IFM-GEOMAR REPORT

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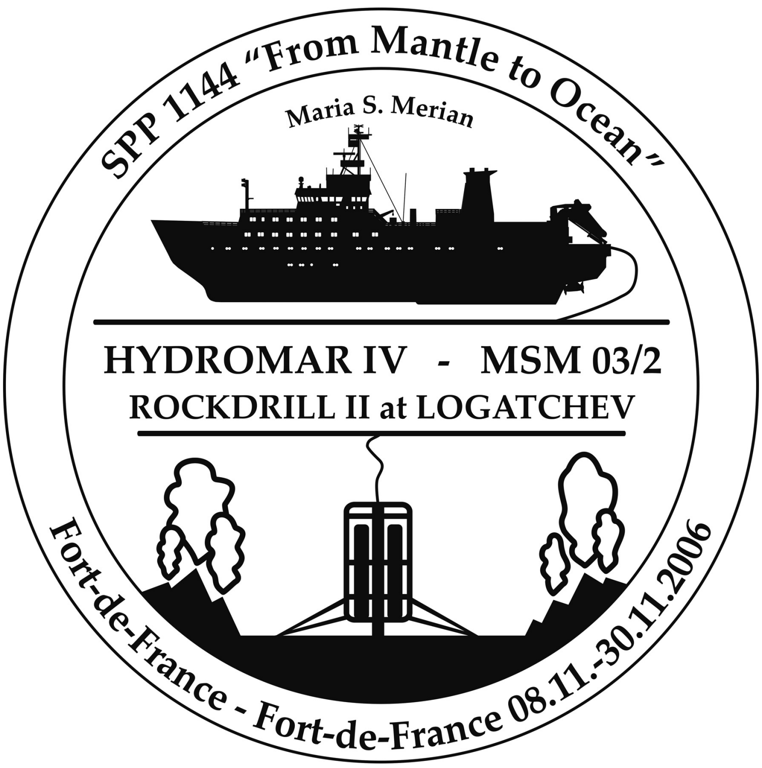
Leibniz-Institut für Meereswissenschaften
an der Universität Kiel

FS Maria S. Merian
Fahrtbericht / Cruise Report MSM 03-2

HYDROMAR IV
The 3rd dimension of the Logatchev hydrothermal field

Fort-de-France - Fort-de-France
08.11. - 30.11.2006



Berichte aus dem Leibniz-Institut
für Meereswissenschaften an der
Christian-Albrechts-Universität zu Kiel

Nr. 34
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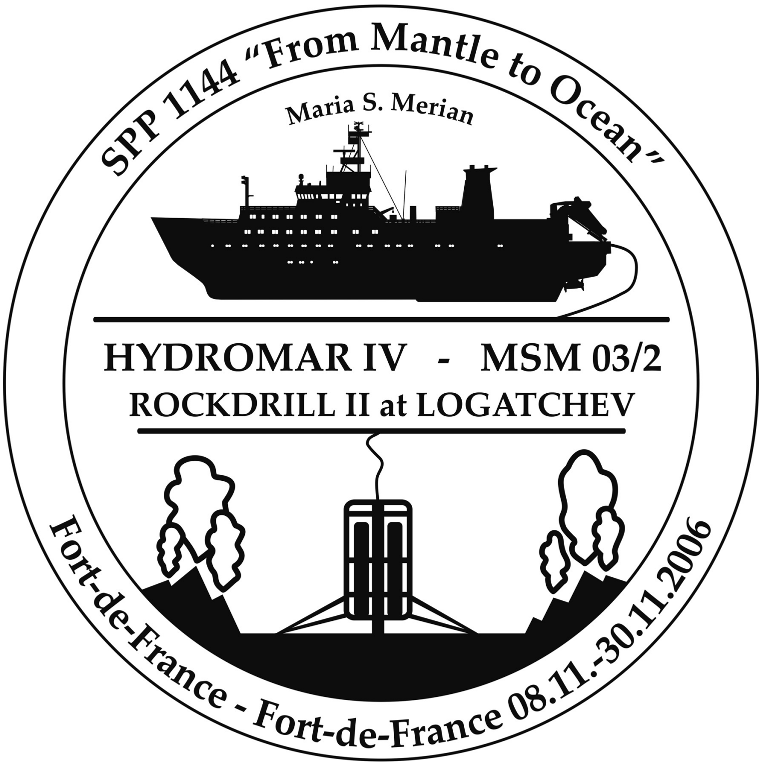

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Sven Petersen

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Leibniz-Institut für Meereswissenschaften / Leibniz Institute of Marine Sciences
IFM-GEOMAR
Dienstgebäude Westufer / West Shore Building
Düsternbrooker Weg 20
D-24105 Kiel
Germany

Leibniz-Institut für Meereswissenschaften / Leibniz Institute of Marine Sciences
IFM-GEOMAR
Dienstgebäude Ostufer / East Shore Building
Wischhofstr. 1-3
D-24148 Kiel
Germany

Tel.: ++49 431 600-0
Fax: ++49 431 600-2805
www.ifm-geomar.de

Inhalt / *Contents*

Anschriften / *Addresses*

Leitstelle Meteor / Maria S. Merian	
Institut für Meereskunde	Telefon: +49 40 428 38 3974
Universität Hamburg	Telefax: +49 40 428 38 4644
Bundesstraße 53	leitstelle@ifm.uni-hamburg.de
20146 Hamburg	

Reederei Briese Schiffahrts GmbH & Co. KG	Telefon: +49 491 92520
Abt. Forschungsschiffahrt	Telefax +49 491 9252025
Hafenstrasse 12	research@briese.de
26789 Leer	

Senatskommission für Ozeanographie	
der Deutschen Forschungsgemeinschaft	Telefon: +49 471 4831 1101
Vorsitzende / *Chairperson:*	Telefax: +49 471 4831 1102
Prof. Dr. Karin Lochte	karin.lochte@awi.de
Alfred Wegener Institut	
Am Handelshafen 12	
27570 Bremerhaven	

Forschungsschiff / *Research Vessel* MARIA S. MERIAN

Rufzeichen:	DBBT
Telefon-Nr.:	
InmarSat Fleet 77/33:	+870 764 354-964 / -965
	+870 764 354-967 / -968
Iridium:	+88 1631 814 467
GSM, Mobilfunk	+49 173 628 4815
Telefax-Nr.:	
InmarSat Fleet 77/73:	+870 764 354-966
	+870 764 354-969
GSM, Mobilfunk	+49 173 642 5052
E-Mail: (Schiffsleitung)	master@merian.io-warnemuende.de

Beteiligte Institutionen / *Participating Institutions*

Leibniz-Institut für Meereswissenschaften (IFM-GEOMAR)

East Shore Campus	West Shore Campus
Wischhofstr. 1-3	Düsternbrooker Weg 20
24148 Kiel, Germany	24105 Kiel, Germany
www.ifm-geomar.de	

BGS
British Geological Survey, Marine Operations Group
2A Niven's Knowe Road
Loanhead, EH20 9AU, UK

COMRA
China Ocean Mineral Resources R&D Association
Fuxingmenwai Ave 1
Beijing 100860, PR China

FUB
Freie Universität Berlin, Fachbereich Geowissenschaften
Malteserstr. 74-100, Haus B
D-12249 Berlin

IUB
International University Bremen, School of Engineering and Science
Campusring 1, 28759 Bremen

MPI Bremen
Max Planck Institute for Marine Microbiology
Celsiusstr. 1
D-28359 Bremen

MPI Mainz
Max-Planck-Institut for Chemistry
Becherweg 27
D-55020 Mainz

SIOSOA
Second Institute of Oceanography, State Oceanic Administration
Hangzhou 310012, PR China

Uni Basel
Mineralogisch-Petrographisches Institut, Universität Basel
Bernoullistrasse 30
CH-4056 Basel

Uni Münster
Geologisch-Paläontologisches Institut, Universität Münster
Correnssstraße 24
D-48149 Münster

VNIIO
VNIIOkeangeologiya
1 Angliski Pr-t
St. Petersburg
Russia, 190121

Teilnehmer / *Participants*

1.	Petersen, Sven, Dr.	Chief Scientist	IFM-GEOMAR
2.	Augustin, Nico	Alteration, Bathymetry	IFM-GEOMAR
3.	Baxter, David	Rockdrill Crew	BGS
4.	Campbell, Neil	Rockdrill crew	BGS
5.	Cherkashov, Georgy, Dr.	Hydrothermal Precipitates	VNIIO
6.	Derrick, John	Rockdrill Crew	BGS
7.	Franz, Leander, PD, Dr.	Petrology	Uni Basel
8.	Han, Xiqiu Dr.	Hydrothermal Precipitates	SIOSOA
9.	Fischer, Sebastian	Petrology	MPI Mainz
10.	Klein, Frieder	Petrology	Uni Bremen
11.	Ockert, Charlotte	Sulfur-Geochemistry	Uni Münster
12.	Perner, Mirjam	Microbiology	IFM-GEOMAR
13.	Peters, Mark	Sulfur-Geochemistry	Uni Münster
14.	Rahders, Erio, Dr.	Hydrogen Storage in Minerals	FUB
15.	Rudzitis, Edgars	Alteration	IFM-GEOMAR
16.	Stepanova, Tamara, Dr.	Hydrothermal Precipitates	VNIIO
17.	Storm, Sonja	Petrology	IFM-GEOMAR
18.	Strauss, Harald, Prof. Dr.	Sulfur-Geochemistry	Uni Münster
19.	Skinner, Alister	Rockdrill crew	BGS
20.	Smith, Dave	Rockdrill crew	BGS
21.	Wilson, Michael	Rockdrill crew	BGS
22.	Wallis, Dave	Rockdrill crew	BGS
23.	Zhou, Ning, Dr.	Hydrothermal Precipitates	COMRA

2.1 Executive Summary

(S. Petersen)

During cruise MSM03/2 of the German R/V Maria S. Merian in November 2006 a new lander-type remotely operated seafloor drill (Rockdrill 2) of the British Geological Survey in Edinburgh (UK) was used to investigate the shallow subsurface in the Logatchev hydrothermal field at 14°45'N on the Mid-Atlantic Ridge. The ultramafic-hosted Logatchev field is situated in 3000 m water depth and has some characteristics that are unique to this hydrothermal system. The chemistry of the high-temperature vents reflects the influence of ultramafic as well as mafic host rocks at depth. Venting at Logatchev takes place within and at the rim of small depressions, so-called smoking craters (Bogdanov et al., 1997) that are unique to the Logatchev hydrothermal field. The formation of these depressions is still not understood. Another characteristic feature of the Logatchev site when compared to most other seafloor hydrothermal systems is a distinct Au-Cu enrichment of the massive sulfides at least partially related to secondary processes effecting primary Cu-rich sulfides. Sites of hydrothermal upflow are suggested by geoelectrical measurements carried out by the Russian R/V Prof. Logatchev in 2004. The observed vertical and horizontal variations of the specific resistivity, caused by higher conductivity in the subsurface, may be interpreted as areas of subseafloor mineralization (unpublished data from G. Cherkashov, 2004, VNII Okeangeologia).

Fig. 2.1: BGS Rockdrill 2 during recovery.

Our main goals were therefore to investigate the nature of the immediate subsurface of the Logatchev field in order to document the nature of the underlying rocks, the possible depth zonations of the mineralization, and alteration as well as their age relationships. Other goals include pore water and sediment sampling in order to better understand the sulfur cycle, and the variability of the subsurface microbiology and their influence on the formation and alteration of hydrothermal mineral precipitates.

The BGS Rockdrill 2 is lowered to the seabed on a power and lift umbilical and takes rock samples using a rotary diamond bit coring system. The drill is designed for drilling in water depths up to 3100 m and, in its current setup, has the capability to core down to 15 m using multiple core barrels and rods. We tested the newly built instrument in water depths around 1700 m at the eastern valley flank near the Logatchev site and cored some basaltic material. The instrument was than taken to the next step and successfully cored on 9 sites during this cruise. Of these, 5 deployments were achieved in water depths around 3000 m. Within the Logatchev field itself several active sites were targeted including the “Quest”, “Irina 1” and “B” smoking crater. Other targets drilled include areas of abundant Fe-oxide staining reflecting past hydrothermal activity and areas of diffuse hydrothermal venting. The deepest hole was drilled to the west of the smoking crater site “B” and reached a depth of 10.5 m. With this and with a total cored length of 48 m, the Rockdrill 2 system proved its ability to routinely operate down to 3050 m of water depth in active hydrothermal systems. Our operations indicate that coring the upper parts of hydrothermal systems, which are often not sampled during (I)ODP operations, is possible using such a system.

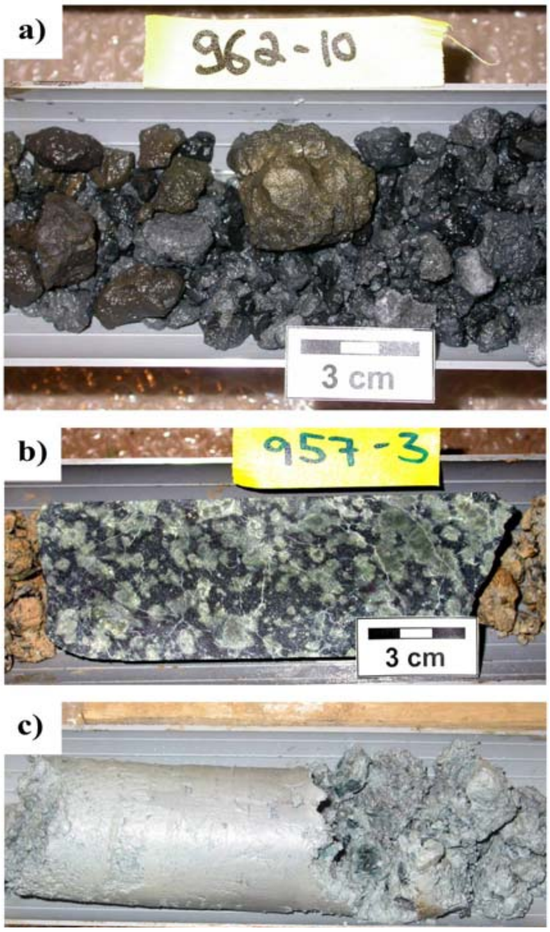


Fig. 2.2: Selection of drillcore material recovered from the subseafloor of the Logatchev hydrothermal field. a) Massive sulfide cobbles associated with altered wall rock fragments at 10.3 meters below the seafloor near site "B". b) Massive serpentinite drilled to the north of "Quest". c) Clay-altered serpentinized material recovered near site "B" (Hole 954RD).

The recovered core is dominated by altered mafic and ultramafic rocks intermixed with minor massive sulfide fragments and some sulfide sand (Fig. 2.2a). Serpentinites and their altered equivalents are also common (Fig. 2.2b,c). Massive sulfides are, overall, rare in the drill core suggesting that most parts of the Logatchev hydrothermal field are underlain be altered talus material with the massive sulfides only forming a thin veneer on top of a clay-altered substrate. The heterogeneity of the host rock material encountered and their rounded nature as well as the abundance of gravel-sized material within the core indicates that most sections cored talus material, an important new information for the evolution of the Logatchev hydrothermal field.

Gravity coring provided additional information about the shallow subseafloor and especially the past hydrothermal activity along and across the NW-SE axis of the hydrothermally active areas. The gravity cores confirmed the gravel-like nature of the subseafloor over wide areas but also recovered intersections of sulfide/oxide mineralization indicating past hydrothermal activity. Rock samples were taken for geochemical and mineralogical studies as well as for investigations of the hydrogen storage capacity of sulfides, the geochemical sulfur cycle and the S-isotopic composition. Microbiological investigations are aimed at identifying microorganisms characteristic for the specific habitats (different rock types) in the subsurface.

During the cruise we also collected bathymetric data around the Logatchev site using the Kongsberg EM120 multibeam system with a reduced beam angle (22°) in order to obtain a higher resolution (~20m) than previous ship-based maps. This detailed bathymetry shows a clear link of the location of the hydrothermal field to crosscutting fault structures. Dredging of a number of locations along the rift valley floor and at a circular depression close to the eastern wall recovered least altered pillow basalt or fragments of basalt flows. Other dredges along the eastern rift valley floor contained mafic intrusive material and ultramafic rocks in variable amounts. Mafic intrusive material often dominates over ultramafic material in the vicinity of the Logatchev field indicating the importance of magmatic processes in the area. Notable is a dredge targeted at the horst structure adjacent to the Logatchev field which recovered coarse-grained gabbronoritic cumulate. Scientists from Germany representing the fields of economic geology, petrology, geochemistry and microbiology, technicians and engineers from the UK as well as scientists from Russia, China and Switzerland participated in the cruise.

2.2 Research Program

(S. Petersen)

The main objective of this cruise was the investigation of the shallow subsurface in the Logatchev hydrothermal field on the Mid-Atlantic Ridge at 15°N by drilling up to 15 m deep cores. The cruise took place within the DFG-SPP 1144 („From Mantle to Ocean: Energy-, Material- and Life-cycles at Spreading Axes“) and will add to the surface sampling realized so far as well as deep sampling carried out by ODP Leg 209. The ultramafic-hosted Logatchev hydrothermal field situated in 3000 m water depth is characterized by large enrichments of Cu, Au, Co, and other valuable elements at the seafloor and supposedly in the shallow subsurface. Hydrothermal fluids are enriched in the gases CH_4 and H_2 which might have a profound influence on the microbiology associated with this hydrothermal system. The surfaces of rocks and minerals in the subsurface of the hydrothermal system represent specific ecological niches for micro-organisms which will be found associated with these interfaces. Apart from the investigation of the depth zonations of the mineralization, its associated alteration as well as its age relationships, the establishment of the variability of the subsurface biosphere and its influence on mineral precipitation are another major scientific aspect of the project.

Detailed sampling of the up to 15 m long drill cores from the Logatchev hydrothermal field using the new Rockdrill 2 device allowed, for the first time, the sampling of the subseafloor of an ultramafic-hosted system. Subsampling of hydrothermal precipitates, fresh and altered rocks as well as micro-organisms attached to the surface of the samples was possible. The investigation of these subsamples aims at studying:

- the vertical extent of mineralization, possible zonation patterns under the Logatchev hydrothermal field site as a whole, and the differences in the subseafloor between different sites (pathways, mixing zones, is the deposit only a thin veneer on top of altered volcanic/plutonic rocks etc.),
- the nature of secondary processes like oxidation on the deposit and how does it affect the release of metals into the environment,
- the mineralogy and isotope geochemistry of secondary phases formed during the hydrothermal alteration of the ultramafic rocks and their vertical distribution,
- the elemental fluxes during oceanic crust-seawater reactions to discuss the role of hydrothermal serpentinization in terms of global seawater-lithosphere chemical exchange,
- what are the time frames of hydrothermal activity at Logatchev? Is there a cyclic nature to hydrothermal activity and are those cycles related to geological events?
- vertical variations in sulfur-based redox reactions resulting in the precipitation of metal sulfides and sulfate,
- the composition of microbial communities in different ecological niches of the hydrothermal environment, in particular those specifically attached to mineral surfaces,
- the melting history of the Logatchev region by completing the sample suite of deep samples from ODP Leg 209 and surface samples with shallow drill samples.

The investigations will contribute information about the exchange of mass and heat between the lithosphere and the hydrosphere in the area of 15°N which is one of the main goals of SPP 1144 („From Mantle to Ocean: Energy, Mass, and Life Cycles at Spreading Axes“). This cruise will take part within the frame of SPP 1144. Subseafloor investigations will also help to interpret the fluid chemistry as well as to understand the distinctive faunal distribution within the Logatchev hydrothermal field.

2.3 Daily Narrative

(S. Petersen)

<u>October 23-26, 2006 (Monday-Thursday)</u>
Two scientists from IFM-GEOMAR (Kuhn, Petersen) and one member of the drill crew from the British Geological Survey (Campbell) met the RV *Maria S Merian* in Lisbon to oversee the arrival of the Rockdrill components, the HATLAPA traction and storage winches plus the new cable, the sheave as well as the lab container. The installation of the base frames for the Rockdrill launch and recovery system and the winches was performed here in Lisbon. The winches were set in place, but could not be tested since the power connection did not fit. On October 27, RV *Maria S Merian* set sail for Fort de France on Martinique in order to meet the scientific party.

<u>November 06, 2006 (Monday)</u>
RV *Maria S Merian* reached the port of Fort de France at 08:30 LT. The team of the British Geological Survey as well as three scientists went on board and started the installation of the Rockdrill as well as setting up the labs. Engineers from the winch manufacturer changed the power supply connectors and installed another sheave to overcome the problem of the fleet angle between the block and the traction winch. Additionally a small device was installed to reduce the grease coating on the cable. Scientists from Germany, Russia and China joined the vessel later in the evening.

<u>November 07, 2006 (Tuesday)</u>
The installation proceeded during the day, often hindered by heavy rainfall. The rest of the scientific party joined the vessel in the evening.

<u>November 08, 2006 (Wednesday)</u>
A first harbour trial was perfomed to test the equipment and to learn the handling procedure of the instrument. During this deployment the launch and recovery system of the Rockdrill 2 was damaged beyond repair and needed to be deinstalled. Due to this failure the departure of the vessel needed to be postponed for one day.

<u>November 09, 2006 (Thursday)</u>
With the pilot on board, R/V Maria S Merian left Fort de France at 09:05 LT and set sail to the east coast of Martinique in order to perform a handling and function test of the new Rockdrill 2. We sailed around the north shore of Martinique and Rockdrill 2 was deployed at 14°50’N / 60°55’W in a water depth of 60m (Station 920RD). Two rods were successfully connected at the seafloor and drilled into the seabed. The recovered core consisted of bluish-grey mud with minor old coral.

<u>November 10, 2006 (Friday)</u>
In the morning of the 10th of November a second seatrial was performed in a water depth of 325m at 14°54’N / 60°47’W (station 921RD). During the first run the hydraulic alarm went on and the instrument had to be brought back to the ship, where additional (vegetable) oil was filled in to overcome the pressure and temperature compaction of the oil which set off the alarm. During the second try (station 922RD) two rods were drilled into the seafloor without any problems proving that the instrument works at this depth. During the last change of barrels and rods the connection to the the instrument was lost and the Rockdrill needed to be lifted out of the ground using the winch. Parts of the lowermost rod were hanging below the drill rig making recovery difficult. However, the deck’s crew was able to retrieve the instrument. After a first check it was decided to continue the cruise. Minor repairs on the drill

rig are necessary and will be perfomed during the transit to the Logatchev field. Estimated date of arrival is Monday November 13.

<u>November 11-12, 2006 (Saturday-Sunday)</u>
The transit is used for a couple of scientific talks including those representing the scientific work of our Russian and Swiss colleagues. The BGS crew is adjusting the Rockdrill as well as the software in order to overcome the problem encountered during the second sea test.

<u>November 13, 2006 (Monday)</u>
The Monday is used to unspool 3100m of the cable in order to take the spin out of the new cable. A bottom weigth of ~ 4 t is assembled by the decks crew. Testing of the winch and the greased cable was performed every 500m to check if slipping occurs during use, but no slipping was encountered and the winch performed well. After this we continued our transit to the Logatchev area.

<u>November 14, 2006 (Tuesday)</u>
During the night we acquired a sound velocity profile (station 923SV) just west of the Logatchev field. The data is needed for the multibeam stations that will be performed during this cruise and also for the use of the Posidonia system (transponder) during Rockdrill stations. After this station we startet a series of three east-west multibeam profiles (station 924MB) running at 8 knots and using a beam angle of 22° resulting in a coverage of 1200 m in a water depth of 3000 m. This narrow beam angle was used to get a smaller footprint of the data when compared with the data obtained by Meteor in 2004. In the morning the Rockdrill was lowered over the eastern rift valley wall in a waterdepth of 1780m in order to drill the rift flanks. The first station (925RD) had to be aborted due to a hydraulic problem, while the second station (926RD) reached the seafloor in a water depth of 1763m. The drill rig had another hydraulic alarm, but was able to drill one core barrel (penetration 0.96m) into the ground before a sensor failure and loss of communication cancelled this station. The core consisted largely of ~ 20 cm of basaltic pebbles. During the remainder of the day a multicorer station (927MUC) was targeted into a small basin southeast of Logatchev and obtained background sediments from this area. The reminder of the night was used to dredge the young volcano west of the Logatchev hydrothermal field (station 928DR), which has been observed but not sampled in 2004, and to dredge a first sample from the rift valley floor (station 929DR). Both stations recovered basalt with some glass. The second dredge also recovered a thick load of slightly Fe-stained sediment.

<u>November 15, 2006 (Wednesday)</u>
In the morning one line was added to the bathymetric map (station 930MB), before Rockdrill 2 was stationed above the eastern rift valley high (1762m water depth). Rockdrill touched down nicely and drilled 2 barrels in basaltic pebbles in a sediment matrix before terminating due to an instrument failure (station 931RD). A second station (932RD) performed the same day was terminated due to a loss of the fibre optical signal. After recovery of the instrument it became apparent that this failure means a longer downtime due to the need to extensively check the cable, connectors and the final repair (re-termination). A multicorer station (933MUC) in a small basin to the northeast of Logatchev was followed by bathymetric mapping to the south of the original grid (934MB).

<u>November 16, 2006 (Thursday)</u>
We continued with a multicorer station of a proposed diffuse site within the Logatchev area (935MUC), however, hydrothermal influence in the recovered sediments is not evident. Three dredges were employed in the rift valley and recovered basaltic material (stations 936-

938DR). Station 937DR (14°48.0'N / 45°02.0'W) is characterized by glassy lava with a thin Fe-oxyhydroxide coating. The early morning hours were used to add to the detailed bathymetric map. Today the windforce was constantly increasing and reached Beaufourt 7 and sometimes even 8.

November 17, 2006 (Friday)

The Rockdrill 2 went down in the morning (940RD) but again a communication failure prohibited reaching the seafloor. Measuring the optical properties of the cable at various depths documented a pressure dependence of the signal intensity. This indicates a break in the cable, close to the mechanical or electronic termination, that still allows some light to pass through at surface or at low pressures but shutting off communication during descend. This behaviour explains the majority of the problems we encountered so far during Rockdrill stations. The cable needs to be reterminated. Three dredges were lowered afterwards. Dredging of the uplifted block situated immediately west of Logatchev recovered gabbronoritic cumulate (station 941DR). Mapping was continued during the night.

November 18, 2006 (Saturday)

Three gravity corer stations (945GC, 946GC, 947GC) were perfomed along a transect between Quest in the north and site "B" in order to obtain samples from the upper sediments for microbial investigations. All stations recovered hydrothermally influenced sediment but failed to show any sulfidic material. This indicates that sulfide mineralization is not as widespread as originally thought. We should keep in mind however, that Russian TV-grabs contained massive sulfides in almost every station performed in this area. In the evening the Rockdrill 2 was deployed again (948RD), however, the communication was lost again and the instrument had to be braught up again. The dredge was used to sample the eastern rift valley wall southeast of Logatchev (949DR).

November 19, 2006 (Sunday)

The morning was used for a fire and general alarm safety drill. The Rockdrill was deployed once more (station 950RD) but the same error occurred again. After this it was decided to use a completely different design for the termination. Dredging (951RD) and a multibeam survey (952MB) completed this day.

November 20, 2006 (Monday)

The morning was used for a gravity core at site "B" (953GC), where we recovered massive sulfide gravel intermixed with hydrothermal sediment and altered rock fragments. In the early afternoon Rockdrill 2 was deployed with the redesigned termination and reached the seafloor safely (954RD) at the rim of the smoking crater at site "B". Drilling continued during the night and it seems that the new termination holds.

November 21, 2006 (Tuesday)

In the morning two "cores" were brought up by the Rockdrill 2 mainly consisting of altered serpentinite mud and gravel providing evidence for a soft underground at Logatchev and a substrate that consists of transported material. While similar material has been brought up in TV-grab samples in 2004, it was unexpected at such depth (the Rockdrill reached a depth of 6 m). After taking out the core barrels, the rig was deployed a second time. We aimed at the diffuse area "F" just south of Irina 2, however, we were unable to land the rig due to the steep morphology encountered. Seven attempts to set down the instrument failed and while moving slightly to the NW we finally set foot at the northwestern base of Irina 2 (955RD). We lost Posidonia subpositioning during descent and therefore the exact drill location is not known. Rockdrill 2 stayed on position and drilled for 21 hours.

November 22, 2006 (Wednesday)
At lunchtime the Rockdrill was back on deck and the core barrels were retrieved. The time was used to add profil lines to the east of our existing map. In the afternoon Rockdrill2 was ready again and was deployed at the smoking crater "Quest" (station 957RD), where we landed safely and started drilling without any problems. It seems that the communication failures have been resolved and that the cause was clearly in the wet end termination of the cable and not in the Rockdrill 2 system.

November 23, 2006 (Thursday)
Station 957RD was still on the move in the morning and during lunchtime on this lovely Thursday. The lower part of the hole got more and more difficult to drill and finally the hole was aborted in the late afternoon reaching a depth of 7 m below seafloor in highly variable lithologies including peridotite and gabbro underlying a thick layer of pelagic sediment. The Rockdrill 2 station was followed by a gravity corer aimed at sampling the interior of the "Quest" smoker which, however, only returned a few pieces of Mn-oxide rich crusts (958GC).

November 24, 2006 (Friday)
At 03:30 in the morning the Rockdrill went down again (959RD), this time to investigate the subseafloor of a site of inactive sulfide formation to the east of the main area of hydrothermal activity. This site coincides with a geoelctrical anomaly discovered by the Russians. Again the steep morphology made it impossible to drill at the site envisaged. We had to move 40 m to the north into an area of thick sediment cover. The Rockdrill was drilling for 15 hours and recovered 6 barrels with hydrothermal sediment, fragments of altered rocks, and Fe-Mn-crusts. No sulfide was encountered. The evening was used for a gravity corer at Irina 1 (960GC) and a short multibeam profile (cross) over Logatchev with the narrowest beam possible (5° on either side), however, the data is not usable because the ship's movement is too fast (2.5 – 3 knots) to allow for a regular gridding of the data.

November 25, 2006 (Saturday)
Shortly after midnight the Rockdrill is going back down (962RD), this time being deployed at site "B". For Posidonia it seems we came down slightly to the west of the crater. The Rockdrill stayed down the entire day.

November 26, 2006 (Sunday)
Drilling is stopped at 08:30 in the morning after having used all 11 barrels on the caroussel. The final depth reached was 10.3 m below the seafloor, the deepest hole we drilled during this cruise. The last two barrels recovered altered host rocks together with pebbles of Cu-rich sulfides. During the remainder of the day we deployed the gravity corer three times (963GC-965GC) in order to sample the upper parts of known hydrothermal deposits in the vicinity of the active areas. The final station of the cruise was devoted to the sampling of a small crater-like structure to the south of Logatchev. The dredge sample consisted of sediment with few pebbles of basaltic material possibly indicating that this structure is also volcanic in origin albite much older than the pillow volcano near the Logatchev field itself. At midnight we set sail for Martinique.

November 27-30, 2006 (Monday-Thursday)
The ship is in transit to Fort-de-France. The time is used to describe the reminder of the samples and to pack the equipment. The cruise report is prepared and the table tennis tournament is taken over the evening hours. A final meeting on the 29th summarizes the

results of the cruise and is used by the different working groups to present their initial results. The Maria S. Merian reached port in the morning of the 30th of November, welcomed by heavy rainfall, and docked at 09:00LT. Few scientists left the ship and flew out the same day, however, most of the scientists stayed until the next day or even longer. This was the end of cruise MSM03/2, which was a very smooth cruise despite the problems with the cable termination at the beginning and despite the fact that the lithologies were different than expected.

2.4 Preliminary Results

2.4.1 Multibeam bathymetric mapping

(N. Augustin, M. Maggiulli)

Detailed multibeam mapping was carried out with a Simrad EM120 by Kongsberg. The main objective was to increase the knowledge of the bathymetry around the Logatchev hydrothermal field as well as the search for structures at the eastern MAR segment valley wall in order to document controlling factors of the hydrothermal activity in the Logatchev area. Eight multibeam mapping stations amounting to 32 hours were carried out with a bathymetric dataset covering ~380 km^2 and consisting of ~2.6 million data points.

The echo sounder system consists of 2 transmitter/receiver units coupled with a Motion Reference Unit installed on RV Maria S. Merian. Four GPS receivers were used to get positional data and were switched automatically internally in the system. System settings of 12 kHz, 2 x 11° opening angle and 191 beams per ping allowed a swath width of about 1200 m at 3000 m water depth corresponding to a resolution of about 20 m. Data acquisition was done with the software SIS® by Kongsberg. Data editing and data post processing was performed using the software Neptune®, also provided by Kongsberg. The final gridding and bathymetric map production was realized by using the software Surfer by Golden Software. The final grid files were produced with the with the Kriging gridding method (Cressie, 1991; Isaaks and Srivastava, 1989) and additionally filtered with a Low-Pass 3 filter with a 3x3 matrix in up to 3 passes depending on the grid file.

The overview map of the MAR rift valley and parts of the eastern MAR segment (Fig. 2.3., 2.4.) are similar to the map processed from the extensive Hydrosweep® mapping performed during the Meteor cruise M60/3 (Kuhn et al., 2004). However, the higher resolution of our data allows close-up views and shows at least 5 volcanic structures in the area of the Logatchev fields as well as abundant tectonic structures that were as clearly visible in the older data set. The structure of a large pillow volcano (“Donut Volcano”; Fig. 2.5.) west of Logatchev-1 and another pillow volcano south of Logatchev-3 is clearly recognizable. OFOS observations perfomed during M60/3 and dredging during our cruise confirmed the presence of basaltic material at “Donut Volcano”. These volcanoes could act as local heat sources for the hydrothermal systems, if hot material is still present in the subseafloor. Other volcanoes are situated 10 km NE of Logatchev-1 and in the rift axis itself - close to the southern border of the mapped area.

With the final grids we are able to produce different views to the bathymetry of the investigated area. A shaded three dimensional view to the bathymetry data shows possible faults lines (Fig. 2.6.). Many of them agree with the structural interpretation of Kuhn et al. (2004). It is obvious that most hydrothermal fields in this area sit directly on or very close to such “faults”.

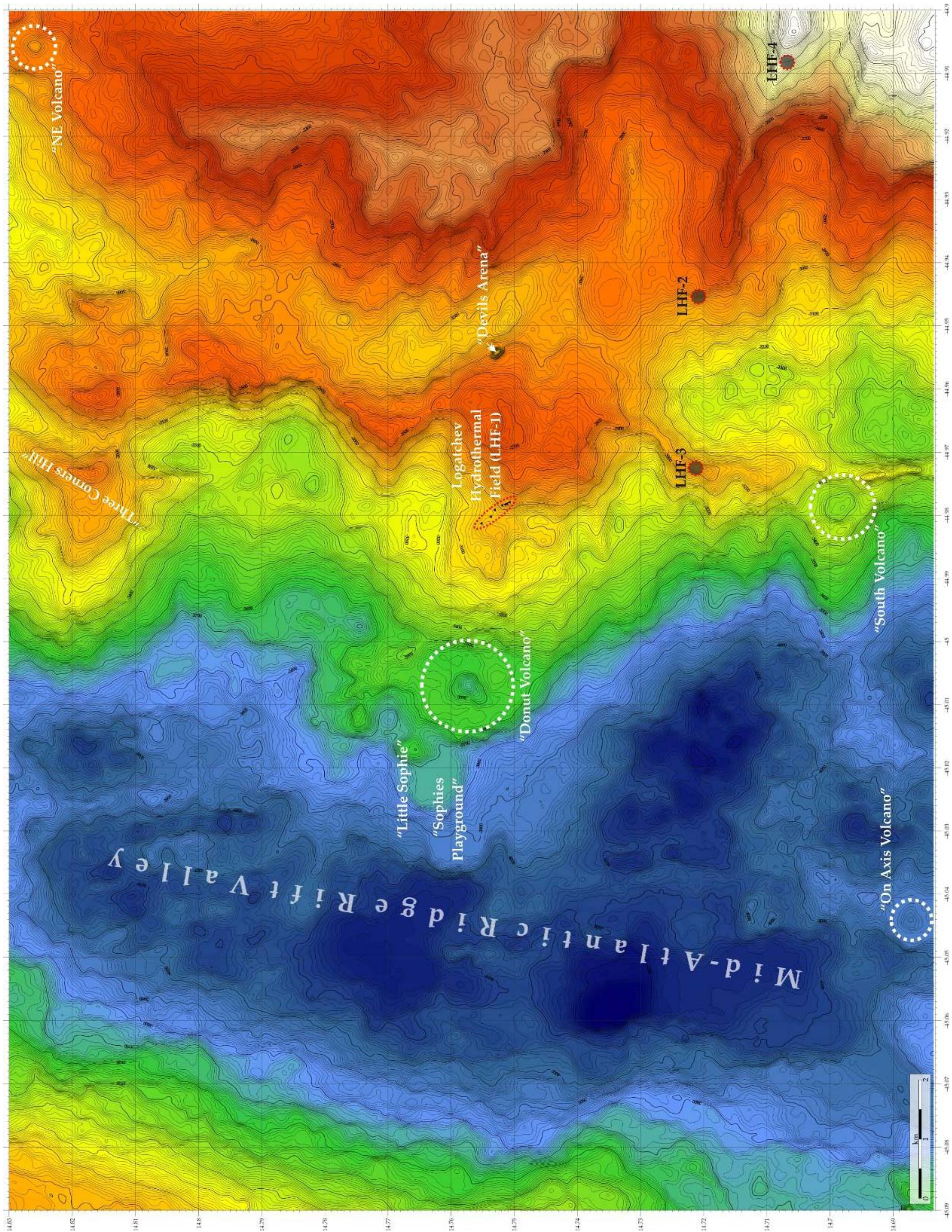


Fig. 2.3.: The map is based on bathymetric data collected by multibeam echo sounder during cruise MSM 03/2. The locations of the Logatchev-1 to -4 hydrothermal fields are marked. Notable is the large volcano west of LHF-1 and another one south of LHF-3 which could act as possible heat sources for the hydrothermal systems in the area. The dots at LHF-1 indicate the position of individual vent sites.

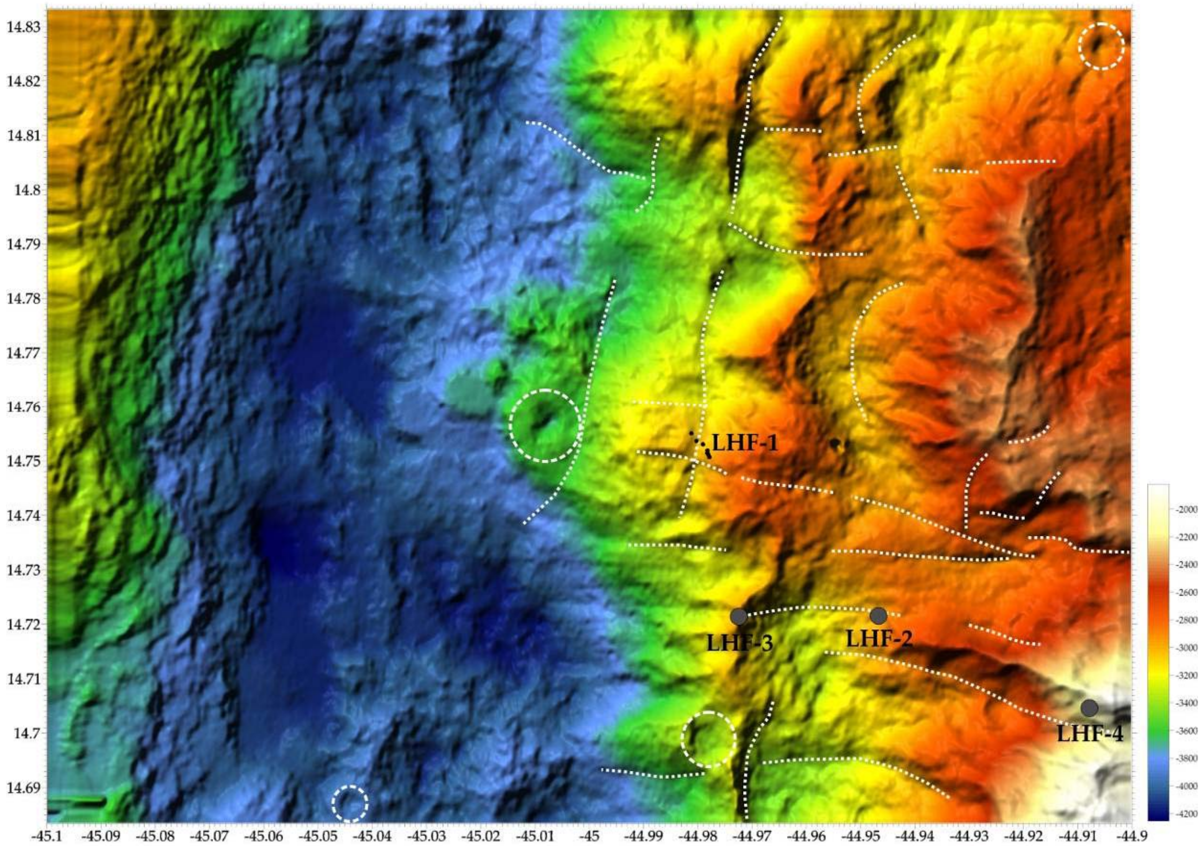


Fig. 2.4.: Shaded 3D view of the mapped area. Volcanoes and proposed faults are marked with dashed lines. The location of the Logatchev fields -1 to -4 are marked (LHF). Note the cross-cutting faults at Logatchev-1 as well as the fault related occurrence of the Logatchev-2 to -4.

One mapping station during MSM 03/2 (Station 956MB) was carried out to get a more detailed view of the main Logatchev field. Therefore the opening angle of the beams was tightened from 11° to 5° each to increase the mapping resolution. With the combination of the two bathymetric datasets (2x11° + 2x5°) we were able to produce a high resolution grid of the immediate Logatchev area (Fig. 2.6.) with a resolution of about 15 m.

Additional to the mapping of the Logatchev area we also mapped parts of the seafloor west of the working area during our transit time from and to port. The opening angle of the seabeam was 2x60° to cover a wider area (about 9 km at 3000 m water depth). The resulting map shows the NS striking ridges of the older parts of the MAR (Fig. 2.7.). Upcoming cruises to Logatchev in 2007 and 2008 should acquire additional, parallel dataset in order to increase the mapped area close to the MAR, since this does not interfer with other working time. The next important step for the SPP 1144 from a bathymetric point of view will be a close up bathymetry of the Logatchev-1 field in ultrahigh resolution using AUV/ROV technique flying just off the bottom in order to identify small scale tectonic structures and its relation to hydrothermal activity.

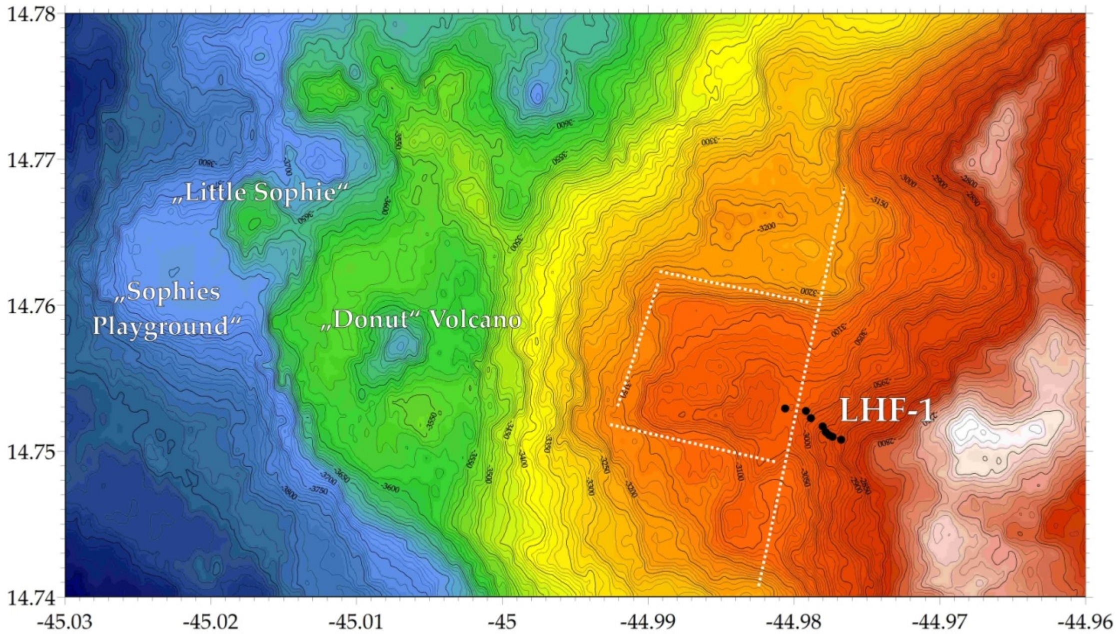


Fig. 2.5.: Detailed bathymetric map of the Logatchev-1 area (LHF-1) with the crater structure of "Donut Volcano". The dots at LHF-1 represent the known vent sites within the Logatchev-1 hydrothermal field (see also Fig. 2.7.). Note the rectangular shape of the structure just west of the Logatchev field indicating local fault control on hydrothermal activity.

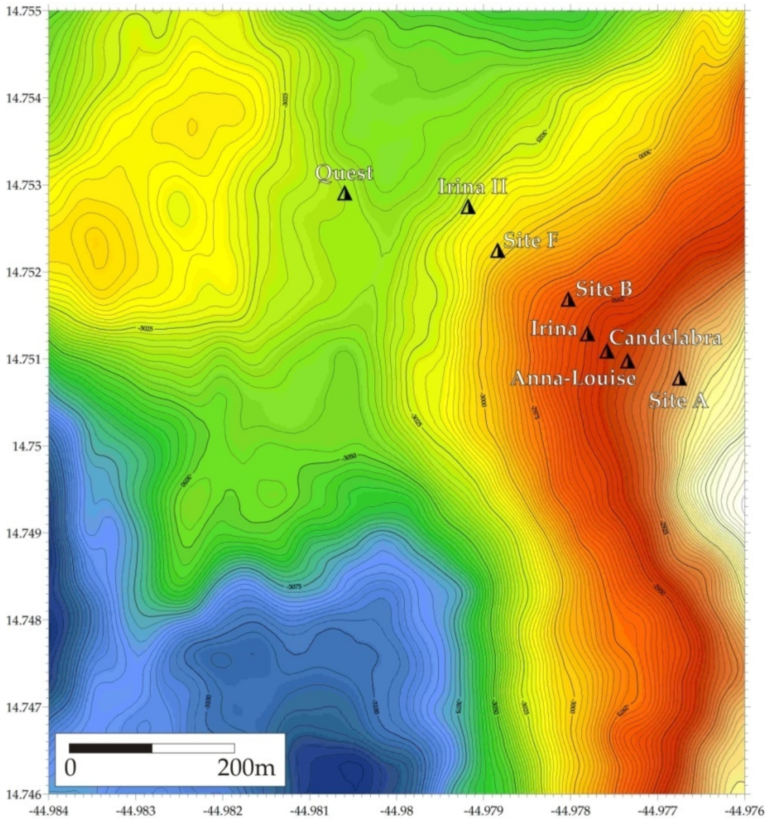


Fig. 2.6.: Detailed bathymetric map of the Logatchev field showing the known individual vent sites in relation to the local bathymetry. Note the relative steep morphology of the southeastern vent sites ("B" to "A").

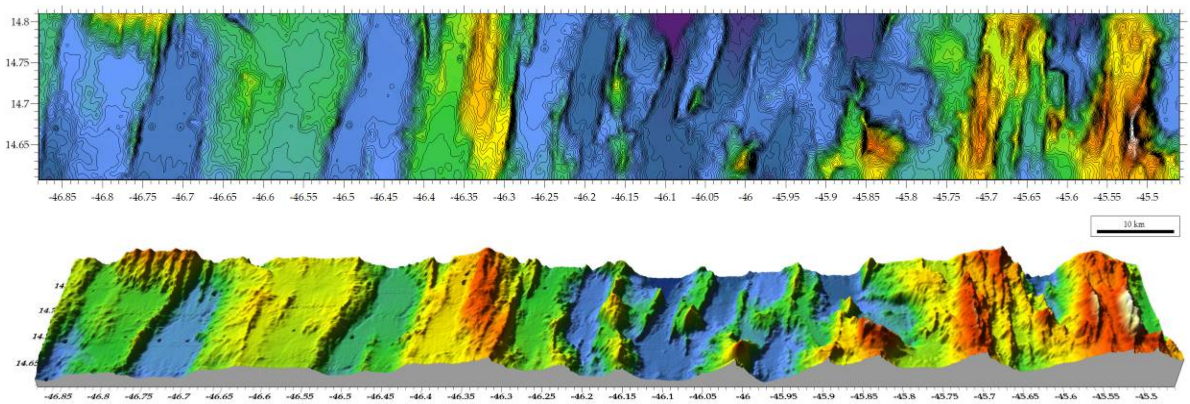


Fig. 2.7.: Map of the seafloor west of the Logatchev area. The NS striking morphology of the older parts of the MAR is clearly visible. Upcoming cruises to the Logatchev area will be able to add data to the north as well as to the south of this map.

2.4.2 Rockdrill stations

(S. Petersen, G. Cherkashov, D. Smith)

The main focus of the cruise was the sampling of the subseafloor using the British Rockdrill 2 instrument. A detailed technical report is given by the BGS crew in the appendix.

In total 14 stations were performed in the working area, not including the 3 test sites in shallow water close to Martinique (Tab. 2.1., Fig. 2.8.). One of the major challenges was a technical problem with the communication line between the Rockdrill 2 at the seabed and the control container on board the Meteor. During several station attempts we lost communication with the instrument at water depths below 2000m. It became obvious that part of the fibre-optic cable on the mobile winch was faulty. At least one fibre was broken and could not be repaired. The cable was cut and reterminated, however, problems reoccurred. It was concluded that the wet-end termination was faulty as well and a completely new design was made from scratch by the BGS people with help from the ship's crew. After these initial drawbacks were overcome the Rockdrill 2 systems worked well with the mobile winch and during the remainder of the cruise all planned station could succesfully be performed.

Topography proved to be very steep locally and prevented the drill rig from working in some planned areas. Several attempts had to be made in order to set the instrument on the seafloor. Stations 926RD and 931RD, conducted at the shallowest part of the eastern rift valley flank of Mid-Atlantic Ridge showed the presence of basaltic material in this area (Fig. 2.9). The Rockdrill 2 instrument sank into the surface on a number of occasions, clearly demonstrating the soft nature of the underlying material (Fig. 2.9). This was not at all expected based on the previous ROV dives.

Five stations were targeted at the main Logatchev hydrothermal site in order to document the nature of the underlying subseafloor rocks, to define the extent of mineralization and alteration, and to test the nature of the geoelectrical response observed by our Russian colleagues. A detailed petrographic description of the drilled samples is given in chapter 2.4.3. In summary, sections of massive sulfide were not encountered in any drillhole indicating that sulfide formation is indeed restricted to the hydrothermal vent sites (smoking craters and mounds) that were not drilled. This sheds light on the importance of drilling information prior to the release of size estimates of seafloor massive sulfide outcrops. Previously the Logatchev 1 area was believed to represent at least 800 m of continous sulfides at the seafloor, this obviously being incorrect. Even stations 954RD and 962RD, located closest to a hydrothermal vent site (site "B") were dominated by altered peridotite and mafic rocks. The heterogeneity of the material recovered in almost all core sections, with massive gabbro next to peridotite next to harzburgite indicates that the host rock at Logatchev is not in-situ, but instead is dominated by talus material (Fig. 2.10). The gravel/sand-like nature of the host rock encountered resulted partly in unstable hole conditions and collapse. Therefore, the stratigraphic relation of some cored sections and the drill core recovery rate are usually only estimates.

Hydrothermally influenced drill core material includes clay-rich sections, Fe-oxyhydroxides, and sulfide pebbles that were encountered up to a depth of 10m (core 962RD) reflecting the cyclic nature of hydrothermal activity at Logatchev. Age dating of these sulfide samples will provide information on the age of these deposits. Drilling at site 959RD indicates that hydrothermal influence is widespread and that the geoelectrical signals measured by the Russian scientists are indeed related to hydrothermal precipitation. The oxidized nature of the drill core, however, can not cause the enhanced resistivity indicating that sulfidic material might occur below.

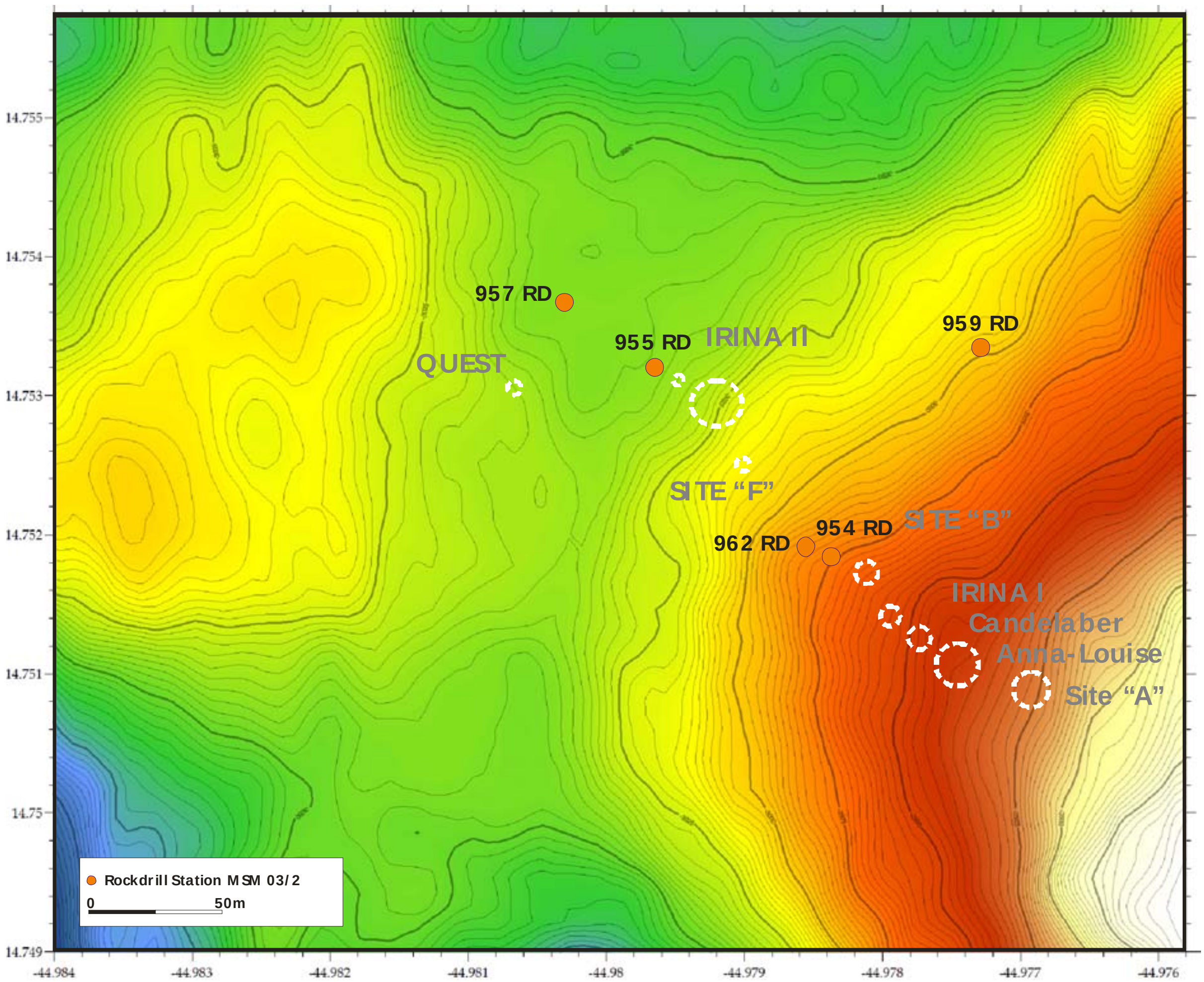
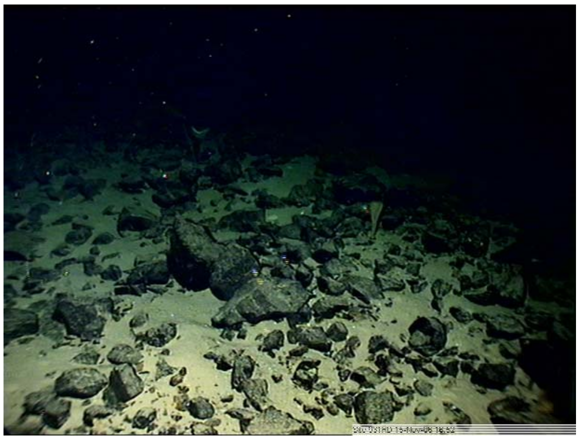


Fig. 2.8.: Location of Rockdrill stations within the main Logatchev hydrothermal field. Stations 932RD and 950RD, also located within the Logatchev field, had no recovery. Location of the vent sites is based on cruise MSM04/3 in the spring of 2007 using ROV Jason-2 (WHOI). Background bathymetry obtained during MSM03/2 (Map processed by N. Augustin, IFM-GEOMAR).

Table 2.1.: Summary of the Rockdrill-2 stations during MSM 03/2 in the Logatchev hydrothermal field. Not included are the 3 testsites in shallow water close to Martinique.

station	lat. / long	water depth	hours on station	total pene-tration	recovery	comment
925RD	*(14°40.502'N / 44°54.473'W)*	1780 m	-	-		aborted
926RD	14°40.501'N / 44°54.497'W	1763 m	1 h	1.0 m	0.25 m (25 %)	1 barrel with basalt
931RD	14°40.509'N / 44°54.525'W	1762 m	2 h	1.8 m	1.7 m	2 barrels with basalt
932RD	*(14°45.184'N / 44°58.875'W)*	3035 m	-	-	-	aborted
940RD	*(14°45.202'N / 44°58.899'W)*	3030 m	-	-	-	aborted
948-1RD	*(14°45.227'N / 44°58.789'W)*	3040 m	-	-	-	aborted
948-2RD	*(14°45.226'N / 44°58.788'W)*	3040 m	-	-	-	aborted
950-1RD	*(14°45.203'N / 44°58.815'W)*	3046 m	-	-	-	aborted
950-2RD	*(14°45.203'N / 44°58.815'W)*	3043 m	-	-	-	aborted
954RD	14°45.112´N / 44°58.703´W (near site „B“)	2977 m	7 h	6.1 m	1.2 m (20 %)	4 barrels drilled, but material was only in 2. (<25%) and 4. (50%) barrel; iron-silica crust, fragment of massive sulfide, strongly alter-ed peridotite, aggregates of pyrite
955RD	14°45.192´N / 44°58.772´W	3016 m	22 h	9.1 m	2.3 m (25 %)	9 barrels drilled; gravel in barrel 3 (<10%), 7 (75%) and 8 (50%, black coating due to heat); gravel of altered gabbroids, peridotites, serpentinites; Py-crust on top of barrel 7.
957RD	14°45.220´N / 44°58.818´W	3045 m	26 h	7.0 m	5.7 m (81 %)	8 barrels drilled; barrel 1 and 2 contained sedi-ments, barrels 3-8 rock fragments
959RD	14°45.199'N / 44°58.637'W (near TV-grab 54)	2997 m	16 h	7.9 m	5.3 m (67 %)	6 barrels drilled, hydrothermal sediments, fragments of altered rocks, Fe-Mn-crusts
962RD	14°45.114'N / 44°58.713'W (near site „B“)	2983 m	31 h	10.3 m	3.7 m (36 %)	11 barrels drilled; barrels 1 and 6 empty; sulfide pebbles at 10 m depth ! Host rocks are gravel-sized serpenti-nized ultramafics

<u>Station 926RD:</u> Seabed dominated by basaltic pebbles in sediment.



<u>Station 932RD:</u> Seabed dominated by basaltic pebbles in sediment.

<u>Station 954RD:</u> The drill rig was placed on a sedimented surface and immediately sank into the bottom.

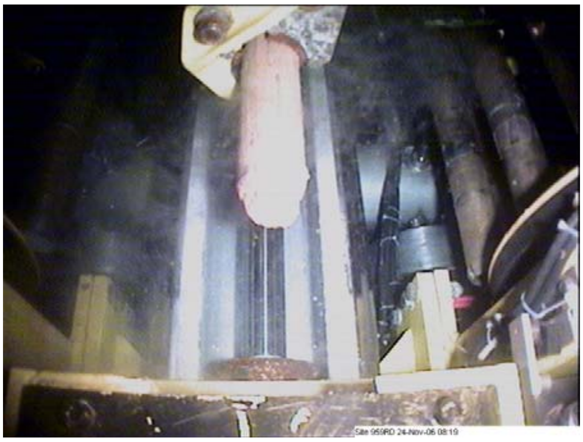
View of the inside of the instrument being covered by sediment up to the propellers (blue).

<u>Station 957RD:</u> The drill rig was placed on a seemingly rocky slope to the northwest of Irina 2 and immediately sank in.

The instrument slid down the slope providing this cross section. Clearly visible is the sediment cover overlying gravel to sand-sized wallrock material.

Fig. 2.9.: Bottom pictures of selected Rockdrill-2 landing sites.

Station 959RD: The instrument at the landing site near the M60/3 TV-Grab station 54GTV



view inside the instrument during core handling

Station 962RD: Located next to the smoking crater site „B“ with Fe-oxyhydroxides visible in the image. Green atacamite (Cu-chloride) is also present at the seafloor.

A small depression formed behind one of the legs during drilling caused by lateral fluid flow.

Fig. 2.9. (continued): Bottom pictures of selected Rockdrill-2 landing sites.

Another surprise came from the last drill station. During drilling fluid flow out of the hole seemed to decrease considerably thereby affecting the drilling progress. Video observations of the surrounding seafloor showed the formation of a depression formed behind one of the legs. This clearly suggests lateral fluid flow through the underlying rock sequence. This also suggests that drilling is not responsible for the small grain size of the drill core (grinding of the core) but that the seafloor is indeed covered by sand- to gravel-sized debris. This information will help to revise the concept of the formation of this massive sulfide deposit and of the formation of the smoking craters, a venting style presently unique to the Logatchev hydrothermal field. It seems likely that such smoking craters can only form in ultramafic-hosted hydrothermal systems where alteration processes and transport of material result in a fine-grained nature of the surrounding host rocks. Smoking craters should therefore not form in basaltic environments.

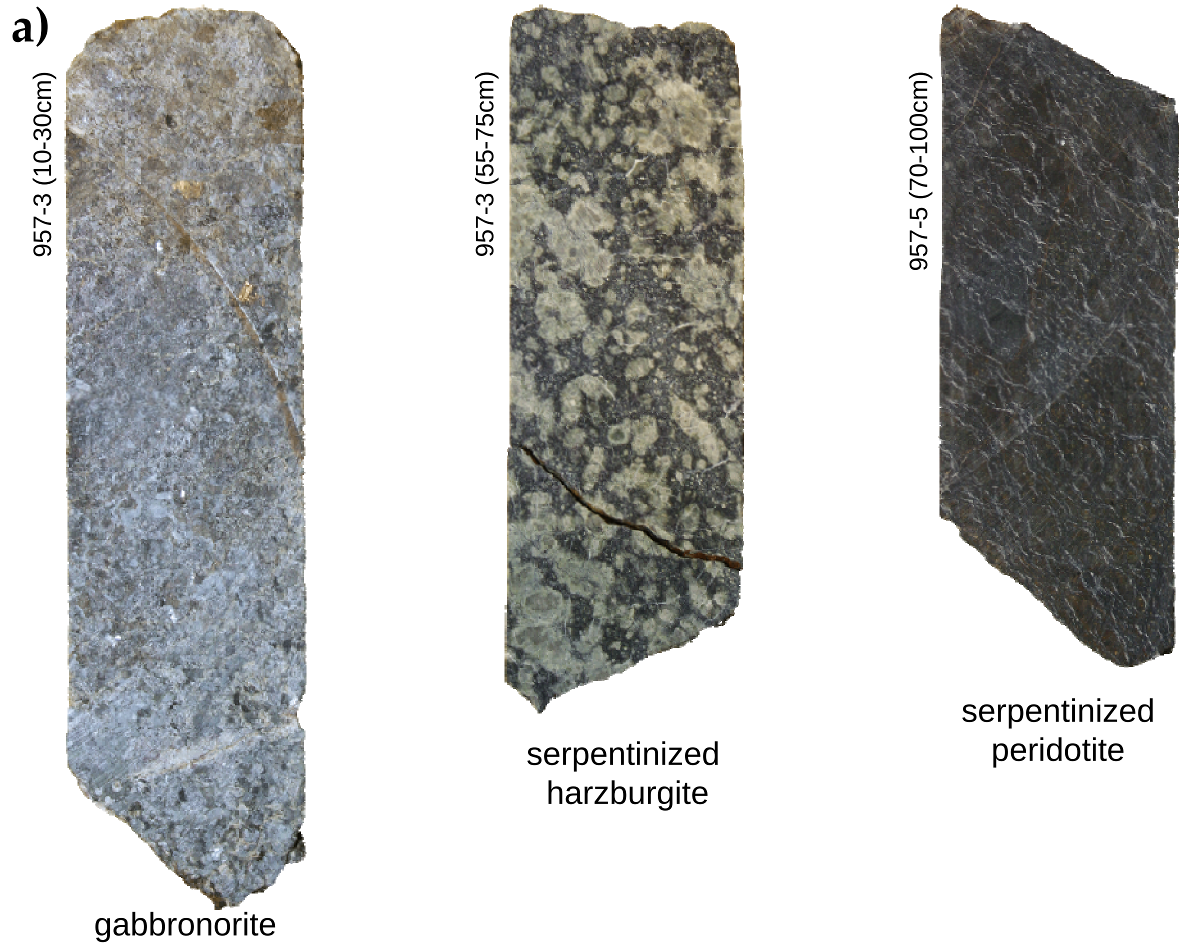


Fig. 2.10.: Selected core fotographs showing a) the heterogeneity of rock type recovered during a single drill hole (957RD) located north of the Irina II mound. b) mineralized core sections (counterclockwise from upper left). Clay-rich material with abundant serpentinized rock fragments next to a smoking crater. Sulfide pebbles within altered host rock (core 962). Sulfide-impregnated serpentinite sand (core 954). Fe-oxyhydroxide bearing sediment and semi-lithified sediment recovered from east of the main hydrothermal area (core 959).

2.4.3 Petrography of the mafic and ultramafic samples

(L. Franz, F. Klein, S. Fischer, T. Stepanova)

2.4.3.1. Occurrence of the rock samples

The rock samples of the MSM 03/2 cruise can be subdivided in two groups:
- Mafic samples of MORB composition and
- Ultramafic samples derived from mantle rocks

All dredges in the middle of the rift valley as well as three dredges on its eastern slope sampled relatively unaltered pillow basalts or fragments of basalt flows (see Fig. 2.11.) These samples were often embedded into a mass of yellow mud mainly consisting of deep sea clay.

Minor amounts of basalt were also recorded in the dredges 942 and 949 on the slope further east, however, their main content consisted of mafic intrusives (fine grained, medium/coarse grained and huge grained gabbronorites) and ultramafic rocks (peridotites and serpentinites). The modal amount of these rocks varied strongly with ultramafic rocks dominating in dredge 949 and mafic rocks being major rock type in dredge 942 (Fig. 2.11.) Dredge 941 only contained one large sample of coarse grained gabbronorite cumulate (Fig. 2.11).

The drill holes yielded similar rock types to the dredges, i.e. basalt in the drill holes 926 and 931 and a mixture of sand, gravel and pebbles made up of weathered mafics and ultramafics in drill holes 932, 950, 954, 957, 959, 962. Below follows a list of the most important dredge stations and drill holes and a short description of their contents.

926RD: This drill hole supplied two different types of basalt. At the top of the core, one sample of fine-grained, distinctly crystallized basalt was found while the rest consisted of pristine, dense, vesicular basalt with rare phenocrysts of olivine. Some pieces of dark brown basaltic glass were also present. Judging from the mainly rounded shape of the samples, they were probably part of the talus. Rock types and amount: 100 % pristine, vesicular basalt.

928DR: Dredge 928 sampled pristine basalt pillows and fragments of them. The samples often had a glassy outer rim with a thickness of up to 5 mm and a vesicular, dense basalt layer (2-4 cm thick) underneath. The microscope revealed tiny aggregates of zeolite, short prismatic epidote and limonite in the vesicles testifying to a late hydrothermal, low-grade overprint. The core section of the pillows consisted of almost vesicular-free basalt with mm-sized olivine phenocrysts. The pillows were coated with Mn-ore and reddish limonite. Rock types and amount: 100 % pristine pillow basalt.

929DR: This dredge contained basalt pillows and distinctly altered basalt fragments. Pillows often had a glassy rim followed by vesicular, dense basalt. A mm-thick coating of grainy Mn-ore covered the pillows. Some of the rock fragments showed a low-grade alteration to chloritized, greenish basalt. Rock types and amount: 100 % pristine vesicular and chloritized basalt.

931RD: Rock drill station 931 presented cores of pristine, mainly vesicular basalt with tiny olivine phenocrysts. Fractures were regularly filled with chlorite and a mixture of carbonate and mud. One core section consisted of greyish-green clastic basalt revealing a distinct chloritisation and limonitization. Rock types and amount: 100 % pristine vesicular and clastic chloritized basalt.

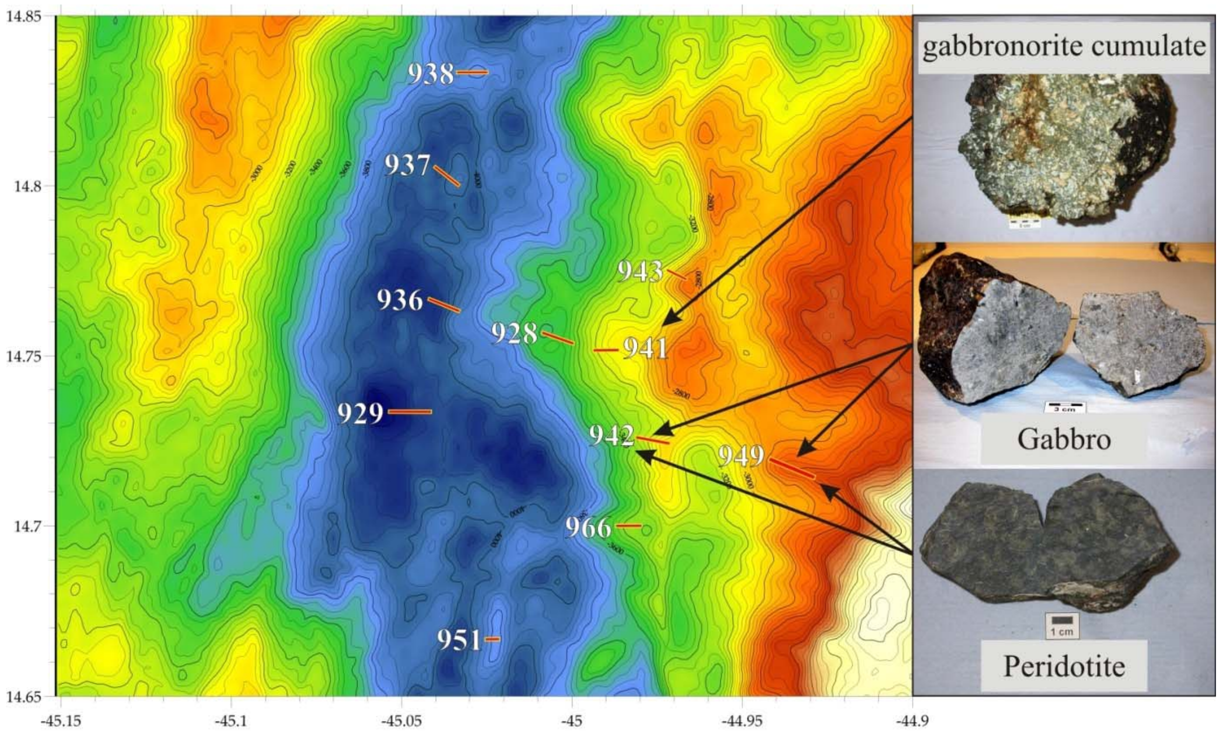


Fig. 2.11.: Content of the dredges from the centre of the rift valley and its eastern slope. With the exception of stations 941DR, 942DR and 949DR all dredges recovered basaltic material.

936DR: Dredge 936 brought numerous pristine, cm-sized samples of dark brown basaltic glass. The samples internally showed an irregular fracturing and a serrated, limonite coated rim section. Flow-textures could be observed while tiny vesicles and phenocrysts of feldspar were rare. In some cases, dense basalt with large, irregular vesicles followed underneath the glass layer. Rock types and amount: 100 % basaltic glass and subordinate dense basalt.

937DR: This dredge was full of light brown clay but also contained some fragments of basalt. The latter showed sharp edges and consisted of dense, greenish weathered, slightly vesicular basalt, which often showed Mn-ore coating. Rock types and amount: 100 % weathered basalt.

938DR: Dredge 938 contained one large pillow and several basalt fragments, which broke loose from that pillow. The outer section of the pillow consisted of 3-5 mm thick, dark brown glass, which often was covered by a mixture of limonite and carbonate. Underneath followed a layer of vesicular, dense, greyish basalt whereas the core of the pillow was made up of homogeneous, dense, vesicle-free basalt. Many cracks of the pillow were coated by limonite and chlorite. Rock types and amount: 100 % pillow basalt.

941DR: This dredge sampled one large boulder of coarse grained gabbronoritic cumulate showing euhedral, widely serpentinized orthopyroxene, brown clinopyroxene with dark green amphibole rims and relatively fresh greenish-blue plagioclase as anhedral intercumulus phase. Secondary minerals like quartz and talc are mainly concentrated in the outer section of the sample. Rock types and amount: one sample of gabbronorite cumulate.

942DR: Dredge 942 yielded a variety of mafic and ultramafic rocks with most samples (60 %) being gabbronorites. These rocks were either coarse- and huge-grained, angular types with homogeneous, equigranular texture and grain distribution. They mainly consisted of euhedral and subhedral pyroxenes, sub- and anhedral plagioclase and ilmenite. Few samples showed spotty retrogression to secondary chlorite and hornblende. One sample of dense, vesicular basalt with a mm-wide, weathered rim section was recovered while the rest of the samples consisted of ultramafics. These rocks were mainly harzburgites with a strong, thorough serpentinization. Most samples displayed a fine-grained mesh texture with cm-sized, anhedral crystals of orthopyroxene, which were largely transformed to serpentine ("bastite"). Tiny fractures in these ultramafics were often filled by white fibres of chrysotile. Most of the samples of this dredge were coated by a grainy layer of Mn-ore. Rock types and amount: 60 % gabbronorite, 38 % serpentinized peridotite, 2 % basalt.

943DR: This dredge contained several samples of dense, vesicular pillow basalt partly bearing numerous olivine phenocrysts. Most basalt samples are relatively fresh although weathering may be present on the surface and on fractures. Especially the outer glassy rim is often transformed to an orange coloured, grainy mass. One sample is covered by a 2-5 cm thick crust consisting of Mn-ore and limonite. Rock types and amount: 100 % pillow basalt.

949DR: Dredge 949 had a majority of ultramafic samples, which showed all stages of secondary overprint. Most of these samples were former harzburgites, which experienced a total serpentinization. Many samples were veined with either dark blue serpentine- as well as zeolite- and carbonate-filled fractures. Several serpentinites were affected by silicification processes, which gave them a compact appearance and a golden-brown colour. Only few rocks exposed relics of primary mantle minerals like orthopyroxene. Remarkable is a serpentinite sample, which is cut by a cm-thick hornblende-gabbronorite vein, around which a cm-wide, dense, contact metamorphic recrystallization of the serpentinite is visible. The mafic samples of this dredge were coarse grained gabbronorites with equigranular textures and distinct coating of Mn-ore. Several mafic intrusives underwent a greenschist-facies overprint transforming them into greenstones with several mm-wide veins consisting of piemontite. Only two small samples consisted of dark grey, dense, vesicular basalt. Rock types and amount: 8% gabbronorite, 12 % greenstone (former gabbronorite), 3 % basalt, 77 % serpentinized peridotite.

951DR: This dredge contained one pillow, which was split up along numerous fractures to many subsamples (MSM 951-1a-r). The pillow revealed a dark brown, outer glassy rim with a thickness of up to 3 mm followed by a dense layer of vesicular basalt bearing numerous phenocrysts of olivine and magnetite. Towards the centre of the pillow, the number of vesicles distinctly decreases. Secondary alteration is visible by limonitized and chloritized fractures and by coating of limonite and Mn-ore on surface of the samples. Rock types and amount: 100 % pillow basalt.

954RD: recovered altered serpentinized mud with 4 barrels drilled, but material was only in second (<25 %) and fourth barrel (50 %) barrel; iron-silica crust, fragment of massive sulfide, strongly altered peridotite, aggregates of pyrite.

955RD: The drill hole 955 yielded gravel of gabbronoritic and peridotitic composition as well as some quartz grains of secondary (hydrothermal) origin. Rock types and amount: hard to estimate, probably a majority of mafic, gabbronoritic rock.

957RD: The drill hole 957 contained sand, gravel and pebbles of gabbronoritic and peridotitic composition as well as several quartz fragments and pebbles of secondary (hydrothermal) origin. Larger boulders supplied massive cores of gabbronoritic, harzburgitic and dunitic composition. Rock types and amount: hard to estimate, probably a majority of mafic, gabbronoritic rock.

962RD: The drill hole 962 yielded gravel of gabbronoritic and peridotitic composition, massive sulfide pebbles (mainly chalcopyrite) and minor quartz grains of secondary (hydrothermal) origin. Remarkable were distinctly pyritized gabbronorite pebbles showing white (talc and sulfate) coating. Rock types and amount: a majority of mafic, gabbronoritic rock, many serpentinized peridotites and minor massive sulfide components.

2.4.3.2. Detailed petrography of the samples

Mafic rocks - Eruptive rocks

Eruptive rocks were mainly pristine MOR basalts in the form of large pillows (Fig. 2.12.A) or fragments of dm-thick basalt flows. Both had a dark brown, outer glassy layer, the latter having a thickness of up to 4 cm (Fig. 2.12.B). Below the glass followed a dense, vesicular basalt layer with a thickness of 2-4 cm whereas the centre of the samples revealed a dense to fine grained variety of vesicular basalt with abundant fractures (Fig. 2.12.C). Both types of basalt were free of any xenoliths or xenocrysts and showed mm-sized phenocrysts of olivine, magnetite and sometimes clinopyroxene.

Only in rare cases, strongly altered clastic basalt occurred. This type showed a distinct chloritisation and limonitization with cm-sized, angular clasts in a dense matrix (Fig. 2.12.D). These rocks probably formed by pyroclastic processes. Most of the basalt samples showed a distinct black coating of Mn-ore on the outside and sometimes also a mm-thick red limonite layer.

Mafic rocks - Intrusive rocks

Two types of intrusive rocks were found. The majority of these rocks were pristine, hardly altered gabbronorites with distinctly variable grain size. The most common rocks (~90 % of all samples) were medium to coarse grained gabbronorites with euhedral ortho- and clinopyroxene and sub- to anhedral plagioclase (Fig. 2.12.E). Subordinately, gabbronorites with small grain sizes (probably dykes or parts of the chilled margin of the intrusions) and huge grained gabbronorites (Fig. 2.12.F) occurred. Remarkably, several samples of serpentinized peridotite with up to cm-thick gabbronorite veins were discovered. These gabbronorite veins either had medium grained and fine grained, equigranular textures and in part induced a contact metamorphism to the serpentinite (Fig. 2.13.A). One dredge sampled a large block of gabbronorite cumulate (Fig. 2.12.G). This sample consisted of euhedral, brown clinopyroxene mantled by green hornblende, euhedral to subhedral orthopyroxene, which was often transformed to serpentine, and intercumulus plagioclase (Fig. 2.12.H). This rock showed distinct traces of sub-sea weathering on the surface.

A second type of intrusive rocks showed a distinct metamorphic overprint. These rocks were either mylonites or greenstones. Mylonites revealed layers or sections of dense, recrystallized feldspar and quartz and mm-sized clasts mainly of pyroxenes (Fig. 2.13.B). A mylonitic foliation was in part well visible. The greenstones did not show any parallel texture but displayed a dense, light green groundmass with relic clasts of feldspar cut by mm-sized, pink veins of piemontite (Fig. 2.13.C).

Ultramafic rocks

All ultramafic rocks, which were derived from upper mantle spinel peridotite, were affected by a strong to total serpentinization. The least overprinted rocks were mainly harzburgites showing a dense to fine-grained mesh texture of former olivine grains and cm-sized orthopyroxene crystals (Fig. 2.13.D), which were mainly transformed to bastite. Relic olivine fragments were only observed in very few cases. Black and dark brown spinel crystals (picotite) and small aggregates were abundant (Fig. 2.13.E). Dunites occurred subordinately and also showed the typical, fine grained mesh texture. Spinel was abundant in the dunites while olivine was totally transformed to serpentine. Dunites also lacked orthopyroxene or bastite.

Three types of strongly altered ultramafics were found. The first type was made up of ultramafic mylonites (Fig. 2.13.F), which showed distinctly boudinaged, elongated orthopyroxene and rare spinel crystals in a foliated, fine grained mass of almost totally serpentinized olivine. Parallel to this mylonitic foliation, fractures filled with chrysotile were observed. In dredge 949, a suite of serpentinites with strong veining of serpentine, carbonate and zeolite was recovered (Fig. 2.13.G). Either dark green veins of serpentine (probably lizardite) and fibrous veins (chrysotile) were recorded. Carbonate formed either monomineralic veins with cm-sized crystals and composite veins together with zeolite. The strongly fractured serpentinite rocks also showed seafloor weathering indicated by orange-red Fe-oxyhydroxide spots and veins. The third type of strongly overprinted serpentinite experienced a thorough silicification, which turned it into a dense, very hard rock with a golden brown colour. Veining of serpentine was also very often observed in these lithologies (Fig. 2.13.H).

Similar to the mafic rocks, the peridotites and serpentinites in most cases had a thick layer of Mn-ore and limonite on the surface. Especially in hydrothermally active zones, this layer reached a thickness of up to 4 cm.

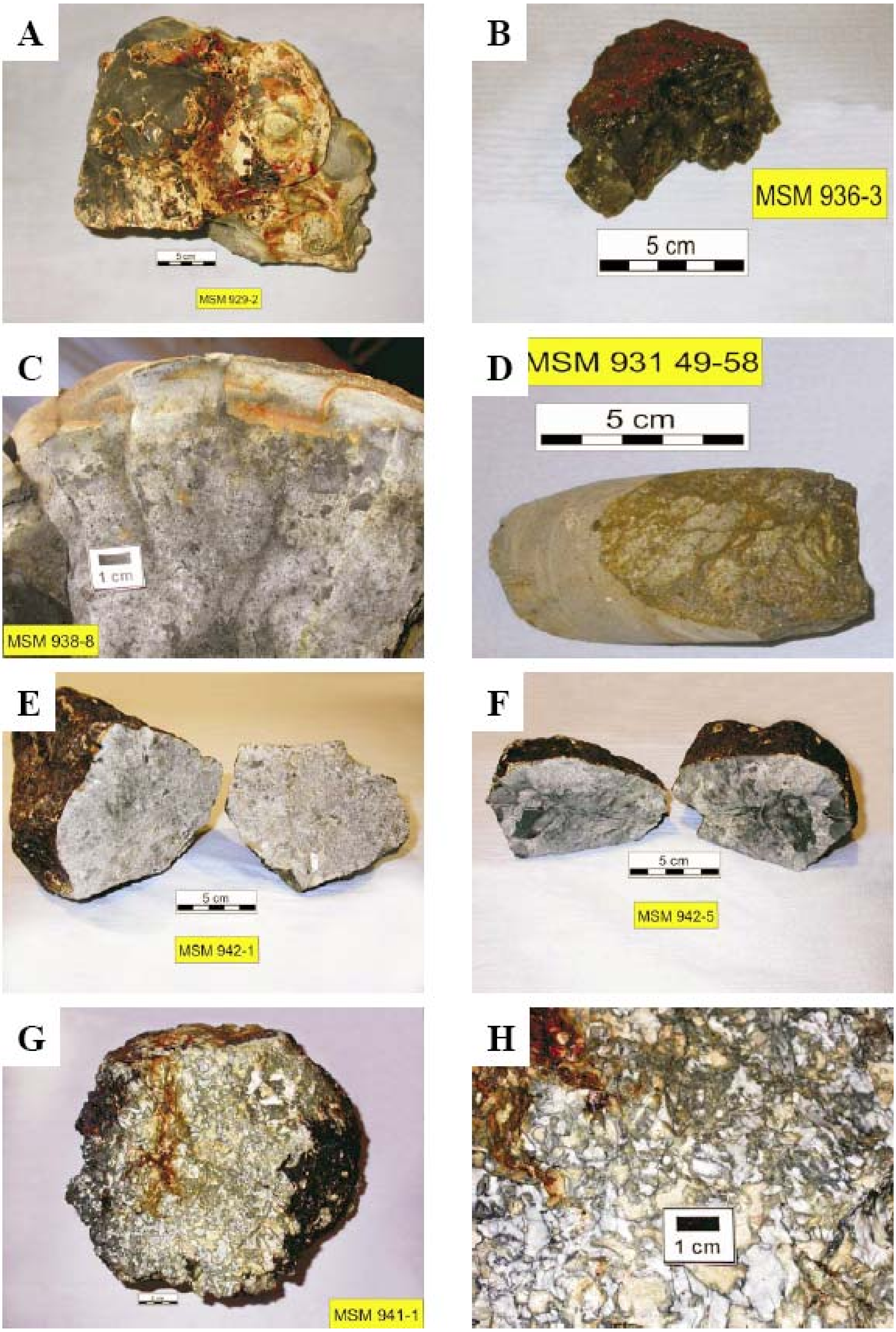


Fig. 2.12.: Photos of mafic extrusive and intrusive rocks. (A) Basalt pillow (B) Basaltic glass (C) Vesicular basalt (D) Clastic basalt (E) Coarse grained gabbronorite (F) Huge grained gabbronorite (G) Gabbronorite cumulate (H) Detail of G showing cumulate texture.

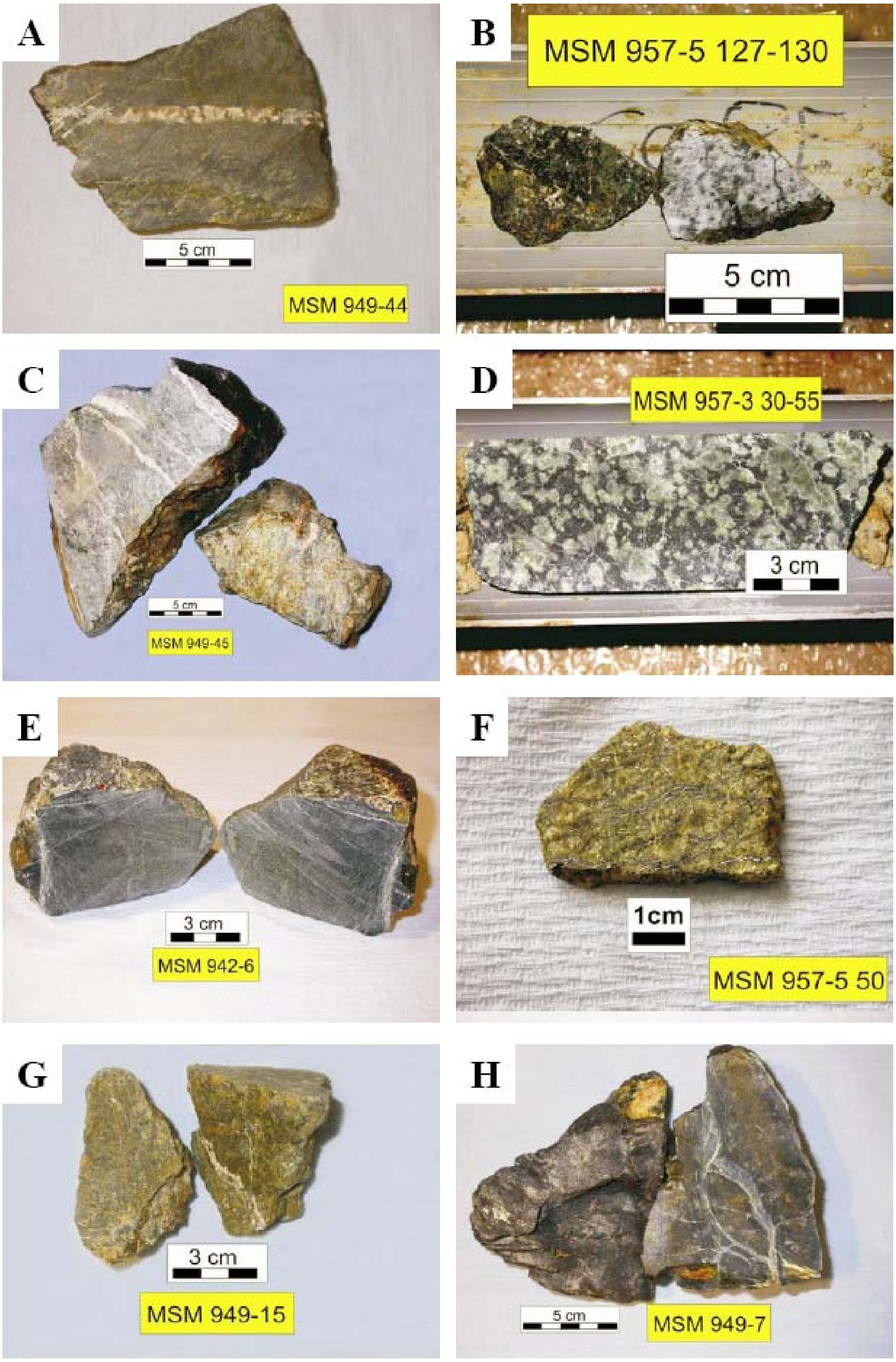


Fig. 2.13.: Photos of mafic and ultramafic rocks. (A) Hornblende gabbronorite vein cutting serpentinite (B) Gabbronorite mylonite (C) Greenstone (D) Serpentinized harzburgite (E) Serpentinized dunite (F) Serpentinized mylonitic peridotite (G) Serpentinized harzburgite with carbonate and zeolite veins (H) Silicified serpentinite.

2.4.4 Gravity Corer Stations

(S. Petersen, G. Cherkashev, X. Han, T. Stepanova, C. Ockert)

In addition to the Rockdrill stations a number of gravity corer stations was conducted in order to document the nature of the subsurface and to allow sampling of sediments for analyses of the sulfur isotopic composition and microbiology. In total nine gravity corer stations were performed within the limits of the Logatchev 1 hydrothermal field (Fig. 2.14, 2.15). Detailed descriptions of the cores can be found in the Appendix.

Station 945GC and 958GC were deployed to the NW of Irina II in an area supposed to contain the Quest smoking crater. Only after our cruise it was revealed during cruise MSM04/3 that the location of this site is approximately 50 m to the SW (Borowski et al., 2007) and that the location obtained during earlier ROV cruises was offset. Therefore it is not surprising, that core 945GC contains pelagic sediment intercalated with serpentinized rock fragments and gabbro. Some Fe-staining is visible and may be due to the plume fallout in the surrounding of the Logatchev field. Station 958 returned empty. Stations 946GC and 947GC were located in-between Irina II and the low-temperature diffuse site „F“ and investigated the shallow subsurface between the two major sulfide bearing complexes: the Irina II mound and the smoking craters to the southeast. Core 946GC recovered a thin horizon of Fe-oxyhydroxides underlain by fine-grained sandy serpentinite. The lower part of the core shows pelagic sediment indicating that ultramafic debris is shed on top of sedimentary units. Core 947GC recovered a thick sequence of Fe-stained hemipelagic and hydrothermal sediment containing abundant atacamite (Cu-chloride) overlying pelagic sediment.

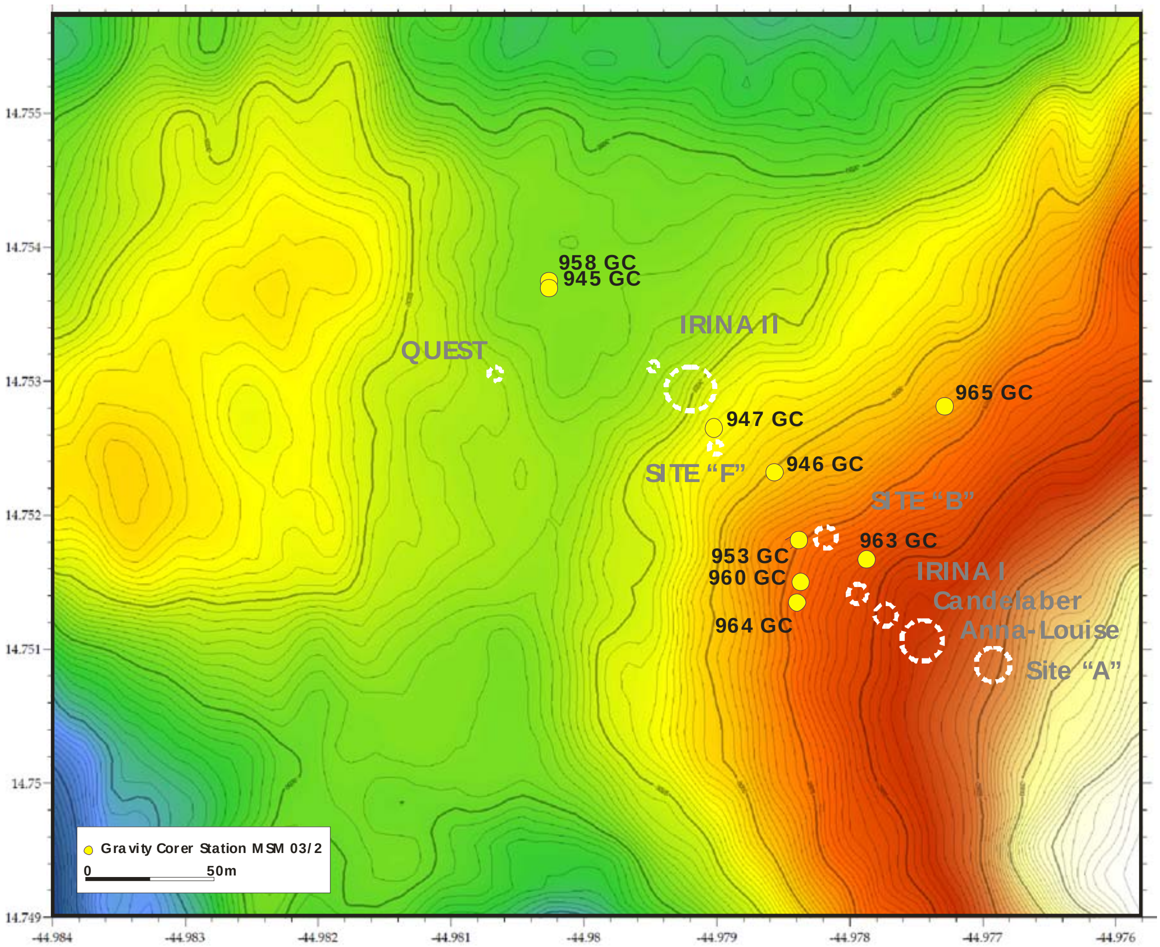


Fig. 2.14.: Location of gravity corer stations during cruise MSM03/2.

Gravity core 953GC was deployed next to the smoking crater „B“ and shows a layer of oxidized sulfides near the top followed by massive Cu-rich sulfides (below 40 cm) indicating that Cu enrichment has been ongoing at Logatchev for some time. These hydrothermal layers are underlain by highly altered serpentinites at depth suggesting, in agreement with the Rockdrill cores, that the sulfides form only a thin veneer on the surface and that large parts of the Logatchev hydrothermal field previously contained in the size calculations for massive sulfide resource estimates, do not contain sulfides to a significant depth. This observation is confirmed by gravity cores 960GC, 963GC and 964RD placed to either side (west and east) of the alignment of hydrothermal mounds and craters (Fig. 2.14). Core 963GC contains massive sulfides intermixed with Fe-oxyhydroxides near the top, the lower part (below 46 cm) is again Fe-stained pelagic sediment. Core 960GC recovered abundant wall rock fragments (altered gabbro) within Fe- and Mn-stained hydrothermal and pelagic sediment. The last core was placed near the TV-grab station M60/3-54GTV where the Russian geoelectrical instruments (G. Cherkashov pers. com.) showed a resistivity low and where the TV-grab recovered sulfides in a oxide matrix. The Rockdrill station placed in this area could not land at this position due to the local topography and is situated ~ 25 m to the north. Core 965GC recovered calcareous sandy clay with strong evidence for hydrothermal activity (Fe-staining), however, massive sulfides were not recovered. This is in agreement with Rockdrill station 959RD indicating that sulfide deposition in this area is indeed localized.

Table 2.2.: Summary of the gravity corer stations during MSM 03/2.

station	lat. / long.	water depth	comment
945 GC	14°45.222´N / 44°58.816´W	3042 m	124 cm core; sandy with rock fragments to typical deep-sea clay, layer with altered disintegrated gabbro
946 GC	14°45.139´N / 44°58.714´W	2998 m	175 cm core; Fe-stained surface layer underlain by clay matrix with wall rock fragments; layer with mixture of chloride and serpentinite; multicoloured sections at depth
947 GC	14°45.159´N / 44°58.741´W	3016 m	160 cm core; homogeneous silty to sandy carbonate matrix with prominant Fe-oxyhydroxides; dense clay matrix with dark red-brown crust-like fracture filling and distinct colour transition; lowermost part contains abundant altered wall rock fragments
953 GC	14°45.109´N / 44°58.703´W	2988 m	254 cm core; iron-silica crusts; sulfide and silicate crust overlying serpentinite mud/sand; few hematite-enriched spots at depth
958 GC	14°45.223´N / 44°58.815´W	3042 m	empty
960 GC	14°45.090´N / 44°58.702´W	2968 m	70 cm core; sediments and mixture of rock fragments
963 GC	14°45.100´N / 44°58.672´W	2952 m	57 cm core; hydrothermal sediment with sulfides
964 GC	14°45.081´N / 44°58.704´W	2972 m	77 cm core; hydrothermal sediment, Fe-Mn-crusts
965 GC	14°45.169´N / 44°58.637´W	2994 m	155 cm core; hydrothermal sediment, Fe-Si-Mn-crusts

Fig. 2.15.: Selected gravity corer sections. Left: Fe-bearing hydrothermal sediments from the vicinity of the Irina II mound (core 947GC). Center: Cu-rich sulfide intersection overlying sand-sized and clay-bearing serpentinite (Core 953GC) next to smoking crater "B". Right: Hydrothermal precipitates in core 963GC.

2.4.5 Sulfur Geochemistry

(H. Strauss, M. Peters)

The sulfur isotopic composition of dissolved sulfide and of sulfide minerals provides important information towards their genesis. With respect to hydrothermal massive sulfides and their secondary alteration products, the sulfur isotopic composition can be utilized (i) to identify the ultimate source(s) of the sulfur, (ii) to characterize the mode(s) of sulfide precipitation, and (iii) to assess the involvement of microbes during sulfide formation and/or oxidation.

During this cruise, massive sulfide samples from cores drilled with the BGS Rockdrill 2 as well as Gravity cores were collected in order to perform a systematic study of the sulfur isotopic composition of primary and secondary sulfide minerals. In the home laboratory, the sulfur isotopic composition of micro-drilled subsamples will be measured for their sulfur isotopic composition. Thereby, the prime focus will be placed upon mineral-specific sulfur isotopes, but the aspect of local variability will be of importance, too.

From sediment cores obtained with the Multicorer as well as from Gravity cores, pore water samples as well as sediment samples were collected for quantification of sulfur abundance and determination of the sulfur isotopic composition. Pore water samples were collected in defined intervals immediately after the sediment cores were on deck, using Rhizon© samplers (Fig. 2.16.). Sediment samples were taken after the core liners had been opened.

The content of dissolved sulfide was measured photometrically on-board. For this, any dissolved sulfide present in the pore water is fixed with a zinc acetate gelatine solution. This solution keeps the precipitated zinc sulfide in a colloidal state.

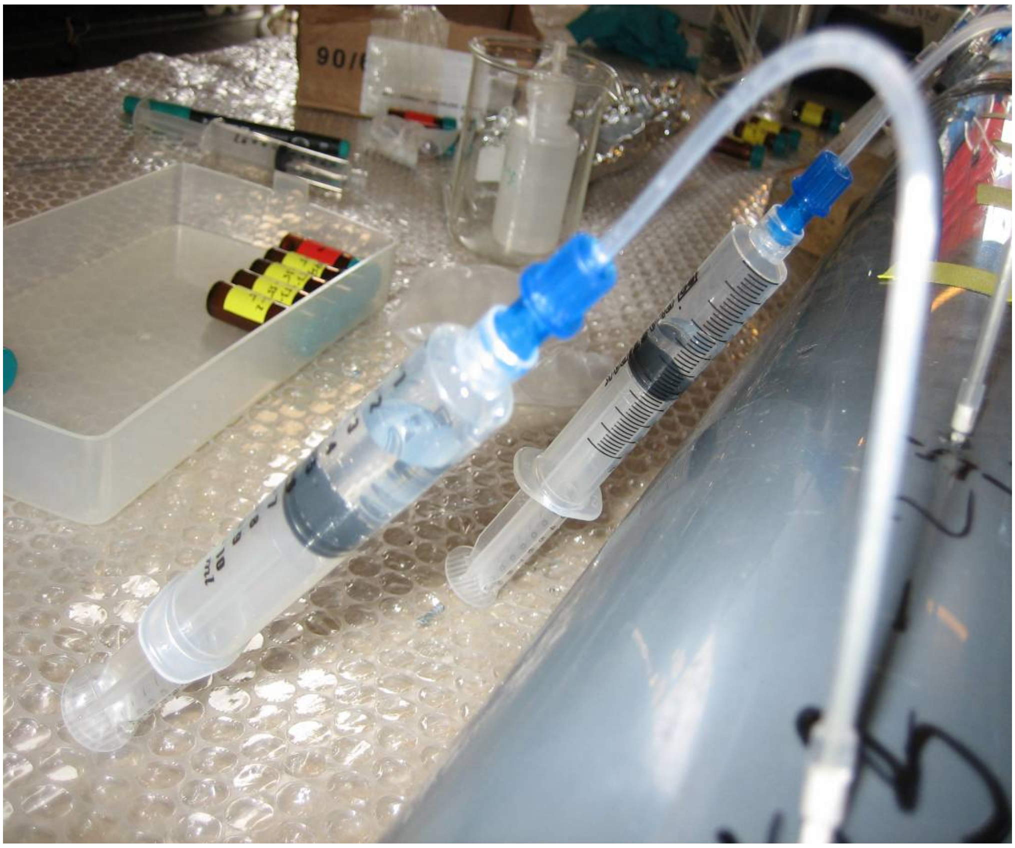


Fig. 2.16.: Sampling pore water with Rhizon samplers

The homogeneously distributed sulfide reacts with N,N-dimethyl-1,4-phenylene-diamine-dihydrochloride to colourless leucomethylene blue. This compound is oxidized by Fe^{3+} ions of an iron chloride solution to methylene blue. Methylene blue absorbs light with a wavelength of 660 nm. One hour after the reagents have been added the solution is measured photometrically. Prior to the photometric determination a calibration curve is constructed by measurement of different calibration solutions, each with a defined sulfides concentration. For this, a fresh stock solution with a sulfide concentration of 5,8mmol/L is used each time. The exact sulfide concentration of the stock solution is determined by titration with a 0,02N thiosulfate solution.

For all pore water samples measured on-board, the concentration of dissolved sulfide was below detection limit. This was true also for pore water samples from gravity core 953, which had a distinct hydrogen sulfide odour after opening the core liner.

2.4.6 Microbiology of the subsurface at the Logatchev hydrothermal field
(M. Perner, C. Ockert)

On previous cruises to the Logatchev hydrothermal field (LHF) hydrothermal fluid emissions have been collected from areas of smoking craters and the main chimney complex Irina II. The previous sampling was conducted to gain an overall view of the microorganisms present at the LHF. However, as hydrothermal fluids rise to the surface they entrain microorganisms

from the subsurface, chimney walls and the orifice. This causes a mixture of microorganisms in the fluid samples which originate from multiple habitats along the fluid pathway.
The aim of this cruise was to identify microorganisms characteristic for specific habitats (different types of rocks) in the subsurface environment of the LHF. For this purpose samples were collected along a vertical profile from 6 gravity cores, 5 Rockdrill cores and 1 multi corer station. Special emphasis was placed on the smoking crater locations at Irina I and Site B, as detailed analyses of the microorganisms and their potential metabolisms has been conducted on previous hydrothermal fluid samples.

2.4.6.1 Samples and methods

1. On board microscopic observations of microorganisms inhabiting freshly taken samples
2. Identification of local microorganisms
- Clone library of 16S rRNA gene (Archaea and Bacteria)
- DGGE
- Cultivation experiments
3. Quantification of the prevailing microorganisms
- Fluorescence in situ Hybridization (FISH)
4. Microbial Metabolisms
- Functional genes encoding key enzymes of hydrogen oxidation (hynL gene)
  Functional genes encoding key enzymes of the reverse tricarboxylic acid, and Calvin Benson-Basham cycle
- Cultivation experiments (started on board and continued in the home lab):
i. along a temperature gradient
ii. use of various electron donors (H_2, H_2S, S°, CH_4)
iii. suitable electron acceptors (O_2, NO_3, Fe^{3+}, S°)

2.4.6.2 Results

1. Microscopic observations of microorganisms inhabiting freshly taken samples revealed a very low abundance of prokaryotes.

2. Molecular analyses of the microbial community structure of the subsurface environment will be conducted in the home lab.

3. The abundance (FISH) of specific groups of bacteria and archaea will be determined in the home laboratory.

4. Cultivation experiments (Fig. 2.17.) revealed that sampled microorganisms are able to grow at temperatures of up to 79.5°C. Additionally it was shown that hydrogen was preferred over sulfide as energy source. A low growth rate was observed for most of the cultured organisms. Further processing will be conducted in the home lab with the aim to obtain pure cultures.

The number of cultures displaying growth was the highest in samples originating from the upper part of the core. In contrast enrichments from the lower part of the core revealed less cultures displaying growth. This could indicate that the microbial diversity is the highest in the upper layer. Alternatively the 9 cultures from the upper layer which revealed growth could also indicate the flexibility of utilization of different substrates by the microorganisms of the “upper layer”. Hence organisms from the lower layer might be more specialized and only grow on specific substrates.

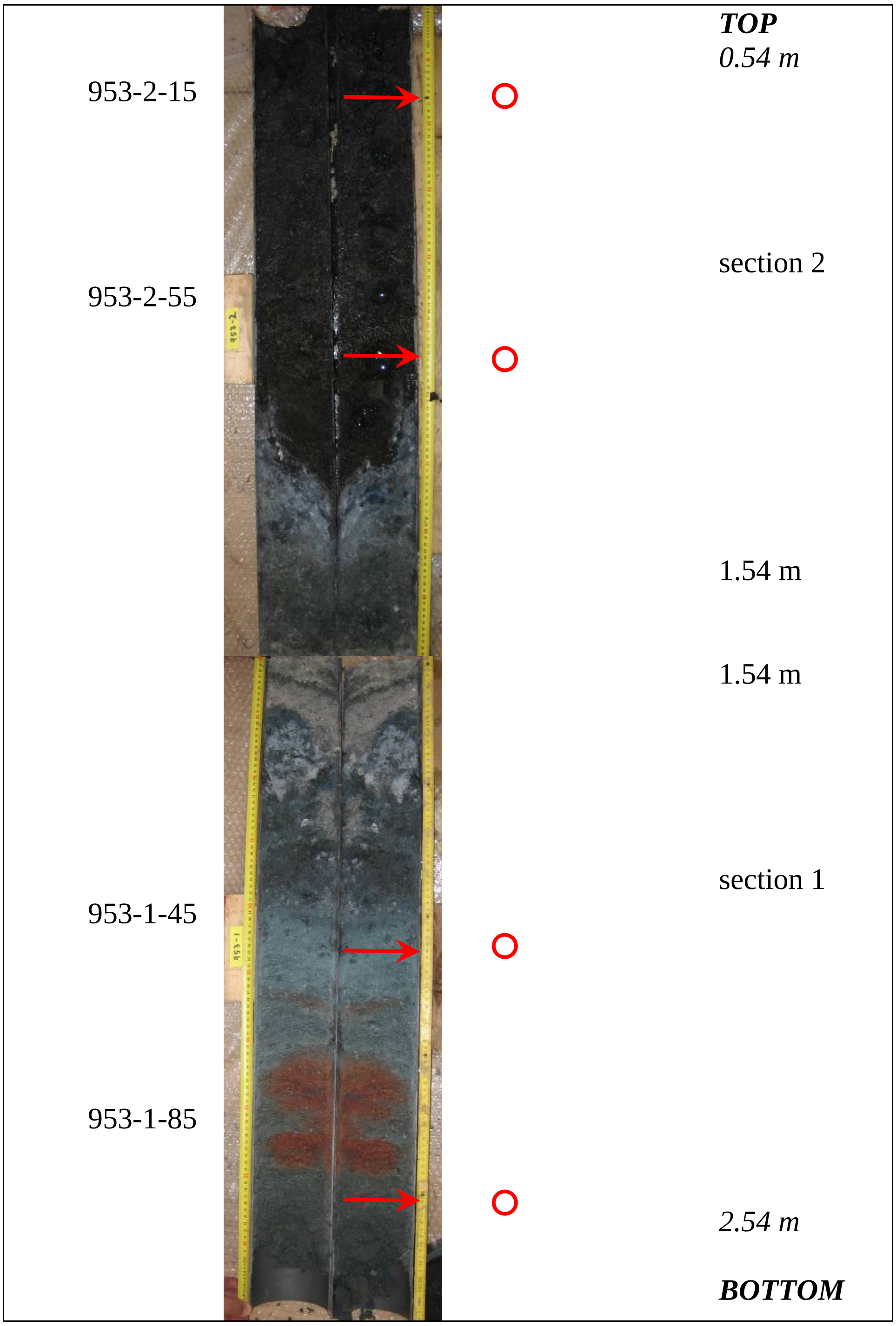


Fig. 2.17.: Sampling points for cultivation experiments in the gravity corer sample 953GC.

Tab. 2.3.: Overviev to H_2/H_2S oxidation and S^0 reduction in microbiological cultures sampled during MSM 03/2

Sample	Number of cultures displaying growth (total number of cultures)	H_2 oxidation	H_2S oxidation	S^0 reduction
953-2-15	9 (12)	+	-	-
953-2-55	4 (12)	+	-	-
953-1-45	1 (12)	+	-	+
953-1-85	4 (12)	+	-	+

Tab. 2.4.: Overviev of microbiological samples taken during cruise MSM 03/2

station	core	depth	FISH	DNA	AA isotopes/lipids	DMSO	Glycerin	plates (cultures)	liquid (cultures)
Muc 935			1	1	0	0	1	+	0
945GC	1	10	1	1	1	0	0	+	0
		20	1	1	1	0	0	-	0
		30	1	1	1	0	0	-	0
		40	1	1	1	0	0	-	0
		50	1	1	1	0	0	-	0
		60	1	1	1	0	0	-	0
		70	1	1	1	0	0	-	0
		80	1	1	1	0	0	-	0
		90	1	1	1	0	0	-	0
	2	10	1	1	1	0	0	-	0
		35	1	1	1	0	0	-	0
946GC	2	45	1	1	1	1	0	-	0
		55	1	1	1	1	0	-	0
		65	1	1	1	1	0	-	0
		75	1	1	1	1	0	-	0
		85	1	1	1	1	0	-	0
		95	1	1	1	1	0	-	0
	1	5	1	1	1	1	0	-	0
		15	1	1	1	1	0	-	0
		25	1	1	1	1	0	-	0
		35	1	1	1	1	0	-	0
		45	1	1	1	1	0	-	0
		55	1	1	1	1	0	-	0
		65	1	1	1	1	0	-	0
		75	1	1	1	1	0	-	0
		85	1	1	1	1	0	-	0
		95	1	1	1	1	0	-	0
947GC	1	5	1	1	1	1	0	+	0
		15	1	1	1	1	0	-	0
		25	1	1	1	1	0	-	0
		35	1	1	1	1	0	-	0
		45	1	1	1	1	0	-	0
		55	1	1	1	1	0	-	0
		65	1	1	1	1	0	-	0
		75	1	1	1	1	0	-	0
		85	1	1	1	1	0	-	0
		95	1	1	1	1	0	-	0
	2	45	1	1	1	1	0	-	0

station	core	depth	FISH	DNA	AA isotopes/lipids	DMSO	Glycerin	plates (cultures)	liquid (cultures)
		55	1	1	1	1	0	-	0
		65	1	1	1	1	0	-	0
		75	1	1	1	1	0	-	0
		85	1	1	1	1	0	-	0
		95	1	1	1	1	0	-	0
953GC	1	5	1	1	1	1	0	-	0
		15	1	1	1	1	0	-	0
		25	1	1	1	1	0	-	0
		35	1	1	1	1	0	-	0
		45	1	1	1	1	0	-	12
		55	1	1	1	1	0	-	0
		65	1	1	1	1	0	-	0
		75	1	1	1	1	0	-	0
		85	1	1	1	1	0	-	12
	2	5	1	1	1	1	0	-	0
		15	1	1	1	1	0	-	12
		25	1	1	1	1	0	-	0
		35	1	1	1	1	0	-	0
		45	1	1	1	1	0	-	12
		55	1	1	1	1	0	-	0
		65	1	1	1	1	0	-	0
		75	1	1	1	1	0	-	0
		85	1	1	1	1	0	-	0
		95	1	1	1	1	0	-	0
	3	55	1	1	1	1	0	-	0
		65	1	1	1	1	0	-	0
		75	1	1	1	1	0	-	0
		85	1	1	1	1	0	-	0
		95	1	1	1	1	0	-	0
954RD	4	15	1	1	0	0	0	-	6
		45	1	1	0	0	0	-	0
		55	1	1	0	0	0	-	0
		65	1	1	0	0	0	-	0
		77	1	1	0	0	0	-	0
	2	5	1	1	0	0	0	-	6
		17	1	1	0	0	0	-	0
		26	1	1	0	0	0	-	0
955RD	7	10	1	1	0	0	0	-	0
		60	1	1	0	0	0	-	0
		107	1	1	0	0	0	-	0
		140	1	1	0	0	0	-	0
	8	30	1	1	0	0	0	-	0
		60	1	1	0	0	0	-	0
		120	1	1	0	0	0	-	0
957RD	1	5	1	1	0	1	0	+	0
		45	1	1	0	1	0	-	0
		95	1	1	0	1	0	-	0
	2	30	1	1	0	1	0	-	0
		90	1	1	0	1	0	-	2
	3	20	1	1	0	1	0	-	2
		70	1	1	0	1	0	-	0
		130	1	1	0	1	0	-	0
	4	15	1	1	0	1	0	-	0
		40	1	1	0	1	0	-	0

station	core	depth	FISH	DNA	AA isotopes/lipids	DMSO	Glycerin	plates (cultures)	liquid (cultures)
		143	1	1	0	1	0	-	0
		145	1	1	0	1	0	-	0
	5	5	1	1	0	1	0	-	0
		130	1	1	0	1	0	-	2
	6	40	1	1	0	1	0	-	0
959RD	1	10	1	1	0	1	0	+	0
		40	1	1	0	1	0	+	0
	2	40	1	1	0	1	0	-	0
		90	1	1	0	1	0	-	0
		130	1	1	0	1	0	-	0
		160	1	1	0	1	0	-	0
	3	30	1	1	0	1	0	-	1
	4	85	1	1	0	1	0	-	0
		130	1	1	0	1	0	-	0
	5	40	1	1	0	1	0	-	0
		140	1	1	0	1	0	-	0
		165	1	1	0	1	0	-	0
		185	1	1	0	1	0	-	0
	6	120	1	1	0	1	0	-	0
960GC	1	35	1	1	1	1	0	+	0
		45	1	1	1	1	0	-	0
		55	1	1	1	1	0	-	0
		65	1	1	1	1	0	-	0
		75	1	1	1	1	0	-	0
		85	1	1	1	1	0	-	0
962RD	1	31	1	1	0	0	0	-	0
		60	1	1	0	0	0	-	0
	2	5	1	1	0	0	0	-	0
	3	32	1	1	0	0	0	-	0
	4	30	1	1	0	0	0	-	0
	5	55	1	1	0	0	0	-	0
	7	93	1	1	0	0	0	-	0
		70	1	1	0	0	0	-	0
	8	60	1	1	0	0	0	-	0
	9	18	1	1	0	0	0	-	0
		130	1	1	0	0	0	-	0
	10	175	1	1	0	0	0	-	1
963GC	3	5	1	1	1	0	1	+	0
		10	1	1	1	0	1	-	2
		15	1	1	1	0	1	-	2
		25	1	1	1	0	1	-	0
		30	1	1	1	0	1	-	2
		40	1	1	1	0	1	-	0
		50	1	1	1	0	1	+	0
Total			136	136	80	91	7	~200	74

2.4.7 Hydrogen storage in sulfide minerals

(E. Rahders)

Introduction

Significant amounts of hydrogen are generated by serpentinisation from ultramafic rocks at the mid-ocean ridges. Hydrogen is the main gas phase flowing through the near seafloor rocks and ore mineralisations. The storage capacity of hydrogen in the solid solution of sulfide minerals remains unknown. Therefore contents of chemically bound hydrogen in solid-solutions of different sulfide minerals from the Logatchev-1 hydrothermal field will be studied. It is strongly suggested that there is a relationship between the variability of the sulfide ore-paragenesis and/or substitution of trace elements e.g. Au, Co and Se in the sulfide mineral phases.

Sampling of sulfides for hydrogen storage

Three stations of two sites of the Logatchev hydrothermal field have been sampled for the hydrogen investigations: close to Site B (one of the smoking craters) and SW of the IRINA II (Tab. 2.5.).

Gravity corer MSM 953GC

Concretionary pebbles of complex secondary copper sulfides were sampled in the dense black colour sequence of gravity corer 953GC from 50-119 cm core depth. Inside of fine-grained black sulfide mud relicts of the former primary mineralization were found. All of the sulfides are considered to be secondary, reworked and replaced. There is no indication of a later low temperature overprint by hydrothermal solutions. In general copper and iron rich sulfide assemblages could be recognized. They all were not fresh, showing in-situ weathering or secondary incrustation.

Drill core MSM 955RD

Agglomerates of pyrite in greenish grey altered mafics of core 955RD were sampled. The pyrites are looking fresh and relatively unweathered. Partially thin iron-hydroxide crusts are recognisable. Some of the material is diagenetically cemented by siliceous solutions. Fine mineral grains of pyroxene and feldspars are visible.

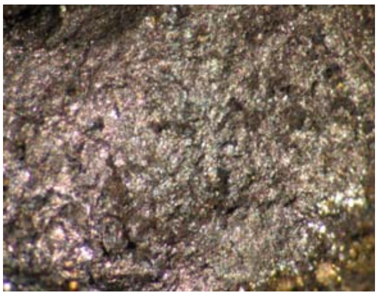
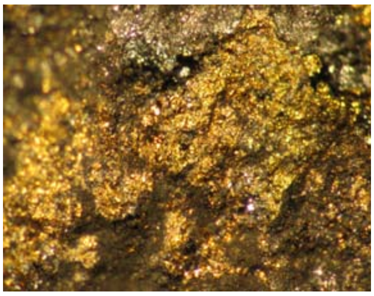
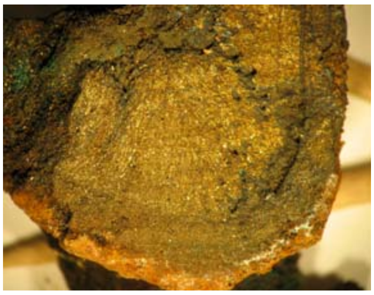
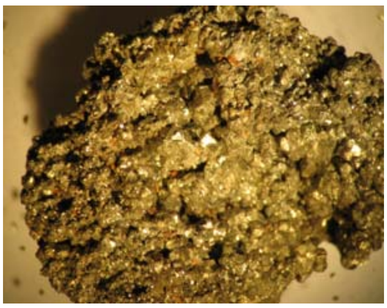
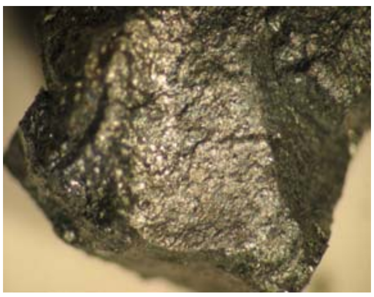
Drill core MSM 962RD

In the cores of station 962RD several rounded (by the process of drilling) sulfide pebbles have been found. The primary zone of ore mineralisation was approximately in the second and third core barrel. Fine black sulfide sediments equal to those described in 953GC where most probably washed out by the drilling process.

Sample preparation

All of them were black coated by the fine secondary sulfide dust. First removal of it was done by washing. Then alteration and weathering crusts had to be scratched away. In some cases there was a contamination by sedimentary detritus. The sulfide samples were carefully crashed into smaller pieces for separating into more or less homogeneous mono-mineral phases, selected under the binoculars. To avoid the weathering processes affecting chemical stability the samples where stored in oxygen free seawater after preparation under the stereo microscope. Schott Duran 50 ml gas dense glass bottles were used for storage and later transport.

Tab. 2.5.: Photographs of sampled sulfides for studies in hydrogen storage

	**MSM 953GC-50** Pebbles of strongly altered copper sulfides, maximum size of 3x4 cm, coated with secondary copper sulfides; consist of chalcopyrite ($CuFeS_2$), chalcosite (Cu_2S), minor pyrite (FeS_2). Scale: lower edge = 5 mm.
	**MSM 953GC-64** Fragment of massive copper sulfide, dense microcristalline, more than 70 % of chalcopyrite and secondary copper-sulfides in a complex merismitic structure. In some fissures euhedral bi-spenoidal chalcopyrite occur sub mm in size. Minor open space is filled by euhedral rhomboedral pyrite with black staining on their surface. Scale: lower edge 8.5 mm.
	**MSM 953GC-107** Iron rich fragments of typical beehive structure, consist of euhedral pyrite and marcasite (FeS_2), typical cauliflower structure (Glaskopf), indicating a lower temperature fazies. Scale: lower edge = 21 mm.
	**MSM 955RD-1** Sulfide fragment of a vent tube was taken from the inner side of the Rockdrill II. It consists of massive chalcopyrite, possibly isocubanite. The outer 3-4 mm rim consist of iron oxides, aragonite and in the transition zone minor contents of pyrite and sphalerite (ZnS). Scale: lower edge = 27 mm.
	**MSM 955RD -3** Iron sulfide, consists nearly to 100% of euhedral pyrite (FeS_2), obviously most of the pyrites have an oktaedral shape, mainly of twins-pentagondodekaeder, only a very few are in a cub habitus. Scale: lower edge = 27 mm
	**MSM 962RD -10** Dense copper sulfides, massive structure, very fresh mainly consist of greyish blue chalcosite Cu_2S (90 %), chalcopyrite $CuFeS_2$ (5 %) and bornite Cu_5FeS_4 (5 %). Scale: Lower edge = 8.5 mm.

Comments and further investigations

All the sulfide minerals that have been sampled did not represent the recent high temperature system. They are of secondary origin, replaced and sedimented. The abundance of the focused outflow of gas rich hydrothermal fluids may have influenced the hydrogen contents. Nevertheless the discovery of autigenous pyrites in the strongly altered and serpentinised mafic rocks could be a further step for understanding the hydrogen storage processes in sulfide minerals.

2.5 Acknowledgements

We gratefully acknowledge the expertise and help of the officers and crew of the Maria S. Merian as well as the professional handling of the Rockdrill team from the British Geological Survey led by Dave Smith. The work was supported by grants from the priority program SPP 1144 of the German Science Foundation (DFG).

2.6 References

Bogdanov, Y.A., Bortnikov, N.S., Vikentyev, I.V., Gurvich, E.G., and Sagalevich, A.M. (1997) A new type of modern mineral-forming systems: black smokers of the hydrothermal field at 14°45'N latitude, Mid-Atlantic Ridge. Geology of Ore Deposits, 39, 68-90.

Cressie, N.A.C. (1991) Statistics for Spatial Data. John Wiley and Sons, Inc., 900 pp.

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2.7 Station list

(By Sonja Storm and Edgars Rudzitis)

Abbreviations: RD = Rockdrill, MUC = Multicorer, GC = Gravity corer, DR = Dredge, MB = Multibeam survey, SV = sound velocity profile.

For Rockdrill, coordinates (differential GPS) are positions determined via Posidonia transponder when drilling was commenced, water depth is ship’s depth. Date is referenced to UTC.

Station	**Date**	**Time [UTC]**	**Latitude / Longitude**	**Depth [m]**	**Brief description**
Martinique					
920 RD	09.11.06 09.11.06	18:22 19:32	14°50.01’N / 60°54.91’W	63 m	test of the Rockdrill in shallow water east of Martinique; at seafloor begin heaving
921 RD	10.11.06 10.11.06	13:47 14:10	14°53.98’N / 60°46.96’W	325 m	test of the Rockdrill in shallow water east of Martinique; at water surface aborted due to hydraulic alarm; begin heaving
922 RD	10.11.06 10.11.06	17:09 20:38	14°53.98’N / 60°46.96’W	325 m	test of the Rockdrill in shallow water east of Martinique; at seafloor begin heaving

Station	Date	Time [UTC]	Latitude / Longitude	Depth [m]	Brief description
near Logatchev					
923 SV	14.11.06	04:41	14°45.16´N / 45°23.29´W	3060 m	acquire sound velocity profile using sound velocity probe
924 MB	14.11.06	07:01	14°45.02´N / 45°04.95´W	3683 m	Multibeam survey using Simrad EM120; max. angle: port: 11°, starboard: 11°; start profile, various courses
	14.11.06	11:12	14°44.50´N / 44°55.05´W	2575 m	end of profile
hilltop on eastern rift valley wall					
925 RD	14.11.06	12:58	14°40.50´N / 44°54.47´W (ship)	1776 m	at water surface, failure, bottom not reached
926 RD	14.11.06	17:00	14°40.501´N / 44°54.497´W	1763 m	at seafloor; drilling
	14.11.06	17:55			begin heaving; ~50 cm core; basalt, glass, pebble of microgabbro
near Logatchev					
927 MUC	14.11.06	20:59	14°42.81´N / 44°57.60´W	3273 m	6 cores of ~22 cm length with pelagic sediment, foraminifera
928 DR	15.11.06	01:25	14°45.40´N / 45°00.50´W	3659 m	start dredging
	15.11.06	02:58	14°45.22´N / 44°59.99´W	3468 m	stop dredging; pristine basalt pillows and fragments of them, often with a glassy outer rim
929 DR	15.11.06	06:50	14°44.00´N / 45°03.20´W	4217 m	start dredging
	15.11.06	07:56	14°44.00´N / 45°02.50´W	4109 m	stop dredging, pillow basalts with glassy rims, Mn-coating
930 MB	15.11.06	10:58	14°44.01´N / 45°05.02´W	3569 m	start profile, various courses
	15.11.06	12:14	14°44.00´N / 45°55.02´W	2748 m	profile end
hilltop on eastern rift valley wall					
931 RD	15.11.06	14:17	14°40.508´N / 44°54.524´W	1762 m	repetition of station 925; at seafloor
	15.11.06	17:15			begin heaving; 2 cores of 1.71 m length; fragments of vesicular to dense basalt; fractures filled with chlorite and a mixture of carbonate and mud
hilltop just to NW of Logatchev					
932 RD	15.11.06	22:13	14°45.184´N / 44°58.875´W	3030 m	at seafloor; aborted due to loss of fibre optic connection; no core
	15.11.06	22:37			begin heaving
near Logatchev					
933 MUC	15.11.06	02:17	14°45.81´N / 44°58.80´W	3224 m	11 cores (30 cm in length) with pelagic sediment; biogenic carboniferous pteropoda-foramini-ferous sandy, silty mud (ooze)
934 MB	16.11.06	04:52	14°43.54´N / 44°54.93´W	2662 m	start profile, various courses
	16.11.06	11:19	14°41.50´N /	3011 m	end of profile

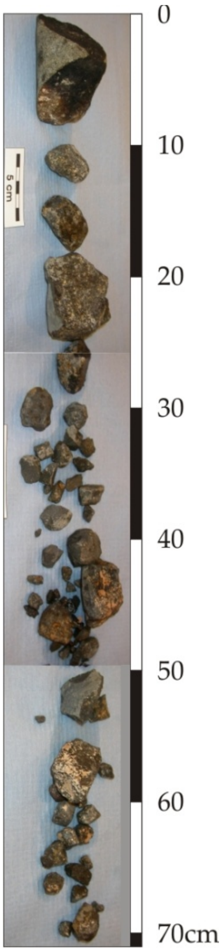
Station	Date	Time [UTC]	Latitude / Longitude	Depth [m]	Brief description
			44°56.46´W		
935 MUC	16.11.06	13:19	14°45.320´N / 44°58.870´W	3055 m	7 cores (15-28 cm in length) with homogeneous pelagic sediment; sandy to silty carboniferous (foraminifera) mud,
936 DR	16.11.06	17:08	14°46.00´N / 45°02.50´W	4167 m	start dredging
	16.11.06	18:09	14°45.80´N / 45°02.00´W	3904 m	stop dredging; numerous pristine, cm-sized samples of dark brown basaltic glass; in some cases dense basalt underneath glass layer
937 DR	16.11.06	22:11	14°48.31´N / 45°02.40´W	4069 m	start dredging
	16.11.06	23:13	14°48.00´N / 45°02.00´W	3964 m	stop dredging; ~100 kg brownish, clay-silty sediment; 100 g of dense greenish weathered, slightly vesicular basalt fragments, often with Mn-coating
938 DR	17.11.06	03:29	14°50.00´N / 45°02.00´W	3859 m	start dredging
	17.11.06	05:05	14°50.00´N / 45°01.50´W	3796 m	stop dredging; large basalt pillow (cut on one side) with glassy outer rim; several rim sections of that pillow; large pillow with Mn-coating and glass layer
939 MB	17.11.06	08:14	14°46.48'N / 44°54.40´W	2597 m	start profile, various courses
	17.11.06	12:00	14°41.59'N / 44°54.70´W	1991 m	end of profile
mound W of Logatchev					
940 RD	17.11.06	13:00	14°45.20´N / 44°58.90´W (ship)	3024 m	at water surface; communication lost
	17.11.06	16:08			on deck
near Logatchev					
941 DR	17.11.06	17:32	14°45.10´N / 44°59.60´W	3170 m	start dredging
	17.11.06	18:25	14°45.10´N / 44°59.20´W	3080 m	stop dredging; pelagic sediment; large boulder (45 cm in diameter) of coarse-grained gabbronoritic cumulate
942 DR	17.11.06	21:44	14°43.55´N / 44°58.85´W	3276 m	start dredging
	17.11.06	22:47	14°43.45´N / 44°58.30´W	3007 m	stop dredging; variety of mafic and ultramafic rocks: coarse to fine grained gabbronorites; harzburgites (some serpentinized), serpentinite, peridotite; most samples coated with grainy layer of Mn-oxide
943 DR	18.11.06	02:41	14°46.50´N / 44°58.30´W	3074 m	start dredging
	18.11.06	03:46	14°46.35´N / 44°58.00´W	2720 m	stop dredging; fragments of dense vesicular basalt and rim sections of

Station	Date	Time [UTC]	Latitude / Longitude	Depth [m]	Brief description
					basaltic pillow with Mn-coating
944 MB	18.11.06 18.11.06	06:42 12:00	14°47.00´N / 44°54.59´W 14°48.50´N / 45°00.28´W	2628 m 3794 m	start profile, various courses end of profile
at Logatchev					
945 GC	18.11.06	13:56	14°45.222´N / 44°58.816´W	3042 m	124 cm core; sandy with rock fragments to typical deep-sea clay, layer with altered disintegrated gabbro; samples only taken from the lower meter
946 GC	18.11.06	16:57	14°45.139´N / 44°58.714´W	2998 m	175 cm core; clay matrix with rock fragments; layer with mixture of chloride and serpentinite; multi-coloured section
947 GC	18.11.06	20:16	14°45.159´N / 44°58.741´W	3016 m	160 cm core; homogeneous silty to sandy matrix with distinct colour transition; layer with altered rock fragments; dense clay matrix with dark brown crust-like fracture filling
948-1 RD	18.11.06 19.11.06	22:55 02:04	14°45.222´N / 44°58.813´W	3047 m	at water surface; communication lost, dive aborted on deck
948-2 RD	19.11.06 19.11.06	03:12 06:46	14°45.222´N / 44°58.813´W	3038 m	at water surface; testing termination, dive aborted on deck
949 DR	19.11.06 19.11.06	08:25 10:02	14°43.16´N / 44°56.50´W 14°42.85´N / 44°55.75´W	2744 m 2568 m	start dredging stop dredging; mainly ultramafic but also mafic samples: serpentinites, altered gabbronorites, serpentinized harzburgites; one remarkable serpentinite sample cut by a cm-thick hornblende-gabbronorite vein
950-1 RD	19.11.06 19.11.06	14:46 17:51	14°45.22´N / 44°58.82´W	3040 m 3047 m	at water surface; communication lost; dive aborted on deck
950-2 RD	19.11.06 19.11.06	21:40 23:24	14°45.21´N / 44°58.79´W	3036 m 3041 m	at seafloor; communication lost; aborted on deck
951 DR	20.11.06 20.11.06	01:50 02:27	14°40.00´N / 45°01.31´W 14°40.00´N / 45°01.50´W	3773 m 3803 m	start dredging stop dredging; basalt pillow showing up to 3 mm thick outer glassy rim followed by dense, vesicular basalt
952 MB	20.11.06 20.11.06	04:55 11:35	14°42.49´N / 44°59.51´W 14°49.50´N / 45°05.36´W	3778 m 2981 m	start profile, various courses end of profile
953 GC	20.11.06	15:28	14°45.109´N / 44°58.703´W	2988 m	254 cm core; iron-silica crusts; sulfide and silicate crusts; mixture of grain sizes from clay to gravel
954 RD	20.11.06	21:09	14°45.112´N /	2977 m	at seafloor; start drilling

Station	**Date**	**Time [UTC]**	**Latitude / Longitude**	**Depth [m]**	**Brief description**
			44°58.703´W		
		03:06			begin heaving; 4 barrels were drilled, but material was only in 2. (<25%) and 4. (50%) barrel; iron-silica crust, fragment of massive sulfide, strongly altered peridotite, pyrite aggregates
955 RD	21.11.06	12:43	14°45.192´N / 44°58.772´W	3016 m	at seafloor
	22.11.06	10:49		3019 m	begin heaving; 9 barrels drilled; gravel in barrel 3, 7. and 8 (black coating due to heat); gravel of altered gabbroids, peridotites, serpentinites; Py-crust on top of barrel 7; Rockdrill 2 “collected” two pieces of massive sulfides of Cu-chimneys in the frame
956 MB	22.11.06	13:20	14°47.99´N / 44°55.51´W	2673 m	start profile, various courses
	22.11.06	16:25	14°41.31´N / 44°54.40´W	1855 m	end of profile
957 RD	22.11.06	19:37	14°45.220´N / 44°58.818´W	3045 m	at seafloor
	23.11.06	21:52			begin heaving; 8 cores drilled; barrel 1 and 2 contained sediments, barrels 3-8 rock fragments
958 GC	24.11.06	00:24	14°45.223´N / 44°58.815´W	3042 m	empty except for a few pieces of sulfide crust
959 RD	24.11.06	06:39	14°45.199´N / 44°58.637´W	2997 m	at seafloor; drilling
	24.11.06	22:17			begin heaving; 6 barrels drilled, hydrothermal sediments, fragments of altered rocks, Fe-Mn-crusts
960 GC	25.11.06	01:05	14°45.090´N / 44°58.702´W	2968 m	70 cm core; sediments and mixture of rock fragments
961 MB	25.11.06	02:08	14°44.98´N / 44°58.75´W	3004 m	start profile, various courses
	25.11.06	04:00	14°45.12´N / 44°58.55´W	2923 m	end of profile
962 RD	25.11.06	06:22	14°45.114´N / 44°58.713´W	2983 m	at seafloor
	26.11.06	13:19			begin heaving; 11 cores drilled; barrel 6 empty; sulfide pebbles at 10 m depth
963 GC	26.11.06	16:05	14°45.100´N / 44°58.672´W	2952 m	57 cm core; hydrothermal sediment with sulfides
964 GC	26.11.06	19:52	14°45.081´N / 44°58.704´W	2972 m	77 cm core; hydrothermal sediment, Fe-Mn-crusts
965 GC	26.11.06	22:05	14°45.169´N / 44°58.637´W	2994 m	155 cm core; hydrothermal sediment, Fe-Si-Mn-crusts
966 DR	27.11.06	00:40	14°42.00´N / 44°59.20´W	3435 m	start dredging
	27.11.06	01:29	14°42.00´N / 44°58.80´W	3419 m	stop dredging; pelagic sediment with a few small pieces of basalt

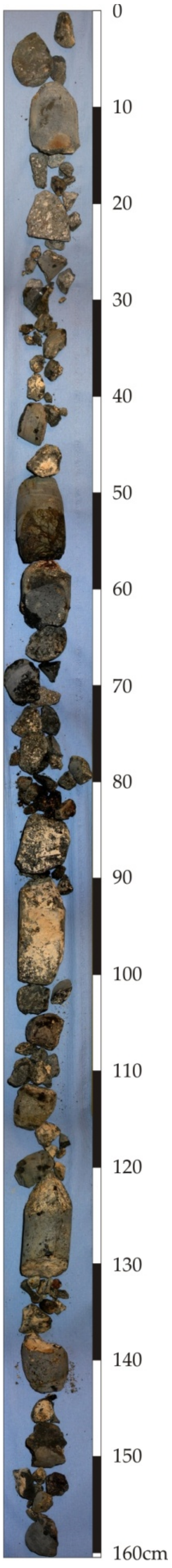
Appendix A: BGS Report

Appendix B: Core Descriptions of Rock Drill-Stations

<table>
<tr><td><u>MSM 03/2
926 RD</u></td><td>Description</td><td>Lat: 14°40.501´N Long: 44°54.497´W
Depth: 1763m Penetration: 1.0m Recovery: 25%</td></tr>
<tr><td>
</td><td><u>0-70cm</u>
- bigger pieces of basalt, fine grained with plg/cpx crystals, joints coated with Mn-oxides, weathering of the outside, core pristine, vesicles; diverse pieces of dense vesicular basalts with rare phenocrysts; some glass pebbles

(section condensed to 25 cm)</td><td>Section was drilled from 0 to 95 cm below the seafloor</td></tr>
</table>

MSM 03/2 **931 RD-2**	**Description**	Lat: **14°40.509´N** Long: **44°54.525´W** Depth: **1762m** Penetration: **1.8m** Recovery: **95%**



0-45cm
- vesicular, fractured basalt; fractures filled with clay/chlorite; dense matrix with rare olivine phenocrysts; vesicles are empty

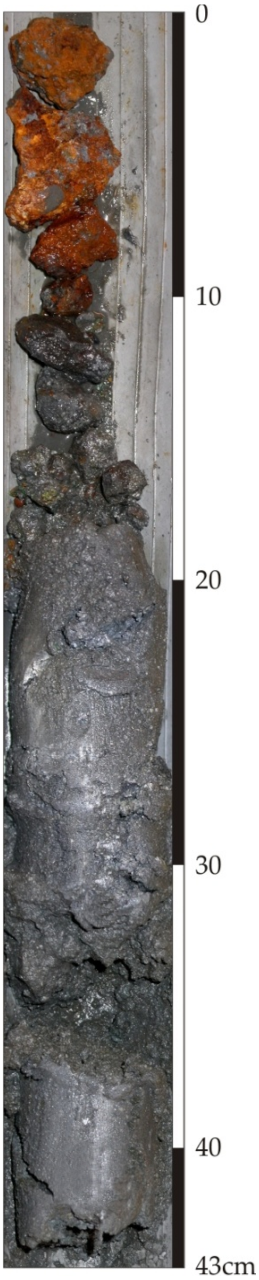
45-58cm
- clastic basalt, greenish chloritized and limonitized, no chrystals visible

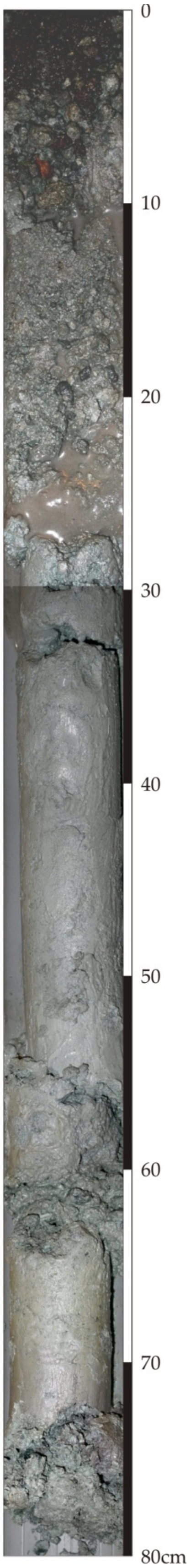
58-100cm
- vesicular, fractured basalt, lower parts more fractured; fractures filled with carbonates and mud, vesicles become rarer

105-130cm
- dense and slightly vesicular basalt

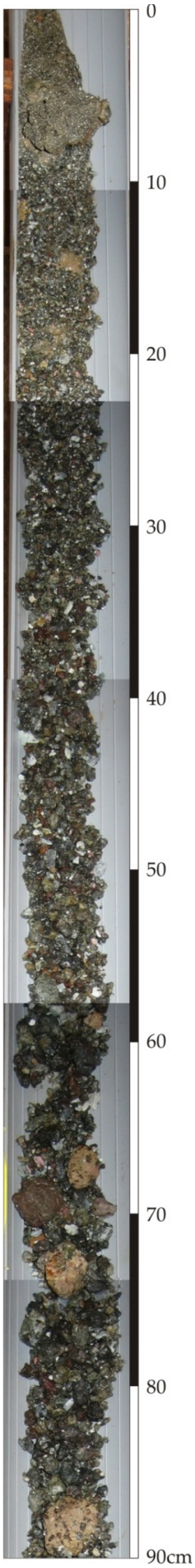
130-145cm
- vesicular basalt, fractures filled with carbonate and mud, Mn-ore

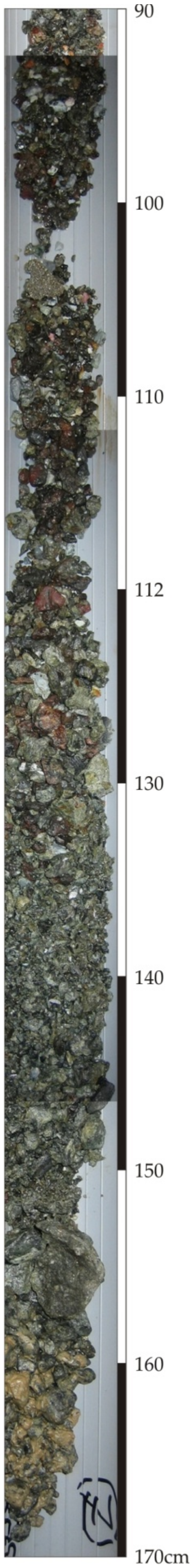
145-160cm
- fragments of dense basalt with few vesicles, fractured, coated with carbonate/mud

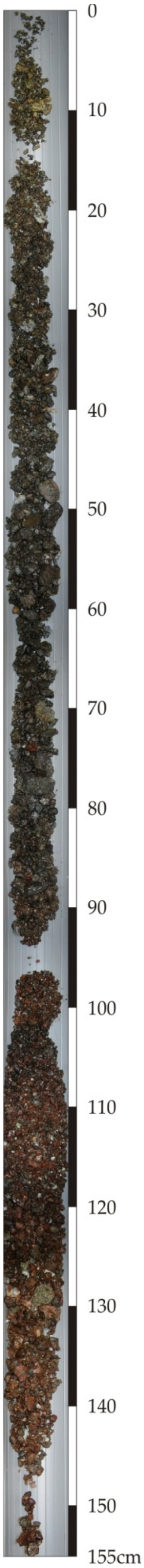
<u>MSM 03/2</u> **<u>954 RD - 2</u>**	**Description**	Lat: **14°45.112´N** Long: **44°58.703´W** Depth: **2977m** Penetration: **6.1m** Recovery: **20%**
 	**<u>0-10cm</u>** - red-brown fragments of FeOOH crust **<u>10-18cm</u>** - fragments of massive sulfides (chalcopyrite and secondary Cu-sulfides) **<u>18-43cm</u>** - dark-greyish clay sized to sandy, strongly altered serpentinite mud consisting talc and finely dispersed sulfides	This section drilled from 154cm to 309 cm (157 cm). The Fe-oxyhydroxides likely represent surface material.

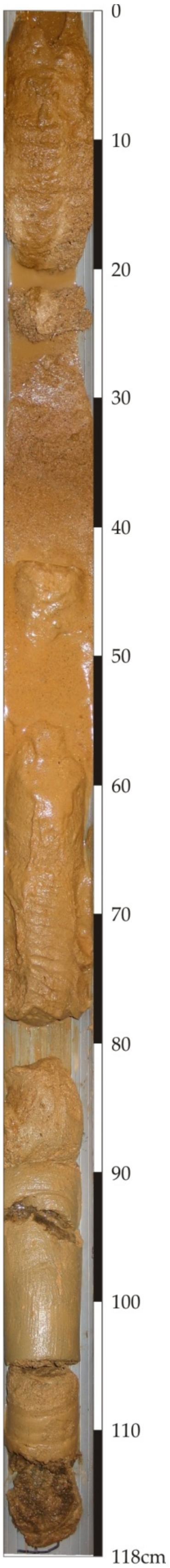
<table>
<tr><th><u>MSM 03/2
954 RD - 4</u></th><th>Description</th><th>Lat: 14°45.112´N Long: 44°58.703´W
Depth: 2977m Penetration: 6.1m Recovery: 20%</th></tr>
<tr><td>
</td><td><u>0-25cm</u>
- dense black to grey serpentinite and gabbro-norite in sandy and clay sized material; mm-sized atacamite fragments and sulfide grains

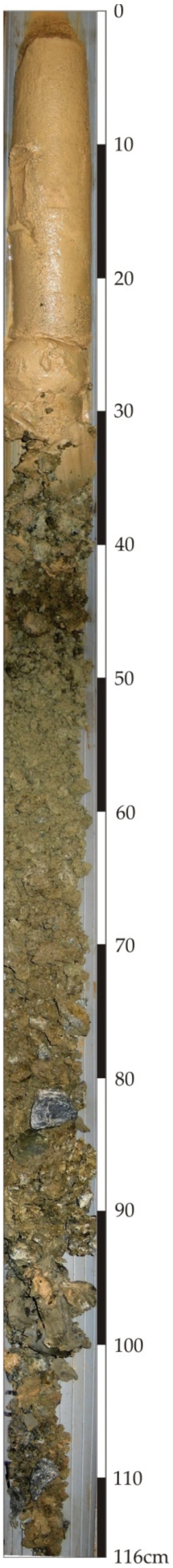
<u>25-80cm</u>
- grey clay sized to sandy, strongly altered serpentinite-talc mud with rock fragments and finely dispersed pyrite</td><td>This section was cored between 462 and 614 cm (152 cm). Again the uppermost pieces represent surface material while the reminder of the material retrieved is believed to represent in-situ material at depth. Reduced water flush during this drilling station and thereby recovered the fine-grained material.</td></tr>
</table>

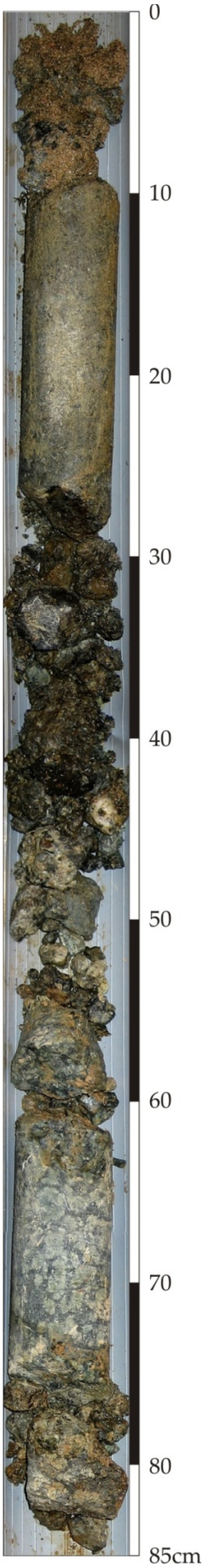
MSM 03/2 **955 RD – 7 (1)**	**Description**	Lat: **14°45.192´N** Long: **44°58.772´W** Depth: **3016m** Penetration: **9.1m** Recovery: **25%**
 	**Top** pyrite-crust (20x40x50mm) with rock-inclusions **0-40cm** - thin gravel - coarse sand mixture of highly altered gabbronorites (50%) and serpentinites (50%); tiny pyrite crystals and aggregates (0.5mm), rare barite, atacamite and hematite **40-90cm** - dark brown to black sand composed of heavily weathered gabbronorite and minor serpentinite, some rock fragments showing hematite impregnation Pyrite 3-5% (~0.5mm); rare atacamite	Section drilled from 795 cm to 948cm (153 cm). Material recovered does not allow for stratigraphy and likely represents a mixture of lithologies encountered during drilling. Fine-grained material is likely flushed out by the drilling fluid.

<u>MSM 03/2</u> **<u>955 RD – 7 (2)</u>**	**Description**	Lat: **14°45.192´N** Long: **44°58.772´W** Depth: **3016m** Penetration: **9.1m** Recovery: **25%**
	**<u>90-112cm</u>** - dark brown to black sand composed of heavily weathered gabbronorite and minor serpentinite, some rock fragments showing hematite impregnation **<u>112-170cm</u>** - greenish gravel composed of heavily weathered serpentinite and minor gabbronorite, some rock fragments showing hematite impregnation (section condensed to maximum of 150 cm)	(continued from above)

MSM 03/2 **955 RD - 8**	**Description**	Lat: **14°45.192´N** Long: **44°58.772´W** Depth: **3016m** Penetration: **9.1m** Recovery: **25%**
	**0-95cm** - dark brown to black sand composed of heavily weathered gabbronorite and serpentinite, some rock fragments showing hematite impregnation, pyrite 1-3% (up to 3mm) **95-155cm** - dark brown to red altered rock fragments composed of heavily weathered, hematite impregnated serpentinite, pyrite 7-10%	This section started drilling at 883cm (883cm to 906cm) slightly higher up then the previous drilling ended. This indicates partial collapse of the hole. The core barrel collected fine-grained material while pushing through the hole until it started coring. This explains the amount of material in the core barrel despite drilling of only 23 cm. Again, stratigraphy is not possible. However the material encountered indicates the heteorgeneity of the subseafloor in this area.

MSM 03/2 **957 RD - 1**	**Description**	Lat: **14°45.220´N** Long: **44°58.818´W** Depth: **3045m** Penetration: **7.0m** Recovery: **81%**
	**0-118cm** - light brown, clay sized to sandy pelagic sediment with Fe-staining	Section "drilled" between 0 cm and 152cm with low rotation and no water flush.

MSM 03/2 957 RD - 2	**Description**	Lat: **14°45.220´N** Long: **44°58.818´W** Depth: **3045m** Penetration: **7.0m** Recovery: **81%**
	**0-35cm** - light brown pelagic sediment **35-116cm** - totally decomposed, chloritized gabbronorites and ultramafics includes in a grayish-green mass of clay; ultramafics: mesh texture, strongly veined, mesh centers partly replaced by Fe-oxihydroxides, dark green to black color; gabbronorites: coarse grained, euhedral px and anhedral plag	Section drilled between 152 and 263cm (111 cm). Sediment seems to be in situ and not from the surface since Fe-oxyhydroxides, oresent in the uppermost core, are not present here. This section also drilled “dry”.

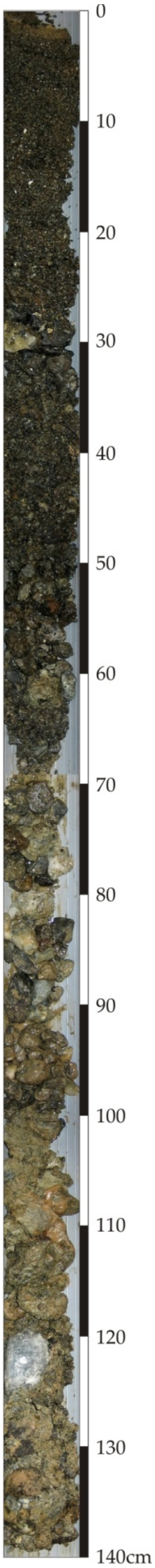
<table>
<tr><th><u>MSM 03/2
957 RD - 3</u></th><th>Description</th><th>Lat: 14°45.220´N Long: 44°58.818´W
Depth: 3045m Penetration: 7.0m Recovery: 81%</th></tr>
<tr><td></td><td><u>0-10cm</u>
- dense black serpentinite and gabbronorite in sandy material

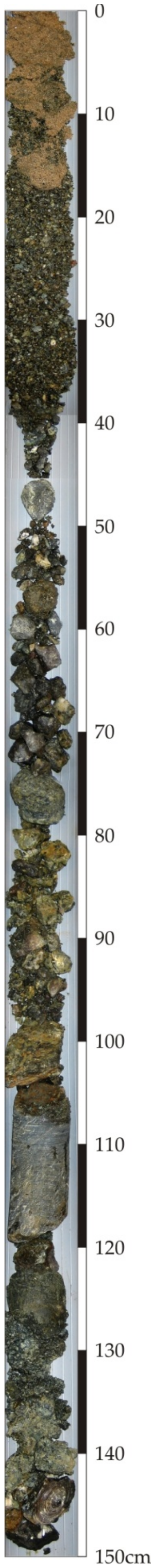
<u>10-30cm</u>
- core of medium grained gabbronorite, pristine cut by felsic 5mm wide vein

<u>30-55cm</u>
- pebbles in subordinate sandy material consisting of medium to coarse grained gabbronorite, dense black serpentinite and felsic material of probably hydrothermal origin

<u>55-75cm</u>
- core of serpentinized peridotite (harzburgite) with dark green to black matrix, mesh texture, cm-sized px, often rimmed by amphibole or serpentine, serpentine veining

<u>75-80cm</u>
- gravel of serpentinized peridotite described above</td><td></td></tr>
</table>

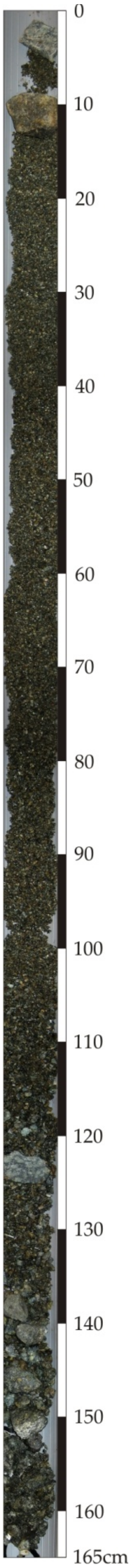
MSM 03/2 **957 RD - 4**	**Description**	Lat: **14°45.220´N** Long: **44°58.818´W** Depth: **3045m** Penetration: **7.0m** Recovery: **81%**
	**0-50cm** - coarse sandy debris of mainly gabbronoritic origin incorporating plag, px, opaques, minor carb. biogeneous material; minor cm-sized samples of veined serpentinite **50-100cm** - pebbles in sandymaterial mainly brecciate, serpenti-nized dark to black ultramafics as well as fragments of secondary quartz-veines; orange-red Fe-oxihydroxides in serpentinites **100-140cm** - greenish-yellow clay incorporating fragments of serpentinized harzburgite (with mesh texture; mesh centers partly replaced by Fe-oxihydroxides), medium grained gabbronorite and gabbronorites with accumulation of felsic material	

<table>
<tr>
<td><u>MSM 03/2
957 RD - 5</u></td>
<td>Description</td>
<td>Lat: 14°45.220´N Long: 44°58.818´W
Depth: 3045m Penetration: 7.0m Recovery: 81%</td>
</tr>
<tr>
<td>
</td>
<td><u>0-18cm</u>
- brown pelagic sediment (clay sized to sandy) mixed with mm-sized serpentinite fragments

<u>18-45cm</u>
- mixture of sand and gravel; small pieces of serpentinite; fragments of opx crystal; Fe-oxihydroxides

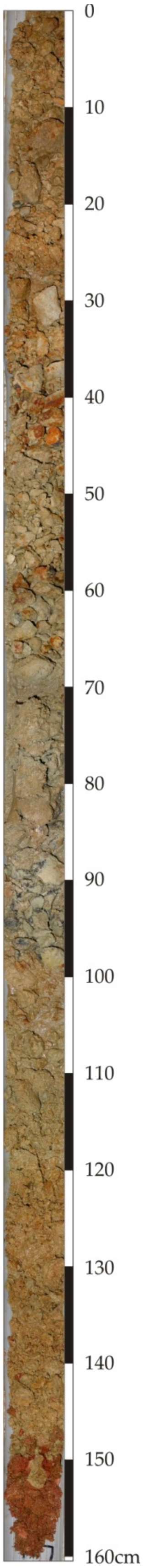
<u>45-105cm</u>
- pebbles of serpentinized peridotite and coarse grained gabbronorites; serpentinites with boudin structure of opx, strongly veined and mesh texture; secondary quartz fragments

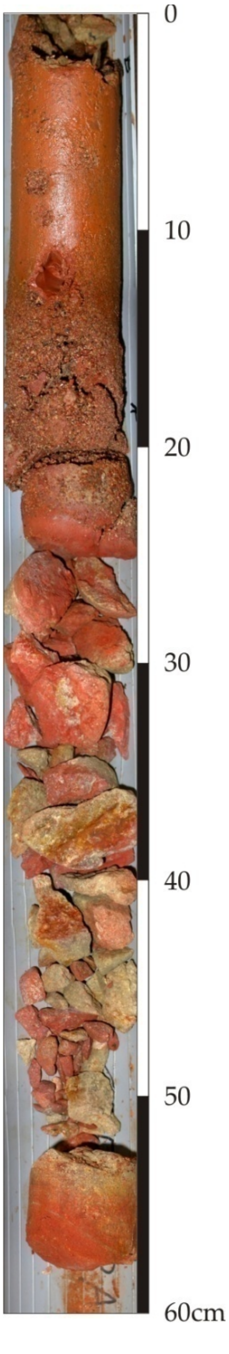
<u>105-120cm</u>
- core of serpentinized dunite with fine veines of chrysotile</td>
<td>Upper part represents surface material.</td>
</tr>
</table>

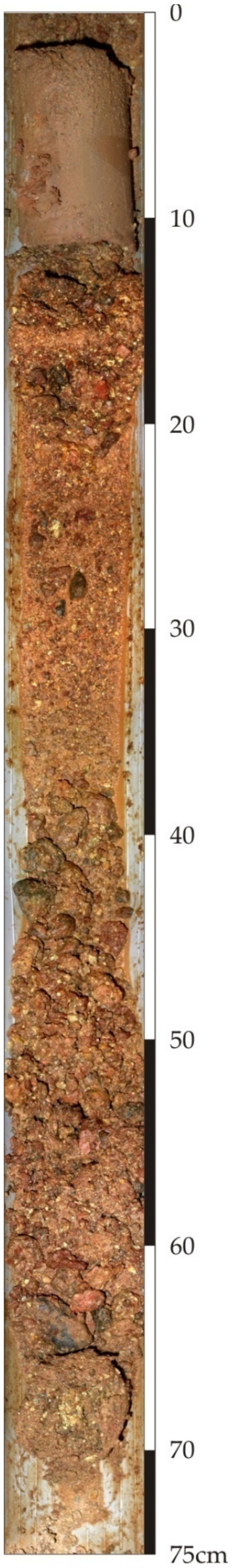
MSM 03/2 **957 RD – 6**	**Description**	Lat: **14°45.220´N** Long: **44°58.818´W** Depth: **3045m** Penetration: **7.0m** Recovery: **81%**
	**collapsed drill hole:** - mixture of sand and gravel made of serpentinites, minor altered gabbronorite and Fe-oxihydroxides	No stratigraphy possible. Hole collapsed. The following barrels 7 and 8 fail to get back down hole. They core but do not reach depth of core run 6. Both have no recovery.

<table>
<tr><th><u>MSM 03/2</u>
<u>959 RD – 1</u></th><th>Description</th><th>Lat: 14°45.199´N Long: 44°58.637´W
Depth: 2997m Penetration: 7.9m Recovery: 67%</th></tr>
<tr><td>
0
10
20
30
40
50
60cm</td><td><u>0-32cm</u>
- red-brown pelagic sediment (clay sized to sandy) with tiny rock fragments

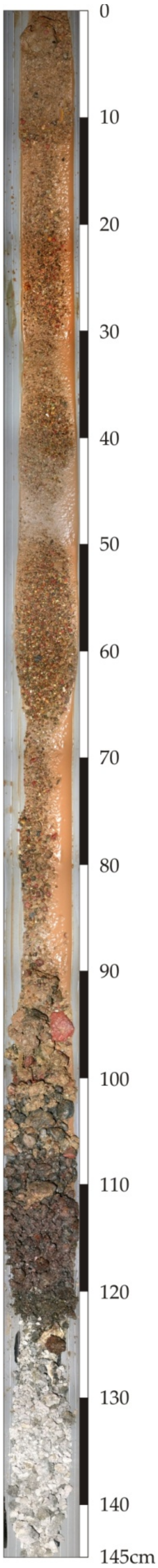
<u>32-60cm</u>
- light-brown pelagic sediment (clay sized) with tiny rock fragments</td><td>Section pushed into the seabed from 0 cm to 152 cm.</td></tr>
</table>

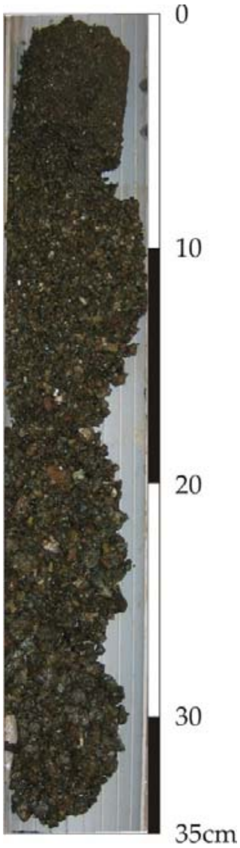
MSM 03/2 **959 RD – 2**	**Description**	Lat: **14°45.199´N** Long: **44°58.637´W** Depth: **2997m** Penetration: **7.9m** Recovery: **67%**
	**0-70cm** - red-brown to brown clay with fragments of host rocks and FeOOH crusts **70-100cm** - grey to brown clay **100-150cm** - brown to orange-brown clay	Section again pushed in from 152 cm to 305 cm (153 cm) with higher resistance after 70 cm.

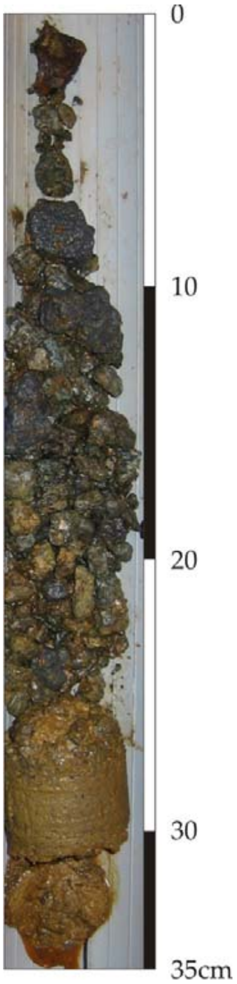
<u>MSM 03/2</u> **<u>959 RD – 3</u>**	**Description**	Lat: **14°45.199´N** Long: **44°58.637´W** Depth: **2997m** Penetration: **7.9m** Recovery: **67%**
 	**<u>0-25cm</u>** - red Fe-oxyhydroxide rich clay with tiny fragments of altered host rocks **<u>25-60cm</u>** - light grey to red Fe-oxyhydroxide rich altered rocks, precursor rocks are unknown	Section drilled from 305 cm to 457 cm (152 cm).

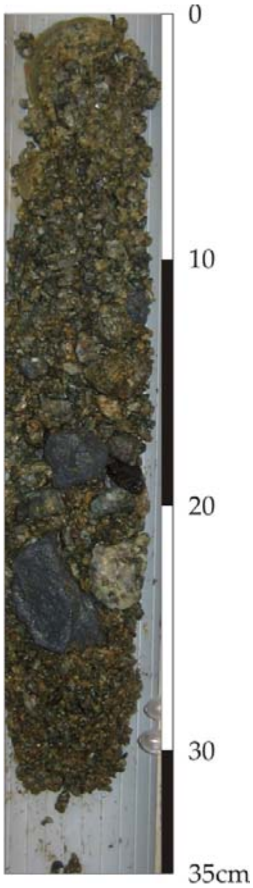
MSM 03/2 **959 RD – 4**	**Description**	Lat: **14°45.199´N** Long: **44°58.637´W** Depth: **2997m** Penetration: **7.9m** Recovery: **67%**
	**0-11cm** - brown clay **11-70cm** - mixture made of light-brown to brown clay and sand as well as diverse types of altered and unaltered rocks (serpentinites and gabbroics) in different size (mm to cm)	Section drilled from 457 cm to 610 cm (153 cm). Lower part of the core does not allow for stratigraphy, but shows the abundance of sand- and gravel-sized wallrock fragments and the heterogeneity of the material.

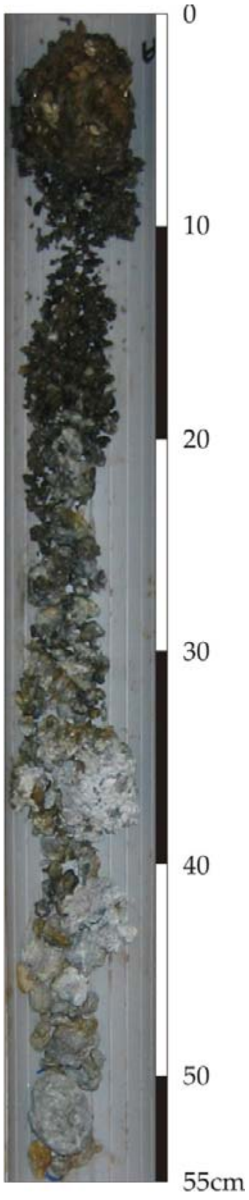
MSM 03/2 **959 RD – 5**	**Description**	Lat: **14°45.199´N** Long: **44°58.637´W** Depth: **2997m** Penetration: **7.9m** Recovery: **67%**
	**0-150cm** - fragments of red to light pink Fe-oxyhydroxide rich altered rocks, precursor rocks are unknown no stratigraphy (Recovery is condensed to 1.4 m = drilled interval)	Section drilled from 602 cm (slightly higher than previous core barrel) to 743 cm (141 cm)

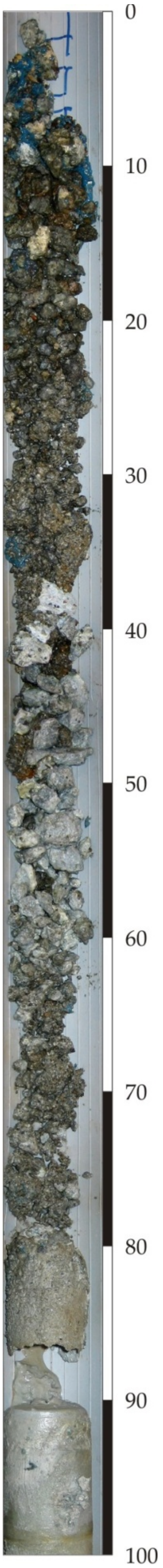
MSM 03/2 **959 RD – 6**	**Description**	Lat: **14°45.199´N** Long: **44°58.637´W** Depth: **2997m** Penetration: **7.9m** Recovery: **67%**
	**0-10cm** - fragments of different size of red to red-brown Fe-oxyhydroxide rich altered rocks in sandy to clay sized mixture of light brown mud, precursor rocks are unknown (upper part condensed to 10 cm !) **10-22cm** - dark red-brown to black gravel mainly consisting of fragments of heavily altered gabbronorite and serpentinite **22-45cm** - gravel of strongly altered talc-rich rocks	This section was drilled from 743 cm to 794 cm (51 cm) when drill bit blocked. After recovery it become obvious that the drill bit was left behind in the hole.

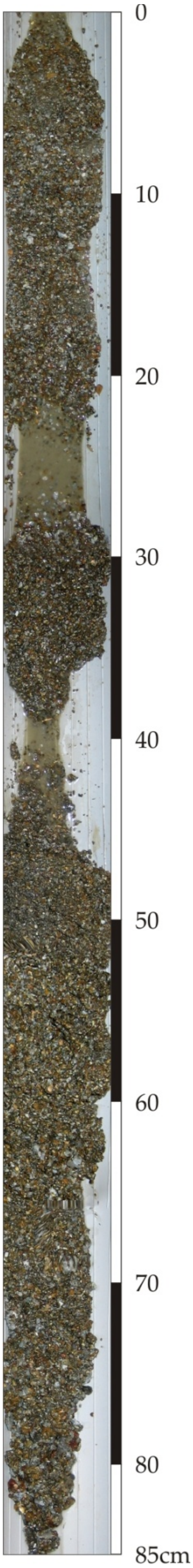
MSM 03/2 **962 RD - 2**	**Description**	Lat: **14°45.114´N** Long: **44°58.713´W** Depth: **2983m** Penetration: **10.3m** Recovery: **36%**
 	**0-35cm** - dark brown to black sand with gravel mainly consisting of heavily altered gabbronorite and minor fragments of serpentinite.	Section drilled from 153 cm to 306 cm (153 cm). Drilling characteristics seem to indicate “voids” in the subseafloor.

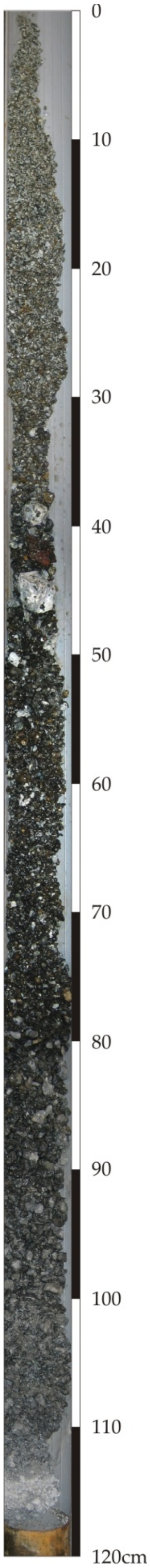
MSM 03/2 **962 RD – 3**	**Description**	Lat: **14°45.114´N** Long: **44°58.713´W** Depth: **2983m** Penetration: **10.3m** Recovery: **36%**
 	**0-5cm** - compact mass of yellow-brown clay containing mm-sized pieces of decomposed pyroxenes and ultramafic fragments **5-25cm** - mixture of massive sulfide fragments, completely serpentinized peridotites and gabbronorites with orange-red spots of Fe-hydroxides - one piece of limmitic crust is present **25-30cm** - mixture of brown mud and fragments of serpentinites and gabbroic rocks	Drilled between 263 cm (slightly higher up than previous core barrel) and 416 cm (153 cm).

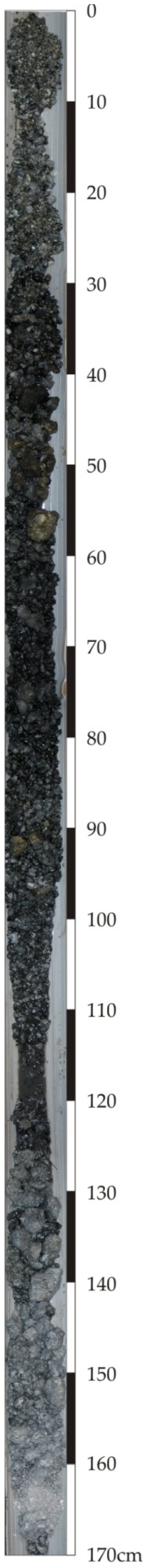
MSM 03/2 **962 RD – 4**	**Description**	Lat: **14°45.114´N** Long: **44°58.713´W** Depth: **2983m** Penetration: **10.3m** Recovery: **36%**
	**0-30cm** - mixture of sand, gravel and pebbles composed of serpentinized ultramafics, weathered gabbroics and pieces of massive sulfides (partly oxidized)	Drilled between 389 cm (again slightly higher up than previous barrel = redrill) and 546 cm (157 cm).

MSM 03/2 **962 RD - 5**	**Description**	Lat: **14°45.114´N** Long: **44°58.713´W** Depth: **2983m** Penetration: **10.3m** Recovery: **36%**
	**0-20** - gravel and pebbles of strongly altered gabbro-norite **20-55** - sand and gravel containing altered gabbronorite and serpentinites showing talc-coating, one larger fragment of gabbronorite	Drilling from 402 cm to 554 cm = redrill of previous section! Since talc-rich material is new for this hole this is assumed to represent the lowermost unit encountered up to now.

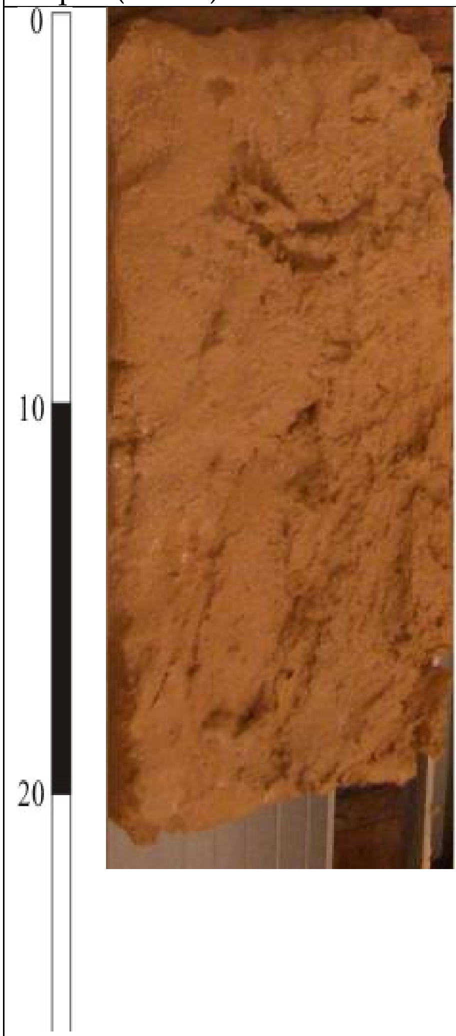
MSM 03/2 **962 RD – 7**	**Description**	Lat: **14°45.114´N** Long: **44°58.713´W** Depth: **2983m** Penetration: **10.3m** Recovery: **36%**
 	**0-40cm** - brownish-grey gravel composed of strongly weathered gabbronorite and fragments of limonite **40-65cm** - gravel and pebbles of strongly altered gabbro-norite showing talc-coating **65-80cm** - gravel and sand of strongly altered gabbronorite with talc-coating **80-100cm** - greenish-grey compact mass of clay and sand with light smell of sulfur	This section drilled from 701 cm to 853 cm (152 cm). Good water flow. Section in-situ.

MSM 03/2 **962 RD - 8**	**Description**	Lat: **14°45.114´N** Long: **44°58.713´W** Depth: **2983m** Penetration: **10.3m** Recovery: **36%**
	**0-47cm** - dark brown to black sand composed of heavily weathered gabbronorite and minor serpentinite (Section condensed to maximum of 47 cm = drilled interval)	Drilled from 853 cm to 900 cm (47 cm). Flushed out fine material.

<u>MSM 03/2</u> **<u>962 RD – 9</u>**	**Description**	Lat: **14°45.114´N** Long: **44°58.713´W** Depth: **2983m** Penetration: **10.3m** Recovery: **36%**
	**<u>0-15cm</u>** - brown sand containing light-grey fragments, mainly made up of weathered and talc-coated particles of gabbronorite (condensed by half from 30cm) **<u>15-59cm</u>** - sand, gravel and minor pebbles with sand containing gabbronorite fragments, gravel and pebbles being talc-coated, gabbronorite and limonite with atacamite. Oxide pieces likely from surface. (section condensed to maximum of 59 cm = drilled interval)	This section was drilled from 900 cm to 959 cm (59 cm) and obviously collected fine-grained gravel and sand that fell into the hole as well.

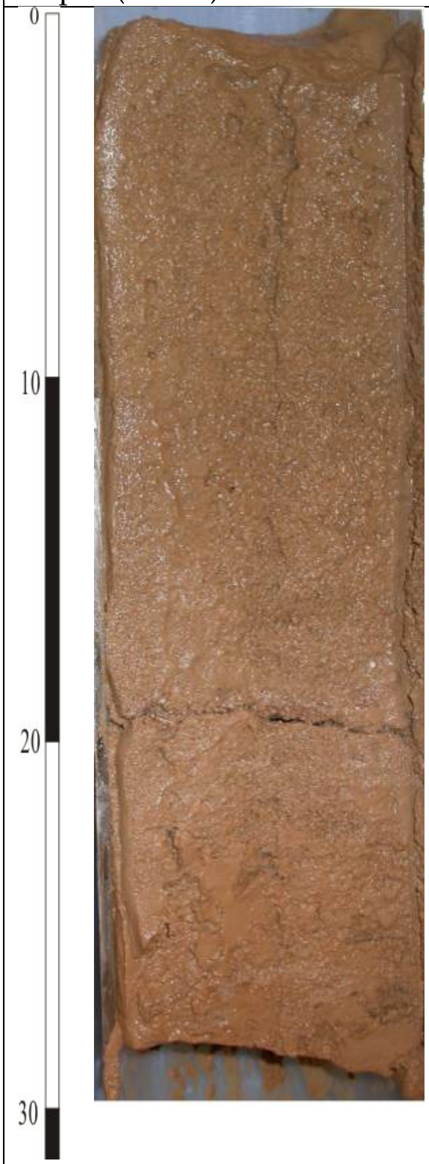
MSM 03/2 **962 RD - 10**	**Description**	Lat: **14°45.114´N** Long: **44°58.713´W** Depth: **2983m** Penetration: **10.3m** Recovery: **36%**
	**0-30cm** - sand and gravel containing serpentinized peridotite and talc-coated gabbronorite with minor fragments of massive sulfide grains and quartz pebbles **30-45cm** - pebbles of minor talc-coated, altered gabbronorite with larger fragments of partly oxidized massive sulfides (chalcopyrite) **45-100cm** - gravel and large amounts of pebbles consisting of talc-coated gabbronorite, serpentinite and some fragments of massive sulfide **100-170cm** - gravel and pebbles of sulfide impregnated gabbronorite showing tiny disseminated crystals of pyrite (this entire section con-densed to maximum of 47cm ! = drilled interval)	Section drilled from 949cm (slightly higher than previous core barrel ended) to 1006 cm (47 cm). No stratigraphy possible, hower, lower part was likely drilled at depth. Large sulfide pebbles and disseminated sulfide within the gabbronorite could indicate presence of sulfides at depth.

Appendix C: Core Descriptions of GC-Stations

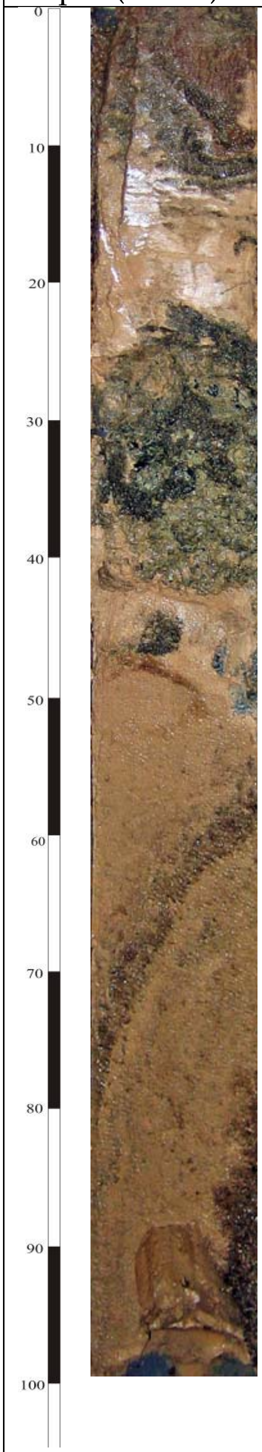
MSM 03/02	Station: MSM 927 MUC
Location: 1.5 km SE of LHF-1 Latitude: 14°42.81′ N Longitude: 44°57.60′ W	Water depth: 3278 m Recovery: 22 cm Date: 14.11.2006 20:58
Depth (cmbsf)	Lithology
	0-10 cm: More sandy (foraminifera) and lighter. Dark yellowish orange (10YR-6/6); homogenous calcareous sandy silty clay; foraminifera bearing
	10-22 cm: Less sandy (foraminifera) and darker. Dark yellowish orange (10YR-6/6); homogenous calcareous sandy silty clay; foraminifera bearing
	Note: Fraction > 0.8 mm: Mostly foraminifera, and abiogenic components (rocks fragments.) Rocks fragments: serpentinites (65%), gabbroids 35%). Serpentinite: greenish brown, impregnated by magnetite. Rare bastite. Gabbroides: pyroxene, plagioclase, their aggregates, amphibolized pyroxene. 2 grains of talc.

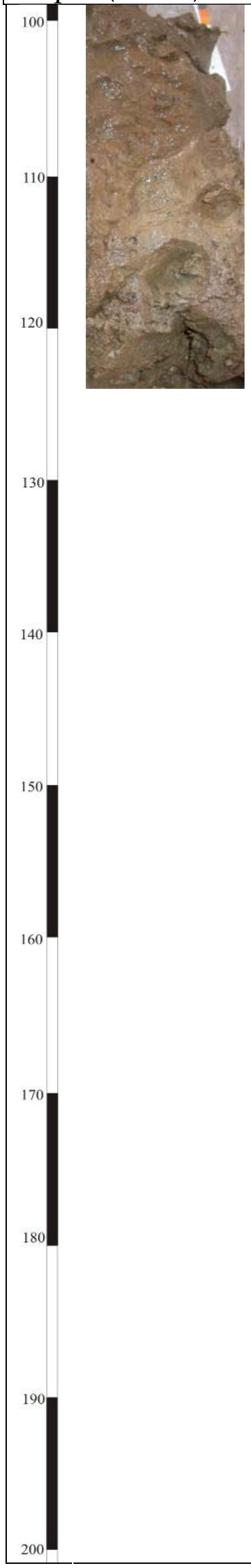
<table>
<tr><td>MSM 03/02</td><td>Station: MSM 933 MUC</td></tr>
<tr><td>Location: 1.3 km N of LHF-1
Latitude: 14°45.81' N
Longitude: 44°58.80’ W</td><td>Water depth: 3225.7 m
Recovery: 29 cm
Date: 15.11.2006 02:15</td></tr>
<tr><td>Depth (cmbsf)</td><td>Lithology</td></tr>
<tr><td rowspan="3"></td><td>0-6cm: Dark yellowish orange (10YR-6/6); foraminiferous sandy to silty clay; abundant forams, few pteropods.</td></tr>
<tr><td>6-10 cm: Dark yellowish orange (10YR-6/6) pteropoda and foraminifera bearing sandy silty clay; abundant foraminifera, numerous pteropoda.</td></tr>
<tr><td>10-29 cm: Dark yellowish orange (10YR-6/6); foraminifera and pteropoda bearing sandy clay; abundant pteropods, minor foraminifera.
29cm: End of core.

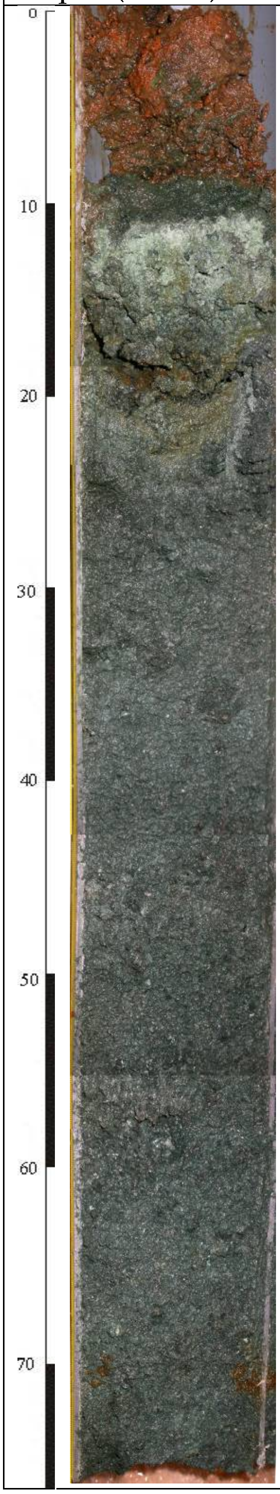
Note:
Fraction >0.8 mm from interval 0-10 cm:
Mostly foraminifera and pteropoda.
Abiogenic components rock fragments and hydrothermal formations.
Rock fragments 55%, hydrothermal formations 45%
Rock fragments:
1.basalts (25%), mostly volcanic glass (thin, elongated, with gas bubbles)
2. serpentinites (20%) and few bastites,greenish brown.
3.gabbroids (10%): pyroxene, rare in aggregation with plagioclase
Hydrothermal formations:
1. 25% - low-temperature, collomorphic, dendritic aggregates (Opal-smectite?). Biogenic?
2. 20% - fragments of iron oxy-hydroxides crusts, atacamite and other secondary green copper minerals.
1 grain (slab shape) of intermetal (Cu-Zn?).
1 grain of barite.
1 grain of aragonite.</td></tr>
</table>

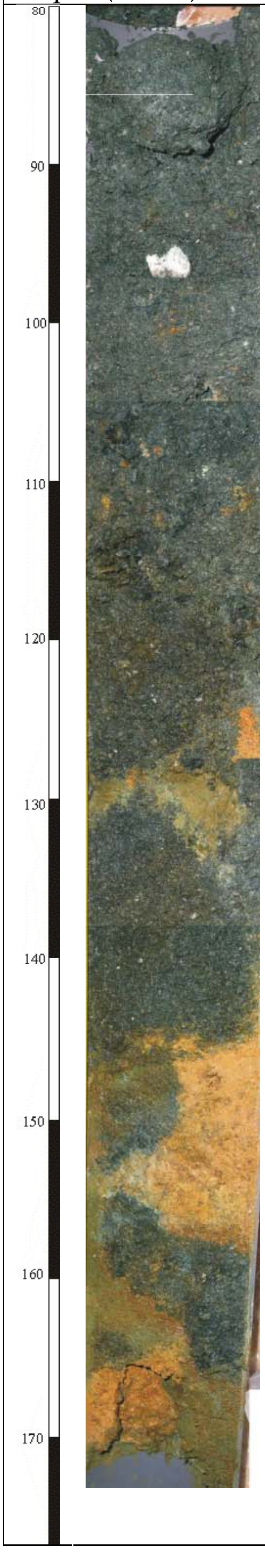
R/V MSM 03/02	Station: MSM 935 MUC
Location: 0.75 km NNW od LHF-1	Water depth: 3045 m
Latitude: 14°45.32' N	Recovery: 29 cm
Longitude: 44°58.87' W	Date: 16.11.2006 13:15
Depth (cmbsf)	**Lithology**
	0-18 cm: Moderate yellowish brown (10Y 5/4). Homogenous sandy silty foaminiferous ooze.
	18-23 cm: Light brown (5YR 6/4), sandy silty foraminiferous ooze
	23-29 cm: Light brown (5YR 6/4), sandy silty foraminiferous ooze. Less foraminifera than overlying layer.
	29cm: end of core. Note: Fraction >0.8 mm Serpentinites (65%) green-brownish, with magnetite, minor chlorite, talc, hematite. Gabbroids (25%). abundant pyroxene, minor plagioclase, amphibolite Hydrothermal: Op-sm aggregates (as at St. 933) about 5%, Fe-Mn aggregates with microdendritic structure (5%).

R/V MSM 03/02	**Station: MSM 945GC**
Location: Logatchev, north of "Quest"	Water depth: 3042 m
Latitude: 14°45.222′ N	Recovery: 122 cm
Longitude: 44°58.816′ W	Date: 18.11.2006, 12:57 UTC

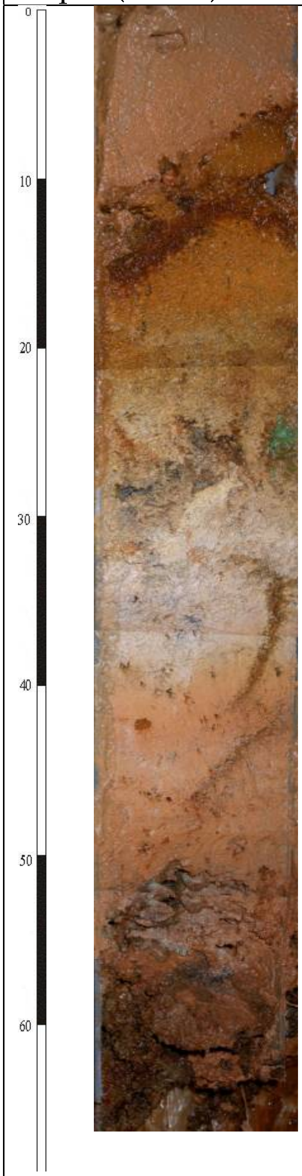
Depth (cmbsf)	Lithology
	0-8 cm: moderate brown (5YR 3/4) sandy clay containing rock fragments
	13-23cm: moderate brown (5YR 4/4) sandy clay containing rock fragments
	23-37cm: olive gray (5Y 3/2) sandy metalliferous mud containing rock fragments, mottled with moderate brown (5Y 3/4) clay
	37-47cm: grayish orange (10YR 7/4) homogenous calcareous sandy clay bearing foraminifera
	47-66cm: grayish olive green (5GY 3/2) sandy clay, containing foraminifera and altered gabbro fragments (up to 5cm diameter at 0.67 m depth)
	66-72cm: grayish orange (10YR 7/4) homogenous sandy clay, containing foraminifera and clasts of altered gabbro
	72-97cm: dark yellowish orange (10YR 6/6) homogenous sandy clay, comparable to the unit above but darker 97-100cm: dark yellowish brown (10YR 4/2) silty clay

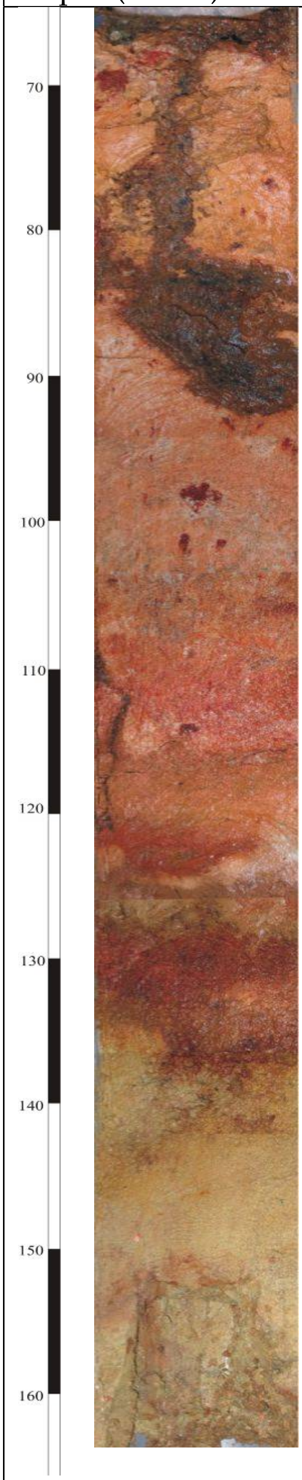
MSM 03/02	**Station: MSM 945 GC (continued)**
Depth (cmbsf)	Lithology
	100-119cm: dark yellowish orange (10YR 6/6) silty clay with rock fragments 119-122cm: olive black (5Y 2/1) sand and gravel, rock fragments 122cm: End of core

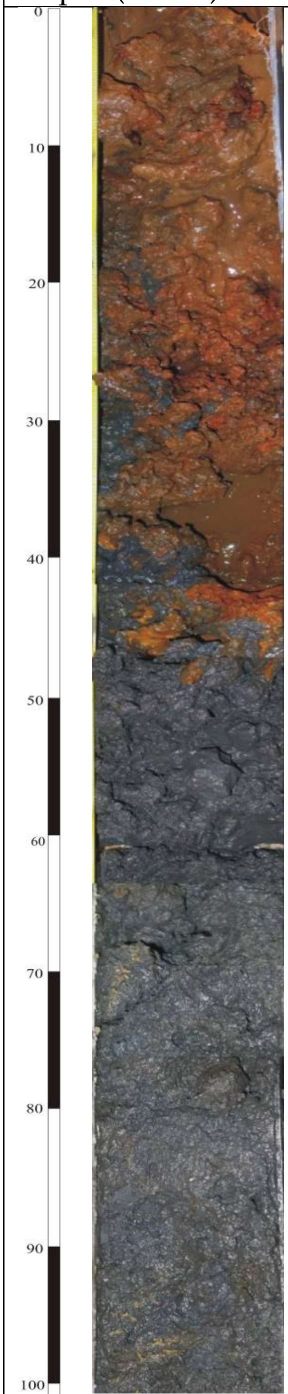
<table>
<tr><td colspan="2">R/V MSM 03/02</td><td>Station: MSM 946GC</td></tr>
<tr><td colspan="2">Location: Between Sites “B” & “F”,LHF-1
Latitude: 14°45.139' N
Longitude: 44°58.714' W</td><td>Water depth: 2998 m
Recovery: 175 cm
Date: 18.11.2006, 17:00 UTC</td></tr>
<tr><td>Depth (cmbsf)</td><td colspan="2">Lithology</td></tr>
<tr><td rowspan="4">
</td><td colspan="2">0-11cm: moderate reddish brown (10R 4/6) silty clay with grayish olive (10Y 4/2) fragments of altered rock (maximum size 8cm)</td></tr>
<tr><td colspan="2">11-20cm: pale green (10G 4/2) silty clay with altered rock fragments</td></tr>
<tr><td colspan="2">20-26cm: dark yellowish green (10GY 4/2) silty clay with altered rock fragments</td></tr>
<tr><td colspan="2">26-142cm: grayish green (10G 4/2) silty to sandy foraminifera bearing clay, containing chlorite and serpentinite, several quartz (?) clasts of up to 3 cm diameter</td></tr>
</table>

MSM03/2	**Station: MSM 946 GC (continued)**
Depth (cmbsf)	Lithology
	26-142cm: grayish green (10G 4/2) silty to sandy foraminifera bearing clay,containing chlorite and serpentinite, several quartz (?) clasts of up to 3 cm diameter
	122-125cm: muddy spot, dark yellow orange (10YR 6/6)
	126-129cm: muddy interlayer, dusky yellow green (5GY5/2)
	142-175cm: multicolored section, (a) moderate yellow (5Y 7/6); (b) light olive (10Y 5/4); (c) dark yellow green (10BY 4/4); (d) dense dry powder of grayish green (10BY 4/4) (few ockerous muddy spot); (e) dark yellow orange (10YR 6/6) 5/2)
	175cm: End of core

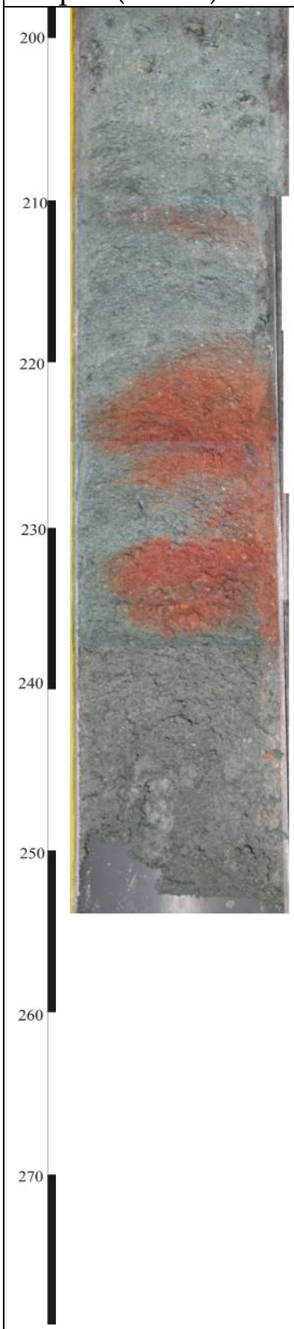
R/V MSM 03/02	**Station: MSM 947GC**
Location: North of "F", LHF-1	Water depth: 3016 m
Latitude: 14°45.159' N	Recovery: 162 cm
Longitude: 44°58.741' W	Date: 18.11.2006, 20:14 UTC

Depth (cmbsf)	Lithology
	0-8/12cm: light brown (5YR 5/6) sandy clay, homogenous
	8/12-17cm: dark brown clay, more dense, fewer coarse grains
	17-40cm: silty to sandy matrix with a distinct colour transition from light brown to dark yellowish orange to grayish orange to very pale orange, some reddish brown spots, at 24-26cm: bright green spot (presumably atacamite)
	40-53cm: light brown matrix (5YR 5/6) with streaks of darker material
	53-68cm: altered rock fragments of different size (up to 8cm), a few pyroxene crystals up to 1cm.

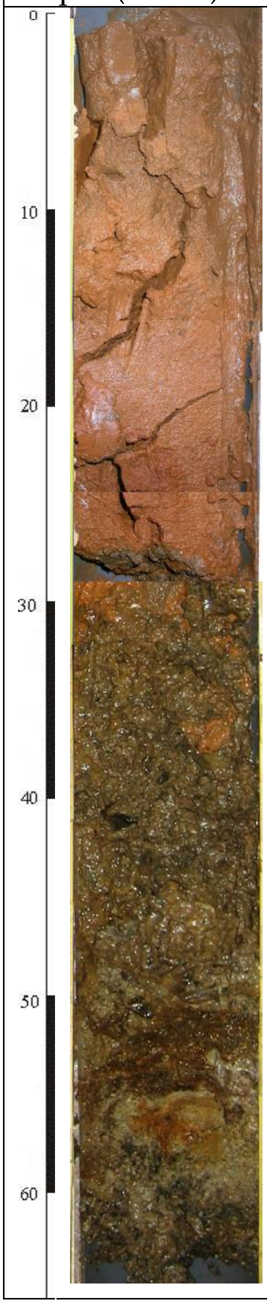
MSM 03/2	**Station 947GC (continued)**
Depth (cmbsf)	Lithology
 	dense clayey matrix, dark brown crust-like fracture filling, looks like gossan, some manganese component sediment colour: bright brown, grayish red crust-like object
	light olive grey (5/2), reduced sediments, semi-lithified clay aggregates towards the bottom 132 – 141 cm: sublayer, moderate brown (5YR 3/4) 162cm: Ende of core

R/V MSM 03/02	**Station: MSM 953 GC**
Location: North of Site“B”, LHF-1 Latitude: 14°45.109' N Longitude: 44°58.703' W	Water depth: 2980 m Recovery: 254cm Date: 20.11.2006, 14.30 UTC
Depth (cmbsf)	Lithology
	Mixture, iron-silica crust (8x5x3 cm) with some atacamite. Crust probably represents the sediment surface. Throughout this core portion, fragments of sulfide chimneys (up to 5 cm) in moderate brown (5YR 4/4) metalliferous sediment are abundant. Fragments of chimneys with numerous channels. Chimney walls consist of chalcopyrite, pyrrhotite. Films of bluish-black secondary Cu-sulfides. Mixture, brownish black (5YR 2/1) metalliferous mud with fragments of sulfide chimneys and silica crusts Mixture, fragments of sulfide chimneys in a black (N1) muddy sulfidic matrix, containing fine grained secondary Cu sulfides. 58-60 cm: Fragments of oxidized chimneys consist of massive chalcopyrite with numerous channels. On the walls of the channels, radial chalcopyrite and pyrrhotite is visible. Opalization (with pyrite) of channels. Py-Op ~ 10%. Films of bluish-black secondary Cu-sulfides on all Cu-sulfides. 88-92 cm: Fragments of small chimneys. These show radial chalcopyrite in the central part of the feeder pipe and dendritic pyrite at the outer part. Amount of pyrite – 20-25%; small buds of wurtzite and dusty sphalerite; Barite – up to 5%. Films of bluish-black secondary Cu-sulfides on all Cu-sulfides. 98-120 cm: Mostly pyrite chimneys and crusts with channels. Buds of marcasite. Secondary minerals are mostly in form of brown crusts (iron oxides?)

MSM 03/02	**Station: MSM 953 GC (continued)**
Depth (cmbsf)	Lithology
	98-120 cm: Mostly pyrite chimneys and crusts with channels. Buds of marcasite. Secondary minerals are mostly in form of brown crusts (iron oxides?)
	120-167 cm: High altered host (ultramafic?) rocks (up to clay). Top part is muddy with some white and black spots; in the lower part, sediment is lighter; coarse material with gravel Sediment colour: pale blue (mostly) In coarse fraction: 160- 167: pyrite 2-5% some grains of skeletal chalcopyrite
	167-254 cm: High altered and disintegrated ultramafic rocks: mixture of different grain sizes fraction particles (from clay to gravel); distinct colour variations with depth: 172-182cm pale blue green; 182-221cm grayish blue green;

MSM 03/02	**Station: MSM 953 GC (continued)**
Depth (cmbsf)	Lithology
	182-221cm grayish blue green; 221-238cm moderate reddish brown (hematitized); minor pyrite 15% (fine crystals) 238-254cm dusty yellowish green 254cm: End of core <u>In coarse fraction:</u> 205-207, 225-230,cc: pyrite 2-5% (octaedric), barite sulfides – products of decomposition/alteration of small Cu chimney – periphery of the mound

R/V MSM 03/02	**Station: MSM 960GC**
Location: Irina-1, LHF-1	Water depth: 2986 m
Latitude: 14°45.090' N	Recovery: 63 cm
Longitude: 44°58.702' W	Date: 25.11.2006, 01:15 UTC



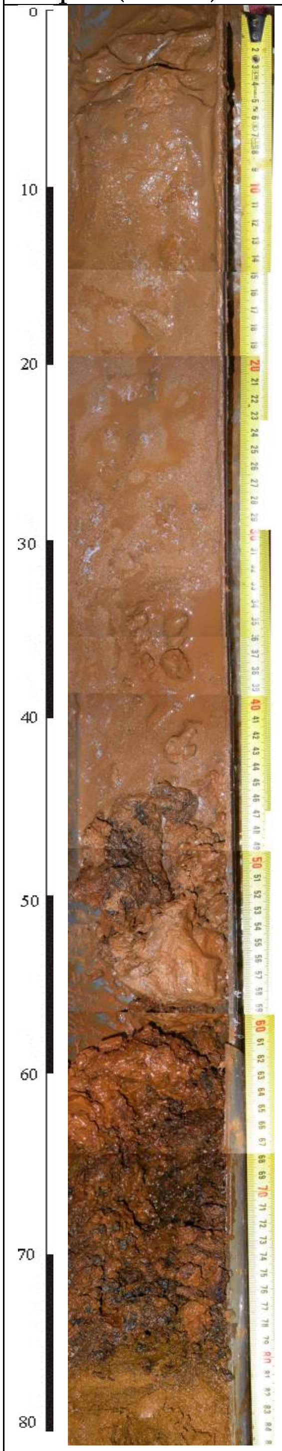
Depth (cmbsf)	Lithology
	0-5cm: Metalliferous sediment homogenous sandy silty clay sediment colour: moderate brown (5YR 3/4) Reaction with HCl – Not. In coarse fraction: fragments of Fe-Mn formations (crusts); fragments of Fe-Si and Cu-Fe-Si crusts (up to 4 mm). One fragment of Cu-sulfide (0.2 mm). Black particles (Mn?). Contact – gradual/transitional
	5-10cm: Metalliferous low carboniferous sediment homogenous sandy silty clay sediment colour: moderate brown (5YR 4/4) Reaction with HCl – weak. In coarse fraction: fragments of Fe-Si and Cu-Fe-Si crusts (up to 4 mm); fragments of Fe-Mn formations (crusts). Contact – gradual/transitional
	11-30cm: Metalliferous carboniferous sediment homogenous clayely sandy silt sediment colour: light brown (5YR 5/6) Reaction with HCl – active. In coarse fraction: Forams - abundant, fragments of Fe-Si and Cu-Fe-Si crusts – up to 5%. Less amount of Fe-Mn crust fragments. Contact – sharp
	30-63cm: Mixture of gabbronorites and peridotites fragments different sizes. Colour – olive grey 5Y 3/2 . Many other colours – yellowish, greenish, greyish. Large pieces of angular pegmatoid gabbronorites up to 5 x 5 x 4 cm with crystals of plag up to 3 cm. Mn minerals in serpentinites. Slight hematitization. Matrix – clay-silt-sand-gravel – products of high alteration of the rocks.

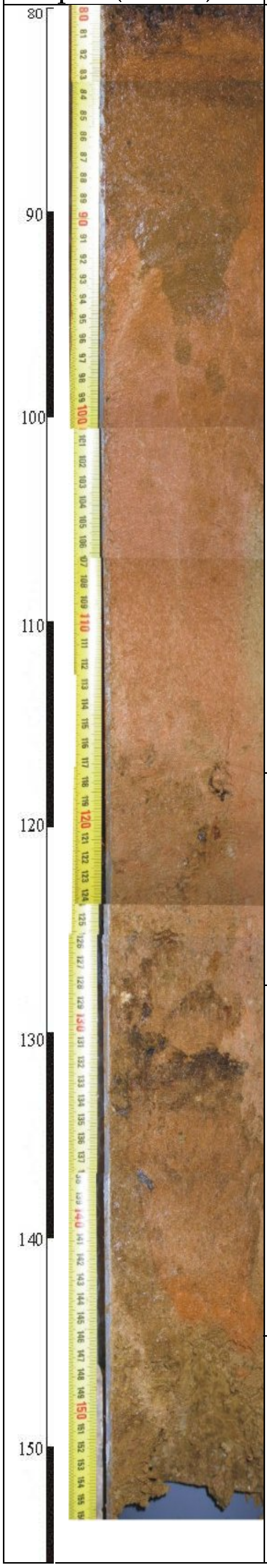
R/V MSM 03/02	**Station: MSM 963GC**
Location: Near Site B, LHF-1	Water depth: 2952 m
Latitude: 14°45.100' N	Recovery: 52 cm
Longitude: 44°58.672' W	Date: 26.11.2006, 13:19 UTC

Depth (cmbsf)	Lithology
	0-5cm: Mixture of metalliferous mud and fragments of Fe-Si crusts with atacamite. Colour – moderate brown (5 YR 3/4). Crusts up to 6 x 4 x 5 cm, with Mn-coating. Contact – gradual/transitional
	5-9cm: Mixture of mud and fragments of massive sulfides (up to 8 x 10 mm, 25% in coarse fraction), pure Fe – crusts (30%), Fe crusts with relics of sulfides (30%) and Fe-aggregates (15%). Colour – dusky brown (5 YR 2/2) & dark reddish brown (10R 3/4). Contact – sharp
	9-14cm: Mixture of grayish black mud and fragments of Cu-sulfides. Color - grayish black (2). Fragments of sulfides (first cm in size) – soft; mostly – secondary sulfides with relics of chalcopyrite. Contact – sharp
	14-20cm: Mixture of mud and fragments of crusts. Crusts – Cu-Fe, mostly atacamite. Colour – moderate brown (5 YR 3/4); Contact – sharp
	20-25cm: Mixture of grayish black mud and fragments of Cu-sulfides and atacamite. Colour - grayish black (2). Fragments of soft Cu-sulfides with relics of chalcopyrite (50%) and Atacamite (50%). Traces – pyrite. At the base – fragments of rocks with Cu-Fe crusts (25%) and atacamite (75%). Contact – very sharp
	25-46cm: Metalliferous homogeneous mud (clay). Colour – mostly - moderate brown (5YR 3/4), interlayer (48-51 cm) dark reddish brown. Lower part (51-57 cm) light brown (5YR 5/6). In the upper part – globules of atacamite (0.2 mm), single barite. In the middle part – globules of atacamite (0.1 mm). In dark spots – small Fe –atacamite crusts, relics of sulfide minerals, Mn dendrites. In cc – rocks fragments, forams, single atacamite
	46-52cm: light brown (5YR 5/6) clay

R/V MSM 03/02	**Station: MSM 964GC**
Location: Irina 1, LHF-1	Water depth: 2972 m
Latitude: 14°45.081' N	Recovery: 76 cm
Longitude: 44°58.704' W	Date: 26.11.2006, 19:52 UTC

Depth (cmbsf)	Lithology
	0-3cm: moderate brown (5YR 4/4) matalliferous calcareous silty clay, soupy, abundant foraminifers and Fe-Mn crust (up to 0,1mm) 3-12cm: moderate brown (5YR 4/4) matalliferous calcareous silty clay, but lighter and less water as above. Containing abundant foraminifera, minor Mn dendrites (<0,1 mm), little atacamite and rock fragments
	12-34cm: light brown (5YR 5/6) matalliferous calcareous silty clay, containing foraminifers (major, but less then above), rock fragments, dusty Mn, and some atacamite (0,1mm). Fe-Mn crust on the bottom
	34-45cm: light brown (5YR 5/6) mixture of sandy silty clay and fragments of rocks, Fe-Mn crust (1-3mm), Mn globules (1-2mm), minor atacamite (0,1mm) and barite (0,7mm). Few foraminifera.
	45-68cm: moderate olive brown (5Y 4/4) mixture of clay and fragments of strongly altered rocks (serpentine), Si-crust and Fe-Mn crust
	68-76cm: moderate olive brown (5Y 4/4),homogeneous dense clay, containing strongly altered rock fragments(serpentinites)

R/V MSM 03/02	**Station: MSM 965GC**
Location: Site “54-GTV”, LHF-1 Latitude: 14°45.169' N Longitude: 44°58.637' W	Water depth: 2994 m Recovery: 155 cm Date: 26.11.2006, 22:05 UTC
Depth (cmbsf)	Lithology
	0-6cm: moderate brown (5 YR 4/4) metalliferous calcareous sandy silty clay, soupy; abundant foraminifera and fragments of Mn crusts (up to 5 mm) 6-34cm: moderate brown (5 YR 4/4), metalliferous calcareous sandy silty clay, lighter than above; abundant foraminifera, fragments of Mn crusts (up to 2x2 cm) present (1-2%) 34-60cm: moderate brown (5YR 4/4) metalliferous calcareous sandy clay with fragments of Fe-Mn crusts and altered rocks; lighter than above unit above. Large Fe-Mn crust at the bottom (4 x 4 x 2 cm)
	60-80 cm: mixture of moderate brown (5YR 4/4), moderate olive brown (5Y 4/4) and dusky brown (2), mixture of dense clay (i.e. Nontronite), fragments of Fe-Mn crusts and rocks. Some atacamite (0.1.mm) and barite (0.7 mm) present, rare foraminifera. At the bottom, pieces of Fe-Si and nontronite crust
	80-118 cm: moderate brown (5YR 4/4) and moderate olive brown (5Y 4/4), dense (semi-lithified) nontronite clay, rare rock fragments

Depth (cmbsf)	Lithology
	80-118cm: moderate brown (5 YR 4/4) sandy silty clay mottled with moderate olive brown (5Y4/4) dense (semi-lithified) nontronite clay, rare rock fragments
	118-127cm: moderate olive brown (5Y 4/4) sandy silty clay, nontronite veins (5mm) and buds-up to 5%, minor foraminifera
	127-145 cm: dark olive brown sandy silty clay, containing nontronite buds, foraminifera, hematite
	145-155cm: light olive brown (5Y 5/6), homogeneous dense nontronite clay, traces of hematite

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Leibniz-Institut für Meereswissenschaften / Leibniz-Institute of Marine Sciences
IFM-GEOMAR
Dienstgebäude Westufer / West Shore Building
Düsternbrooker Weg 20
D-24105 Kiel
Germany

Leibniz-Institut für Meereswissenschaften / Leibniz-Institute of Marine Sciences
IFM-GEOMAR
Dienstgebäude Ostufer / East Shore Building
Wischhofstr. 1-3
D-24148 Kiel
Germany

Tel.: ++49 431 600-0
Fax: ++49 431 600-2805
www.ifm-geomar.de