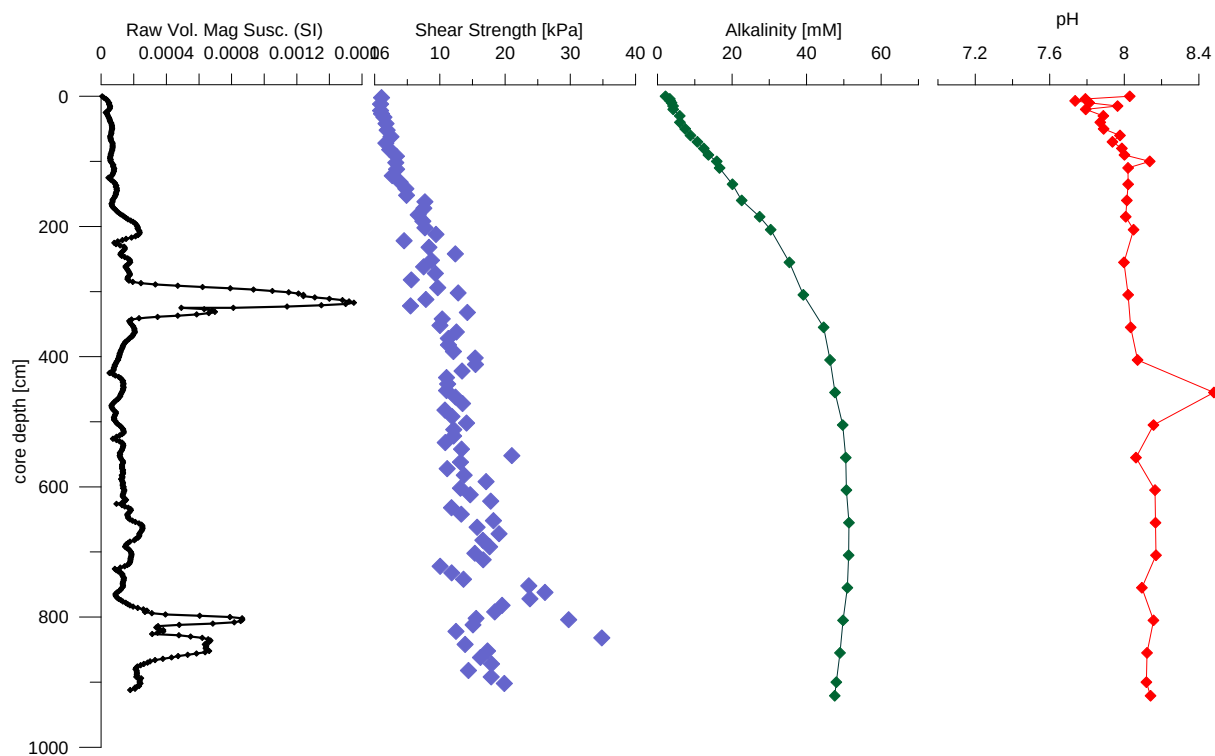


Fig. 9.3.8: Compiled shipboard results of sediment core GeoB 16433-1.

GeoB 16435-1

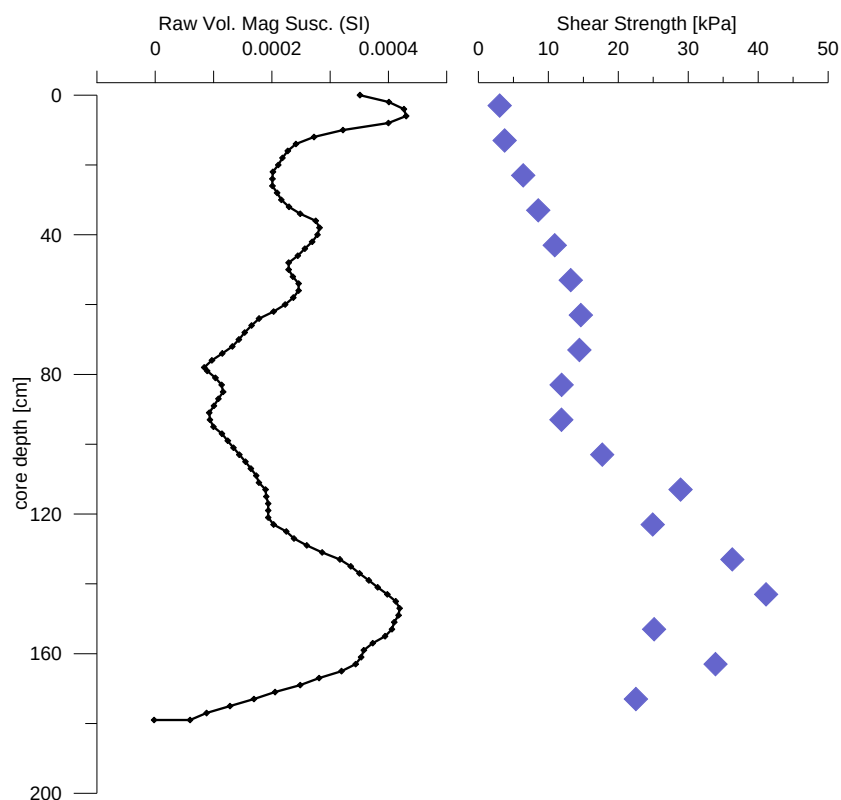


Fig. 9.3.9: Compiled shipboard results of sediment core GeoB 16435-1.

GeoB 16437-1

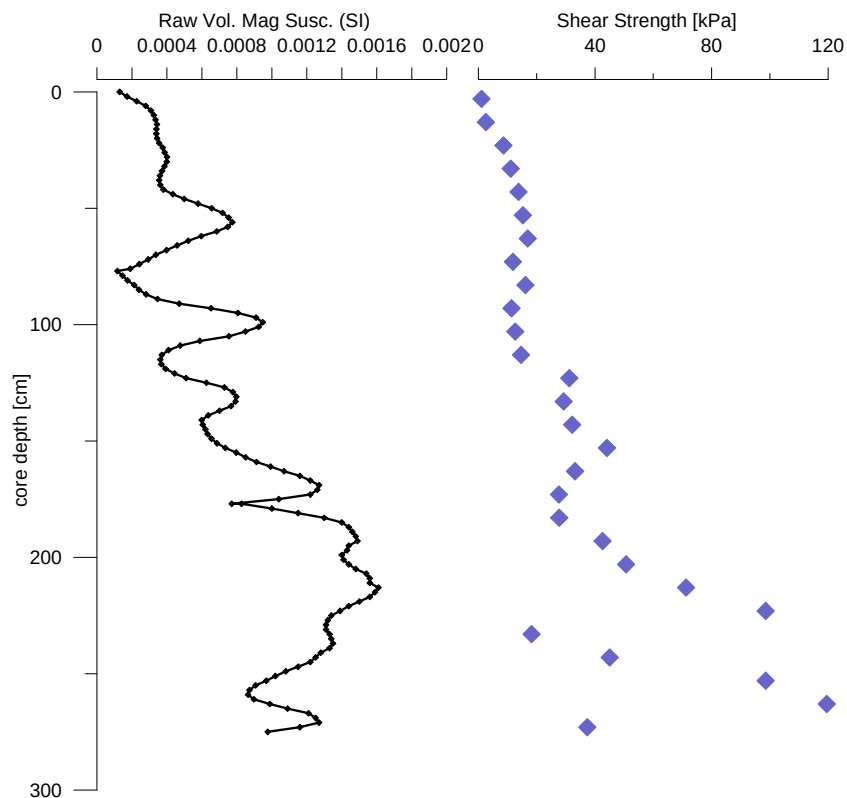


Fig. 9.3.10: Compiled shipboard results of sediment core GeoB 16437-1.

GeoB 16439-1

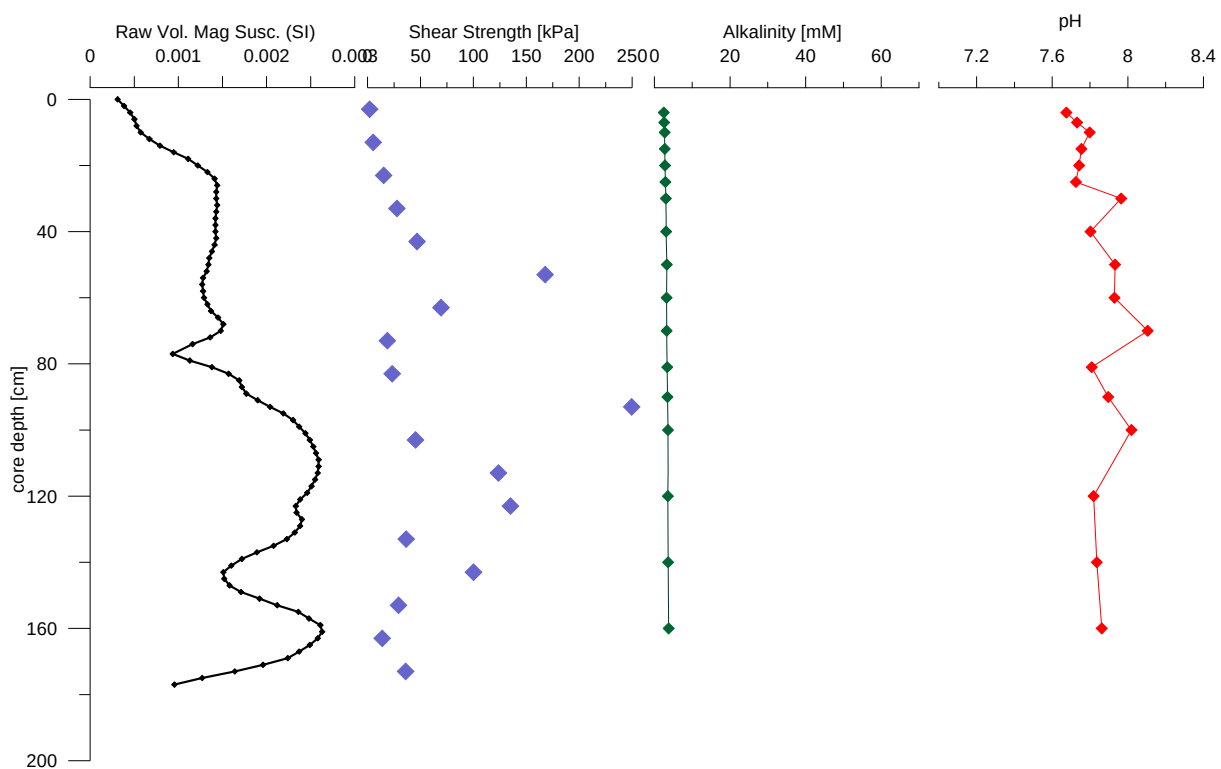


Fig. 9.3.11: Compiled shipboard results of sediment core GeoB 16439-1.

GeoB 16442-1

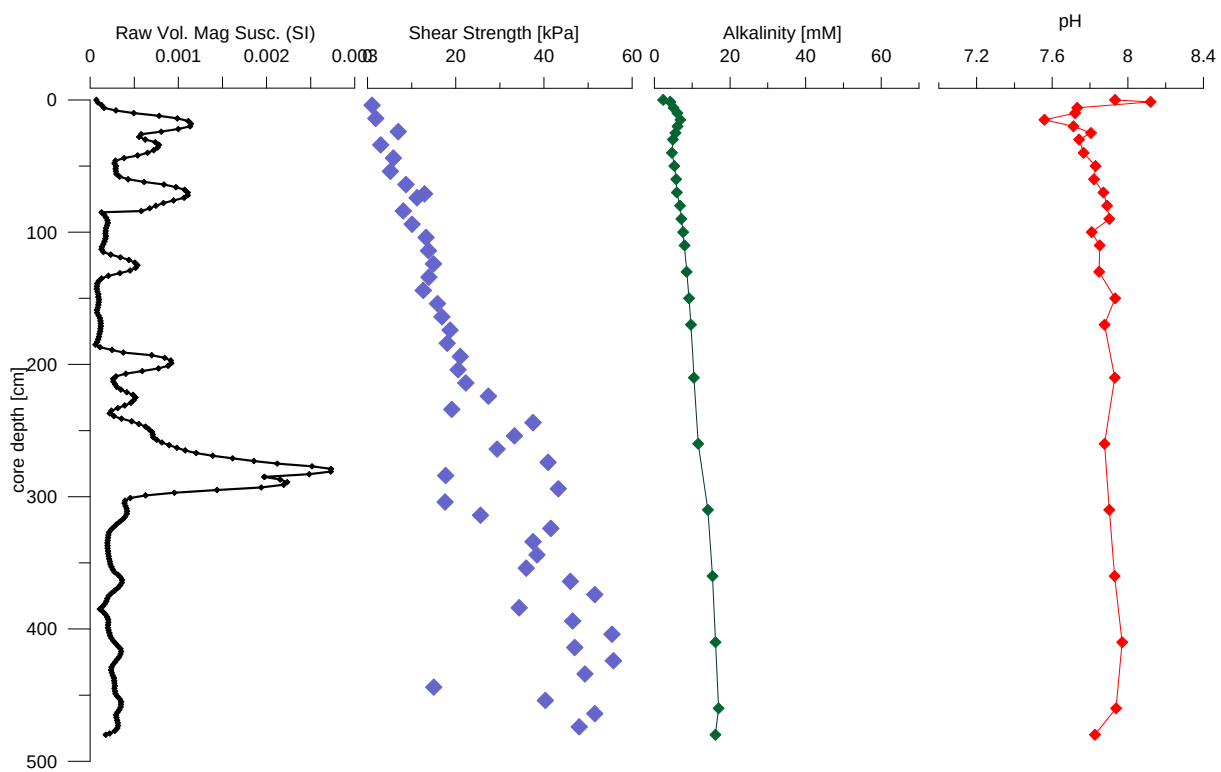


Fig. 9.3.12: Compiled shipboard results of sediment core GeoB 16442-1.

GeoB 16444-1

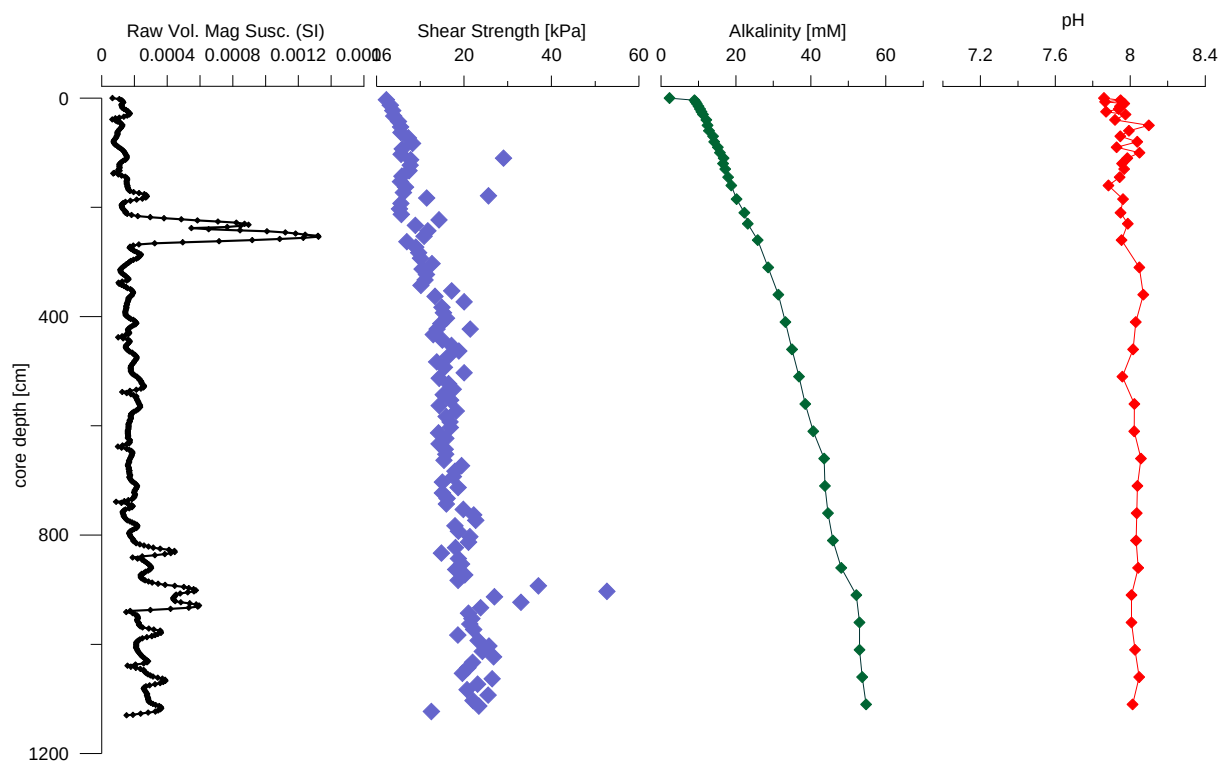


Fig. 9.3.13: Compiled shipboard results of sediment core GeoB 16444-1.

GeoB 16447-1

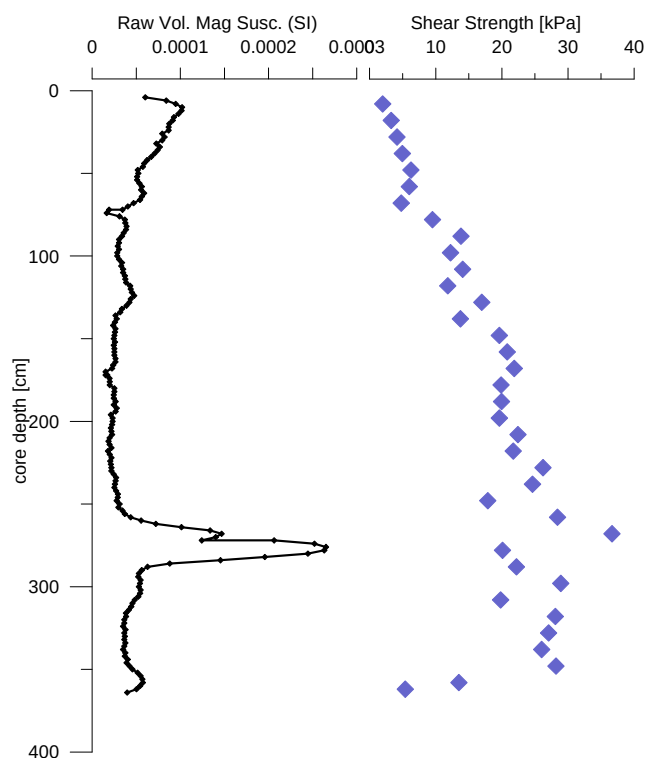


Fig. 9.3.14: Compiled shipboard results of sediment core GeoB 16447-1.

GeoB 16449-1

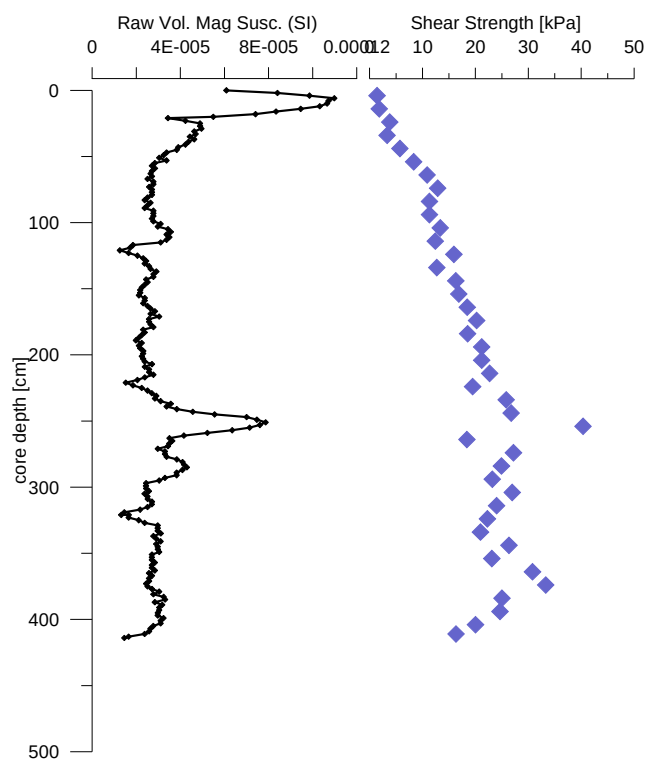


Fig. 9.3.15: Compiled shipboard results of sediment core GeoB 16449-1.

Universität Bremen
MARUM –Zentrum für Marine Umweltwissenschaften

Schlussbericht für das BMBF Projekt

SONNE-Tohoku: Untersuchung der Verlagerung des Meersbodens vor der Küste Honshu durch das 2011 Tohoku-Oki-Erdbeben, SO219A

Zusammenfassung

Förderkennzeichen: 03G0826A

Projektleiter: Prof. Dr. Gerold Wefer

Projektzeitraum: 01.12.2011- 31.05.2012

Bremen, Februar 2013

Zusammenfassung des Fahrtberichtes SO219A

Am 11. März 2011 erschütterte ein Erdbeben der Stärke 9 die nordöstliche Küste der japanischen Insel Honshu. Das Epizentrum des sogenannten Tohoku-Oki Erdbebens lag etwa 70 km östlich vor der Oshika-Halbinsel von Tohoku, wo das Beben in einer Tiefe von etwa 32 km stattfand. Es war das größte je in Japan registrierte Beben und löste einen Tsunami von bis zu 40 Metern Höhe aus, der weite Gebiete an der japanischen Küste überflutete. Das Beben wurde durch die Kollision der Ochotskischen Platte mit der Pazifischen Platte verursacht, die hier unterhalb Nordost-Japans abtaucht. Erste Vermessungen japanischer Schiffe direkt nach dem Beben zeigten, dass sich, im Vergleich zu Daten die bereits 1999 sowie 2004 aufgezeichnet wurden, der Kontinentalhang um etwa 50 m Richtung Südosten verschoben hat und der Meeresboden um etwa 5 m angehoben wurde. Zudem deuten die Daten auf große Rutschungsmassen hin, die im Zuge des Bebens in dem Tiefseegraben abgelagert wurden. Die Fahrt SO219A mit dem FS SONNE in das Erdbebengebiet fand als Reaktion auf das verheerende Tohoku-Oki Beben statt, mit der Zielsetzung, wichtige Beiträge zum besseren Verständnis des Ablaufs des Bebens sowie des Tsunamis zu leisten.

Der Fokus des ersten Fahrtabschnittes lag auf der Vermessung der Bodenmorphologie des Kontinentalhanges mit dem bordeigenen Fächerecholot und Parasoundsystem, der Inspektion von ODP Bohrloch-Observatorien auf eventuelle, durch das Beben verursachte Schäden, dem Bergen und Ausbringen von Ozeanboden-Messinstrumenten sowie der visuellen Untersuchung des Meeresbodens. Mit Hilfe des Tauchroboters ROV MARUM-QUEST 4000 konnten die Observatorien am Kontinentalhang gefunden und untersucht werden: Eines zeigte sich als relativ intakt, eines wies leichte Schäden auf. Weitere Ozeanbodenseismik- und Drucksysteme wurden ausgesetzt, die in Zukunft die seismischen Aktivitäten in der Region aufzeichnen werden. Zwei weitere Tauchgänge wurden mit dem FS SONNE-Videoschlitten OFOS im Forearc-Becken durchgeführt, es konnten Bakterienmatten und anstehendes, verfestigtes Sedimentgestein beobachtet werden.

Einige Profile der insgesamt mehr als 2700 nautischen Meilen während der SO219A-Fahrt aufgezeichneten, detaillierten bathymetrischen Vermessungen wiederholten bereits vor dem Beben vermessene Schnitte. Durch deren Vergleich lassen sich nun morphologische Veränderungen entlang des Kontinentalhanges sowie des Tiefseegrabens identifizieren. Größte Änderungen zeigen sich östlich des Epizentrums. Nördlich und südlich davon liegende Profile weisen nur geringe oder keine Änderungen auf.

Neben der weiteren bathymetrischen Vermessung des Arbeitsgebietes stand während des zweiten Fahrtabschnittes die Beprobung des Meeresbodens mittels Schwerelot und Multicorer im Vordergrund. Dabei konnten sowohl entlang eines E-W Profiles am Kontinentalhang, eines N-S Profiles entlang der Achse des Japan Grabens als auch im Forearc-Becken Sedimentkerne gewonnen werden. Insgesamt 95 m Sedimentkerne wurden an Bord zunächst für geochemische Porenwasseranalysen beprobt, anschließend geöffnet, beschrieben und ihre physikalischen Eigenschaften (Scherfestigkeit und magnetische Suszeptibilität) gemessen. Der Multicorer wurde zweimal eingesetzt. Die dominante Lithologie der Sedimente aus dem Tiefseegraben sowie des Forearc-Beckens ist ein hemipelagischer Diatomeenschlamm, wechsellagernd mit groben und feinen Sand- und Siltlagen und/oder Aschelagen. Charakteristisch für diese Sandlagen sind meist hohe Werte der magnetischen Suszeptibilität.

Die Sedimente vom Kontinentalhang hingegen sind von sogenannten ‚Mass Transport Deposits‘ dominiert, die von früheren Rutschungen entlang des Hanges zeugen. Teilweise enthalten diese Kerne große Kristalle des authigenen Minerals Ikaite. In allen Kernen nimmt die Scherfestigkeit mit der Tiefe zu, jedoch zeigen sich verschiedene Gradienten, entsprechend verschiedener Konsolidierungsstadien. Erste Porenwasseranalysen an Bord deuten zum Teil in den oberflächennahen ein bis zwei Metern auf eine relativ rezente Durchmischung der Sedimente hin, während die konstanten Gradienten in den tieferen Bereichen der Kerne eine kürzlich stattgefundene Umlagerung der Sedimente ausschließen lassen. Die erheblichen morphologischen Unterschiede nach dem Tohoku-Oki Beben lassen sich somit nicht durch große submarine Rutschungen erklären, vermutlich wurden kleinere Trübestrome verursacht.

Die gewonnenen Daten und Sedimente werden im Anschluss an die Fahrt gemeinsam mit Kooperationspartnern aus Japan und der Schweiz weiter ausgewertet und untersucht.

Wir danken Kapitän L. Mallon und seiner Crew für die gute Zusammenarbeit an Bord sowie dem Bundesministerium für Bildung und Forschung (BMBF) und der Deutschen Forschungsgemeinschaft (DFG) für die Finanzierung der Fahrt.