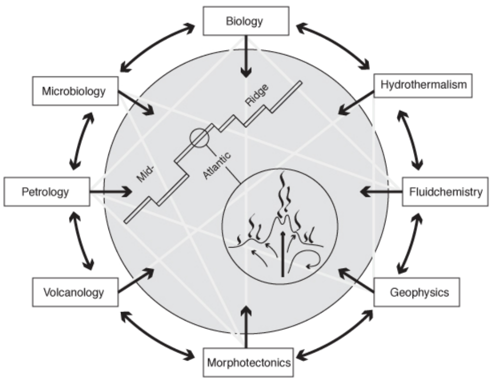
MARIA S. MERIAN

Cruise No. 04, Leg 3

Fort de France – Las Palmas, 23 January – 14 February, 2007

HYDROMAR III
Temporal and spatial variability of hydrothermal, geochemical and biological systems at the Logatchev hydrothermal vent field, Mid-Atlantic Ridge at 14°45' N



Cruise within the framework of the DFG SPP 1144:
"From Mantle to Ocean: Energy-, Material- and Life-cycles at Spreading Axes"

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3.2 Research Program

(Christian Borowski)

The Logatchev Hydrothermal Vent Field (LHF) at 14°45' N on the Mid-Atlantic Ridge (MAR) is one key area for the investigation of spatial and temporal heterogeneity of bio-geo interface processes in hydrothermal vents within the DFG priority program SPP 1144 "From Mantle to

Ocean: Energy-, Material- and Life-cycles". Logatchev is one of only a few ultramafic-hosted hydrothermal systems worldwide. It is located on a small plateau on the eastern flank of the rift valley in an area of the MAR that is dominated by mantle rocks with subordinate basaltic material. The hydrothermal fluids are influenced by subsurface serpentinization processes and as a consequence they are rich in methane and hydrogen.

MSM 04/3 was the third in a series of SPP cruises to Logatchev. The overall goal was to continue the investigations of spatial and in particular temporal variability patterns of the hydrothermal activity started with RV Meteor cruises M 60/3 and M 64/2 in January 2004 and May 2005, respectively. The main working tool of the cruise was the ROV Jason II from the Woods Hole Oceanographic Institution which was used to recover and redeploy geophysical instruments and geochemical in-situ measurement devices, and for accurate sampling of hydrothermal fluids, sediments, macrofauna and microorganisms. During 12 days of work time in the LHF area, we performed eleven successful dives with a total of 105 hours of bottom time. Other instruments used were the CTD/Rosette water sampler, Miniature Automated Plume Recorders (MAPR, NOAA) and the Kongsberg EM 120 multi-beam echosounder.

One of the major objectives of the cruise was to replace instruments which had been set up in the LHF in May 2005 for geophysical long-term measurements of microseismicity, tilt, acceleration, and temperature of the ocean floor, and temperature and pressure in the bottom-near water column. The data provide unique information on local seafloor motions for a recording period of 8 months. They serve as proxies for changes in the conditions of the fluid regime and for local spatial and temporal variability of habitats, and are essential for time series investigations of hydrothermal fluids and biological activity. With the replacement of the moorings we continue data collection until December 2007 when the instruments will be recovered by the next SPP cruise to the LHF.

By using LBL navigation with Jason II, we recalibrated the geographical positions of the hydrothermal structures and established an accurate map which revealed that the active LHF harbors one more smoking crater than previously recognized. The sampling program performed by the ROV included the recovery of hot and diffuse fluids from all active structures for geochemical and microbiological investigations, push cores from microbial mats and samples of symbiotic and other macrofauna. Other in-situ data collected included high-T-measurements with an 8 channel T-probe and small-scale profiling of physical and geochemical gradients such as T, O_2 and H_2S in hydrothermal sediments, microbial mats and mussel beds with an ROV operated profiler module.

Plume mapping with the CTD and MAPRs revealed that the major direction of the hydrothermal plume extension was N-S. Additional information on the activity patterns in a wider area around the presently known LHF vents is expected from the analyses of high resolution bathymetric mapping using the Kongsbergs EM 120 multi-beam echosounder. We continued the mapping program that was started during Maria S. Merian cruise MSM 03/2 in December 2006 and extended the observation area northwards towards the 15-20-Fracture Zone.

3.3 Narrative of the Cruise

(Christian Borowski)

Friday 19. Jan. 2007: The loading of the ROV and scientific equipment started around 11:30 and was finished some three hours later.

Saturday 20. Jan. – Monday 22. Jan. 2007: Mobilization of the ROV began Saturday 08:00 a.m. and continued during the next three days. The scientific team arrived on Monday and started setting up the laboratories and scientific instruments including the CTD and ROV periphery equipment.

Tuesday 23. Jan. 2007: Thanks to an excellent cooperation between ship crew, ROV team and science, the ROV mobilization was completed within only three days. Jason II successfully passed a harbour test in the late morning and Maria S. Merian left Fort de France as scheduled on 23 January around noon time. We rounded Martinique on the south side and took heading towards the Mid-Atlantic Ridge.

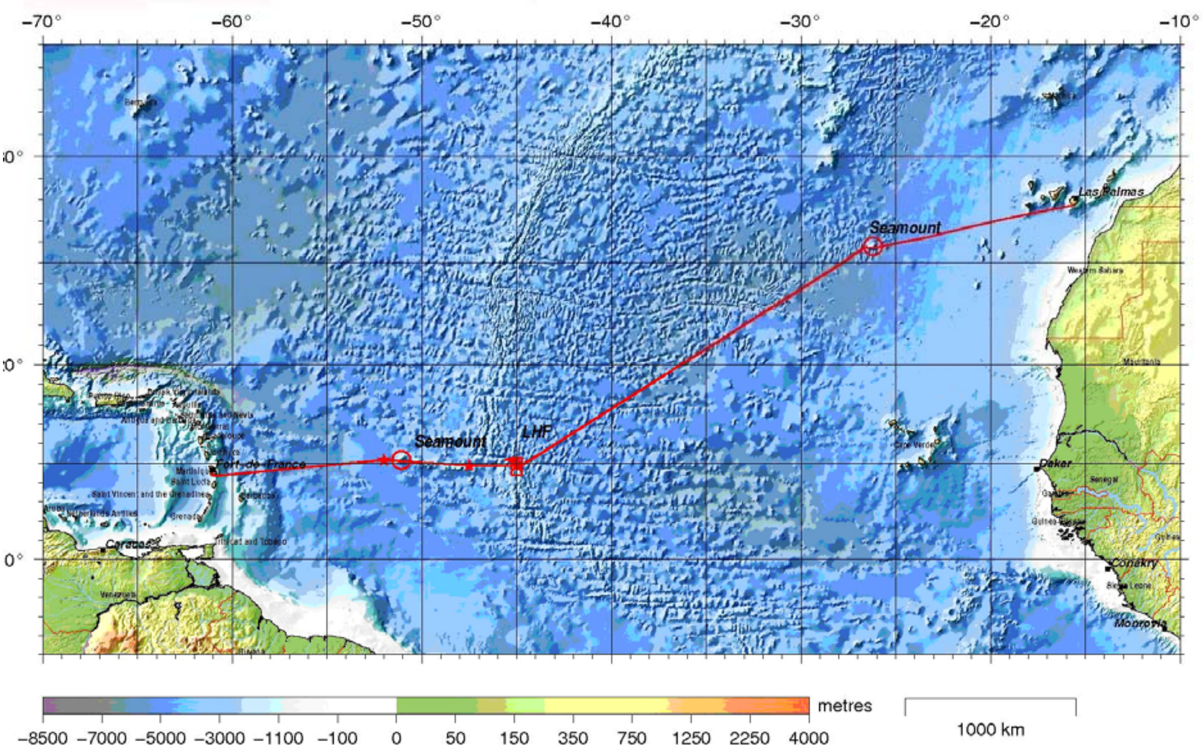


Figure 3-1. Cruise track of MSM 04/3 from Fort de France, Martinique, to Las Palmas, Gran Canaria, with the LHF target area on the MAR at 14°45’ N.

Wednesday 24. Jan. – Friday 26. Jan. 2007: During the following three days, we travelled with 12 kn and recorded bathymetry data after leaving the EEZ of Martinique. We initially followed a seamount chain at 15°N until 47°20'W where we slightly changed direction towards Logatchev (fig. 3-1). A first stop for a CTD/Rosette background cast in 5000 m water depth was made in the evening of 25 January at 15°7.68'N, 51°22.41'W.

Saturday 27. Jan. 2007: We reached Logatchev in the early morning and began station work with setting out two underwater navigation LBL transponders. Calibration of the LBL transponders took some 6 hours and the ROV Jason II was launched for its first dive (Jason II dive no. 253) from a German vessel at 14°44.91'N, 44°58.97'W in 3074.8 m water depth. The purpose was to gain orientation in the area around the“Irina II“structure and start sampling for biota and fluids. This short dive ended successfully after 6 hours. Three CTD/Rosette casts followed during the night.

Sunday 28. Jan. 2007: Jason II dive no. 254 to “Irina II” and “OBT site”; purpose of the dive: recover moored ocean bottom pressure meter (OBP) and ocean bottom tilt meter (OBT), deploy new OBT, put out in-situ measurement devices, sampling for biota and fluids; dive time 9.5 h. An unusual incident happened in the afternoon when we received a pan-pan call from a sailing boat with a broken mast in only 35 nm distance to the north of us. They asked for support with food, water and diesel in order to be able to continue sailing with reduced speed to their destination in the Caribbean. We interrupted our work in the early evening, reached the boat around midnight and supplied the two sailors with what they needed. After reassuring ourselves that they would be able to safely continue their travel we wished them good luck and spent the rest of the night with bathymetry mapping on the northern flank of the 15-20-Fracture Zone.

Monday 29. Jan. 2007: Jason II dive no. 255 to “Irina II” and “OBT site”; purpose: deploy in-situ measurement devices, sampling for biota and fluids; dive time 10.5 h. During the night: plume mapping tow-yo on a SE-NW profile across Logatchev with CTD/Rosette / MAPRs.

Tuesday 30. Jan. 2007: Jason II dive no. 256 to “OBT site”, “Irina II” and marker “Anya” using the elevator for transport of equipment from bottom to surface; purpose of the dive: deploy new OBT, recover in situ measurement devices, sampling for biota and fluids; dive time 10.5 hours. After recovery of the elevator, bathymetry mapping of the Logatchev area.

Wednesday 31. Jan. 2007: Jason dive no. 257 to the smoking craters “Site B”, “Irina I” and “Anna-Louise” in the southern LHF area; purpose of the dive: hot fluid sampling, in situ measurements, dive time 11.5 h. During this dive we discovered that the southern hydrothermal structures include four instead of three to this date named smoking craters. All four structures had been visited by earlier cruises as it was evidenced by deep-sea markers deposited on the crater rims, but the two southernmost craters had not been recognized as independent structures. The night was spent with plume mapping by CTD/Rosette / MAPR tow-yo on a S-N profile across the Logatchev field.

Thursday 01. Feb. – Friday 02 Feb. 2007: Jason II dive no. 258 to “Irina II” and “Quest”; purpose of the dive: in situ measurements, sampling for sediments, fluids and biota using the elevator for equipment transport; dive time 24 h. After recovery of the elevator, bathymetry mapping south of the 15-20-Fracture Zone. In the evening, begin of Jason II dive 259 to “OBT site”, marker “Anya” and “Quest”; purpose of the dive: in situ measurements, sampling for sediments, fluids and biota using the elevator for transport of equipment and samples; dive time 13 h.

Saturday 03. Feb. – Sunday 04 Feb. 2007: Recovery of ROV and elevator in the morning. During the day, one plume mapping tow-yo with CTD/Rosette / MAPRs on a NE – SW profile across the Logatchev area. In the evening start of Jason II dive no. 260 to “Quest”, “Irina II” and the southern smoking craters; purpose of the dive: in-situ measurements, sampling for fluids, sediments and biota using the elevator for transport of equipment and samples; dive time: 23 h. After recovery of the elevator in the evening, bathymetry mapping south of the 15°20’ fractures zone.

Monday 05. Feb. 2007: Jason II dive no. 261 to marker “Anya”, “Irina II”, “Quest” and “Site F”; purpose of the dive: recover T-loggers, in-situ measurements, sampling for sediments, fluids and biota; dive time 12.5 h. In the evening deployment of a 25 m vertical temperature mooring midway between “Irina II” and “Site B”.

Tuesday 06. Feb. 2007: During night until morning, two CTD/Rosette casts south of Logatchev. Later in the morning, Jason II dive no. 262 to “OBT site”, “Site F”, southern smoking craters and “Site A”; purpose of the dive: deploy OBT, in-situ measurements, fluid sampling, sediment sampling using the elevator for transport of equipment; dive time 12.5 h. After recovery of the elevator, 3 CTD/Rosette casts south of LHF.

Friday 07. Feb. 2007: In the morning, deposit wood logs for a long term colonization experiment in the Logatchev field at 14°45.158’N, 44°58.696’W in 3003 m water depth using the deep-sea wire. After that, Jason II dive no 263 to “Quest” and “Irina II”; purpose: bring out long-term temperature loggers at “Quest”, sample fluids and biota; dive time: 6 h. In the afternoon, recovery of the two LBL navigation transponders. End of station work at 19:00 LT. We left Logatchev for transit back to Las Palmas with the EM 120 multibeam echosounder recording bathymetry data.

Saturday 08. Feb. - Wednesday 14. Feb. 2007: Six days of transit at an initial speed of 9.5 kn because of oncoming wind and current. The transit time was used for demounting the ROV and the scientific laboratories and for packing as far as possible. We initially headed towards a seamount at 25°50’N, 26°15’W in order to record its bathymetry. We passed the seamount on Sunday, temporarily reduced speed to 8 kn while crossing it, and continued afterwards with 12 kn speed towards Las Palmas. We reached Gran Canaria in the early morning of Wednesday and waited off the coast of Las Palmas for harbor clearance. Maria S. Merian berthed at early noon time. Unloading of the ROV and scientific equipment started immediately and was completed within the afternoon. The science group and ROV team left the ship on Thursday 15. February.

Summary of station work:

Station work time	12 days, 27. Jan. - 07. Feb
Jason II dives:	11 (incl. 2x 24 h dives)
Total ROV bottom time	100.5 h
Free-fall elevator deployments	4
CTD-MAPR tow-yos	3
CTD/Rosette stations	9
Moorings deposited	2
Moorings recovered	1
Multi-beam bathymetry surveys	6

3.4 Preliminary Results

3.4.1 Multibeam Bathymetry

(Dietmar Bürk)

Objectives, data collection and processing

Bathymetric data exist at resolutions of 100 – 200 m showing large-scale tectonic features in the larger 15-20° N area (Fujiwara et. al. 2003, Escartin and Cannat 1999) and in the rift valley around the LHF that was mapped recently during RV Meteor cruise M 60/3 (Kuhn et al., 2004). The proposed objective of the bathymtetric survey in MSM 04/3 was to use the Kongsberg EM120 echosounder for a high resolution mapping of selected key areas in the direct vicinity of the LHF in order to study the relationships between the tectonic fault pattern and hydrothermal activity. However, this goal was already to a large extent achieved by the mapping in November 2006 which was performed as a replacement program during Maria S. Merian cruise MSM 03/2. The focus of the mapping in this cruise was therefore adjusted to additionally collecting high resolution bathymetry data of the 15°20' N Fracture Zone (15-20 FZ). Due to the limited time of only 12 working days and the priority of the ROV diving operations, the bathymetric mapping of the LHF and the 15-20 FZ was limited to 4 surveys with a total of 38:47 hours. Additional bathymetric data were collected in the deep oceanic basins during the transits from Fort de France and to Las Palmas before and after the station work.

We used the Kongsberg EM120 echo sounding system that operates at a frequency of 12 kHz with a maximum ping rate of 5 Hz and processes 191 beams per ping at an opening angle of up to 150 degrees (optional equidistant or equiangular). The widths of single beams of the transmitting and receiving transducers are 1x1, 1x2, 2x2 or 2x4 degrees. Measurements of the actual depth use a combination of amplitude (near-range measurements) and phase detection (mid- and far ranges). Data acquisition was performed with the Kongsberg SIS® software and data were processed with the open source software MB-System, release 5.0.8 from MBARI and LDEO (Caress and Chayes, 1996). Various grids were produced and the final maps generated with the Generic Mapping Tools (GMT), version 4.1 (Wessel and Smith, 1998).

Transit to Logatchev

The multibeam echosounder was started after leaving the 70 nautical miles zone of Martinique (opening angle of the beams = 2 x 65 degrees, ping frequency ~ 0.05 Hz). The transit speed of the ship was 12 kn and the resolution of the along-track recording is 120 m. The initial ship track followed a seamount chain at 15° N. Between 47°20' W and 45°10' W we added a swath north to the transit bathymetry mapping performed by cruise MSM 03/2. The eastern end of this line closes the gap between the MSM 03/2 transit mapping in the south and bathymetric data collected earlier in the north (Fujiwara et. al. 2003, Escartin and Cannat 1999).

Inside Corner at the 15-20 Fracture Zone

The so-called inside corner of the south segment of the MAR marks the transition of the south segment to the 15-20 FZ zone. This area mapped during 3 nights with a number of lines (Fig. 3-2). The survey started in the night of 28/29 January following the emergency operation for the German S/V Spica with a line along the northern rim of the 15-20-transform fault. All survey lines were mapped at 8 kn ship speed and with an opening angle of 2 x 45°, with the only exception of the initial transit from the LHF to the position of the emergency operation which was performed at 12 kn.

The map on figure 4 shows a number of topographic highs south of the 15-20 FZ possibly representing so-called megamullions which are typical features of large detachment faults located at inside corners. The map also shows that the LHF is situated in a large fault zone that can be traced from 14°43’ N to almost 15°02’ N. This fault zone may be associated with to date unknown hydrothermal vent activity.

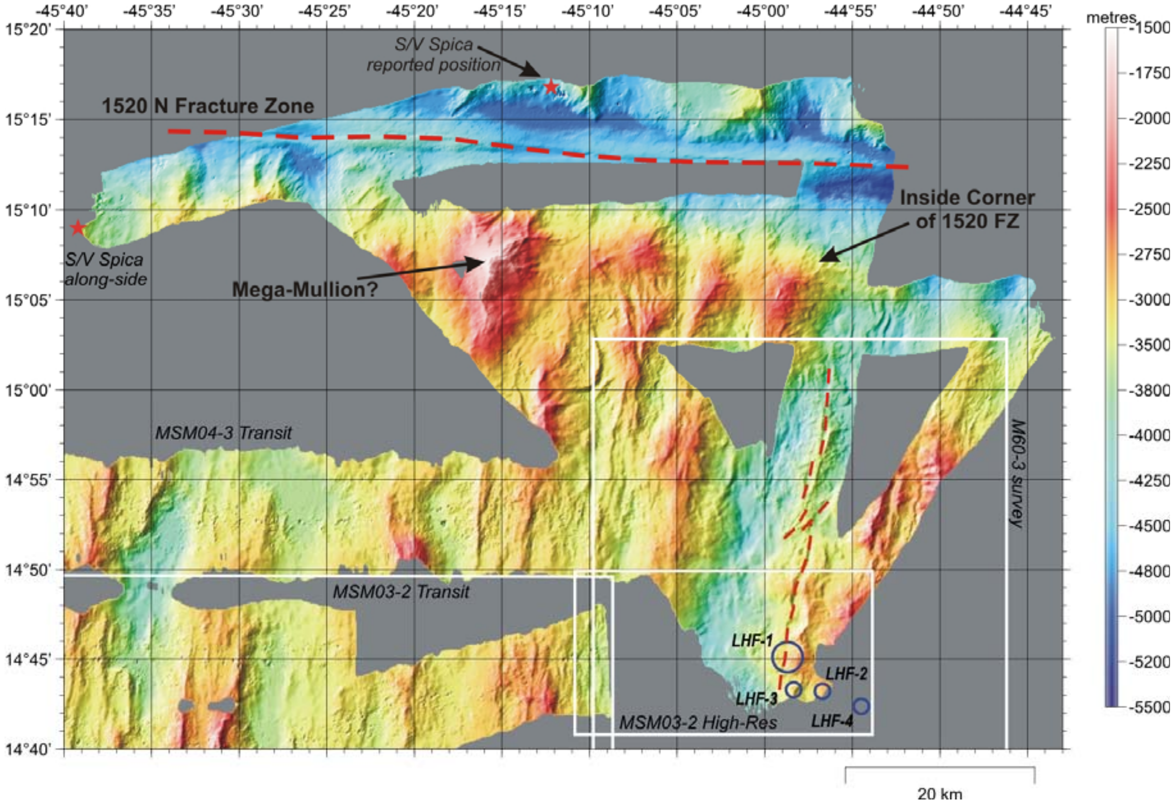


Figure 3-2. Pre-processed and gridded bathymetry data of the 15-20 FZ and inside corner down to the LHF. Gaps could not be closed due to time constraints.

High-resolution survey of LHF 1

Although the resolution of the new LHF maps produced with the new Kongsberg EM 120 echosounder during MSM 03/2 was much higher than that of existing maps, there was still a potential for a further resolution increase by optimizing the sampling strategy. The resolution of a bathymetric measurement on the seafloor is determined by the covered swath width, the number of available beams and the physical resolution which equals manly the footprint size of a single beam (i.e. in 3000 m water depth 52 m in across- and along-track directions at 1° single beam angle). Beams within one footprint area do not resolve separate seafloor features, and the potential for increasing resolution by narrowing the swath width is therefore limited. However, repeated independent sampling of the same area of sea floor with overlapping lines increases the statistical sample size and thus can be used to increase the spatial resolution. In order to increase the resolution beyond that of the MSM 03/2 mapping, we minimized footprint overlap (by choosing an opening angle of 2 x 40° vs. 2 x 11° during MSM 03/2) while we kept to 0.5 nm line spacing. The resulting 5.4-fold across-track oversampling of individual footprint measurements lead to a 2.3-fold resolution increase ($\sqrt{5.4} = 2.3$). At a ship speed of 4-5 kn and ping frequency of 0.12 Hz, the along-track resolution is approximately 20 m.

The survey covered an area of approximately 150 km^2 including the active hydrothermal structures of the LHF and some peripheral morphological features identified in MSM 03/2 (“Little Sophie”, “Sophies Playground”, “Donut Volcano”). At a scale of 1:80.000 the newly acquired bathymetry largely resembles that of the MSM 03-2 survey, with the exception that the deep depression of “Devils Arena” is missing. Post processing after the cruise has revealed that this not a result of filtering or data editing, but that this structure is actually not present in the data. (Fig. 3-3). The active hydrothermal vent structures remain below the resolution limit.

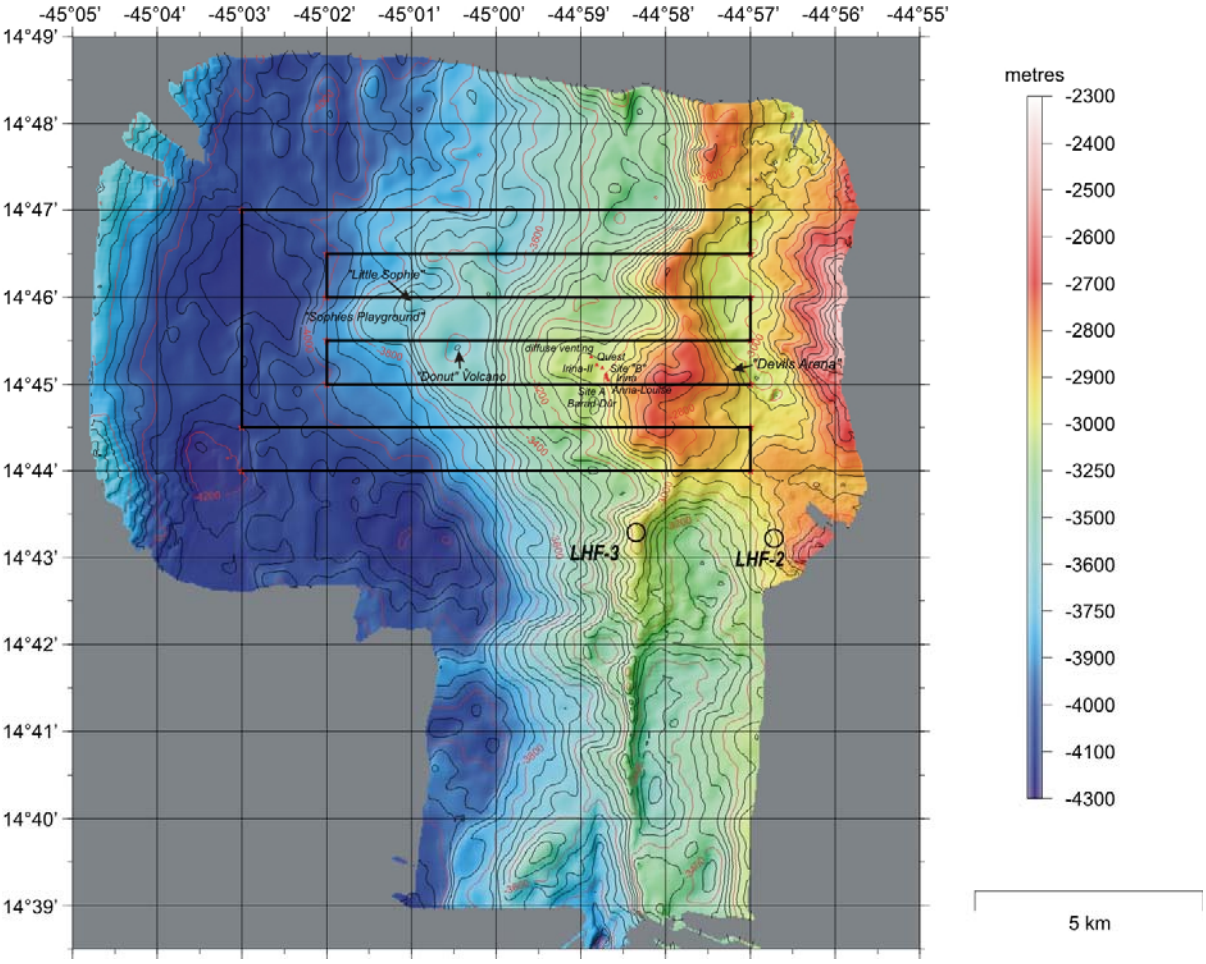


Figure 3-3. High-resolution survey at Logatchev Hydrothermal Vent Field showing vent locations and some morphological features (pre-processed and gridded data). The grid was combined with data acquired during transit to CTD casts south of LHF-1.

Determination of the minimum possible grid spacing (i.e. resolution) without using data interpolation revealed that a grid with cells of 20 x 20 m contains almost no empty cells, while a further decrease of cell size resulted in a progressive increase of empty cells. Grids with smaller cell sizes therefore rely on interpolated data and provide less resolution. A comparison with MSM 03/2 data showed that the same gridding method resulted in more gaps. The quality of the data can also be determined by plotting the number of data points in single grid cells. Figure 3-4 shows that the MSM 04/3 data are more evenly distributed and show less gaps than the MSM

03/2 data. However, despite of rather similar seeming results of the resolution tests, it is important that MSM 04/3 data to a much higher degree represent independent footprint measurements and therefore are considered much more accurate.

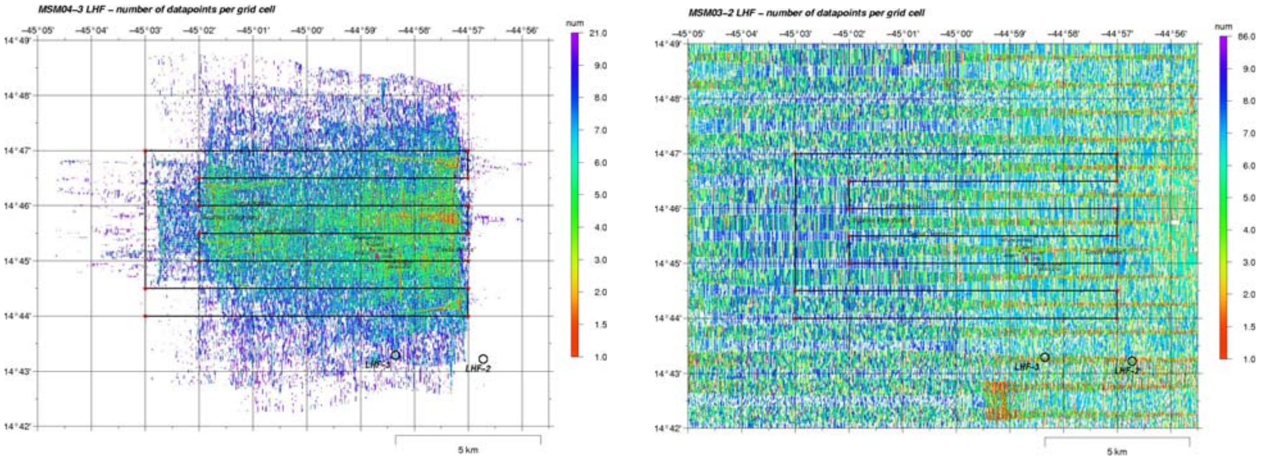


Figure 3-4. Number of datapoints per grid cell for surveys MSM 04/3 (left) and MSM 03/2 (right).

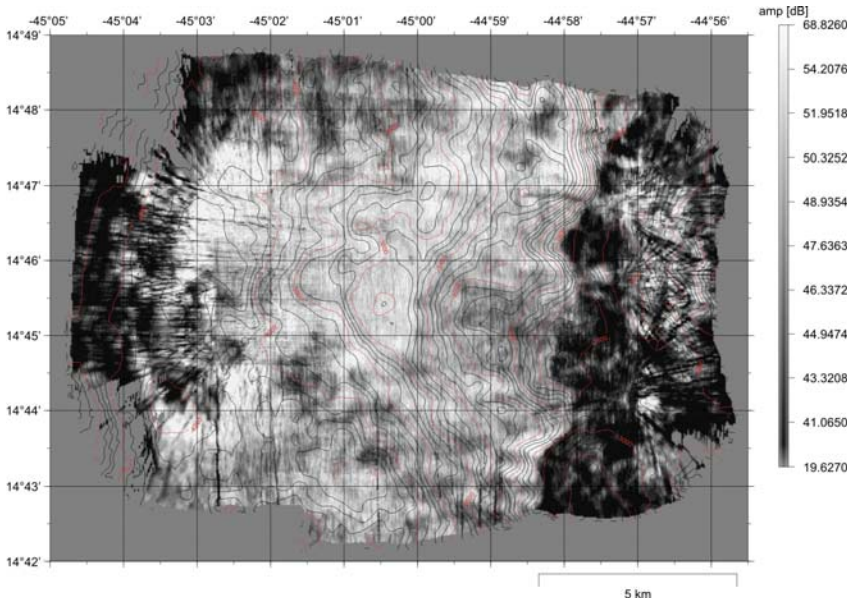


Figure 3-5. Gridded amplitude data from EM120 raw data. Color scale is in normal mode, i.e. bright tones represent high backscatter, dark tones are low backscatter. The grid size is 30 metres. Note the stong difference between the topographic highs and the Mid-Atlantic Central Valley.

Associated with the depth measurements are the amplitude values of the returning signal. Gridded and plotted on a map they show the backscatter of the seafloor, bright tones representing strong and dark tones low backscatter (Fig. 3-5). The clear backscatter difference between the topographic highs (dark) and the lower levels down to the central ridge axis indicates strong influence of the topography on the returning signal. This may represent a lithologic border between outcropping ultramafic rocks or gabbros on the topographic ridges and talus and sediments in the lower areas. The plateau with the hydrothermal vent sites appears as a dark tongue directed towards the rift valley.

Transit to Las Palmas

The transit to Las Palmas was used to map a large seamount at 26°12.00' W, 25°47.50' N with one line of swath bathymetry. The seamount rises from 5000 m to 1800 m water depth and is approximately 45 km (E-W) by 40 km (N-S) wide at its base. Despite a very large opening angle of the swath (2 x 65°), the seamount was not covered entirely. The swath width therefore varies between 21.5 km at the base of the seamount and 8.5 km on the summit. Additional lines were not recorded because of limited time.

3.4.2 Calibration of the Geographic Coordinates of the Active LHF Structures Using Jason II and Discovery of a "new" Smoking Crater

(Christian Borowski)

The ROV Jason II

Jason II is a two-body system with 6500-m depth capacity consisting of the Jason II vehicle and the depressor Medea (Fig. 3-6). The depressor serves as a shock absorber, buffering the vehicle from movements of the ship. A 10-kilometer fibre-optic cable delivers electrical power and commands from the ship through Medea down to Jason which then returns data and live video imagery. Jason II is linked to Medea via a 35-m long and 20-mm wide neutrally buoyant tether. The two-component design allows very stable positioning of Jason II in the water column, e.g., the vehicle can always keep cm-precise position in front of 3-dimensional seafloor structures without bottom contact and independent of the surface water sea state. The length of the tether determines Jason's radius for free operation around Medea, while travelling larger distances requires relocation of Medea by moving the ship. Jason II navigates with a long baseline transponder navigation system using frequencies that range between 7.5 and 14 kHz and with a RDI 300 kHz bottom-tracking Doppler Velocity Log (300 m range). Jason's video and photo imagery equipment includes one 3-chip colour camera (scientists pan & tilt), two 1-chip colour cameras (pilot's pan & tilt, Light bar) three utility color cameras (manipulator, basket, aft-looking), and a digital still camera (operated by scientists). Jason has two hydraulic 7-function manipulator arms (Kraft Predator II with force feed back and Shilling Orion), a hydraulic forward sampling drawer ("basket": 98 x 152 cm) and two hydraulic lateral swing arms (51 x 51 cm each) that can be used for storage of samples or equipment. Jason's payload for scientific instruments or samples is 130 kg. Additional equipment or sample material can be transferred between surface and seafloor with an acoustically released free-falling elevator that has 90 kg payload. Jason II was launched and recovered by RV Maria S. Merian's crane no. 3 over the starboard side, while Medea was operated via the large ship A-frame. Launching and recovery procedures required the full ROV team on deck.

Three separate ROV team watches each with a pilot, an engineer and a navigator allowed continuous shift rotation during the dives in a 4-hours-on, 8-hours-off rhythm. The operation on the seafloor additionally required three scientists in the control van (PI, protocol, video operation). Turnaround time for vehicle deployment between the dives was 12 hours. For practical reasons, we always coordinated the launching and recovery of Jason II with the same ship watch and thus kept dive times to lengths of either 12 or 24 hours.

Figure 3-6. The ROV Jason II. A: Launching of the vehicle Jason II; B: launching of Medea; C: View from Medea on Jason II during operation on the seafloor; D: Free-fall elevator.

Foto and video documentation

Video imagery of the entire dives obtained with three cameras (3-chip science, pilot and light bar) and still camera fotos are stored on DVDs (videos in NTSC and Pal formats). Frame grabs of the three video streams are accessible online together with the control van dive protocols in the "Virtual Van" on http://4dgeo.whoi.edu/jason.

Calibration of the geographical positions of LHF structures

Initial descriptions of the LHF included geological overview maps and micro-scale maps of the biologically most active structures which lacked exact coordinates (Krasnov et al. 1995, Gebruk et al. 2000). The relative positions of the vents to each other remained somewhat vague and as a consequence, the re-localization of sites during later expeditions was time consuming. The LBL navigation system of Jason II offered the opportunity to accurately map the hydrothermal vent structures and calibrate their geographic coordinates.

Two LBL navigation transponders equipped with 200-300 m long tethers in order to minimize acoustic shadows were positioned some 0.8 and 1.3 nautical miles upslope of the LHF vents in 2566 m and 2510 m water depth (14°46.188'N, 44°58.028'W and 14°45.420'N, 44°57.954'W). The additionally used Doppler Velocity Log used with the Jason DVL software provided highly accurate relative positions to the ship. During a total of 11 dives, we repeatedly visited all known hydrothermal structures that align along roughly 520 m distance in NW-SE direction between the smoking crater "Quest" and the chimney structure of "Site A". The resultant coordinates of the positions of the LHF hydrothermal vent structures are listed below (Figs 3-7, 3-8; Tab. 3-1).

Discovery of the previously unrecognized smoking crater "Candelabra"

Apart from the exact positions of the vents, the accurate navigation data also revealed that the south-eastern hydrothermal structures have been misinterpreted in the past. Gebruk et al. (2000) described the three smoking craters "Site B", "Irina I" and "Anna-Louise" aligning approximately in N–S direction in the southern part of the active LHF. Our data clearly show that a fourth smoking crater is present between "Irina I" and the double crater structure "Anna-

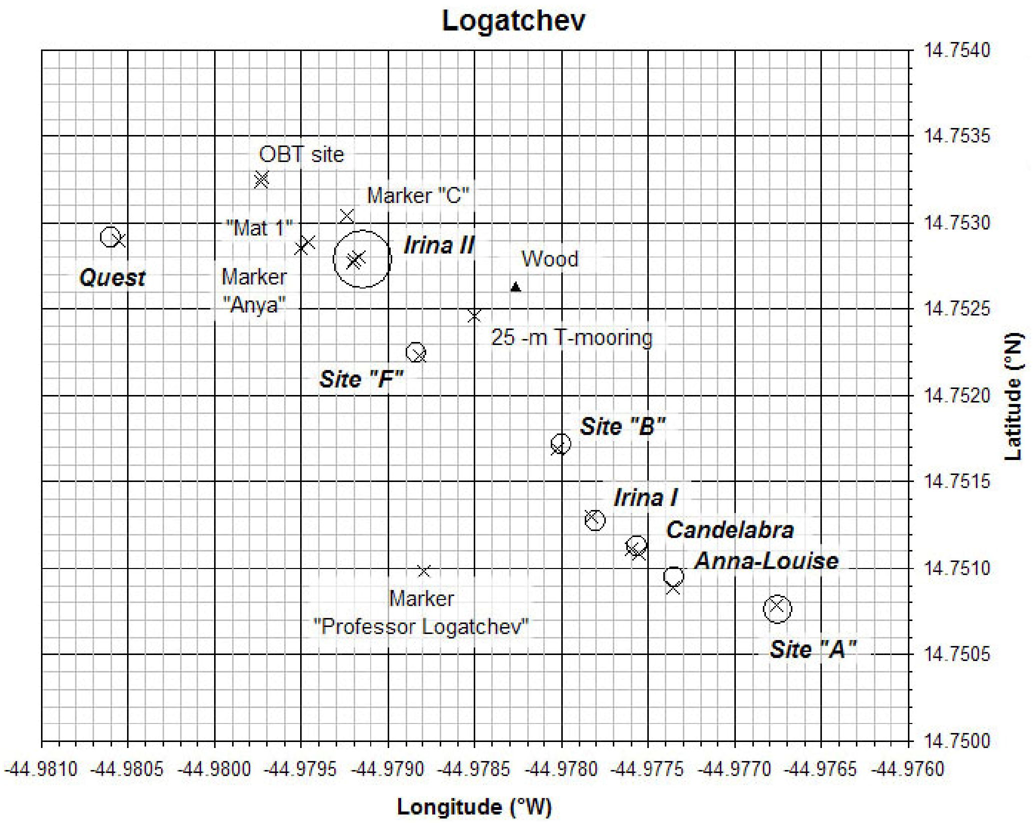


Figure 3-7. Calibrated geographic positions of active LHF structures (circles) and some markers (crosses) deposited by MSM 04/3 and earlier cruises. "OBT site" is the location of OBT and OBP deposition during M 64/2 and this cruise. Marker positions of the hydrothermal structures represent the coordinates given in table 3-1. "25-m T-mooring" marks the position of a vertical temperature logger mooring deposited during this cruise. "Wood" marks the position of a wood log deposited for colonization experiments. "Mat 1" was sampled for microbiological studies. Markers "C", "Anya", and "Professor Logatchev" were deposited during earlier cruises.

Table 3-1. New coordinates of the LHF hydrothermal vent structures obtained by LBL-navigation with Jason II.

Site	Latidtude	Longitude	Water Depth	Distance between structures
Quest	14°45.175'N	44°58.836'W	3026 m	
				121 m
Marker Anya	14°45.171'N	44°58.770'W	3029 m	
				38 m
Irina II	14°45.167'N	44°58.752'W	3021 m	
				67 m
Site F	14°45.135'N	44°58.728'W	2963 m	
				110 m
Site B	14°45.100'N	44°58.686'W	2946 m	
				50 m
Irina I	14°45.076'N	44°58.668'W	2935 m	
				33 m
Candelabra	14°45.067'N	44°58.656'W	2926 m	
				30 m
Anna-Louise	14°45.057'N	44°58.644'W	2911 m	
				70 m
Site A	14°45.046'N	44°58.608'W	2914 m	

Louise" (Figs 3-7, 3-8, Tab. 3-1). This "new" crater has been marked and sampled during earlier cruises including M 60/3 and M 64/2, but was never recognized as a separate structure and was considered by mistake either as "Irina I" or "Anna-Louise". The new structure is smaller than the double crater "Anna-Louise" and resembles "Irina I" and "Site B" in size. We named it "Candelabra" referring to a black smoker on its rim which had already been named during Meteor cruise M 60/3.

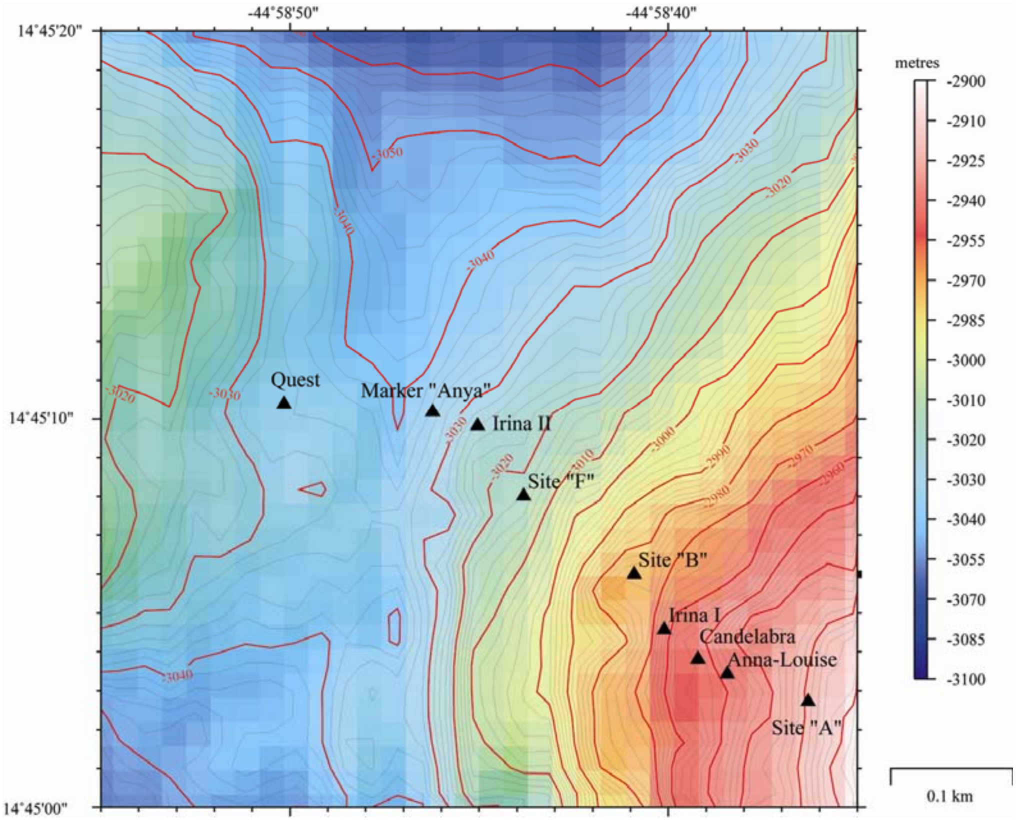


Figure 3-8. Detailed bathymetric map of the LHF including the hydrothermal structures according to Jason II LBL navigation data. Contour interval is two metres.

3.4.3 Gas Chemistry

(Robin Keir, Oliver Schmale, Peggy Wefers)

During MSM 04/3, methane and hydrogen were measured in vent fluids, in samples collected from the water column and in gas samples from experimental kinetic studies. Additional water samples were collected for helium isotope analysis at the University of Bremen, and gas samples were preserved for carbon isotope analysis on the methane component. The measurements on the vent fluids and water column samples are part of an ongoing monitoring program of the Logatchev biology and chemistry and are described in this section.

Vent fluids were obtained on nearly every ROV dive with a titanium sampling device (called a "Major", see section 3.4.6) that extracts about 600 ml of fluid with a spring-loaded piston. In total, 26 vent samples wer analyzed for methane and hydrogen. In addition 12 CTD casts were carried out. Three of these were tow-yo deployments, in which the CTD-Rosette was raised and lowered through the plume while being towed by the ship at about 0.5 knot. The tracks of the tow-yos crisscrossed over the Logatchev vent field. Figure 3-9 shows the tow-yo tracks and the positions of the conventional CTD stations

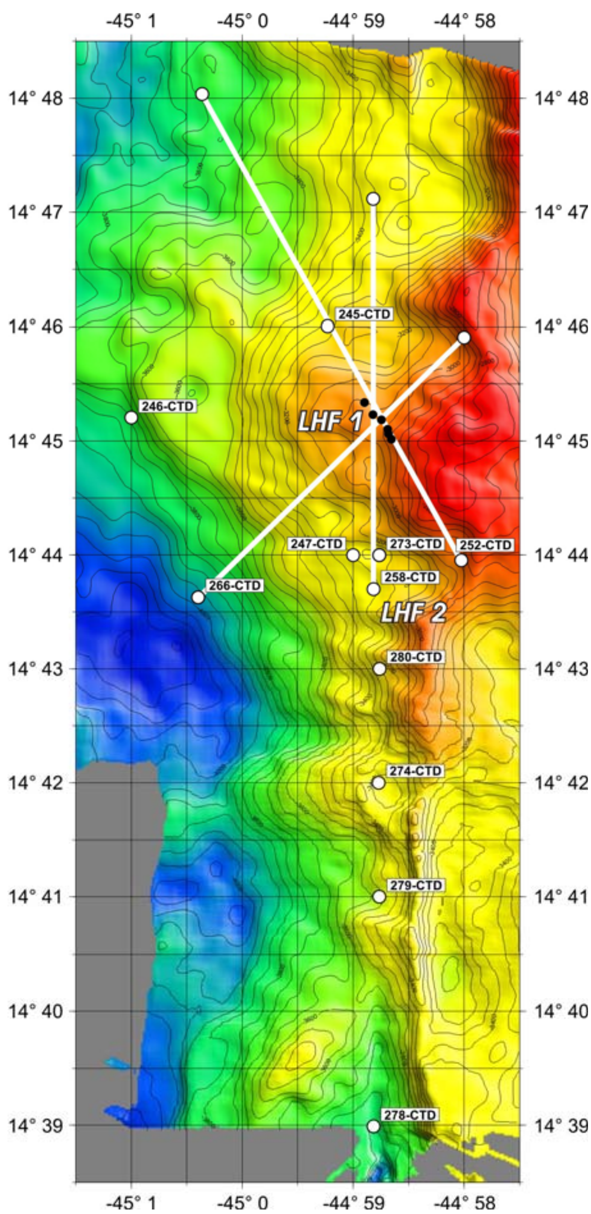


Figure 3-9. CTD positions and Tow-Yo tracks

Methods

The CTD casts were carried out using a Sea-Bird Electronics, Inc. SBE 911plus system (Table 3-2). The underwater unit was attached to a SBE 32 carousel water sampler equipped with 24 10-liter Hydrobios-Freeflow bottles. For later offshore calibration of the conductivity sensor, two or three salinity samples were taken per cast. In addition to the continuous conductivity, temperature and depth analyses of the water column, turbidity was recorded with PMEL MAPRs (NOAA / Pacific Marine Environmental Laboratory; Miniature Autonomous Plume Recorder). The MAPRs sensor data is recorded internally and was not accessible during CTD deployments.

For the on-board CH_4 and H_2 analyses of fluid samples, a modification of the vacuum degassing method described by Lammers and Suess (1994) was used to extract the gases (Rehder et al., 1999). In the case of seawater collected by the CTD-rosette, 1600 ml was drawn into pre-evacuated 2200 ml glass bottles. During this sampling, most of the dissolved gas exsolves into the remaining headspace. The amount of water taken was measured with a flow meter (Engolit Flow Control 100S/Typ DMK). The extracted gas phase was subsequently recompressed to atmospheric pressure, and the concentration of CH_4 and H_2 was determined by gas chromatography. For the determination of dissolved CH_4 a Shimadzu GC14A gas chromatograph equipped with a flame ionization detector was used in connection with a Shimadzu CR6A Integrator. Nitrogen was used as carrier gas, and separation was performed using a 4 m 1/8’ SS column packed with Porapack Q (50/80 mesh) run isothermally at 50°C. The H_2 concentration of the extracted gas was determined using a TRACE Ultra gas chromatograph (Thermo Electron) equipped with HaySep Q, and Molecular Sieve 5 A columns. Helium was used as carrier gas. The run was performed isothermally at 50°C. The eluted gas was detected via PDD (pulsed discharge detector).

Table 3-2. Sample list for CTD-stations

Station	Profile	Long. W	Lat. N.	CH4	$\delta^{13}CH_4$	H_2	He
242-CTD	001	51°22.410	15°07.677	4			
245-CTD	002	44°59.229	14°46.006	20	20	20	
246-CTD	003	45°01.000	14°45.205				
247-CTD	004	44°59.001	14°43.999				
252-CTD	005	Tow-Yo		20	20	20	
258-CTD	006	Tow-Yo		23	23	23	23
266-CTD	007	Tow-Yo		22	22	22	
273-CTD	008	44°58.765	14°43.999	12	12	12	12
274-CTD	009	44°58.769	14°42.000	13	13	13	13
278-CTD	010	44°58.817	14°38.991	12	12	12	12
279-CTD	011	44°58.764	14°40.999	10	10	10	10
280-CTD	012	44°58.763	14°42.999	12	12	12	12

In order to extract the gas from the vent fluids, the outlet of the "Major" sampler was connected to an evacuated 250 ml or 500 ml flask, and after filling out the dead volume in the line, the fluid was drawn into the flask by the vacuum. Normally, vent fluid must be forced out of a "Major" by applying strong pressure to the piston. However, once the dead volume was cleared, the vacuum in the flask was sufficient to draw down the piston without pushing against the spring. Typically, 80 ml of black smoker fluid and 300 ml of diffuse vent fluid were sufficient to collect the necessary amount of gas (>15 ml). Since the CH_4 and H_2 concentrations in the gas were often very high, most of these samples were diluted by 1:1000 with Helium in a gas mouse before analysis. ROV samples are listed in Table 3-3.

Table 3-3. Sample list for ROV-stations

Station	CH_4	$\delta^{13}CH_4$	H_2	He
244	2	2	2	1
251	4	4	4	
253	4	4	4	
257	3	3	3	1
259	4	4	4	
267	3	3	3	
271	3	3	3	
275	3	3	3	1
282				1

After the analyses, the remaining gas was preserved for the determination of the stable carbon isotopic ratio in methane. These sub-samples were drawn into pre-evacuated glass vials containing 2 ml of supersaturated salt solution and sealed with a butyl rubber septum. The samples are stored upside down in order to prevent air contamination during storage.

For measurements of the He concentrations and isotopic signature, water samples were taken from Hydrobios-Freeflow bottles of the rosette and sealed head space free and gastight in copper tubes (sample volume 40 ml). Special containers for sampling fluid on a vent were tested for handling by the ROV pilots. The sampling containers can keep a pressure of more than 3·107 Pa and avoid phase separation of vent fluids and gases. He isotope measurements will be performed at the IUP, section of Oceanography, at the University of Bremen with a fully automated UHV mass spectrometric system (for details see Sültenfuß and Massmann, 2004).

Preliminary Results

The vent fluids obtained with "Major" samplers often contained very high concentrations of hydrogen and methane. The gas content of the various black smoker fluids was typically about 10% methane and 40% hydrogen. The highest dissolved concentrations of these gases were measured in a sample from Irina II, which contained 1.5 mmol L^{-1} methane and 5.9 mmol L^{-1} hydrogen. The 4:1 ratio of hydrogen to methane appears to be characteristic of all of the Logatchev black smoker fluids (Fig. 3-10).

Diffuse vent fluids, however, exhibited lower hydrogen to methane ratios. As on Meteor cruise M 64/2, a correlation was observed between particle, methane, and hydrogen concentrations at some stations. This was apparent at Station 273, 3.9 km south of the LHF (Fig. 3-11).

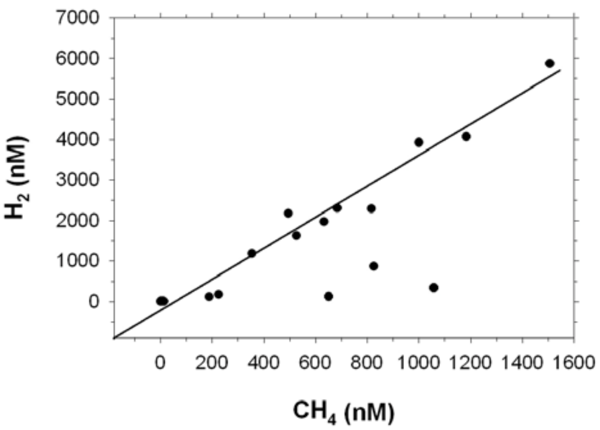
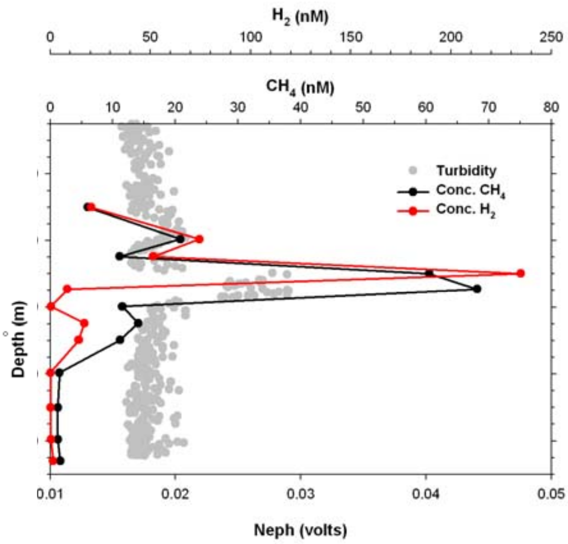


Figure 3-10. Hydrogen versus methane from black smoker fluid measurements



3-11. Particle, methane, and hydrogen concentrations at Station 273 CTD.

However, at other stations the correlation between these properties was rather poor. A scatter diagram of all water column measurements of hydrogen and methane indicates that at least some of the time near the vent field, the ratio of H_2 to CH_4 in the plume is similar to that of the black smokers, but at other times and away from the field, this ratio is lower (Fig. 3-12). Helium and carbon isotope measurements will be conducted during the next several months, and these should shed more insight on the processes controlling plume concentrations.

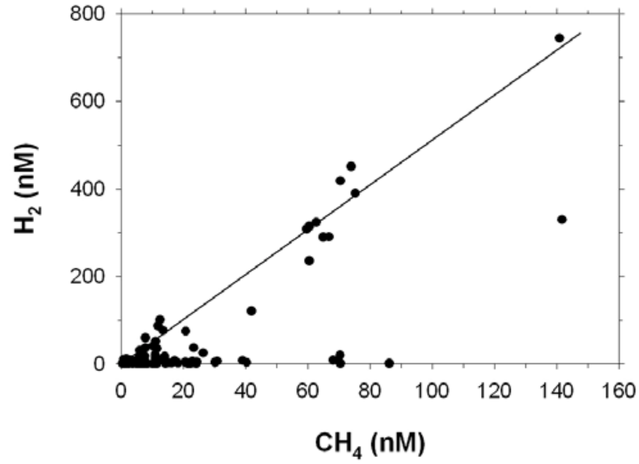


Figure 3-12. Hydrogen versus methane from water column measurements.

3.4.4 Logatchev Longterm Environmental Monitoring – LOLEM

(Marcus Fabian)

Overview

The project LOLEM monitors environmental parameters with long-term observation instruments in the Logatchev Hydrothermal Vent Field area. Ocean Bottom Tiltmeters (OBT; Fabian and Villinger, in press) continuously record sea floor tilt and low-frequency sea floor acceleration. An Ocean Bottom Pressuremeter (OBP) monitors changes in the absolute ocean bottom water pressure. A 25-m-mooring is used for vertical temperature profiling in the near bottom water column. A small-scale distributed temperature sensing system including 20 individual single-channel Miniaturized Temperature Loggers (MTL; Pfender and Villinger, 2002) and four 8-channel temperature loggers are part of a mussel-field experiment in collaboration with the MPI-Bremen. The data records are proxies for the conditions of the fluid regime (tilt, acceleration, water pressure) and also for local changes in the environment of biological communities (temperature data). The fluid regime can change when local crust deformations and micro-earthquakes alter fluid pathways in the sub-surface. This may also affect the temperature regime. The long-term monitoring data is therefore essential for all research disciplines in the SPP. Moreover, the data directly reflect local seafloor motions (tilt, acceleration, water pressure) which are forced by tectonics, hydrothermalism and micro-earthquakes on the Mid-Atlantic Ridge.

As an additional part of LOLEM, a temperature probe was developed for in situ measurements of small-scale gradients in high and low temperature environments. The probe is operated by the ROV and measure temperature profiles under real-time control with eight sensors aligned along 28 cm length. The probe can be used to measure environmental temperature gradients in e.g. bacterial mats, mussel bed communities and hot fluids of black smokers.

Cruise MSM 04/3 with RV Maria S. Merian and ROV Jason II

During this cruise, ROV Jason II recovered the OBT, OBP, 25-m temperature mooring and MTL arrays that had been deposited by RV Meteor cruise M 64/2 in May/June 2005 (Lackschewitz et al. 2005. Almost all instruments have successfully collected the expected long-term data. Figure 3-13 provides an overview of the available data and the schedule until the next cruise MSM 06/2. The instruments spent nearly two years on the sea floor and all housings were considerably affected by strong corrosion. Five MTL were seriously damaged by very hot fluids and lost their data. OBT, OBP, the mooring and the MTL were replaced by new instruments. The ROV T-lance was used on the ROV Jason II during all dives and provided useful data for the cruise participants. Since MSM04/3 was shortened by more than a week, the basic scientific program had to be reduced and station work in the LHF was rather condensed. However, despite rather strong corrosion, the old OBT could be repaired and re-deployed. Now, the new OBT-2, the old OBT-1, the new OBP-2, a new temperature mooring, 10 new MTL for the "Irina II"-mussel field experiment and 9 new MTL for the "Quest" mussel field experiment record long-time data in the LHF. The map in Fig. 3-14 shows the positions of the new instruments in black and the old positions in grey.

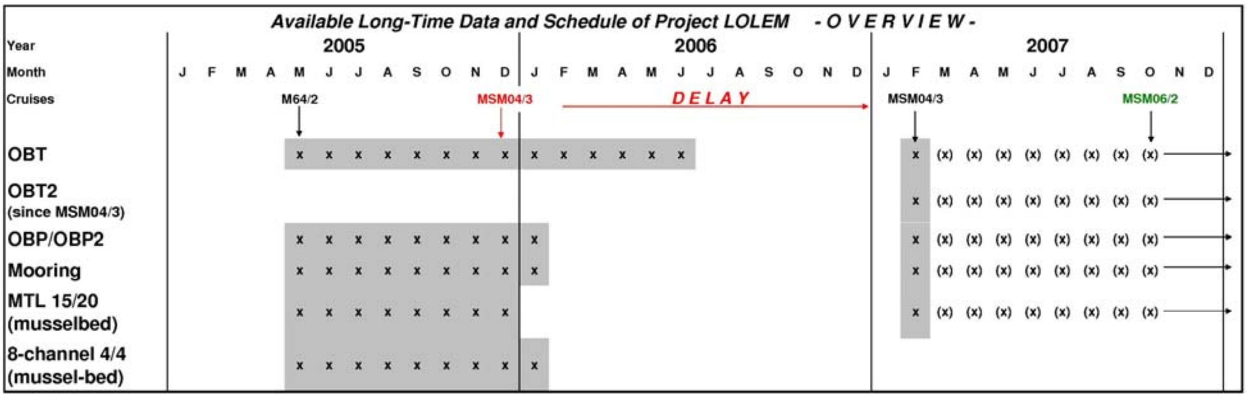


Figure 3-13: Long-term data collection by LOLEM instruments until to date and in the future. Crosses on grey background mark the available data. Crosses in brackets during 2007 mark the measurements by instruments deposited during MSM04/3. Due to the postponement of this cruise from end of 2005 to January/February 2007 there is a data gap of about one year in 2006.

OBT and OBP

OBT and OBP were deposited in 3035 m water depth. OBT measures vertical tilt in two perpendicular horizontal directions and low frequency vertical acceleration at frequencies of up to 0.5 Hz, while OBP measures absolute water pressure at a resolution of 1 mm. OBP data will be used to assess vertical sea floor displacements and therefore complete the OBT data. Tilt data show very strong steps and spike-like signal patterns in the initial record period which cannot yet be clearly interpreted (Fig. 3-15A). Water temperature fluctuations are small and appear to have no influence on the tilt measurements. At the end of the data record there is a larger step in tilt. The observed pattern may indicate an alternation of relatively calm phases with phases in which strong tilt steps appear. This hypothesis must be verified with future measurements. The OBP data show a clear tidal signal (Fig. 3-15B) and therefore need correction before an assessment of seafloor displacement. Residual data of the OBP will be compared and correlated with tilt and acceleration data and the results of SPP co-workers, which concentrate on local tectonics and earthquakes.

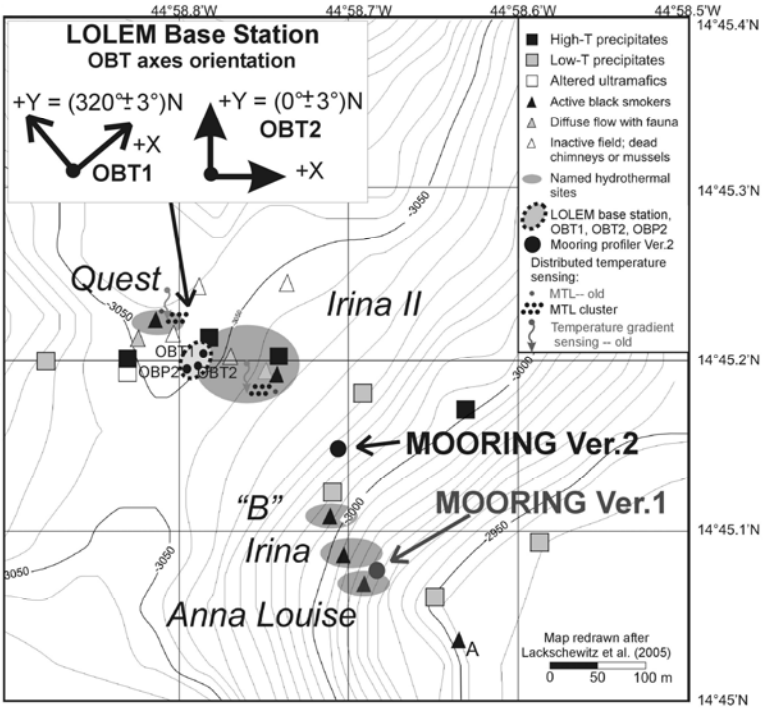


Figure 3-14: Map of the LHF with instrument positions of OBT1, OBT2, OBP2, the new mooring in version 2 and the two mussel field experiments with the distributed temperature sensing system (MTL cluster) consisting of in all 19 MTL sensors.

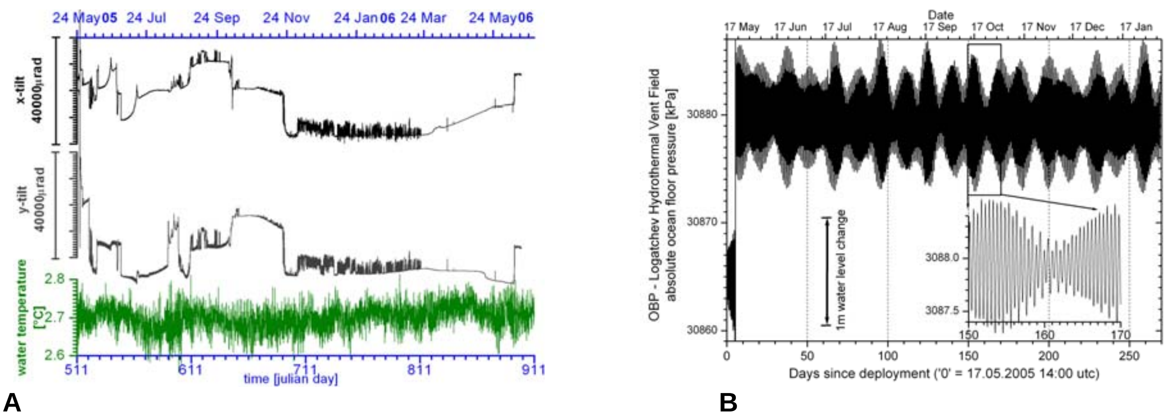
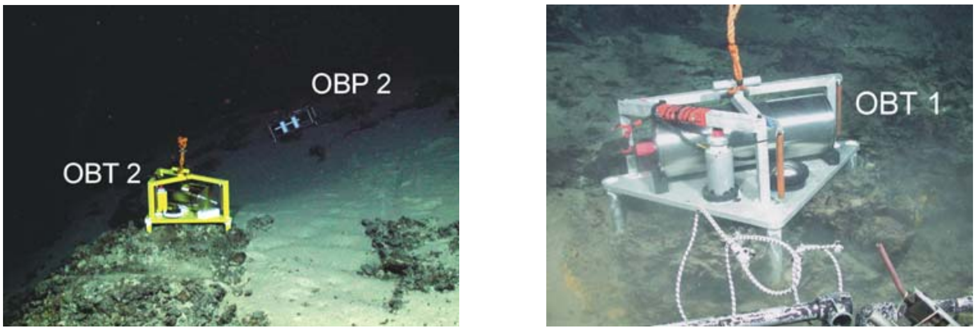


Figure 3-15. Long-term data collections in LHF of ocean bottom tilt and ocean bottom pressure fluctuations. A: Ocean bottom tilt measured for approximately 400 days by OBT: X-Tilt, Y-Tilt and water temperature. The water temperature fluctuates frequently, but within a very small range. B: Ocean bottom pressure data measured by OBP. This instrument was relocated on the seafloor a few days after deployment and finally placed next to the OBT. This movement is reflected in the suden jump in the data in the beginning of the collction interval. Tides of about 1 m water level change dominate. The enlarged view in the inset shows the very accurate tide-signal. Acceleration data will be provided later. The high frequent sampling rate of 1 Hz produced a rather large data set which will be analysed separately.

One major objective for this cruise was the replacement of the instruments on the seafloor with fresh ones. The new instruments were installed on the same positions at 14°45.194’N, 44°58.773’W. This site is marked with two white passive markers and an anchored buoy with a Sonardyne Beacon (ID 15). The recovered old OBT (OBT-1) furnished with fresh batteries and re-deposited together with another passive marker on a new position some 30 m NE to the other instruments. The two OBTs were levelled by the ROV Jason II using a deep sea level (Fabian and Heesemann, 2006). All instruments need stable ground and therefore sit on top of small piles of rocks (Fig. 3-16).

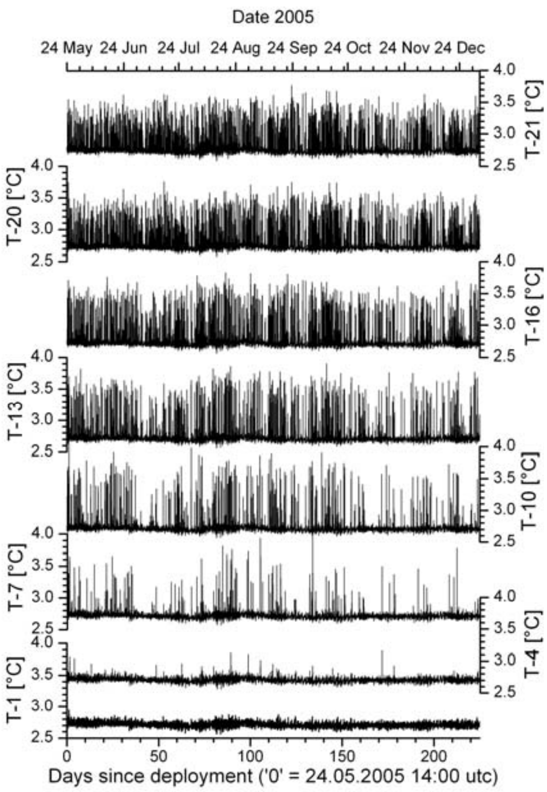


A B

Figure 3-16. A: OBT-2, OBP-2 on the positions of OBT-1 and OBP-1. B: Old OBT-1 on its new position.

25-m-Mooring –Vertical temperature profiler

The 25 m-mooring includes 24 temperature sensors which are aligned in 1-m distance from each other along the mooring rope. The data collected are most likely directly related to the temperature anomaly caused by hot fluids of nearby black smoking craters Irina I and Anna-Louise (Fig. 3-17A). The new mooring was deposited between the active smoker sites “Irina II“ and “Site B” at 14°45.149’ N, 44°58.714’ W in 3000 m depth (see Fig. 3-15). It is marked with a Sonardyne Beacon that is attached to the mooring rope (ID 14; Fig. 3-17B).



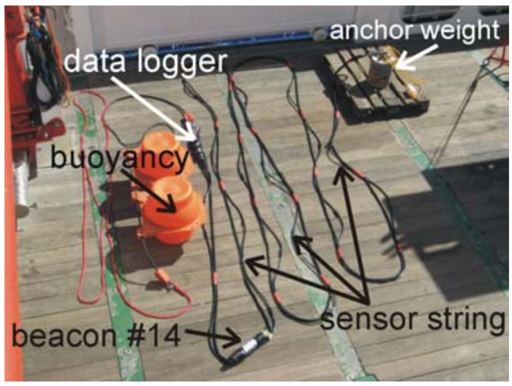
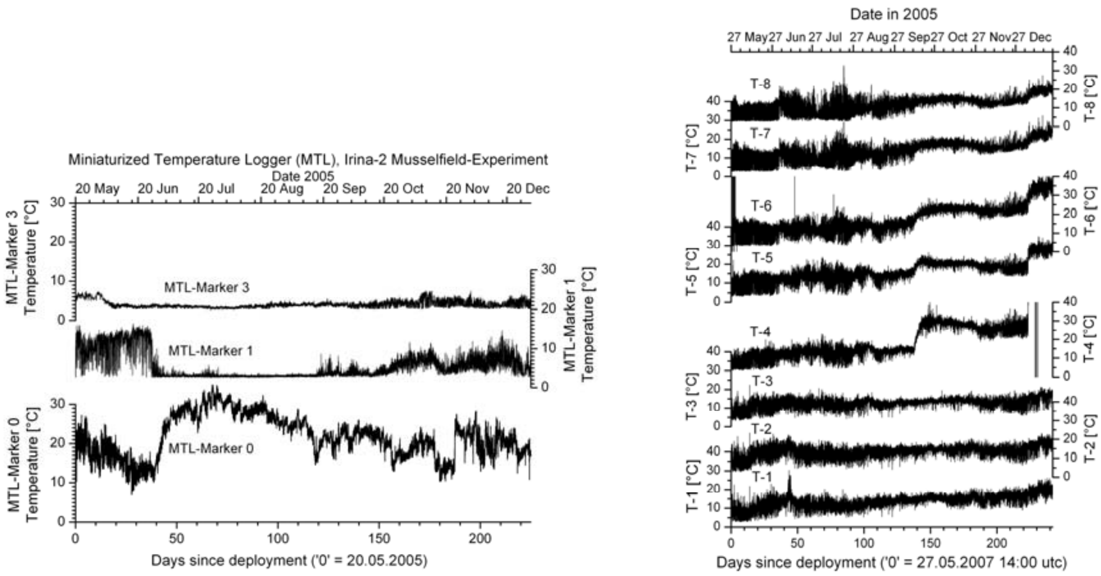


Figure 3-17. Vertical temperature mooring. Left: Temperature time series data, here as examples of every third logger in a vertical distance of 3 m, starting with logger T1 next to seafloor to loggers T20 in 20 m and T21 in 21 m height above sea floor. Temperature variations with higher values appear significantly more frequently at larger heights above seafloor. Top: Photo of the new mooring version 2 on board Maria S. Merian before deployment.

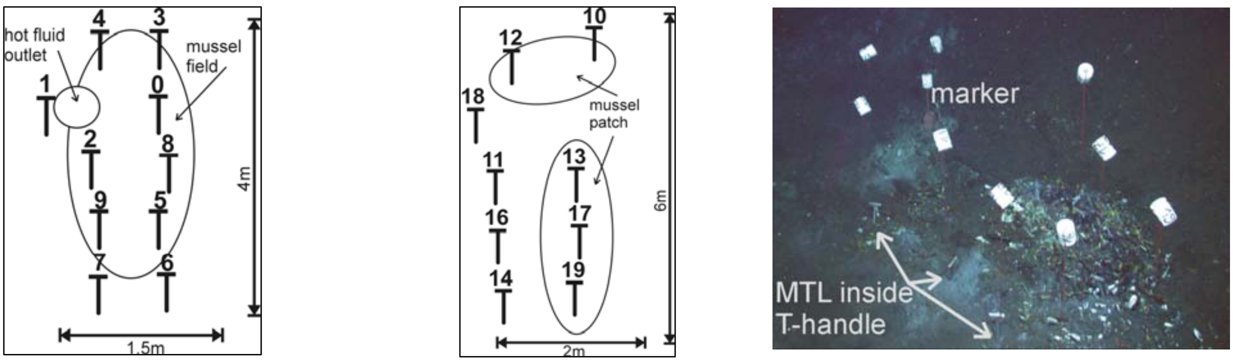
Distributed temperature sensing system

The distributed temperature sensing system serves for measurements on a meter to centimetre scale within and across mussel fields or individual mussel patches. The two sensor arrays that had been deposited by cruise M 64/2 in the “Irina II“ mussel field and across a mussel patch next to the “Quest” “ smoking crater were entirely recovered (For the layout of the sensor arrays see Lackschewitz et al., 2005). Figure 3-18 shows examples of the time series data collected by single channel temperature loggers (Fig 3-18A) and an 8-channel temperature logger (Fig. 3-18B). Replacement of temperature loggers during this cruise included only MTL in “Irina II“and “Quest”, while no other 8-channel T-loggers were deposited. The new arrangements of the MTL arrays in “Irina II “and “Quest” are illustrated in figure 3-19.



A B

Figure 3-18. Temperature time series measurements of MTL and 8-channel loggers. A: Three time series of MTL recovered from the“Irina II“mussel field. B: Time series of an 8-Channel temperature logger from the “Quest” mussel patch. Lateral distances between the MTL are below one meter (A), and the distance between individual sensors T1 to T8 along the probe of the 8-channel logger is 4 cm (B).



A B C

Figure 3-19. New arrangement of MTL temperature sensors. A: At site “Irina II“with 10 instruments, B: At site “Quest” with 9 instruments. The numbers correspond to individual MTL numbers. C: Photo of the “Quest”T-loggers. One of the floats is a passive marker, the other nine mark the MTL sensors.

8-channel in situ T-lance

The 8-channel in situ T-lance is a temperature measurement tool for the determination of absolute temperatures and gradients in low-temperature and high-temperature environments (Fig. 3-20). The instrument is operated by the manipulator arm of the ROV, and online control of the sensor data allows real-time observation of the in situ temperatures along the 28-cm long probe. We used this tool for direct measurements of hot fluids exiting the LHF black smokers and for measurements of temperature gradients in diffuse fluid outlets, mussel beds, sediments and under bacterial mats. The highest temperature of 349°C was measured in fluids of Anna-Louise, while maximum temperatures at other smoking craters varied between 330°C and 347°C (Tab. 3-4). The fluids exiting from "Irina II" beehives were cooler than those of other LHF vents including a separate black smoker only a few meters apart from the "Irina II" main sulphide structure. These lower temperatures are most likely influenced by mixing with ambient seawater that is either entrained through the beehive walls or by turbulences caused by the probe introduced into the thin beehive exit tubes. However, the comparable small variation between maximum temperatures of the various hot emission sites may indicate that all LHV vents are fed by the same source fluid.

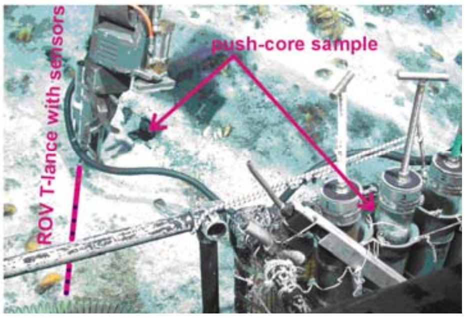


Figure 3-20. Temperature measurement with the ROV T-lance in a white mat next to a push core sample location.

Table 3-4. Maximum emanation temperatures of hot fluids at various LHF structures.

Station	T (°C)	Vent site
259-23	347	Quest
244-1	293	Irina II, beehive 1 on main structure
259-27	300	Irina II, beehive 2 on main structure
244-5	340	Irina II, separate black smoker SE of main structure
257-1	340	Site B
257-2	343	Site B
257-15	335	Candelabra
275-6	349	Anna-Louise
275-3	330	Site A

Temperature measurements in sediments below bacterial mats at site "Mat #1" and "Site F" indicated that the heat flow in the mat habitats is primarily conductive (Fig. 3-21A). The steep and stable temperature gradients of up to more than 100°C in some mat places indicate the presence of fluid close-by in the subsurface that is comparably weakly mixed with seawater. Measurements in diffuse fluid outlets in the "Irina II" mussel bed revealed also steep gradients of more 120°C within the 28 cm. Within the mussel bed layer, however, temperatures did rarely exceed 10°C. Time series measurements showed irregular temperature gradients in diffuse outlets and in the mussel beds indicating horizontal mixing of the diffuse fluids (Fig. 3-21B).

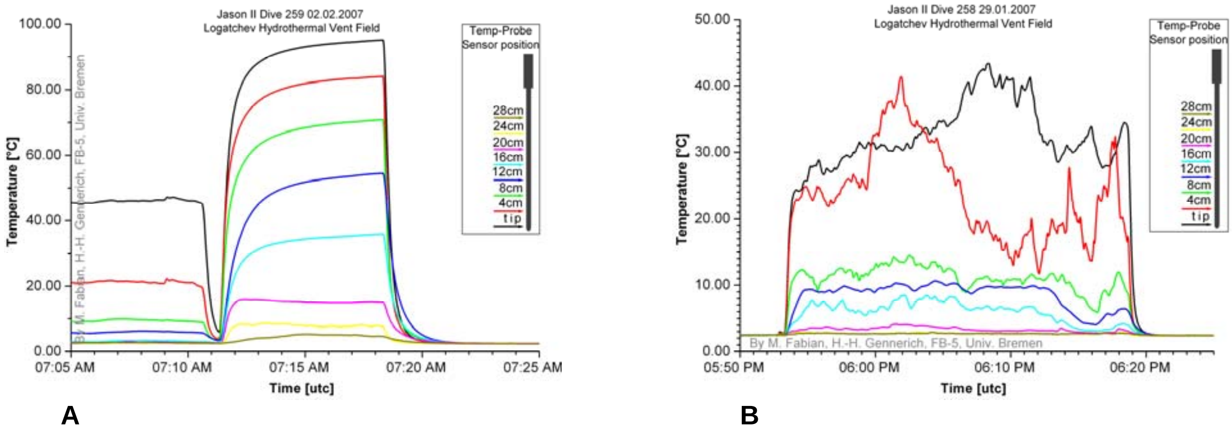


Figure 3-21. Temperature profiles measured with the 8-Channel T-lance in sediment below a bacterial mat at site "Mat #1" (A) and in the "Irina II" mussle bed (B). The eight sensors are interspaced by 4 cm distance along the probe. The black line represents the temperature measurements of the sensor on the probe tip, while the "28 cm"-sensor data respesents the interface between sediment or mussel bed and water. A: The highest temperature of ~100°C occured at the tip of the probe in 28 cm sediment depth. The constant temperature decrease towards the sediment surface indicates conductive heat flow without advective fluid flow. The breakdown of the profile after 6 minutes was caused by the relocation of the probe to another spot in the bacterial mat. B: Irregular temperature profile in a diffuse hydrothermal fluid outled below the "Irina II"mussel bed. Temperatures were lower than 10°C within the mussel bed layer (top 16 cm, sensors "28 cm" to "12 cm") and increased rapidly in the diffuse fluid outled below (>24 cm depth, sensors "8 cm" to "tip"). Crossing time series data lines of the lowermost sensors "4 cm" and "tip" and also irregulate data lines of all other sensors indicate advective heat flow and variable horizontal mixing of the fluid flow below and within the mussel bed.

3.4.5 Fluid Geochemistry of Hot and Diffuse Hydrothermal Fluids

(K. Schmidt, C. Jost)

We investigate the temporal and spatial variability in the fluid geochemistry of the Logatchev field by annual sampling of hydrothermal fluids. During this cruise, all high-temperature LHF vent sites were sampled including the newly recognized smoking crater Candelabra.

Water samples for the analyses of major and trace elements, isotopic composition of selected compounds, and the analyses of organic compounds were obtained from the water column (CTD stations) and from discrete fluid emanation sites (ROV dives). Temperature measurements for hot and diffuse venting sites were conducted with the 8-channel temperature probe (s. section 3.4.4).

"Major" Water Samplers

We used "Major" water samplers (titanium syringes) operated by the Jason II manipulator arm to collect hot and diffuse hydrothermal fluids (Figs 3-22, 3-23). Six samplers were available, two of them belonging to the priority program while four samplers were provided by Jason II. All six "Majors" fit in the Jason II sample basket determining the maximum number of samples that could be retrieved during one dive. The "Majors" are designed for sampling hot water for chemical and biological analyses and are constructed of inert the materials titanium, teflon and silicon in order to preserve water chemistry. Thin black coatings in the sample chamber after sampling hot fluids indicated sulphide precipitation. We obtained a total of 20 hot and and 18 diffuse fluid samples.

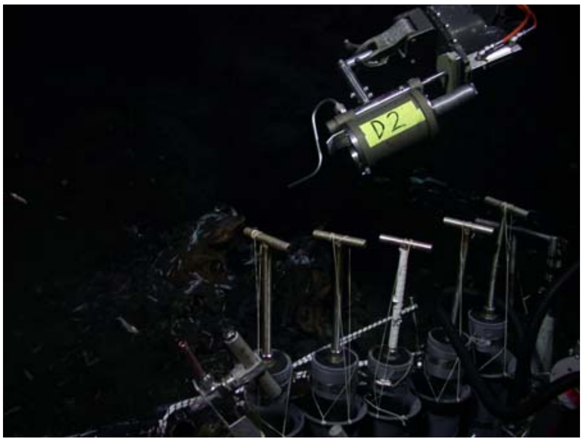


Figure 3-22: “Major” water sampler operated by the ROV manipulator arm.

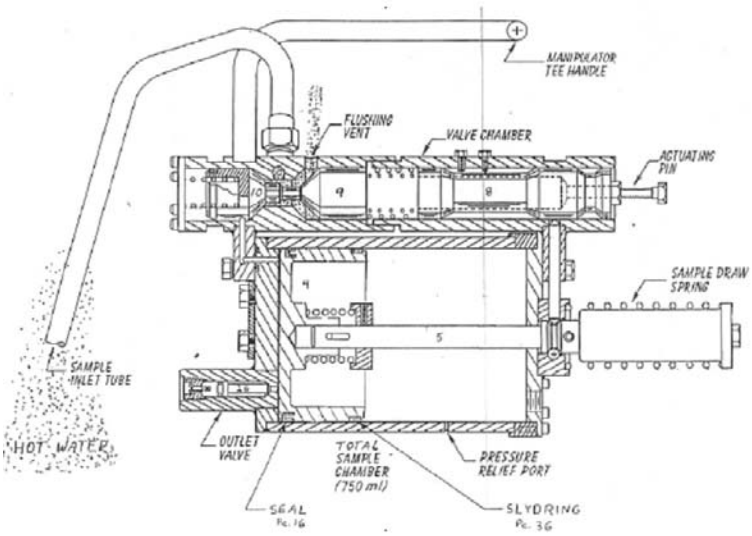


Figure 3-23. “Major” water sampler in cocked mode. Hot (and smoky) fluid passes the inlet tube and exits again through the flushing valve, indicating that the inlet tip is well positioned for sampling undiluted fluids. Pushing the actuation pin with a hydraulic piston of the manipulator arm closes the flushing valve, opens a valve to the sample chamber and releases the syringe piston. A large spring pulls the released piston and the chamber thereby fills with fluid. The sample is removed in the lab by manually pushing it out with the piston or by vacuum extraction (for gas sampling).

Treatment of fluid samples

Fluids were sub-sampled from the “Major” syringes and split into aliquots immediately upon their arrival on board. Small unfiltered aliquots (30 ml) from all fluid samples were measured directly upon retrieval for, ph, Eh, concentrations of total Fe, Fe-II, S^{2-}, Ca, Mg and Cl^-. Other aliquots served for the following chemical and isotopic analyses:

- abundance and isotopic composition of free and dissolved CH_4 and H_2: 100-300 ml
- concentrations of dissolved and particulate major and trace elements: 2x 50-250 ml
- concentrations of selected anions: 50 ml
- abundance and isotope geochemistry of sulphide: 400 ml
- abundance and isotopic composition of inorganic carbon: 10 ml
- isotopic composition of H_2 and O_2: 2x 2 ml
- identification of amino acids: 20-60 ml
- isotopic composition of Cr: 100 ml
- cultivation of microorganisms: 400 ml

For the determination of concentrations of dissolved major and trace elements, aliquots of 50-100 ml were pressure-filtrated with Nitrogen (99.999%) on polycarbonate filtration units (Sartorius, Germany) at 1 bar through pre-cleaned 0.2 µm Nucleopore PC membrane filters.

Selected sample aliquots were acidified to pH 1 was with 100 µl sub-boiled concentrated nitric acid per 50 ml (for ICP analyses) and with supra-pure HCl to pH 2 (for analysis of Cr isotopes). All work was performed in a class 100 clean bench (Slee, Germany) using only all-plastic labware (polypropylene, polycarbonate, PFA Teflon). Rinse water was ultrapure (>18.2 Mohm), dispensed from a Millipore Milli-Q system.

Methods used for on-board analyses

pH and Eh measurements

For all samples collected with either the CTD/Rosette or during ROV dives, pH and Eh were measured with WTW electrodes (Ag/AgCl reference electrode) on unfiltered sample aliquots immediately after sample recovery.

Chloride titration

In order to determine whether or not phase separation affected the chemical composition of the hydrothermal fluids, fluid samples from hot vents were subjected to chloride concentration analysis. Measurements were performed as titration with 0.1 M AgNO3 solution, using fluorescene-sodium as indicator. CTD/Rosette samples from a water column profile served as a reference.

Magnesium and calcium titration

The content of Ca and Mg was calculated after a sample titration using Erio T as an indicator and alkaline buffer medium (pH 10 with NH_4Cl/NH_3 buffer solution). The pH was first adjusted to 10 and after addition of a small amount of Erio T, the solution was titrated from red to blue with EDTA 0.1 M solution. Ca concentrations were determined using Murexid as an indicator and alkaline medium (pH $\geq$ 12 with NaOH 2 M solution). The pH was adjusted, Murexid was added, and the solution was titrated from red to violet with EDTA 0.1 M soluytion. The Ca content was then subtracted from the total content of Ca and Mg to obtain the Mg concentrations.

Photometric determination of iron concentrations

The principle of this method is the determination of an orange-red ferroin complex, which is formed by Fe(II) ions in the fluid sample after 15 minutes reaction time with 1,10-phenantroline at a pH range of 3 to 5. Additionally to the quantification of Fe(II), it is also possible to measure the Fe_{tot} fraction in the sample by reducing all Fe with ascorbic acid. Fe(III) is determined as difference between Fe_{tot} and Fe(II). Analyses were performed with a Biochrom Libra S12 spectral photometer. The absorption was measured at 511 nm using a quartz cell with 1 cm path length. Fe concentrations were measured only in filtered samples of hydrothermal fluids. Samples with concentrations above 100 mg L^{-1} were measured in diluted samples.

Photometric determination of sulphide

Diluted sulphide in the samples was first preserved by the addition of zinc acetate in sufficient amounts to precipitate sulphide as ZnS. Aliquots of each sample were treated with colour reagent N,N-dimethyl-1,4-phenylenediammonium dichloride and the catalyser ferric iron solution. Measurements were performed using a Biochrom Libra S12 spectral photometer and the absorption was measured at 660 nm using a quartz cell with 1 cm path length.

Voltammetric determination of trace element concentrations

Concentrations of sulphide and trace metals were analysed by voltametry. This method can differentiate with high sensitivity between different redox species and, in combination with UV digestion of the water samples, between free and complexed forms of ions in solution. All voltammetric measurements were performed using a 757 VA Computrace stand (Metrohm) with a standard PC. The three-electrode configuration included a multi-mode electrode (MME) as the working electrode, an Ag/AgCl reference electrode (3 M KCl), and a platinum wire as the auxiliary electrode. Unfiltered fluid samples were analysed for total dissolved sulphide in alkaline solution using the method after Metrohm Application Bulletin 199/3e. Manganese was determined using anodic stripping voltammetry (ASV) in borate buffer medium, according to Metrohm Application Bulletin 123/3e.

Further analyses in the home laboratories

Selected samples will be analysed at Univ. Kiel for the compositions of major elements (Mg, Ca, Ba, Sr, Na, K, Si, Fe, Mn, B, Cl) and trace elements (e.g., I, Br, Li, Al, Cs, Ba, Sr, Y-REE, Fe, Mn, Cr, V, Cu, Co, Ni, Pb, U, Mo, As, Sb, W, PGE) by ICP-OES (Spectro Ciros SOP CCD) and ICP-MS using both collision-cell quadrupole (Agilent 7500cs) and high-resolution sector-field based instrumentation (Micromass PlasmaTrace2).

The Jacobs University group will use voltammetry for further trace metal analyses (Zn, Cd, Pb, Cu, Co, Ni, Ti, V, Mo, U, Tl, Pt). ICP-MS and ICP-OES measurements of minor elements and trace metals listed above will be also performed by JUB in order to compare results between laboratories. Li and Na will be analysed by flame photometry, and photometric methods will be used to determine anionic compounds (silicate, phosphate, sulphate, chloride). The duplicate coverage of some elements with different methods will serve for an evaluation of the methods and the data.

The isotopies of sulphur (in sulphides and sulphates), oxygen (in sulphates; fluid samples), and hydrogen (fluid samples) will analysed at the Westfälische Wilhelms-Universität Münster.

At the Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) in Hannover T

The concentrations of amino acids in the fluids (HPLC-FD), their racemization (GC-FID) and their isotopic composition (GC-irmMS) will be analysed for selected samples by Bundesanstalt für Geowissenschaften and Rohstoffforschung. Concentrations of ammonium and its nitrogen isotopic composition will be investigated. The concentration and carbon isotopic composition of DIC will be analysed by a Finnigan Gasbench-Delta Plus-MS coupling.

Preliminary results

The chemical and isotopic characterization of hydrothermal vent fluids strongly depends upon the sampling procedure and the sampling location in the orifice. As LHF chimney structures are often very friable and brittle (namely beehive structures at the "Irina II" main structure and smoking holes at the Irina I crater), the sampling of hydrothermal fluids was not an easy task. This is reflected in the varying sample quality with different proportions of intermixed seawater.

Fluid samples obtained with the "Major" samplers from high-temperature vents are generally of high quality (<30% seawater, estimated from Ca concentration). The pH ranged in these samples from 3.5 to 4.5 while sulphide concentrations ranged were 0.5 to 0.8 mM. Total iron concentrations reached up to 3.5 mM. Chloride concentrations did not show significant depletion and were similar to seawater (within the range of an analytical error of 5%). Phase separation was not evident. The exact hydrothermal fluid proportion in the obtained samples will be finally quantified in the home laboratories (Mg concentration with ICP-OES). More details on the fluid concentrations of diluted sulphide and a number of trace metals analysed onboard are listed n the appendix.

The high Fe/H_2S ratios and the high concentrations of dissolved CH_4 and H_2 (up to 1.5 mM and 6 mM, respectively; see section 3.3.4: gas chemistry) fit to a hypothesis according to which alteration of ultramafic rocks occurs in the reaction zone of the LHF system. Similar to the results of previous analyses, our preliminary results do not indicate major differences between the different LHF vents. However, Fe concentrations increased significantly since Meteor cruise M 64/2 in 2005 (3.5 mM vs. 2.5 mM). The temperatures did not rise since then and therefore cannot have affected the fluid chemistry. Changes in the alteration pattern in the sub-seafloor should be considered for an alternative explanation.

3.4.6 Microbiology of Diffuse Fluids at the Logatchev Hydrothermal Field

(M. Perner)

In previous cruises to the LHF, hot hydrothermal fluid emissions have been collected from areas of smoking craters and the main chimney complex Irina II. Previous samplings served for gaining an overall view of the microorganisms present at the LHF. As hydrothermal fluids rise to the surface, they entrain microorganisms. This causes a mixture of microorganisms in the fluid samples which originate from multiple habitats along the fluid pathway. Our aim for this cruise was to identify microorganisms that are characteristic for diffuse hydrothermal fluids of specific locations. Emphasize was put on diffuse outflow from the “Irina II” main structure, the surrounding mussel patch and diffuse fluids from the mussel patch near “Quest”.

Samples and methods

Fresh samples were examined on board under the microscope for the presence of microorganisms. Identification of Archaea and Bacteria and analyses of their abundances will follow in the home laboratory by constructing clone libraries and using DGGEs and Fluorescence in situ Hybridization (FISH) on the basis of 16S rRNA genes. Cultivation experiments were conducted for autotrophic prokaryotes, which use either H_2 or reduced sulphur compounds for energy generation.

Microbial Metabolisms were investigated on board by CO_2 incorporation measurements (measurements by J. Petersen). The investigation of microbial metabolisms will be continued in the home laboratory by the use of functional genes encoding key enzymes of the reverse tricarboxylic acid and Calvin Benson-Basham cycle. The CO_2 incorporation measurements were conducted for two diffuse fluid sites (main structure “Irina II” and mussel patch at Irina II) using H_2 and S^{2-} as electron donors. Functional genes encoding key enzymes of hydrogen oxidation (hynL gene) will also be investigated in the home laboratory.

Cultivation experiments have been started on board and will be continued in the home laboratory:

i. along a temperature gradient
ii. use of various electron donors (H_2, H_2S, S^0, CH_4)
iii. suitable electron acceptors (O_2, NO_3, Fe^{3+}, S^0)
iv. along a sulphide gradient

One specific culture was chosen for measurements on H_2 uptake and H_2S production (through reduction of elemental sulphur). The decline of H_2 and the increase of S^{2-} was measured over a period of 42 hours (by P. Wefers and K. Schmidt). The culture was sub-sampled at various intervals during the experiment for the analysis of the prokaryotic assemblage.

Results

Microscopic observations of microorganisms inhabiting freshly taken samples revealed relative low abundances of prokaryotes. Molecular analyses of the microbial community based on 16S rRNA and functional genes in the home laboratory will reveal abundance and activity patterns of specific bacterial and archaeal groups. The experimental enrichment of "Irina II" diffuse fluid samples with vitamins along a sulphide gradient showed that sulphide-oxidizing microorganisms are best adapted to sulphide concentrations of 50 µM (Fig. 3-24A). After enrichment of the diffuse fluid with various energy donors and electron acceptors, the majority of the prokaryotes grew optimally around 44°C (Fig. 3-24B).

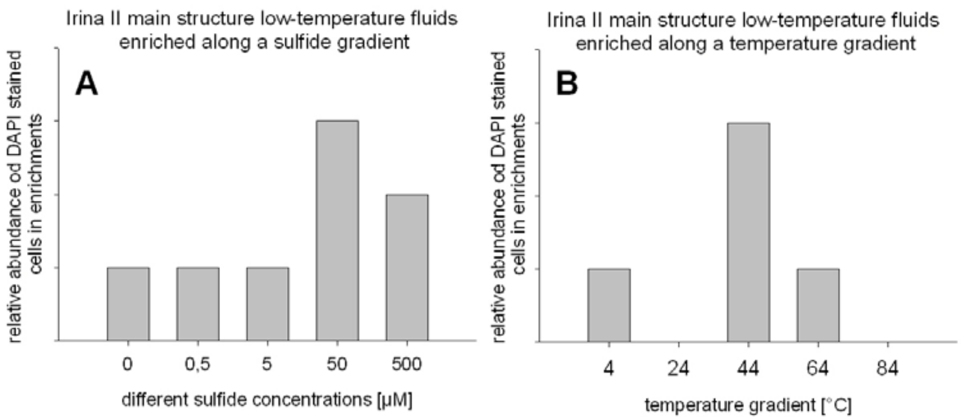


Figure 3-24. Relative abundance of DAPI stained cells after cultivation along gradients of sulphide concentration (A) and temperature (B). Samples originate from fluids of the main structure at Irina II. At 24°C and 84°C, no growth was observed in the cultures (B).

Cultivation experiments also revealed that certain microorganisms grow at temperatures of up to 95.5°C and that some groups are more characteristic for specific locations than others (Fig. 3-25A-E).

One culture from diffuse fluids at a "Irina II" mussel patch showed production of sulphide (from elemental sulphur) and was chosen for detailed analyses. The medium used selects for autotrophic Epsilonproteobacteria. At 37°C, a decline of the H_2 content and concentrations of sulphide was determined for prokaryotes inhabiting this culture (Fig. 3-26). Constant H_2 concentrations in a reference culture confirmed that the observed consumption of H_2 can be attributed to microbial uptake rather than leakage from the cultivation apparatus.

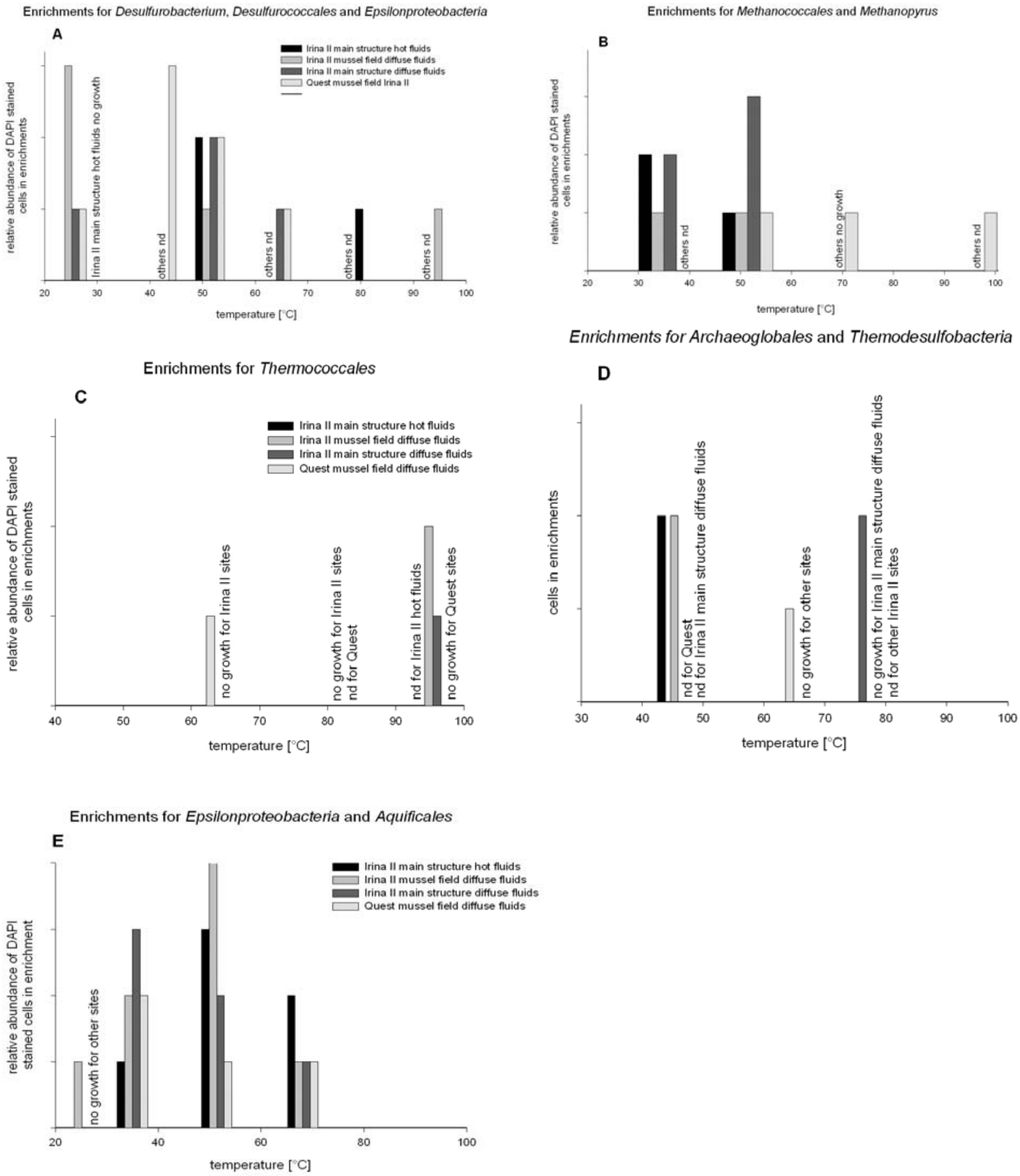


Figure 3-25. Relative abundance of DAPI stained cells in cultures enriched for *Desulfurobacterium,* Desulfurococcales and Epsilonproteobacteria (A), Methanococcales and *Methanopyrus* (B), Thermococcales (C), Archaeoglobales and Thermodesulfobacteria (D) and Epsilonproteobacteria and Aquificales (E) at various temperatures ("others no growth" = no cultures for other locations exist; nd = not determined)

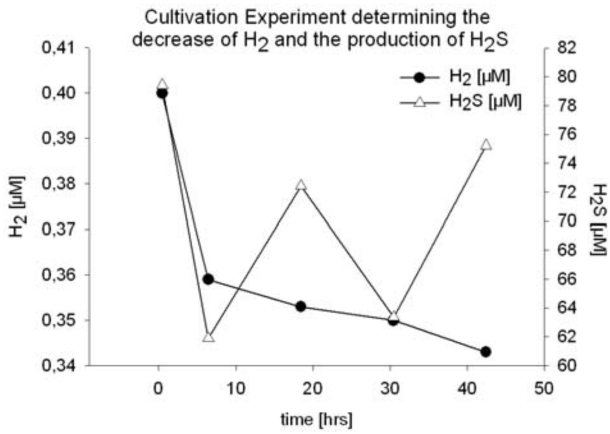


Figure 3-26. An enrichment selecting for H_2 oxidizing and S° reducing Epsilonproteobacteria at 37°C was chosen for detailed analyses of the decline of H_2 and production of H_2S over a period of time (Fluid chemistry measurements by P. Wefers and K. Schmidt).

The CO_2 incorporation experiments (conducted by J. Petersen) showed that more CO_2 is being fixed through H_2S than through H_2 (Fig. 3-27). This was observed in samples from an "Irina II" mussel patch and the main chimney structure.

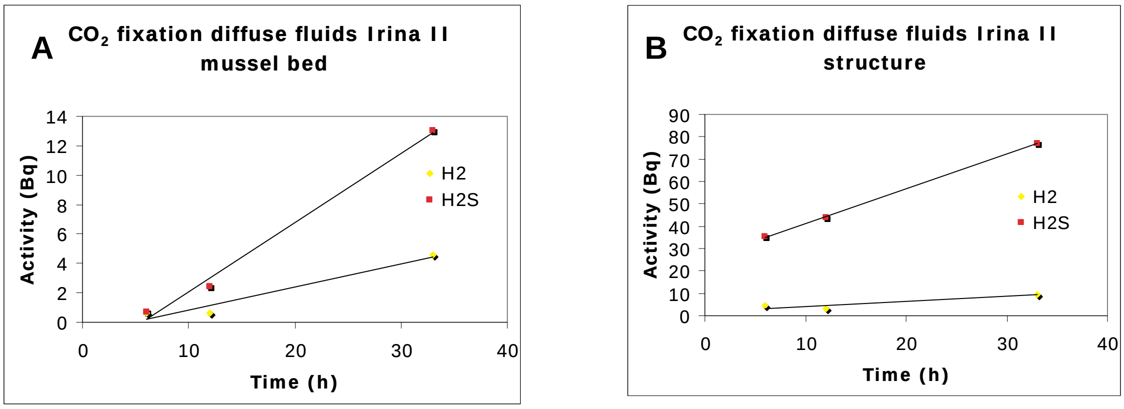


Figure 3-27. CO_2 incorporation experiments on diffuse fluids collected in an "Irina II" mussel patch (A) and the main structure (B) using H_2 and H_2S as electron donors. CO_2 incorporation experiment conducted by J. Petersen)

3.4.6 Hydrothermal symbioses

(J. Petersen, S. Wetzel)

The main goal of the symbiosis research group for this cruise was to investigate the transfer of energy from vent fluids to the dominant members of the faunal community at Logatchev, the mussels *Bathymodiolus puteoserpentis*. These mussels have greatly reduced guts, and their main source of nutrition is symbiotic bacteria that live in their gills. Two types of symbionts coexist in the gill cells: thiotrophic bacteria that use reduced sulphur compounds such as sulphide as an energy source and fix CO_2 as a carbon source, and methanotrophic bacteria that use methane as both an energy and a carbon source. The energy sources for the mussel symbioses are delivered by the hydrothermal fluids that carry high concentrations of sulphide, methane, hydrogen, and other reduced compounds. The concentrations of these energy sources vary over time and space and play a major role in determining the biomass, activity and productivity of the vent community. We have defined these interactions between hydrothermal and biological processes as the geobiological coupling between vent fluids and symbiotic primary producers. During this cruise, we contributed to our ongoing studies of geobiological coupling at MAR vents by:

1) Identifying the energy sources used by the mussel symbionts
2) Comparing the rates at which different energy sources are used by the symbionts
3) Comparing how consumption rates of different energy sources are related to their concentrations at vent sites

To collect geochemical data at a scale relevant to the mussel community, we worked in close collaboration with the fluid and gas chemistry groups.

Mussels were collected using the ROV manipulator arm in nets at the two different sites where mussels are found at Logatchev, "Irina II" and "Quest". Table 3-5 is a summary of sampling sites with the relevant habitat parameters including profiler data (Microsensor group), temperature data (online and from in situ temperature loggers), and fluid chemistry that were measured.

Table 3-5. Mussel collection sites and corresponding in situ, temperature, and fluid data. n. d. = not detected, - = no data available

Site	Mussel sample	Incubation	Profiler data	Temperature data		Fluid data				
	Station number		Station number	Temperature logger	Online °C	Station number	$[CH_4]$ (µM)	$[H_2]$ (µM)	$[S^{2-}]$ (µM)	pH
Irina II	244 ROV/9	H_2, H_2S, CH_4								
	251 ROV/11			Logger #8	23	251 ROV/10	0,648	0,586	-	7,95
	251 ROV/14			Logger #4	33	251 ROV/13	0,875	1,724	-	8,03
	253 ROV/1			Logger #9	28	251 ROV/7	1,265	0,682	-	8,01
	253 ROV/7			Logger #2	15	253 ROV/5	0,335	0,184	n. d.	8
	253 ROV/8	H_2, H_2S, CH_4, ^{13}C		Logger #0		253 ROV/6	1,668	4,125	n. d.	7,99
	259 ROV/29	H_2S								
	263 ROV/12	H_2, H_2S, CH_4	263 ROV		148	263 ROV/10	3579,795	196,187	< 6	8,18
	267 ROV/1	H_2S								
	282 ROV/3	^{13}C				282 ROV/2	n. d.	n. d.	25	6,18
Quest	259 ROV/12	^{13}C			151					
	267 ROV/7			Logger #298	111					
	267 ROV/8			Logger #11	10 to 13					
	267 ROV/13			Logger #16	3	267 ROV/12	0,412	0,024	-	8,19
	271 ROV/5	H_2, H_2S, CH_4			113	271 ROV/4	353,836	1178,615	32	6,4

On board, the mussels were dissected and prepared for morphological and molecular analyses in the home laboratory. For on board analyses of uptake rates of energy sources, gill tissues (that contain the bacterial symbionts) were incubated in methane, sulphide, and hydrogen and the decrease of these energy sources over time was measured in the headspace or fluid of the incubation vial. Carbon fixation rates were determined radioactively, using $^{14}CO_2$ for sulphide and hydrogen, and $^{14}CH_4$ for methane. Vials with mussel foot tissue (that is symbiont free) or with only sea water were used as controls.

Although not all results from our onboard experiments were available at the time of writing, some first results can already be reported. Sulphide is clearly used as an energy source by the mussel symbionts at both “Irina II” and “Quest”, based on experiments showing a much greater decrease of sulphide in vials containing mussel gill tissues than in the controls with foot tissue or seawater (Figs 3-28, 3-29). In correspondence to the linear decrease in sulphide, $^{14}CO_2$ fixation rates increased linearly until sulphide concentrations apparently became too low for further $^{14}CO_2$ fixation (Figs 3-27, 3-28). The rate of sulphide uptake was higher at “Quest” (Fig. 3-29) than at “Irina II” (Fig. 3-28), which corresponds well with the higher sulphide concentrations measured in the mussel habitat at “Quest” compared to “Irina II” (Table 3-5). This may indicate a correlation between conditions in the mussel habitat and symbiotic activity.

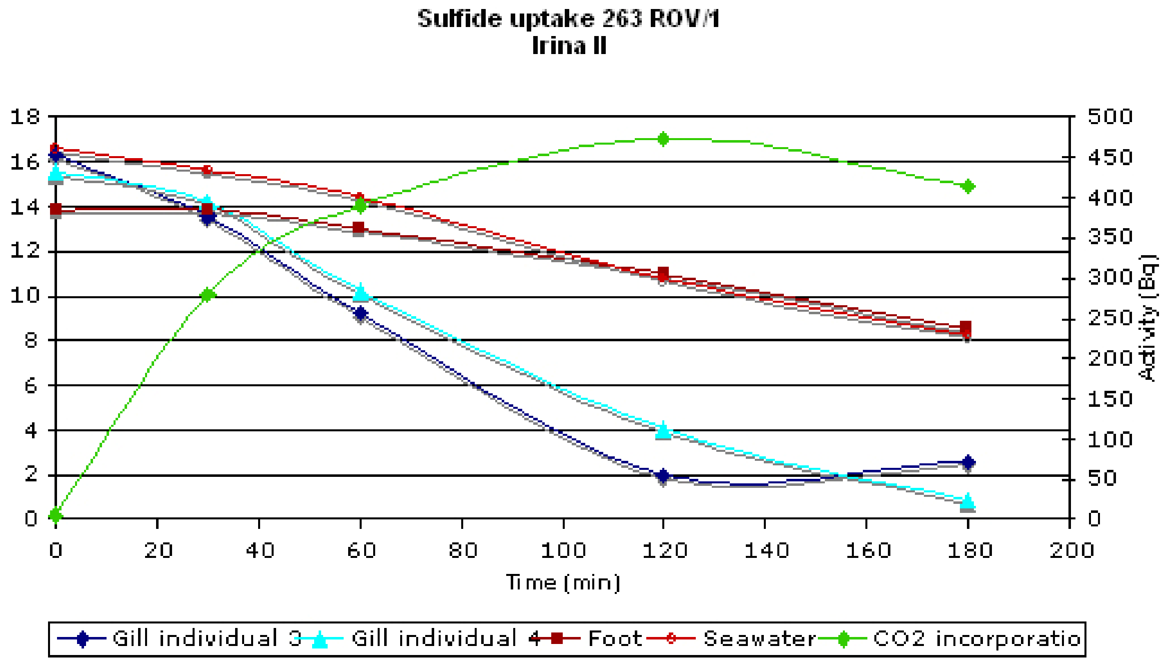


Figure 3-28. Irina II: Decrease of sulphide in symbiont-containing gill tissues from 2 mussel individuals (blue lines) is linear until approx. 3 µM sulphide, while almost no decrease of sulphide was observed in seawater (red line) and symbiont-free foot tissue (burgundy line). Fixation of $^{14}CO_2$ (green line) increased linearly, but leveled off at the end of the experiment, in correspondence to the leveling off of sulphide uptake rates.

In addition to sulphide, we were also able to show that hydrogen is used as an electron donor for CO_2 fixation by the mussel symbionts. Again in the case of hydrogen, we observe that at the “Irina II” site, measured hydrogen concentrations are lower than at “Quest” (Table 3-5), and correspondingly, that the rate of $^{14}CO_2$ incorporation by mussel symbionts in the presence of hydrogen is higher at “Quest” than at Irina II.

In summary, our first results indicate that both sulphide and hydrogen can be used as energy sources by mussel symbionts, and that the rates at which these energy sources are used correlate with their concentrations in the mussel environment. It is surprising that at Irina II that CO_2 is fixed more efficiently with sulphide than with hydrogen, as the oxidation of hydrogen provides the bacteria with more energy than the oxidation of sulphide. The reasons for this need to be investigated during future cruises.

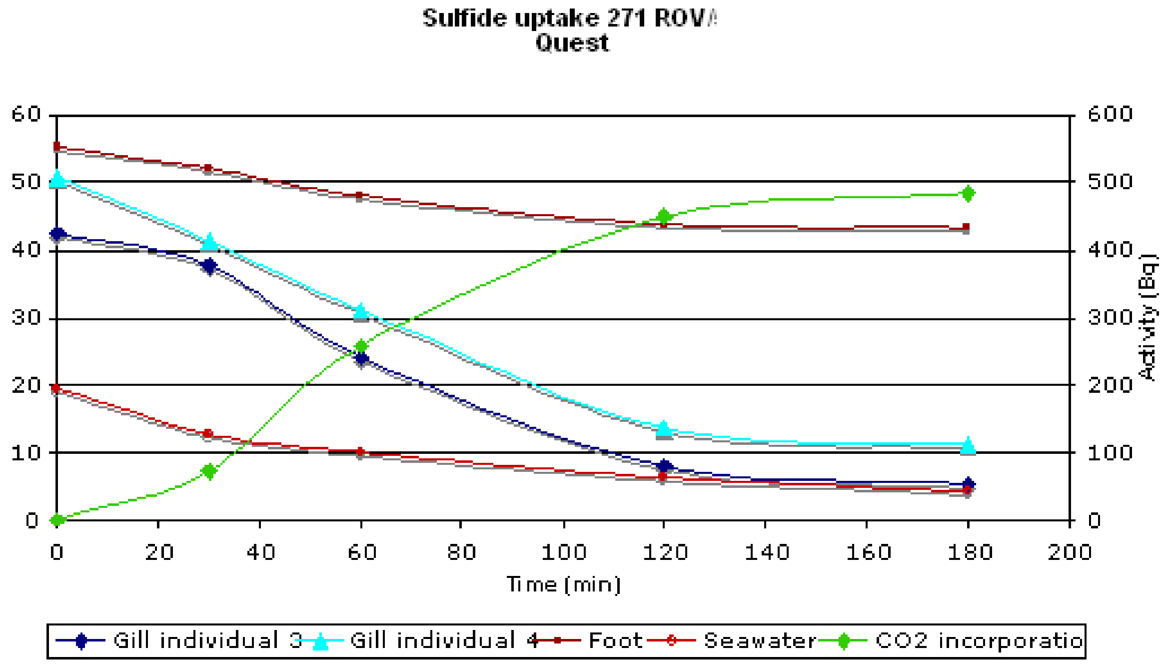


Figure 3-29. "Quest": Decrease of sulphide in symbiont-containing gill tissues from 2 mussel individuals (blue lines) is linear until approx. 10-15 µM sulphide, while almost no decrease of sulphide was observed in seawater (red line) and symbiont-free foot tissue (burgundy line). As for Irina II, fixation of $^{14}CO_2$ (green line) increased linearly, but levelled off at the end of the experiment.

3.4.7 Metagenomics: Diversity and Function of chemosynthetic microbial communities in hydrothermal vent sediments

(R. Schauer)

The main goal of the Metagenomics group was to continue the investigation of microbial communities in three different hydrothermally influenced sediment locations started with Meteor cruise M 64/2. Two sites located near or between hot smokers and that were sampled during M 64/2 (257 ROV, 263 ROV) are characterised by a white surface and are. The third site lies close to a mussel field next to "Quest". Another important task was to sample the hydrothermal buoyant plume for metagenomic analyses of the plume specific microbial community.

Molecular/ microbial methods

Sediments were sampled using the Jason II operated push cores. Immediately upon retrieval, the sediment cores were sectioned into slice of 1 or 2 cm. Sub-samples of 3 x 1 g of each slice were frozen at -20°C for DNA extraction and diversity studies. 5-10 g of sediment were frozen at -80 °C for metagenomic analyses. The rest of the slices was fixed with 50% ethanol in phosphate buffered saline (PBS) and 4% formaldehyde (FA/PBS) for 3-6 h, respectively, for cell count determination, and catalyzed reporter deposition fluorescence in situ hybridisation (CARD-FISH). A dilution series was prepared for cultivation experiments with aerobic and anaerobic media. Thiosulphate was used as an electron donor in aerobic media, while for the anaerobic cultivation media selective for nitrate-reducers and sulphate-reducers were prepared by using various electron donors.

Deep-water collected with the CTD-rosette in the buoyant hydrothermal plume were used for metagenomic analyses of microbial plume population. Microbial diversity in the plume will be analysed from 245 CTD and 280 CTD and compared to the diversity in non-plume deep-water environment sampled with 242 CTD. Large volumes of each CTD cast (50 – 220 L) were filtered on 142-mm wide cellulaseacetate membranes (0.22 µm pores) in order to concentrate plume microorganisms. 2 L of plume water were additionally concentrated on polycarbonate membrane filters (0.22 µm pores) for DNA-extraction. The plume samples were fixed with 1% FA/PBS for 12-14 h for CARD-FISH experiments.

Samples and preliminary results

Continuing investigations of sediment samples from M 64/2 have revealed a high microbial diversity. In particular, sediments with a characteristic white surface and the brownish sediment close to “Quest” (Fig. 3-30) show strong differences in their bacterial and archaeal composition.

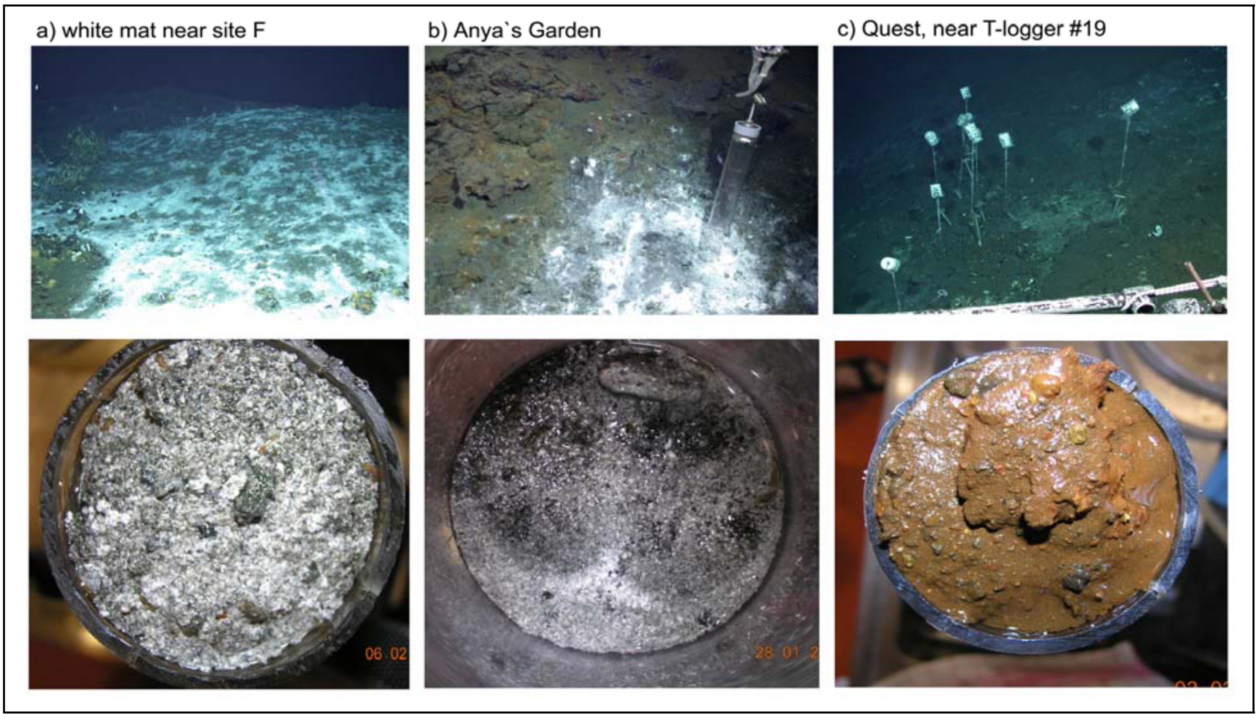


Figure 3-30. Sampling sites for hydrothermally influenced sediments and corresponding push core samples. a) White mat at “Site F”; b) “Mat #1” close to Anya`s Garden; c) brown sediment next to “Quest”.

Measurements of microbial turnover rates in sediments

Turnover rates of specific microbial processes were measured experimentally with radio tracer experiments. Sub-sample mini-cores (1 cm diameter) were pushed into the core surface by vacuum sucking. Pre-drilled ports at 1 cm intervals along the length of the mini cores were sealed with a silicone based aquarium sealant. They served for the injection of radiotracers in the various experiments: Sulphate reduction rate experiments used 5 µl (100 kBq)/injection

Table 3-6. Locations of push core samples that will be used for metagenomic analyses.

Site	location	Sediment sample	position	profiler data	temperature data	Fluid data
				Station number	station number	station number
Anya`s Garden (marker 23)	white mat	249 ROV-6 249 ROV-7 259 ROV-5 263 ROV-1 263 ROV-2 263 ROV-3	14°45.171 44°58.768 14°45.174 44°58.773 14°45.171 44°58.768	249 ROV-1	249 ROV-3 (55 °C , 28 cm) 249 ROV-4 (61 °C, 28 cm) 249 ROV-5 (31°C, 28 cm) 249 ROV-8 (65 °C, 28 cm) 249 ROV-9 (28 °C, 28 cm) 259 ROV-2 (24 °C, 28 cm) 259 ROV-3 (23 °C, 28 cm) 259 ROV-4 (22 °C 28 cm)	none
Quest	near T-logger #19	259 ROV14 259 ROV18 259 ROV21 271 ROV-7	14°45.178 44°58.900 14°45.1822 44°58.8302	None	259 ROV-15 (81 °C, 28 cm) 259 ROV-16 (17°C, 28 cm) 259 ROV-17 (48 °C, 28 cm) 259 ROV-19 (8 °C, 28 cm) 259 ROV-20 (5 °C, 28 cm) 271 ROV-9 (11 °C, 28 cm)	none
Quest	next to marker 27	267 ROV16 267 ROV17		None	none	none
White mat (marker 26)	near site F	271 ROV14 271 ROV15 271 ROV21	14°45.1356 44°58.7306	275 ROV-1	271 ROV-16 (99 °C, 28 cm) 271 ROV-17 (82 °C, 28 cm) 271 ROV-22 (5 °C, 28 cm) 271 ROV-23 (7 °C, 28 cm)	271 ROV18
Soft sediment	next to chamber	251 ROV-1	14°45.1942 44°58.7791	None	251 ROV-2	none
Irina I	bacterial mat on rock	257 ROV-9		None	none	none

radioactively labelled $^{35}SO_4^{2-}$ solution; the rates of anaerobic oxidation of methane was determined with 5 µl (0,24 kBq)/injection $^{14}CH_4$-tracer; methanogenesis rate measurements used 3 µl (111 kBq)/injection ^{14}C-labelled bicarbonate. After injection, the experiments incubated for 24 h at room temperature. Microautoradiography fluorescence in situ hybridisation experiments (MAR-FISH) used injections of 5 or 10 µl of ^{14}C-labeled bicarbonate (incubation time: 8-9 h at room temperature). For the determination of sediment porosity, the sediment cores sub-sampled with cut-off luer syringes. The syringe cores were sealed with Parafilm and stored at -20°C.

The tracer experiments will show activity patterns of sulphate reducers, anaerobic methane oxidizers (AOM) and methanogenic microorganisms along the sediment cores. MAR-FISH experiments will serve for a determination of the abundance of autotrophic bacteria, which use CO_2 as single carbon source.

Diversity analyses and metagenomics

The push core samples obtained from the sites listed in table 3-6 will be used to investigate the microbial diversity of microbial communities in hydrothermally influenced sediments. The results will be compared with existing data in order to estimate the variability of the microbial communities in hydrothermally influenced sediments. We will test if diversities are homogeneous within cores and if single cores are representative for the microbial community of entire sites. A main focus will lie on investigations of the metabolic pathways of the dominant microorganisms in the three selected sites. Fosmid libraries will be constructed and analysed for the inventory of functional genes indicating the metabolic capacities of the determined microorganisms.

Apart from sediments, we also sampled microbial mat from the surface of a rock piece collected next to the Irina I smoking crater in the southern LHF area. (Fig. 3-31). Microscopic examination revealed that this mat is dominated by *Beggiatoa*-resembling filaments with small inclusions. The size and shape of the inclusions suggest that they may consist of stored elemental sulphur, and that these filamentous microorganisms may use sulphide as an energy source which they oxidise to elemental sulphur. We expect more information on the diversity and possible ecological roles of these organisms by phylogenetic analyses on the basis of 16S rRNA including the screening of clone libraries and CARD-FISH experiments.

Fig 3-31: Bacterial mat on rock pieces. A and B: Stereo-microscopy image of the bacterial mat on rock pieces; C: light microscopy image of single microbial mat filaments from rock surfaces in A and B.

3.5. Station Lists

Table 3-7. Begin of stations and bottom contact/gear at depth/start profile. Position data in italics = Posidonia coordinates, bold italics = LBL coordinates.

Station no.	Station type	Jason dive no.	Date	Begin station (surface)				ROV bottom contact / CTD at depth / Start profile			
				Time UTC	Lat	Long	Depth	Time UTC	Lat	Long	Depth
241-EM120	Multi-Beam Echosounder		24.01.2007					01:00	14° 28.450 'N	59° 32.360 'W	3152.5
242-CTD	CTD		25.01.2007	17:05	15° 07.408 'N	51° 22.246 'W	5007.2	18:21	15° 07.408 'N	51° 22.246 'W	5007.5
243-LBL-TR	LBL Transponder Mooring		27.01.2007	03:18	14° 46.170 'N	44° 57.980 'W	2747.4		***14° 46.188 'N***	***44° 58.028 'W***	2747.4
243-a-LBL-TR	LBL Transponder Mooring		27.01.2007	04:07	14° 45.390 'N	44° 57.920 'W	2765.4		***14° 45.420 'N***	***44° 57.954 'W***	2765.4
244-ROV	ROV Dive	J2-253	27.01.2007	11:37	14° 44.546 'N	44° 58.582 'W	3074.8	13:27	***14° 45.552 'N***	***44° 59.127 'W***	3025.0
245-CTD	CTD		27.01.2007	21:45	14° 46.000 'N	44° 59.230 'W	3272.6	22:58	14° 46.010 'N	44° 59.230 'W	3275.2
246-CTD	CTD		28.01.2007	02:06	14° 45.200 'N	45° 01.000 'W	3779.9	03:29	14° 45.210 'N	45° 01.000 'W	3790.6
247-CTD	CTD		28.01.2007	05:56	14° 44.000 'N	44° 59.000 'W	3286.5	07:30	14° 44.000 'N	44° 59.000 'W	3298.6
249-ROV	ROV Dive	J2-254	28.01.2007	11:52	14° 45.030 'N	44° 58.558 'W	3021.6	13:51	***14° 45.156 'N***	***44° 58.752 'W***	3024.2
250-EM120	Multi-Beam Echosounder		28.01.2007					21:55	14° 47.210 'N	44° 59.280 'W	3493.4
251-ROV	ROV Dive	J2-255	29.01.2007	11:30	14° 45.036 'N	44° 58.564 'W	3019.8	13:17	***14° 40.030 'N***	***45° 00.033 'W***	3021.3
252-CTD	CTD / MAPR tow-yo		30.01.2007	00:10	14° 43.950 'N	44° 58.030 'W	2968.0	01:56	14° 43.950 'N	44° 58.020 'W	2959.5
253-ROV	ROV Dive	J2-256	30.01.2007	13:32	14° 45.024 'N	44° 59.006 'W	3034.8	15:21	***14° 40.007 'N***	***45° 00.005 'W***	3030.0
254-ELEV	Elevator		30.01.2007	14:23	14° 45.180 'N	44° 58.770 'W	3031.8				
255-ELEV	Elevator		30.01.2007								
256-EM120	Multi-Beam Echosounder		31.01.2007					01:37	14° 44.990 'N	44° 56.940 'W	3018.9
257-ROV	ROV Dive	J2-257	31.01.2007	11:33	14° 44.576 'N	44° 58.582 'W	3052.7	13:01	***14° 40.012 'N***	***45° 00.000 'W***	2952.5
258-CTD	CTD / MAPR tow-yo		01.02.2007	01:36	14° 43.700 'N	44° 58.820 'W	3316.2	02:55	14° 43.700 'N	44° 58.820 'W	3315.9
259-ROV	ROV Dive	J2-258	01.02.2007	11:50	14° 44.588 'N	44° 59.024 'W	3079.8	13:20	***14° 45.134 'N***	***44° 58.829 'W***	3032.3
260-ELEV	Elevator		01.02.2007	13:22	14° 45.190 'N	44° 58.750 'W	3019.9				
261-ELEV	Elevator		02.02.2007								
262-EM120	Muliy-Beam Echosounder		02.02.2007					15:15	14° 47.560 'N	44° 56.360 'W	2901.6
263-ROV	ROV Dive	J2-259	02.02.2007	23:57	14° 45.024 'N	44° 58.582 'W	3049.8	01:28	***14° 40.048 'N***	***44° 59.986 'W***	3037.2
264-ELEV	Elevator		03.02.2007	00:37	14° 45.190 'N	44° 58.750 'W	3018.1				
265-ELEV	Elevator		03.02.2007								
266-CTD	CTD / MAPR tow-yo		03.02.2007	14:45	14° 43.630 'N	45° 00.400 'W	3940.3	16:03	14° 43.363 'N	45° 00.390 'W	3939.9
267-ROV	ROV Dive	J2-260	04.02.2007	00:30	14° 44.570 'N	44° 59.024 'W	3111.0	01:57	***14° 45.118 'N***	***44° 58.786 'W***	3026.1
268-ELEV	Elevator		04.02.2007	01:20	14° 45.180 'N	44° 58.770 'W	3041.8				
269-ELEV	Elevator		05.02.2007								
270-EM120	Multi-Beam Echosounder		05.02.2007					02:17	14° 56.880 'N	45° 05.920 'W	2808.4
271-ROV	ROV Dive	J2-261	05.02.2007	11:37	14° 45.018 'N	44° 59.042 'W	3083.5	13:08	***14° 45.157 'N***	***44° 58.654 'W***	3042.5
272-MOOR-T	Temperature Mooring		06.02.2007	00:35	14° 45.096 'N	44° 58.432 'W	3013.0	02:33	*14° 45.093 'N*	*44° 58.425 'W*	3018.6
273-CTD	CTD		06.02.2007	04:36	14° 43.990 'N	44° 58.780 'W	3301.0	05:48	14° 44.000 'N	44° 58.760 'N	3273.7
274-CTD	CTD		06.02.2007	08:20	14° 42.000 'N	44° 58.760 'W	3415.3	09:33	14° 42.000 'N	44° 58.760 'W	3409.2
275-ROV	ROV Dive	J2-262	06.02.2007	11:40	14° 45.036 'N	44° 59.030 'W	3071.4	13:11	***14° 40.039 'N***	***44° 59.971 'W***	3040.2
276-ELEV	Elevator		06.02.2007	12:22	14° 45.190 'N	44° 58.760 'W	3020.8				
277-ELEV	Elevator		07.02.2007								
278-CTD	CTD		07.02.2007	01:35	14° 38.990 'N	44° 58.820 'W	3808.1	02:47	14° 38.990 'N	44° 58.820 'W	3841.1
279-CTD	CTD		07.02.2007	05:04	14° 41.000 'N	44° 58.770 'W	3530.7	06:16	14° 41.000 'N	44° 58.760 'W	3526.7
280-CTD	CTD		07.02.2007	08:34	14° 43.000 'N	44° 58.760 'W	3224.1	09:38	14° 43.000 'N	44° 58.760 'W	3199.8
281-MOOR-W	Wood Log Deposition		07.02.2007	11:39	14° 45.160 'N	44° 58.700 'W	3000.6	12:41	*14° 45.158 'N*	*44° 58.696 'W*	3014.6
282-ROV	ROV Dive	J2-263	07.02.2007	14:02	14° 45.006 'N	44° 59.066 'W	3117.5	15:30	***14° 40.006 'N***	***44° 59.990 'W***	3021.3
283-LBL-TR	LBL Transponder Mooring		07.02.2007								
284-LBL-TR	LBL Transponder Mooring		07.02.2007								
285-EM120	Multi-Beam Echosounder		07.02.2007					22:00	14° 47.620 'N	44° 54.310 'W	5373.6

Table 3.8. End of profile/mooring recoveries and end of station. Position data in bold italics = LBL coordinates.

Station no.	Station type	Jason dive no.	Date	Off bottom / End of profile / Mooring released				End of station (on deck)		
				Time UTC	Lat	Long	Depth	Time UTC	Lat	Long
241-EM120	Multi-Beam Echosounder		27.01.2007	02:52	14° 46.910 'N	44° 58.720 'W	3310.0			
242-CTD	CTD		25.01.2007					19:32	15° 07.408 'N	51° 22.246 'W
243-LBL-TR	LBL Transponder Mooring		27.01.2007							
243-a-LBL-TR	LBL Transponder Mooring		27.01.2007							
244-ROV	ROV Dive	J2-253	27.01.2007	18:36	***14° 45.201 'N***	***44° 58.782 'W***	2747.6	20:13	14° 45.420 'N	44° 58.240 'W
245-CTD	CTD		27.01.2007					00:31	14° 46.000 'N	44° 59.230 'W
246-CTD	CTD		28.01.2007					05:02	14° 45.210 'N	45° 01.000 'W
247-CTD	CTD		28.01.2007					09:09	14° 44.000 'N	44° 59.000 'W
249-ROV	ROV Dive	J2-254	28.01.2007	19:54	***14° 45.186 'N***	***44° 58.738 'W***	3033.0	21:33	14° 45.414 'N	44° 58.018 'W
250-EM120	Multi-Beam Echosounder		29.01.2007	10:47	14° 44.270 'N	45° 00.010 'W	3630.6			
251-ROV	ROV Dive	J2-255	29.01.2007	21:34	***14° 45.164 'N***	***44° 58.749 'W***	3022.6	23:25	14° 45.336 'N	44° 58.054 'W
252-CTD	CTD / MAPR tow-yo		30.01.2007	08:47	14° 48.040 'N	45° 00.310 'W	3747.0	09:55	14° 48.030 'N	45° 00.310 'W
253-ROV	ROV Dive	J2-256	30.01.2007	22:08	***14° 45.202 'N***	***44° 58.777 'W***	3033.1	00:02	14° 45.306 'N	44° 58.096 'W
254-ELEV	Elevator		30.01.2007							
255-ELEV	Elevator		30.01.2007	23:24			2984.9	01:10	14° 45.060 'N	44° 58.420 'W
256-EM120	Multi-Beam Echosounder		31.01.2007	10:44	14° 44.000 'N	45° 01.170 'W	4049.7			
257-ROV	ROV Dive	J2-257	31.01.2007	22:22	***14° 45.069 'N***	***44° 58.668 'W***	2936.8	00:02	14° 45.264 'N	44° 58.066 'W
258-CTD	CTD / MAPR tow-yo		01.02.2007	09:48	14° 47.012 'N	44° 58.820 'W		10:54	14° 47.012 'N	44° 58.820 'W
259-ROV	ROV Dive	J2-258	02.02.2007	10:08	***14° 45.210 'N***	***44° 58.786 'W***	3036.5	12:05	14° 45.444 'N	44° 58.132 'W
260-ELEV	Elevator		01.02.2007							
261-ELEV	Elevator		02.02.2007	12:40	14° 44.760 'N	44° 58.780 'W	3058.9	14:43	14° 44.840 'N	44° 58.440 'W
262-EM120	Muliy-Beam Echosounder		02.02.2007	23:23	14° 44.940 'N	44° 59.130 'W	3113.0			
263-ROV	ROV Dive	J2-259	03.02.2007	11:01	***14° 45.200 'N***	***44° 58.743 'W***	3034.2	12:49	14° 45.366 'N	44° 58.132 'W
264-ELEV	Elevator		03.02.2007							
265-ELEV	Elevator		03.02.2007	12:20	14° 45.500 'N	44° 58.380 'W	2954.7	13:56	14° 45.410 'N	44° 58.490 'W
266-CTD	CTD / MAPR tow-yo		03.02.2007	22:43	14° 45.910 'N	44° 58.010 'W		23:48	14° 45.910 'N	44° 58.000 'W
267-ROV	ROV Dive	J2-260	04.02.2007	21:26	***14° 45.181 'N***	***44° 58.764 'W***	3036.2	23:21	14° 45.366 'N	44° 58.018 'W
268-ELEV	Elevator		04.02.2007							
269-ELEV	Elevator		05.02.2007	22:30	14° 45.450 'N	44° 58.410 'W	2946.4	00:57	14° 45.670 'N	44° 58.740 'W
270-EM120	Multi-Beam Echosounder		05.02.2007	09:51	14° 58.480 'N	45° 04.500 'W	2770.2			
271-ROV	ROV Dive	J2-261	05.02.2007	22:02	***14° 45.171 'N***	***44° 58.776 'W***	3045.9	23:57	14° 45.264 'N	44° 58.048 'W
272-MOOR-T	Temperature Mooring		06.02.2007							
273-CTD	CTD		06.02.2007					07:11	14° 44.000 'N	44° 58.760 'W
274-CTD	CTD		06.02.2007					10:51	14° 42.000 'N	44° 58.760 'W
275-ROV	ROV Dive	J2-262	06.02.2007	21:58	***14° 45.125 'N***	***44° 58.734 'W***	2998.2	23:56	14° 45.306 'N	44° 57.576 'W
276-ELEV	Elevator		06.02.2007							
277-ELEV	Elevator		07.02.2007	23:30	14° 45.170 'N	44° 58.930 'W	2879.5	00:38	14° 45.530 'N	44° 58.850 'W
278-CTD	CTD		07.02.2007					04:06	14° 38.990 'N	44° 58.820 'W
279-CTD	CTD		07.02.2007					07:36	14° 41.000 'N	44° 58.760 'W
280-CTD	CTD		07.02.2007					10:51	14° 43.000 'N	44° 58.760 'W
281-MOOR-W	Wood Log Deposition		07.02.2007				3014.6	13:41	14° 45.160 'N	44° 58.700 'W
282-ROV	ROV Dive	J2-263	07.02.2007	18:00	***14° 45.160 'N***	***44° 58.748 'W***	3017.7	19:53	14° 45.324 'N	44° 58.180 'W
283-LBL-TR	LBL Transponder Mooring		07.02.2007	19:34	***14° 46.188 'N***	***44° 58.028 'W***	2944.1	20:30	14° 45.430 'N	44° 58.030 'W
284-LBL-TR	LBL Transponder Mooring		07.02.2007	20:36	***14° 45.420 'N***	***44° 57.954 'W***	5833.0	21:31	14° 46.220 'N	44° 58.090 'W
285-EM120	Multi-Beam Echosounder		13.02.2007							

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