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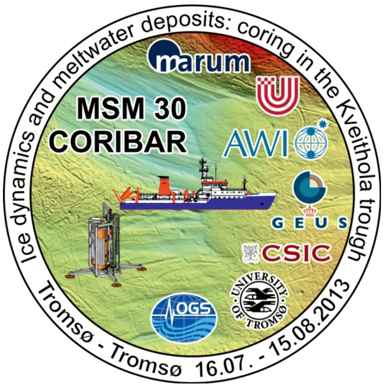
CORIBAR
ICE DYNAMICS AND MELTWATER DEPOSITS: CORING IN THE KVEITHOLA TROUGH, NW BARENTS SEA

CRUISE MSM 30

16.07. – 15.08.2013,
TROMSØ (NORWAY) – TROMSØ (NORWAY)



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1 Summary

The CORIBAR cruise – an international project between the institutions MARUM (Bremen), OGS (Trieste), CSIC (Barcelona), UiT (Tromsø), GEUS (Copenhagen) and AWI (Bremerhaven) – aimed at drilling glacigenic sediments with the MARUM-owned seafloor drill rig MeBo in a palaeo-ice stream depositional system in the western Barents Sea. The Kveithola Trough system was selected as target area because its former ice stream had a restricted extent and is, thus, expected to have sensitively responded to changes in regional climate and sea level.

The corresponding deposits occur in two different settings at the continental margin: a) as time-successive grounding-zone wedges inside the Kveithola Trough (tills, thick glacio-marine drapes, and young drift deposits); and b) as a Trough Mouth Fan on the continental slope (rhythmic plumites, glacigenic debrites, and younger submarine landslides). The scientific objective of this cruise was to use these deposits to: a) reconstruct high-glacial and deglacial ice advance and retreat dynamics as a result of climatic variability; b) investigate the sedimentation dynamics at the continental slope in response to meltwater discharge and ice-stream history; c) understand the sedimentation dynamics and depocentre formations on the associated shallow continental shelf; and d) reconstruct the sea-ice history with regard to changes in marine productivity and deep-water formation processes.

MeBo is a drill rig which can be deployed down to 2,000 m water depths and drill up to 70 m below seafloor. During Cruise MSM30, MeBo was used for the first time in Polar Regions, not only to obtain long sediment cores from glacigenic deposits but also to gain experience in drilling in high-latitude environments. Several MeBo deployments had, however, to be stopped due to technical incidents. MeBo was finally deployed 9 times at 5 sites during this cruise. 113 m were cored in total with an average recovery rate of 53 %.

MeBo drilled well and with great recovery through the 15-m thick uppermost stratified marine unit, which is composed of cohesive soft sediments. Low flush-water pumping rates and higher torque resulted in a certain improvement of core recovery rates in the highly compacted grounding zone wedge deposits. The underlying till deposits inside the Kveithola Trough were, in contrast, highly consolidated and cohesive which resulted in a poor core recovery. Adjusting penetration speed, flush-water volume, and torque will be the future challenge for optimizing core recovery in these glacigenic deposits. Highly consolidated sediments were also encountered on the Kveithola Trough Mouth Fan inside a landslide scar funnel. There, the debrite unit was very cohesive and only strong flushing led to continuous drilling advance. The underlying marine deposits (plumites) were, in contrast, very soft and permeable which led to an immediate drainage of the flushing water into this unit. Result was an immovable stuck of the drill string in the debrite unit.

The MeBo drilling program was flanked by conventional (gravity and vibro) sediment coring. Aims were: a) to reconstruct deglacial to Holocene palaeoclimatic and palaeoceanographic variability; b) to date the episodes of ice stabilization; and c) to calculate timing and rates of slope instability. Sediment surface sampling was necessary to depict the modern oceanographic and sedimentary environments.

Intensive multibeam mapping has led to an extension of the existing regional bathymetric map obtained during preceding cruises of the CORIBAR partners. This mapping revealed various morphological elements of the slope (shelf-edge gullies, young landslides, elongated

slide scars) and of the shelf (current-leading channels, ice plough mark pattern, grounding-zone wedge boundaries).

Densely spaced PARASOUND profiling was added to the few existing seismo-acoustic lines and allowed detailed insight into: a) the shallow subbottom architecture of the Trough Mouth Fan on the slope (plumites intercalated with glacigenic debrites and overlain by landslide bodies); b) the grounding-zone wedge succession (till successions overlain by a thick glacio-marine sequence) and drift system inside the Kveithola Trough (current-induced deposits of variable thickness, moats); and c) the glacigenic landscape surrounding the trough (channels, several moraine generations, local depression fills).

Zusammenfassung

Die CORIBAR-Expedition – eine internationale Initiative der Institutionen MARUM (Bremen), OGS (Triest), CSIC (Barcelona), UiT (Tromsø), GEUS (Kopenhagen) und AWI (Bremerhaven) hatte zum Ziel, glazigene Ablagerungen mit dem Meeresboden-Bohrgerät MeBo (MARUM) in einem Paläo-Eistrom-System in der westlichen Barentssee zu erbohren. Die Wahl fiel auf das Kveithola-Trogsystem, da dessen ehemaliger Eisstrom eine begrenzte Ausdehnung hatte. Die Erwartung ist, dass der Eisstrom deswegen auf regionale Änderungen von Klima und Meeresspiegel besonders sensitiv reagierte.

Die entsprechenden Ablagerungen treten in zwei unterschiedlichen Gebieten auf: a) als grounding-zone wedges innerhalb des Kveithola-Trogs (Moränen, glazio-marine Decken, jüngere Drift-Körper) und b) als Abfolge des vorgelagerten Hangfächers (Plumite, glazigene Debrite, jüngere submarine Rutschungen). Die wissenschaftliche Zielsetzung dieser Expedition war es, diese verschiedenen Ablagerungen zu erbohren, um: a) die Vorstoß- und Rückzugsdynamik des Eisstroms als Reaktion auf Klimavariabilität zu rekonstruieren; b) die Sedimentdynamik am Kontinentalhang unter dem Einfluss von Schmelzwasseraustritt und Eisstrom-Entwicklung zu untersuchen; c) die Sedimentationsprozesse und die Bildung von Ablagerungszentren auf dem umgebenden flachen Schelf zu beleuchten; und d) die Entwicklung der Meereisausdehnung im Hinblick auf Änderungen in der marine Produktivität und Tiefenwasserbildung zu rekonstruieren.

MeBo kann bis in 2000 m Wassertiefe eingesetzt werden und bis zu 70 m tief bohren. Während der Expedition MSM30 kam MeBo erstmalig in einer polaren Region zum Einsatz, nicht nur um lange Sedimentkerne von glazigenen Ablagerungen zu bekommen, sondern auch um Bohrerfahrungen in hohen Breiten zu sammeln. Mehrere MeBo-Einsätze mussten aufgrund technischer Probleme abgebrochen werden. Insgesamt hat MeBo in 9 Einsätzen an 5 Stationen 113 m abgeteuft, bei einem durchschnittlichen Kerngewinn von 53 %.

MeBo bohrte mit sehr gutem Kerngewinn durch die 15 m mächtige stratifizierte marine Deckschicht, die aus kohäsivem, weichem Sediment besteht. In den darunterliegenden, stark kompaktierten Ablagerungen des grounding-zone wedges führten niedrige Spülwasser-Pumpraten und ein hohes Drehmoment zu einer leichten Erhöhung des Kerngewinns. Die darunter folgenden glazigenen Moränen waren dagegen so stark kompaktiert und kohäsiv, dass der Kerngewinn sehr gering ausfiel. Die Anpassung von Vortriebsgeschwindigkeit, Spülwasservolumen und Drehmoment wird die zukünftige Herausforderung sein, um glazigene Ablagerungen zu erbohren. Kompaktierte Sedimente in Form eines 20 m mächtigen Debrits stehen auch in einem Rutschungskanal auf dem Hangfächer an. Trotz der Klebrigkeit dieser

Sedimente ging der Bohrvortrieb hier mit hohem Spüldruck kontinuierlich voran. Die unterlagernden marinen Sedimente (Plumite) waren dagegen so weich und durchlässig, dass der Spüldruck sofort abfiel und die Bohrung dadurch zum Erliegen kam.

Das Bohrprogramm wurde durch eine ausgedehnte konventionelle Kernnahme (Schwere- und Vibrolot) begleitet. Ziel dieser Kernkampagne war es, a) die paläoklimatische und paläozeanographische Variabilität während Deglazial und Holozän zu rekonstruieren, b) eine Datierung von Stabilisierungsepisoden des Eisstroms zu ermöglichen und c) Episoden von Hanginstabilität zeitlich einzuordnen. Darüber hinaus ermöglicht eine gezielte Beprobung von Sedimentoberflächen die moderne ozeanographische und sedimentäre Situation zu erfassen.

Die intensive Kartierung mit dem Fächerecholot erweiterte die bereits existierende regionale bathymetrische Karte, die die CORIBAR-Partner während vorangegangener Expeditionsfahrten erstellt haben. Diese Kartierung zeigt eindrücklich, wie die unterschiedlichen morphologischen Elemente am Hang (Kanäle an der Schelfkante, jüngere Rutschungskörper, langgezogene Rutschungskanten) und auf dem Schelf (strömungsführende Kanäle, Eisberg-Rinnenmuster, grounding-zone wedges) entwickelt sind.

Die engmaschige PARASOUND-Profilierung, als Ergänzung zu den wenigen zuvor existierenden seismo-akustischen Linien, ermöglichte einen detaillierten Einblick in die oberflächennahe Architektur des Trogfächers am Kontinentalhang (Plumite in Wechselfolge mit glazigenen Debriten und marinen Rutschungskörpern) und in die große Vielfalt von Ablagerungen auf dem Schelf um den Kveithola-Trog (laterale Abfolge von grounding-zone wedges, Drift-System im inneren Trog, glazigene Kanäle, verschiedene Generationen von Moränen, lokale Muldenfüllungen).

2 Participants

Name	Given Name	Institution	Duty on Board
Hanebuth	Till, J.J.	MARUM	Chief Scientist
Bergenthal	Markus	MARUM	MeBo
Caburlotto	Andrea	OGS	Geolab
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Düßmann	Ralf	MARUM	MeBo
Freudenthal	Tim	MARUM	MeBo
Hörner	Tanja	AWI	Geolab
Kaszemeik	Kai	MARUM	MeBo
Klar	Steffen	MARUM	MeBo
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Sabbatini	Anna	PUM	Wet lab
Schmidt	Werner	MARUM	MeBo
Stachowski	Adrian	MARUM	MeBo
Urgeles	Roger	CSIC	Geolab

AWI	Alfred-Wegener-Institute for Marine Polar Research, Bremerhaven, Germany.
BAUER	BAUER Group, Schrobenhausen, Germany.
CSIC	Institute of Marine Sciences, CSIC, Barcelona, Spain.
GeoB	Dept. of Geosciences, University of Bremen, Germany.
GEUS	Geological Survey of Denmark and Greenland, Copenhagen, Denmark.
MARUM	Center for Marine Environmental Sciences, University of Bremen, Germany.
OGS	National Institute for Oceanographic and Geophysic Sciences, Trieste, Italy.
PUM	Department of Environmental and Life Sciences, Polytechnical University of Marche, Ancona, Italy.
UiT	Department of Geology, University of Tromsø, Norway.

3 Research Program

3.1 Scientific Hypotheses and Targets

The rate of ice-sheet retreat across polar continental shelves, ice-stream collapses and their relationships to short-term sea-level changes during deglacial periods are a matter of debate. Ice streams that extend over large regions show an averaged and, thus, smoothened signal of large-scale environmental variability. However, if the associated catchment area and ice reservoir of an ice-stream system are locally restricted, the deposits which typically form in such an environment should sensitively record these ice advance and retreat dynamics. Rapid deglacial climatic changes in the northern Atlantic realm have forced the local ice sheet of the Kveithola Trough and the regional sea-ice cover to respond sensitively and rapidly. These ice dynamics and the post-glacial development are assumed to have left particular footprints in the form of various glacigenic and glacio-marine deposits:

1. The continental-slope deposits (Trough Mouth Fan systems, TMF) recorded these deglacial ice dynamics sensitively by the formation of plumite (meltwater suspension plume deposits) successions but have also interacted with the ocean-current system. We wanted to understand the mechanisms of generation and dispersal patterns of sediment-laden meltwater discharges and to investigate the sedimentation and stability dynamics on glacially influenced continental slopes in response to the cyclic glacier-induced sediment deposition. Further, we planned to analyze the palaeoceanographic and climatic changes since MIS 5 (6?), concentrating on glacial-interglacial and shorter-term millennial variability.
2. Variations in meltwater discharge, ice-stream dynamics, and sea-level rising were related to the deglacial ice sheet retreat history and are recorded by the ice-margin deposits (Grounded-Zone Wedge systems, GZWs) inside the Kveithola trough. We wanted to reconstruct the chronology of the deglaciation stages of the Svalbard/Barents Sea Ice Sheet for developing the conceptual understanding of ice-stream dynamics as well as in the context of rapidly changing climatic and environmental conditions since the last glacial maximum.
3. The nearby shallow continental shelf which must have acted as the local material source for sediments delivered by the ice-stream. Confined depocentres are expected, thus, to contain information on these processes and on the connection between the surrounding bank areas and the trough itself. We wanted a) to understand the formation dynamics of such shelf depocentres; b) to use these deposits as environmental archives for environmental changes; and c) to trace back the material sources, pathways and the driving forces leading to sediment dispersal.
4. The sea-ice history is closely linked to the climatic variability with strong impact on the marine productivity and deep-water formation processes. We wanted to a) reconstruct former sea-ice positions and their dynamics, and b) to apply sea-ice proxies for assessing the climate-model credibility in simulating high-latitude ocean and sea-ice processes.

3.2 Strategy of the Cruise

The main intention of this international initiative between the institutions – MARUM (Bremen), OGS (Trieste), CSIC (Barcelona), UiT (Tromsø), GEUS (Copenhagen) and AWI (Bremerhaven) – aimed at obtaining 70-m long sediment cores with the MARUM-owned seafloor drill rig MeBo, flanked by a sediment-acoustic and conventional coring program.

Continental slope drilling sites on the Kveithola TMF: The locations of two MeBo sites were selected where the glacially induced debris flow deposits are either absent or so reduced, that a continuous record of glacial-marine/meltwater plume sedimentation is accessible spanning the last two to three glacial stages (MIS (6?-) 5, 4-3, 2-1). These continental-slope records would provide an open-water counterpart to the proximal records of deglaciation to be obtained from the GZWs and the shallow continental shelf. Such a record would also strongly extend the few available short-time palaeoclimatic records from the Storfjorden TMF.

Continental shelf drilling sites inside the Kveithola Trough: A transect of 5 MeBo sites was planned to sample the post-glacial (Holocene), deglacial, proglacial, and subglacial sedimentary sequence. Three sites were located in the outer part of the trough at the toe of (or immediately in front of) each GZW, and would allow dating each phase of stillstand during general ice-sheet retreat. Two sites were located in the inner part of the trough on a 40-m thick sedimentary drift, to retrieve a high-resolution sedimentary record of the overlying post-glacial ice-retreat history. This core transect would provide ages for the phases of ice-stream retreat and palaeoceanographic information throughout the retreat of the ice grounding line.

Shallow continental shelf coring sites (outside the Kveithola Trough): Preferable targets for conventional coring were late-Quaternary depression fills, confined sediment depocentres, drift bodies, sediment drapes, and marginal trough deposits. These depocentres would serve as environmental archives to reveal a) the development of local sedimentary dynamics, b) information on the proximal material sources, and c) changes in the Holocene climatic/oceanographic history as a complement to the records from the TMF. Another important aspect was d) to decipher deglacial to Holocene sea-level dynamics.

3.3 Realization of the Program during the Cruise

Prior to MeBo drilling at a particular site, a pre-site survey consisting of bathymetric mapping, sediment echosounder profiling, sediment surface sampling, and gravity coring was scheduled for each site. Beside the MeBo drilling plan, we wanted to close gaps in the acoustic dataset from previous cruises of our international collaboration partners, and take additional sediment cores since core material from this region was sparse prior to our cruise.

MeBo has drilled at two sites successfully but met geological problems there, which provided important information to improve future project strategies and technical approaches for scientific offshore drilling in polar regions. However, since MeBo had various technical problems (s. Chapter 5.5), the conventional mapping, profiling and coring program was extended in accordance with the contingency plan, as designed during the cruise application.

With a slight extension of the study area, offset coring at two places, and an unexpected large number of sediment cores and PARASOUND profiles, we are confident that this material will help to replace some of those MeBo cores, which we finally did not get, to answer the central questions of the CORIBAR project.

4 Narrative of the Cruise

During the first week, we mainly conducted a program serving as preparation for the seven pre-selected MeBo drilling sites (Table 4.1). Seafloor morphology and the first tens of meters subbottom stratigraphy were profiled with the shipboard multibeam and PARASOUND echosounder systems. The seafloor surface and first meters of deposits were sampled by multicoring, giant box coring, and 3- to 12-m deep gravity coring. Beside their own scientific value, these data were thought to provide information for a save deployment of MeBo.

Whilst the weather conditions changed rapidly from sunny and calm to hazy and wet, the wave conditions remained always calm. We first ran a long seismo-acoustic profile along the entire Kveithola trough and half-way down the slope fan. Then, we run cross-profiles at these stations to obtain a three-dimensional picture, and have sampled these three sites afterwards. The coring worked very well and we received a long core from the oldest grounding-zone wedge at the outer Kveithola trough, and one from the associated trough-mouth fan at 1,700 m water depth. We took a third core from an eroded channel-like slide-scar structure at the fan, a structure which should serve as a window into deeper strata during MeBo coring, and received a long core with highly consolidated slide material.

Since MeBo had a number of technical issues to solve, we started to extend the already existing high-resolution bathymetric map of our CORIBAR partners in the distal zone of the trough-mouth fan. Numerous landslides characterize the seabed morphology in that area. The PARASOUND profiles show a series of glacigenic debrite lenses interbedding plumite and hemipelagic sediments, and younger landslide bodies at the surface. These deposits illustrate the large amount of debris supplied by the Kveithola ice stream during glacial periods, the significant activity of meltwater plumes during the deglaciation phase and the widespread slope instability during interglacial times. Finally, we run PARASOUND profiles along two of the channels which appear frequently at the uppermost slope and are expected to serve as conduits for dense waters and suspended sediments coming out of the Kveithola trough. To evaluate the role of these gullies in terms of sediment transport, we took two cores from their thalwegs which contained rocky debris and sandy turbidites at the surface.

The second week of our cruise was a successful performance with regard to our scientific objectives, the prime target of our program – to drill down long sediment cores with MeBo – could, however, still not be put into practice. During the early stage of drilling at the first site, a severe failure occurred in the hydraulic system of the drill rig. It was turned out that the required cleansing of this system could not be achieved on board. With three weeks of cruise time still ahead, we decided to return to Tromsø at the end of weekend for repairing the hydraulics with land-based support. The permission for this stay in the harbour came within two working days. In the meantime, we continued our research survey and finished first the preparation program for the MeBo drilling sites inside the Kveithola Trough. At the outer edges of two grounding-zone wedges we received long, fine-grained sediment cores from the area-draping Holocene cover.

We used two consecutive nights to cover the drift deposit at the innermost part of the trough by a dense grid of PARASOUND profiles. We cored across this drift at four stations afterwards with the aim to receive material from the high-accumulation center (best temporal resolution), from the margin with reduced accumulation rates (deepest look back into the past) and the marginal moat (current velocity). We also mapped the sedimentary infill of a 50-km long, structurally controlled channel located north of the trough, which is supposed to re-direct shelf bottom currents towards the drift deposit.

In respect to our contingency plan, we went next to the mouth area of the neighbouring Storfjorden Trough. The previous cruise of our Spanish collaboration partners has shown that some tills are covered by younger sediments here, thin enough for gravity coring. First physical property measurements on the two cores we took indicated that we penetrated these deposits which will able us to estimate the former ice coverage thickness. Finally, we run a number of parallel multibeam lines at the toe of the Kveithola trough-mouth fan to extend the edges of the already existing high-resolution bathymetric map generated by our Spanish, Italian and Norwegian partners during preceding cruises.

The third week began with the stay in the harbour of Tromsø from Monday to Thursday, where two hydraulics specialists from Germany and the MeBo technicians have repaired the hydraulic system of MeBo. We arrived back in our study area on Friday night. New technical complications have, however, continued to hamper the successful deployment of MeBo. We, thus, took sediment surfaces and gravity cores along two transects with seven stations in total on the bipartite sediment drift body located in the innermost part of the Kveithola Trough. The northward diverging structural channel was sampled through three gravity cores since its filling can directly be correlated to the trough's drift and we expect additional information on the regional oceanographic conditions and sediment dispersal pattern from these deposits. We run a grid of PARASOUND profiles across this area during the nights. The aim was to take sediment cores along a transect in the sense of offset coring (contingency plan) allowing to receive material from different successive units of the drift. Thus, such a composite core would in parts replace one long MeBo core.

During the remaining nine days, we have deployed MeBo five times. The first two sites were located at two successive grounding-zone wedges (GWZ) inside the Kveithola Trough. Drilling depths were 35 and 40 m penetrating the 20-m thick glacio-marine surface unit and the underlying tills of the GWZs. Both operations had to be stopped when the drilling advance came to a standstill due to the stiffness of the tills. Nevertheless, a GWZ was at least successfully drilled by a scientific group for the first time. The material retrieved (though the core recovery was limited due to the fact that high-pressure drill-hole flushing was required) allows an inside into the formation processes behind such glacigenic bodies.

We deployed MeBo at two further stations at the Kveithola trough mouth fan (TMF). The target was the continuous succession of various types of TMF-characteristic deposits (hemipelagites, plumites, glacigenic debrites, landslide deposits) allowing the reconstruction of the fan formation history and of the ice-sheet dynamics on longer time scales. Two drilling attempts had to be aborted due to technical failures. A third was located inside an erosional channel-like scar structure which we wanted to use as a geological window into much deeper, thus older strata (back into the Eemian times or older). After having inter-penetrated a 20-m thick debritic landslide unit which covers these old successions, the flush water fully drained away into the underlying, much softer hemipelagic deposits. The thick landslide material had, however, a rather sticky consistency and that the bore rods stuck.

In addition to these MeBo deployments, we sampled seabed sediments and took sediment cores at 11 stations during this week. The shallow-shelf areas north and south of the Kveithola Trough host small depression fills and various types of moraine deposits which we have drilled with a vibro corer, providing ground-truthing to our numerous PARASOUND lines across the area. We also have completed a depth transect from the trough's mouth down to the TMF's toe at 2,000 m water depth, collecting surface sediments for palaeoceanographic studies. We received two sediment cores, especially taken for the analysis of regional methane fluxes. Profiling surveys performed during the nights extended the bathymetric map of the study area significantly, in particular run along the trough's northern and southern margins, around the trough's mouth, and at the TMF's toe. Thus, we are able now to understand the sub-recent as well as ancient processes in detail which have and had control on sediment dispersal as well as on slope instability.

Table 4.1. Cruise program.

Date	Work during day	Work during night	Area
July 12	Arrival in Tromsø, Meeting chief scientists	-	Tromsø harbour
July 13	Mob of MeBo	-	Tromsø harbour
July 14	Mob of MeBo	-	Tromsø harbour
July 15	Mob of MeBo	-	Tromsø harbour
July 16	Depart 14:00, transit to study area	Transit	-
July 17	Transit	Arrival, mapping/profiling	Entire Kveithola Trough
July 18	1st coring station, MeBo drilling #1 (Site B)	Mapping/profiling	Outer Kveithola Trough
July 19	2 coring stations (MeBo sites A1, A2)	Mapping/profiling	Distal Kveithola TMF
July 20	Mapping/profiling, 1 coring station	Mapping/profiling	Proximal Kveithola TMF
July 21	2 coring stations (gullies)	Mapping/profiling	Central Kveithola Trough
July 22	1 coring station, MeBo drilling #2 (Site F)	Mapping/profiling	Inner Kveithola Trough
July 23	2 coring stations (MeBo Sites D, E)	Mapping/profiling	Central Kveithola Trough
July 24	Mapping/profiling	Mapping/profiling	Inner Kveithola Trough, N' channel
July 25	2 coring stations (tills)	Mapping/profiling	Storfjorden Trough, N' channel
July 26	4 coring stations (drift)	Mapping/profiling	Inner Kveithola Trough
July 27	2 coring stations (TMF slope)	Mapping/profiling	Toe of Kveithola TMF
July 28	Depart 06:00, transit to Tromsø	Transit	Transit
July 29	Arrival 11:00	Reparation	Tromsø harbour
July 30	Reparation	Reparation	Tromsø harbour
July 31	Reparation	Reparation	Tromsø harbour
Aug 01	Reparation	Depart 14:00, transit to study area	Tromsø harbour
Aug 02	Transit	Mapping/profiling	S' flank of Kveithola Trough
Aug 03	5 coring stations + 2 MeBo deployments #3 (Side D), #4 (Side D)	MeBo drilling #4 (Site D) until 01:30	Central Kveithola Trough
Aug 04	5 coring stations (drift, channel)	Mapping/profiling	Kveithola Trough head region
Aug 05	MeBo drilling #5 (Site D)	MeBo drilling #5 (Site D)	Central Kveithola Trough
Aug 06	MeBo drilling #5 (Site D) until 05:00; mapping/profiling	Mapping/profiling	S' flank of Kveithola Trough
Aug 07	Mapping/profiling	MeBo drilling (Site B)	S' flank of Kveithola Trough
Aug 08	MeBo drilling #6 (Site B) until 09:00; coring 2 stations (upper slope, slide)	MeBo drilling #7 (Site A2)	Middle Kveithola TMF
Aug 09	MeBo drilling #7 (Site A2) until 05:00; 3 coring stations	Multibeam, Parasound	Middle Kveithola TMF
Aug 10	4 coring stations S and N of the trough	Multibeam, Parasound	Area north of the Kveithola trough
Aug 11	MeBo drilling #8 (Site A2)	MeBo drilling #8 (Site A2)until 19:00; afterwards Multibeam, Parasound	Middle Kveithola TMF

Aug 12	Transit to Site A1	MeBo drilling #9 (Site A1) until 16:00	Middle Kveithola TMF
Aug 13	Multibeam, Parasound	2 coring stations (scar offset coring)	Middle Kveithola TMF
Aug 14	Depart 02:00, transit to Tromsø	Transit	Transit
Aug 15	Arrival 09:30, demob MeBo	-	Tromsø harbour
Aug 16	Demob MeBo, meeting chief scientists	-	Tromsø harbour
Aug 17	Return home	-	-

5 Methods and Preliminary Results

5.1 EM122 Deep Water and EM1002 Shallow Water Multibeam Echosounder

(A. Özmaral, M. Rebesco, R. Urgeles, and watch team)

5.1.1 Technical Description

The shipboard, moderate-deep water EM122 multibeam echsounder (MBES) can perform seabed mapping to full ocean depth. The nominal sonar frequency is 12 kHz with an angular coverage sector of up to 150° and 432 beams per ping. The angular coverage used during the cruise was 2×65°; the width of the useable mapping data is typically three tofour times the water depth. The transmit fan is split in several individual sectors with independent active steering according to vessel roll, pitch and yaw, therefore, it enables all soundings being put on a best fitting line that is perpendicular to the survey line, thus ensuring a uniform sampling of the bottom and possible 100% coverage. The EM122 transducers are linear arrays in a Mills cross configuration with separate units for transmit and receive.

During cruise MSM 30, system settings below were used for EM122 multibeam surveys:

- (Runtime Parameters – Sounder Main)
- Max. angle: 2×65°
- **Max coverage:** depending on water depth, usually higher than angular limit
- **Angular coverage mode:** AUTO (MANUAL results in less beams being used)
- Beam spacing: EQDIST
- Ping mode: AUTO
- Pitch stabilization: On
- Heading filter: MEDIUM

The shipboard, shallow-water EM1002 multibeam echosounder (MBES) operates in a variety of depths, from shallow water down to 1,000 m depth. The EM1002 MBES has a semi-circular transducer array with a radius of 45 cm and an angular extent of 160°, which is used both to transmit and receive the signals. EM 1002 operates at a frequency of 95 kHz and in order to increase the coverage, the system has three different pulse lengths such as 0.2 ms, 0.7 ms, and 2 ms (longer pulse lengths usually perform best at depths greater than 600 meters while shorter pulse lengths at depths less than 200 meters). When the angular coverage exceeds 100°, the hydro-acoustic transmission fan is divided into three separate sectors which means that inner and outer fan sectors have different specific frequencies, therefore, multiple echoes due to normal incidence can be reduced. Transducer array produces 111 individual beams with a width of 2°x2° which results in high range sampling with a maximum ping rate above 10 Hz. The system is electronically stabilized for the roll of the transmitting fan and receiving beams. EM1002 survey conducted during the cruise MSM 30 when the water depths were shallower than 400 m. Moreover, the sound velocity profile was measured each time just before the EM 1002 was deployed from the moonpool.

The EM122 and EM 1002 operation software is the Seafloor Information System (SIS) which displays the acquired data in real time and provides calibration. The integrated sound-speed-profile-editor is used to prepare and apply measured sound velocity profiles (SVP). Sound velocity data helps calculating the true position and depth values of the soundings. The sound velocity profiler SVPlus is designed to obtain high quality sound velocity and temperature data from the water column. After lowering the SV probe to the desired depth, gathered upcast and downcast sound velocity and also temperature values over depth were uploaded to the PC and then to the SVP Editor in SIS. By using the SVP editor, ASCII format file was converted to the *.asvp format read by SIS, so that, each measured sound speed profile was defined as one of the most important runtime parameters, subsequently the EM and PARASOUND survey was continued.

During cruise MSM30, sound velocity and temperature profiles were measured at nine locations whenever the water depths were changing noticeably.

5.1.2 Post-Processing

Raw data from the Kongsberg data acquisition software (SIS) were imported to the MB-system software for the processing on board. First, the raw data was converted to the editable format, then the cleaned data from artifacts was gridded. X-Y gridding was chosen as 25 meters. Once the grid was created, final map was generated by the free software Mirone and then imported to the Kingdom Suite for the interpretation together with the PARASOUND profiles and sediment cores.

5.1.3 Preliminary Results

The MBES survey was conducted together with PARASOUND profiling during the entire cruise time. Multibeam lines were run (Fig. 5.1) in order to extend the edges and close data gaps of the already existing high-resolution bathymetric map generated by Spanish, Italian and Norwegian partners during preceding cruises.

At the continental slope, numerous landslides show an imprint in the seabed morphology. Several gullies cut into the uppermost slope up to the shelf edge. On the slope fan, channel-like structures and collapse scars appear as remains of elongated downslope failures. The channels floors are often characterized by blocky features and terraces as result of submarine landsliding.

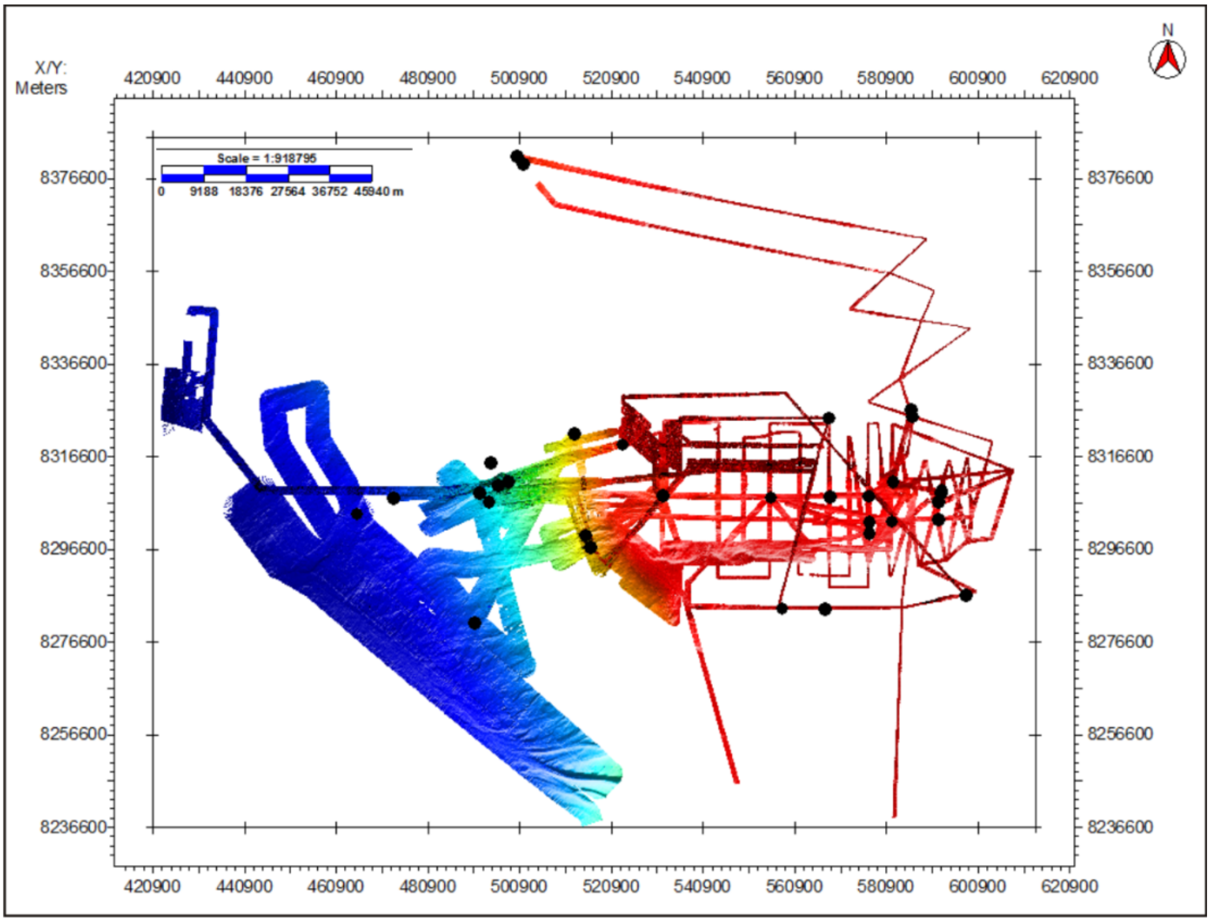


Fig. 5.1. EM 122, EM 1002 and PARASOUND lines on the MSM 30 study area (black dots indicates the core stations).

On the shallow shelf and inside the Kveithola Trough, the new data show in great detail ice-stream related mega-scale glacial lineations, plough marks of drifted icebergs, and grounding-zone wedges. We added numerous lines at the trough margin and slightly outside to the existing data from a previous cruise. These lines illustrate how bottom currents interact with the trough morphology after having crossed the shallow-shelf banks. We also used the bathymetric mapping of the innermost trough area and a N-S directed channel-like feature of probably tectonic origin to select suited positions for the following PARASOUND profiling of local depocentres filling these depressions.

Figure 5.2 shows the compilation of MSM30 and previous cruise mapping surveys. The MBES survey performed during MSM 30 cruise extended the existing map at the margins of the Kveithola Trough as well as at the distal part of the trough-mouth fan.

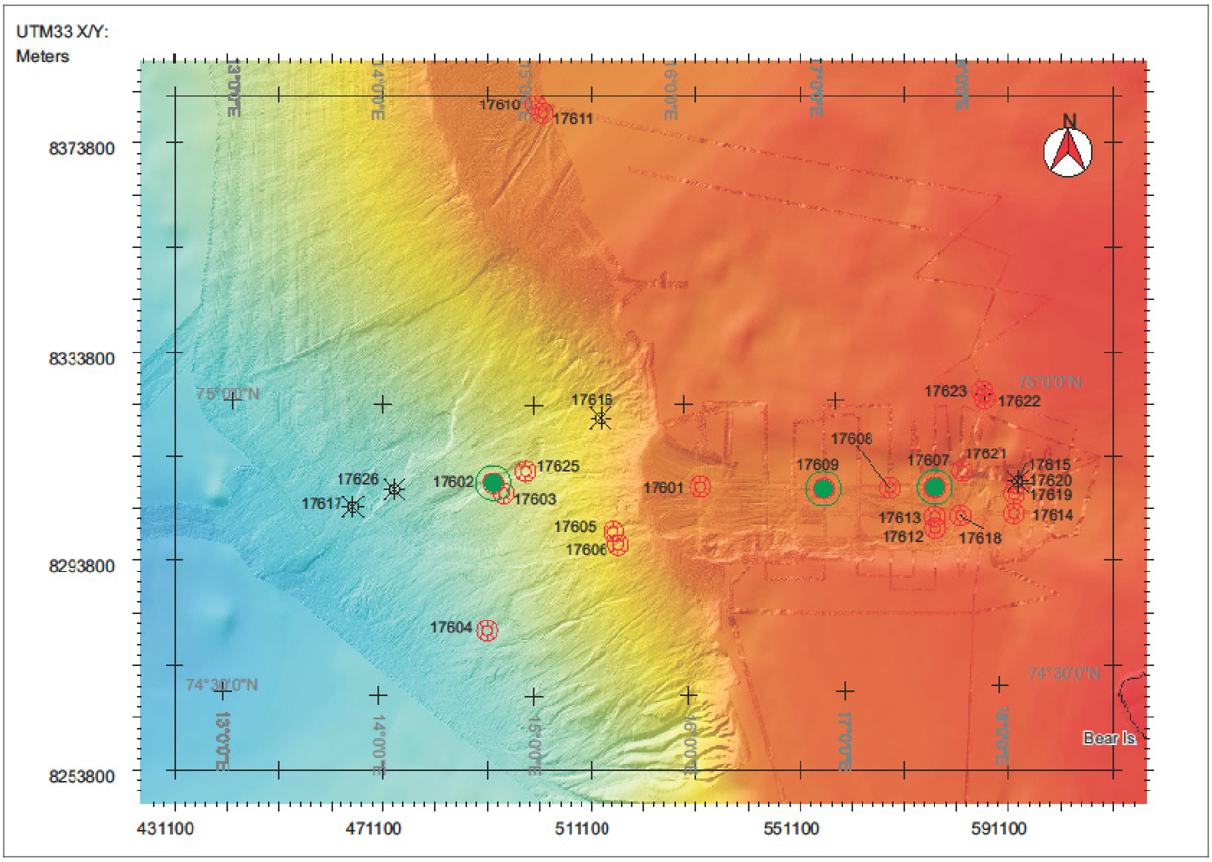


Fig. 5.2. Bathymetric data from cruise MSM 30 added to the existing map of the preceding cruises. Low resolution data filling data gaps is derived from GEBCO bathymetry. Coring stations are also shown in the map.

5.2 Sediment Echo Sounding (PARASOUND)

(A. Özmaral, M. Rebesco, R. Urgeles, and watch team)

5.2.1 Technical Description

RV MARIA S. MERIAN is equipped with the hull-mounted PARASOUND DS III-P70 system (Atlas Hydrographic). During cruise MSM30 the PARASOUND System was operated in order to a) map distinct depositional bodies and erosional structure to obtain a detailed insight into the three-dimensional geometries, and to b) select suitable sites for the deployment of MeBo and conventional sediment coring.

The PARASOUND system generates two primary frequencies (PHF: Primary High Frequency) selectable between 18 and 33 kHz transmitting in a narrow beam which allows lower received reverberation levels and, thus, higher penetration. The nonlinear acoustic interaction of the primary frequencies within the water column (Parametric Effect) takes place in the emission cone of these high frequency signals with the aperture angle of 4.5° x 5°. This cone is generated by rectangular plate of approx. 1 m^2 in size on which there is a transducer array with 128 transducers. Therefore, the beam footprint at the seafloor has a diameter of 7 % of the water depth, which inhibits significant diffraction hyperbolas, therefore, provides an increased lateral resolution compared to 3.5 kHz conventional subbottom profiling systems.

As a result of the parametric effect mentioned above, two secondary harmonic frequencies are generated: one parametric signal is the difference (approx. 4 kHz) called Secondary Low

Frequency (SLF) and the other parametric signal is the sum of two primary frequencies (approx. 40 kHz) called Secondary High Frequency (SHF). The parametric frequency and 70 kW transmission power allows subbottom penetration up to 200 m (depending on the sediment composition) with a vertical resolution of about 40 cm.

On RV MARIA S. MERIAN, PARASOUND DS III-P70 is controlled by the server software Atlas Hydromap Control which is used to run the system, and Atlas Parastore-3 which is used for online visualization of received data, data storage, and printing. Parastore-3 provides also replaying of recorded data, post-processing and further data storage in different output formats (PS3 and/or SEG-Y). For any further details the reader is referred to the operator manuals of Atlas Hydromap Control (ATLAS_Hydrographic, 2007a) and Atlas Parastore (ATLAS_Hydrographic, 2007b)

During cruise MSM 30, the PHF and SLF data were continuously acquired and stored. The SLF frequency was set to 4 kHz. The SLF data were suited for imaging the sedimentary column, while the 18 kHz PHF data were used for imaging the water column. Most of the PARASOUND lines were operated by defining a sinusoidal source wavelet of 2 period and 0,500 ms length with rectangular pulse shape in order to gather good relation between signal penetration and vertical resolution. Also, transmission sequence was set to quasi-equidistant mode, by chosen desired time interval between the transmission pulses which was 400 ms, was used in order to increase the horizontal resolution compared to single pulse mode. For the PARASOUND lines conducted at shallow-shelf depths, the receiver amplification was reduced for the SLF data. Moreover, vessel speed was tried to be kept as not exceeding 7 knots.

5.2.2 Data Storage and Processing

During the cruise, the PHF and SLF data were stored in the ASD (ATLAS Sounding Data) file format with phase and carrier. The ASD is a hybrid file format for storage of complete sounding profiles. While ASD files contain the complete sounding including the whole water column, usually only the sediment response of the signal is of interest for scientific needs. Therefore, in parallel to ASD file storage also the depth window, which is chosen by the operator for visualization may be stored in standard echo sounder or seismic data formats. Currently, storage in the SEG-Y, SEG-D format, and PS3-format is supported. PS3 is a compressed data format, closely related to the SEG-Y standard, consisting of a 16 byte/sample data record with a 240 byte data header which contains most of the auxiliary information.

A 200 m window of the SLF data were stored in the PS3 format and subsequently converted into SEG-Y by the software ps3sgy (H. Keil, University of Bremen) which also provided post processing of the SLF data such as calculating the envelope of the seismic traces, subtracting the mean to reduce the noise, eliminating the outlier navigation data and converting the positions to UTM projection. The converted SEG-Y files then imported into the Kingdom Suite (Seismic Micro Technology) software as envelope data by manually setting the depth range of each SEG-Y file for the interpretation on board. All visualized and stored data has been already heave corrected.

5.2.3 Preliminary Results

The PARASOUND profiles indicate an upper well-stratified sedimentation environment on the Trough Mouth Fan, inside the Kveithola Trough, and in local depressions on the surrounding shallow shelf. A signal penetration for this continuous stratified unit was up to 40 m below seafloor for the 4 kHz SLF signal based on a sound velocity of 1500 m/s. This signal penetration was the deepest ever obtained in the study area. Penetration depth at the slope was up to 60 m.

The survey started with a long seismo-acoustic profile along the entire Kveithola trough and halfway down the slope fan (Fig. 5.3). On the slope, the PARASOUND profiles show a series of glacigenic debrite lenses interbedded with plumites and hemipelagic sediments as well as younger landslide bodies at the surface. These sediments are indicative of the large amount of debris supplied by the Kveithola ice stream during glacial periods, the significant activity of meltwater plumes during the deglaciation phase and the overall instability of the slope during interglacial times. We also ran PARASOUND profiles along two of the erosional gullies at the uppermost slope. These gullies are expected to serve as conduits for suspended sediments flowing out of the Kveithola trough and the cores show to what extent these gullies are still truly active nowadays.

A confined, contouritic drift deposit at the innermost part of the Kveithola Trough was covered with a dense grid of profiles. This drift appears as a mounded structure with two distinct depositional centers. While this body is fully attached to the southern wall of the trough, it is separated from the northern wall by a marked channel (Fig. 5.4). This channel might direct a through-bottom current. There is also a clear communication of the northward extending shallow-shelf channel with the Kveithola Trough in terms of current activity as well as with the drift body in terms of sediment dispersal and deposition pattern.

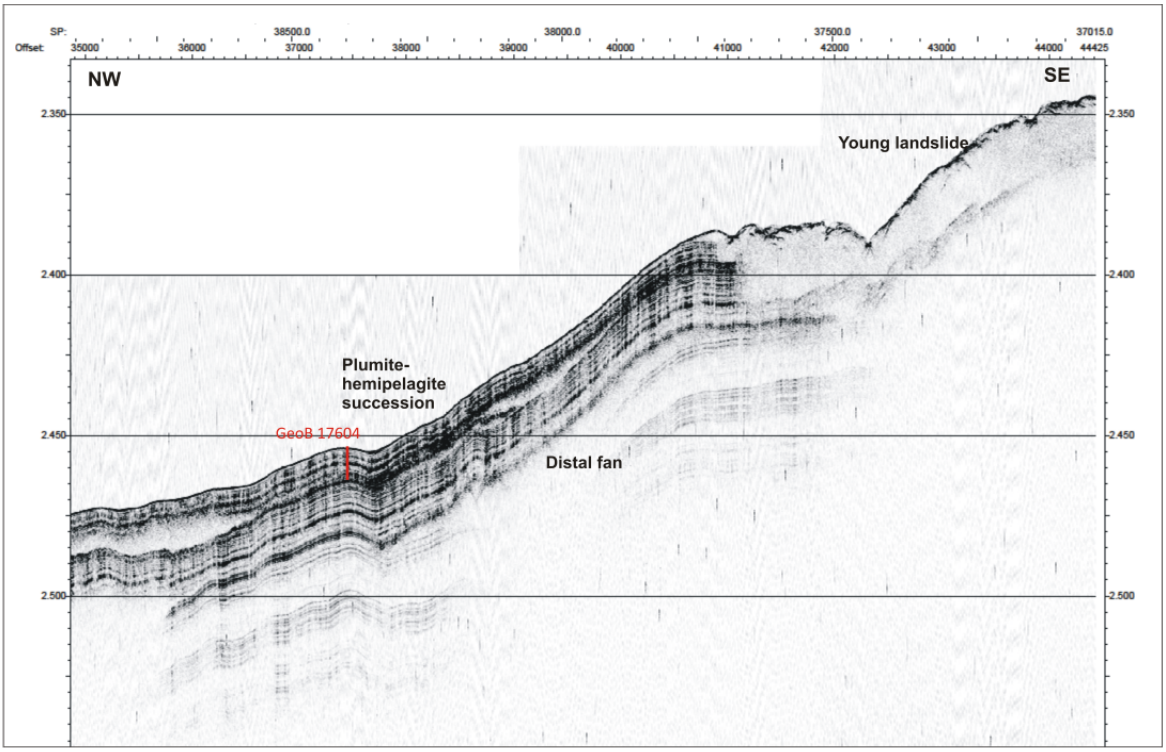


Fig. 5.3. PARASOUND profile across the distal Kveithola trough mouth fan and the coring station GeoB17604.

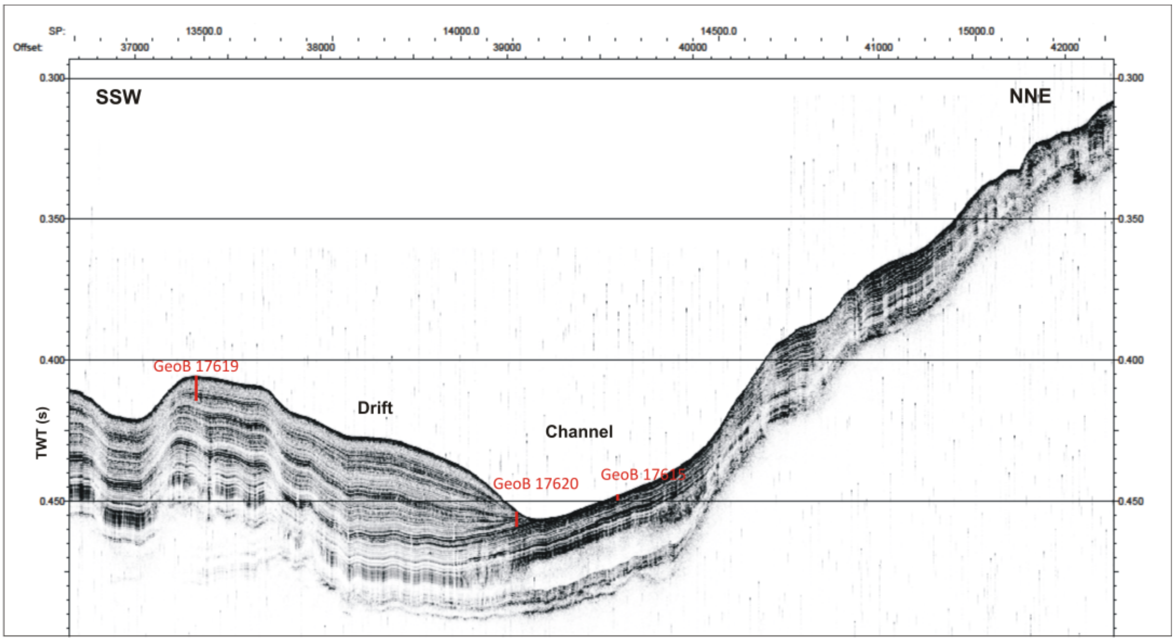


Fig. 5.4. The current-induced drift in the inner Kveithola Trough with high sediment accumulation on the left side and non-deposition of sediments on the right flank, forming a channel structure that is also one of the coring stations (GeoB17615, 17619 and 17620).

Additional PARASOUND profiling was performed in the southeastern area of the northerly Storfjorden Trough. Figure 5.5 shows how successive till generations overlap each other here. These deposits are interpreted as to indicate ancient ice-stream positions related to the Last Glacial Maximum (LGM) and the Deglacial. These tills are overlain by a thin drape of marine sediments. The generally rough topography results from drifted iceberg plough marks (Fig. 5.5).

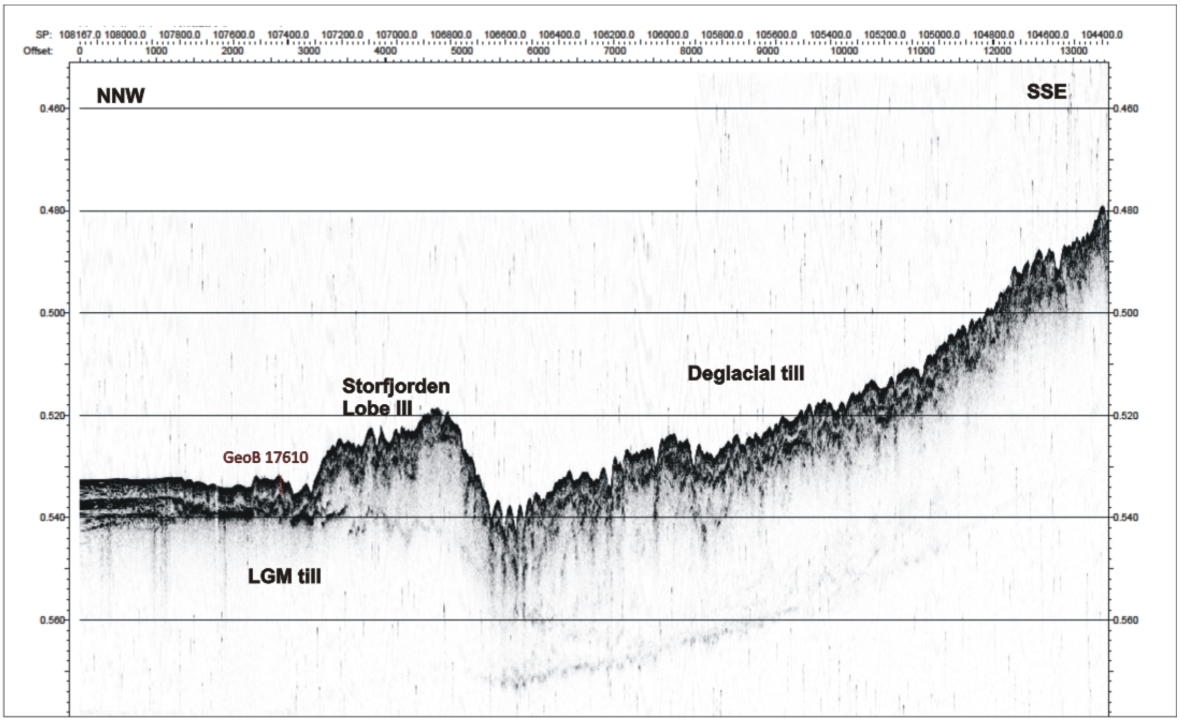


Fig. 5.5. PARASOUND profile on Storfjorden trough mouth showing overriding till generations and the coring station GeoB17610.

5.3 Sediment Surface Sampling and Shallow Coring

(R.G. Lucchi, A. Sabattini, L. Nicolaisen, A. Caburlotto, T. Hörner, G. Osti)

Sediment surface sampling was performed employing a multicorer equipped with eight plastic liners with a length of 50 cm and a diameter of 6 cm, and a giant box corer with a 50x50x50 cm steel box. At all coring sites, either a multicore or a giant box core was taken first to either obtain an undisturbed surface including the uppermost fluffy layer (multicorer) or to get insight into the character of the seabed in case coarse-grained or strongly consolidated deposits were expected (giant box corer).

Routine sub-sampling was performed onboard for preliminary compositional analyses of the sediments, and for shore-based sedimentological, micropalaeontological, biological, geochemical and biochemical purposes for which all of the samples were stored at +4°C or -20°C according to the protocol foreseen for the specific shore-based analysis (Tables 5.1 and 5.2).

A qualitative investigation of benthic foraminifera was performed on both the sediments from the giant box corer and the multicorer on board already. Small sediment sub-samples were scooped off the sediment surface using a spoon and immediately washed through a 125-µm sieve using cleaned seawater and the residues analyzed under a stereomicroscope.

A schematic description of the methods for sub-sampling and type of analyses of the sediments from both devices are indicated in the following.

5.3.1 Multicorer (MUC)

The eight tubes of the multicorer were treated as documented in the following:

Living Foraminifera, geochemical and biochemical analyses: 3 cores for each deployment were sub-sampled with a 3.6 x 24.5 cm coring tube (surface area ~10 cm^2). Pseudo-replicates for each MUC station were frozen at -20°C and 1 pseudo-replicate from only 8 stations was collected on board and sediment samples sectioned at 0.5-cm thick layers to a depth of 2 cm and 1-cm thick layers to a depth of 10 cm; each un-sieved slice was fixed and stored in 4% formalin solution buffered with sodium borate. 10 superficial samples (0-1 cm), collected from the rest of the undisturbed top MUC cores, were stored at -20°C. GEUS (Morigi), Polytechnic University of Marche (Sabbatini).

- **Recent Foraminifera analyses**: 1 core for some deployments (Stations 17603-1; 17609-3; 17616-1; 17617-1; 17626-1) was recovered and frozen at -20°C. GEUS (Morigi, Nicolaisen).
- **Sedimentological analyses and processes**: 2 cores for each deployment were recovered: 1 frozen at -20°C and 1 was sectioned on board every 1 cm for all tube length and sediment samples split in 2 subsamples and recovered in small plastic containers and cooled at +4°C. MARUM (Hanebuth, Lantzsch).
- **Sedimentological analyses**: 1 core for each deployment was recovered and cooled at +4°C. OGS (Lucchi).
- **Organic matter analyses and diagenesis processes**: from 1 to maximum 3 cores for each deployment were recovered and frozen at -20°C. OGS (OGS-BIO or OGS-1,-2,-3,-4).
- **Organic pollutants analyses**: 1 core for 1 deployment (Stations 17607-1) was recovered and frozen at -20°C. University of Siena (Corsolini).
- **Geochemical analyses**: 1 core for 1 deployment (Stations 17607-1) was recovered and frozen at -20°C. University of Florence (Traversi).

- **Biomarker analyses**: 1 superficial sample (0-1 cm) for each deployment was stored at -20°C and 1 core for some deployments (Stations 17609-3; 17617-1) was recovered and frozen at -20°C. AWI (Hörner, Stein).

5.3.2 Giant Box Corer (GBC)

The sediments recovered with the giant box corer were described and photographed on both the sediment surface and the vertical section. Samples were obtained by sub-sampling the box core with a longitudinally pre-cut plastic liner that was subsequently split in two-half sections. The sediments were described for textural and structural characteristics, color change, and macro-fauna content.

The giant box corer was sampled as documented in the following:

- **Living Foraminifera analyses including geochemical and biochemical assays**: 3 cores for each deployment were sub-collected with a 3.6 x 24.5 cm coring tube (surface area ~10 cm^2). Pseudo-replicates for each GBC station were frozen at -20°C. 10 superficial samples (0-1 cm) were stored at -20°C. GEUS (Morigi), Polytechnic University of Marche (Sabbatini).
- **Diatom analyses**: 1 core for some deployments (Stations 17601-2; 17603-2; 17607-4) was recovered and cooled at +4°C. University of Naples (De Stefano).
- **Pollen analyses and radioisotopes:** 1 core for some deployments (Stations 17601-2; 17603-2; 17607-4; 17608-2; 17609-1; 17615-1) was recovered and cooled at +4°C. ISMAR, CNR (Alvisi).
- **Sedimentological analyses and processes**: 2 cores for each deployment were recovered: 1 frozen at -20°C and 1 was sectioned on board every 1 cm for all tube length and sediment samples split in 2 subsamples and recovered in small plastic containers and cooled at +4°C. 2 superficial samples (0-1 cm) were stored at +4°C. MARUM (Hanebuth, Lantzsch).
- **Sedimentological analyses**: 1 core for each deployment was recovered and cooled at +4°C. OGS (Lucchi).
- **Organic matter analyses and diagenesis processes**: from 1 to maximum 2 cores for each deployment were recovered and frozen at -20°C. OGS (OGS-BIO or OGS-1,-2,-3,-4).
- **Organic pollutants analyses**: 1 core for some deployments (Stations 17601-2; 17603-2; 17605-1; 17606-1) was recovered and frozen at -20°C. University of Siena (Corsolini).
- **Geochemical analyses**: 1 core for some deployments (Stations 17601-2; 17603-2; 17605-1; 17606-1; 17615-1) was recovered and frozen at -20°C. University of Florence (Traversi).
- **Biomarker analyses**: 1 superficial sample (0-1 cm) for each deployment was stored at -20°C. AWI (Hörner, Stein).

5.3.3 Material Obtained

Tables 5.1 and 5.2 report detailed information of MUC and GBC sub-sampling. Detailed descriptions of the GBCs are provided in the Appendix.

Table 5.1. MUC station list (sup = superstitial water).

Date	Site GeoB	Event	Core	Recovery [cm]	Remarks
18.07.2013	17601	1	1	34,5	GEUS R1 Foraminifera frozen -20°C
			2	34,5	OGS-1 frozen -20°C
			3	33,5	GEUS R2 Foraminifera frozen -20°C
			4	33,5	OGS-2 frozen -20°C
			5	32,2	OGS-3 frozen -20°C
			6	34,8	MARUM-Till/Hendrik cooled +4°C
			7	34	MARUM-Till/Hendrik cooled +4°C
			8	35	GEUS R3 Foraminifera formalin
19.07.2013	17603	1	1	21,5	GEUS R1 Foraminifera frozen -20°C
			2	34	GEUS-Line frozen -20°C
			3	38	OGS-1 frozen -20°C
			4	21,5	GEUS R2 Foraminifera frozen -20°C
			5	38	MARUM-Till/Hendrik cooled +4°C
			6	35	MARUM-Till/Hendrik frozen -20°C
			7	19	GEUS R3 Foraminifera frozen -20°C
			8	37	OGS-2 frozen -20°C
20.07.2013	17604	1	1	22	GEUS R1 Foraminifera + surface frozen -20°C
			2	39	OGS-Renata cooled +4°C
			3	22	GEUS R2 Foraminifera + surface frozen -20°C
			4	37	MARUM-Till/Hendrik frozen -20°C
			5	38	MARUM-Till/Hendrik cooled +4°C
			6	23	GEUS R3 Foraminifera + surface formalin
22.07.2013	17607	1	1	34	MARUM-Till/Hendrik cooled +4°C
			2	32	MARUM-Till/Hendrik frozen -20°C
			3	25	GEUS R1 Foraminifera + surface frozen -20°C
			4	34	OGS-BIO frozen -20°C
			5	25	GEUS R2 Foraminifera + surface frozen -20°C
			6	31	Corsolini frozen -20°C
			7	18	GEUS R3 Foraminifera + surface formalin
			8	31	Traversi frozen -20°C
23.07.2013	17608	1	1	34	MARUM-Till/Hendrik frozen -20°C
			2	36	MARUM-Till/Hendrik cooled +4°C
			3	36,5	GEUS R1 Foraminifera frozen -20°C
			4	36,5	OGS-BIO frozen -20°C
			5	38	GEUS R2 Foraminifera frozen -20°C
			6	35,5	GEUS R3 Foraminifera formalin
23.07.2013	17609	3	1	23	MARUM-Till/Hendrik cooled +4°C
			2	23	MARUM-Till/Hendrik frozen -20°C
			3	26	MARUM-AWI-Tanja frozen -20°C
			4	29	GEUS-Line frozen -20°C
			5	28	GEUS R1 Foraminifera frozen -20°C
			6	24	OGS-BIO frozen -20°C
			7	26	GEUS R2 Foraminifera frozen -20°C
			8	28	GEUS R3 Foraminifera formalin
25.07.2013	17610	1	1	36	MARUM-Till/Hendrik cooled +4°C
			2	35	MARUM-Till/Hendrik frozen -20°C
			3	33	GEUS R1 Foraminifera frozen -20°C
			4	34	GEUS R2 Foraminifera frozen -20°C
			5	36	GEUS R3 Foraminifera formalin

			6	38	OGS-BIO frozen -20°C
			sup	15	MARUM-AWI Arctic biomarker, surface frozen -20°C
			7	36	OGS-Renata cooled +4°C
25.07.2013	17611	2	1	31	MARUM-Till/Hendrik cooled +4°C
			2	35	MARUM-Till/Hendrik frozen -20°C
			3	37	OGS-Renata cooled +4°C
			sup	34	GEUS R1 Foraminifera only surface, frozen -20°C
			sup	23	GEUS R2 Foraminifera only surface frozen -20°C
			sup	31	GEUS R3 Foraminifera only surface frozen -20°C
			sup	18	MARUM-AWI Arctic biomarker, surface frozen -20°C
26.07.2013	17612	1	1	19	MARUM-Till/Hendrik cooled +4°C
			2	18	MARUM-Till/Hendrik frozen -20°C
			3	18	GEUS R1 Foraminifera + surface frozen -20°C
			4	20	GEUS R2 Foraminifera + surface frozen -20°C
			5	19	GEUS R3 Foraminifera + surface frozen -20°C
			6	14	OGS-BIO frozen -20°C
			sup	14	MARUM-AWI Arctic biomarker, surface frozen -20°C
			7	19	OGS-Renata cooled +4°C
26.07.2013	17613	1	1	30	OGS-Renata cooled +4°C
				0	Empty
			2	23	MARUM-Till/Hendrik cooled +4°C
			3	27	MARUM-Till/Hendrik frozen -20°C
			4	24	GEUS R1 Foraminifera + surface frozen -20°C
				0	Empty
			sup	20	MARUM-AWI Arctic biomarker, surface frozen -20°C
			5	24	GEUS R2 Foraminifera + surface frozen -20°C
26.07.2013	17614	1	1	29	MARUM-Till/Hendrik cooled +4°C
			2	32	MARUM-Till/Hendrik frozen -20°C
			3	32	OGS-BIO frozen -20°C
			sup	33	GEUS R1 Foraminifera only surface frozen -20°C
			sup	22	MARUM-AWI Arctic biomarker, surface frozen -20°C
			4	34	OGS-Renata cooled +4°C
			sup	32	GEUS R2 Foraminifera only surface frozen -20°C
			sup	31	GEUS R3 Foraminifera only surface frozen -20°C
26.07.2013	17616	1	1	35	MARUM-Till/Hendrik cooled +4°C
			2	29	GEUS R1 Foraminifera + surface frozen -20°C
			3	37	GEUS R2 Foraminifera + surface frozen -20°C
			4	38	OGS-Renata cooled +4°C
			sup	36	MARUM-AWI Arctic biomarker, surface frozen -20°C
			5	33	GEUS R3 Foraminifera + surface frozen -20°C
			6	39	GEUS-Line frozen -20°C
			7	38	MARUM-Till/Hendrik frozen -20°C
27.07.2013	17617	1	1	40	MARUM-Till/Hendrik cooled +4°C
			sup	16	MARUM-AWI Arctic biomarker, surface frozen -20°C
			2	39	GEUS R1 Foraminifera + surface frozen -20°C
			3	35	MARUM-AWI-Tanja frozen -20°C
			4	39	GEUS R2 Foraminifera + surface frozen -20°C
			5	38	GEUS R3 Foraminifera + surface frozen -20°C
			6	34	MARUM-Till/Hendrik frozen -20°C
			7	36	GEUS-Line frozen -20°C
03.08.2013	17618	1	1	30	MARUM-Till/Hendrik cooled +4°C
			2	30	MARUM-Till/Hendrik frozen -20°C
			3	30	GEUS R1 Foraminifera + surface frozen -20°C

			sup	25	MARUM-AWI Arctic biomarker, surface frozen -20°C
			4	29	GEUS R2 Foraminifera + surface frozen -20°C
			sup	29	GEUS Foraminifera, surface frozen -20°C
			5	28	GEUS R3 Foraminifera + surface frozen -20°C
			6	30	OGS-Renata cooled +4°C
04.08.2013	17619	1	1	31	MARUM-Till/Hendrik cooled +4°C
			2	36	MARUM-Till/Hendrik frozen -20°C
			3	37	OGS-Renata cooled +4°C
			4	35	GEUS R1 Foraminifera + surface frozen -20°C
			sup	34	GEUS Foraminifera, surface frozen -20°C
			5	33	GEUS R2 Foraminifera + surface frozen -20°C
			sup	30	MARUM-AWI Arctic biomarker, surface frozen -20°C
			6	31	GEUS R3 Foraminifera + surface frozen -20°C
04.08.2013	17622	1	1	41	MARUM-Till/Hendrik cooled +4°C
			2	34	MARUM-Till/Hendrik frozen -20°C
			3	35	GEUS R1 Foraminifera + surface frozen -20°C
			sup	35	GEUS Foraminifera, surface frozen -20°C
			4	34	GEUS R2 Foraminifera + surface frozen -20°C
			sup	33	MARUM-AWI Arctic biomarker, surface frozen -20°C
			5	38	GEUS R3 Foraminifera + surface frozen -20°C
			6	40	OGS-Renata cooled +4°C
08.08.2013	17624	1			Empty
08.08.2013	17624	2			Empty
09.08.2013	17626	1	1	39	MARUM-Till/Hendrik cooled +4°C
			sup	30	MARUM-AWI Arctic biomarker, surface frozen -20°C
			2	39	GEUS R1 Foraminifera + surface frozen -20°C
			3	39	GEUS-Line frozen -20°C
			sup	39	GEUS Foraminifera, surface frozen -20°C
			4	39	GEUS R2 Foraminifera + surface frozen -20°C
			5	37	MARUM-Till/Hendrik frozen -20°C
			6	38	GEUS R3 Foraminifera + surface frozen -20°C
09.08.2013	17628	1	1	37	MARUM-Till/Hendrik cooled +4°C
			2	39	MARUM-Till/Hendrik frozen -20°C
			sup	36	MARUM-AWI Arctic biomarker, surface frozen -20°C
			3	37	GEUS R1 Foraminifera + surface frozen -20°C
			sup	38	GEUS Foraminifera, surface frozen -20°C
			4	38	GEUS R2 Foraminifera + surface frozen -20°C
			5	39	OGS-Renata cooled +4°C
			6	38	GEUS R3 Foraminifera + surface frozen -20°C

Table 5.2. GBC station list (sup = superstitial water).

Date	Site	Event	Core	Recovery [cm]	Remarks
18.07.2013	17601	2	sup	0-1	MARUM-AWI Arctic biomarker, surface frozen -20°C
			sup	0-1	GEUS Foraminifera surface frozen -20°C (organic matter, proxies, living foraminifera)
			1	41	OGS-Renata cooled +4°C
			2	40	OGS-4 frozen -20°C
			3	39	Traversi frozen -20°C
			4	41	De Stefano cooled +4°C
			5	38	Corsolini frozen -20°C
			6	43	Alvisi cooled +4°C

19.07.2013	17602	1	sup	0-1	MARUM-AWI Arctic biomarker, surface frozen -20°C
			sup	0-1	MARUM-Hanebuth/Lantzsch surface cooled +4°C
			sup	0-1	GEUS Foraminifera surface frozen -20°C (organic matter, proxies, living foraminifera)
			1	18	GEUS R1 Foraminifera frozen -20°C
			2	18	GEUS R2 Foraminifera frozen -20°C
			3	19	GEUS R3 Foraminifera frozen -20°C
			4	48	MARUM-Hanebuth/Lantzsch cooled +4°C
			5	47	MARUM-Hanebuth/Lantzsch cooled +4°C
			6	46	OGS-Renata cooled +4°C
19.07.2013	17603	2	sup	0-1	MARUM-AWI Arctic biomarker, surface frozen -20°C
			sup	0-1	MARUM-Hanebuth/Lantzsch surface cooled +4°C
			sup	0-1	GEUS Foraminifera surface frozen -20°C (organic matter, proxies, living foraminifera)
			1	48	OGS-3 frozen -20°C
			2	48	OGS-4 frozen -20°C
			3	48	Corsolini frozen -20°C
			4	48	De Stefano cooled +4°C
			5	49	Traversi frozen -20°C
			6	48	Alvisi cooled +4°C
			7	49	OGS-Renata cooled +4°C
21.07.2013	17605	1	sup	0-1	MARUM-AWI Arctic biomarker, surface frozen -20°C
			sup	0-1	MARUM-Hanebuth/Lantzsch surface cooled +4°C
			sup	0-1	GEUS Foraminifera surface living foraminifera
			1	41	MARUM-Hanebuth/Lantzsch cooled +4°C
			2	39	MARUM-Hanebuth/Lantzsch cooled +4°C
			3	39	Traversi frozen -20°C
			4	38	OGS-Renata cooled +4°C
			5	39	Corsolini frozen -20°C
21.07.2013	17606	1	sup	0-1	MARUM-AWI Arctic biomarker, surface frozen -20°C
			sup	0-1	MARUM-Hanebuth/Lantzsch surface cooled +4°C
			sup	0-1	GEUS Foraminifera surface frozen -20°C (organic matter, proxies, living foraminifera)
			1	18	GEUS R1 Foraminifera frozen -20°C
			2	13	GEUS R2 Foraminifera frozen -20°C
			3	19	GEUS R3 Foraminifera frozen -20°C
			4	38	OGS-Renata cooled +4°C
			5	39	Corsolini frozen -20°C
			6	39	Traversi frozen -20°C
			7	41	MARUM-Hanebuth/Lantzsch cooled +4°C
			8	39	MARUM-Hanebuth/Lantzsch cooled +4°C
22.07.2013	17607	4	sup	0-1	MARUM-AWI Arctic biomarker, surface frozen -20°C
			sup	0-1	MARUM-Hanebuth/Lantzsch surface cooled +4°C
			sup	0-1	GEUS Foraminifera surface frozen -20°C (proxies)
			1	51	OGS-Renata cooled +4°C
			2	52	De Stefano cooled +4°C
			3	54	Alvisi cooled +4°C
23.07.2013	17608	2	sup	0-1	MARUM-AWI Arctic biomarker, surface frozen -20°C
			sup	0-1	MARUM-Hanebuth/Lantzsch surface cooled +4°C
			sup	0-1	GEUS Foraminifera surface frozen -20°C (organic matter, proxies, living foraminifera)
			1	48	OGS-Renata cooled +4°C
			2	49	Alvisi cooled +4°C
			3	46	MARUM-Hanebuth/Lantzsch cooled +4°C

23.07.2013	17609	1	sup	0-1	MARUM-AWI Arctic biomarker, surface frozen -20°C
			sup	0-1	MARUM-Hanebuth/Lantzsch surface cooled +4°C
			sup	0-1	GEUS Foraminifera surface frozen -20°C (organic matter, proxies, living foraminifera)
			1	35	OGS-Renata cooled +4°C
			2	36	Alvisi cooled +4°C
			3	33	MARUM-Hanebuth/Lantzsch cooled +4°C
26.07.2013	17612	3			Box deformed
26.07.2013	17615	1	sup	0-1	MARUM-AWI Arctic biomarker, surface frozen -20°C
			sup	0-1	MARUM-Hanebuth/Lantzsch surface cooled +4°C
			sup	0-1	GEUS Foraminifera surface frozen -20°C (proxies)
			1	25	MARUM-Hanebuth/Lantzsch cooled +4°C
			2	24	MARUM-Hanebuth/Lantzsch cooled +4°C
			3	25	OGS-Renata cooled +4°C
			4	22	Alvisi cooled +4°C
			5	25	OGS-BIO frozen -20°C
			6	22	Traversi frozen -20°C
04.08.2013	17620	1	sup	0-1	MARUM-AWI Arctic biomarker, surface frozen -20°C
			sup	0-1	MARUM-Hanebuth/Lantzsch surface cooled +4°C
			sup	0-1	GEUS Foraminifera surface frozen -20°C (organic matter, proxies, living foraminifera)
			1	34	MARUM-Hanebuth/Lantzsch cooled +4°C
			2	36	MARUM-Hanebuth/Lantzsch cooled +4°C
			3	35	OGS-Renata cooled +4°C
			4	33	OGS-BIO frozen -20°C
			5	20	GEUS R1 Foraminifera frozen -20°C
			6	20	GEUS R2 Foraminifera frozen -20°C
			7	20	GEUS R3 Foraminifera frozen -20°C
04.08.2013	17621	1	sup	0-1	MARUM-AWI Arctic biomarker, surface frozen -20°C
			sup	0-1	MARUM-Hanebuth/Lantzsch surface cooled +4°C
			sup	0-1	GEUS Foraminifera surface frozen -20°C (organic matter, proxies, living foraminifera)
			1	36	MARUM-Hanebuth/Lantzsch cooled +4°C
			2	35	MARUM-Hanebuth/Lantzsch cooled +4°C
			3	35	OGS-Renata cooled +4°C
			4	34	OGS-BIO frozen -20°C
			5	20	GEUS R1 Foraminifera frozen -20°C
			6	20	GEUS R2 Foraminifera frozen -20°C
			7	20	GEUS R3 Foraminifera frozen -20°C
04.08.2013	17623	1	sup	0-1	MARUM-AWI Arctic biomarker, surface frozen -20°C
			sup	0-1	MARUM-Hanebuth/Lantzsch surface cooled +4°C
			1	34	MARUM-Hanebuth/Lantzsch cooled +4°C
			2	35	MARUM-Hanebuth/Lantzsch cooled +4°C
			3	35	OGS-Renata cooled +4°C
			4	35	OGS-BIO frozen -20°C
11.08.2013	17624	3	sup	0-1	MARUM-AWI Arctic biomarker, surface frozen -20°C
			sup	0-1	MARUM-Hanebuth/Lantzsch surface cooled +4°C
			sup	0-1	GEUS Foraminifera surface frozen -20°C (organic matter, proxies, living foraminifera)
			sup	sup	rest of sediment in a plastic bag
			1	11,5	MARUM-Hanebuth/Lantzsch cooled +4°C
			2	11	MARUM-Hanebuth/Lantzsch cooled +4°C
			3	8,5	GEUS R1 Foraminifera frozen -20°C
			4	9	GEUS R2 Foraminifera frozen -20°C

			5	9	GEUS R3 Foraminifera frozen -20°C
08.08.2013	17625	1	sup	0-1	MARUM-AWI Arctic biomarker, surface frozen -20°C
			sup	0-1	MARUM-Hanebuth/Lantzsch surface cooled +4°C
			1	48,5	MARUM-Hanebuth/Lantzsch cooled +4°C
			2	49	MARUM-Hanebuth/Lantzsch cooled +4°C
			3	48,5	OGS-Renata cooled +4°C
			4	48	OGS-BIO frozen -20°C
09.08.2013	17627	2	sup	0-1	GEUS Foraminifera surface living foraminifera
			sup	0-1	MARUM-AWI Arctic biomarker, surface frozen -20°C
			sup	0-1	MARUM-Hanebuth/Lantzsch surface cooled +4°C
			1	40	MARUM-Hanebuth/Lantzsch cooled +4°C
			2	44	MARUM-Hanebuth/Lantzsch cooled +4°C
			3	38,5	OGS-Renata cooled +4°C
			4	38	OGS-BIO frozen -20°C
10.08.2013	17629	1	sup	0-1	MARUM-AWI Arctic biomarker, surface frozen -20°C
			sup	0-1	MARUM-Hanebuth/Lantzsch surface cooled +4°C
			sup	sup	rest of sediment in a plastic bag
10.08.2013	17630	1	sup	0-1	MARUM-AWI Arctic biomarker, surface frozen -20°C
			sup	0-1	MARUM-Hanebuth/Lantzsch surface cooled +4°C
			sup	sup	rest of sediment in a plastic bag
10.08.2013	17631	1	sup	0-1	GEUS Foraminifera surface living foraminifera
			sup	0-1	MARUM-AWI Arctic biomarker, surface frozen -20°C
			sup	0-1	MARUM-Hanebuth/Lantzsch surface cooled +4°C
			1	18	MARUM-Hanebuth/Lantzsch cooled +4°C
			2	17	MARUM-Hanebuth/Lantzsch cooled +4°C
			3	20	OGS-Renata cooled +4°C
			4	20	OGS-BIO frozen -20°C
10.08.2013	17632	1	sup	0-1	GEUS Foraminifera surface living foraminifera
			sup	0-1	MARUM-AWI Arctic biomarker, surface frozen -20°C
			sup	0-1	MARUM-Hanebuth/Lantzsch surface cooled +4°C
			1	39,5	OGS-Renata cooled +4°C
			2	39	OGS-BIO frozen -20°C
			3	38	MARUM-Hanebuth/Lantzsch cooled +4°C
			4	38	MARUM-Hanebuth/Lantzsch cooled +4°C
13.08.2013	17633	1			Device did not close
13.08.2013	17633	2			Device did not close
13.08.2013	17634	1	sup	0-1	MARUM-AWI Arctic biomarker, surface frozen -20°C
			sup	0-1	MARUM-Hanebuth/Lantzsch surface cooled +4°C
			sup	0-1	GEUS Foraminifera surface frozen -20°C (organic matter, proxies, living foraminifera)
			1	42	MARUM-Hanebuth/Lantzsch cooled +4°C
			2	42	MARUM-Hanebuth/Lantzsch cooled +4°C
			3	44	OGS-Renata cooled +4°C
			4	43	OGS-BIO frozen -20°C
			5	15	GEUS R1 Foraminifera frozen -20°C
			6	15	GEUS R2 Foraminifera frozen -20°C
			7	15	GEUS R3 Foraminifera frozen -20°C

5.3.4 Preliminary Results

Five depositional settings were identified on the basis of surface depositional structures, type of sediment and the present ecosystem characteristics:

- Kveithola Drift area (MEBO Sites E and F) including the northern moat

(Sites 17607, 17608, 17612, 17613, 17614, 17615, 17618, 17619, 17620, 17621)

- North-South oriented channel/fault
  (Sites 17622, 17623)
- Kveithola GZWs (MEBO Sites B and D)
  (Sites 17601, 17609)
- Kveithola slope: i) upper slope and gullies; ii) middle-lower slope areas
  (Sites 17602, 17603, 17604, 17605, 17606, 17616, 17617, 17624, 17625, 17626, 17627, 17628, 17633, 17634)
- Kveithola trough northern and southern banks
  (Sites 17629, 17630, 17631, 17632)

Kveithola Drift Area

Surface sediments in the Kveithola drift area are fine grained, soft and soupy with a "jelly-like" consistency. The surface is usually cracked and slightly hummocky (Fig. 5.6A) with, cm-large, open holes similar to burrows. The sediment surface of box Core 17621-1 contained a small, mounded feature characterized by flat, black (organic matter rich) sediments at the top (Fig. 5.6B).

Fig. 5.6. A: Cracked/fractured hummocky surface; B: Mounded organic matter rich feature.

All the sediments recovered in the drift area are characterized by a strong smell of H_2S with black sediments, rich of organic matter (Fig. 5.7A), abundant worm tubes (Fig. 5.7B), and occasionally red/pink polychaeta (Fig. 5.7C) found at the sea-bottom sediment surface or just below, into the soft sediments.

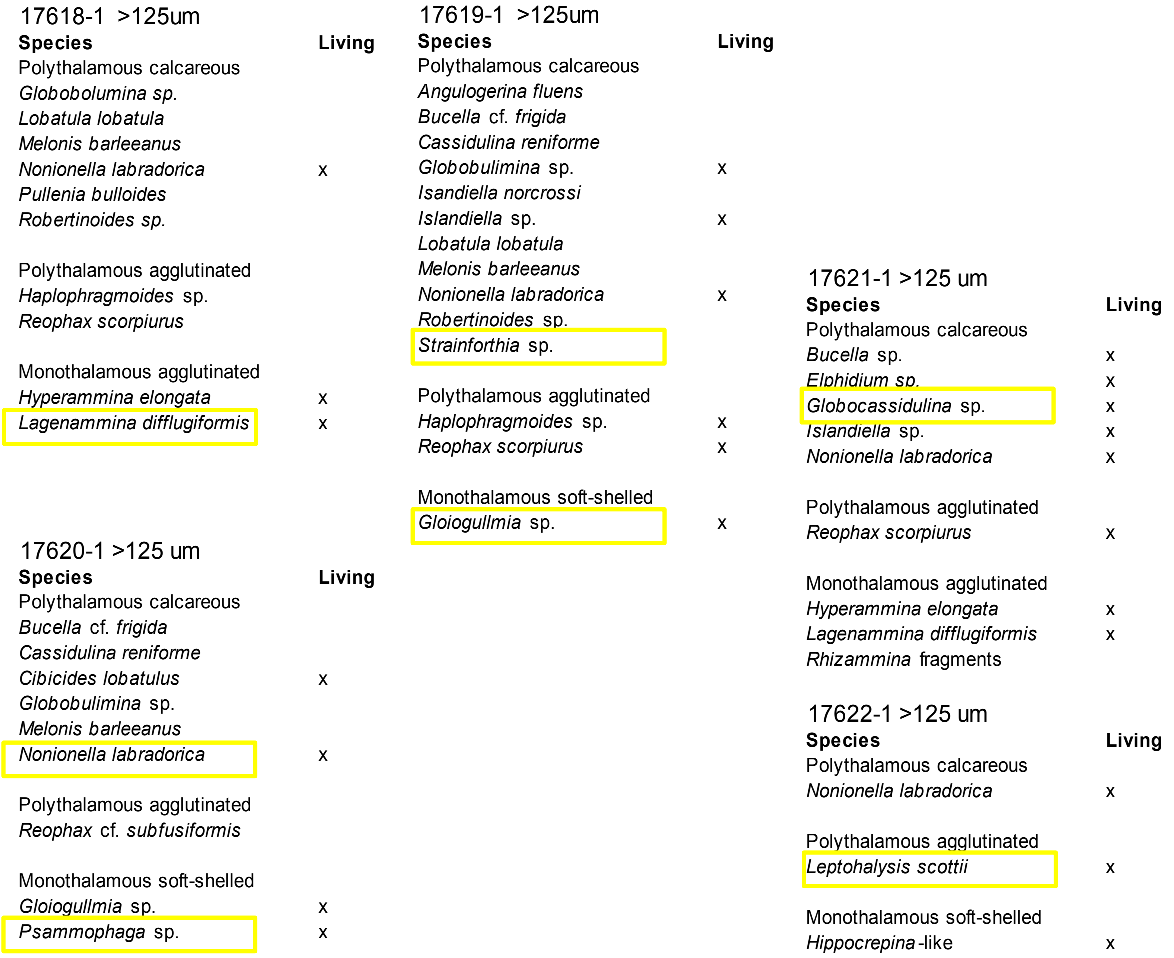
Fig. 5.7. A: Black organic matter rich sediments; B: abundant worm tubes; C: red polychaete.

The recent (uppermost 3 cm) and living benthic foraminifera assemblage in the drift area is characterized by the presence of typically oxygen-depleted environmental taxa including the calcareous species *Nonionella labradorica*, *Globobulimina* sp. and *Stainforthia* sp. together with the occurrence of some monothalamous agglutinated species such as *Lagenammina difflugiformis* and multilocular agglutinated species like *Reophax scorpiurus*.

Benthic foraminifera ("allogromiids" *sensu lato*) such as *Gloiogullmia* sp. and *Psammophaga* sp. are also present. The latter types of species are included in the Low Oxygen Foraminifera Assemblage and they usually occur in severely oxygen-depleted environments throughout the oceans in both shallow and deep waters (Figs. 5.8 and 5.9).

Leptohalysis scottii and *Psammophaga* sp. 1., found in temperate waters, have an opportunistic behaviour in response to the pulse of high nutritional quality organic carbon, whereas species belonging to the genus *Islandiella*, *Cassidulina* and *Nonionella* occur typically in the recent benthic arctic foraminifera fauna.

The area of the Kveithola drift, thus, appears a stagnant environment (any evidence of bottom currents), strongly affected by low-oxygen, stressed environmental conditions in which foraminifera developed a life strategy aimed to increase the efficiency of food utilization and maximum resistance to ecological stress.



17618-1 >125um

Species	**Living**
Polythalamous calcareous	
Globobolumina sp.	
Lobatula lobatula	
Melonis barleeanus	
Nonionella labradorica	x
Pullenia bulloides	
Robertinoides sp.	
Polythalamous agglutinated	
Haplophragmoides sp.	
Reophax scorpiurus	
Monothalamous agglutinated	
Hyperammina elongata	x
Lagenammina difflugiformis	x

17620-1 >125 um

Species	**Living**
Polythalamous calcareous	
Bucella cf. *frigida*	
Cassidulina reniforme	
Cibicides lobatulus	x
Globobulimina sp.	
Melonis barleeanus	
Nonionella labradorica	x
Polythalamous agglutinated	
Reophax cf. *subfusiformis*	
Monothalamous soft-shelled	
Gloiogullmia sp.	x
Psammophaga sp.	x

17619-1 >125um

Species	**Living**
Polythalamous calcareous	
Angulogerina fluens	
Bucella cf. *frigida*	
Cassidulina reniforme	
Globobulimina sp.	x
Isandiella norcrossi	
Islandiella sp.	x
Lobatula lobatula	
Melonis barleeanus	
Nonionella labradorica	x
Robertinoides sp.	
Strainforthia sp.	
Polythalamous agglutinated	
Haplophragmoides sp.	x
Reophax scorpiurus	x
Monothalamous soft-shelled	
Gloiogullmia sp.	x

17621-1 >125 um

Species	**Living**
Polythalamous calcareous	
Bucella sp.	x
Elphidium sp.	x
Globocassidulina sp.	x
Islandiella sp.	x
Nonionella labradorica	x
Polythalamous agglutinated	
Reophax scorpiurus	x
Monothalamous agglutinated	
Hyperammina elongata	x
Lagenammina difflugiformis	x
Rhizammina fragments	

17622-1 >125 um

Species	**Living**
Polythalamous calcareous	
Nonionella labradorica	x
Polythalamous agglutinated	
Leptohalysis scottii	x
Monothalamous soft-shelled	
Hippocrepina-like	x

Fig. 5.8. Foraminifera species identified in the Kveithola drift area.

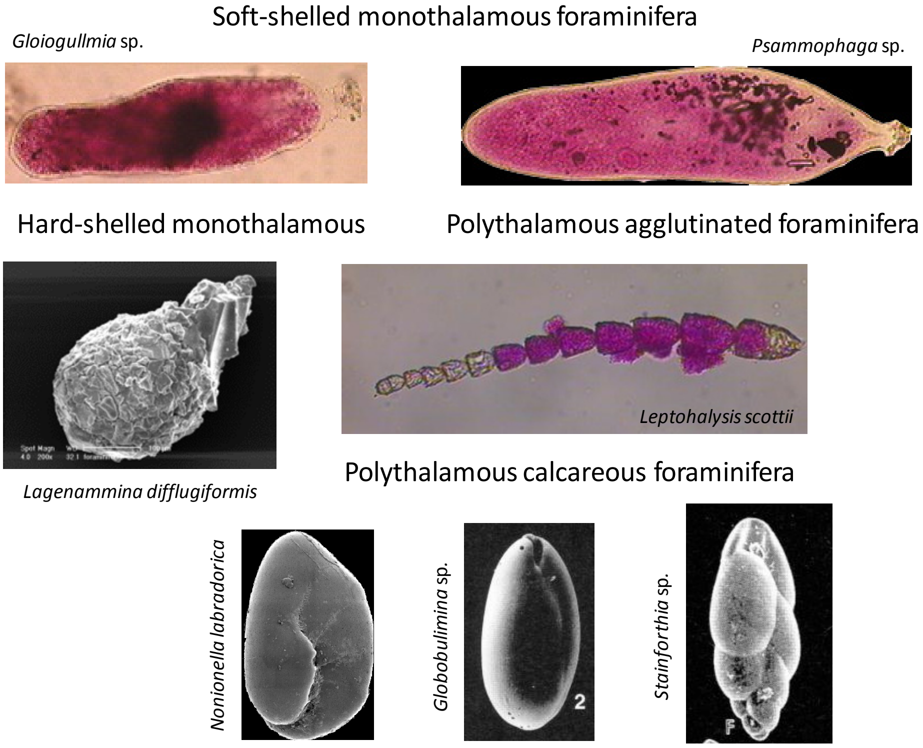


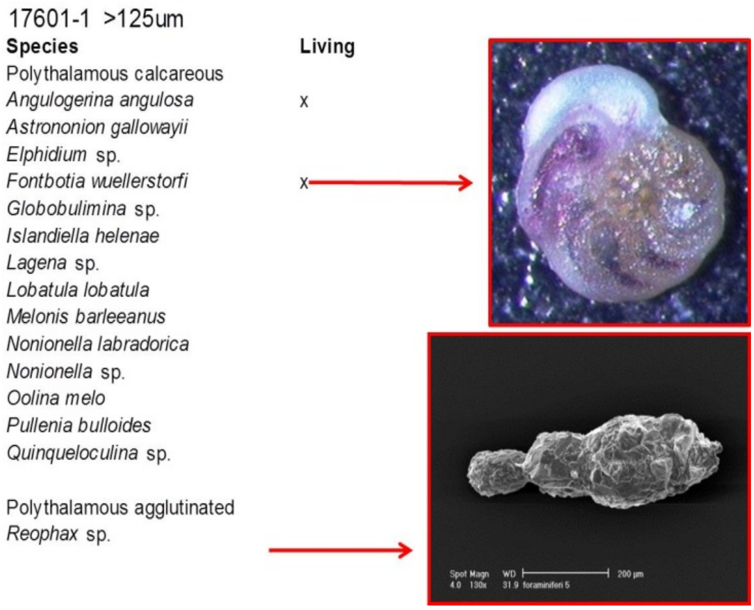
Fig. 5.9. Benthic foraminifera species identified in the Kveithola drift area.

In the northern drift's moat the sediments at the surface are formed by 2-3 cm of sandy clay with sparse shells and IRD (Site 17615). The presence of coarser sediments with living organisms such as Ophiuridae (sea-stars) and Bryozoa, suggests the presence of weak but persistent bottom currents preventing sedimentation of fines.

North-South Oriented Channel/Fault

The sedimentation in the channel/fault area (Sites 17622, 17623) is very similar to what described for the drift area with evidences of stressed environmental conditions. The benthic foraminifera fauna is dominated by *Nonionella labradorica* and *Leptohalysis scottii*, with presence of red polychaetes in the surface sediments.

The sediments have a strong smell of H_2S with sediment facies in the deeper, gravity core sequences, similar to the facies of the mud-breccia in which pervasive porosity of the sediments was related to gas expansion/expulsion after core opening of the gas-rich sediments. Contrarily to the drift area, the presence of coarser surface sediments in the channel/fault corridor with sandy silts and abundant shells, suggest a somehow more energetic depositional environment.



17601-1 >125um

Species	**Living**
Polythalamous calcareous	
Angulogerina angulosa	x
Astrononion gallowayii	
Elphidium sp.	
Fontbotia wuellerstorfi	x
Globobulimina sp.	
Islandiella helenae	
Lagena sp.	
Lobatula lobatula	
Melonis barleeanus	
Nonionella labradorica	
Nonionella sp.	
Oolina melo	
Pullenia bulloides	
Quinqueloculina sp.	
Polythalamous agglutinated	
Reophax sp.	

Fig. 5.10. Benthic foraminifera species identified in the Kveithola slope. Kveithola GZWs (sites B and D)

The GZW area at Site D (Site 17609) presents some similarities with the drift area. Surface sediments are soft, soupy silty clays with abundant worms, shells and IRD, with little evidences of bottom currents. A red polychaete was recovered from the uppermost soft sediments. The sedimentary sequence contains a debris flow with sandy matrix, broken shells and mud-chips.

The GZW area at Site B (Site 17601) is characterized by fine-grained, clean sands at the sea surface with large scale ripple-like features suggesting the presence of moderately strong and persistent bottom currents. This is supported by the presence of abundant living actiniarias, and the presence of elevated epifaunal taxa, such as *Fontbotia wuellerstorfi*, and *Lobatula lobatula* used as indicators of bottom current activity. These types of benthic foraminifera taxa feed on particles transported by bottom currents, and the presence of *Melonis barleeanus, Nonionella labradorica and Reophax* sp. suggests high seasonality of the trophic sources (Fig. 5.10).

i) Upper-slope and gullies area

The upper part of the slope (Sites 17616, 17624) is characterized by gravelly sands suggesting a highly hydrodynamic environment that is confirmed by the presence of the epibenthic foraminifera species living on the coarse sediment such as *Lobatula lobatula* (Fig. 5.11), whereas specimens of *Cassidulina reniforme* indicate seasonal availability of trophic sources typical of cold northern waters. We report also the occurrence of not yet described (unclassified at the species level), soft-shelled monothalamous taxa.

Two types of gullies were sampled: an active-gully (Site 17605) and an abandoned/palaeo-gully (site 17606) discriminated on the basis of morphological characteristics visible on the multi-beam and sub-bottom records.

The uppermost 15 cm of the active-gully sedimentary sequence contains a sandy debris flow with gravelly sands and mud-chips. The surface appears undulated with ripple- or dune-like features suggesting high-energy emplacement of the debris flow that overlies a scoured base (Fig. 5.12A). The presence of clean sands and abundant Ophiuridae, suggest the existence of present moderate-low bottom currents.

The uppermost 25 cm of the palaeo-gully sedimentary sequence contains reversely-graded sands containing mats of sponge spiculae trapping foraminifera tests. The clean sandy surface with small amplitude ripples and the presence of living sponges suggests the existence of present moderate-low bottom currents preventing deposition of fines (Fig. 5.12B).

17605-1 >125um (Gully1)

Species	**Living**
Polythalamous calcareous	
Angulogerina angulosa	x
Cassidulina reniforme	
Elphidium sp.	
Islandiella helenae	x
Lobatula lobatula	
Melonis barleeanus	
Oolina melo	
Pullenia bulloides	

17606-1 >125um (Gully 2)

Species	**Living**
Cassidulina reniforme	x
Cibicides pseudoungerianus	
Fontbotia wuellerstorfi	
Islandiella sp.	
Melonis barleeanus	
Oolina melo	
Pullenia bulloides	

17616-1 >125um

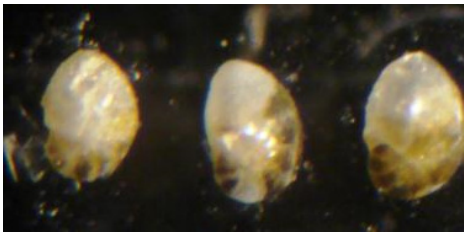
Species	**Living**
Polythalamous calcareous	
Nonionella labradorica	x
Angulogerina angulosa	
Cassidulina sp.	x
Cibicides pseudoungerianus	
Islandiella sp.	x
Lagena striata	
Melonis barleeanus	
Oolina mela	
Pullenia bulloides	
Polythalamous agglutinated	
Reophax scorpiurus	
Monothalamous agglutinated	
Lagenammina difflugiformis	x

17624-1 >125 um

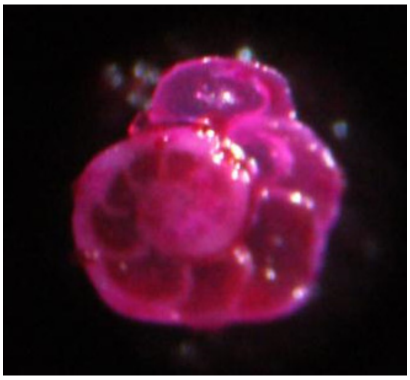
Species	**Living**
Polythalamous calcareous	
Fontbotia wuellerstorfi	
Monothalamous soft-shelled	
Allogromiid sp.	x
Psammosphaerid sp.	x

17624-3 >125 um

Species	**Living**
Polythalamous calcareous	
Angulogerina angulosa	
Buccella sp.	
Cassidulina reniforme	x
Elphidium sp.	
Islandiella helenae	
Lobatula lobatula	x
Melonis barleeanus	
Oolina melo	



Nonionella labradorica



Lobatula lobatula

Fig. 5.11. Benthic foraminifera assemblage of the Kveithola upper slope.

Fig. 5.12. Sediment surface on A: active gully; B: abandoned/palaeo gully.

ii) Middle-lower slope areas

On the middle-slope the sediments were collected from inside and outside the submarine landslide scar ls-2.

Inside the landslide scar the sediments were recovered at different water depth: 1350 m (Site 17625), 1398 m (Site 17627) and 1490 m (Site 17602 corresponding to MeBo Site A2).

The sediment surface at the shallower site is wavy/undulated with ripple-like feature made of soupy clayey sands suggesting deposition under vigorous bottom currents. Below the uppermost few cm of sands, the sequence contains pervasively bioturbated silty clays with sparse silty patches. This facies is consistent with contour current associated deposition that in some stages took over, in this area, to the previous terrigenous deposition characterized by terrigenous clayey sediments with sparse IRD (Site 17625).

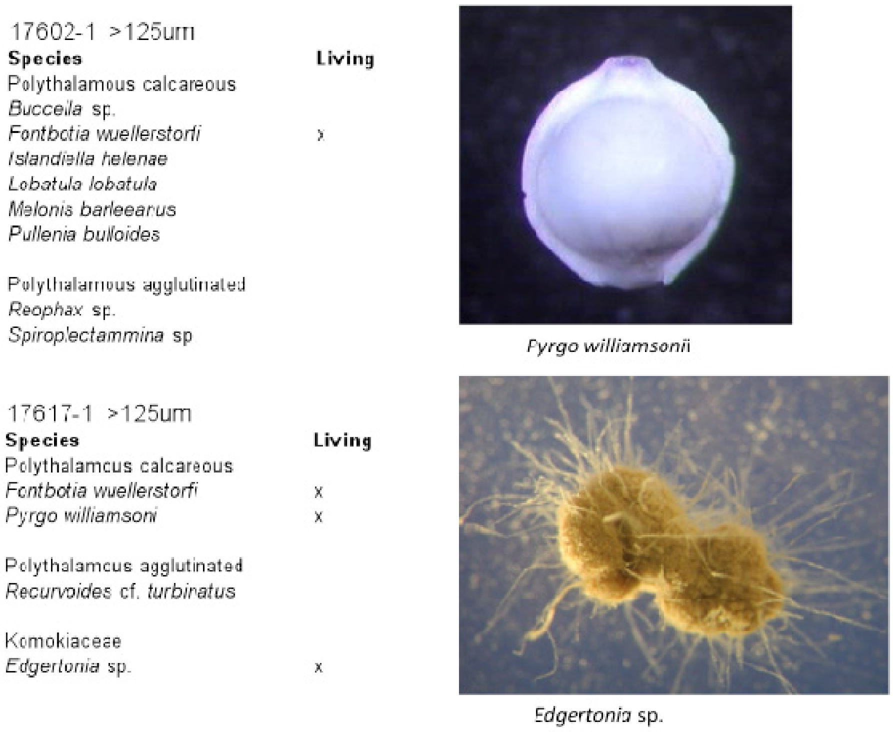
Pervasively bioturbated sediments have been observed also in other two deeper sites where the grain size progressively decreases and the surface wavy features become smoother suggesting low-energy bottom currents. High salinity (38 ‰), pore water measured on the surface sediments of Site 17627 at 1398 m water depth, may indicate brine cascading take place inside the scar of landslide ls-2.

Outside the landslide scar (Site 17603 corresponding to MeBo Site A1), clayey silt sediments settled over a flat, smooth surface. The uppermost 40 cm of the sequence contains structureless clays suggesting a very-low energy depositional environment.

On contrary, Core 17634, collected from a small, perched terrace on the south-eastern side wall of landslide ls-2, contained evidences of strong bottom currents with scoured sediment surface composed by clean sands containing abundant IRD and large tests of benthic foraminifera (*Pyrgo williamsonii*).

In the middle and lower-slope (Sites 17602, 17617) areas we report the dominant presence of one miliolid species (*Pyrgo williamsonii*) together with specimens belonging to the polythalamous agglutinated genus *Recurvoides*. They are typical of oligotrophic deep-sea areas. The group of *Pyrgo* species is reported to persist in a very irregular food supply conditions and in the recent North Atlantic sediments, this species is associated with North Atlantic Deep

Waters (NADW). We notice also the presence of giant foraminifera (i.e., Komokiaceae) and allogromiids whose frequency also increases in food-deficient areas (Fig. 5.13).



17602-1 >125um

Species	**Living**
Polythalamous calcareous	
Buccella sp.	
Fontbotia wuellerstorfi	x
Islandiella helenae	
Lobatula lobatula	
Melonis barleearus	
Pullenia bulloides	
Polythalamous agglutinated	
Reophax sp.	
Spiroplectammina sp	

17617-1 >125um

Species	**Living**
Polythalamous calcareous	
Fontbotia wuellerstorfi	x
Pyrgo williamsoni	x
Polythalamous agglutinated	
Recurvoides cf. *turbinatus*	
Komokiaceae	
Edgertonia sp.	x

Fig. 5.13. Benthic foraminfera association in the middle-lower slope.

Kveithola Trough Northern and Southern Banks

The four GBCs recovered from the shelf banks around the Kveithola Trough outlined different hydrodynamic characteristics of the northern and southern areas with high-energy environments in the southern banks (very coarse sands with abundant cobbles and large shells; Sites 17629, -30, -31) and medium-low energy in the northern part (clayey sands; Site 17632).

5.4 Conventional Sediment Coring

(H. Lantzsch, A. Caburlotto, G. Osti, J. Llopart)

During cruise MSM30 contrasting environmental settings have been targeted by conventional sediment coring. Hemipelagic muds represent the predominant sediment type within the Kveithola Trough and its related Trough Mouth Fan, whereas mostly sandy and gravelly sediments occur on the shallow shelf surrounding the Kveithola Trough. Therefore, we have used two sampling tools for deeper sediment penetration (Fig. 5.14):

5.4.1 Gravity Corer (GC)

A Gravity Corer with lengths of 3, 6, or 12 m and a top weight of about 1.5 tons was used to sample material from predominately muddy environments. The gravity corer was deployed at the continental slope as well as within the Kveithola Trough and surrounding shallow shelf.

5.4.2 Vibrocorer (VC)

A VKG-5 vibrocorer was of essential use to obtain subbottom samples from coarse-grained shallow shelf areas. The maximum core length is 504 cm with a diameter of 10 cm. Deployed with a 300-m long electricity cable which needs to be run by hand in parallel to the steel wire, coring at maximum water depths of 220 m is possible during calm weather conditions.

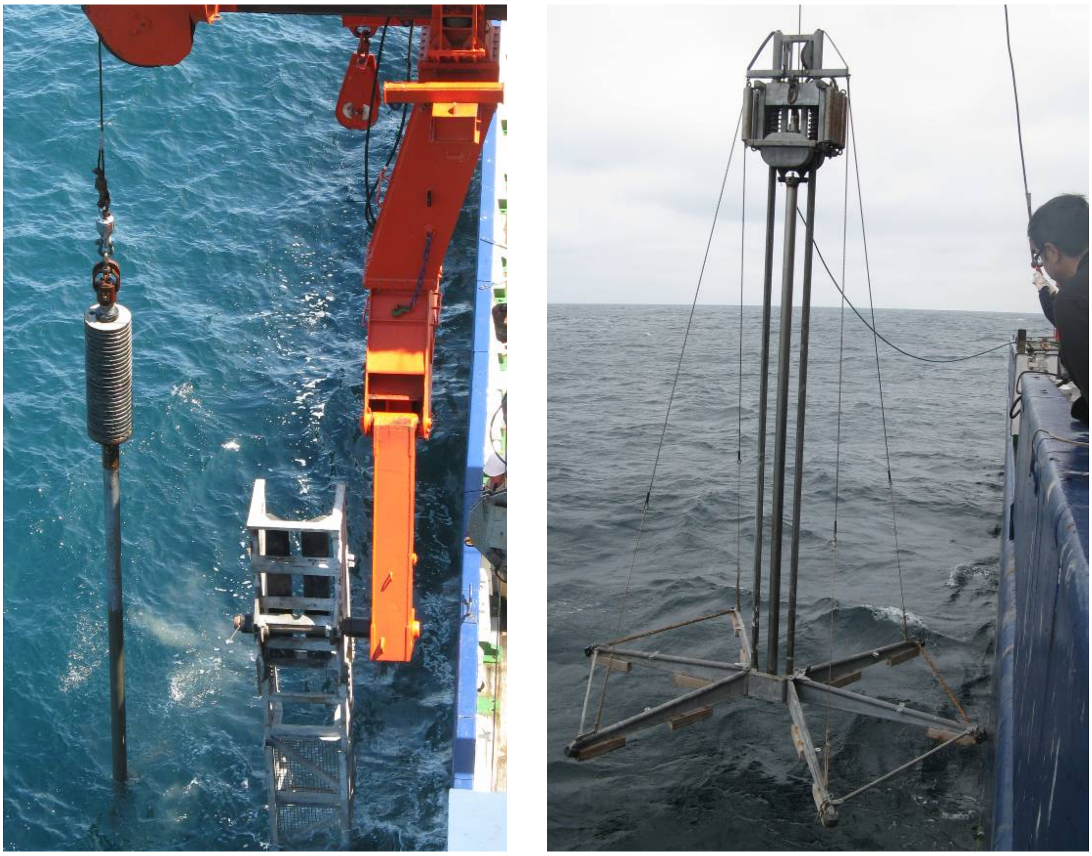


Fig. 5.14. Gravity corer (left) and vibrocorer (right).

5.4.3 Material Obtained

Gravity Coring

We deployed the gravity corer at 26 stations (Table 5.3): (1) on the continental slope (e.g., Kveithola and Storfjorden Trough mouth fans, slope slides and within slide scars, inside gullies); (2) inside the Kveithola Trough (e.g., sedimentary drape, contourite deposits); and (3) on the shallow continental shelf north of the Kveithola Trough (e.g., local depression fills, within a channel-like feature). In addition, all MeBo sites were first sampled by gravity coring to receive the upper meters of the sediment column undisturbed, and to be able to flush the first meters during MEBO coring.

After retrieval, the core liners were cut into 1-m long sections. Geotechnical measurements (compression and shear strength) were applied at the base cut of each section. The segments were closed with caps and labeled according to the general GeoB scheme. In order to apply first non-destructive measurements on the unopened sections after the cruise (x-ray, multi-sensor core logging), all segments remained un-opened.

Table 5.3. Gravity Corer station list.

Date	Site	Event	Recovery [cm]	Remarks
18.07.2013	17601	3	509	
18.07.2013	17601	5	537	
19.07.2013	17602	2	286	Over-penetration
19.07.2013	17602	3	456	
19.07.2013	17603	3	990	
20.07.2013	17604	2	632	
21.07.2013	17605	2	285	Over-penetration, +5cm in plastic bag
21.07.2013	17605	3	405	
21.07.2013	17606	2	438	
22.07.2013	17607	2	829	
22.07.2013	17607	5	920	
23.07.2013	17608	3	819	
23.07.2013	17609	2	626	
25.07.2013	17610	2	349	
25.07.2013	17611	1	225	
26.07.2013	17612	4	270	
03.08.2013	17613	2	294	Over-penetration
26.07.2013	17614	2	796	
03.08.2013	17618	2	812	
04.08.2013	17619	2	550	
04.08.2013	17619	3	682	
04.08.2013	17620	2	491	
04.08.2013	17621	2	576	
04.08.2013	17621	3	786	
04.08.2013	17622	2	434	
04.08.2013	17623	2	442	
08.08.2013	17625	2	364	
09.08.2013	17627	3	474	
09.08.2013	17628	2	720	
10.08.2013	17632	2	236	
13.08.2013	17633	3	575	Over-penetration
13.08.2013	17634	2	604	

Vibro coring

During cruise MSM30, we took 3 sediment cores with the vibrocorer from water depths between 120 and 180 m (Table 5.4). We mainly targeted tills and local depressions/channels on the shallow shelf south of the Kveithola Trough. Once a core was on deck, the plastic liners were cut into 1-m long sections, closed with caps and labeled according the scheme generally applied to GeoB cores. As for the gravity cores, the segments will be opened during the following onshore science party after initial non-destructive logging.

Table 5.4. Vibrocorer station list.

Date	Site	Event	Recovery [cm]	Remarks
10.08.2013	17629	2	493	
10.08.2013	17630	2	160	
10.08.2013	17631	2	506	

5.5 Seafloor Drilling With MeBo

(T. Freudenthal, M. Bergenthal, S. Dippold, R. Düßmann, K. Kaszemeik, S. Klar, K. Noorlander, U. Rosiak, W. Schmidt, A. Stachowski)

5.5.1 Technical Description

During cruise MSM30, the seafloor drill rig MeBo (Fig. 5.15) was used for getting sediment cores longer than 40 m. This device is a robotic drill that is deployed on the sea bed and remotely controlled from the vessel (Fig. 5.16). The complete MeBo-system, including drill, winch, launch and recovery system, control unit, as well as workshop and spare drill tools is shipped within six 20' containers. A steel armoured umbilical with a diameter of 32 mm is used to lower the 10-tons heavy device to the sea bed where four legs are being armed out in order to increase the stability of the rig. Copper wires and fibre optic cables within the umbilical are used for energy supply from the vessel and for communication between the MeBo and the control unit on the deck of the vessel. The maximum deployment depth in the current configuration is 2000 m water depth.

Fig. 5.15. The sea floor drill rig MeBo on RV MARIA S. MERIAN.

The mast with the feeding system forms the central part of the drill rig (Fig. 5.16). The drill head provides the required torque and rotary speed for rock drilling and is mounted on a guide carriage that moves up and down the mast with a maximum push force of 4 tons. A water pump provides sea water for flushing the drill string for cooling of the drill bit and for removing the drill cuttings. Core barrels and rods are stored on two magazines on the drill rig. We used wire-line core barrels (HQ) and hard metal drill bit with 55 mm (push coring) and 63 mm (rotary drilling) core diameter. The stroke length was 2.5 m (aluminium rods) or 2.35 m (steel rods).

With complete loading of the magazines a maximum coring depth of more than 70 m can be reached. Station time can reach more than 24 hrs per deployment.

A Spectrum Gamma Ray probe can be used for borehole logging. The probe is equipped with a 30 cm long scintillation crystal combined with a photo-multiplier. Light impulses that are generated by gamma ray collisions with the scintillation crystal are counted and analyzed concerning the energy spectrum. The three naturally occurring gamma ray emitters - potassium, uranium and thorium - generate different energy spectra. A GeoBase software package is used to calculate a best fit for the spectra. By combining the results of the Spectrum fit with the gamma ray counts the concentrations of K, U, and Th are calculated.

The SGR-Memory is an autonomous tool that is used with the MeBo drilling system. When the maximum coring depth is reached the inner core barrel is replaced by the probe. The gravity point of the sensor is located about 75 cm above the drill bit and measures through the drill pipe. The probe is hooked up the bore hole together with the drill pipe during recovery of the drill string (logging while tripping). Tripping speed was about 0.6m per minute.

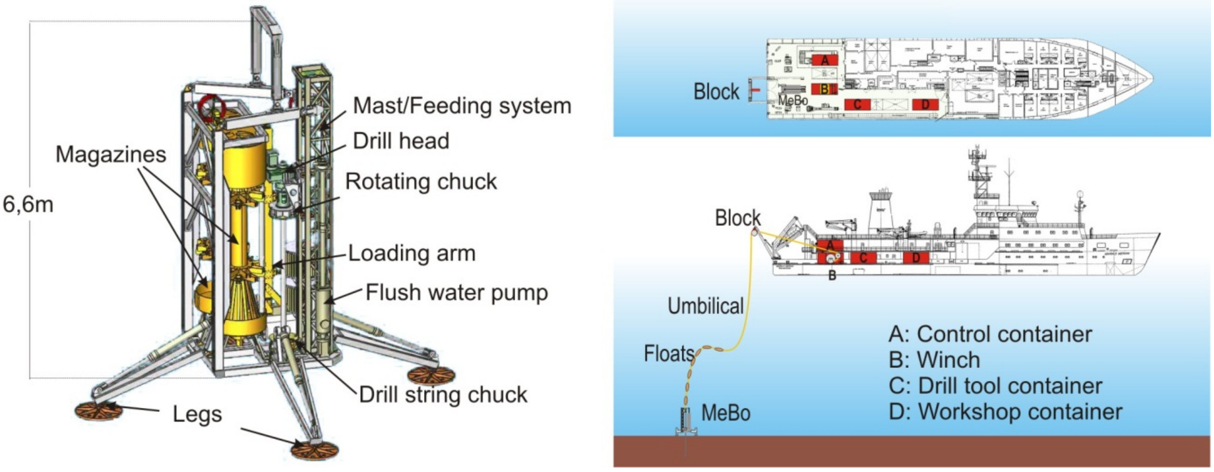


Fig. 5.16. Schematic overview on the MeBo drill rig (left) and its deployment from a research vessel (right).

5.5.2 Material Obtained

MeBo was deployed 9 times at 5 sites during this cruise. In total, MeBo was deployed for 104.5 hours, drilling 143 m deep in total. During several of these deployments, the drill string was flushed through the uppermost meters, i.e. the depths already covered by gravity cores at these sites. 113 m were cored in total with an average recovery rate of 53 %. Unfortunately, several MeBo deployments had also to be stopped premature due to a number of different technical incidents. Of these, a main failure of a hydraulic pump during the second deployment required an intensive cleaning of the hydraulic system from dispersed metal chips. Therefore, less MeBo deployments than initially planned were conducted.

Detailed information on deployment of MeBo and recovery of sediments is summarized in the station list (Table 5.5). The cores will be opened after the cruise during the onshore sampling party after logging.

Table 5.5. Station list for MeBo deployments.

Station GeoB	Deployment duration [hrs:min]	Latitude [N]	Longitude [E]	Water depth [m]	Drill depth [cm]	Coring length [cm]	Recovery	Remarks
17601-4	07:55	74°51,53'	16°05,84'	370	0	0		Failure of energy supply
17607-3	09:25	74°50,74'	17°38,32'	300	1011	1011	694 cm 69%	Hydraulic pump failure
17609-4	03:40	74°51,05'	16°54,32'	370	270	270	171 cm 63%	Broken wire
17607-6	09:50	74°50,75'	17°38,36'	300	1356	769	622 cm 81%	Blocked inner core barrel
17609-5	21:55	74°51,03’	16°54,29’	370	3555	3310	1386 cm 42%	
17601-6	24:15	74°51,53'	16°05,83'	380	4055	4045	1672 cm 41%	
17602-4	09:30	74°52,05'	14°43,96'	1500	1210	495	369 cm 75%	Failure in wire line system
17602-5	11:10	74°52,31'	14°42,90'	1530	2110	925	854 cm 92%	
17603-4	06:50	74°51,00’	14°48,05'	1440	740	495	259 cm 52%	Failure in wire line system

5.5.3 Preliminary Results

The main aim of this cruise was to gain experience with deep drilling in polar regions, with special regard to glacigenic deposits. Despite the technical problems, we have collected important experience with drilling into such difficult materials.

MeBo drilled well and with great recovery through the uppermost stratified marine unit, which is composed of cohesive but soft sediments. Core recovery rates in the compacted glacigenic deposits underlying this marine unit (the grounding-zone wedge unit) could be improved to a certain extent by a reduction of flush water pumping intensity and by an increase of the applied torque on the drill string. The underlying glacigenic deposit inside the Kveithola Trough (tills) was compacted and very sticky which resulted in high sleeve friction on the drill string. The required decision for increasing the flush-water volume to overcome the sleeve friction resulted in reasonable penetration but rather poor core recovery. Optimizing the adjustment of penetration speed, flush-water volume and torque will be the challenge for improving core recovery in these glacigenic deposits.

For the drill site on the Trough Mouth Fan inside the scar channel, the debrite unit appeared sticky and compacted again but strong flushing lead to continuous drilling advance with good core recovery. However in this case, the marine deposits (plumites) underlying this debrite unit were so soft and permeable that the flushed water drained away immediately into this unit. Effect was an immediate and immovable stuck of the drill case in the debrite unit.

Thus, we obtained highly valuable material never drilled before. The recovery was, however, rather restricted due to the difficult-to-drill glacigenic deposits which showed exceptional and unexpected high stickiness and compaction properties.

Spectral Gamma Ray Borehole Measurements

The spectrum gamma ray probe was deployed at Site 17601 (deployment GeoB17601-6; Table 5.6). A general increase with depth in natural gamma ray intensity (NGR) from 60 to 95 gAPI is observed (Fig. 5.17). This increase is probably related to the increasing grade of compaction. Three units can be distinguished according to these data. The upper unit from 0 to 14 m below sea floor is characterized by higher variability of NGR compared to the lower units and by a general increase in NGR from 60 to 80 gAPI with depth. This unit corresponds to the postglacial stratified drape identified in the PARASOUND profiles. The middle unit from 14 to 26 m shows fairly constant NGR values around 80 gAPI. This unit corresponds to grounding-zone wedge deposits identified in previous seismic lines. The lower unit from 26 to 39 m is characterized by a general down-hole increase in NGR from 80 to 95 gAPI but less internal variability compared to the uppermost unit. This unit corresponds to glacial till deposits identified in previous seismic lines. The middle and lower units are separated by a zone of a local gamma intensity minimum (77 gAPI) above a local maximum (96 gAPI). This zone corresponds to a drop in penetration rate during the drilling and may be explained by a gravel layer separating both units. The comparison with drilling and PARASOUND data shows, that SGR borehole logging is well suited to distinguish the marine and glacial depositional units from each other.

Table 5.6. Station list for the SGR-Memory deployments.

Station GeoB	Latitude [N]	Longitude [E]	Water depth [m]	Logged interval [m]
17601-6	74°51,53'	16°05,83'	380	39,1 - 0

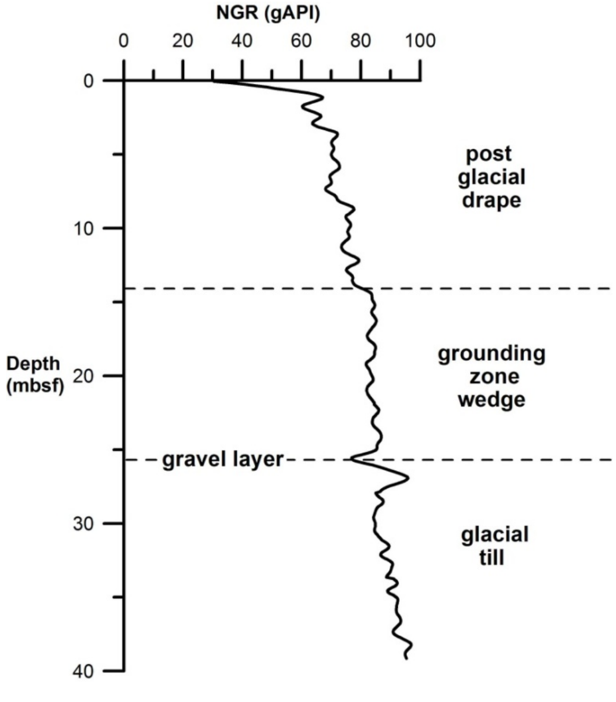


Fig. 5.17. Results of spectral gamma ray bore hole logging at site GeoB16601.

5.6 Physical Properties

(R. Urgeles, J. Llopart)

5.6.1 Technical Description

Shipboard measurements of shear strength quantify and contribute to characterizing variations in the sediment records caused by environmental changes, depositional and erosional events, and other geological phenomena. They further help to correlate core lithology, downhole geophysical logs, and seismic data.

Undrained peak shear strength measurements during cruise MSM30 were performed using two handheld instruments:

- A Pocket Vane Shear Tester
- Geotester Dial Type Pocket Penetrometer

The measurements were not performed at *in-situ* stress conditions and thereby underestimate the true undrained peak shear strength *in-situ*. All shear strength measurements were performed in the x-y plane, i.e., all shear strengths were measured with the rotation axis perpendicular to the bedding plane. The measurements were typically performed at the base of each section in gravity cores and at the top and base of the core catcher section in MEBO cores.

Pocket Vane Shear Tester

The pocket vane shear tester is used to obtain approximations of shear strength of cohesive soils. The standard vaned foot uses a scale of 0 to 1 with the smallest division on the dial being 0.05 kg/cm^2 (tsf). This permits a visual interpretation to the nearest 0.01 kg/cm^2 (tsf). In addition to the standard vane, high and low capacity vanes can be used giving respective values of 0 to 2.5 and 0 to 0.2 tsf (kg/cm^2). The device can be used on any reasonably flat surface that is slightly larger than the vane surface being used. The Pocket Shear Vane can be used with fully-saturated, fine-grained soils with an undrained strength independent of normal pressure, including a wide range of clays from soft to stiff consistency.

Geotester Dial Type Pocket Penetrometer

A pocket penetrometer (Geotester STCL-5) was used to obtain additional undrained shear strength measurements. The penetrometer is a flat-footed, cylindrical probe that is pushed 6.4 mm into the split-core surface. The penetrometer is calibrated as an unconfined compression test, which (for an ideal clay) measures twice the undrained shear strength, or 2 τ_{fu}. The scale on the dial is converted into shear strength (in kilopascals) using the following equation:

$$\tau_{fu} = [(S_u \times 10) \times g]/2$$

where τ_{fu} = undrained shear strength (kPa),
S_u = penetrometer reading (kg/cm^2), and
g = acceleration due to gravity (9.81 m/s^2).

The maximum shear strength that can be measured with the pocket penetrometer is 220 kPa. The Geotester STCL-5 comes with 5 different plungers ranging from 6.35 (0.25 inch) to 25 mm (1 inch approx.). Inner dial is 0 to 6.0 tsf or kgf/cm^2 readable to 0.1. Outer dial is 0 to 11 kg also readable to 0.1 kg. Charts are provided to estimate safe bearing pressure depending on plunger used and soil type.

For every site, the undrained shear strength is presented in plots with the undrained peak shear strength from the torvane system (black lines) and the penetrometer (red line) superimposed on a chirp profile indicating the core location.

5.6.2 Preliminary Results

Shear strength results characterize well the different echofacies observed on PARASOND profiles and properly display areas where erosion processes are characteristic of the seafloor, such as in areas of recent slope failure. The frequency of measurements (1 per section), sediment disturbance (particularly in MeBo cores) and uncertainties related to the measurement do not allow however core to core correlation using such type of data. In general the trends observed in the pocket penetrometer and in the torvane match relatively well indicating that measurements are consistent. The torvane shear strength measurements are however consistently lower than those performed using the pocket penetrometer, which probably can be attributed to a larger sensitiveness and lower induced disturbance during the measurement process of the penetrometer.

Kveithola Trough Post-Glacial Sediment Cover

Shear strength measurements performed on the Kveithola Trough show relatively modest values not exceeding 25 kPa. The upper first meter of sediment shows relatively low values of shear strength in all cases. Were cores penetrated drift sediments, which contain a higher fraction of coarser sediment the undrained shear strength increases rapidly to ~15 kPa and remains relatively constant through depth (Figs. 5.18 and 5.19). On the other hand, where the gravity corer penetrated the lower hemipelagic drape (Sites 17601, 17609, 17620) the shear strength increases gradually with depth, but remains relatively low along the core.

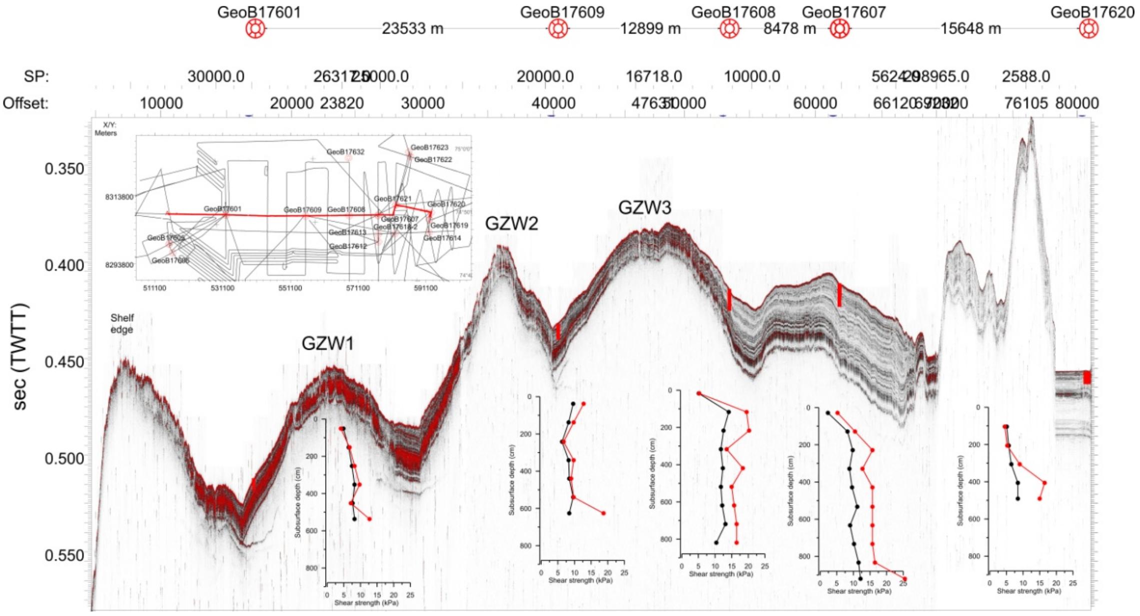


Fig. 5.18. Composite PARASOUND profile (see red line on inset for location) illustrating the post-glacial sediment architecture of the Kveithola Trough, the location of the cores in red (labeled on top of the seismic section) and the corresponding undrained shear strength profiles. All profiles are displayed at the same scale. Black lines display undrained shear strength measured with the torvane, while red lines display undrained shear strength measured with the pocket penetrometer.

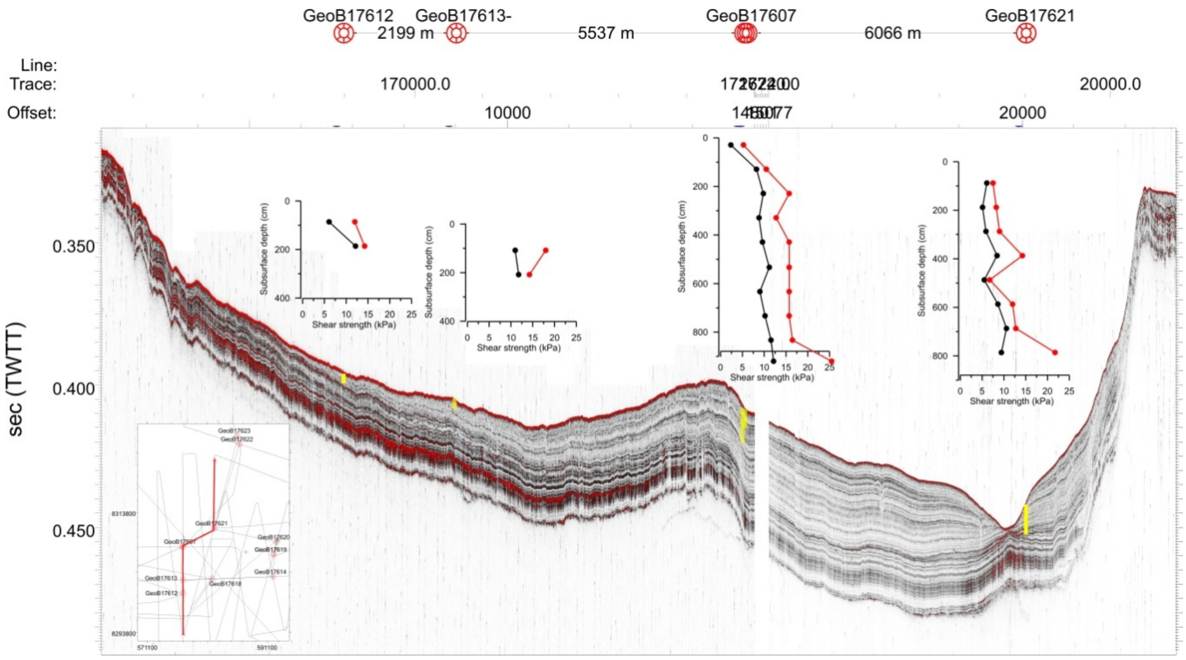


Fig. 5.19. Composite PARASOUND profile (see red line on inset for location) illustrating the post-glacial sediment architecture of the Kveithola Trough, the location of the cores in yellow (labeled on top of the seismic section) and the corresponding undrained shear strength profiles. All profiles are displayed at the same scale. Black lines display undrained shear strength measured with the torvane, while red lines display undrained shear strength measured with the pocket penetrometer.

Glacial Sediment of the Kveithola and Storfjorden Troughs

Occurrence of large diameter lithified clasts within glacial deposits make challenging sampling and measurement of physical properties. The measurements, which were performed in the clayey matrix, are often affected by surrounding clasts. On Storfjorden measured shear strengths of no more than 10 kPa were found in the upper 3 m of gravity cores. These values suggest that the thin hemipelagic drape, as seen in PARASOUND and previous TOPAS profiles, was sampled. Only the lower part of the cores, where shear strength rapidly increases to ~25 kPa, cored the uppermost deposits of two chaotic glacially related depositional bodies. The relatively high shear strengths, considering the penetration depths, indicate a high degree of consolidation for these sediments, likely related to glacial loading (Figs. 5.20 and 5.21). MeBo also penetrated a grounding zone wedge and basal tills at Site 17601-6 (Fig. 5.22; see Fig. 5.18 for location). Core recovery was relatively low, particularly in glacigenic sediments, where cobbles in a muddy matrix where the predominant lithology. The undrained shear strength was only measured in the MeBo cores with the pocket penetrometer. The grounding zone wedge displays a marked increase in shear strength with respect to the above hemipelagic drape, increasing from a background value of ~20 kPa to more than 60 kPa (Fig. 5.22). The largest values of undrained shear strength are recorded in the basal tills at the bottom of the borehole, with values exceeding 100 kPa (Fig. 5.22). Nevertheless, the strength behavior within these glacigenic sediments is quite erratic and likely indicative of severe disturbance. Where measurements could be performed at the top and bottom of the core catcher sections (often the only section where sediment was actually recovered when coring in glacigenic sediments with MeBo), large differences in undrained shear strength could also be measured, which is interpreted as additional evidence for sediment remolding.

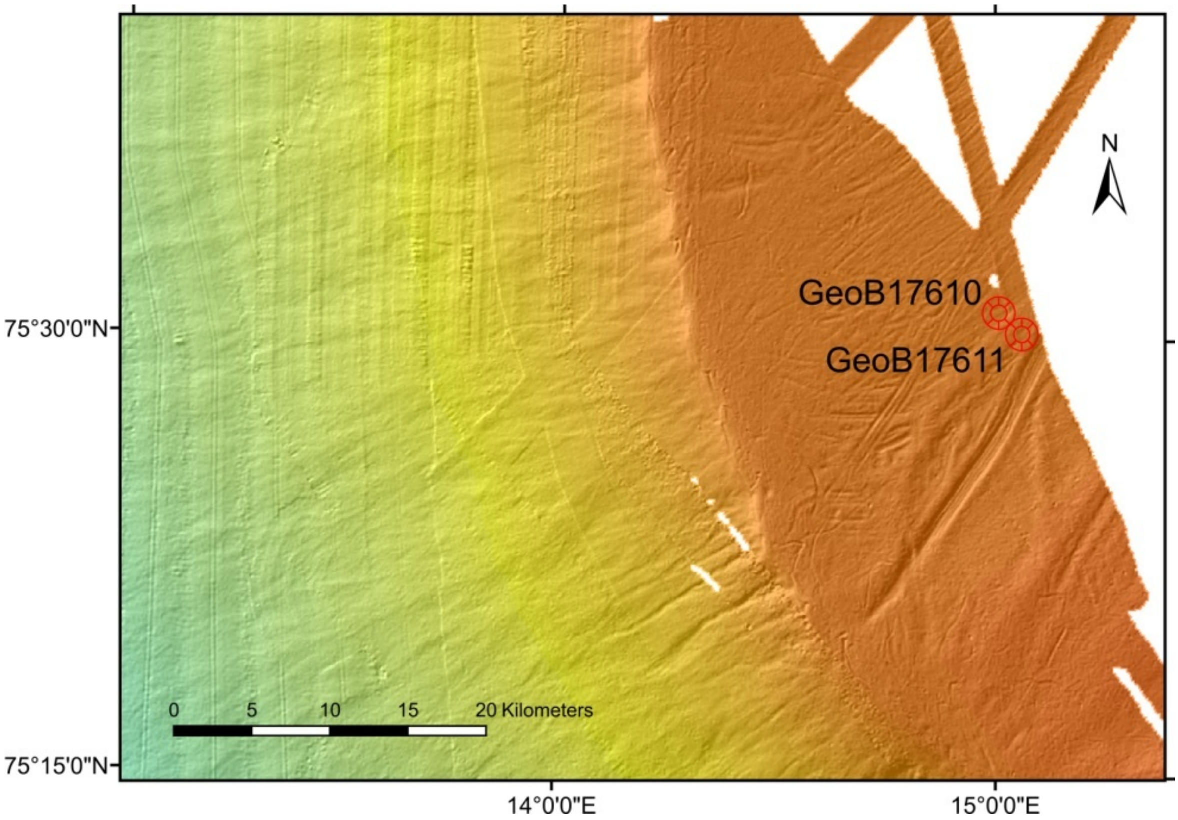


Fig. 5.20. Location of sampling Sites 17610 and 17611 recovered in glacial depositional bodies of the Storfjorden Trough.

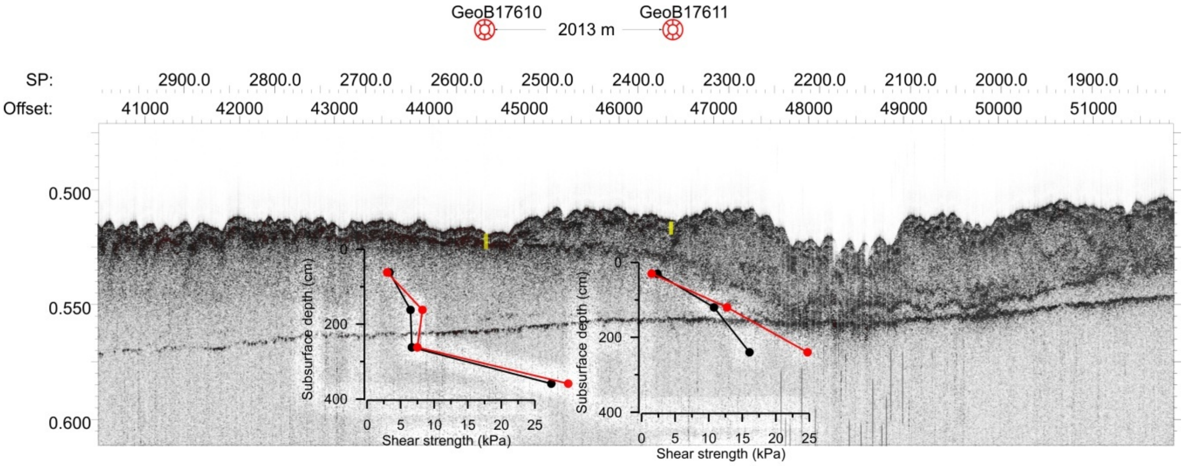


Fig. 5.21. TOPAS profile (acquired during RV Hesperides cruise SVAIS) illustrating two glacial depositional bodies in the Storfjorden Trough, the location of the cores in yellow (labeled on top of the seismic section) and the corresponding undrained shear strength profiles. All profiles are displayed at the same scale. Black lines display undrained shear strength measured with the torvane, while red lines display undrained shear strength measured with the pocket penetrometer.

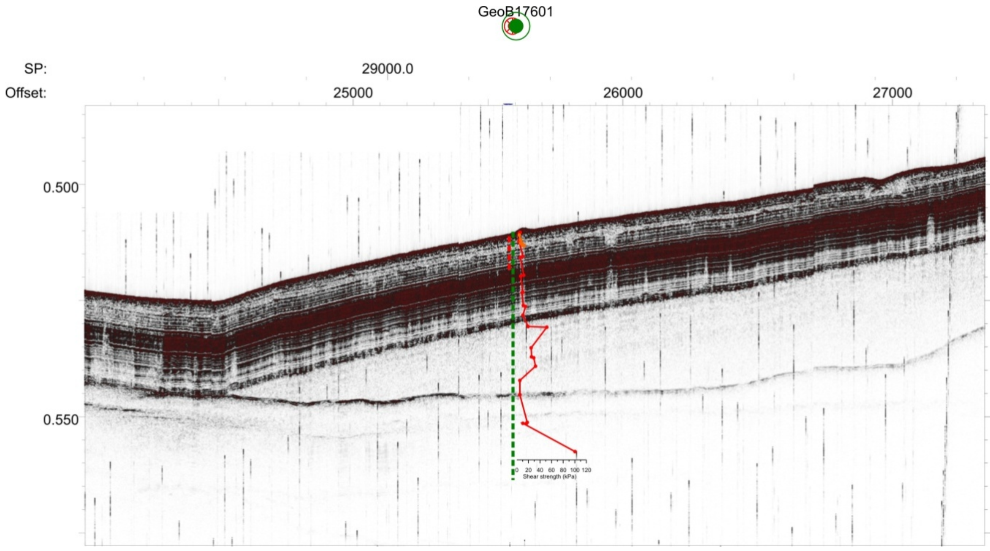


Fig. 5.22. PARASOUND profile illustrating Grounding Zone Wedge 1 in the Kveithola Trough (see also Fig. 5.18), the location of MEBO Site 17601-6 in green (labeled on top of the seismic section) and the corresponding undrained shear strength profile. Red line display undrained shear strength measured with the pocket penetrometer.

The Kveithola Trough Mouth Fan

In terms of undrained shear strengths, cores recovered on the slope of the Kveithola Trough Mouth Fan can be roughly classified between those that were acquired within landslide scars and those that were acquired on undisturbed sediment. The cores collected within landslide scars present much higher shear strengths than those collected outside (Figs. 5.23 and 5.24). Cores 17603, 17604 and 17628 show relatively low shear strengths with maximum values slightly higher than 20 kPa, which translates into the deeper penetration obtained at those stations (Fig. 5.24). At a depth of around ~4.5 m the shear strength measured in cores within the landslide scar is 50 to 300 % higher than those outside the landslide scar. The high shear strengths in those sediment cores are interpreted in this case to result from over-consolidation due to sediment removal by the landslide processes. Cores 17625, 17633 and 17634, all of them located near relatively steep scars, record the highest shear strengths (Fig. 5.24). These high shear strengths possibly indicate that relatively old material was cored at those locations. The upper part of Core 17633 display however relatively low shear strengths values, similar to those of undisturbed sediments, indicating that the upper part is probably much younger material and that the core includes an important hiatus. Cores 17602 and 17627 display somewhat lower shear strengths than Cores 17625, 17633 and 17634, which likely indicates that landslides debris where cored at those stations (Figs. 5.24, 5.25, and 5.26).

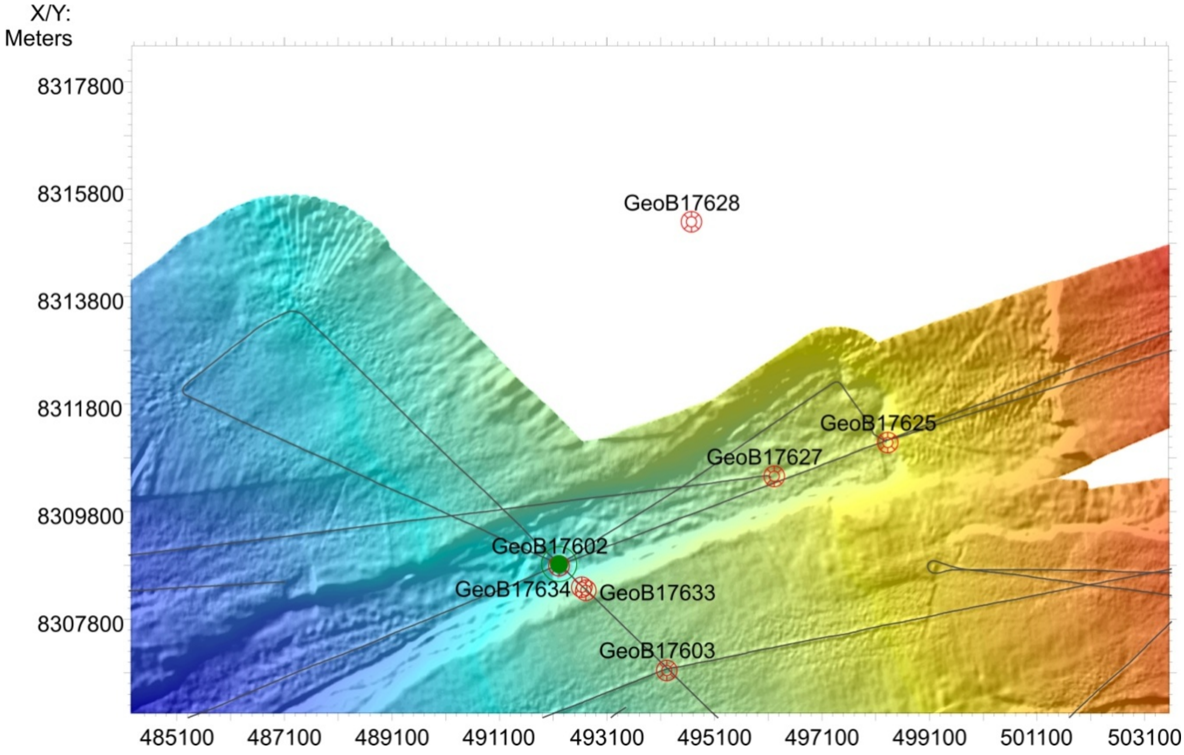


Fig. 5.23. Location of sampling stations nearby landslide in the Kveithola Trough Mouth Fan.

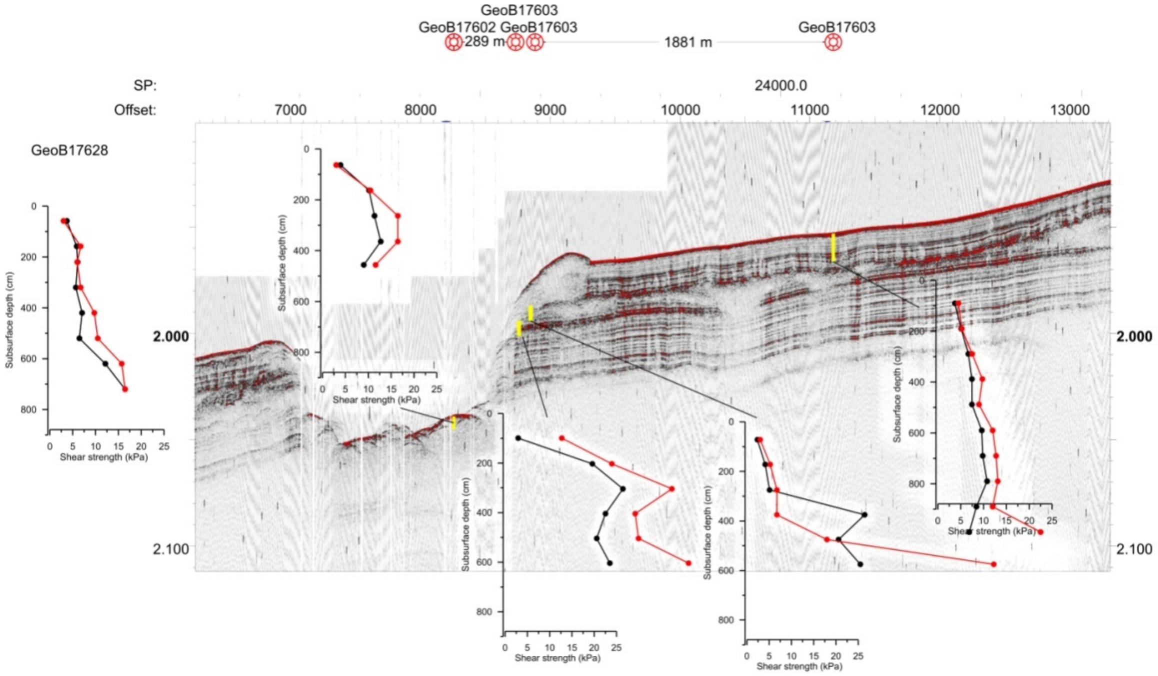


Fig. 5.24. PARASOUND profile (see Fig. 5.23 for location) illustrating the sediment echofacies of the Kveithola Trough Mouth Fan, the location of the cores in yellow (labeled on top of the seismic section) and the corresponding undrained shear strength profiles. All profiles are displayed at the same scale. Black lines display undrained shear strength measured with the torvane, while red lines display undrained shear strength measured with the pocket penetrometer. Core 17628 is not intersected by the profile.

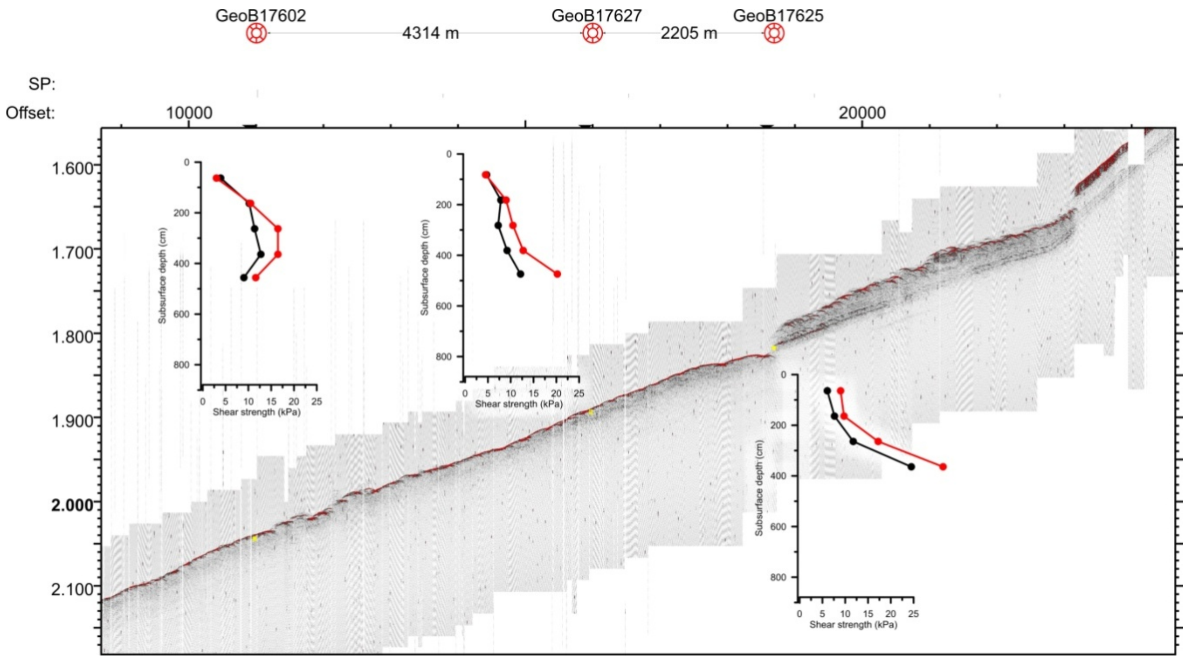


Fig. 5.25. Composite PARASOUND profile (see Fig. 5.23 for location) illustrating the sediment echofacies of the Kveithola Trough Mouth Fan, the location of the cores in yellow (labeled on top of the seismic section) and the corresponding undrained shear strength profiles. All profiles are displayed at the same scale. Black lines display undrained shear strength measured with the torvane, while red lines display undrained shear strength measured with the pocket penetrometer.

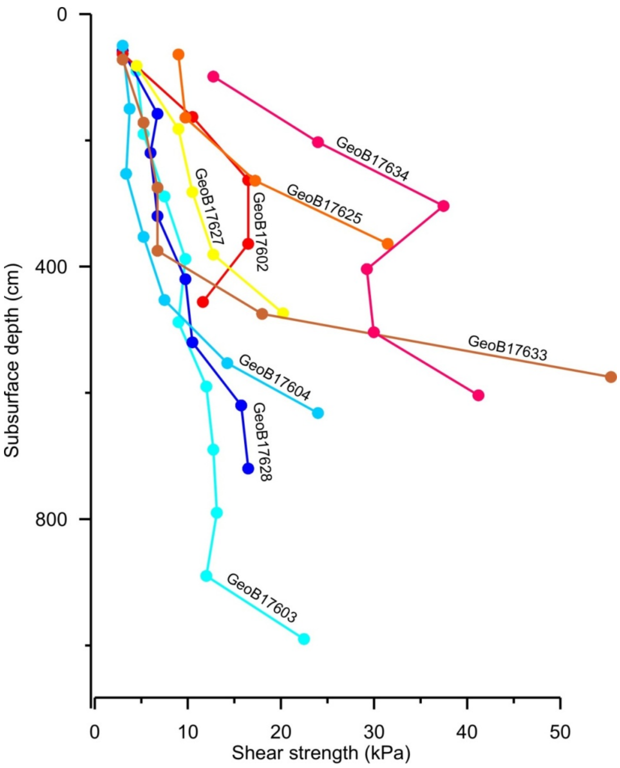


Fig. 5.26. Undrained shear strength profiles for cores collected on the Kveithola Trough Mouth. Bluish lines display undrained shear strength measured in cores outside the landslide scars, while yellow to red lines display undrained shear strengths for cores collected within the landslide scar.

5.7 Pore-Water Extraction

(M. Rebesco, G. Osti)

Pore-water samples from selected sediment cores were taken during the cruise, mainly with the purpose to detect a possible presence of gas in the sediments.

The cores that we selected for pore water extraction were (Tab. 5.7):

17622-2 (Gravity core in the so-called “channel” north of Kveithola);
17519-3 (Gravity core on the crest of the “inner drift” within Kveithola);
17627-3 (Gravity core within the landslide on the continental slope);
17628-2 (Gravity core outside the landslide on the continental slope);
17602-4 and -5 MeBo cores within the landslide on the continental slope).

The extraction of pore water from these sediments was performed using rhizons that are a sort of cylindrical filters, attached via tubing to a syringe.

The extraction method comprised the following steps:

- ‘Wet’ rhizon (rh) = rh were soacked in water, then all water was removed by using the arm as a centrifuge. In this way, there was no remaining water inside the rh, but the rh-filter material is wet. It is important that the rh is ‘wet’ otherwise the flow-through of porewater (pW) would be minimal.
- Attach rh to tubing and insert rh fully into sediment (if the full filter-surface is not within sed, then air will be sucked in).
- Attach tubing to syringe, pull syringe-plug to create underpressure and block syringe with wood-stick spare-part to start sucking/pW-sampling.
- Usually after a few minutes, the first waterdrops appeared in the tubing/syringe. We threw away the first few drops or ml (since these may still be ‘contaminated’ with the distilled water for the ‘wetting’ or cleaning). In very stiff sediments there may be only a few mls recovered, thus even more important to throw away contaminated fluid, else the effect on the measured concentrations is major.
- Usually, we continued for 2 hours (longer pW collection, means that: a. pW is recovered from a larger area; b. there is more risk of oxygen-contamination, sulphide oxidation, etc…; c. drying out sediment may permit air to pass into rhizon).
- Once finished pW sampling, the pW was put from syringe into septum vial. Before we added acid (100 uL 6N HCl) through septum using needle, closed, swirled gently to mix (acidification is to remove the H2S; at the same time it keeps trace elements in solution rather than to oxidize/precipitate e.g. Fe,Mn).
- We used the last drop from the syringe to measure salinity with a refractometer.

Table 5.7. List of cores sampled for pore waters.

Core	Depth [cm]	Salinity
17622-2	20	37
	50	37
	85	37
	120	37
	150	36
	185	36
	220	36
	250	36

Core	Depth [cm]	Salinity
17628-2	90	37
	110	37
	130	37
	150	37
	170	37
	190	37
	210	37
	230	37

	285	36
	320	36
	350	35
	385	35
	420	35
17619-3	50	37
	150	36
	250	36
	350	36
	450	36
	550	36
	650	35
17627-3	30	37
	63	37
	96	37
	129	37
	162	37
	195	36
	228	36
	261	37
	294	36
	327	36
	360	36
	393	35
	426	34
	459	32
17628-2	10	37
	30	37
	50	37
	70	37

	250	37
	270	37
	290	37
	310	36
	330	36
	350	36
	370	36
	390	36
	410	36
	430	36
	450	36
	470	36
	490	36
	510	36
	530	35
	550	36
	570	35
	590	35
	610	35
	630	35
	650	35
	670	35
	690	35
	710	33
17602-4	1P - 2W - 15 cm from top	850
	2P - 2W - 15 cm from top	1110
17602-5	1P - 2W - 15 cm from top	1320
	2P - 2W - 15 cm from top	1580
	3P - 2W - 15 cm from top	1815

6 Outlook – the CORIBAR Consortium Project

After the material and data have arrived at MARUM in Bremen, the cores will be first X-radiographed, and scanned with a Multi-Sensor Core Logger for natural gamma, magnetic susceptibility and density to obtain a first stratigraphic frame. Based on this information, we will meet during one or two post-cruise sampling parties to open the cores (with exception of some whole round samples for geotechnical investigations). The cores will be scanned for XRF element distribution, described and photographically scanned. Based on these initial results a comprehensive sampling scheme will be defined by the collaboration partners during this sampling party. The taken sets of samples will be distributed among the partners and associated scientists in accordance with the CORIBAR Contract.

Similarly, the PARASOUND and multibeam data will be processed in Bremen (A. Özmaral) and distributed among the partners afterwards.

In this collaborative sense, joint publications will arise combining the different results from seismo-acoustic, geological, sedimentological-geochemical, geotechnical and palaeoceanographic investigations. We also plan NICESTREAM-CORIBAR workshops for an intense exchange during data production and interpretation. A first manuscript is planned to be written immediately after the cruise providing an evaluation of the progress and new experience in drilling glacigenic deposits with the MEBO system.

7 Station List MSM30

7.1 List of Station Data

All stations, devices, and samples were, synchronously to material coring/sampling, registered with the software ExpeditionDIS-Geob which ran in test mode during this cruise.

Station No.		Date	Gear	Time	Latitude	Longitude	Water depth	Recovery	Remarks
MERIAN	**MARUM**			**[UTC]**	**[°N]**	**[°S]**	**[m]**	**[cm]**	
MSM30/463-1	GeoB17601 - 1	18.07.2013	MUC	06:39	74° 51,53'	16° 5,81'	370,9	50	
MSM30/463-2	GeoB17601 - 2	18.07.2013	GBC	07:07	74° 51,53'	16° 5,82'	3842	43	
MSM30/463-3	GeoB17601 - 3	18.07.2013	GC	07:34	74° 51,53'	16° 5,82'	383,7	509	
MSM30/463-4	GeoB17601 - 4	18.07.2013	MeBo	10:18	74° 51,53'	16° 5,84'	380	0	Stopped after bottom contact.
MSM30/463-5	GeoB17601 - 5	18.07.2013	GC	16:37	74° 51,53'	16° 5,82'	369,1	537	
MSM30/508-1	GeoB17601 - 6	07.08.2013	MeBo	11:41	74° 51,32'	16° 5,50'	380	4060	
MSM30/466-1	GeoB17602 - 1	19.07.2013	GBC	07:02	74° 52,04'	14° 43,96'	1489,4	48	
MSM30/466-2	GeoB17602 - 2	19.07.2013	GC	08:41	74° 52,04'	14° 43,96'	1493	286	Over-penetration.
MSM30/466-3	GeoB17602 - 3	19.07.2013	GC	10:19	74° 52,05'	14° 43,93'	1491	456	
MSM30/512-1	GeoB17602 - 4	08.08.2013	MeBo	22:10	74° 52,04'	14° 43,58'	1512	1210	
MSM30/523-1	GeoB17602 - 5	11.08.2013	MeBo	12:05	74° 52,19'	14° 42,54'	1530	2110	
MSM30/467-1	GeoB17603 - 1	19.07.2013	MUC	16:17	74° 51,00'	14° 48,09'	1425,7	38	
MSM30/467-2	GeoB17603 - 2	19.07.2013	GBC	17:30	74° 51,00'	14° 48,08'	1425	49	
MSM30/467-3	GeoB17603 - 3	19.07.2013	GC	18:43	74° 51,00'	14° 48,09'	1430,6	990	
MSM30/525-1	GeoB17603 - 4	12.08.2013	MeBo	13:19	74° 51,00'	14° 48,05'	1440	740	
MSM30/469-1	GeoB17604 - 1	20.07.2013	MUC	13:47	74° 36,95'	14° 41,75'	1796,2	39	
MSM30/469-2	GeoB17604 - 2	20.07.2013	GC	15:12	74° 36,96'	14° 41,73'	1797,8	632	
MSM30/471-1	GeoB17605 - 1	21.07.2013	GBC	06:20	74° 47,09'	15° 31,27'	768,2	41	
MSM30/471-2	GeoB17605 - 2	21.07.2013	GC	07:01	74° 47,09'	15° 31,28'	768,1	285	Over-penetration.
MSM30/471-3	GeoB17605 - 3	21.07.2013	GC	08:05	74° 47,09'	15° 31,27'	768,9	405	
MSM30/472-1	GeoB17606 - 1	21.07.2013	GBC	09:11	74° 45,69'	15° 33,28'	778,5	41	
MSM30/472-2	GeoB17606 - 2	21.07.2013	GC	09:49	74° 45,69'	15° 33,28'	778,1	438	
MSM30/474-1	GeoB17607 - 1	22.07.2013	MUC	06:40	74° 50,74'	17° 38,35'	297,6	34	
MSM30/474-2	GeoB17607 - 2	22.07.2013	GC	07:06	74° 50,74'	17° 38,35'	301,9	829	section 2 lowermost 4 cm in a bag (degassing)
MSM30/474-3	GeoB17607 - 3	22.07.2013	MeBo	09:03	74° 50,74'	17° 38,32'	300	1011	
MSM30/474-4	GeoB17607 - 4	22.07.2013	GBC	15:14	74° 50,71'	17° 38,27'	295,2	54	
MSM30/474-5	GeoB17607 - 5	22.07.2013	GC	16:03	74° 50,71'	17° 38,28'	298,2	920	Degassing.
MSM30/497-1	GeoB17607 - 6	03.08.2013	MeBo	15:33	74° 50,75'	17° 38,36'	300	1356	
MSM30/476-1	GeoB17608 - 1	23.07.2013	MUC	08:38	74° 50,86'	17° 20,86'	298	38	
MSM30/476-2	GeoB17608 - 2	23.07.2013	GBC	08:57	74° 50,86'	17° 20,85'	301	49	
MSM30/476-3	GeoB17608 - 3	23.07.2013	GC	09:20	74° 50,86'	17° 20,85'	313	819	
MSM30/477-1	GeoB17609 - 1	23.07.2013	GBC	10:55	74° 51,04'	16° 54,35'	315	36	
MSM30/477-2	GeoB17609 - 2	23.07.2013	GC	11:20	74° 51,04'	16° 54,33'	318,1	626	
MSM30/477-3	GeoB17609 - 3	23.07.2013	MUC	11:50	74° 51,04'	16° 54,36'	316,8	29	
MSM30/494-1	GeoB17609 - 4	03.08.2013	MeBo	07:20	74° 51,05'	16° 54,32'	315	270	

MSM30/505-1	GeoB17609 - 5	05.08.2013	MeBo	07:25	74° 51,03'	16° 54,21'	320	3555	
MSM30/479-1	GeoB17610 - 1	25.07.2013	MUC	06:14	75° 30,99'	15° 0,53'	390,6	38	
MSM30/479-2	GeoB17610 - 2	25.07.2013	GC	06:41	75° 30,99'	15° 0,53'	387,1	349	
MSM30/480-1	GeoB17611 - 1	25.07.2013	GC	07:53	75° 30,11'	15° 3,41'	384,1	225	Dropstone 15 cm between section 1 + 2.
MSM30/480-2	GeoB17611 - 2	25.07.2013	MUC	08:25	75° 30,11'	15° 3,41'	383,4	37	
MSM30/482-1	GeoB17612 - 1	26.07.2013	MUC	06:58	74° 46,45'	17° 37,73'	288	20	
MSM30/482-2	GeoB17612 - 2	26.07.2013	GC	07:21	74° 46,45'	17° 37,73'	278,3	0	Bended, only CC and bagsample (not for analyses).
MSM30/482-2	GeoB17612 - 3	26.07.2013	GBC	07:55	74° 46,44'	17° 37,73'	284,5	0	Box deformed.
MSM30/495-1	GeoB17612 - 4	03.08.2013	GC	12:53	74° 46,46'	17° 37,75'	286,7	270	
MSM30/483-1	GeoB17613 - 1	26.07.2013	MUC	08:52	74° 47,74'	17° 37,89'	301,8	27	
MSM30/496-1	GeoB17613 - 2	03.08.2013	GC	13:31	74° 47,74'	17° 37,89'	298,3	294	Over-penetration.
MSM30/485-1	GeoB17614 - 1	26.07.2013	MUC	10:41	74° 47,64'	18° 8,74'	295,1	34	
MSM30/485-2	GeoB17614 - 2	26.07.2013	GC	11:07	74° 47,64'	18° 8,76'	287	796	
MSM30/486-1	GeoB17615 - 1	26.07.2013	GBC	12:09	74° 50,94'	18° 10,94'	325,9	31	
MSM30/488-1	GeoB17616 - 1	26.07.2013	MUC	22:22	74° 58,83'	15° 26,56'	800,7	39	
MSM30/490-2	GeoB17617 - 1	27.07.2013	MUC	15:37	74° 49,43'	13° 49,01'	2004,6	40	
MSM30/493-1	GeoB17618 - 1	03.08.2013	MUC	04:23	74° 47,71'	17° 47,92'	295,8	30	
MSM30/493-2	GeoB17618 - 2	03.08.2013	GC	04:49	74° 47,71'	17° 47,92'	299,5	812	
MSM30/499-1	GeoB17619 - 1	04.08.2013	MUC	06:28	74° 49,64'	18° 9,28'	295,7	37	
MSM30/499-2	GeoB17619 - 2	04.08.2013	GC	06:53	74° 49,64'	18° 9,28'	298,9	550	Technical failure.
MSM30/499-3	GeoB17619 - 3	04.08.2013	GC	07:57	74° 49,64'	18° 9,28'	298,1	682	
MSM30/500-1	GeoB17620 - 1	04.08.2013	GBC	08:41	74° 50,74'	18° 10,53'	333,1	36	
MSM30/500-2	GeoB17620 - 2	04.08.2013	GC	09:06	74° 50,74'	18° 10,52'	336	491	
MSM30/501-1	GeoB17621 - 1	04.08.2013	GBC	11:06	74° 52,26'	17° 49,42'	337	36	
MSM30/501-2	GeoB17621 - 2	04.08.2013	GC	11:30	74° 52,26'	17° 49,42'	327,2	576	Over-penetration.
MSM30/503-3	GeoB17621 - 3	04.08.2013	GC	16:15	74° 52,26'	17° 49,42'	327,1	786	
MSM30/502-1	GeoB17622 - 1	04.08.2013	MUC	12:44	74° 59,69'	17° 59,59'	167,1	41	
MSM30/502-2	GeoB17622 - 2	04.08.2013	GC	13:02	74° 59,69'	17° 59,59'	158,4	434	
MSM30/503-1	GeoB17623 - 1	04.08.2013	GBC	13:35	75° 0,46'	17° 58,85'	150,2	35	
MSM30/503-2	GeoB17623 - 2	04.08.2013	GC	14:14	75° 0,46'	17° 58,85'	150,2	442	
MSM30/510-1	GeoB17624 - 1	08.08.2013	MUC	13:35	74° 57,56'	15° 48,22'	392,7	0	Empty.
MSM30/510-2	GeoB17624 - 2	08.08.2013	MUC	14:00	74° 57,56'	15° 48,22'	394	0	Empty. Some medium-coarse sandy grains.
MSM30/522-1	GeoB17624 - 3	11.08.2013	GBC	06:26	74° 57,56'	15° 48,20'	388,7	11,5	Sandy sediment.
MSM30/511-1	GeoB17625 - 1	08.08.2013	GBC	16:42	74° 53,28'	14° 56,54'	1350,1	49	
MSM30/511-2	GeoB17625 - 2	08.08.2013	GC	17:48	74° 53,28'	14° 56,54'	1350,2	364	
MSM30/513-1	GeoB17626 - 1	09.08.2013	MUC	06:59	74° 51,34'	14° 5,16'	1893,4	39	
MSM30/514-1	GeoB17627 - 1	09.08.2013	GBC	10:01	74° 52,94'	14° 52,19'	1398	0	Empty. Technical failure.
MSM30/514-2	GeoB17627 - 2	09.08.2013	GBC	10:55	74° 52,94'	14° 52,19'	1398,2	44	
MSM30/514-3	GeoB17627 - 3	09.08.2013	GC	12:27	74° 52,94'	14° 52,18'	1399,2	474	
MSM30/515-1	GeoB17628 - 1	09.08.2013	MUC	14:05	74° 55,48'	14° 48,99'	1347,5	39	
MSM30/515-2	GeoB17628 - 2	09.08.2013	GC	15:12	74° 55,48'	14° 48,99'	1345,1	720	
MSM30/517-1	GeoB17629 - 1	10.08.2013	GBC	07:36	74° 37,80'	17° 57,75'	127,8	4	Almost empty, sandy material.

MSM30/517-2	GeoB17629 - 2	10.08.2013	VC	08:33	74° 37,80'	17° 57,75'	127,2	493	
MSM30/518-1	GeoB17630 - 1	10.08.2013	GBC	10:21	74° 37,91'	17° 16,89'	150,1	10	Almost empty, sandy sediment.
MSM30/518-2	GeoB17630 - 2	10.08.2013	VC	10:54	74° 37,91'	17° 16,89'	150,6	160	
MSM30/519-1	GeoB17631 - 1	10.08.2013	GBC	12:08	74° 38,12'	16° 57,77'	171,1	20	
MSM30/519-2	GeoB17631 - 2	10.08.2013	VC	12:40	74° 38,12'	16° 57,78'	173	506	
MSM30/520-2	GeoB17632 - 1	10.08.2013	GBC	16:23	74° 59,99'	17° 21,78'	171,1	39,5	
MSM30/520-3	GeoB17632 - 2	10.08.2013	GC	16:54	74° 59,98'	17° 21,78'	168,5	236	
MSM30/527-1	GeoB17633 - 1	13.08.2013	GBC	12:33	74° 51,86'	14° 44,66'	1483	0	Empty. Device did not close.
MSM30/527-2	GeoB17633 - 2	13.08.2013	GBC	13:39	74° 51,85'	14° 44,66'	1480,4	0	Empty. Device did not close.
MSM30/527-3	GeoB17633 - 3	13.08.2013	GC	14:57	74° 51,85'	14° 44,66'	1474,6	575	Over-penetration.
MSM30/528-1	GeoB17634 - 1	13.08.2013	GBC	16:18	74° 51,88'	14° 44,58'	1491,4	43	
MSM30/528-2	GeoB17634 - 2	13.08.2013	GC	17:52	74° 51,88'	14° 44,58'	1483	604	

7.2 Coring-Site Selection Strategy

The following table provides a detailed documentation to which scientific purpose a particular site was selected, according to the notes of the cruise leader T. Hanebuth.

Site GeoB	WD [m]	Recovery [cm]	Location	Local settings	Scientific purpose
"LEG I"					
17601	373	520	Outer Kveithola Trough	Holocene draping the outer margin of GWZ 2	Dating this stagnation phase during ice-stream retreat; Analyzing the overburden; Preparation of MeBo Site B: 2nd GWZ
17602	1489	456	Middle Kveithola TMF	Slide material filling a scar funnel	Channel deposition in contrast to normal slope conditions (A1); Preparation of MeBo Site A2
17603	1430	990	Middle Kveithola TMF	Thickly stratified succession at slope	Deglacial to Holocene meltwater dynamics; Preparing MeBo Site A1: drilling a continuous expanded deglacial succession
17604	1796	632	Distal Kveithola TMF	Stratified succession intercalated by several glacigenic debrites and younger landslides	The latest glacigenic debrite event (LGM?), analyzing the overburden
17605	770	405	Upper-slope gully	Seemingly active gully with no obvious younger sediment filling	Function as modern pathway for waters exiting the Kveithola Trough
17606	780	438	Upper-slope gully	Seemingly abandoned gully with certain sediment refill	For comparison with assumedly active gully (Site 17605)
17607	296	829 920	Inner Kveithola Trough	Center of well-stratified drift	Formation history of the shallow-water drift; Reconstructing the post-glaciated + Holocene climatic (sea-ice) history; Preparation of MeBo Site F
17608	304	819	Middle Kveithola	30 m thick drape with plenty	Preparation of MeBo Site E

			Trough	of gas flames and pockmarks	
17609	317	626	Middle Kveithola Trough	Thick post-glacial sediment drape	Preparation of MeBo Site D
17610	390	349	S' outer Storfjorden Trough	Thin young drape covering the last till	Dating this event of stagnation, understanding ice-thickness and compressibility-permeability characteristics of glacial sediments
17611	385	225	S' outer Storfjorden Trough	Thin young drape covering the assumedly LGM till	Dating this event of till formation = ice-stream margin; understanding ice-thicknes and compressibility-permeability characteristics of glacial sediments
17612	285	~250 270	Inner Kveithola Trough	Southern flank of drift, continuous record with reduced accumulation	Accumulation pattern across the drift; Archiving the early phase of drift formation (cp. Sites 17607, 17614)
17613	296	294	Inner Kveithola Trough	Center of drift, highly expanded stratigraphic record	Accumulation pattern across the drift, formation dynamics
17614	285	796	Inner Kveithola Trough	Center of innermost drift portion, highly expanded stratigraphic record	Accumulation pattern across the drift, formation dynamics
17615	330	(GBC)	Inner Kveithola Trough	Channel/moat at the northern edge of the drift	Current intensities, drift formation dynamics
17616	800	(MUC)	Proximal Kveithola TMF	Stratified upper-slope sediment succession	Palaeoceanographic depth transect
17617	2,005	(MUC)	Distal Kveithola TMF	Stratified lower-slope sediment succession	Palaeoceanographic depth transect
(Tromsø)					
"LEG II"					
17618	296	812	Inner Kveithola Trough	The new discovered, supposedly youngest GZW	Ice sheet dynamics; Preparation of a potential MeBo Site G
17619	295	682	Inner Kveithola Trough	Thick stratified succession in the center of the eastern drift body	Drift evolution; environmental reconstruction during ice-free times; climatic history
17620	315	491	Inner Kveithola Trough	Pinching out of younger drift unit at the drift's moat channel, thus coring the deeper part of the drift body (= offset coring)	Drift evolution; environmental reconstruction during early times possibly with sea ice occasions; climatic history
17621	294	575 600	N' channel	Edge of current-induced deposit and underlying drape unit	Regional current system, regional sediment dispersal dynamics, communication between channel as conduit and trough deposition
17622	157	434	N' channel	Center of channel deposit with highest accumulation	Regional current system, regional sediment dispersal dynamics, communication between channel as conduit and trough deposition
17623	151	442	N' channel	Marginal channel deposit with two successiv fill units and the underlying substratum	Regional current system, regional sediment dispersal dynamics, communication between channel as conduit and trough deposition
17624	393	(MUC)	Shelf edge	No penetration, shelf edge	Palaeoceanographic depth transect (forams) in the core of the NC/WSC

17625	1320	364	Upper slide scar at TMF	Young landslide covering the hemipelagic succession just above a head wall	Age and condition of underlying assumed glide plain material
17626	1890	(MUC)		Lower TMF	Palaeoceanographic depth transect
17627	1401	482	At TMF	Upper slide scar	Methane flux through the slided succession
17628	1350	720	At TMF	Outside upper slide scar	Methane flux through normal slope succession
17629	127	493	S of Kveithola Trough	Margin of local channel-like depression filled by successive units, just south of the trough	Characteristics of deposits in the trough-surrounding shallow-shelf area
17630	150	160	S of Kveithola Trough	Thin widespread till sheet + underlying substratum, just south of the trough	Characteristics of deposits in the trough-surrounding shallow-shelf area
17631	174	506	S of Kveithola Trough	Margin of one of the small but frequently occurring “channel” fills in till landscape + underlying substratum, just south of the trough	Characteristics of deposits in the trough-surrounding shallow-shelf area
17632	170	236	N of Kveithola Trough	Stratified succession draping a shelf bank depression	Pendant to the drape unit inside the trough and the N-directed channel
17633	1478	575	At TMF	Half way on southern flank of scar channel	Offset coring in attempt to replace parts of the MeBo Site A1
17634	1488	604	At TMF	Half way on southern flank of scar channel	Offset coring in attempt to replace parts of the MeBo Site A1
34 Sites		167			

8 Data and Sample Storage and Availability

All sediment cores and surface samples got GeoB numbers and are stored at the MARUM GeoB core repository and registered in the new DIS sample-management software.

Samples and data produced can be obtained from the CORIBAR consortium on request for the period of five years after the cruise. After five years, all sample material will be fully accessible in accordance with the MARUM core repository regulations.

Data sets which are part of scientific articles will be made publically available on www.pangaea.de.

9 Acknowledgements

We are grateful for the permissions received by the Norwegian Petroleum Directorate, the Norwegian Armed Forces, the Directorate of Fisheries, and for the support by the local harbour authorities.

We acknowledge the great support by *Leitstelle* in Hamburg, *Auswärtiges Amt* in Berlin, and *Deutsche Botschaft* in Oslo for their intense and prompt support, especially with regard to the unscheduled return to Tromsø harbour.

We also would like to thank Captain Matthias Günther and his highly professional crew for the great cooperation and communication during the entire cruise with its frequently arising new challenges. Special thanks go also to the bosom Sebastian Plinck his great guys on deck for their remarkable spontaneity and flexibility.

We want further to express our gratitude to the MARUM logistics group for their professional support.

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The Italian PNRA supported a share of the MeBo logistics and the participation of the Italian team (Renata G. Lucchi, Michele Rebesco and Andrea Caburlotto) to CORIBAR cruise.

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Chief scientist Till Hanebuth acknowledges a Heisenberg fellowship (HA 4317/4-2) by the *Deutsche Forschungsgemeinschaft*.

The CORIBAR research cruise and project is embedded into the international NICESTREAM project (http://sites.google.com/site/ipynicestreams/home).

It also contributes to the AWI – MARUM strategic alliance AMAR.

ANNEX

Documentation of Giant Box Cores

Cruise **CORIBAR**, *R/V Maria S. Merian*, 16 July-15 August 2013

Core **GeoB 176 01-2**	Sediment recovery: **40 cm**
Coordinates: **74°50.714' N - 17°38.274' E**	Water depth: **295.5 m**
Observers: **Lucchi, Caburlotto, Sabbatini**	Date: **18-07-2013**

SURFACE SEDIMENT DESCRIPTION

Clean very fine sand with sparse worms, rare shells and 5 living actiniaria (anthozoa)

Colour: 2.5Y 4/3 olive brown

cm	PHOTO	Lithology	COLOUR	SEDIM. STRUCT.	LITHOLOGIC DESCRIPTION
10 20 30 40 50		silty clay	2.5Y4/3 olive brown 2.5Y 5/2 grayish brown	{{ {{ {{ {{	0-8 cm soupy brownish silty clay bioturbated 8-40 cm grayish structureless silty clay {{ bioturbation

Cruise **CORIBAR**, *R/V Maria S. Merian*, 16 July-15 August 2013

Core **GeoB 176 02-1**

Sediment recovery: **49 cm**

Coordinates: **74°52.039' N - 14°43.969' E**

Water depth: **1490.7 m**

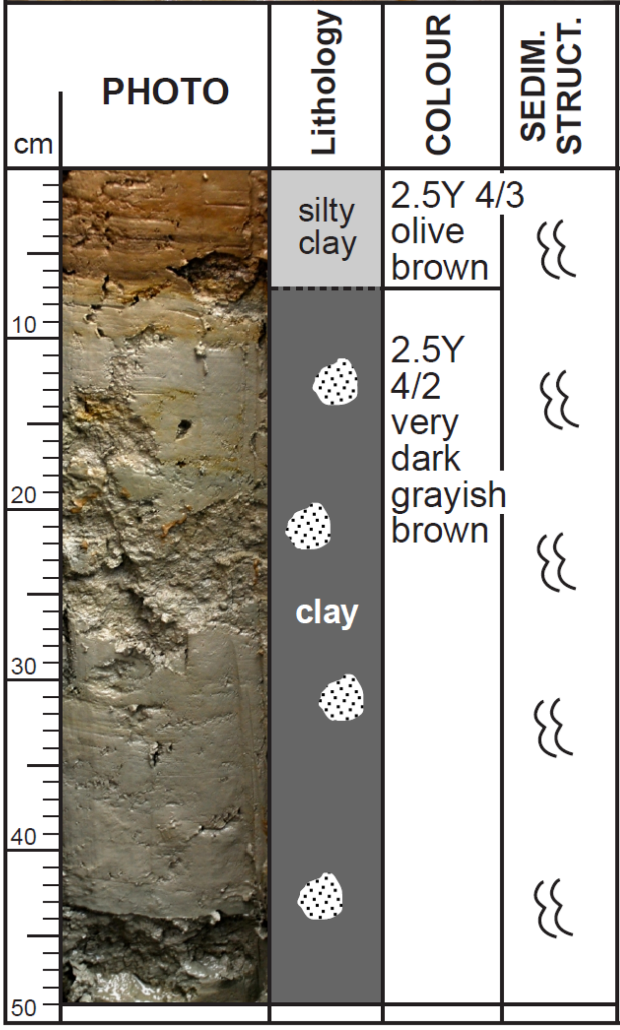
Observers: **RG Lucchi, A Sabbatini**

Date: **19-07-2013**

SURFACE SEDIMENT DESCRIPTION

Soft, soupy brownish mud with sparse echinoids (sea-stars), and worm tubes

Colour: 2.5Y 4/3 olive brown



LITHOLOGIC DESCRIPTION

0-6 cm brownish silty clay

6-49 cm bioturbated gray clay with sparse silty patches

⦚ bioturbation

∴ silty/sandy patches

Cruise **CORIBAR**, *R/V Maria S. Merian*, 16 July-15 August 2013

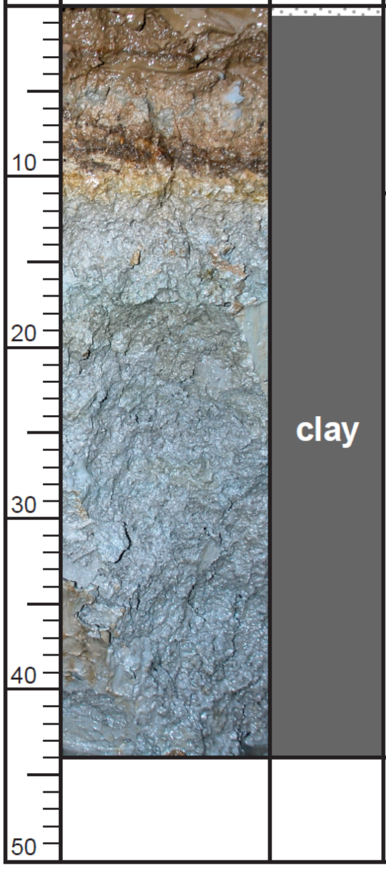
Core **GeoB 176 03-2**	Sediment recovery: **44 cm**
Coordinates: **74°51.002' N - 14°48.084' E**	Water depth: **1432 m**
Observers: **RG Lucchi, A Sabbatini**	Date: **19-07-2013**

SURFACE SEDIMENT DESCRIPTION

Soft, soupy clayey silt
with worm tubes

Colour: 2.5Y 4/4 olive brown

cm | **PHOTO** | **Lithology** | **COLOUR** | **SEDIM. STRUCT.** | **LITHOLOGIC DESCRIPTION**



2.5Y
4/4

2.5Y 3/2

5Y
5/1
gray

Structureless sediment
very fine grained (clay)

0-12 cm brownish clay with a thin silty layer at the top. Between 8-9 dark brown interval
12-44 cm soft gray clay

░ silt

Cruise **CORIBAR**, *R/V Maria S. Merian*, 16 July-15 August 2013

Core **GeoB 176 05-1**

Sediment recovery: **48 cm**

Coordinates: **74°47.091' N - 15°31.265' E**

Water depth: **766.5 m**

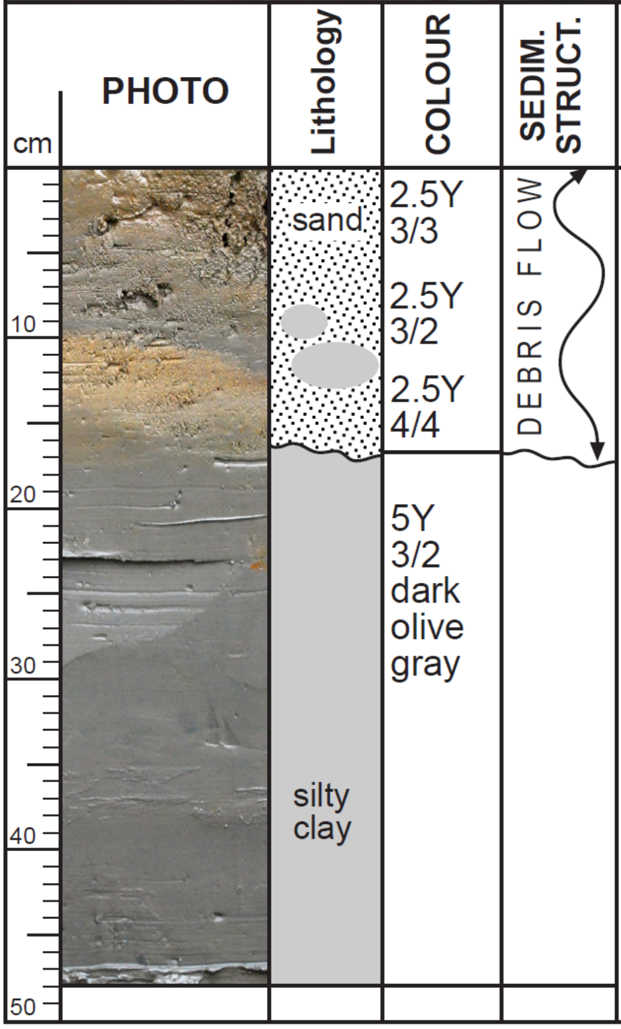
Observers: **RG Lucchi**, A Sabbatini

Date: **21-07-2013**

SURFACE SEDIMENT DESCRIPTION

Sandy surface with many rock/mud pebbles.
The surface is undulated on a large scale (large ripples? Dunes?). Many sea-stars, shells, and worms

Colour: 2.5Y 3/3 dark olive brown



LITHOLOGIC DESCRIPTION

0-16 cm debris flow with sandy matrix containing forams and mud chips.
At 16 cm sharp irregular surface.

16- 48 cm dark gray silty clay

Cruise **CORIBAR**, *R/V Maria S. Merian*, 16 July-15 August 2013

Core **GeoB 176 06-1**

Sediment recovery: **36 cm**

Coordinates: **74°45.690’ N - 15°33.294’ E**

Water depth: **778.2 m**

Observers: **RG Lucchi, A Sabbatini**

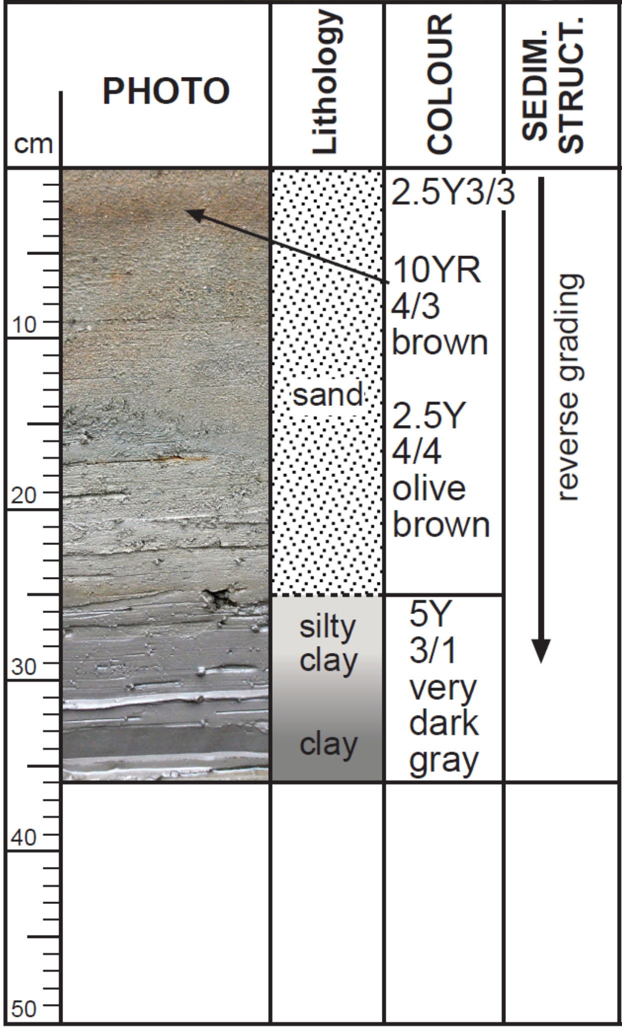
Date: **21-07-2013**

SURFACE SEDIMENT DESCRIPTION

Smooth clean sandy surface with small amplitude ripples. Presence of sea-stars and sponges.

Colour: 2.5Y 3/3 dark olive brown

sponges



LITHOLOGIC DESCRIPTION

0-24 cm clean fine-medium sand gradually fining downwards (reverse grading). The sands contain mats of sponge spiculae with trapped forams

24-36 cm soupy dark gray silty clay and clay with black agglomerates of organic matter

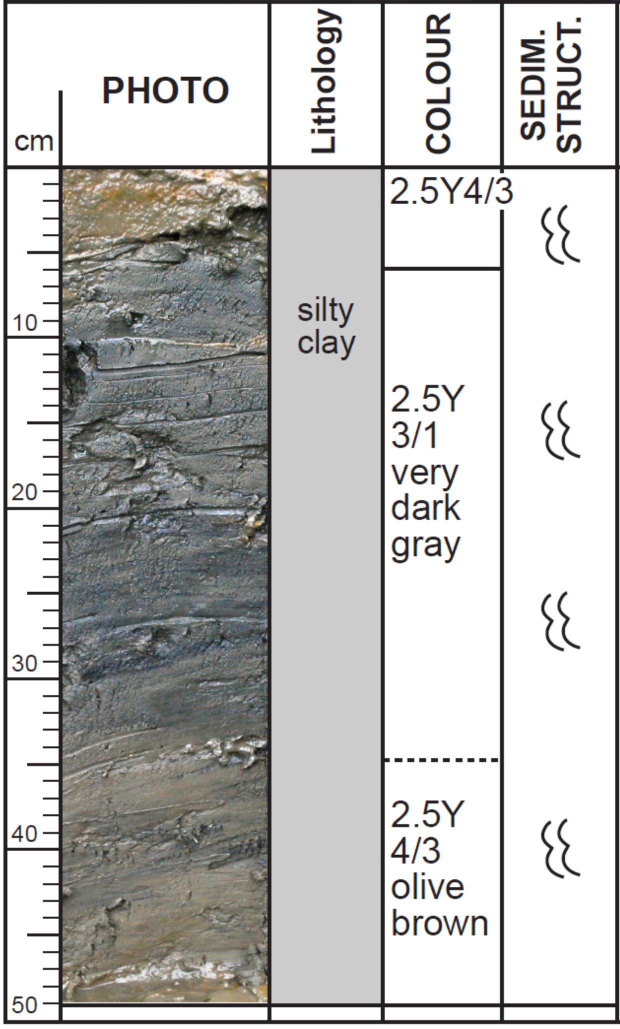
Cruise **CORIBAR**, *R/V Maria S. Merian*, 16 July-15 August 2013

Core **GeoB 176 07-3**	Sediment recovery: **49 cm**
Coordinates: **74°50.714' N - 17°38.274' E**	Water depth: **295.5 m**
Observer: **RG Lucchi, A Sabbatini**	Date: **22-07-2013**

SURFACE SEDIMENT DESCRIPTION

Soft, soupy silty clay with abundant worm tubes.
Strong smell of H_2S
Colour: 2.5Y 4/3 olive brown

black worm tubes



LITHOLOGIC DESCRIPTION

0-6 cm soupy brownish silty clay

6-36 cm very dark gray/black silty clay. The sediment is pervasively bioturbated with abundant worm tubes and organic matter.

36-49 cm brownish silty clay with patchy black intervals

≀ bioturbation

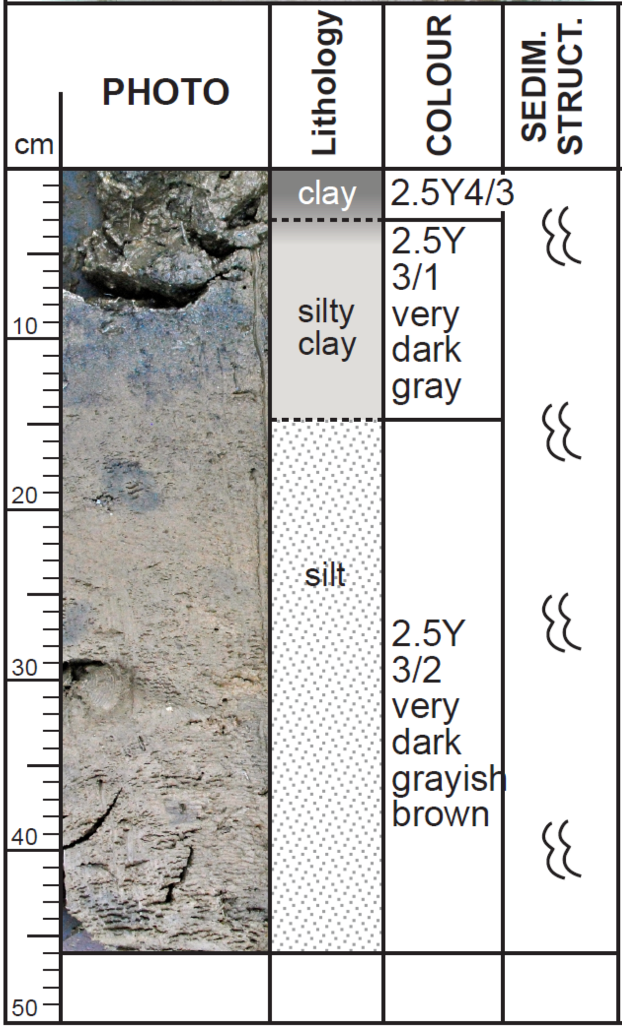
Cruise **CORIBAR**, *R/V Maria S. Merian*, 16 July-15 August 2013

Core **GeoB 176 08-2**	Sediment recovery: **46 cm**
Coordinates: **74°50.858' N - 17°20.853' E**	Water depth: **304.9 m**
Observer: **RG Lucchi, A Sabbatini**	Date: **23-07-2013**

SURFACE SEDIMENT DESCRIPTION

Soft, soupy sandy clay (jelly-like). Hummocky ripple-like structures at the top. Abundant worm tubes.

Colour: 2.5Y 4/2 dark grayish brown



LITHOLOGIC DESCRIPTION

0-3 cm soupy brown sandy clay

3-14 cm mottled brown silty clay with abundant black worm tubes and organic matter (strong smell of H_2S)

14-46 cm bioturbated clayly silt with black mottles

large shell at 32 cm

≋ bioturbation

Cruise **CORIBAR**, *R/V Maria S. Merian*, 16 July-15 August 2013

Core **GeoB 176 09-1** Sediment recovery: **38 cm**

Coordinates: **74°51.043’ N - 16°54.354’ E** Water depth: **314.7 m**

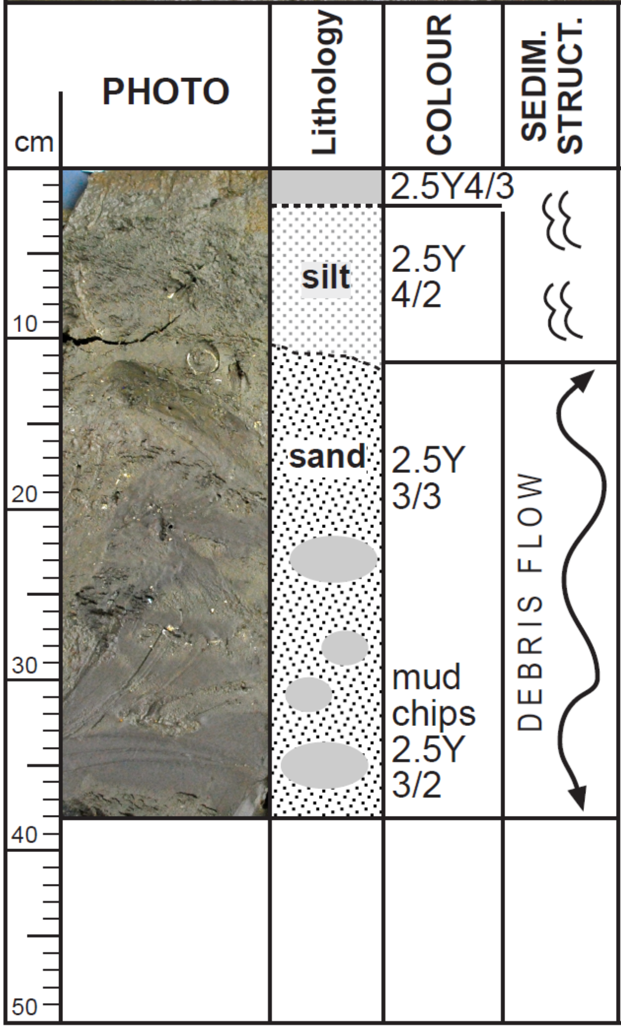
Observers: **RG Lucchi, A Sabbatini** Date: **23-07-2013**

SURFACE SEDIMENT DESCRIPTION

Soft, soupy silty clay (jelly-like) with worms, shells, and pebbles. Slightly hummocky, fractured surface.

Colour: 2.5Y 4/3 olive brown

red/pink polychaete 6-7 cm long



LITHOLOGIC DESCRIPTION

0-2 cm brown sandy clay

2-11 cm bioturbated silty with shells

11-38 cm debris flow with sandy matrix and mud chips. Abundant broken shells

≀≀ bioturbation

■ silty clay

Cruise **CORIBAR**, *R/V Maria S. Merian*, 16 July-15 August 2013

Core **GeoB 176 15-1**

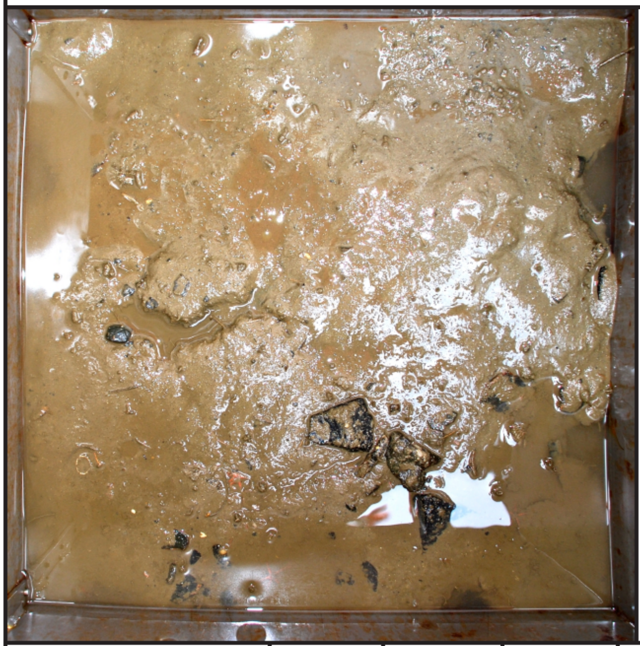
Sediment recovery: **38 cm**

Coordinates: **74°51.043' N - 16°54.354' E**

Water depth: **314.7 m**

Observers: **RG Lucchi, A Sabbatini**

Date: **23-07-2013**

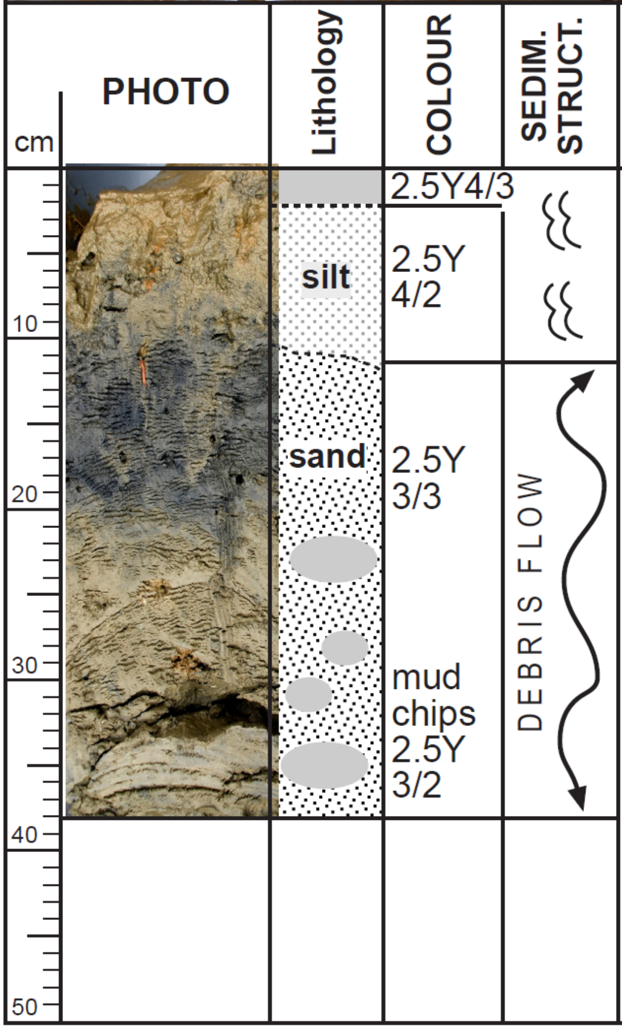


SURFACE SEDIMENT DESCRIPTION

Soft, soupy sandy clay (jelly-like consistency) with worms, shells, and pebbles. Slightly hummocky, fractured surface.

Colour: 2.5Y 4/3 olive brown

ophiuridae over a bryozoa



LITHOLOGIC DESCRIPTION

0-2 cm brown sandy clay

2-11 cm bioturbated silty with shells

11-38 cm debris flow with sandy matrix and mud chips. Abundant broken shells

{{ bioturbation

▨ silty clay

worm

Cruise **CORIBAR**, *R/V Maria S. Merian*, 16 July-15 August 2013

Core **GeoB 176 20-1**

Sediment recovery: **35 cm**

Coordinates: **74°50.740' N - 18°10.530' E**

Water depth: **334.9 m**

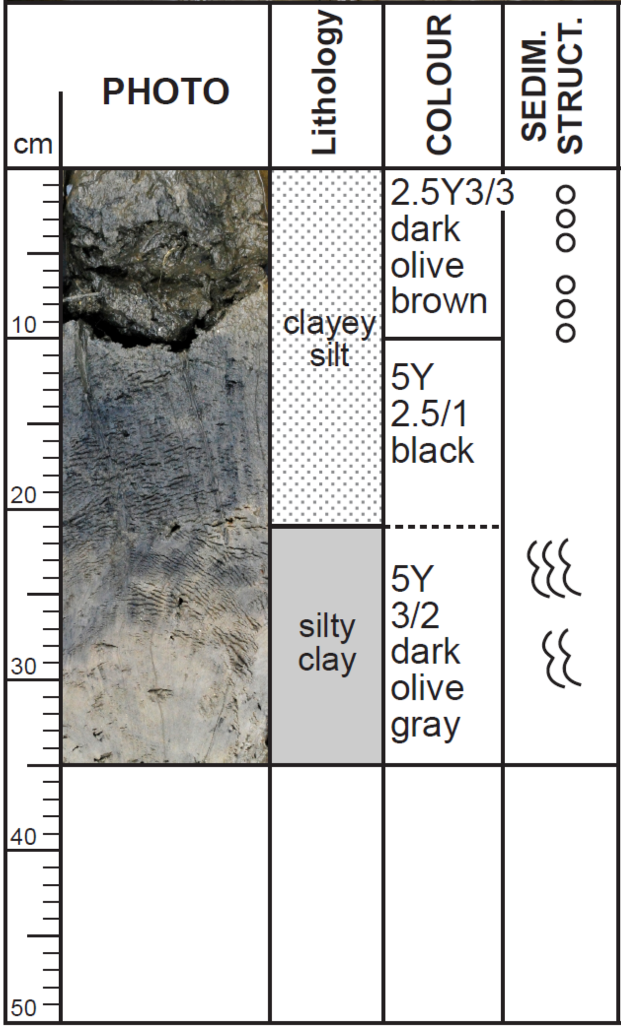
Observers: **RG Lucchi**, **A Sabbatini**

Date: **04-08-2013**

SURFACE SEDIMENT DESCRIPTION

Soupy, soft (jelly like), clayey silt.
Slightly hummocky and fractured sediment surface with large burrow-like holes open at the surface.
Abundant worm tubes.

Colour: 2.5Y 3/3 dark olive brown



LITHOLOGIC DESCRIPTION

0-10 cm soupy, soft, clayey silt.

10-22 cm stiff, black clayey silt with worms

22-28 cm gray mud with black mottles

28-35 cm stiff gray mud

○ soupy sediments

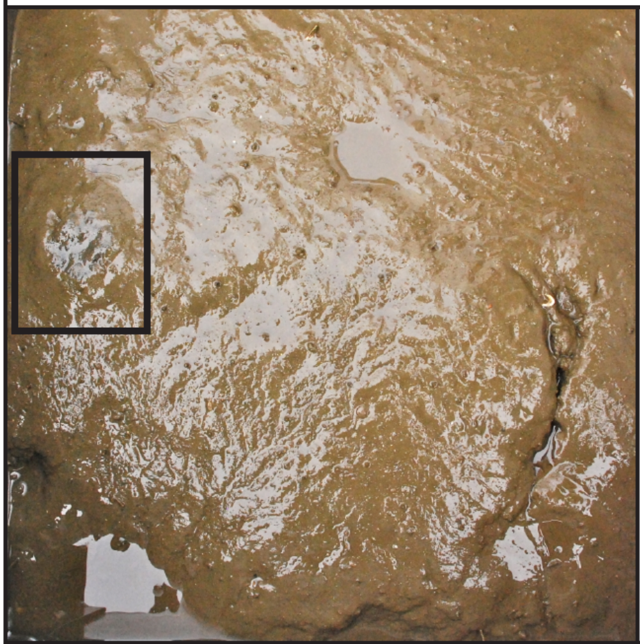
≀ bioturbation/mottling

Cruise **CORIBAR**, *R/V Maria S. Merian*, 16 July-15 August 2013

Core **GeoB 176 21-1** | Sediment recovery: **40 cm**

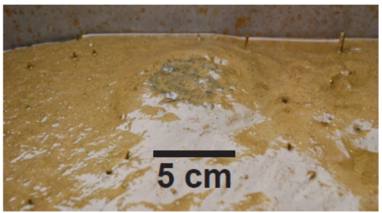
Coordinates: **74°52.258' N - 17°49.420' E** | Water depth: **326.8 m**

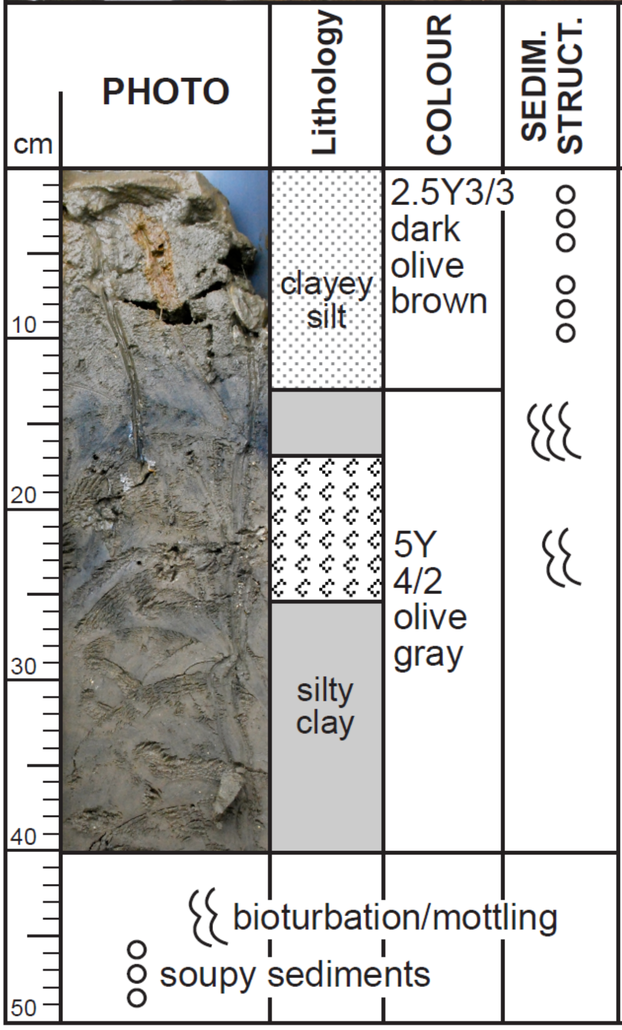
Observers: **RG Lucchi**, **A Sabbatini** | Date: **04-08-2013**



SURFACE SEDIMENT DESCRIPTION

Soupy, soft (jelly like), clayey silt. Slightly hummocky and fractured sediment surface with large burrow-like holes open at the surface and a mounded feature with black sediment on top (detail). Colour: 2.5Y 3/2





LITHOLOGIC DESCRIPTION

0-13 cm soft, soupy, clayey silt. Recovery of two living red polychaetes in the upper part of the sediments.

13-40 cm stiff gray mud.

17-25 cm shell debris with sparse pebbles (rounded cobble 15 cm-large recovered within the box core). ▨

Black mottles between 14-25 cm

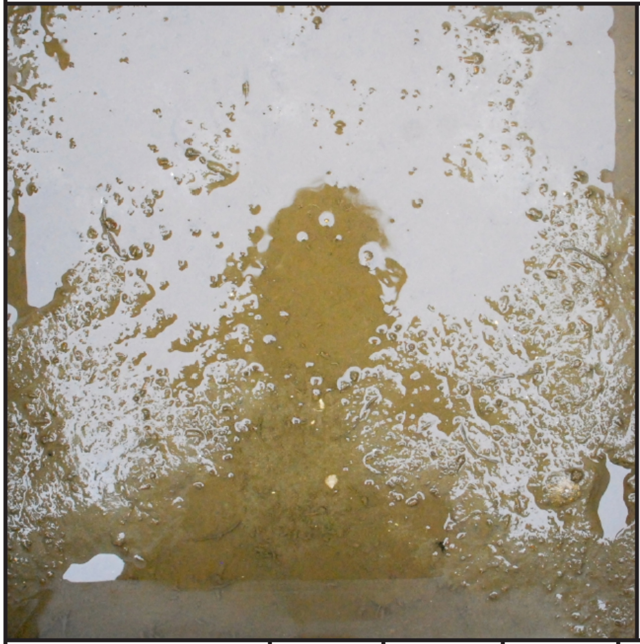
red polychaete

Cruise **CORIBAR**, *R/V Maria S. Merian*, 16 July-15 August 2013

Core **GeoB 176 23-1** | Sediment recovery: **42 cm**

Coordinates: **75°0.458' N - 17°58.839' E** | Water depth: **151.3 m**

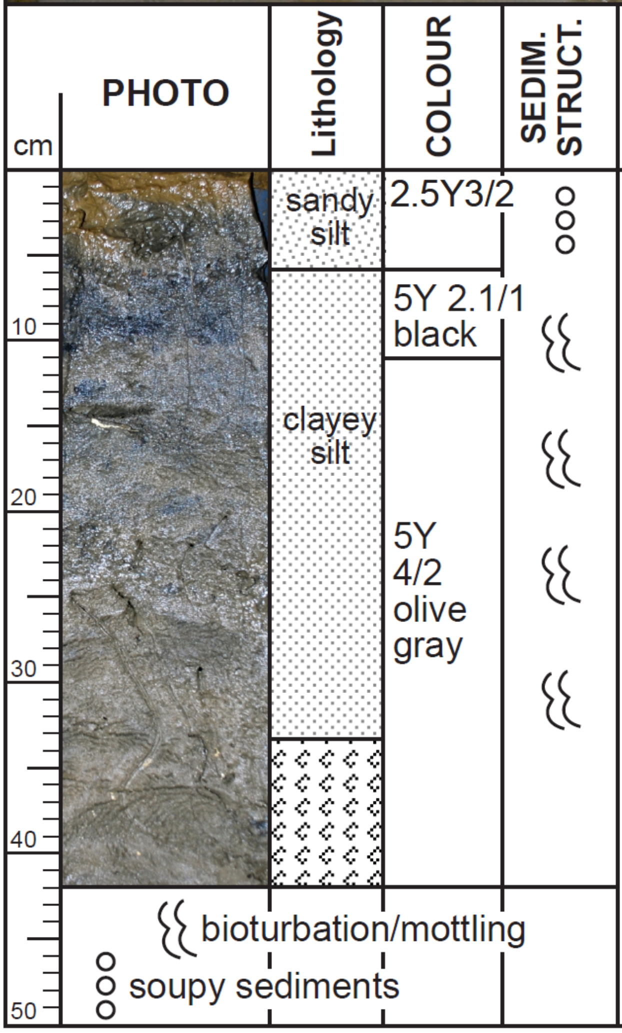
Observers: **RG Lucchi, A Sabbatini** | Date: **04-08-2013**



SURFACE SEDIMENT DESCRIPTION

Soft, soupy (jelly like), sandy silt with abundant worms and shells.

Colour: 2.5Y 4/3 olive brown



LITHOLOGIC DESCRIPTION

0-6 cm soft, soupy, brown sandy silt with worms and red polychaetes.

6-29 cm mottled grayish brown clayey silt (black mottles).

15-16 cm shell

29-42 cm brown silt with sparse broken shells

red polychaete

Cruise **CORIBAR**, *R/V Maria S. Merian*, 16 July-15 August 2013

Core **GeoB 176 24-3** | Sediment recovery: **11 cm**

Coordinates: **75°47.564' N - 15°48.196' E** | Water depth: **390.3 m**

Observers: **A Caburlotto**, **A Sabbatini** | Date: **11-08-2013**

SURFACE SEDIMENT DESCRIPTION

Almost empty box corer.
Gravelly sand with abundant shell's fragments

Colour: 5Y 4/1 dark gray

Cruise **CORIBAR**, *R/V Maria S. Merian*, 16 July-15 August 2013

Core **GeoB 176 25-1**

Sediment recovery: **52 cm**

Coordinates: **74°53.281’ N - 14°56.535’ E**

Water depth: **1350 m**

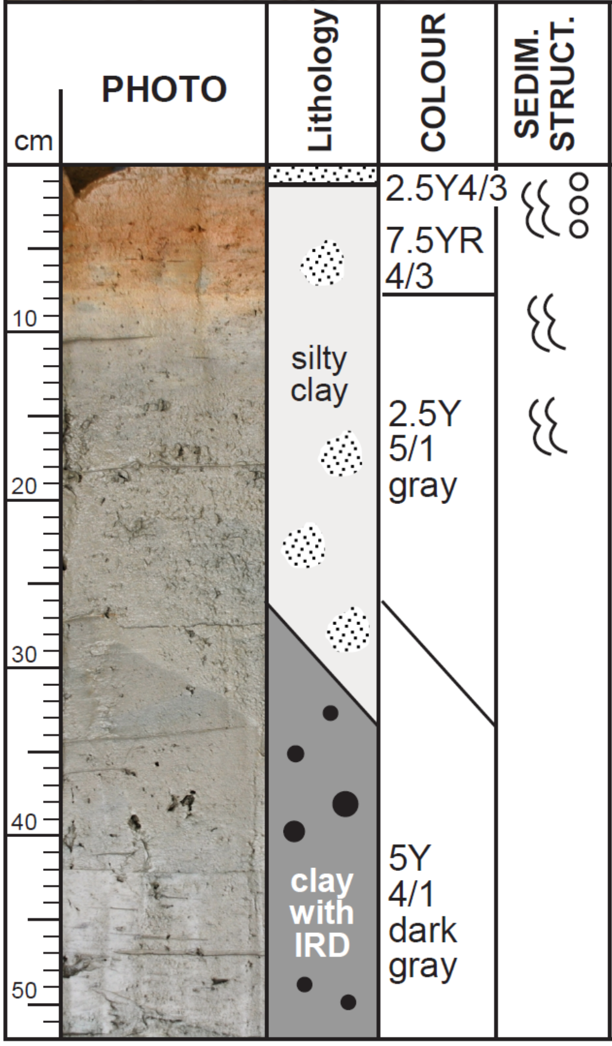
Observers: **RG Lucchi**, **A Sabbatini**

Date: **08-08-2013**

SURFACE SEDIMENT DESCRIPTION

Soft, soupy sandy mud with abundant sea-stars and worms. Slightly undulated/wavy surface

Colour: 2.5Y 4/3 olive brown



LITHOLOGIC DESCRIPTION

0-1 cm soft, soupy, brown clayey sand ▨

1-7 cm soft brown silty clay with silt patches

7-26 (34) cm soft, gray silty clay with silty patches. Oblique boundary with the underlaying sediments

26 (34)-52 cm dark gray clay with sparse pebbels (IRD)

≀≀ bioturbation/mottling

○ soupy sediments

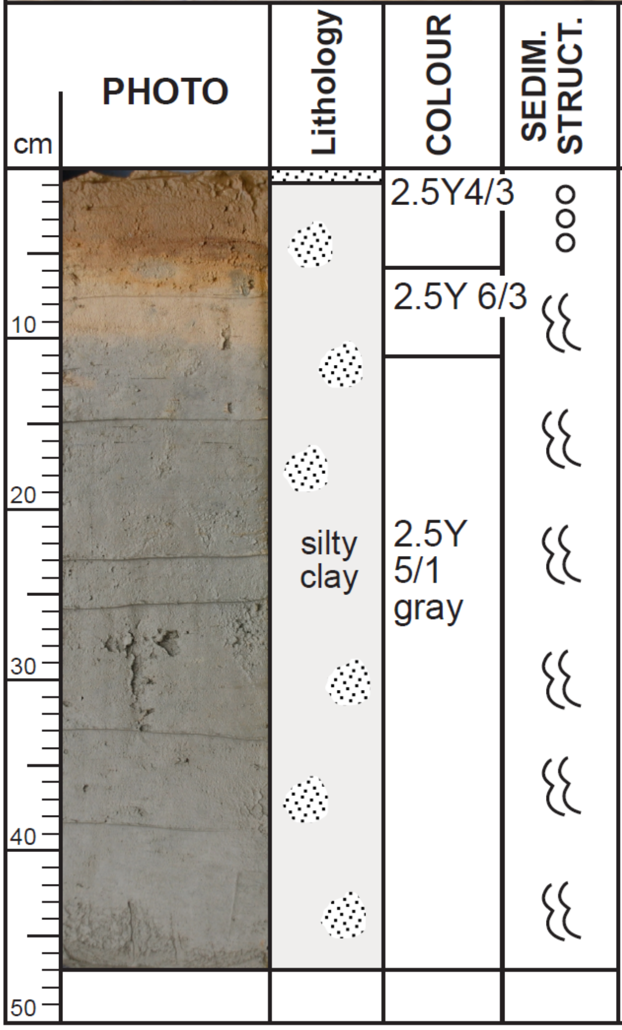
Cruise **CORIBAR**, *R/V Maria S. Merian*, 16 July-15 August 2013

Core **GeoB 176 27-2**	Sediment recovery: **47 cm**
Coordinates: **74°52.941' N - 14°52.185' E**	Water depth: **1402.9 m**
Observers: **RG Lucchi**, **A Sabbatini**	Date: **09-08-2013**

SURFACE SEDIMENT DESCRIPTION

Soft, soupy, sand with abundant sea-stars.
Water salinity at the bottom 38‰

Colour: 2.5Y 4/3 olive brown



LITHOLOGIC DESCRIPTION

0-1 cm sand

1-6 cm soft, soupy, brown silty clay

6-10 cm soft light brown silty clay

10-47 cm soft gray silty clay

The whole section appears bioturbated with silty patches

{{ bioturbation/mottling

ooo soupy sediments

Cruise **CORIBAR**, *R/V Maria S. Merian*, 16 July-15 August 2013

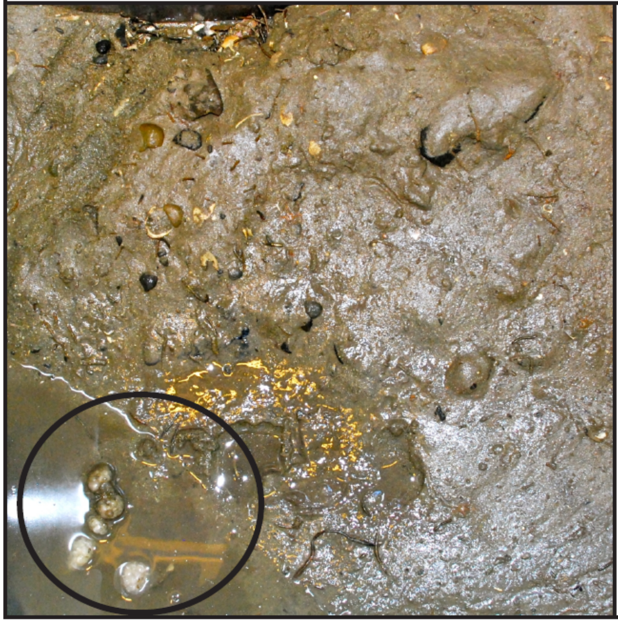
Core **GeoB 176 29-1**	Sediment recovery: **6 cm**
Coordinates: **74°37.798' N - 17°57.749' E**	Water depth: **130.6 m**
Observers: **RG Lucchi**, **A Sabbatini**	Date: **10-08-2013**

SURFACE SEDIMENT DESCRIPTION

Almost empty box corer
Coarse-medium sand
with abundant large shells
and pebbles/cobbles (IRD).

Cruise **CORIBAR**, *R/V Maria S. Merian*, 16 July-15 August 2013

Core **GeoB 176 30-1**	Sediment recovery: **8 cm**
Coordinates: **74°37.908' N - 17°16.886' E**	Water depth: **149.4 m**
Observers: **RG Lucchi**, **A Sabbatini**	Date: **10-08-2013**



SURFACE SEDIMENT DESCRIPTION

Fine sand with abundant
shells, IRD and living
organisms (detail below).

Cruise **CORIBAR**, *R/V Maria S. Merian*, 16 July-15 August 2013

Core **GeoB 176 31-1**
Sediment recovery: **20 cm**

Coordinates: **74°38.122' N - 16°57.774' E**
Water depth: **172.7 m**

Observers: **RG Lucchi**, **A Sabbatini**
Date: **10-08-2013**

SURFACE SEDIMENT DESCRIPTION

Fine, clean sand with worms, sea-stars and actiniarias at the surface (detail below). Large holes at the surface.

Colour: 2.5Y 4/3 olive brown

cm	PHOTO	Lithology	COLOUR	SEDIM. STRUCT.	LITHOLOGIC DESCRIPTION
10 20		sand	2.5 4/3 olive brown		0-20 cm medium-grained clean sand. Red worm at the top
30 40 50					

Cruise **CORIBAR**, *R/V Maria S. Merian*, 16 July-15 August 2013

Core **GeoB 176 32-1**

Sediment recovery: **49 cm**

Coordinates: **74°59.985’ N - 17°21.781’ E**

Water depth: **169.4 m**

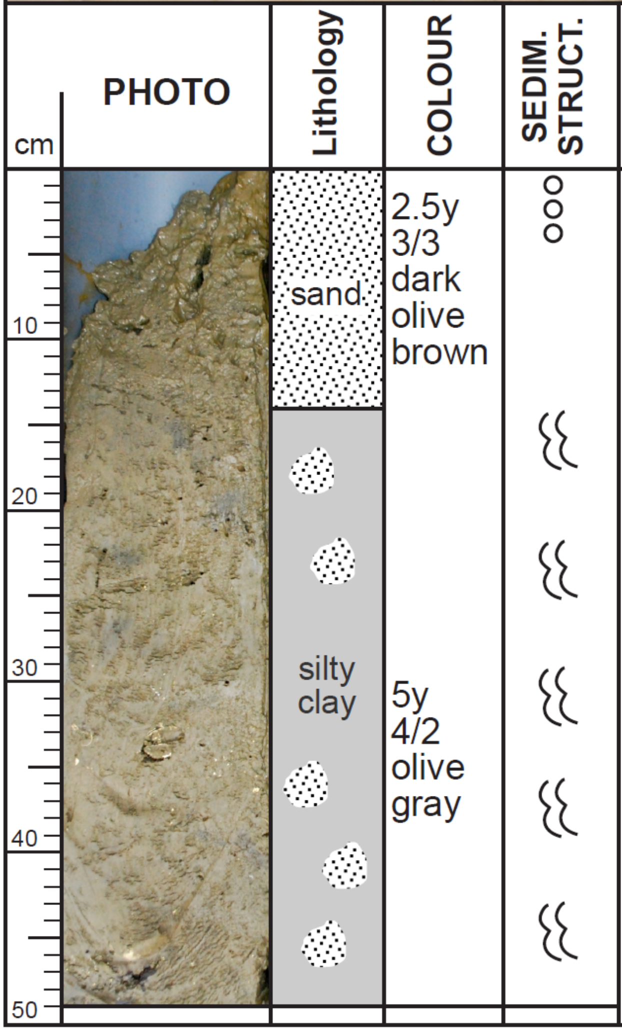
Observers: **RG Lucchi**, **A Sabbatini**

Date: **10-08-2013**

SURFACE SEDIMENT DESCRIPTION

Soft, soupy clayey sand with abundant worms and shells.

Colour: 2.5Y 3/3 dark olive brown



LITHOLOGIC DESCRIPTION

0-14 cm soft, soupy clayey sand

14-20 cm bioturbated silty clay

20-49 cm bioturbated silty clay with abundant broken shells.

The whole section contains silty patches.

○○○ soupy sediments

≀≀ bioturbation/mottling

Cruise **CORIBAR**, *R/V Maria S. Merian*, 16 July-15 August 2013

Core **GeoB 176 34-1**

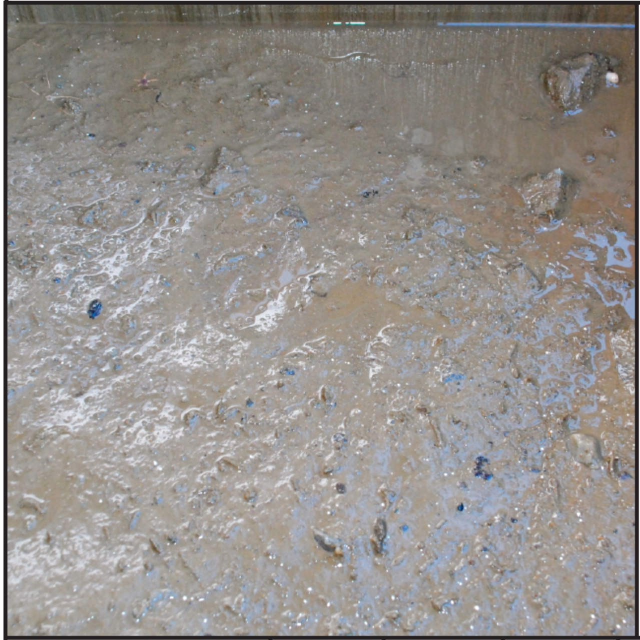
Sediment recovery: **47 cm**

Coordinates: **74°51.877’ N - 14°44.380’ E**

Water depth: **1494 m**

Observers: **RG Lucchi**, **A Sabbatini**

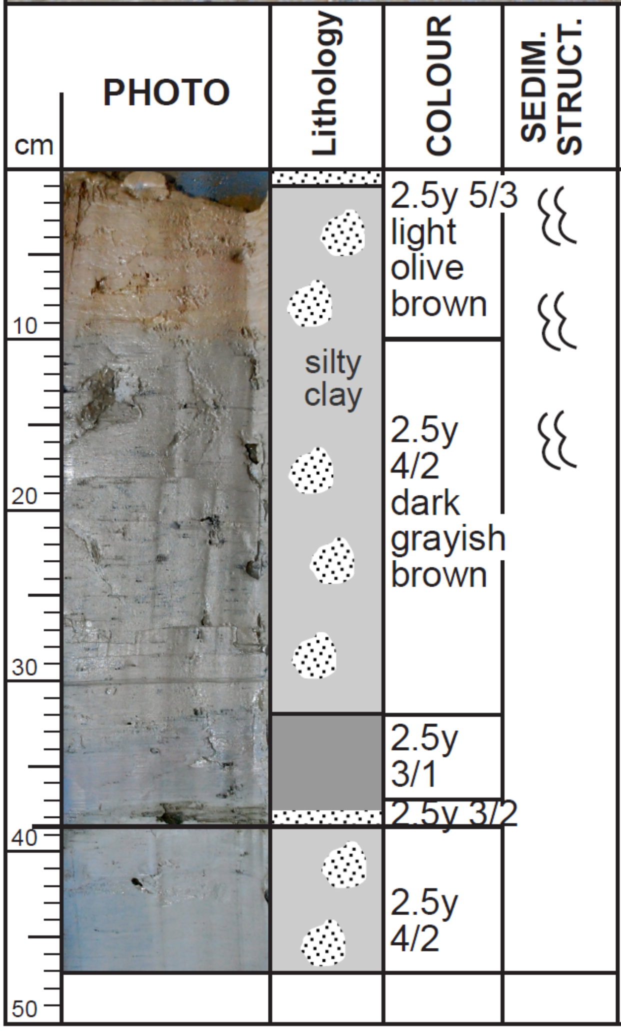
Date: **13-08-2013**



SURFACE SEDIMENT DESCRIPTION

Clean sand with abundant IRD and benthic foraminifera pyrgo. The scoured surface suggests presence of strong currents at the sea bottom.

Colour: 2.5Y 5/3 light olive brown



LITHOLOGIC DESCRIPTION

0-1 cm clayey sand

1-10 cm brown silty clay with bioturbation and silty patches

10-32 cm gray silty clay with silty patches

32-37 cm very dark gray structureless silty clay

37-38.5 cm green silty layer

38.5-47 cm very dark gray structureless silty clay

≀≀ bioturbation/mottling

From report No. 289 onwards this series is published under the new title:
Berichte aus dem MARUM und dem Fachbereich Geowissenschaften der Universität Bremen
A complete list of all publications of this series from no. 1 to 292 (1986 – 2012) was printed at last in issue no. 292.

No. 289 – Mohtadi, M. and cruise participants (2012). Report and preliminary results of RV SONNE Cruise SO 223T. TransGeoBiOc. Pusan – Suva, 09.09.2012 – 08.10.2012. 47 pages.

No. 290 – Hebbeln, D., Wienberg, C. and cruise participants (2012). Report and preliminary results of R/V Maria S. Merian cruise MSM20-4. WACOM – West-Atlantic Cold-water Corals Ecosystems: The West Side Story. Bridgetown – Freeport, 14 March – 7 April 2012. 120 pages.

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