Maria S. Merian-Berichte

BOREHOLE MICROBIAL OBSERVATORY SCIENCE IN BASALTIC OCEAN CRUST: THE NORTH POND AREA ON THE WESTERN MID-ATLANTIC RIDGE FLANK AT 23°N

Cruise No. 20, Leg 5

April 11 – May 10, 2012, Freeport (Bahamas) – St.John's (Canada)

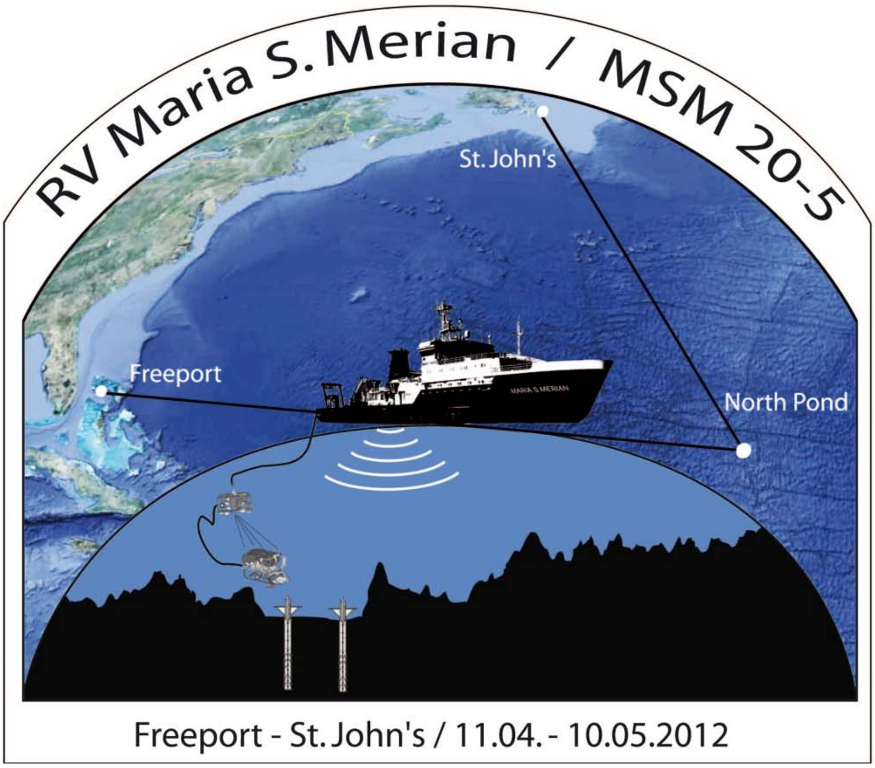

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Table of Contents

1 Summary

Wolfgang Bach

The extent and activity of microbial life in the upper ocean crust is unknown, but hydrologically active, young ridge flanks may host a large microbial biomass that is possibly supported by oxidative alteration reactions of basalt. MARIA S. MERIAN cruise 20/5 had the primary objective of conducting operations on subseafloor observatories (CORKs) installed to examine hydrological-geochemical-microbiological interactions in a sedimented area (North Pond) on the western flank of the mid-Atlantic Ridge at 22°45'N, 46°05'W in 4450 m water depth. The remotely operated vehicle (ROV) *Jason* of the Woods Hole Oceanographic Institution was the main operational tool, used to carry out installations of a shallow observatory and numerous operations on two deep observatories, installed during Expedition 336 of the Integrated Ocean Drilling Program in the fall of 2011. In nine *Jason* lowerings, the following objectives were achieved: At observatories in Holes U1382A and U1383C, seafloor Osmo samplers were retrieved and new ones were installed, GeoMICROBE sleds were deployed and attached to fluid sampling lines, basement fluid samples were recovered from all observatory zones in the subseafloor (down to 331.5 m subbasement in Hole U1383C) and sediment samples were push-cored. In Hole U1383B, a scaled-down observatory was fully installed by ROV operations to seal off the seafloor near close-by Hole U1383C and set up for future sampling and inter-borehole experimentation. Pressure data were downloaded from all holes. A partially installed observatory in Hole 395A was inspected and prepared for future operations. Seafloor mapping using the ROV's Multibeam system, rock sampling from the steep slopes surrounding the sedimented area around the drill holes, further sediment sampling and heat flow surveys complemented the ROV-based work conducted during the cruise.
Moreover, a 5500 km^2 area around our North Pond study site was mapped using the Ship's EM 120 Multibeam echosounding system. Despite lost time due to the delayed delivery of a container with critical observatory gear and rough weather around mid-cruise, all major cruise objectives were achieved. The observatories are fully operational and the North Pond experiment is underway.

Zusammenfassung

Wolfgang Bach

Ausmaß und Aktivität mikrobiellen Lebens in der oberen Ozeankruste sind unbekannt; jedoch könnten hydrologisch aktive, junge Rückenflanken die große Mengen mikrobieller Biomasse beherbergen, die eventuell durch Oxidation der Ozeanbodenbasalte ernährt werden. Die Aus fahrt 20/5 der MARIA S. MERIAN diente primär der Durchführung von Arbeiten an Bohrlochobservatorien (CORKs), die zwecks der Untersuchung gekoppelter hydrologisch-geochemisch-mikrobieller Prozesse in der westlichen Flanke des Mittelatlantischen Rückens bei 22°45'N und 46°05'W in ca. 4450 m Wassertiefe eingerichtet wurden. Das "remotely operated vehicle" (ROV) *Jason* der Woods Hole Oceanographic Institution wurde eingesetzt, um die Installation eines Observatoriums vorzunehmen und verschiedene Operationen an zwei tiefen Observatorien durchzuführen, die bereits im Vorjahr im Rahmen der Expedition 336 des Integrated Ocean Drilling Programs installiert wurden. In neun Tauchgängen mit *Jason* konnten eine Vielzahl von Ergebnissen erzielt werden. An den Observatorien in den Bohrungen U1382A

und U1383C, wurden Osmo-Probenschöpfer geborgen und neue installiert, GeoMICROBE-Schlitten wurden ausgesetzt und an den Bohrlochköpfen angeschlossen, Formationsfluide wurden aus allen Zonen der Observatorien gepumpt und für chemische und mikrobiologische Untersuchgen vorbereitet; weiterhin wurden Sedimentproben genommen. In Bohrung U1383B wurde ein kleines Observatorium allein durch ROV-Einsatz installiert, um den Meeresboden in der Nähe von Bohrung U1383C zu versiegeln und zukünftige Experimente einzuleiten. Ein partiell installiertes Observatorium in Bohrung 395A wurde für eine künftige Bergung des Instrumentenstrangs vorbereitet. Fächerecholot-Vermessung des Meeresboden mit dem Reson-System des ROVs, Festgesteinsbeprobung der Hänge um North Pond herum, weitere Sedimentbeprobung sowie Wärmeflussmessungen wurden zusätzlich durchgeführt. Außerdem konnte ein 5500 km^2 großes Gebiet um North Pond herum mit dem EM 120 Fächerecholotsystem des Schiffs vermessen werden. Obwohl durch Verzögerungen im Antransport wichtiger Instrumente und zwischenzeitlich raue See Arbeitszeit verloren ging, konnten die kritischen Ziele der Ausfahrt vollständig erreicht werden. Die Observatorien sind uneingeschränkt funktionstüchtig und das North Pond Experiment kann nun seinen weiteren Lauf nehmen.

2 Participants

Name	**Discipline**	**Institution**
Wolfgang Bach	Geology/Chief scientist	Univ. Bremen
Katrina Edwards	Microbiology/Chief scientist ROV	USC
C. Geoff Wheat	Geochemistry	Univ. Alaska
Sam Hulme	Geochemistry/ROV mapping	MLML
Brian Glazer	Geochemistry	Univ. Hawaii
Chih-Chiang Hsieh	Biogeochemistry	Univ. Hawaii
Huei-Ting Lin	Biogeochemistry	Univ. Hawaii
Peter Girguis	Microbiology	Harvard Univ.
Ulrike Jaekel	Microbiology	Harvard Univ.
Beth Orcutt	Microbiology	Bigelow Lab
Janis Thal	Geology/EM120 mapping	Univ. Bremen
Heinrich Villinger	Geophysics	Univ. Bremen
Michael Brown	Videography	Los Angeles
Alberto Collasius	ROV Expedition leader	WHOI
Mario Fernandez	ROV	WHOI
Scott Hansen	ROV	WHOI
Baxter Hutchinson	ROV	WHOI
Akel Kevis-Stirling	ROV	WHOI
James Pelowski	ROV	WHOI
Ben Tradd	ROV	WHOI
James Varnum	ROV	WHOI
Korey Verhein	ROV	WHOI

USC	Department of University of Southern California
MLML	Moss Landing Marine Laboratories
WHOI	Woods Hole Oceanographic Institution

3 Research Program

Wolfgang Bach, Katrina Edwards

Rationale: The uppermost part of the permeable ocean crust harbors the largest hydrologically active aquifer on Earth. It is well known that the geochemical changes associated with basalt alteration in the uppermost oceanic crust play an important role in setting ocean chemistry. It is unknown what role microorganisms play in mediating this seawater–ocean crust exchange. Worse still, the extent to which microbes colonize, alter, and evolve in subsurface rock is not known. Several lines of observation suggest that oxidative ocean crust alteration takes place primarily during the first 10 m.y. of ocean crust evolution. It is possible that hydrologically active, young ridge-flank crust releases energy associated with the oxidation of ferrous iron in the basalt, and a sizeable microbial biomass may be supported by these oxidative alteration reactions (Bach and Edwards, 2003; Edwards et al., 2005; 2011).

Background: Research cruise MSM20/5 is part of a larger international effort to investigate the origin and nature of microbial communities within basaltic basement below an isolated sediment "pond" located on 7–8 Ma seafloor on the western flank of the Mid-Atlantic Ridge at 23°N. The cornerstone of the program is an array of several borehole “CORKed” microbial observatories being designed to allow long-term (decadal), manipulative, community-based experiments, observations, and sampling.

These operations are critical to the success of the larger program aimed at studying the basalt-hosted biosphere. Our studies will document and elucidate microbial community composition harbored within a young ridge flank, assess the role of microbes in the weathering of oceanic crust, and quantify relations between crustal hydrogeology and microbial community development. We closely cooperate with colleagues from the US (Katrina Edwards, lead-PI), who have secured complete funding for building all of the borehole and wellhead instruments.

Specifically, we seek to answer the following research questions:

What is the nature of microbial communities harbored in young ridge flanks? Are these communities unique, particularly in comparison with seafloor and sedimentary communities?

What are the mechanisms for microbial growth within the oceanic crust? What is the level of microbial activity and abundance within different subsurface areas?

What is the role of microbes in weathering the oceanic crust, under both oxidative and reducing conditions?

How are microbial communities in young basement rocks influenced by subsea-floor hydrogeology? Does hydrogeology impact the microbial distribution?

The North Pond study site is a sediment pond on the western flank of the Mid-Atlantic Ridge, which is underlain by hydrologically active upper oceanic crust. The North Pond Microbial Observatory investigates the origin, nature, and activity of microbial communities within basaltic basement below an isolated sediment "pond" located on the western flank of the Mid-Atlantic Ridge at 22°45'N and 46°05'W.

Integrated Ocean Drilling Program (IODP) Expedition 336 (Sept.-Nov. 2011) installed subseafloor observatories (CORKs) in this young ridge flank to examine the extent and the consequences of microbial life within the basaltic ocean crust (Expedition 336 Scientists, 2012). The observatories will enable us to monitor conditions and study processes in situ after the drilling-induced disturbance and contamination of the borehole environment have dissipated.

Sampling microbiological and geochemical studies are conducted on basement and sediment samples retrieved from the vicintiy of the CORKed hole.

Two observatories were successfully installed, a single-zone CORK in upper basement between 90 and 210 mbsf (Hole U1382A), and a multiple-zone CORK (Hole U1383C) monitoring and sampling three zones to 331.5 mbsf (meters below sea floor). CORK observatories comprise packer seals and a string of osmotic pressure driven fluid sampling (Janasch et al., 2004; Wheat et al., 2011) and incubation devises (Orcutt et al., 2010a; 2010b), as well as temperature and oxygen sensors, all protected by perforated fiber glass casing. Additionally, pressure sensors and additional osmo samplers were installed in the CORK head, where they connect to the subseafloor through umbilical lines. The North Pond microbial observatory is in place and set up to collect unique data and samples for several years.

Program: During cruise MSM20-5, these observatories were sampled for the first time, using the *Jason* ROV of the Woods Hole Oceanographic Institution (WHOI). A third scaled-down observatory (CORK-lite) was installed using the ROV. The primary goal of the cruise was the deployment and recovery of seafloor instrument packages on each of the three borehole observatories post drilling and to sample borehole fluids. We also conducted ROV-based sediment sampling and heat flow measurements as well as mapping and rock sampling up the basement outcrops surrounding North Pond.

We undertook observatory dives in two areas: (1) at Holes 395A and U1382A, located 50 m west of 395A, and at Site U1383 6 km north of that area. A typical wellhead-tending dive started with free-fall launching of equipment and diving of the ROV to the seafloor, where the deployed instruments were located, transported to the wellheads and installed there. Operations included the download of pressure data. A pump was attached to valves on the wellheads and water was retrieved from the borehole. Water samples were collected using gas-tight and large-volume (60 L) water samplers. During sampling, in situ concentration measurements of gases and other species were being conducted. Specifically designed Osmo sampler packages and GeoMICROBE sleds were deployed on the seafloor at Holes U1382A (210 mbsf) and U1383C (331.5 mbsf) to allow continued sampling of fluids and in situ geochemical measurements throughout the period until the next cruise. In Hole U1383B (89 mbsf), a CORK-lite was installed and equipped with downhole osmo samplers and a pressure logger (Wheat et al., submitted).

In periods of ROV downtime bathymetry surveys of the larger North Pond area and CTD casts with rosette water samplers were performed to collect sound velocity profiles and water samples. Multibeam and Parasound surveys during the night hours were carried out to better constrain the geological setting of North Pond, by determining the distribution and thickness of sediment, the morphology of constructional volcanic ridges, the orientation and throw of faults, and the shape of core complex features. Rock sampling of outcrops in the vicinity of North Pond provided material for geomicrobiological and petrological studies.

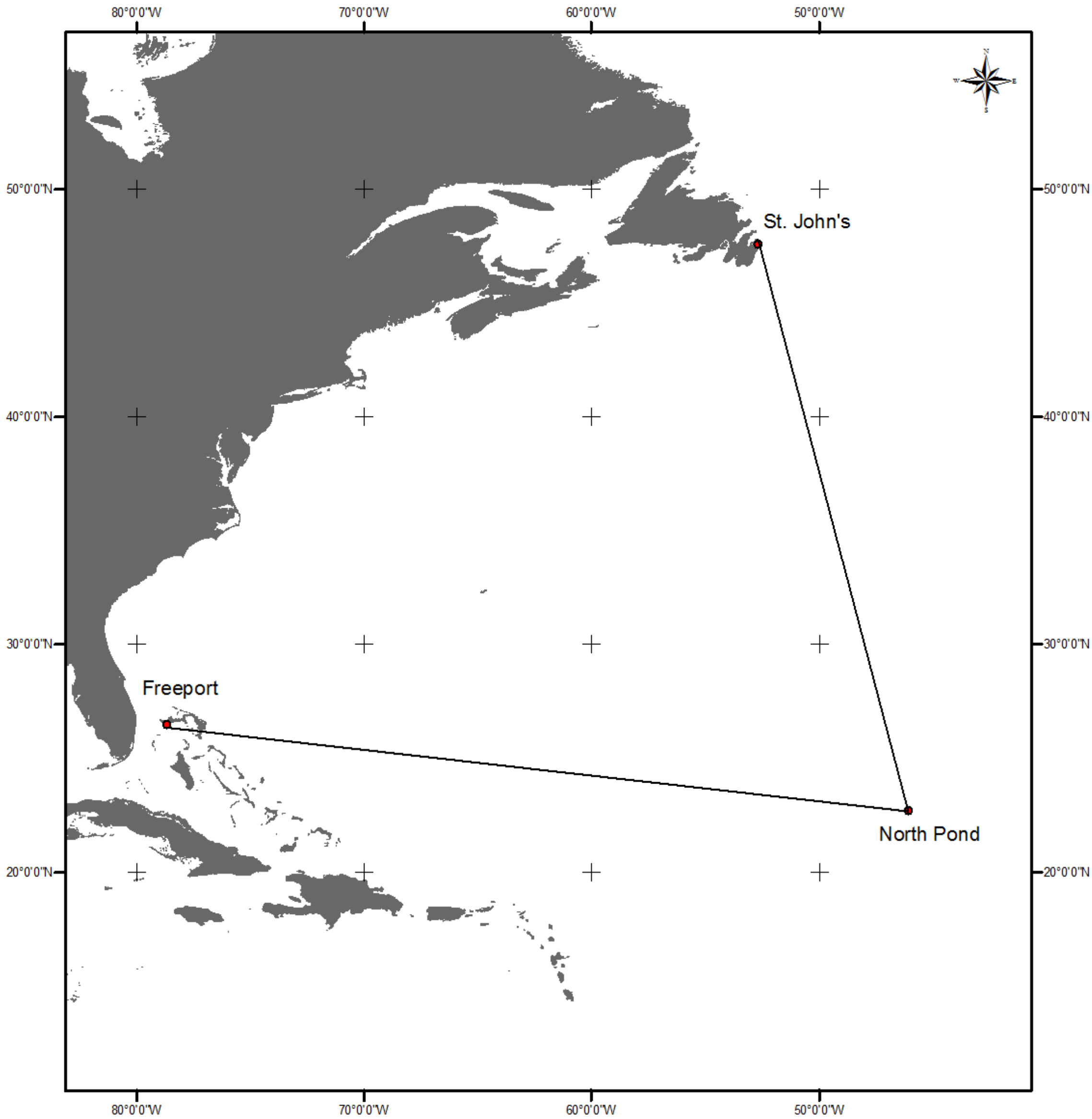


Fig. 3.1 Track chart of R/V MARIA S MERIAN Cruise MSM20/5.

4 Narrative of the Cruise

Wolfgang Bach

Loading of the five containers for ROV *Jason* and its winch as well as two power generators took place on April 7, 2012. Two rented containers were unloaded the next day and the gear was lifted onto the deck and into the ship's hold. The science party started unpacking and setting up in the various labs onboard the *MERIAN*. The science crew finally boarded the R/V MERIAN in the morning hours of April 10, 2012 in Freeport, Bahamas. In the early morning hours of April 10, the ship moved to the bunker station. The delivery of a container with observatory gear from the University of Hawaii was delayed due to an unforeseeable strike in Panama that paused onward shipment. Also, bunkering was delayed until the night hours of April 11. Knowing that the container would not be arriving before April 12, 2012, we left the port at 0830 on the 12th to conduct a *Jason* dive test in 500 m water depth 12 nm off the coast of Freeport. The test dive went well, as it indicated that all critical components of *Jason* were fully operational. Around noontime of the 13th, we received notice from the port agent that our container was express-unloaded from the container vessel it had arrived on and was ready for us to pick up in the afternoon. We loaded said container at 1630 that day and began our transit soon thereafter. During the 6-day transit to our work area around 22°45'N, 46°05'W we recorded echosounding data after we had reached international waters. The time during transit was used to prepare the labs and observatory instruments. Staging of the latter is elaborate and we made good use of the fairly long transit.

In the early morning hours of the 20th, we arrived at North Pond and conducted a CTD/hydrocast in 4400 water depth close to the site of the first dive with *Jason*. We obtained large volumes of deep sea water and near-surface water for microbiological background studies required for interpretations of results from sub-seafloor water samples. We also recorded a sound velocity profile needed for the Multibeam echosounding surveys that made up most of our night program.

The first dive (J2-623) on April 20th was intended to visit Hole U1383B and U1383C. Besides visually assessing the state of the CORK wellhead in Hole U1383C and the reentry cone with ROV landing platform in Hole U1383B, we achieved a number of incentives. Pressure data were downloaded from seafloor and all three sub-seafloor intervals of the CORK observatory in Hole U1383C. Fluids were pumped from the umbilical line that runs all the way down to the deepest zone to retrieve fluids. In situ electrochemical measurements were carried out during pumping. Gas-tight fluid samplers were triggered and an Osmo package that was mounted in the wellhead during IODP Expedition 336 was recovered using a small elevator built during *MERIAN's* transit. Hole U1383B was inspected and determined fit for deployment of the CORK body during the following dive.

On April 21, Dive 624 began soon after releasing the CORK body for Hole U1383B to the seafloor. *Jason* found the CORK and transported it to the borehole, where it was installed in the re-entry cone. Four sediment cores were taken in the vicinity of Hole U1383B before we transited 1km to the east to recover rock samples. Coming up on the slopes bounding North Pond, we encountered an outcrop and took three samples, of which two were placed in *Jason*'s bioboxes to allow for microbiological studies. On the way back to Hole U1383B, four more push core samples of sediment were taken from the steep (30-35°) west-facing slope. The floats of the Hole U1383B CORK were released before the dive was ended.

Dive 625 on April 22 followed the deployment of a seafloor Osmo package (fluid sampling and microbial incubation experiments) near Hole U1382A. The Osmo package was located at the seafloor and moved to the borehole. The valve to the pressure line on the wellhead of Hole U1382A was opened for a hydrostatic test. During the test period, the ROV transited to Hole 395A for visual inspection of the re-entry cone with ROV landing platform. The wellhead of Hole 395A had broken off upon installation during IODP Expedition 336, and the purpose of the inspection was to determine the state of the topmost part of the borehole Osmo assemblage in terms of possibilities for recovery during a later cruise. The ROV landing platform was seen to rest on the re-entry cone in an off-center position, in which it would have interfered with later manipulations at this partial CORK. It was decided to move the platform during a subsequent dive. Back at Hole U1382A, we attempted to measure heat flow, but the probe failed. The valve to the pressure line was closed to test the seal of the CORK wellhead. In the meantime, the seafloor Osmo package was move onto the landing platform. Next, pressure data were downloaded and the geochemical fluid sampling line was purged with an actuator pump mounted on the ROV. Fluids were then pumped and collected with a gas-tight fluid sampler. Fluids were next pumped from the microbiology line of the wellhead and collected in large-volume fluid samplers as well as gas-tight samplers. Voltammetric sensor measurements were conducted simultaneously.

Dive 626 on April 23rd followed on the deployment of the downhole Osmo package near Hole U1383B. *Jason* dove to a location 1.4 nm east of Site U1383 near the top of the steep eastern wall and recovered rocks (basalt, dolerite, and breccias) from scarce outcrops of apparent talus. *MERIAN* dragged *Jason* to Site U1383, where the deployed Osmo string was located and transported to Hole U1383B. The rest of the dive was spent, installing the downhole instrument package, consisting of a sinker bar, Osmo sampling / incubation devices and a temperature logger. A pressure logger was placed on the ROV landing platform and connected to the wellhead.

Dive 627 on April 24 began with rock sampling from a steep slope 1.6 nm southeast of Site U1382, where three pieces of peridotite talus were recovered. Floating devices, needed to move the ROV landing platform in the re-entry cone of Hole 395A, had been lowered to the seafloor before. They were located, moved to Hole 395A, and attached to the landing platform, which was subsequently removed from the re-entry cone by *Jason*. Visual documentation of the damaged observatory was recorded to help in the planning of future attempts of recovering the instrument string installed in that hole during IODP Expedition 336.

Dive 628 on April 25 deployed the first of two GeoMICROBE sleds and installed it on top of the ROV landing platform in the re-entry cone of Hole U1382A. Subsequently, basement fluids were pumped and sampled from the hole.

There was no dive on April 26, due to a tear in *Jason*'s tether that needed fixing. However, the seafloor Osmo package for Hole U1383C was launched that morning. Heavy seas on the following two days further delayed the next dive. The downtime in seafloor operations was used to map the larger area around North Pond with the ship's Multibeam and Parasound systems.

Operations on April 29 began with the launch of the GeoMICROBE sled for Hole U1383C. Dive 629 to Site U1383 was next. *Jason* located the Osmo package and moved it to Hole U1383C. The pressure logger was picked up at Hole U1383C and moved to Hole U1383B. Heat flow was measured there, before the valve to the pressure line was opened and the pressure logger was installed. Push cores of sediment were collected next. Fluids were then collected from the shallow and middle horizon in Hole U1383C. The GeoMICROBE sled was located and moved to Hole U1383C. It was attached to the wellhead after opening the valve to the geochemistry line and pumping on it. Subsequently, fluids were collected from the shallow and middle horizons. The Osmo package was attached to the geochemistry sampling line to the deepest zone. Next, the GeoMICROBE sled was connected to the microbiology lines to all three zones. *Jason* moved to Hole U1383B and measured heat flow there. Pressure data were downloaded and Holes U1383D and U1383E were "snow-plowed" to prevent recharge of seawater into the crust. The ship moved to a site of basement sampling at 22°49.89'N, 46°02.78'W in 4100 m water depth and dragged *Jason* to that location on a westfacing slope 1.9 nm north of Site U1383. We collected a sample of clayey ooze and four samples of basalt before the dive was ended after 24 hours.

Dive 630 took place on May 1 with the purpose of sampling fluids from the deepest horizon in Hole U1383C. Also, pressure data were downloaded.

The final dive, 631, began on May 2 near Hole U1384A, where sediment push core samples were collected and heat flow was measured. A steep, eastfacing wall 1.3 nm NW of that hole was visited to collect a sample of basalt. Throughout the dive, ROV-based Multibeam surveys were conducted during the transits from one waypoint to the next. The next sampling station was 1.7 nm to the south, in an area where previous surveys had indicated high heat flow around a local high within North Pond. Outcrops of pillow basalt were located and sampled on the east-facing wall of that high, and heat flow measurements and sediment push core sampling was also conducted near the base of a large outcrop. The dive continued with a 1 nm transit to the northeastern bounding wall of North Pond, where a steep slope was targeted for basalt sampling. No outcrops were found in that area and *Jason* moved to another local basement high 2 nm to the NW. Outcrops of clayey material (sediment or altered rock) and occasional hard pillow basalt were observed there, but sampling was unsuccessful. Our dive track continued to a local graben-like structure 1.5 nm WSW of that site. Two samples of basalt were recovered from a steep westfacing slope. Heat flow was measured and sediment samples were push-cored. *Jason* then drove 1.8 nm to the west and landed in Long Pond, after transiting down a very steep wall with an elevation change of almost 1000 m. A 500-m long transect of heat flow measurements was carried out, with *Jason* gradually moving east in 100 m increments. Sediment samples were taken from Long Pond at a site closest to the steep wall. We then abandoned the dive in the evening hours of May 3rd.

Shortly before midnight on that day, our transit to St. John's started. Leaving the North Pond site, we conducted a 5-hr long bathymetry survey with a heading of 350 to map the 8-Ma time slice of crust up to the Kane Fracture Zone. We arrived in St. John's in the afternoon of May 9th, after an uneventful transit. Unloading proceeded swiftly on the following day, and on May 11th all samples and gear had been sent on their way to the various labs and the return travel of the science crew began.

5 Preliminary Results

5.1 Hydroacoustics

Janis Thal

The multi-beam echosounding system (MBES) Kongsberg EM 120 of the MARIA S. MERIAN was used for deep-sea bathymetric surveys. The system is mounted on the hull of the research vessel and provides 191 beams with spacings that can be set up equidistant or equiangular. The emission beam can be adjusted to opening angles up to 130° across-track while the opening angle along-track is fixed to 2°. Resulting footprints are dependent on water-depth (2° along-track and 2° across-track). The echo received from the seafloor consists of 191 reflected beams from frequency coded (11.25 to 12.6 kHz) acoustic signals. For further details see Table 5.1.

The absolute water depth can be estimated by using a sound velocity profile (SVP) describing ray-bending in the water column and by knowing the two-way travel time for each beam. Measurement accuracy is achieved by using a combination of phase for the central beams and amplitude for the lateral beams.

On the first station at North Pond a CTD-cast was conducted to obtain an accurate SVP. An SVP-sensor on the ROV *Jason* supported accurate SVP measurements during the whole cruise.

Raw depth data obtained by the MBES and recorded by Kongsbergs SIS-Software contain along-track distance, across-track distance and depth information. This raw data is already corrected for

sound-velocity changes in the water-column by a SVP and for heave/pitch/roll movement by data from the motion reference unit (MRU).
The raw bathymetric data was processed on board during the cruise using the software “MB-System”. Data were checked for outliers in the navigation. Such outliers were removed and replaced with interpolated values. Obvious outliers in the swath data were removed. After this procedure, xyz files were exported, gridded (2 arc-seconds) and used for preparation of preliminary maps using the software GMT (Wessel & Smith, 1995). The resulting map is shown in Fig. 5.1.

Table 5.1: Technical Data Kongsberg EM 120

Main Frequency	12 kHz (varying between 11.25 and 12,60 kHz for sector-coding)
Beams	191/Ping
Opening angle	2 x 2°
Beam width	equidistant or equiangular
Coverage	<=130°
Operating depth	20...11000 m
Depth resolution	10...40 cm
Pulse length	2, 5, 15 ms

The bathymetric survey can be subdivided into 3 parts:

1. Transit from Freeport (Grand Bahamas) to North Pond
2. Detailed mapping of North Pond and surrounding ridges
3. Transit from North Pond to St. John’s (Canada)

1) The Multibeam survey during transit from Freeport was outside the main objectives of MSM20-5. The speed during transit was ~ 12 knots. No CTD runs were performed prior to North Pond. A sound velocity profile from the former cruise (MSM20-4) was used. The beam angle was 120°.
2) While on site, the time between the ROV dives was dedicated to Multibeam surveying. The objective was to produce a high-resolution map of the whole area around North Pond. An area of ~ 5500 km² has been covered with a grid-resolution of 2 arc-seconds. A beam angle of 90° was used.
3) The Multibeam survey during transit from North Pond to St. John’s was performed with an average speed of 11 knots and a beam angle of 120°.

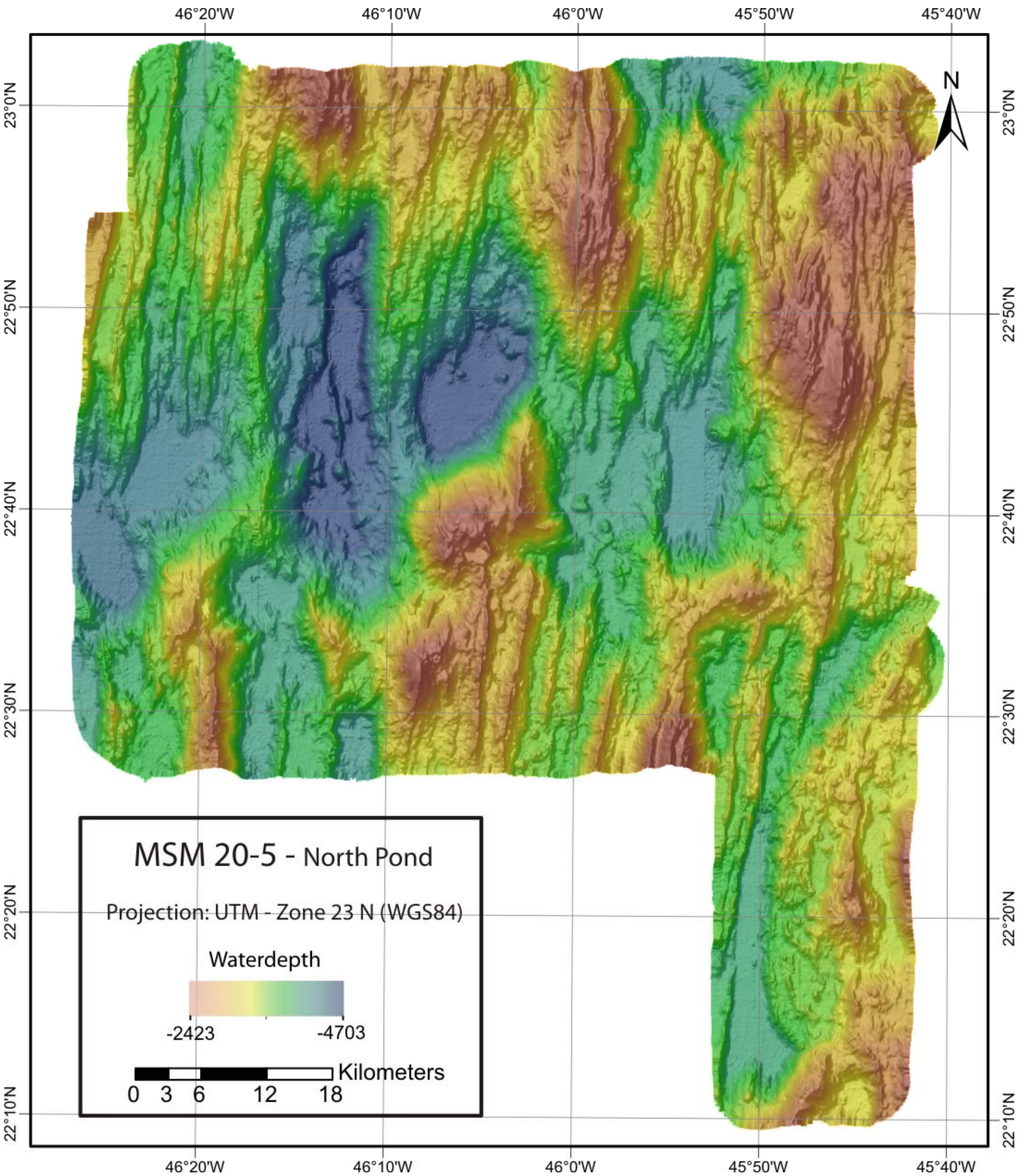


Fig. 5.1 Bathymetric map of the North Pond area of R/V MARIA S MERIAN Cruise MSM 20/5. The oval-shaped North Pond and the elongate N-S trending Long Pond emerge as prominent lows.

5.2 CTD/Rosette operation

Heiner Villinger, Peter Girguis

Two hydrocasts were run with the ship's Seabird 9plus CTD and rosette. The first cast on April 20, 2012 was conducted shortly after the arrival at North Pond in order to establish a sound velocity profile needed for the planned bathymetric survey. Seawater samples were also collected at that station. During the deployment, it became apparent that the sensors (O_2 sensor #1, fluorometer, transmissometer) were not functioning well. The second hydrocast was carried out on April 26, 2012 to allow geochemists to collect additional seawater samples during a day of ROV downtime. Temperature profiles of the two casts in comparison with the results from a cast from MSM 11/1 and the ROV Jason CTD data are shown in Fig. 5.2.

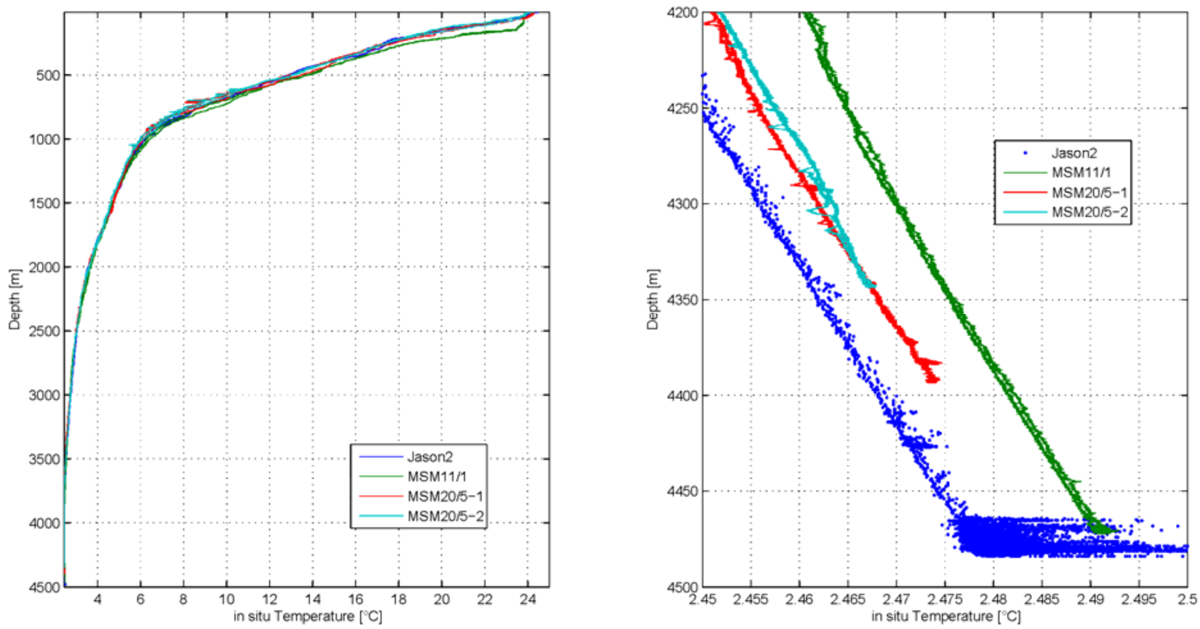


Fig. 5.2 Comparison of temperature profiles from two CTD casts during MSM20/5, one cast from MSM11/1 and data from the ROV Jason CTD.

5.2.1 Water sampling

Prior to the first deployment, the CTD was rinsed with freshwater prior to deployment, but due no substantive effort was made to sterilize the bottles prior to use. We sent the CTD to within 200 m of bottom and – to avoid the nephaloid layer – fired the bottles there. In addition, we fired a bottle at ~60m below sea level to collect water with a “maximum” chlorophyll signature, and water at ~20 m below sea level for a postdoc at the Max Planck Institute, Bremen.

For the second hydrocast, the rosette, again, was rinsed with freshwater prior to deployment. All bottles were fired at 100 m above sea floor, and samples were processed as described in section 5.3.6.

5.3 ROV Jason operations

Katrina Edwards, Wolfgang Bach

ROV *Jason* is a ~30 HP scientific mission configured ROV with two full-function manipulators, a retractable sample basket, a full-ocean depth Reson multibeam sonar, a CTD, a digital still camera, and multiple HD color cameras. *Jason* is connected via a ~40m long neutrally buoyant tether to its fiber-optic cable junction vehicle, *Medea*. *Medea* is the junction of the fibre-optic 0.680 cable from the ship. *Jason* is navigated using a combination of downlooking acoustic doppler velocity log (DVL) and a high frequency acoustic ranging system between *Medea* and *Jason*. The ship's USBL system *Posidonia* did not work reliable on Jason, due to the great water depth and unresolved interferences with *Jason*. *Jason* dove without any bottom deployed transponder net and relied more heavily on DVL navigation. The DVL navigation provides a high data rate (typically 1Hz) position value but tends to drift or be plain wrong if bottom lock is lost. The boreholes were used as fixed points to which the DVL navigation is fit to. This re-navigated data was completed on board during the cruise. Deep submergence operations with *Jason* began in a daily dive mode to accomplish the various installations at and retrievals from the boreholes at Sites U1382 and U1383. A typical basket configuration is depicted in Fig. A1 Usually, a dive would start at 0800 local time and end around 2000 local time. With 2.5 to 3 hours of time for descent to the seafloor and ascent back to sealevel, we had 6-7 hours of time for borehole-tending operations and occasional sediment and hard rock sampling activities. Retrieval of the Osmo well head packages installed during IODP Expedition 336 were accomplished in the course of our dive program. These installments were replaced by seafloor Osmo packages designed and built by Sam Hulme to ascertain fluid sampling for the period between this cruise and a follow-up cruise around the turn of 2013 and 2014. These packages include fluid sampling lines as well as microbial incubation chambers. GEOMICROBE sleds (Cowen et al., 2012) were also installed to the wellheads of Holes U1382A and U1383C. A major objective of cruise MSM 20/5 were the ROV-guided installments of a CORK in Hole U1383B and preparation work on Hole 395A. All these activities are detailed in the following sections. Occasional sampling of surrounding outcrops were conducted whenever suitable to the daily-dive mode of operation. Towards the end of the cruise, the durations of the dives were increased to allow for extended geological/microbiological sampling of basalt and sediment at sites away from the borehole locations. During our last dive (J2-631), this work program was supplemented by ROV-based multibeam mapping, using *Jason's* Reson mapping system.

A visual of a Jason launch is presented in Fig. 5.3. The locations of the boreholes in the North Pond area are presented in Fig. 5.4. The tracks of nine dives in the North Pond area are shown in Fig. 5.5.

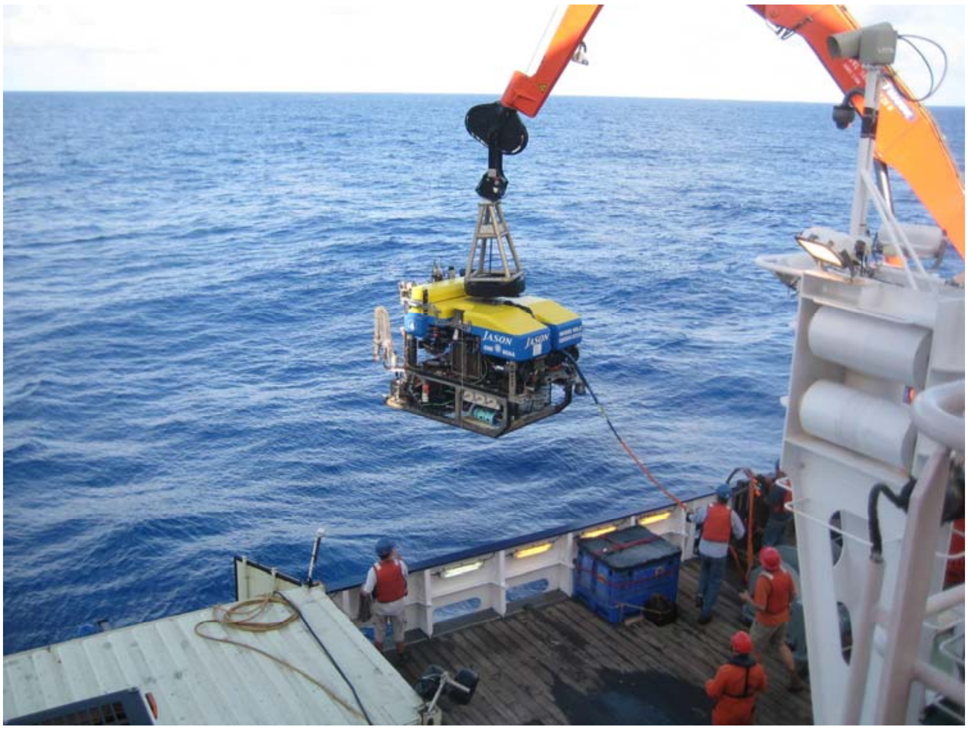


Fig. 5.3 ROV Jason is launched using the starboard aft crane on the main deck

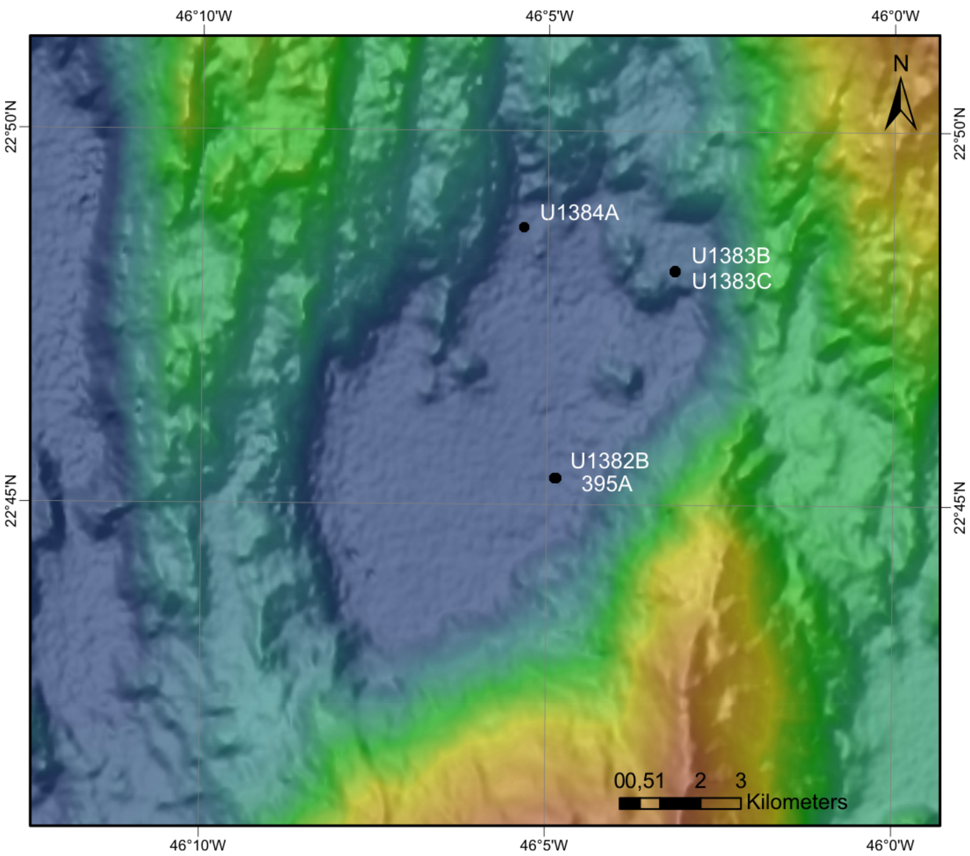


Fig. 5.4 Locations of boreholes in the North Pond area

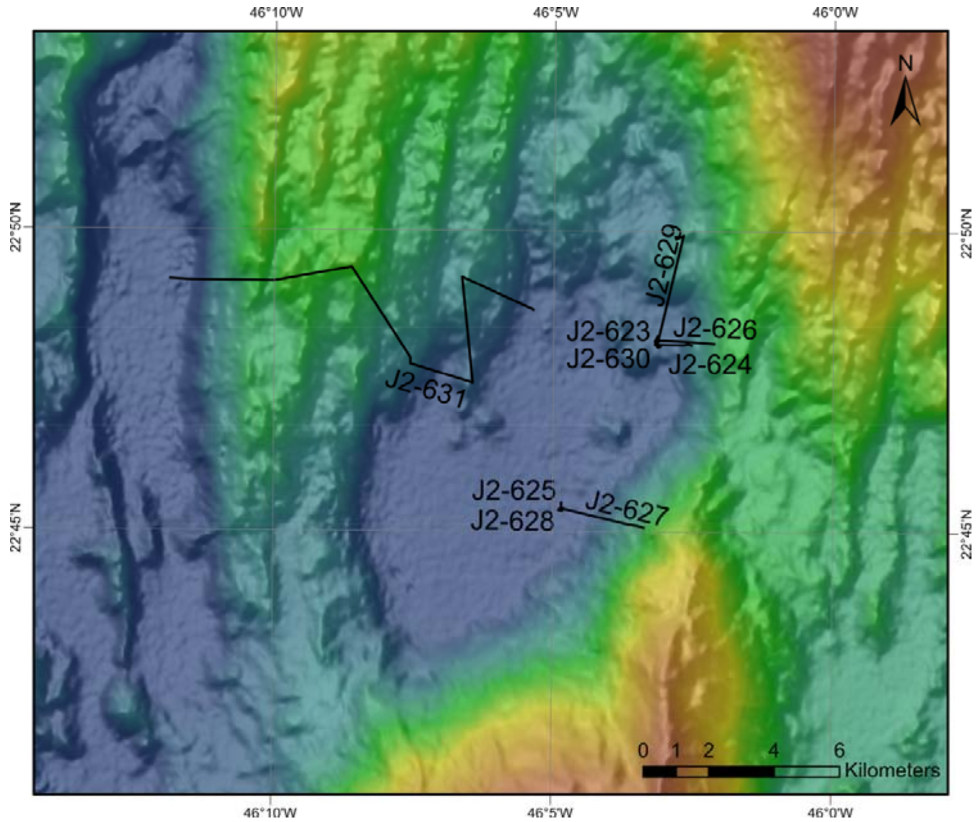


Fig. 5.5 Track lines of *Jason* dives 623 – 631

5.3.1 Deployment of the CORK-Lite Body in Hole U1383B

Geoff Wheat

Hole U1383B was drilled on IODP Expedition 336, but drilling in the hole ceased when the tri-cone bit failed, resulting in a "junked" hole. Nevertheless this hole was cased through the sediment section into upper basalt and cemented. The primary bit was an 18-inch bit that allowed the 16-inch casing to be deployed. A 14.75-inch tri-cone bite was used to clear a path for 10.75 inch casing to be deployed; however, bit destruction ended drilling operations. An ROV platform was deployed later. This platform was modified with strength members below the platform so that it would guide itself in place when deployed from the ship in a "free-fall" mode. On our first dive (J2-623, April 20, 2012) the plan was to inspect the platform to verify its location (centered) and determine if it was in a good enough position to lower the 15-inch seal on the CORK-Lite body through the 30-inch diameter hole of the ROV platform.

The CORK-Lite body was modified from machine drawings before deployment. Blue-green 0.5-inch polypro rope was used to join the lifting bar with the CORK-Lite body. The original design was to use cables and pull pins. The *Jason* team opted to use rope, which is easier to cut and release than pull pins with 800 pounds of buoyancy. Therefore, in the future the lifting wings of the CORK-Lite body can be replaced with a single piece of sheet metal (presently there is a single sheet upon which two plates are welded so that the pin can bisect a lifting rope). The rope was hung from the lifting bar with shackles and through a shackle on the wings of the CORK-Lite body and around one side of the body to the other wing and shackle and back to the lifting bar. Tygon tubing was used to protect the rope from chaffing. Holes on the wings that were designed to accommodate the pull pins were enlarged to account for the larger diameter of the shackle pins.

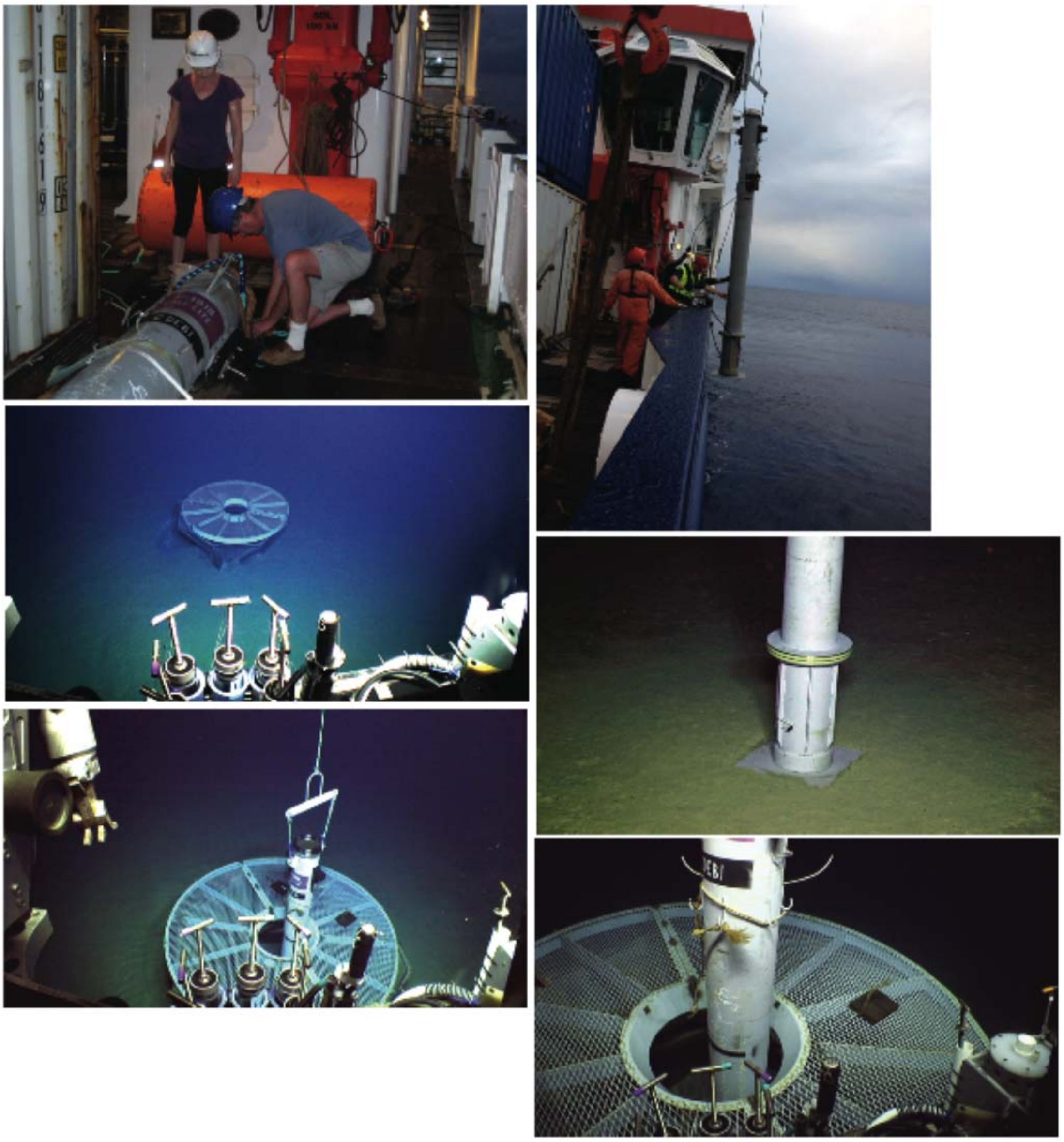


Fig. 5.6 Preparation, launch and installation of the CORK lite in Hole U1382A

The CORK-Lite body was deployed as shown in Fig. 5.6 on dive J2-624, April 21, 2012. First, the CORK-Lite body was located. The entire package was lifted to make sure it was heavy enough once the boot was released. The pull pin for the boot was released and Jason grabbed the bail on the lifting bar to move it in place. While in transit to the borehole, the estimated weight in water using the thrusters on *Jason* was about to 90 lbs. The original estimated weight on bottom was 71 lbs. This suggests that the buoyancy is 20 lbs less than stated. Probably the most likely suspect is the large float. The large float should be downgraded to 385 lbs. The rigging of the CORK deployment is depicted in Fig. A2.

Once at the wellhead, the CORK-Lite body slid into place perfectly. A line was drawn from the bottom seal to indicate where the body should rest relative to the ROV platform once it is in place. This line is several inches offset from the mark that was indicated from the lifting wings. This discrepancy needs to be rectified. Nevertheless it looked like it was in place. This was difficult to determine given the angle of the vehicle, cameras, and the lights. Once in place and with the floats still attached, *Jason* was used to push the CORK-Lite body and it did not move. We felt confident that it was secure and continued with the dive. At the end of the dive a knife was used to cut the rope to release the floats and the floats were recovered.

5.3.2 Deployment of the CORK-Lite Instrument String in Hole U1383B

Geoff Wheat, Beth Orcutt, Katrina Edwards

The instrument string for the CORK-Lite at Hole U1383B was deployed just before dive J2-626, April 23, 2012. The rigging is shown below (Fig. A3) along with depths of casing, sediment-basalt interface, cement, and hole penetrations. The instrument package consists of three self-contained temperature recorders (1 Anteres and 2 Hobo probes) and seven OsmoSampler systems (Standard, Gas, Acid Addition, BOSS, Enrichment, and 2 each of the MBIO packages). The Standard OS included one 8-membrane pump and 3 teflon coils. The MBIO were identical to the Standard OS but included a FLOCS element at the intake before the Teflon tubing (Fig. 5.7). The Gas OS included one 8-membrane pump and 3 copper coils. The other three were made using 5 teflon coils, one 8-membrane pump, and one 2 membrane pump. Solutions that were added to the sample intake are as follows:

Acid Addition – 20 ml of 6N subboiled HCL/500 ml
BOSS – 75% RNA later and 2 ml of saturated $HgCl_2$ in 500 ml
Enrichment – 1.2 mM nitrate solution in sterile seawater solution

The three FLOCS units contained in the Enrichment and two MBIO packages were nearly identical to each other, and they were made using left-over materials for IODP Exp. 336. The mineral assemblages on the inside and outside of the FLOCS were also similar to those used during IODP Exp. 336. The enrichment package contained FLOCS chambers 106 and 107, and the MBIO packages contained FLOCS chambers 108, 109, 128, and 129. The mineral composition of these FLOCS are as follows:

Mineral/Chamber	**106**	**108**	**128**
U1382A 3R3 massive basalt	B668	B669	B722
U1382A 8R1 phyric basalt	B670	B671	B723
olivine	B672	B673	B724
fayalite	B674	B675	B725
sphalerite	B676	B677	B726
chalcopyrite	B678	B679	B727
pyrrhotite	B680	B681	B728
hematite	B682	B683	B729
	107	**109**	**129**
3971-B010 glassy basalt	B430	B433	B730
pyrite	B431	B434	B731
glass beads & wool	B432	B435	B732

Contents and IDs rock slides above chambers:

Mineral/Chamber	**106**	**128**	**129**	**Mineral/chamber**
X45-395A-9R2 basalt	B652	B733	B734	Olivine
X45-395A-35R1 basalt	B653	B735	B736	X45 395A 9R2 basalt
X45-395A-58R2 basalt	B654	B737	B738	Pyrrhotite
Barite	B655	B739	B740	AT20-4055-B6 basalt glass chips
	107			
sphalerite	B656			
pyrite	B657			
goethite	B658			
hematite	B659			
	108			
rhyolite	B660			
4055 B6 glassy basalt	B661			
X45-395A-15R4 basalt	B662			
X45-395A-18R1 basalt	B663			
	109			
olivine	B664			
chalcopyrite	B665			
pyrrhotite	B666			
magnetite	B667			

Fig. 5.7 Incubation substrates mounted in the FLOCS units in Hole U1382A

The idea was to put the instrument string in the safety of the casing while the sample intakes are positioned below the casing and in open hole. The instrument string was fabricated and attached to the intake line using a stainless steel weak link set to 1800 lbs. The 12-meter-long spectra rope was replace with 0.5-inch green/blue polypro rope with a loop every meter along the length. The idea was that *Jason* could lower the intakes line one meter at a time, going hand over hand and then hand over hand on the instrument package and finally let the spectra slide through the manipulator to slow its decent while looking for the cap. Once the cap was seen the rope would be released and the manipulator moved out of the way. Snap shots of the preparation and deployment of the CORK lite instrument string in Hole U1382A are presented in Fig. 5.8.

The biggest problem with the intake was to get all of the OS packages attached to the umbilical safely. This was completed for all with the exception of the central sampler. A better system has to be devised, but considering that we used all parts remaining from Exp 336, it was quite successful.

The first portion of dive J2-626 was to collect rocks on a nearby outcrop. Upon arriving to the instrument string on the seafloor it was apparent that the weights were off. Ideally, the sinker bar would be touching the bottom with the line slightly elevating it. Instead, the sinker bar was completely in the mud, the bottom 12 m of line and intake were on the bottom and the instrument string was resting on the bottom. The descent weights were removed and the sinker bar and OS package picked up and transferred to the wellhead. At the wellhead we tried to lower the package into CORK-Lite from an elevation of 12 m. This did not work and the sinker bar got below the ROV platform. It was removed and placed in the hole. When the sinker bar was released in the hole it took more umbilical until a loop got caught on a handle. This loop was cut and the rest was pulled into the hole. The instrument string was pulled against the casing and stable. *Jason* went to the top of the instrument string, picked it up and put it in the hole. The string was then successfully lowered into the hole and the spectra was run though the manipulator in a controlled fashion. Once the cap was observed, the manipulator release the line and let it fall in place. The manipulator was used to center the cap and let it fall in position. The two ropes were cut and the top was spun 12 times to latch into the CORK-Lite body. All three valves were closed on the CORK-Lite. The only thing that was needed to complete the deployment was to attach the pressure logger, but there was no time. Note that the valve on the top plug should have had a lanyard of yellow rope to help close/open the valve, but the pilot had no problem as it was. To alleviate such problems in the future, a larger sinker bar should be used or a series of sinker bars held with polypro rope. Thus they could be cut to relieve weight if that were appropriate.

During dive J2-629 we moved the pressure logger from the ROV platform on Hole U1383C and placed it on the platform on Hole U1383B. The valve on the CORK-Lite was opened and the intake for the pressure valve was attached. Before leaving to do more operations at Hole U1383C we circled the borehole twice to get a good look at it from all sides. Later in the dive we went back to the pressure logger and downloaded the data. The data indicate that the CORK-Lite sealed the hole.

*** For CORK-Lite: If the valve is open (vertical) then turn the valve counterclockwise to close finishing in the horizontal position.
*** Note for all chemistry and MBIO valves – turn clockwise to open
*** Note for pressure lines – if valve is open then turn clockwise 180 degrees

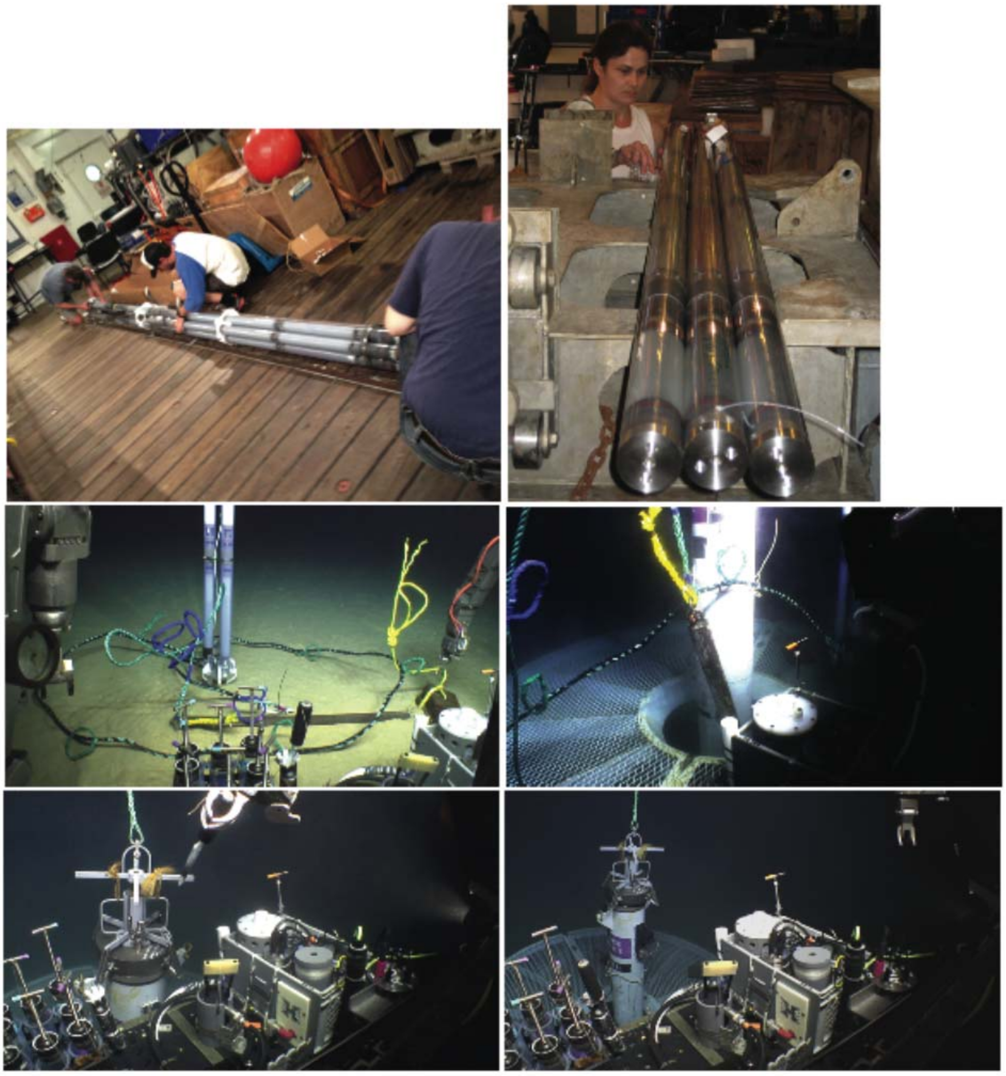


Fig. 5.8 Preparation and deployment of the CORK lite instrument string in Hole U1382A

5.3.3 DSDP Hole 395A ROV Platform Move

Geoff Wheat

During IODP Expedition 336 an L-CORK was installed into DSDP Hole 395A. However, sometime near the end of operations at the hole the wellhead was ripped from the casing. In the process, the ROV platform was moved and punctured. From the drillship the platform looked off center. On Dive J2-625, April 22, 2012 we inspected Hole 395A. The ROV platform had two of the four centering spikes inside the re-entry cone. We were able to look down the cone, by shutting off the lights on the light bar, using only the light on the swing arm – there was too much backscatter of light on the ROV platform from the lights on the light bar. We could not see what was at the base of the re-entry cone. *Jason* was then moved to the edge of the cone and pulled the platform. It moved a little bit. It was then suggested that we come back with floats to make the move easier.

Just before dive J2-627, April 24, 2012, the following floats and weights were launched. We used an *Alvin* weight stand to hold all of the weights. The floats were located and the decent weights were released by cutting the line. *Jason* picked up the package using the cross plate on the weight stand and headed toward Hole 395A (Fig. 5.9). The estimated in water weight was

120 lbs, about 25 lbs greater than expected. Had we downgraded the buoyancy on the big float by 20 lbs (as in dive J2-624), then the weights would have matched. We reached the wellhead and put the weight stand to the side of the reentry cone where bags of cement (?) and a section of 4 inch pipe reside.

The rigging needs some discussion. We wanted a 12-m length of rope from the float to the ROV platform to give us some flexibility. We also wanted a float so that once the hook was in place it would not fall off and so that the line would not get caught on the platform. We also added a ring above the hook so that they could hold the ring and cut the rope, thus the hook would not fall into the wellhead. Lastly we added a rubber shock absorber so that once the floats were cut from the weights it would adsorb that initial pull. To make sure everything was in place at the seafloor the float and hook were shackled to the D-ring at the base of the large float using a special shackle with a t-handle and a cotter pin with a pull line (Fig. 5.10). We used rubber bands to tie the 9-m-long extension line to the D-rings on the large float. These rubber bands immediately broke before reaching the water. We should have used socks to hold the rope in place and out of the way of operations.

Once at the wellhead, the shackle was released and the float and hook taken over to the center of the wellhead. We could not hook onto the bottom of the inner cone. Instead we hooked one of the tabs (square hole) that appeared to be a lifting point or the point where the platform is held during deployment on the JOIDES Resolution. The hook was in place and the 35 lb float released, holding the hook in place and the line above the platform. The weights were cut and the entire platform jumped up off the cone and settled again. The platform was up on one side. After a short discussion of several options it was decided to place the platform 10 m NNW of the wellhead. During IODP 336 it was decided to leave the platform in place. During the discussion it was clear that the Jason pilots did not need the platform to fish for and remove the instrument string. We discussed the possible need for the platform but decided that if we really needed it we could make a bridle to move it and center it. During the move, the estimated weight of the package was “at least 100 lbs”. The move was short so a better weight estimate was not possible. This is in agreement with the weight of the platform in air (998 lbs in air and roughly 950 lbs in water) and buoyancy of the floats (ideally 887 lbs but seem to be tracking 20 lbs less to 867 lbs). The platform was set aside and at the end of the dive the floats were cut and the hook recovered on a subsequent dive.

In retrospect, we should have used less buoyancy and distributed it over more of the platform, then use the driving force of the vehicle to center the platform, or to use *Medea* to lift it in place. Another option would have been to make a lighter weight version out of the same material that they use for elevators (fiberglass grating)

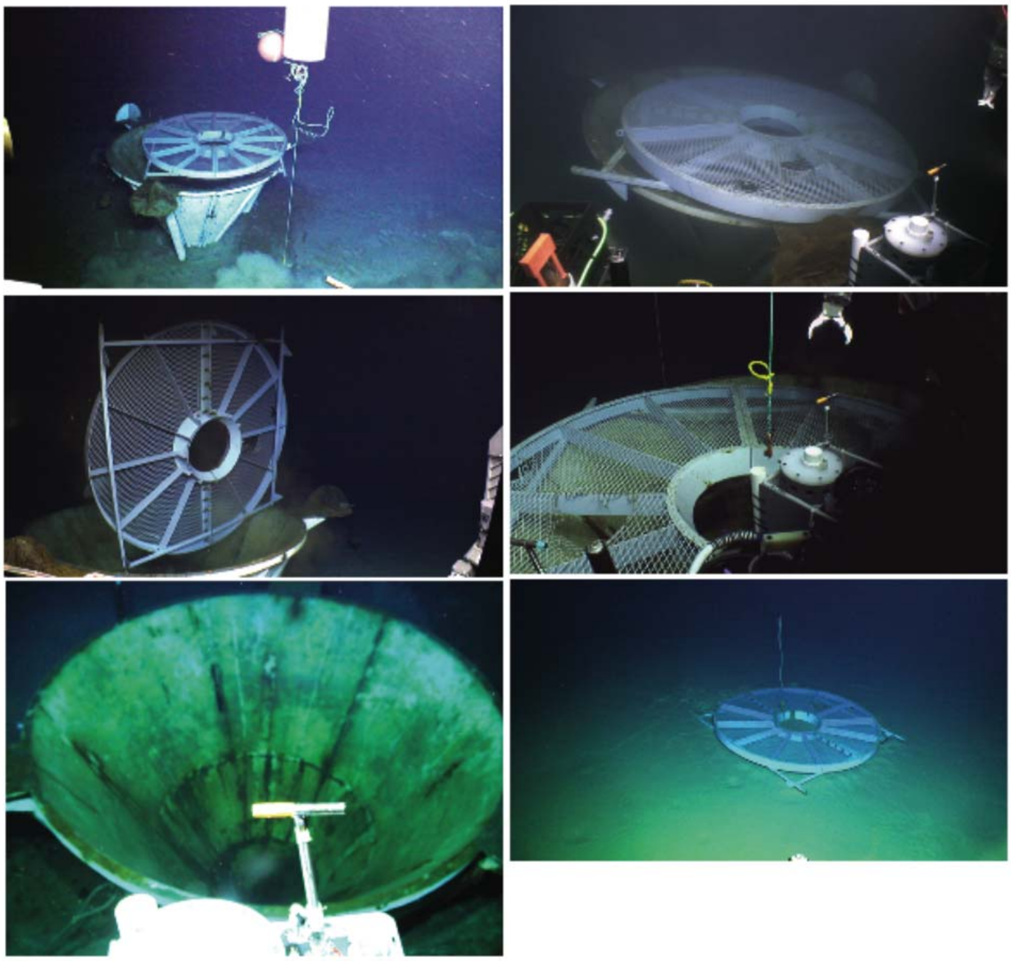


Fig. 5.9 Sketch depicting the layout of the CORK lite deployment in Hole U1382A

Fig. 5.10 Sketch depicting the layout of the CORK lite deployment in Hole U1382A

5.3.4 Fast Flow Osmo Platform Deployments

Beth Orcutt, Sam Hulme

Two newly developed osmotically-powered fluid sampling platforms were deployed by the ROV Jason at the CORKs at Holes U1382A (Figs. A6 and A7) and U1383C (Figs. A8 and A9). These systems are centered around 115 L polyethylene drums lined with a flexible PVC bladder filled with purified water. This fresh-water reservoir is exposed to seawater through a semi-permeable membrane attached to the lid of the drum. Attached to the outside of the drum is a bulkhead fitting which penetrates the drum but not the PVC bladder full of fresh water, and to which a PEEK line is connected as the pump intake. As the fresh water is drawn out of the bladder through the membrane due to the higher salt content of the ocean, the PVC bladder collapses within the rigid drum creating a negative hydrostatic pressure within the drum. This negative pressure is transferred to the intake line and provides the driving force for the pump. Three of these pumps were affixed to each of the two platforms by polyester strapping and weights were placed around the bottom edge of the platform and to a 4m rope as a drogue weight for deployment. The platforms weighed -45kg in water without weights or floats and the water weight during deployment was -100 kg with the drogue and platform weights attached. The platform at Hole U1382A has a 13 kg float and the Hole U1383C platform a 16 kg float, making each one weigh 32 and 29 kg in the water. Each platform was placed on the seafloor next to the chemistry bay of the CORKs with a total height of 2.3 m above the seafloor (slightly below the ROV landing platform; Figs. A6 and A8).

A variety of experiments were attached in line with the pump intake, which was ultimately attached to the CORK umbilicals within the chemistry bays (Figs. A7 and A9). For Hole U1382A two of the pumps were attached to the CORK and one was left open to seawater for collection of reference samples to use as a starting endmember of the formation fluids. Combinations of 4 unique experiments (detailed below) were deployed on these platforms: FLOCS microbial colonization experiments (Fig. A10); acid-addition OsmoSamplers; *in situ* filtration and extraction columns; and optode-sensor oxygen concentration dataloggers. At Hole U1382A the platform had 3 packages: (1) a FLOCS combined with *in situ* filtration and extraction columns with the intake located beneath the platform; (2) an acid addition Osmosampler, FLOCS, and *in situ* filtration and extraction columns with the intake connected to the upper umbilical of Zone1; and (3) a FLOCS and acid addition OsmoSampler connected to the upper umbilical of Zone2. The platform deployed at Hole U1383C also had 3 packages: (1) an oxygen monitor, acid addition Osmosampler, FLOCS, and *in situ* filtration and extraction columns with the intake connected to the upper umbilical of Zone1; (2) a FLOCS and acid addition OsmoSampler connected to the upper umbilical of Zone2; and (3) an acid addition Osmosampler, FLOCS, and *in situ* filtration and extraction columns with the intake connected to the upper umbilical of Zone3. There was also an additional oxygen monitor attached beneath the platform at Hole U1383C to monitor ambient oxygen at the seafloor.

Six sets of three FLOCS were made for the well-head deployments (Fig. A10). Each set consisted of: one sleeve filled with J2-241-R9/10 Loihi basalt fragments and glass wool, one sleeve filled with pyrrhotite fragments and glass wool, and one sleeve filled with three plastic grids of rock coupons and glass wool (Table 5.2). The three plastic grids were mounted with AT11-20-40550B6 EPR basalt glass, X45 395A 18R1 North Pond rocks, and pyrrhotite.

Table 5.2: List of sample codes for the FLOCS chambers and cassettes

Set	Chambers		
	Basalt	Pyrrhotite	Grids (basalt glass, 395A rocks, pyrrhotite)
1	110	116	122 (B704, B705, B706)
2	111	117	123 (B707, B708, B709)
3	112	118	124 (B710, B714, B718)
4	113	119	125 (B711, B715, B719)
5	114	120	126 (B712, B716, B720)
6	115	121	127 (B713, B717, B721)

Sets 1-3 were deployed on the Hole U1382A well-head on dive J2-625. Set 1 is connected to the red umbilical that is connected to the upper left valve 1. Set 2 is connected to intake sucking bottom seawater from underneath the platform. Set 3 is connected to the black umbilical that is connected to the upper right valve 2. Sets 4 – 6 were deployed on the Hole U1383C well-head on Dive J2-629. Set 4 was contained in a blue milkcrate and attached to the black umbilical. Set 5 was contained in a blue milkcrate and attached to the green umbilical. Set 6 was contained in a black milkcrate and attached to the red umbilical. Sets 4 and 6 are in milk crates containing the metal and organic extraction columns. The fast flow pumps have a check valve to prevent fluid from moving out of the barrel pumps into the sample lines, if they over pump.

The acid-addition Osmosamplers were connected to the main fluid flowpath by a tee connector in order to sub-sample the continuous flow of fluid into the pump intake. These OsmoSamplers contain 2 additional osmotic pumps that pump at a much slower rate in order to preserve a time-series of the water chemistry. One of the pumps pumps at a 10x faster rate, and is connected to a small-diameter Teflon coil on both the intake and outflow. The other pump is also connected to two Teflon coils of shorter length on both the intake and outflow. The intake of the large pump is connected via a tee to the outflow of the small pump, and both are connected to the main fluid line. The small pump outflow is filled with a 0.5 N HCl solution, which is mixed with the incoming fluid, acidifying the sample, which then flows into the coil attached to the large-pump intake. The inflow of the small pump is attached directly to the fluid sampling line by a tee providing an unadulterated fluid sample.

The *in situ* filtration and extraction experiment was specifically designed for this deployment and consisted of 4 components. The first component was a polycarbonate tube (i.e. a spare FLOCS chamber) filled with quartz wool with the intake on the bottom and outflow on the top. This acted as a simple particle trap to prevent premature fouling of the filter. The tube was pre-cleaned by soaking in 10% HCl for several days and then pre-filled with 0.2 μm filtered ship DI water. A 0.2 μm filter capsule was placed next inline of this system to remove any non-dissolved particles and microbial organisms. The filtered water then entered a Kynar column filled with a layer of prefilter resin beads to bind dissolved organics, a layer of 8-hydroxyquinoline resin beads to bind dissolved metals, and another layer of prefilter resin beads to contain the 8-HQ. This column was closed on each end by 4 layers of 35 μm woven PEEK mesh that held the resin beads in place with minimal induced backpressure on the system. The last component in this flowpath was an additional Kynar column filled entirely with MnO_2 resin beads to bind Ba and Ra from the fluids. In between the filter and the first Kynar column a tee fitting was connected to a Teflon coil filled with a pH 6.4 bicarbonate buffer solution and attached to the outflow from an OsmoSampler.

Fast Flow Osmo Sampler Recoveries – Two osmotically-powered pumping experiments were recovered on this expedition that had been deployed on IODP Expedition 336 on the CORKs inserted into Holes U1382A and U1383C. The package recovered from Hole U1383C appeared to have failed during deployment due to the turbulent nature of lowering the CORK ~4500m (Fig. A11). This failure appeared to have occurred on the small diameter PEEK line that attached the pump head to the fresh water reservoirs. As a result, no water was sampled from the formation during the first 6 months at Hole U1383C. The experiment recovered from Hole U1382A recovered 8.5 L of fluid from the umbilical attached to the upper sample line of Zone1 in the chemistry bay (Fig. A12). This was less than the predicted volume based on laboratory experiments, and discoloration on the membranes indicated that fouling of the membrane by contaminants in the water was the reason for this sub-optimal performance. The design currently deployed at the two CORKs eliminates these possibilities of failure by using a much more robust connection between the pump head and fresh water chamber and by using highly-purified water from the ship's chemistry lab. FLOCS experiments connected to these fast flow deployments were also recovered and processed to examine the potential colonization of different rock substrates (Fig. A13). Due to the pump failure, the Hole U1383C FLOCS experiment did not experience borehole fluids and likely sucked bottom seawater through the colonization chamber.

5.3.5 Deployment of GeoMICROBE Sleds

Huei-Ting Lin, Chih-Chiang Hsieh and Jim Cowen

In this expedition, we deployed two autonomous sensor and fluid sampling systems called GeoMICROBE instrumented sleds (Cowen et al., 2012). The GeoMICROBE system couples with CORK fluid delivery lines to draw large volumes of fluids from crustal aquifers to the seafloor. These fluids are pumped past a series of in-line sensors and an in situ filtration and collection system. The GeoMICROBE's major components include a primary valve manifold system, a positive displacement primary pump, sensors (e.g., fluid flow rate, temperature, dissolved O_2, electrochemistry-voltammetry analyzer), a 48-port in situ filtration and fluid collection system, computerized controller, seven 24 V–40 A batteries and wet-mateable (ODI) communications with submersibles. The two sleds are designed to have identical flotation packages (Fig. A4). A radio beacon and a flasher are attached to the top floatation package.

One GeoMICROBE sled (Sled-3) was deployed in the morning before Dive J2-628. On the seafloor, *Jason* made a wet weight measurement of the sled package (using thruster data) and the weight was ~170 lb, heavier than the estimated weight (Table 5.3). Therefore, all the seven travel weights were removed from the Sled before *Jason* carried the sled to CORK U1382A. After the sled was moved to the CORK U1382A, it was positioned on the platform. The sled itself was observed to be slightly wobbly because the drop weights attached to the bottom of the sled extended beyond the sled frame's base such that the weights, rather than the sled frame itself, rested on the platform. Additional weights were added to the sled to stabilize the sled on the platform. After the Han's connector was attached to the lower valve of zone 2 in the Bio-Bay of the cork (Fig. 5.11), the sensors and communication of the sled were checked from the *Jason* control van via the ODI cables. All the sensors (flow, temperature, O_2 etc.) were functioning properly. This sled will collect fluids from ~50 m below the sediment/basement interface at U1382A.

The second sled (Sled-2) was deployed in the morning before Dive J2-629 near U1383C. Based on the wet weights measured by the *Jason* thruster, this sled was ~120 lb heavier than the estimated weight (Table 5.3). Only two travel weights were removed before transferring the sled to CORK U1383C. Two additional weights were added to the sled after the sled was positioned on the platform of CORK U1383C. This sled is equipped with three Han's connectors and a 3-to-1 manifold valve system for simultaneous connection to three separate CORK fluid delivery lines, so its deployment was more complicated than that of the first sled. Nevertheless, all three connectors were attached to the lower valves of the three different zones on the CORK Bio-Bay in an organized fashion (Fig. 5.12). The deep (zone 1), middle (zone2) and shallow (zone 3) horizons have fluid intakes at 170 m, 130m and 70m, respectively, below the sediment/basement interface. We also checked the sensors and communication of this sled from JASON control van and noticed that the flow sensor indicated zero flow despite the pump running at significant rpm's, suggesting either a dysfunctional flow sensor or no flow passing through the flow sensor. During Dive J2-630, it was determined that the three-to-one solenoid valves on the sled require higher voltage to open. Once higher voltage was applied, the solenoid valve was open, and shimmering water (fresh water used to prime the system) was observed to flow out from the sled's exhaust port. The sled's sampling program was quickly revised to rectify the solenoid valve voltage issue. The revised program was then uploaded to the sled through *Jason* via the ODI connection.

Both sleds are pre-programmed to collect whole fluids in 500mL-Tedlar bags and to collect particles on filters for multiple parameters at a 2 or 3 month interval over the next 18-month period. To preserve samples, some 500mL-Tedlar bags are pre-charged with formaldehyde and all filter holders are pre-charged with either glutaraldehyde or with RNA-Later.

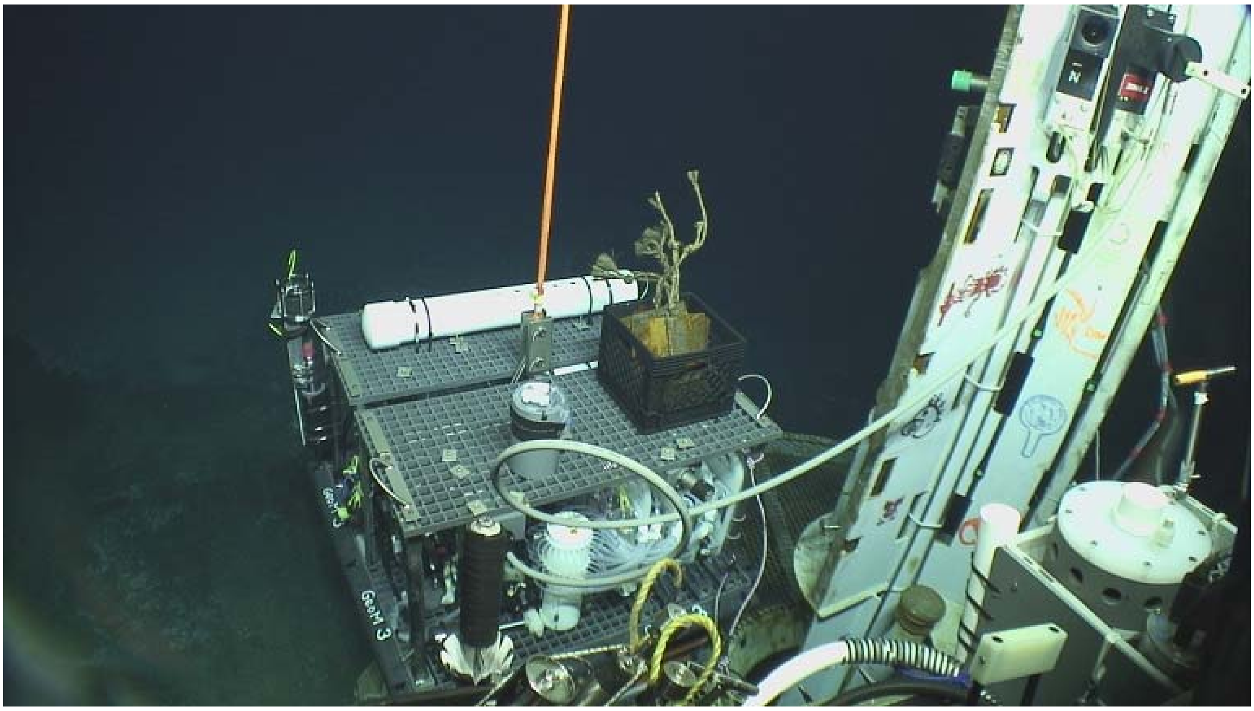


Fig. 5.11 GeoMICROBE Sled connected to CORK U1382A microbial bay; Tefzel fluid delivery line.

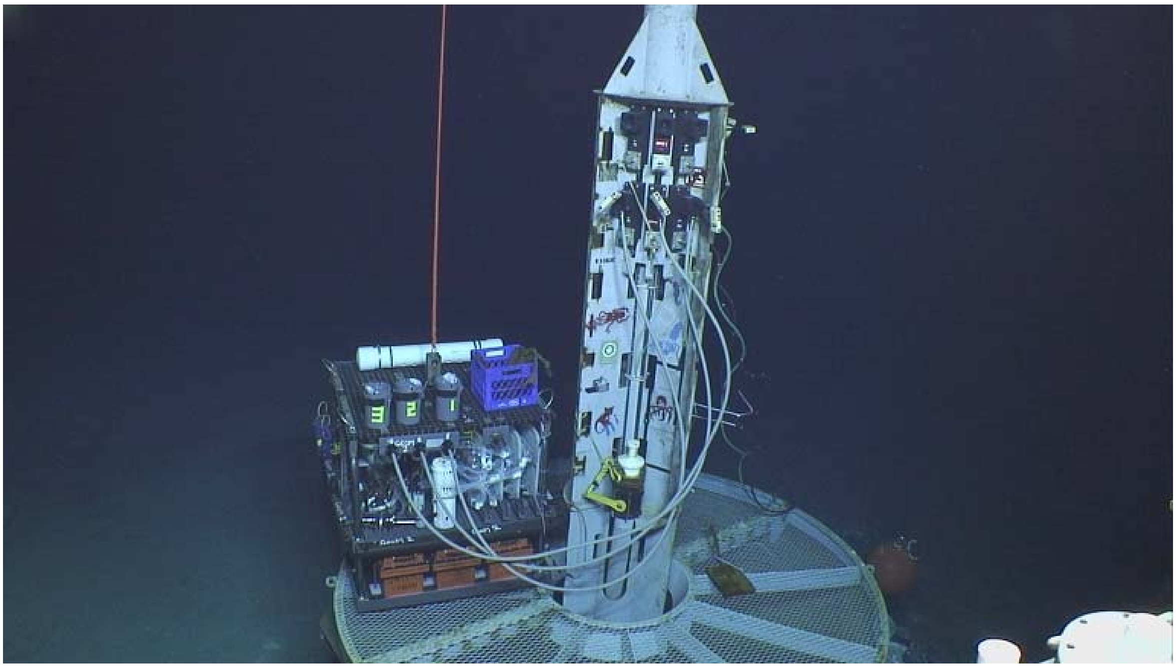


Fig. 5.12 GeoMICROBE Sled connected to CORK U1383C microbial bay. Three umbilicals connect to three Tefzel fluid delivery lines, which extend to deep (170 m), middle (130m) and shallow (70m) horizon.

Table 5.3: Set-up of GeoMICROBE sleds deployed during MSM20/5

Component	Wet Wt ea. (lbs)	# needed (GeoM-2)	# needed (GeoM-3)	GeoM-2 Air	GeoM-2 Wet	GeoM-3 Air	GeoM-3 Wet	Weight date
Non-float components								
sled*	1	variable		1548	**564**	1478	**532**	1/26/2012
5/8" galv anchor shackles w/bolt (9)	1.5	9	9		**13.5**		**13.5**	2/6/2012
3/8" galv anchore shackles (grab float (1)	1	1	1		**1**		**1**	2/6/2012
MetOcean (Novatech) radio beacon	1	2.1	2.1	3.6	**2.1**	3.6	**2.1**	Manuf
MetOcean (Novatech) flasher	1	2.2	2.2	3.7	**2.2**	3.7	**2.2**	Manuf
beacon/flasher frame and hardware	-0.1	2	2		**-0.2**	2	**-0.2**	2/6/2012
Temporary Jason Homers/beacons (**homer air wt. measured; water wt. estimated)		1	1	**12**	**12**	**12**	**12**	
2 shackles & 2 grabe rings (borrowed from Geoff)					**5**			
floatation								
1 3x3 McLane float pack (G8800-3)	1	-190	-190	145	**-190**	145	**-190**	Manuf
two 3x4 Mclane float packs (G6600-3)	2	-254	-254	410	**-508**	410	**-508**	Manuf
Syntactic 'grab' float with eye-bolt	-12	1	1	21	**-12**	21	**-12**	2/6/2012
Tot.l Wgts for Moorings GeoM-2 and GeoM-3 (no Alvin Wts)				2143.3	**-110**	2075.3	**-147**	
Descent (travel) weights	16	4	7		**64**		**112**	
Drop (for ascent) weights	16	9	9		**144**		**144**	
Total Wt of Descending Mooring (original calculation)					**97.6**		**108.6**	
Deployment date		**4/30/2012**	**4/25/2012**					
Wt. measured on seafloor by JASON thursters					**220**		**280**	
Remove some (or all) travel weights	**16**	**2**	**7**		**-32**		**-112**	
Wt. calculated from JASON thrust measurement after removing 'Travel' wts					**188**		**168**	
Add back travel weight	**16**	**2**	**4**		**32**		**64**	
Final Mooring Wt on platform calculated from JASON thrust measurement					**220**		**232**	
Final number of travel weights on sleds on platforms	**16**	**4**	**4**					
Total Wt of Ascending Mooring (all 9 drop weights released and travel weights removed) calculated from JASON measurements					**12**		**24**	
Desired ascent mooring wt					**-100**		**-100**	
Minimum required Additional buoyancy based on JASON thruster measurements					**-112**		**-124**	

*Sleds included: Rabbit controller; ISEA controller; SBE; Flow sensor;2 McLane pumps and2 manifolds; 4 sample trays (no samplers); primary 321 (GeoM-2 only; no umbilicals or Hans connectors on either sled); primary pump; Isea 321; electrode flow cell, Optode; pH sensor; mooring lines (include thimbles and 3 rings; not shackles); titanium "cheek-plate and pin sled shackle"; 7 DSPL batteries; two 3-ft PVC tubes; milk-crate; battery splice box

5.3.6 Water Sampling and in situ measurements

Peter Girguis, Brian Glazer, Chin-Chiang Hsieh, Ulrike Jaekel, Huei-Ting Lin

The purpose of our water sampling efforts was to:

(A) Collect approximately 90 liters of formation fluid from the single horizon at U1382A
(B) Filter *in situ* for POC and RNA/DNA/proteins from the single horizon at U1382A
(C) Collect approximately 90 liters of formation fluid from each of three horizons at U1383C
(D) Filter *in situ* for POC and RNA/DNA/proteins from each of three horizons at U1383C

The formation fluids were collected using the ROV-based mobile pumping system, which is capable of filling 6 x 15L foil lined bags (medium volume bag sampler, MVBS), ~5 x 500mL tedlar bags, and filtering up to two filters *in situ*. Sample processing is described below.

In addition, we collected and processed bottom water recovered via CTD/rosette (see section 5.2.1). These samples were processed in the same manner as the formation fluid.

The GeoMICROBE sleds (Cowen et al., 2012) were configured to collect and fix fluids over the next ~18 months. The sled at U1382A was configured to sample one fluid horizon, while the sled at U1383C was configured to sample three horizons (via a bank of solenoid valves that are actuated to connect each horizon to the sampling line when appropriate).

Prior to the expedition, we collectively decided to prioritize fluid collection from the deepest horizon at U1383C, followed by the shallow horizon at U1383A, then the shallow horizon at U1383C, and lastly the middle horizon at U1383C.

Fluid filtration setup — Two Cole Parmer variable speed Masterflex™ pumps equipped with quick-loading pumpheads and platinized silicone tubing (size 15) were set up in the 4°C coldroom. One end of the silicone tubing was fit with a stiff-wall ¼" O.D., 4" long piece of Teflon tubing, equipped with a JACO compression fitting. The other end of the tubing was equipped with a barb that led to a Luer-lok™ male fitting. The pump tubing was sterilized first with 10% HCl, then rinsed with ship's deionized (DI) water, rinsed again with 70% ethanol, followed by another DI water rinse. The pumps were run at approximately 60% speed.

Mass spectrometry / E-Chem setup — To facilitate rapid analyses of the recovered fluids with minimal perturbation, we assembled the two chemical analyzers onto a continuous flow fluid line. We started with a very short (2") length of ¼" Teflon tubing equipped with JACO fittings to couple to the MVBS. This tubing was quickly adapted to 1/8" PEEK to prevent gas escape. The fluid went into the mass spectrometer membrane inlet, which also has a small stir-bar in it and sat atop an electric stir plate. The fluid went in the front of the inlet and came out the top (to clear bubbles). From here, the fluid went to a PEEK flow cell containing the electrochemical working, reference and counter electrode. After passing through the PEEK flow cell, the fluid went to a small Cole Parmer peristaltic pump, which is what pulled fluid through the line at a rate of 20 mL per minute. The spent water went right to a waste container.

To analyze formation fluid, we turned on the pump and started sucking on the water sampling lines while detecting the concentrations of dissolved gases with the in situ mass spectrometer right away. Voltammetric scans were run during flow, and periodically flow was stopped to collect scans without noise from the peristaltic pump. The pump was then turned back on and the run was continued. We did this for at least 20 minutes per sample.

Dive J2-623 (4/20/2012): Water sampling of the deepest horizon in Hole U1383C commenced at~ 18:30 (UTC) and continued to 20:00 PM. Due to the limited time, we flushed the lines for ~45 minutes, then fired two (orange and blue) gastights and filled all six bags. This left little more than 10 minutes for POC filtration. No 0.2 micron filtering took place during this dive. Glazer logged oxygen data continuously during pumping operations. Upon recovery, one of the six bags broke. Girguis made the decision to prioritize the Huber/Girguis efforts. The Cowen lab was provided with one bag for all their needs. Glazer was provided with about half a bag. From this half a bag, Glazer and Girguis analyzed the fluids for dissolved volatiles and ions using their coupled membrane inlet mass spectrometer and electrochemistry system (as described above) and Glazer subsampled for iron and sulfur speciation, and STXM particle analysis.

Dive J2-628 (4/25/2012): This dive was in part dedicated to fluid sampling of the single horizon in Hole U1382A. We flushed the lines, fired off an orange and black gastight and filled all six bags, did a POC filtration for about 20 minutes before it showed signs of occlusion (completed about 8L of water through the filter). We observed that O_2 concentrations in the line (while flushing) were significantly lower than the formation fluid. We then collected the GeoMicrobe sled (which appears to be 200 lbs over weight) and successfully deployed it at Hole U1382A.

Dive J2-629 (4/26/2012): Re-sampling the deep horizon in Hole U1383C included filling all six MVBS bags and some small bags with formation fluids. During this effort, we again observed that O_2 was significantly lower in the line than the formation fluid, only this time we collected that fluid in bags (see below). We did a POC filter from the deep horizon, but no RNA filter. We next sampled the middle horizon entirely in small bags and did a POC Filter as well as an RNA filter. On deck, we processed all the deep horizon water following the plan laid out before the cruise. We also froze water for geochemical analyses back home (frozen in serum vials, up to three per horizon).

We did not do any shipboard filtration of the mid horizon water, given its modest volumes. Only smaller volumes (up to 200ml) were filtered onto GTTP filters for later microbial community analysis by CARD-FISH. Small volumes (up to 60ml in total) were preserved for cell counts and single cell genomics. We did, as mentioned, freeze for geochem and since this is unfiltered water, it should be amenable to DNA Extraction to look at the diversity at the very least. Also for the mid horizon, we froze putative low O_2 water, as well as formation fluid water, for comparison.

We have both mass spectrometer and electrochemical data from the deep horizon fluids as well as one of these small, “low O_2” bag samples.

Dive J2-630 (4/27/2012): This was a dedicated water collection dive. We went to U1383C and began by filling the large bags with deep horizon fluid and the small bags with mid horizon fluid again. We also did in situ POC and RNA filtration from BOTH horizons during this dive.

It should be noted that the volumes filtered *in situ* were in the range of 5L, but varied among sites because of the particulate load. By watching the pump current draw as an indicator of load, we filtered as much water as practical, without damaging pump or membrane, or bursting tubing etc. The Jason virtual van log has notes on how much water was filtered and for how long, etc.
On board ship, sample of the deep horizon were recovered. Water samples were provided for E-chem, iron and sulfur speciation, and STXM particle analysis. Mid-level water was frozen for geochemical and microbiological work back in the home labs, and about 1L of the "low oxygen water" from the middle horizon was saved for rate measurement studies. We ran both mass spec and e-chem on both deep and mid horizons. The rest of the water was pumped into our storage vessel (a stainless steel fermentation reactor).

5.3.7 Sediment Sampling

Beth Orcutt

Surface sediments from within and around North Pond were collected using ~40 cm length, 7cm diameter PVC push cores from the *ROV Jason II*. At each sampling location, 2-4 cores were collected from within a 50cm radius, and often in the immediate vicinity of a heat flow probe measurement. Prior to deployment, push cores were primed with a dilute bleach solution in freshwater. Shipboard, cores were processed in an environmental control room kept at roughly 3^{o}C. Typically, one core was used for oxygen profile measurements (made with a PreSens oxygen optode) and then subsequent sectioning for samples for porosity, total organic carbon, DNA, and cell count analyses. Another replicate core was used for the collection of porewater using Rhizon samplers. Additional cores were preserved for shore based recalcitrant carbon and DNA analyses.

A total of 36 push cores were collected during the cruise (Fig. 5.13, Table A1), although a few were lost due to complications with the core liners. A total of 30 porewater samples were collected for major and minor ion analyses (Table A2).

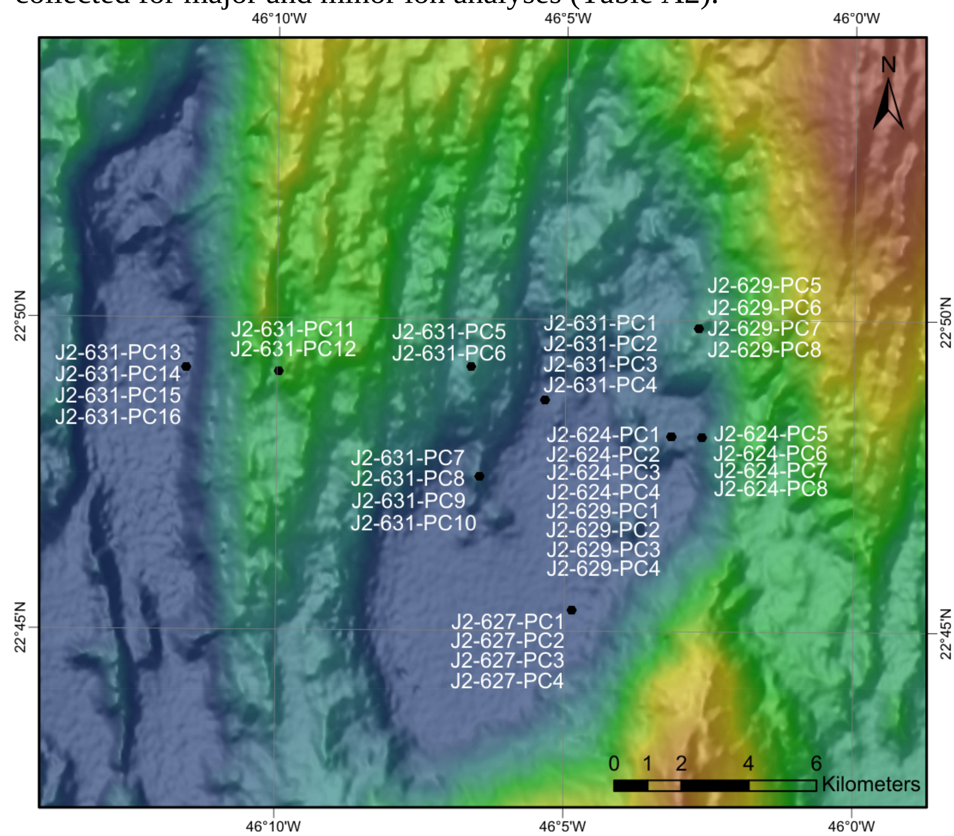


Fig. 5.13 Locations of sediment psuh core samples collected during cruise MSM20/5

5.3.8 Hard Rock Sampling and Rock Descriptions

Wolfgang Bach

Hard rock samples were collected during five dives (624, 626, 627,629, and 631) and comprise basalt, dolerite and mantle peridotite (Table A3). A detailed rock description is presented in Table A4. Dives 624 and 626 recovered rocks from very steeply dipping slopes that form the eastern border of North Pond at a latitude of 22°48.1'N. The outcrops are situated mid-slope and they have a highly jointed and clastic appearance. Parts of the outcrop appear breccia-like (talus?), other parts expose more massive rock that is strongly jointed (Fig. 5.14). Samples collected are basalt, dolerite, and breccia. The difference between the basalt and dolerites is gradual, none of the basalts are glassy or aphanitic. Both rock types are variably plagioclase-olivine±clinopyroxene phyric.

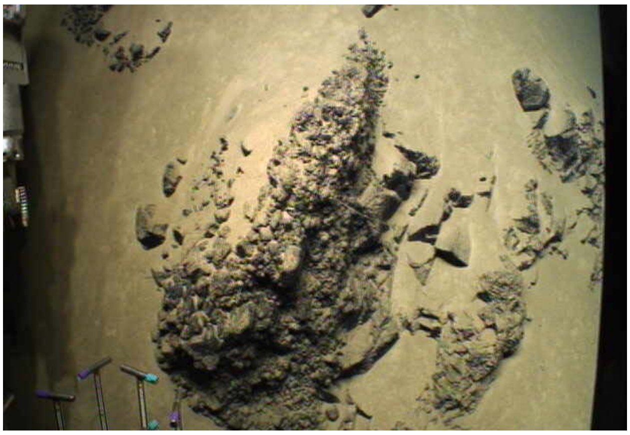


Fig. 5.14 Outcrop from which J2-624 samples were collected

One possible interpretation is that the dolerites represent exposed footwall of the master fault along which North Pond was down-faulted. The breccias may represent rafted parts of the fault zone itself, composed predominantly of cataclastized rock from the hanging wall.

Rocks from a very steeply dipping slope ESE of Site U1382 were sampled during dive 627. The slope is heavily sedimented and the sediment surface is scarred with minute erosional canyons, the floors of which are littered with rock debris (Fig. 5.15). All rock samples collected here are talus of serpentinized mantle peridotite with a minor norite dikelet. It is likely that similar rocks crop out further up the slope (additional 50-100 m of elevation change from sampling sites to top of slope). The source of rock debris can only be the N-S- trending ridge that sits on top of the pronounced dome, which forms the southern border of North Pond. Our sampling establishes the ultramafic nature of that ridge.

Fig. 5.15 Outcrop from which sample J2-627-R3 was recovered

The track of Dive 629 Samples took us up a steep, west-facing slope, 2 km north of Site U1383 and near the gravity core station GeoB 13504 of MSM cruise 11/1. Exposed is a small headwall of clayey ooze with minor Mn-oxide coating (sample J2-629-R1). Outcrops of thickly Mn-oxide crusted basalt are also present. Sampling there was very difficult. Samples are strongly weathered and the outcrop is probably an old untectonized flow front. Occurrences of solitary rocks can be found on the lower reached of the slope. It is unlear weather these occurences are outcrops of intact lava flows or talus. Basalts are noticeably more vesicular and finer grained than the basalts sampled before. This textural difference in addition to the results of the bathymetry measurements indicate that the sampled feature is probably a flow front.

Samples are from a steep west-facing slope, 2 km north of Site U1383 and near the gravity core station GeoB 13504 of MSM cruise 11/1. Exposed are a small headwall of clayey ooze with minor Mn-oxide coating (Fig. 5.16). Outcrops of thickly Mn-oxide crusted basalt are also present (Fig. 5.17). Sampling there was very difficult. Samples are strongly weathered and the outcrop is probably an old untectonized flow front. Occurrences of solitary rocks can be found on the lower reached of the slope. It is unclear whether these occurrences are outcrops of intact lava flows or talus.

Fig. 5.16 Outcrop from which sample J2-629-R1 was recovered

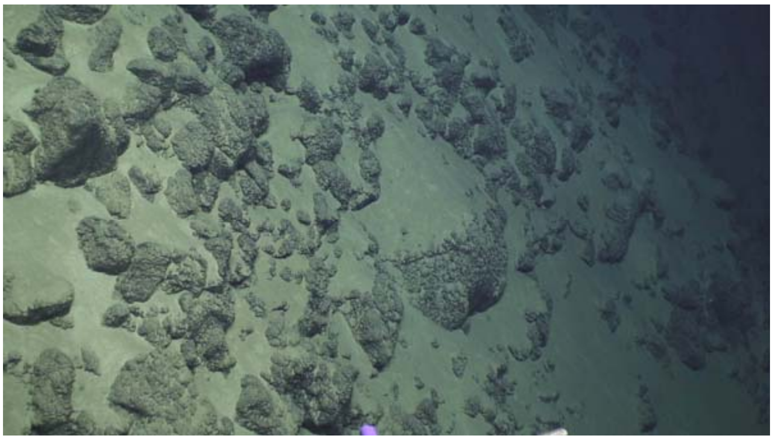


Fig. 5.17 Outcrop from which sample J2-629-R2 was recovered

Outcrops sampled during dive 631 in the NW of North Pond are on steep slopes and expose pillow and lobate lava (Figs. 5.18 and 5.19). There is little evidence for faulting and talus fans, bar the occasional truncated pillow tube. Overall, the outcrops appear to be steep flow fronts exposing numerous intact pillows and lava tubes. Some of the steeper scarpes may represent the headwalls of normal fault. Still, they are now draped with flows. Two of four samples have glassy rinds, which was not observed in any samples from the slopes E and SE of North Pond.

Fig. 5.18 Outcrop from which sample J2-631-R1 was taken

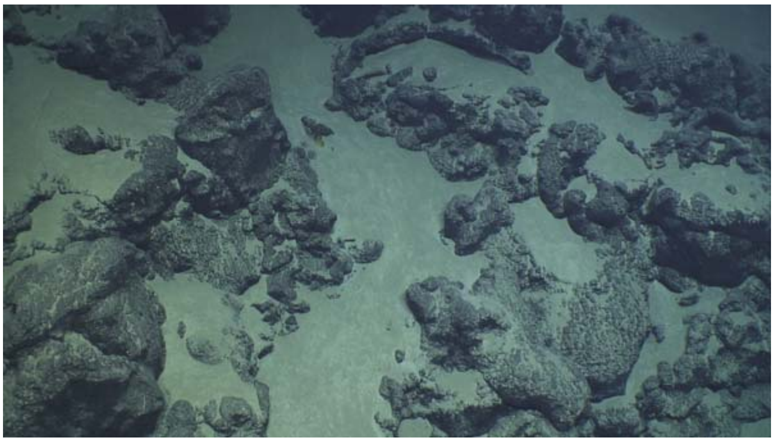


Fig. 5.19 Outcrop from which samples J2-631-R3 and R4 were taken

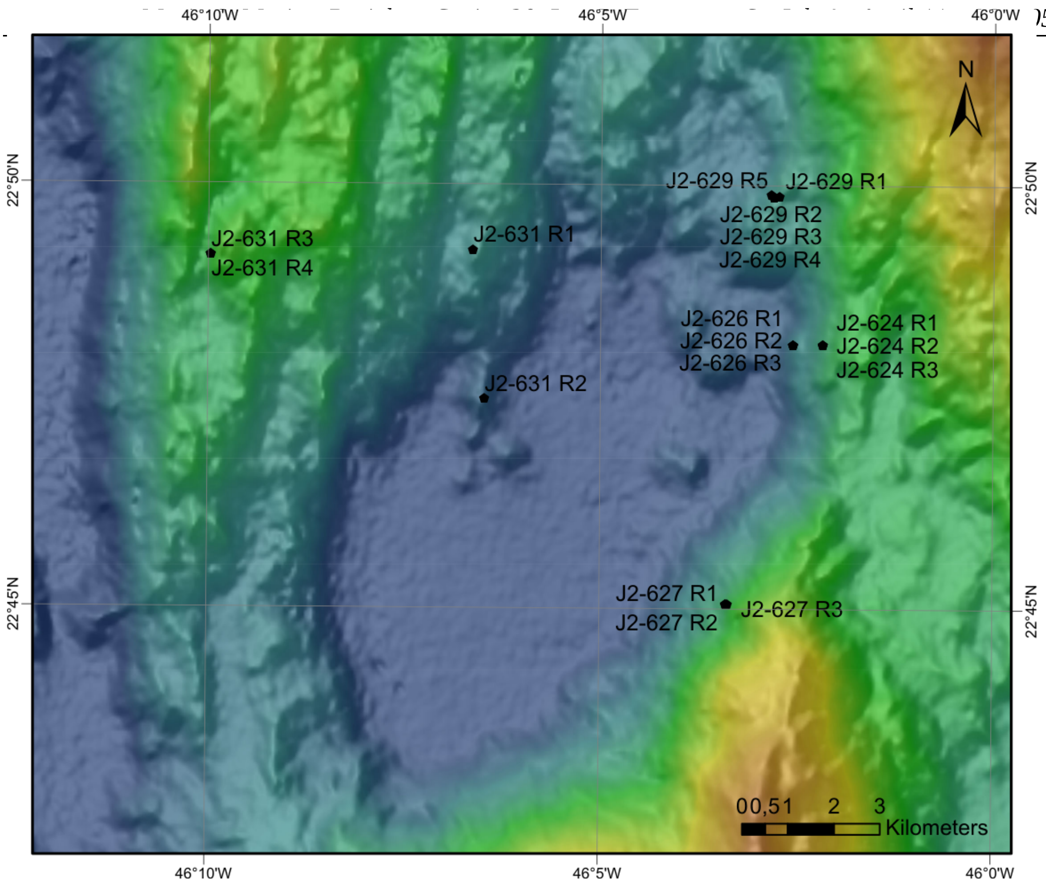


Fig. 5.20 Map of North Pond showing the locations of rock samples

5.3.9 Heat flow

Heiner Villinger

Heatflow measurements during MSM 20/5 were made with the WHOI ROV Heatflow Probe mostly in conjunction with taking push cores. Most of the measurements were made during Jason Dive 631 which was a long transect from the western boundary of North Pond over a ridge into Long Pond (see Fig. 5.21 and Table 5.4). Due to the soft sediments the 60cm long heatflow probe could always be completely pushed into the sediment.

The WHOI Heatflow Probe consists of a titanium rod which houses 5 equally spaced temperature sensors (thermistors) and a heating wire for in situ thermal conductivity measurements and attached pressure housing for the electronics. Data are transmitted in realtime to the ship via a serial interface. Online data (resistances and temperatures) are logged to the Jason data base with a sampling interval of 0.5 s. Unfortunately temperatures are rounded off to 0.01°C by which we lose the necessary resolution needed especially in the case of low heatflow i.e. small temperature differences over the whole length of the probe. Therefore temperatures were recalculated with a resolution of 0.001°C using the stored resistances.

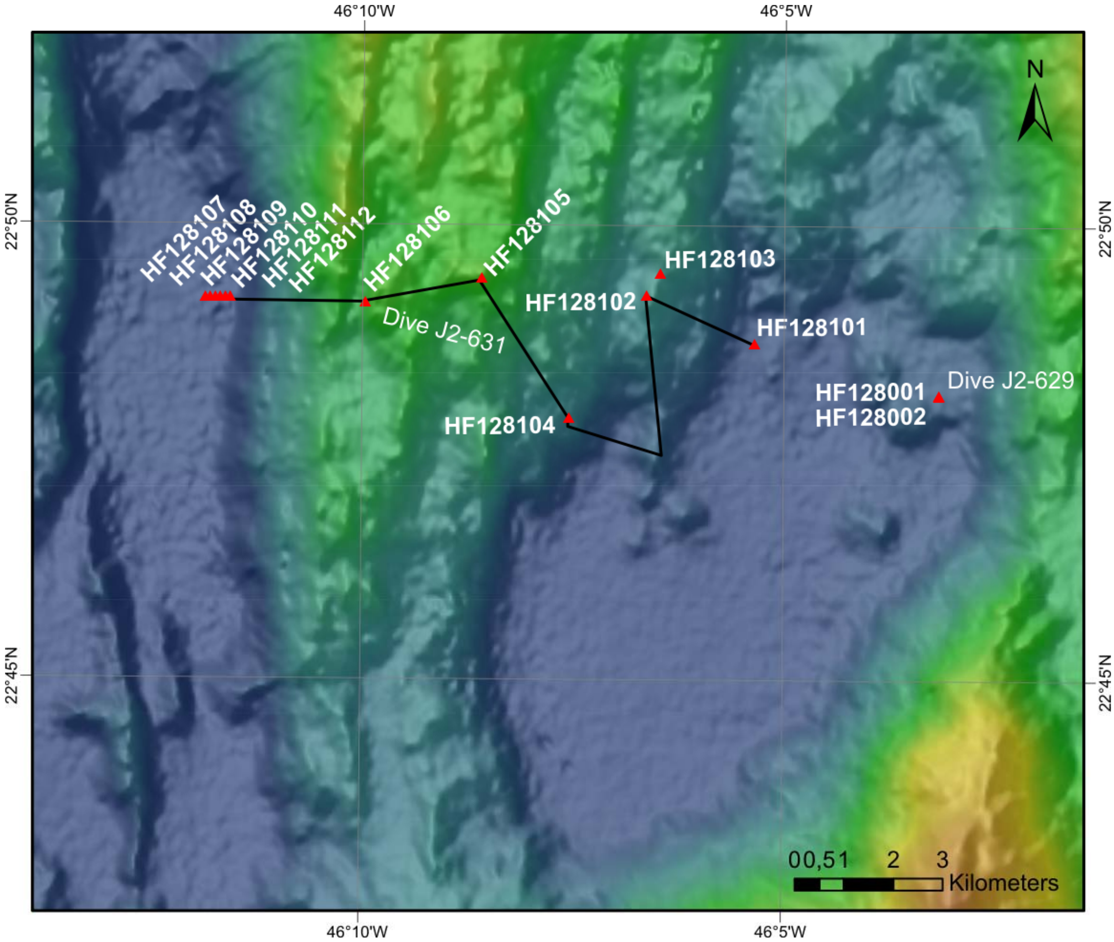


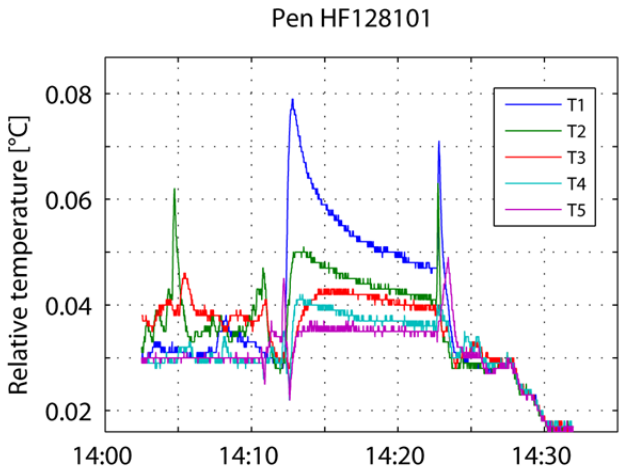
Fig. 5.21 Map of North Pond showing the locations of heat flow stations

We used exclusively a 0.6m long probe with a temperature sensor spacing of 0.1m. No in situ thermal conductivity measurements were made as numerous measurements from MSM 11/1 (Schmidt-Schierhorn et al., 2012) show that sediments in North Pond have a very uniform thermal conductivity of 0.97 W/mK.

Temperature measurements were preliminary processed on board by extrapolating the decay to in situ temperatures by using a simple 1/time method. Values on the western boundary of North Pond confirm the high heatflow values previously found by conventional seafloor heatflow measurements (Langseth et al., 1992; Schmidt-Schierhorn et al., 2012) but also confirm the high local variability. Figure 5.22 shows that the temperature measurements with the WHOI heatflow probe have sufficient resolution to measure small temperature gradients provided that the temperature resolution has been increased to 0.001K after the recalculation based on resistances. The fact that the temperature of the uppermost sensor is significantly higher than expected from the gradient may be due to the fact that the CORK seafloor temperatures show an increase in bottom water temperatures by about 0.02°C since the installation of the CORKs in November 2011. Close to this low heatflow site we measured a very high value approaching almost 1000 mW/m² (see Fig. 5.23). This high value may be an indication of diffusive outflow at close by outcrops.

Table 5.4: Locations of heat flow measurements during MSM20-5

Penetration	Depth	Date	Time		Latitude		Longitude	
			Start	End	North		West	
	(m)		(UTC)	(UTC)	DD	MM	DD	MM
			Dive J2-629					
HF128001	4412	29.04.2012	15:14:00	15:24:00	22	48.1326	46	3.1601
HF128002	4412	30.04.2012	02:31:00	02:40:00	22	48.1384	46	3.1596
			Dive 631					
HF128101	4457	02.05.2012	14:12:30	14:22:00	22	48.7098	46	5.3507
HF128102	4136	02.05.2012	18:08:00	18:21:00	22	49.2289	46	6.6331
HF128103	4365	02.05.2012	23:02:00	23:16:30	22	49.4711	46	6.4742
HF128104	4207	03.05.2012	03:15:00	03:25:30	22	47.8863	46	7.5450
HF128105	3708	03.05.2012	08:09:00	08:20:00	22	49.4207	46	8.5865
HF128106	3852	03.05.2012	14:05:00	14:15:30	22	49.1482	46	9.9684
HF128107	4685	03.05.2012	19:09:30	19:18:30	22	49.1916	46	11.8636
HF128108	4684	03.05.2012	19:36:00	19:44:30	22	49.1916	46	11.8045
HF128109	4684	03.05.2012	20:00:00	20:08:00	22	49.1914	46	11.7462
HF128110	4684	03.05.2012	20:25:00	20:34:00	22	49.1960	46	11.6867
HF128111	4684	03.05.2012	20:51:00	20:59:00	22	49.1958	46	11.6267
HF128112	4684	03.05.2012	21:17:00	21:29:00	22	49.1955	46	11.5679



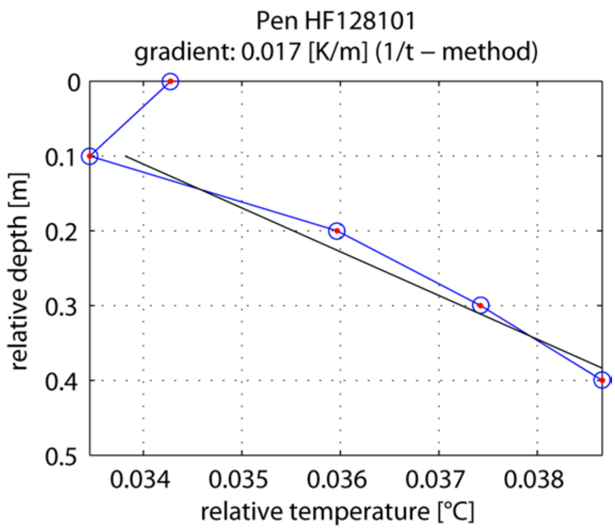


Fig. 5.22 Example of a heatflow measurement with a low heatflow of about 17 mW/m²

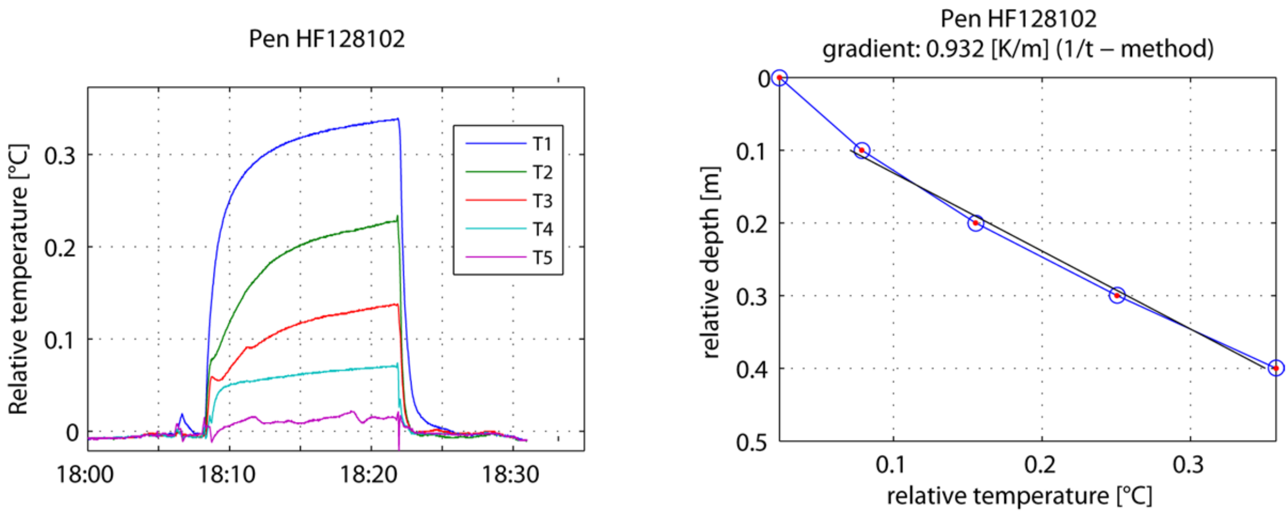


Fig. 5.23 Example of a very high heat flow measurement with of about 932 mW/m²

5.3.10 ROV MULTIBEAM Survey

Sam Hulme

A Reson 7K 400khz multibeam sonar was mounted on *Jason* for lowering 631 in order to conduct detailed mapping transects in the northwestern area of North Pond. A set of 7 waypoints was picked based on locations of interest for rock and sediment sampling and heat-flow measurements. The intention was to drive the ship at 0.7 knots from one waypoint to the next while *Jason* drove behind the ship at an altitude of 80m. There was no USBL navigation for the survey, so the vehicle position was calibrated at each waypoint when *Medea* was hanging directly below the ship. The shipboard GPS coordinates were used as a reference position for the Doppler navigation system on board *Jason*. Notes were made throughout the entire survey on times of temporary losses of Doppler navigation due to steep slopes or irregular terrain. Due to incomplete navigation records, extensive processing of the data will be necessary in order to co-align transect starting and end points as well as georeference the survey with existing bathymetric maps of the region. During the survey, the Reson Multibeam was able to detect differences in surface roughness that indicated the presence or absence of outcrops and notes were made of the time and depth of zones of potential outcrops.

The first waypoint was at Hole 1384A, a sediment coring site from IODP Leg 336 where surface sediments were needed to complete the oxygen profile of the site. Waypoint 2 was a local high located 2.3 km WNW along a north-trending ridge above the pond. Waypoint 3 was located back in the pond 3.3 km to the south, which enabled mapping to be conducted along the ridge.

Upon reaching waypoint 3, the Reson signature indicated an outcrop was present below the vehicle, and this was confirmed when the vehicle descended to the seafloor. The next transect was 1.8 km WNW across the pond basin to a location on the slope surrounding the pond. While the Reson indicated the presence of an outcrop towards the base of this slope, the area surrounding the waypoint where Jason descended was completely sedimented.

The next transect continued upslope 3.5 km to the NW along a ridge crest. Many outcrops were apparent in the Reson data along this transect, and were visually confirmed in the ROV camera at a depth of 4025m on a very steep scarp. An extensive outcrop was found to the east of waypoint 5, but attempts to sample it were unsuccessful due to the friable nature of the material. The next two transects were 2.3 and 3.3 km in a westerly direction. The first one went from one local high to another at a similar water depth and stopping before descending the steep slope into another sediment pond west of North Pond. The microbathymetry recorded during Dive 631 is depicted in Fig. 5.24.

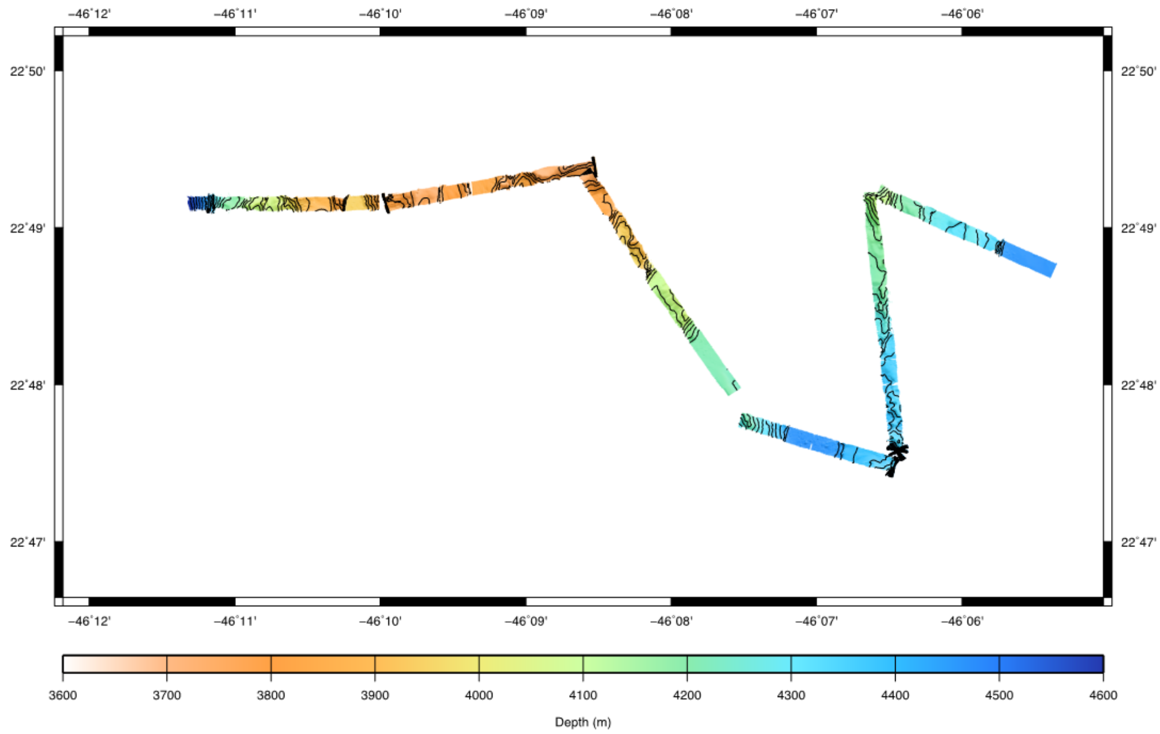


Fig. 5.24 Jason-based microbathymetry recorded during dive 631

6 Ship’s Meteorological Station

There was no meteorologist on board during the cruise.

7 Station List MSM20/5

Station No.	Date	Gear	Time	Latitude	Longitude	Depth	Remarks/Recovery
	2012		[UTC]	[x°y.z'N]	[x°y.z'W]	[m]	
MSM20/175-1	20-Apr	CTD/RO	3:52	22° 47.00	46° 04.00	4448.5	surface
MSM20/175-1	20-Apr	CTD/RO	5:28	22° 47.00	46° 04.00	4447.2	at depth
MSM20/175-1	20-Apr	CTD/RO	7:05	22° 47.00	46° 04.00	4451.3	on deck
MSM20/175-2	20-Apr	ELEV	9:40	22° 48.12	46° 03.16	4407.3	elevator in water
MSM20/175-2	20-Apr	ELEV	9:42	22° 48.12	46° 03.16	4407.3	elevator released
MSM20/175-3	20-Apr	ROV	10:44	22° 48.12	46° 03.16	4407.3	ROV in water (J2-623)
MSM20/175-3	20-Apr	ROV	10:52	22° 48.12	46° 03.17	4410.4	MEDEA in water
MSM20/175-3	20-Apr	ROV	13:26	22° 48.11	46° 03.17	4422.3	at depth
MSM20/175-3	20-Apr	ROV	19:35	22° 48.11	46° 03.17	4422.3	off bottom
MSM20/175-2	20-Apr	ELEV	20:07	22° 48.07	46° 03.09	4422.4	elevator released
MSM20/175-2	20-Apr	ELEV	21:50	22° 48.04	46° 03.07	4425.7	elevator sighted
MSM20/175-3	20-Apr	ROV	22:40	22° 48.06	46° 03.04	4428.1	MEDEA on deck
MSM20/175-3	20-Apr	ROV	22:47	22° 48.06	46° 03.04	4431.7	ROV on deck (end of dive)
MSM20/175-2	20-Apr	ELEV	23:30	22° 49.60	46° 03.12	4236.7	on board
MSM20/176-1	21-Apr	MB+PS	0:29	22° 47.36	45° 57.64	3835.1	start profil
MSM20/176-1	21-Apr	MB+PS	2:18	22° 47.31	46° 13.33	4677.3	profile end
MSM20/176-1	21-Apr	MB+PS	2:37	22° 48.67	46° 13.30	4686.7	start profil
MSM20/176-1	21-Apr	MB+PS	4:26	22° 48.66	45° 57.61	3753.3	profile end
MSM20/176-1	21-Apr	MB+PS	4:44	22° 50.00	45° 57.50	3618.5	start profil
MSM20/176-1	21-Apr	MB+PS	6:34	22° 49.99	46° 13.31	4565.3	profile end
MSM20/176-1	21-Apr	MB+PS	6:51	22° 51.30	46° 13.45	4462.3	start profil
MSM20/176-1	21-Apr	MB+PS	8:08	22° 51.33	46° 02.37	3892.7	profile end
MSM20/177-1	21-Apr	ROV	9:03	22° 48.12	46° 03.16	4421.3	CORK in water
MSM20/177-1	21-Apr	ROV	9:21	22° 48.12	46° 03.16	4422.1	CORK released
MSM20/177-1	21-Apr	ROV	10:47	22° 48.13	46° 03.13	4423.1	ROV in water (dive J2-624)
MSM20/177-1	21-Apr	ROV	10:50	22° 48.14	46° 03.12	4423.1	MEDEA in water
MSM20/177-1	21-Apr	ROV	13:38	22° 48.13	46° 03.13	4421.9	at depth
MSM20/177-1	21-Apr	ROV	20:37	22° 48.09	46° 03.14	4418.8	start rising to the surface
MSM20/177-1	21-Apr	ROV	20:37	22° 48.09	46° 03.14	4418.8	floats released
MSM20/177-1	21-Apr	ROV	21:18	22° 47.99	46° 03.13	4424.2	floats sighted
MSM20/177-1	21-Apr	ROV	23:05	22° 48.02	46° 03.13	4423.9	MEDEA on deck
MSM20/177-1	21-Apr	ROV	23:16	22° 48.02	46° 03.13	4423.9	ROV on deck (end of dive)
MSM20/177-1	22-Apr	ROV	0:00	22° 50.63	46° 03.44	4316.8	floats recovered
MSM20/178-1	22-Apr	MB+PS	0:53	22° 44.97	45° 58.22	4015.2	start profil
MSM20/178-1	22-Apr	MB+PS	3:08	22° 44.93	46° 12.81	4462.5	profile end
MSM20/178-1	22-Apr	MB+PS	3:32	22° 43.40	46° 12.98	4531.9	start profil
MSM20/178-1	22-Apr	MB+PS	5:49	22° 43.40	45° 58.27	4055.5	profile end
MSM20/178-1	22-Apr	MB+PS	6:14	22° 41.92	45° 58.18	4077.3	start profil
MSM20/178-1	22-Apr	MB+PS	8:32	22° 41.86	46° 12.87	4455.4	profile end
MSM20/179-1	22-Apr	ROV	9:48	22° 45.35	46° 04.90	4489.9	Osmo sampler in water
MSM20/179-1	22-Apr	ROV	9:50	22° 45.35	46° 04.90	4490.2	Osmo sampler released
MSM20/179-1	22-Apr	ROV	11:07	22° 45.35	46° 04.90	4488.9	ROV in water (dive J2-625)
MSM20/179-1	22-Apr	ROV	11:11	22° 45.35	46° 04.90	4489.6	MEDEA in water
MSM20/179-1	22-Apr	ROV	11:54	22° 45.43	46° 04.88	4493.6	at depth
MSM20/179-1	22-Apr	ROV	20:04	22° 45.37	46° 04.92	4490.8	off bottom
MSM20/179-1	22-Apr	ROV	22:33	22° 45.48	46° 05.43	4495.7	MEDEA on deck
MSM20/179-1	22-Apr	ROV	22:44	22° 45.47	46° 05.46	4493	ROV on deck (end of dive)
MSM20/180-1	22-Apr	MB+PS	23:51	22° 40.38	45° 58.22	4087.5	start profil
MSM20/180-1	23-Apr	MB+PS	2:08	22° 40.33	46° 12.81	4530	profile end
MSM20/180-1	23-Apr	MB+PS	2:32	22° 38.95	46° 12.83	4490.3	start profil
MSM20/180-1	23-Apr	MB+PS	4:47	22° 38.96	45° 58.27	3969.5	profile end
MSM20/180-1	23-Apr	MB+PS	5:12	22° 37.47	45° 58.23	3971.1	start profil
MSM20/180-1	23-Apr	MB+PS	7:27	22° 37.43	46° 12.78	4283.8	profile end
MSM20/181-1	23-Apr	ROV	8:45	22° 48.20	46° 03.12	4423.1	borehole osmo package in water
MSM20/181-1	23-Apr	ROV	9:13	22° 48.13	46° 03.16	4420	borehole osmo package released

Station No.	Date	Gear	Time	Latitude	Longitude	Depth	Remarks/Recovery
	2012		[UTC]	[x°y.z'N]	[x°y.z'W]	[m]	
MSM20/181-1	23-Apr	ROV	10:41	22° 48.13	46° 02.15	4008.6	ROV in water (dive J2-626)
MSM20/181-1	23-Apr	ROV	10:44	22° 48.13	46° 02.15	3999.5	MEDEA in water
MSM20/181-1	23-Apr	ROV	13:10	22° 48.13	46° 02.15	4021.1	at depth
MSM20/181-1	23-Apr	ROV	19:16	22° 48.12	46° 03.18	4419.3	floates released
MSM20/181-1	23-Apr	ROV	19:24	22° 48.12	46° 03.18	4420.3	off bottom
MSM20/181-1	23-Apr	ROV	20:03	22° 48.12	46° 03.30	4421.1	floats sighted
MSM20/181-1	23-Apr	ROV	21:58	22° 47.80	46° 03.30	4445.7	MEDEA on deck
MSM20/181-1	23-Apr	ROV	22:06	22° 47.81	46° 03.30	4459.4	ROV on deck (end of dive)
MSM20/181-1	23-Apr	ROV	23:07	22° 50.86	46° 03.60	4304.0	floats retrieved
MSM20/182-1	23-Apr	MB+PS	23:40	22° 52.33	46° 01.50	3542.7	start profil
MSM20/182-1	24-Apr	MB+PS	0:12	22° 52.34	45° 58.06	3031.9	profile end
MSM20/182-1	24-Apr	MB+PS	0:41	22° 53.97	45° 57.89	3060.2	start profil
MSM20/182-1	24-Apr	MB+PS	3:08	22° 53.95	46° 13.76	4120.1	profile end
MSM20/182-1	24-Apr	MB+PS	3:36	22° 55.59	46° 13.73	3780.7	start profil
MSM20/182-1	24-Apr	MB+PS	6:03	22° 55.56	45° 57.88	3109.2	profile end
MSM20/182-1	24-Apr	MB+PS	6:30	22° 57.20	45° 57.96	3293.8	start profil
MSM20/182-1	24-Apr	MB+PS	7:40	22° 57.18	46° 05.53	3375.8	profile end
MSM20/183-1	24-Apr	ROV	9:12	22° 45.35	46° 04.86	4490.1	floats&weights released
MSM20/183-1	24-Apr	ROV	9:20	22° 45.35	46° 04.86	4490.7	Information
MSM20/183-1	24-Apr	ROV	10:36	22° 45.10	46° 03.50	4076.3	ROV in water (dive J2-627)
MSM20/183-1	24-Apr	ROV	10:39	22° 45.10	46° 03.50	4075.9	MEDEA in water
MSM20/183-1	24-Apr	ROV	13:05	22° 45.10	46° 03.50	4076.2	at depth
MSM20/183-1	24-Apr	ROV	19:20	22° 45.35	46° 04.92	4491.1	floats released
MSM20/183-1	24-Apr	ROV	19:39	22° 45.35	46° 04.92	4491.0	off bottom
MSM20/183-1	24-Apr	ROV	19:56	22° 45.35	46° 05.13	4491.0	floats sighted
MSM20/183-1	24-Apr	ROV	21:50	22° 45.35	46° 05.13	4492.3	MEDEA on deck
MSM20/183-1	24-Apr	ROV	22:02	22° 45.35	46° 05.12	4491.1	ROV on deck
MSM20/183-1	24-Apr	ROV	22:53	22° 45.76	46° 03.10	4135.5	floats retrieved
MSM20/184-1	25-Apr	MB+PS	0:36	22° 35.38	46° 12.90	3850.7	start profil
MSM20/184-1	25-Apr	MB+PS	2:53	22° 35.34	45° 58.17	3937.9	profile end
MSM20/184-1	25-Apr	MB+PS	3:22	22° 33.63	45° 58.26	3888.3	start profil
MSM20/184-1	25-Apr	MB+PS	5:31	22° 33.60	46° 13.70	3605.1	profile end
MSM20/184-1	25-Apr	MB+PS	5:47	22° 34.17	46° 14.54	3808.8	start profil
MSM20/184-1	25-Apr	MB+PS	7:45	22° 49.84	46° 14.59	4359.9	profile end
MSM20/185-1	25-Apr	SLED	8:53	22° 45.34	46° 04.88	4488.7	GEOMICROBE sled in water
MSM20/185-1	25-Apr	SLED	9:04	22° 45.35	46° 04.89	4492.3	GEOMICROBE sled released
MSM20/185-2	25-Apr	ROV	10:34	22° 45.35	46° 04.89	4492.1	ROV in water (dive J2-628)
MSM20/185-2	25-Apr	ROV	10:38	22° 45.35	46° 04.89	4491.5	MEDEA in water
MSM20/185-2	25-Apr	ROV	13:17	22° 45.38	46° 04.80	4495.6	at depth
MSM20/185-1	25-Apr	ELEV	20:00	22° 45.39	46° 04.85	4495.2	floats released
MSM20/185-2	25-Apr	ROV	20:29	22° 45.38	46° 04.84	4494.0	off bottom
MSM20/185-1	25-Apr	ELEV	22:05	22° 45.43	46° 04.74	4491.9	floats sighted
MSM20/185-2	25-Apr	ROV	22:45	22° 45.48	46° 04.66	4487.1	MEDEA on deck
MSM20/185-2	25-Apr	ROV	22:53	22° 45.50	46° 04.61	4486.0	ROV on deck (end of dive)
MSM20/185-1	25-Apr	ELEV	23:05	22° 45.47	46° 04.37	4476.0	floats retrieved
MSM20/186-1	26-Apr	MB+PS	0:56	22° 31.47	46° 16.07	4066.9	start profil
MSM20/186-1	26-Apr	MB+PS	5:11	22° 31.39	45° 43.90	3451.2	profile end
MSM20/186-1	26-Apr	MB+PS	5:37	22° 33.57	45° 43.82	3758.6	start profil
MSM20/186-1	26-Apr	MB+PS	7:14	22° 33.55	45° 57.77	3778.7	profile end
MSM20/187-1	26-Apr	ROV	8:58	22° 48.12	46° 03.17	4416.8	Osmo sampler in water
MSM20/187-1	26-Apr	ROV	8:59	22° 48.12	46° 03.17	4418.3	Osmo sampler released
MSM20/187-1	26-Apr	ROV	14:30	22° 48.12	46° 03.17	4418.1	Dive abandoned
MSM20/187-2	26-Apr	CTD/RO	15:05	22° 48.12	46° 03.17	4416.5	surface
MSM20/187-2	26-Apr	CTD/RO	16:27	22° 48.12	46° 03.17	4417.1	at depth
MSM20/187-2	26-Apr	CTD/RO	17:51	22° 48.12	46° 03.17	4420.0	on deck
MSM20/188-1	26-Apr	MB+PS	20:25	22° 35.47	45° 58.05	3950.6	start profil
MSM20/188-1	26-Apr	MB+PS	22:45	22° 36.40	45° 42.89	3630.6	profile end

Station No.	Date	Gear	Time	Latitude	Longitude	Depth	Remarks/Recovery
	2012		[UTC]	[x°y.z'N]	[x°y.z'W]	[m]	
MSM20/188-1	26-Apr	MB+PS	23:00	22° 37.30	45° 43.90	3531.3	start profil
MSM20/188-1	27-Apr	MB+PS	2:25	22° 57.76	45° 43.91	2997.9	profile end
MSM20/188-1	27-Apr	MB+PS	2:49	22° 57.94	45° 45.54	2982.1	start profil
MSM20/188-1	27-Apr	MB+PS	6:17	22° 37.31	45° 45.54	3570.5	profile end
MSM20/188-1	27-Apr	MB+PS	6:36	22° 37.23	45° 47.13	3223.3	start profil
MSM20/188-1	27-Apr	MB+PS	10:01	22° 57.80	45° 47.21	3320.8	profile end
MSM20/188-1	27-Apr	MB+PS	10:26	22° 57.91	45° 48.84	2997.3	start profil
MSM20/188-1	27-Apr	MB+PS	13:54	22° 37.30	45° 48.82	3680.0	profile end
MSM20/188-1	27-Apr	MB+PS	14:19	22° 37.21	45° 50.67	3412.6	start profil
MSM20/188-1	27-Apr	MB+PS	17:47	22° 57.84	45° 50.69	3501.5	profile end
MSM20/188-1	27-Apr	MB+PS	18:15	22° 57.90	45° 52.71	3421.6	start profil
MSM20/188-1	27-Apr	MB+PS	21:42	22° 37.34	45° 52.74	3765.1	profile end
MSM20/188-1	27-Apr	MB+PS	22:07	22° 37.25	45° 54.64	3774.7	start profil
MSM20/188-1	28-Apr	MB+PS	1:36	22° 57.83	45° 54.68	3513.9	profile end
MSM20/188-1	28-Apr	MB+PS	1:46	22° 58.58	45° 54.57	3506.7	start profil
MSM20/188-1	28-Apr	MB+PS	3:28	22° 58.58	45° 43.63	3191.4	profile end
MSM20/188-1	28-Apr	MB+PS	3:52	23° 0.24	45° 43.47	3250.1	start profil
MSM20/188-1	28-Apr	MB+PS	8:59	23° 0.12	46° 17.47	4014.2	profile end
MSM20/188-1	28-Apr	MB+PS	9:28	22° 58.52	46° 16.43	3349.5	start profil
MSM20/188-1	28-Apr	MB+PS	11:01	22° 58.51	46° 06.44	3313.8	profile end
MSM20/188-1	28-Apr	MB+PS	12:06	22° 52.64	46° 12.67	4571.9	start profil
MSM20/188-1	28-Apr	MB+PS	12:27	22° 50.56	46° 12.51	4684.1	alter course
MSM20/188-1	28-Apr	MB+PS	12:57	22° 47.59	46° 12.39	4693.5	alter course
MSM20/188-1	28-Apr	MB+PS	13:46	22° 42.81	46° 11.40	4531.1	profile end
MSM20/188-1	28-Apr	MB+PS	15:42	22° 29.51	46° 21.76	3878.4	start profil
MSM20/188-1	28-Apr	MB+PS	20:53	23° 0.39	46° 21.79	3669.1	profile end
MSM20/188-1	28-Apr	MB+PS	21:19	23° 0.50	46° 19.69	3871.8	start profil
MSM20/188-1	29-Apr	MB+PS	2:31	22° 29.61	46° 19.68	3012.5	profile end
MSM20/188-1	29-Apr	MB+PS	2:54	22° 29.53	46° 17.57	4014.3	start profil
MSM20/188-1	29-Apr	MB+PS	6:40	22° 56.98	46° 17.57	3572.9	profile end
MSM20/189-1	29-Apr	ROV	8:30	22° 48.12	46° 03.17	4420.3	GEOMICROBE sled in water
MSM20/189-1	29-Apr	ROV	8:39	22° 48.12	46° 03.17	4419.5	GEOMICROBE sled released
MSM20/189-1	29-Apr	ROV	10:40	22° 48.12	46° 03.16	4421.8	ROV in water (dive J2-629)
MSM20/189-1	29-Apr	ROV	10:44	22° 48.13	46° 03.15	4418.5	MEDEA in water
MSM20/189-1	29-Apr	ROV	13:38	22° 48.13	46° 03.05	4419.7	at depth
MSM20/189-1	30-Apr	ROV	12:06	22° 49.90	46° 02.82	4123.1	off bottom
MSM20/189-1	30-Apr	ROV	14:26	22° 49.89	46° 02.43	4063.5	MEDEA on deck
MSM20/189-1	30-Apr	ROV	14:32	22° 49.89	46° 02.41	4064.9	ROV on deck
MSM20/190-1	30-Apr	MB+PS	17:02	22° 31.18	45° 43.94	3457.5	start profil
MSM20/190-1	30-Apr	MB+PS	20:15	22° 12.17	45° 43.90	3143.8	profile end
MSM20/190-1	30-Apr	MB+PS	20:37	22° 12.04	45° 45.76	3320.1	start profil
MSM20/190-1	30-Apr	MB+PS	23:49	22° 31.00	45° 45.78	3886.7	profile end
MSM20/190-1	1-May	MB+PS	0:13	22° 31.14	45° 47.86	3576.3	start profil
MSM20/190-1	1-May	MB+PS	3:25	22° 12.16	45° 47.88	3396.4	profile end
MSM20/190-1	1-May	MB+PS	3:49	22° 12.02	45° 50.06	3874.9	start profil
MSM20/190-1	1-May	MB+PS	7:03	22° 31.14	45° 50.10	3491.0	profile end
MSM20/191-1	1-May	ROV	10:39	22° 48.12	46° 03.17	4416.7	ROV in water (dive J2-630)
MSM20/191-1	1-May	ROV	10:42	22° 48.12	46° 03.17	4421.0	MEDEA in water
MSM20/191-1	1-May	ROV	13:21	22° 48.11	46° 03.19	4417.0	at depth
MSM20/191-1	1-May	ROV	20:13	22° 48.11	46° 03.16	4420.1	off bottom
MSM20/191-1	1-May	ROV	22:34	22° 47.98	46° 02.84	4425.1	MEDEA on deck
MSM20/191-1	1-May	ROV	22:42	22° 48.01	46° 02.80	4417.5	ROV on deck
MSM20/192-1	1-May	MB+PS	23:32	22° 41.29	46° 04.33	3185.4	start profil
MSM20/192-1	2-May	MB+PS	0:03	22° 38.74	46° 04.31	3160.1	profile end
MSM20/192-1	2-May	MB+PS	1:30	22° 29.11	45° 51.40	3617.5	start profil
MSM20/192-1	2-May	MB+PS	5:16	22° 29.06	46° 22.66	3880.7	profile end
MSM20/192-1	2-May	MB+PS	5:44	22° 30.09	46° 24.08	3702.2	start profil

Station No.	Date	Gear	Time	Latitude	Longitude	Depth	Remarks/Recovery
	2012		[UTC]	[x°y.z'N]	[x°y.z'W]	[m]	
MSM20/192-1	2-May	MB+PS	8:47	22° 54.31	46° 24.17	3571.1	profile end
MSM20/193-1	2-May	ROV	10:44	22° 48.71	46° 05.35	4465.7	ROV in water (dive J2-631)
MSM20/193-1	2-May	ROV	10:48	22° 48.71	46° 05.35	4466.5	MEDEA in water
MSM20/193-1	2-May	ROV	13:25	22° 48.71	46° 05.35	4465.9	at depth
MSM20/193-1	3-May	ROV	21:38	22° 49.18	46° 11.57	4687.3	off bottom
MSM20/193-1	3-May	ROV	23:54	22° 48.78	46° 11.32	4396.5	MEDEA on deck
MSM20/193-1	4-May	ROV	0:03	22° 48.78	46° 11.27	4382.7	ROV on deck
MSM20/194-1	4-May	MB+PS	0:56	22° 47.73	46° 05.28	4483.3	start profil
MSM20/194-1	4-May	MB+PS	5:08	23° 39.53	45° 54.73	2373.4	profile end

8 Data and Sample Storage and Availability

Beth Orcutt, Wolfgang Bach

1. Oxygen profiles were measured by Beth Orcutt and the data will be made available on Pangaea within 2 years.
2. Porewater samples will be analyzed for major and minor ion contents by Geoff Wheat and the data will be made available on Pangaea within 2 years.
3. Porosity and total organic carbon analyses will be conducted by Beth Orcutt and the data will be made available on Pangaea within 2 years
4. Samples for quantitative PCR analysis and total cell counts will be analyzed by shore based participant Axel Schippers and the data will be made available within 2 years.
5. Select samples for DNA analysis will be analyzed by Katrina Edwards and the DNA sequence data will be published in public databases (i.e. GenBank) within 5 years.
6. Select samples for recalcitrant carbon analyses will be analyzed by Ulrike Jaekel and Peter Girguis and the data will be made available within 5 years.
7. Rock samples will be analyses by XRF for major element concentrations and ICP-MS for trace elements. Rocks will be stored in the rock storage of Wolfgang Bach at the University of Bremen. Data will be made available on Pangaea within 2 years.

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