IFM-GEOMAR REPORT

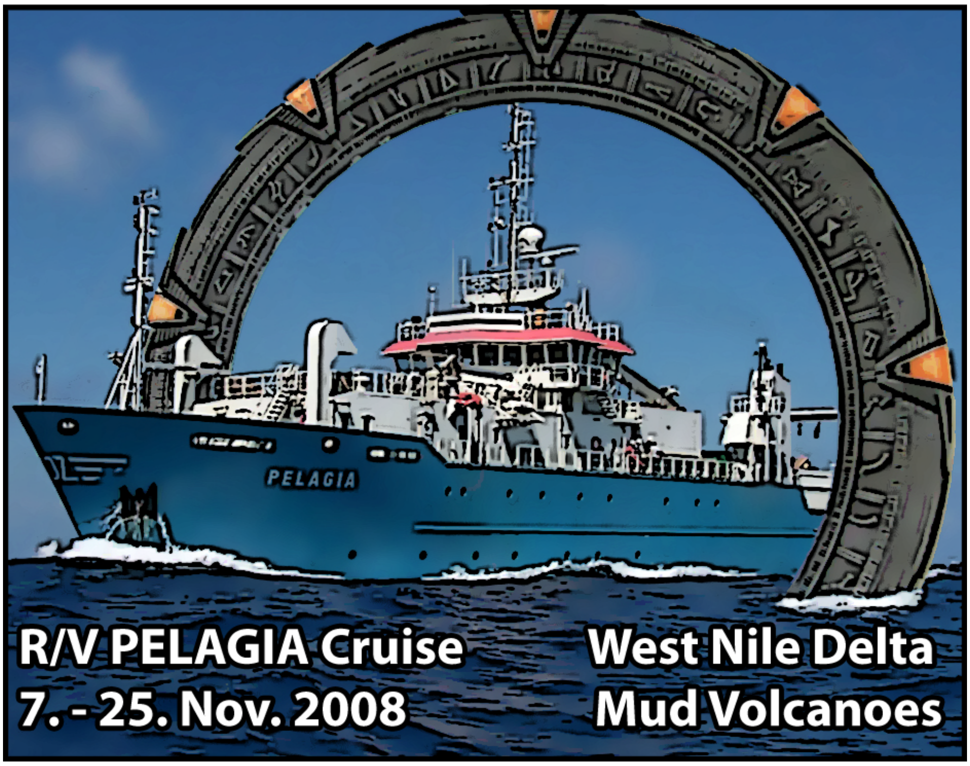
IFM-GEOMAR

Leibniz-Institut für Meereswissenschaften
an der Universität Kiel

RV PELAGIA
Fahrtbericht / Cruise Report Cruise 64PE298

West Nile Delta Project Cruise - WND-3

Heraklion - Port Said
07.11.-25.11.2008



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

Nr. 27
April 2009

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1. ABSTRACT

Cruise 64PE298 was the third expedition of the West-Nile Delta project which is run by IFM-GEOMAR and funded by RWE-Dea. The two mud volcanoes North Alex and Giza became subject once more to geophysical and bio-geochemical examinations .
ROV dives were undertaken to view the seafloor structure by video and to operate an active source for the marine electromagnetic (CSEM) measurements. Furthermore, the ROV supported the installation of temperature observatories and CAT meters, both for long-term monitoring. Multichannel seismic data acquisition was carried out to acquire a structural image of the mud volcanoes. Heat flow probing was repeated along the same traverses that had already been investigated during the previous cruises in order to document possible time-related changes. Sediment samples were taken at selected spots to investigate the bio-geochemical microstructure of the sediments to better describe origin, composition and activity of gas production from the mud volcanoes.

2. INTRODUCTION

Submarine mud volcanoes have been discovered all over the world on both active and passive margins (Kopf, 2002). Fluid formation and fluidization processes occuring at depths of several kilometers below the sea floor are driving complex systems of geochemical, geological and microbial processes. As mud volcanoes act as natural leakages for oil and gas reservoirs, these near-surface phenomena can be used for monitoring processes that occur at great depth. Detailed studies have shown that most mud volcanoes are associated with unique ecosystems often fueled by methane seepage (e.g. Werne et al., 2004; de Beer et al., 2006). Even though microbial communities act as a filter (Niemann et al., 2006), it has been shown that methane emitted from mud volcanoes reaches the mixing layer in the upper water column (Sauter et al., 2006).

To quantify the role of mud volcanoes in global budgets, it is important to understand their activity (cf. Wallmann et al., 2006). Despite the fact that some mud volcanoes such as the Håkon Mosby mud volcano on the Barents Sea slope have been investigated for years, their functioning is still poorly understood and little is known about temporal variations of mud volcano activity (Feseker et al., 2008).

Apparently rooted at depths of more than 5 kilometers, Giza mud volcano (Giza MV) and North Alex mud volcano (North Alex MV) are located in the immediate vicinity of designated gas production wells on the upper slope of the western Nile deep-sea fan (Fig. 1.1). In the context of the West Nile Delta Project at IFM-GEOMAR, these two mud volcanoes were selected for detailed investigation aiming to provide new insights into the dynamics of these unique sea floor features and their relation to gas reservoirs.

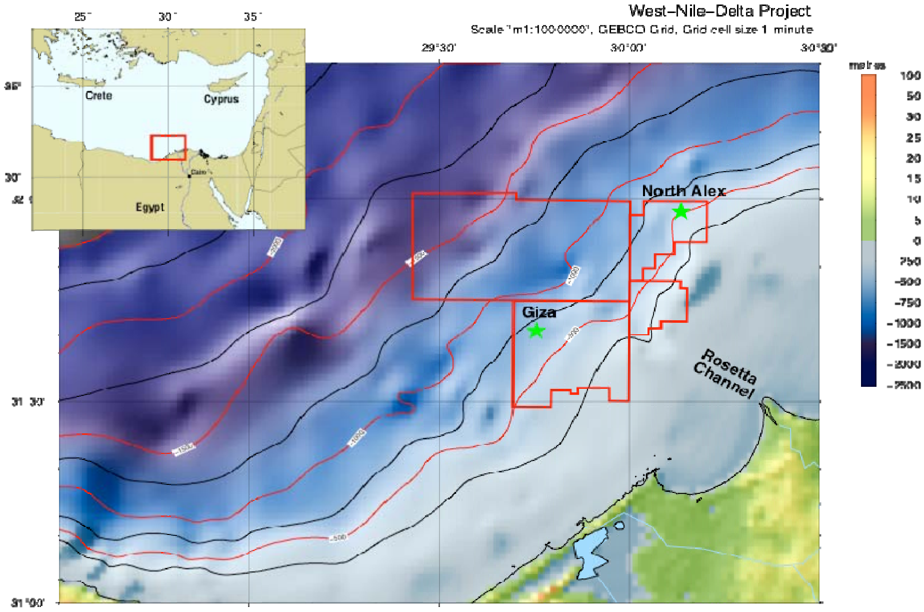


Figure 1.1: Location map of Giza and North Alex mud volcanoes.
Red lines indicate borders of concession / research areas.

Based on findings from the previous POSEIDON cruise in 2008 it is assumed that North Alex is the currently more active mud volcano. Hence, investigations were concentrated there, while only minor activities were dedicated to Giza.

Apart from a repetition of the temperature measurements from 2008, it was the seismic and coincident Controlled-Source electromagnetic (CSEM) investigations which were of main interest on this cruise. The repetition of the heat flow measurements was performed with the aim of documenting the temporal variability of the system in order to detect changes in activity. Joint seismic and CSEM profiling of seismic is to support an interactive analysis of the internal structure and distribution of gas and fluids. In addition, the cruise schedule contained video observation and bio-geochemical sampling. ROV based video observation was to confirm active gas expulsion and hence precisely determine sampling locations for the MUC.

3. Geological Setting

The West Nile Delta forms part of the source of the large turbiditic Nile Deep Sea Fan. Crustal tectonics in the geodynamic framework around the Nile Fan are mainly influenced by the Suez-Rift area, the Arabian-African plate motion, and the subduction collision with the Anatolian Plate (Loncke et al., 2004). Since the late Miocene sediments have formed an up to 10 km thick pile, which includes about 1 – 3 km of Messinian evaporates (Mascle et al., 2006). The sediment load of the overburden implies strong overpressures and salt-related tectonic deformation. Both are favourable for fluid migration towards the seafloor guided by the fractured margin. Deep-cutting channel systems like the Rosetta channel characterize the continental slope. Bathymetric expressions of slides and numerous mud volcanoes in the area are expressions of active processes, which contribute to the ongoing modification of the slope. The western deltaic system, Rosetta branch, has formed an 80 km wide continental shelf. Here at 500 m and 700 m water depth the mud volcanoes Giza and North Alex developed two major bathymetric features, which proved to be active gas and mud-expelling structures.

4. CRUISE NARRATIVE

R/V PELAGIA arrived in the port of Heraklion on the island of Crete on 6 November at 07:00 local time. At that time, four trucks with equipment for the upcoming cruise 64PE298 – WND-3 were already waiting at the pier side. Unloading and rearrangement of equipment from the previous cruise took the entire day. In the afternoon the C-14 lab container, the compressor container and a 20" flat with the ROV Cherokee components were installed using an onshore mobile crane.

On 7 November all 17 scientific crew members arrived on board at 08:00 local time. As R/V PELAGIA was to carry a lot of equipment for forthcoming cruises mcontainers and open equipment needed to be arranged in the main hatch. Therefore, unloading of the two trucks sent from IFM-GEOMAR to Crete was delayed until 10:30 , when a fork lift was available to get the boxes and winches lifted from the trucks within the range of the ships' cranes. At 13:00, the trucks had been unloaded and a huge pile of equipment was waiting at the pier side to be settled on board. With the dedicated help of crewmembers, NIOZ technicians and the science party, all gear had been loaded by 20:00. First laboratory work places had already been set up and equipment well secured when R/V PELAGIA sailed at 21:30 .

After 37 hours of transit the Egyptian observer was picked up from a supply vessel in front of the port of Alexandria on 9 Nov. at 10:00. After completion of a CTD run and a depth test for the ocean-bottom release units, measurements started during the night with two profiles of heat flow probe stations.

The daytime of 10 Nov. was used to deploy Ocean Bottom Seismometers (OBS) and Ocean Bottom Magnetotelluric (OBMT) stations. In the afternoon, first a first multi-corer (MUC) was operated for the first time without success. Obviously the weight needed to be adjusted to the soft sediments at the ground. During the night the measurements with the heat flow probe were continued and completed. Unfortunately, it turned out that soon after the start of the profile the winch cable had got stuck underneath the top of the probe and hence the following penetrations were heavily tilted. As there was no coaxial wire available, there had been no way of observing this online. Therefore parts of the measurements needed to be repeated later.

During 11 Nov., deployment of the OBMT stations continued. Intensive tests were run to build up a working 2-D streamer system It turned out that parts of the rented streamer components were not fully operational. During the night the ROV was deployed the first time for a visual inspection of the area and to identify possible deployment positions for the CAT meters.

After the successful dive of the ROV the new skid for the Controlled-Source Electromagnetics (CSEM) was mounted and test deployments of the ROV were completed to adjust for the best buoyancy of the system. Furthermore, acoustic ranging and Ultra-Short-Baseline (USBL) measurements were done to relocate the OBMT positions at the seafloor with best precision. A second reconnaissance dive with the ROV was run until midnight.

The early hours of 13 Nov. were used to shoot the first MCS airgun profiles. Due to compressor failures, the program had to be interrupted two times. During the daylight hours, the MUC was deployed successfully. A first deployment of the ROV, equipped with a 10-m antenna for the CSEM measurements, was stopped due a failure in the ROV and a broken antenna arm. At 20:00, MCS profiling was started again to be run until the next morning.

14 Nov. was used for further MUC deployments, with limited success. After the ROV had been repaired and the mounting of the CSEM antenna arms had been improved, the ROV was deployed for CSEM measurements again.

Successful measurements were completed until 01:00 on 15th Nov., followed by seismic measurements until 10:00. Afterwards, two CAT meters were successfully deployed using the 11-mm cable of PELAGIA and the USBL navigation to measure the depth position. Before the ROV set out to dive for the final installation of the CAT meters, one OBMT station was recovered to check for the success of the previous CSEM measurements. After installation of the CAT meters the ROV was used to map out the rim of the rough seafloor observed in the center of the North Alex mud volcano.

At midnight on 16 Nov. the third seismic transect was started. Due to a major failure of one of the four compressors, gun pressure could only be held at 165 bar instead of the previous 195 bar. In the morning, the ROV was deployed for another CSEM measurement. In the evening, six OBS were redeployed for a long-term observation until July 2009. At the same time, five OBMT stations were redeployed to enable service preparations for the following CSEM measurements.

Three CAT meters were deployed on the 17 Nov. at 06:00, followed by the ROV, which dived to complete the installation of the CAT meter hoses. Until 18:00, the MUC was used to take geological samples an the second heat flow profile was repeated. The night hours were used for another ROV dive with the CSEM system.

In the early morning of 18 Nov., R/V PELAGIA moved from North Alex to Giza mud volcano. At 10:00, two heat flow profiles were started, followed by a reconnaissance ROV dive.

On 19 Nov., MCS seismic profiling started at 05:30. During the day a second heat flow observatory was prepared for deployment as well as a CAT meter. Both were deployed in the afternoon. At 19:00 the ROV was deployed to complete the installation of the observatory and the CAT meter. Additional observations were made at some Pockmarks outside the center of the mud volcano before the ROV was recovered.

During the night of 20 Nov., a multibeam survey was conducted at Giza mud volcano prior to PELAGIA`s transit back into the North Alex working area. In the morning, MMR measurements were performed to provide electromagnetic signals for the OBMT stations. After the first set of transmissions the winch failed and the 500-m-long cable dropped down to the seafloor with a GAPS transponder attached. While the ROV was prepared for recovery of wire and transponder three tiltmeters were deployed. For the first time ever a CAT meter was mounted on the frame of one of them. The ROV set out for installation of this CAT meter in the evening.

During the night of 21 Nov. the bathymetric map of North Alex was completed by additional multibeam tracks. During the day, the first OBMT stations were recovered before the ROV dived at 16:00 to recover the lost wire. The operation went smooth and at 17:30 wire and transponder were safely recovered. OBMT recovery continued during the evening.

In the night of 22 Nov. additional multibeam lines were recorded. A final ROV dive was used to take push cores samples at the southern Pogo field. During the afternoon the remaining OBMT stations were recovered. Due to wind and wave conditions, work was continued by recording multibeam profiles.

On 23 Nov. at 21:30 the scientific work was completed and R/V PELAGIA set course for Port Said.

5. CREW

Ship's crew

Name	Position
John Ellen	Captain
Joep van Haaren	Chief Officer
N.N.	2nd Officer
Jaap Seepma	Chief Engineer
N.N.	2nd Engineer
Roel van der Heide	Sailor ab
Sjaak Maas	Sailor ab
G.P. Vermeulen	Sailor ab
J.A. Israël Vitoria	Sailor ab
Mustafa Mehdi	Assistent
Freddy Hiemstra	Assistent
Garl Mik	Cook

Science crew

Name	Institute	Function
Joerg Bialas	IFM-GEOMAR	Chief Scientist, Seismics
Warner Brueckmann	IFM-GEOMAR	Co-Chief Scientist, Fluid Flow
Klaus Cramer	E+JE	Compressor technician
Thomas Feseker	IFM-GEOMAR	Temperature, Heat flow
Sebastian Hoelz	IFM-GEOMAR	CSEM
Marten Lefeldt	IFM-GEOMAR	Seismics
Tina Treude	IFM-GEOMAR	Bio-Geochemistry
Gero Wetzel	IFM-GEOMAR	Heat flow technician
Stephanie Reischke	IFM-GEOMAR	Bio-Geochemistry
Martin Wollatz-Vogt	IFM-GEOMAR	CSEM technician
Marion Jegen	IFM-GEOMAR	CSEM
Jens Greinert	NIOZ	Navigation
Dries Boone	RCMG	ROV technician
Willem Versteeg	RCMG	ROV technician
Jeroen Vercruysse	RCMG	ROV technician
Arne Baeyens	RCMG	ROV technician
Alison LaBonte	Univ. Victoria	Fluid Flow
Ltd. Com. Yacout Mohamed Abdel Monem	Alex Navy	Observer

6. INSTRUMENTATION

6.1. MULTIBEAM

During 64PE289 the ship's fixed EM302 multibeam system was used for seafloor mapping during transit and seismic surveys. The EM302 is a 30-kHz, 288-beam (1° by 2° beam angle) system, which is fully motion compensated. A separate sound velocity probe next to the transducers guarantees a correct sound velocity value during transmission and reception. Prior to all surveys, a CTD profile was taken to get the correct sound velocity profile for the area (Figure 6.1.1).

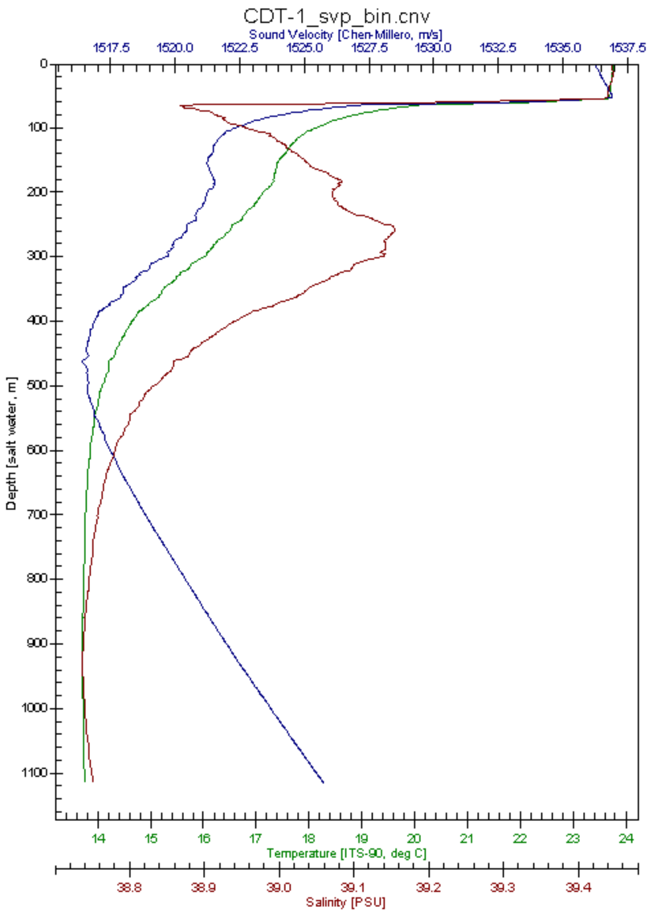


Figure 6.1.1: Temperature, salinity and sound velocity profile taken at 32°02.55' N, 029°56.06' E.

The data were processed with the Kongsberg Neptune software for application of the correct sound velocity profile and dumping xyz bathymetric data. For editing, the data were imported into Fledermaus PFM-Editor, edited and dumped as edited xyz data. Maps were produced with GMT (Generic Mapping tools). Figure 6.1.2 to 6.1.4 give an overview of the mapped area and the wider area around Giza and North Alex mud volcano. The data are only quick-edited, and more processing, including backscatter analyses, will be done at the institute.

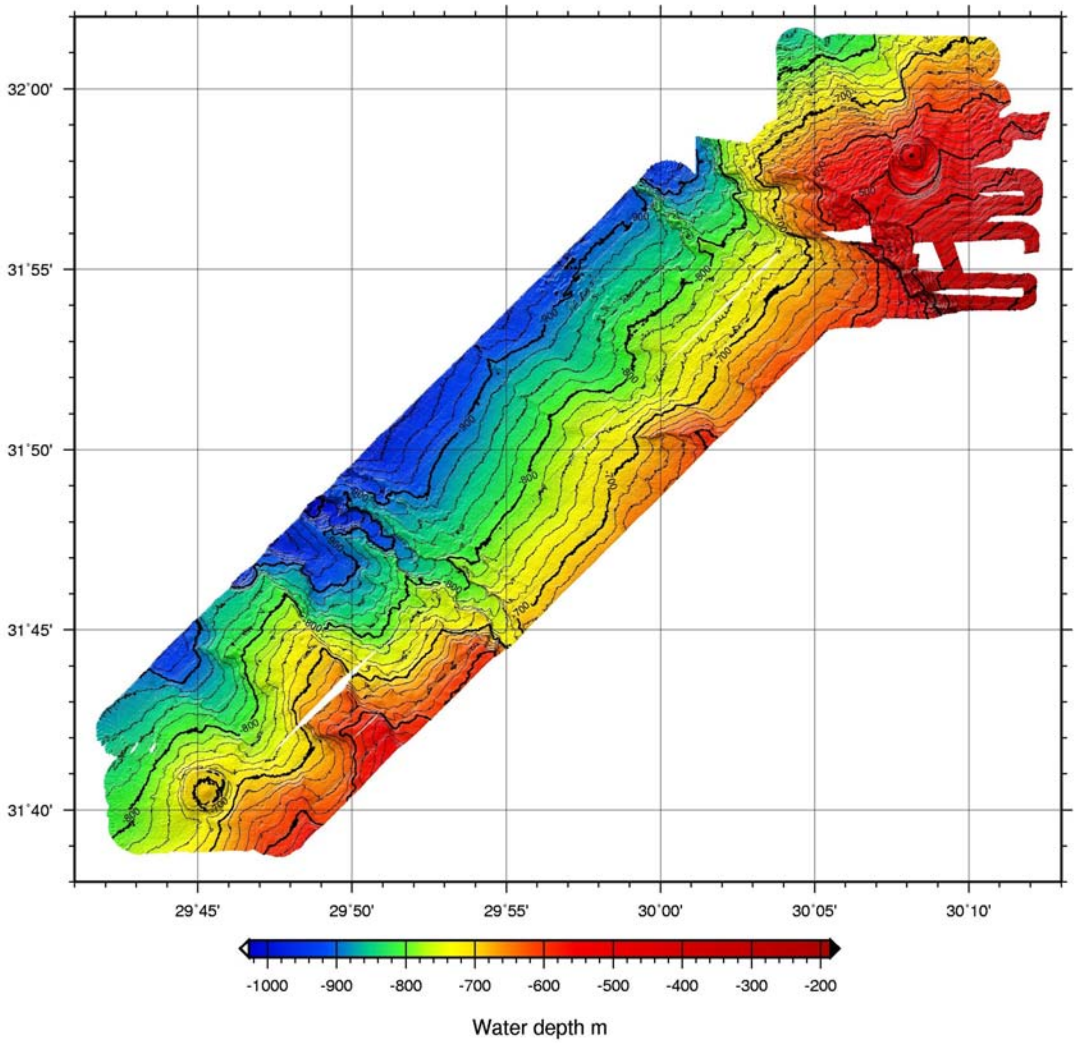


Figure 6.1.2: Overview of the entire area mapped during 64PE289 (grid size 0.5 seconds in x and y, illumination from 330°).

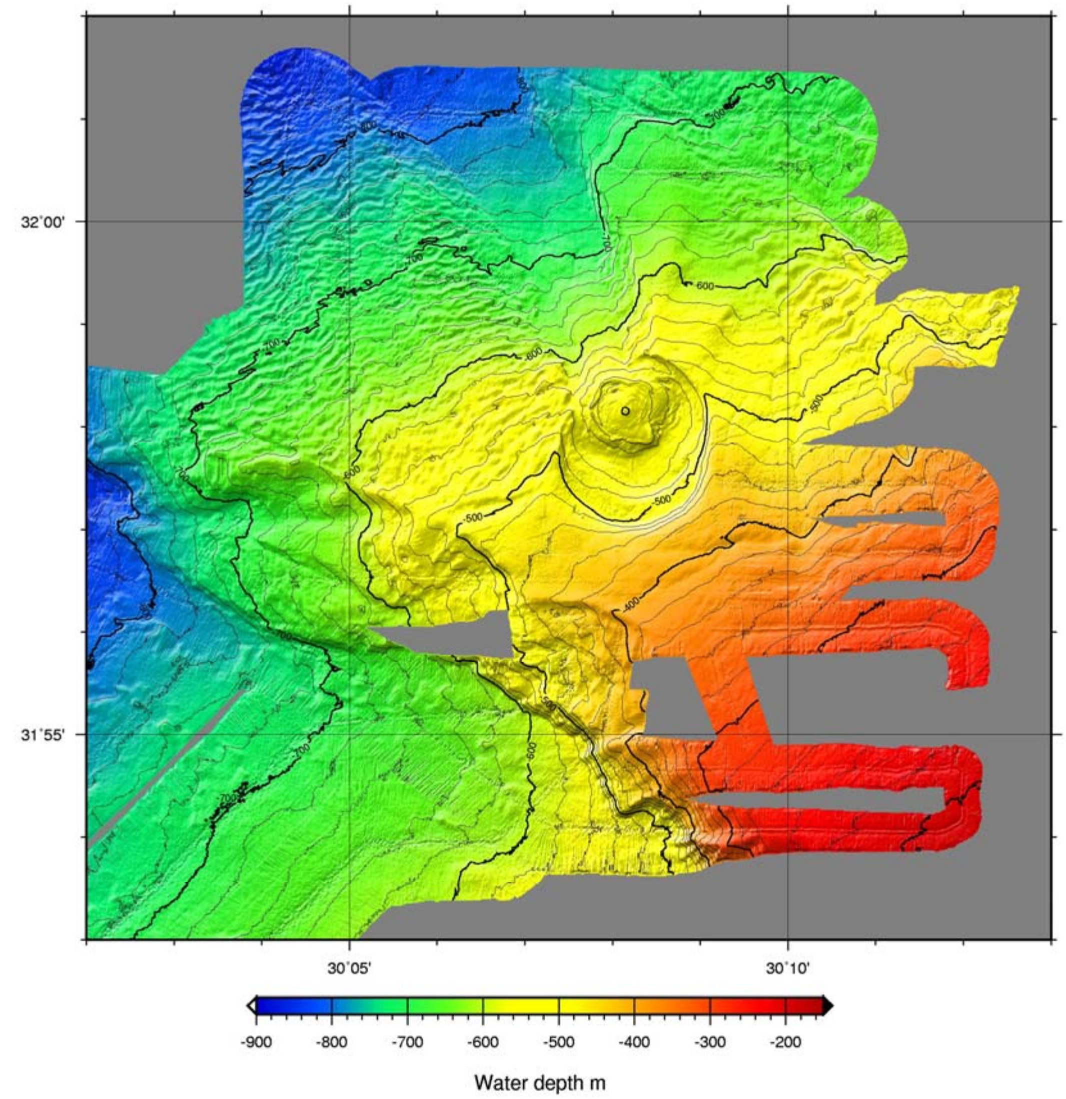


Figure 6.1.3: Bathymetric map of the North Alex mud volcano area (grid size 0.5 seconds in x and y, illumination from 330°).

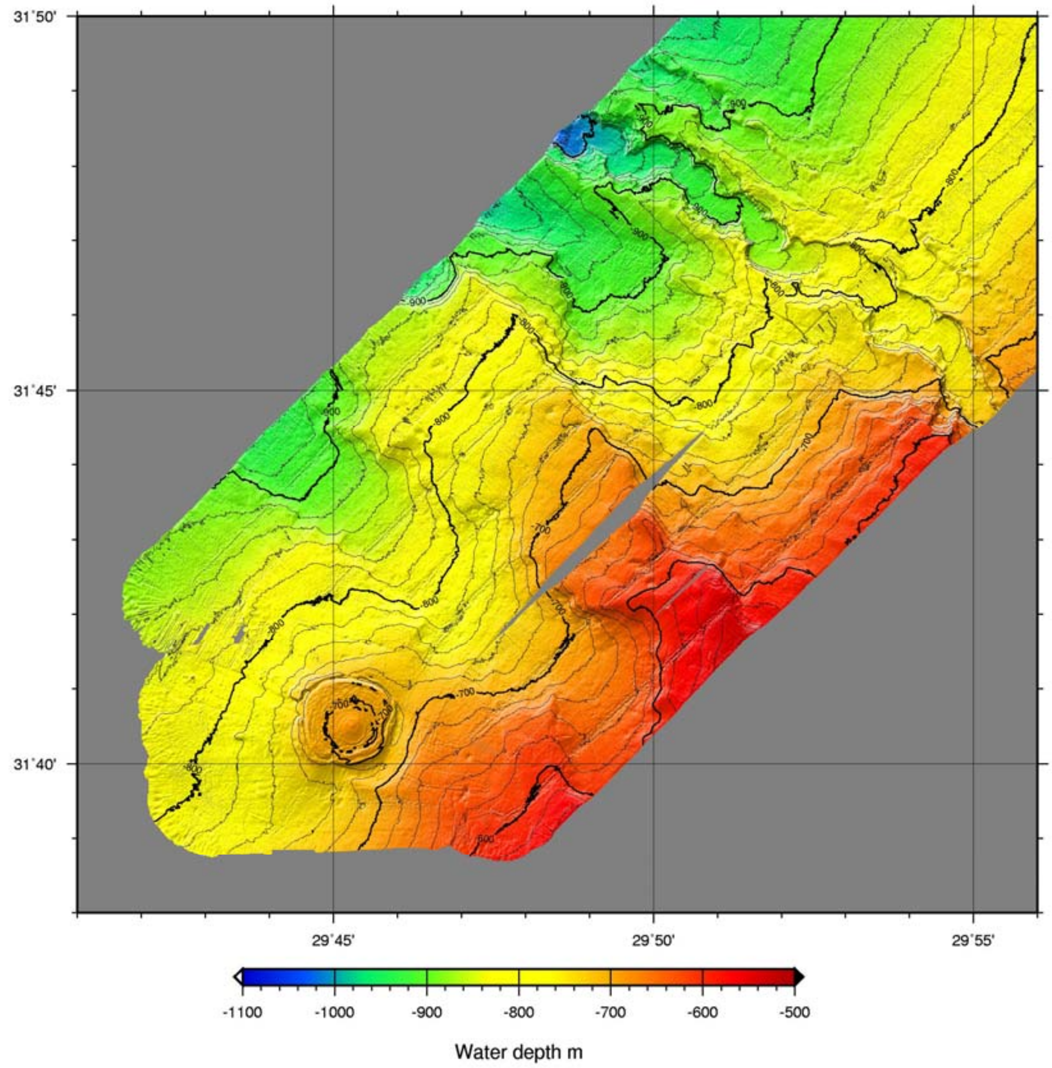


Figure 6.1.4: Bathymetric map of the Giza area with the active Rosetta canyon to the NE (grid size 0.5 seconds in x and y, illumination from 330°).

6.2. SEISMICS

6.2.1. COMPRESSOR

For operation of the airgun, four Junkers compressors were provided in a 10“ container (Fig. 6.2.1.1) together with 800 l of storage volume. The compressors were capable to deliver 8 m^3 of compressed air per minute at a pressure of 190 bar. This amount was sufficient to operate the desired GI airgun of 105/ 105 cinch volume with a shot interval of 7 sec.

Fig. 6.2.1: Left: Junkers compressor container with pressure reservoir.
Right: view inside the compressor container showing two of the four Junkers compressors.

Diesel fuel was provided from the ship's bunker using two 200-l-barrels, which lasted for 11 hours of operation. During the survey, one of the compressors failed due to a broken piston. The pressure supply hose for the gun was then connected right away to the air outlet of the compressors instead of the pressure reservoir. This gained us another 5 bar of pressure and the remaining three compressors could serve the gun at apressure of170 bar, which was sufficient to keep the dense shot spacing and a good source signal.

6.2.2. AIRGUN

For this survey, a GI airgun with a 105-cinch generator and a 105-cinch injector volume was provided (Fig. 6.2.2.1). During previous surveys it turned out that a towing depth of 2.5 m provides a good compromise between signal strength and frequency content. The gun was towed 12 m behind the starboard stern of R/V PELAGIA. A removable block at the rail was used to arrange the towing wire provided by the assistant winch of the A-frame into a shallow towing angle. About 20.000 shots were fired at a ship speed of 3 kn. The airgun shots were triggered by a LongShot gun controller, which was integrated into the seismic recording system described in paragraph 6.2.3.

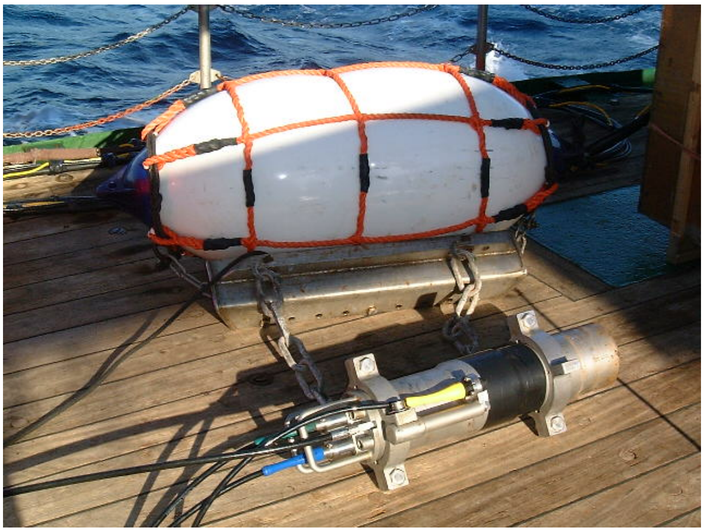


Figure 6.2.2.1: GI airgun with gun hanger and floatation.

6.2.3. STREAMER

Multichannel reflection seismic recording was to be carried out with a Geometrics GeoEel seismic streamer. Five sections of 25 m each together with a 100-m-long tow cable and a 12.5-m vibration isolation section were available. Unfortunately it turned out that one of the sections and the tow cable did not provide a stable data connection. Therefore, a 12.5-m spare section had to serve as leading (Fig. 6.2.3.1).

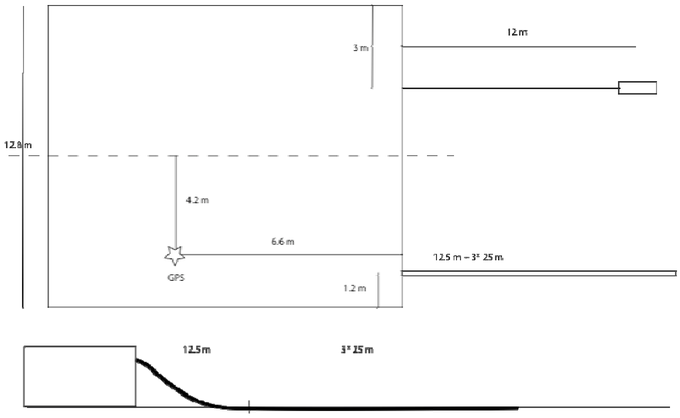


Figure 6.2.3: Arrangement of airgun and streamer during the MCS survey with R/V PELAGIA.

The active streamer sections comprise of 8 channels. Within the 25-m section, groups of 4 hydrophones are separated by 3.125 m. Within the 12.5-m section, 2 hydrophones form a group at 1.625 m offset. In total, 32 channels were deployed. From the online monitor it is estimated that the data recorded at channels 10 to 32 provide a sufficient signal-to-noise ratio for later data processing. All data was stored in SEG-D format and converted into SEG-Y floating point data after each survey.

The onboard seismic recording system (Fig. 6.2.3.2) integrates the GPS time-based gun controller, the streamer power supply, a PC for data quality control and data storage as well as an MBS data logger used to record the trigger signal with respect to the OBS time base. A differential GPS provides a 1-pps signal and the corresponding time information through a ZDA string. Both are fed into a timing box where the desired shot interval is selected. The timing box then provides a 5 V TTL pulse at each shot time for the various control systems. The ZDA and GGA string of the shot time are stored on a SD card as well to serve as shot log record. The TTL fire signal is distributed to the LongShot gun controller, which ignites the GI airgun at an aim point of 60 ms. The streamer control unit uses the TTL ignition pulse to start recording the streamer data at the same time. The GGA string of the GPS is fed to the recording PC via serial interface, so that the shot time is integrated into the seismic data trace header. As a third user, a data logger of the OBS system is used to record the ignition TTL signal.

6.2.4. OBS

The Ocean-Bottom-Seismometers have been developed by IFM-GEOMAR since 1991. The actual “Lobster” design (Fig. 6.2.4.1) comprises four cylinders made from syntactic foam, which provide the buoyancy. They are mounted in a titanium frame to which pressure tubes with batteries and recording electronics are mounted. A 40-kg steel frame serves as anchor and is fixed to the frame with an acoustic release system. A 4.5-Hz, three-component seismometer is included into the frame as well as a hydrophone. Radio beacon, flash light and flag serve as recovery aids once the unit has been released and floats awaiting recovery.

Figure 6.2.4.1: Ocean-Bottom-Seismometer – OBS - during deployment.

In order to record active seismic signals, an MBS type data logger is installed in the system, capable to record events at a 250-Hz sampling frequency. For long-term observation of passive seismic events, a low power consumption data logger (MLS) is installed, which samples at 100 Hz.

6.2.5. TILTMETER

Together with the long-term observation of seismic, thermal and fluid activity, tiltmeters (Fig. 6.2.5.1) are used to observe possible changes in the slope of the seafloor within the central part of the mud volcano. The tiltmeters record variations of the slope angle within a nano radians resolution and hence should be capable to resolve possible seafloor reactions to fluid events.

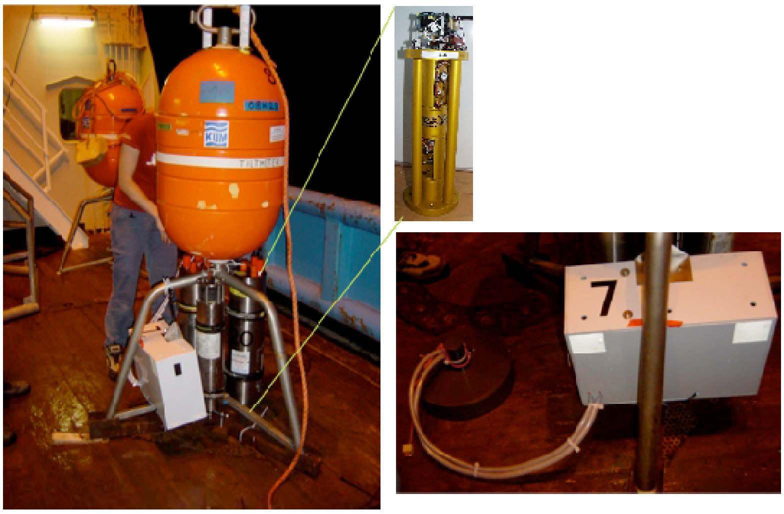


Figure 6.2.5.1: Ocean-Bottom-Tiltmeter (OBT)
Left: Tiltmeter frame with flotation and pressure tubes below.
Top right: The tiltmeter itself, two sensors with levelling system on top of each other.
Bottom right: CAT meter housing mounted to the tiltmeter frame

Two of the instruments could be deployed by the deep sea winch of R/V PELAGIA using the GAPS USBL to measure the drop position 30 m above the seafloor.

For the first time we achieved a combined deployment of a CAT Meter mounted into the same frame as the tiltmeter (Fig. 6.2.5.1 right).

6.3. MARINE ELECTROMAGNETICS

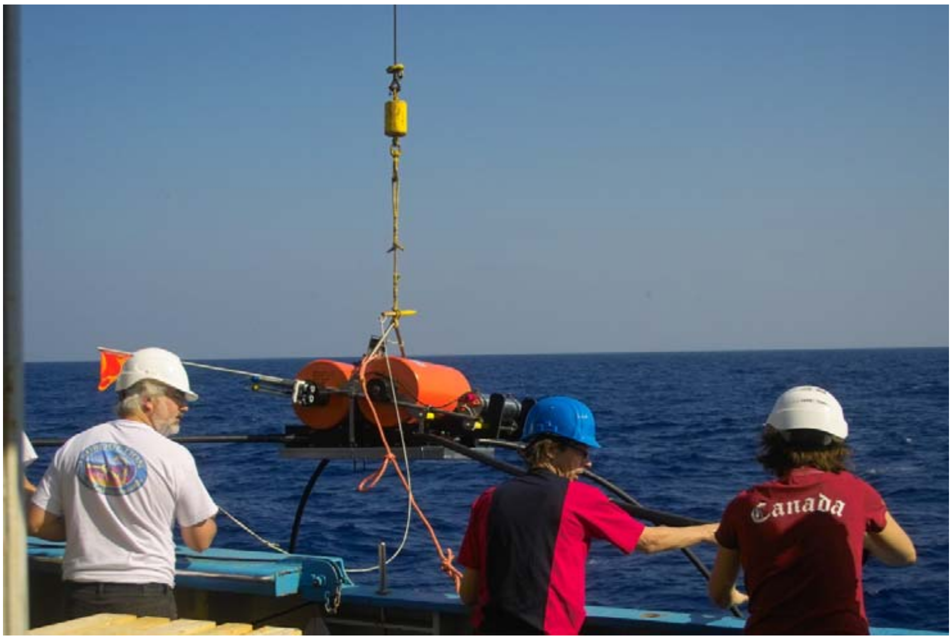


Figure 6.3.1.1: Upper panel: Hybrid marine EM receivers capable of recording low-frequency electric and magnetic field data as well as high-frequency electric field data.
Bottom Lower panel: Deployment of 10-m electric dipole transmitter mounted on ROV for the active source EM experiment.

The presence of fluids and gas causes orders of magnitude of difference in the electrical resistivity of the subsurface. Marine electromagnetic experiments, from which electrical resistivity as a function of depth may be derived, are therefore a method of choice to image distributions of gas and fluid in the subsurface. Through a time-varying electromagnetic source field, currents are induced in the subsurface, whose strength depends on the resistivity of the subsurface. The primary source fields as well as the secondary induced electric and magnetic fields are measured at the receiver by orthogonal horizontal electric dipole antennas and a three-component magnetometer. We performed two types of experiments during the cruise. A deeply penetrating (10 km penetration depth) passive source EM experiment and a newly developed, high-resolution active source EM experiment with a penetration depth of approx. 200m.

6.3.1. PASSIVE SOURCE EM EXPERIMENT

This type of experiment uses naturally varying low-frequency (< 1 Hz) magnetic fields produced by currents in the ionosphere as source signal. The measurement therefore does not require the deployment of a transmitter but only of receivers on the seafloor. The OBMT stations (Fig. 6.3.1.1, upper panel) consist of a highly sensitive 3-component fluxgate magnetometer which has been originally designed for space applications by MAGSON GmbH. Electric fields are recorded by 2 orthogonal electric dipole antennas, consisting of 2 electrodes mounted on 10-m-long PE tubes. Sampling of the fields as well as horizontal tilt variations occur at 10 Hz. Magnetometer, data recorders and battery packs are contained in titanium cylinders which are mounted on a titanium frame with syntactic floats. The instruments are weighed down by concrete anchors and deployed free-fall. For recovery, an anchor release mechanism is initiated by a transponder signal so that the instrument rises to the surface.

6.3.2. ACTIVE SOURCE EM EXPERIMENT

Next to this traditional passive-source EM experiment we also performed a newly developed ROV-operated controlled-source time domain EM tomography experiment looking at resistivity variations in the upper hundreds of meters. Here, a skid carrying a 10-m electric dipole source and transmitter electronics has been mounted on a ROV and is moved around the seafloor radiating electromagnetic energy to stationary receivers from different directions and distances. The dipole is fed with a bipolar 20-Ampere square wave. Unprecedented accuracy in navigation through Gaps transponders on receiving stations as well as the ROV allowed for highest precision for the active source EM measurements.

Two types of receivers were used in the experiments. The five OBMT stations are actually hybrid systems and are capable of simultaneously measuring 2 components of the horizontal electric field and 3-component magnetic field variations for passive EM at low frequencies as well as 2-component electric field variations at 1 kHz for active source EM. Switching between high and low frequency sampling circuits is achieved through a transponder signal from deck.

In order to increase spatial coverage for the active source experiment, five additional, newly developed 2-component electric field receivers sampling to 5 kHz to 10 kHz were deployed

6.4. TEMPERATURE AND HEAT FLOW MEASUREMENTS

The ascent of warm mud and water at mud volcanoes creates temperature anomalies close to the seafloor. In-situ sediment temperature and thermal conductivity measurements provide an excellent means of rapidly detecting areas affected by seepage and mud expulsion and form the basis of modeling studies to quantify transport processes at mud volcanoes. Due to the time scales associated with the conduction of heat in marine sediments, repeated temperature measurements and long-term temperature observations are also useful to describe temporal variability of seepage over periods of months and years.

6.4.1. HEAT FLOW PROBE

A standard violin-bow-type heat flow probe was used to obtain in-situ sediment temperature and thermal conductivity data. The active length of the probe is 5.67 m with 22 evenly spaced temperature sensors. Each sensor measures temperature at a resolution of less than 1 mK and is calibrated to an accuracy of better than 2 mK. In addition, sensors for tilt, pressure, absolute temperature, and acceleration are incorporated to provide detailed information about the state of the instrument during the measurement.

For each measurement, the heat flow probe is lowered to the seafloor at a speed of around 1 m/s until it has entered the sediment. Upon penetration, the probe is left in position for around 7 minutes to allow the temperature sensors to adjust to ambient sediment temperature. Temperature readings are recorded at a sampling rate of 1 s. Equilibrium temperatures may be calculated by extrapolation from the recorded temperature time series.

After the sediment temperature profile has been recorded for the first seven minutes, an in-situ thermal conductivity measurement may be conducted by applying a controlled heat pulse to a heating wire along the sensor string of the probe. The depth-dependent thermal conductivity of the sediments may be calculated from the temperature time series recorded during the dissipation of the heat pulse for approximately 7 minutes following the heat pulse.

The heat flow probe is equipped with sufficient power supply and memory to operate for up to 3 days continuously. Several measurements may be conducted during one deployment by heaving the probe merely a few tens of meters while the ship approaches the position of the next measurements. For all stations, the position is determined using a GAPS-Transponder mounted on the cable 50 m above the heat flow probe.

6.4.2. ROV-OPERATED TEMPERATURE PROBE

In addition to the winch-operated heat flow probe, a short temperature probe was used for precisely positioned in-situ temperature measurements in the sediments and in the bottom water to be performed during dives of the ROV Cherokee. The active length of this temperature probe is 0.5 m with 8 temperature sensors. Each sensor measures temperature at a resolution of 0.6 mK and is calibrated to an accuracy of better than 2 mK. Programmed to record temperature readings at a sampling rate of 5 s, the temperature probe may be operated for several days continuously. If the instrument is mounted to the frame of the ROV (Fig. 6.4.2.1), the temperature time series recorded by the probe may be combined with the navigation log to compile maps of bottom water temperature. For in-situ sediment temperature measurements, the probe was mounted to the manipulator of the ROV and inserted into the sediment for around seven minutes at selected locations (Fig. 6.4.2.2). The equilibrium temperatures are calculated by extrapolation from the time series recorded during this time in the same way as for the heat flow probe.

In addition to the measurements performed using the ROV, the short temperature probe was also mounted to the multicorer (Fig. 6.4.2.3) in order to provide information about the thermal regime from which sediment samples were taken.

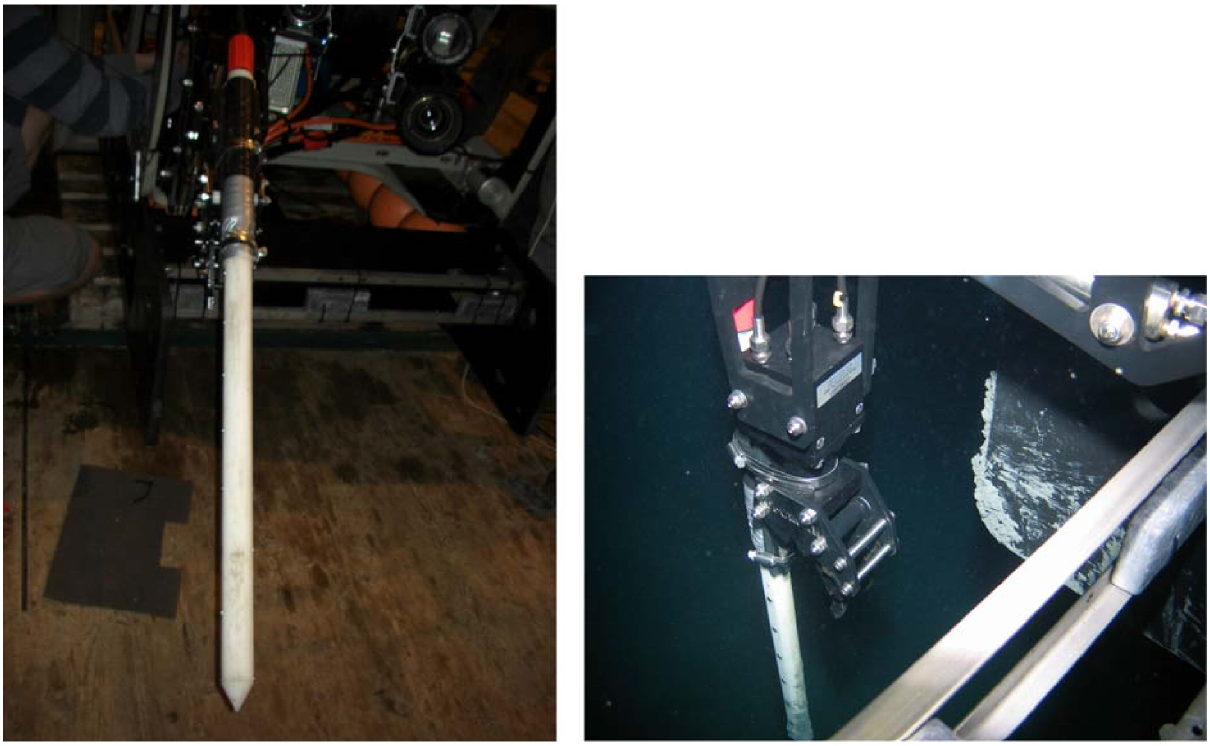


Figure 6.4.2.2: ROV-operated Temperature Probe.

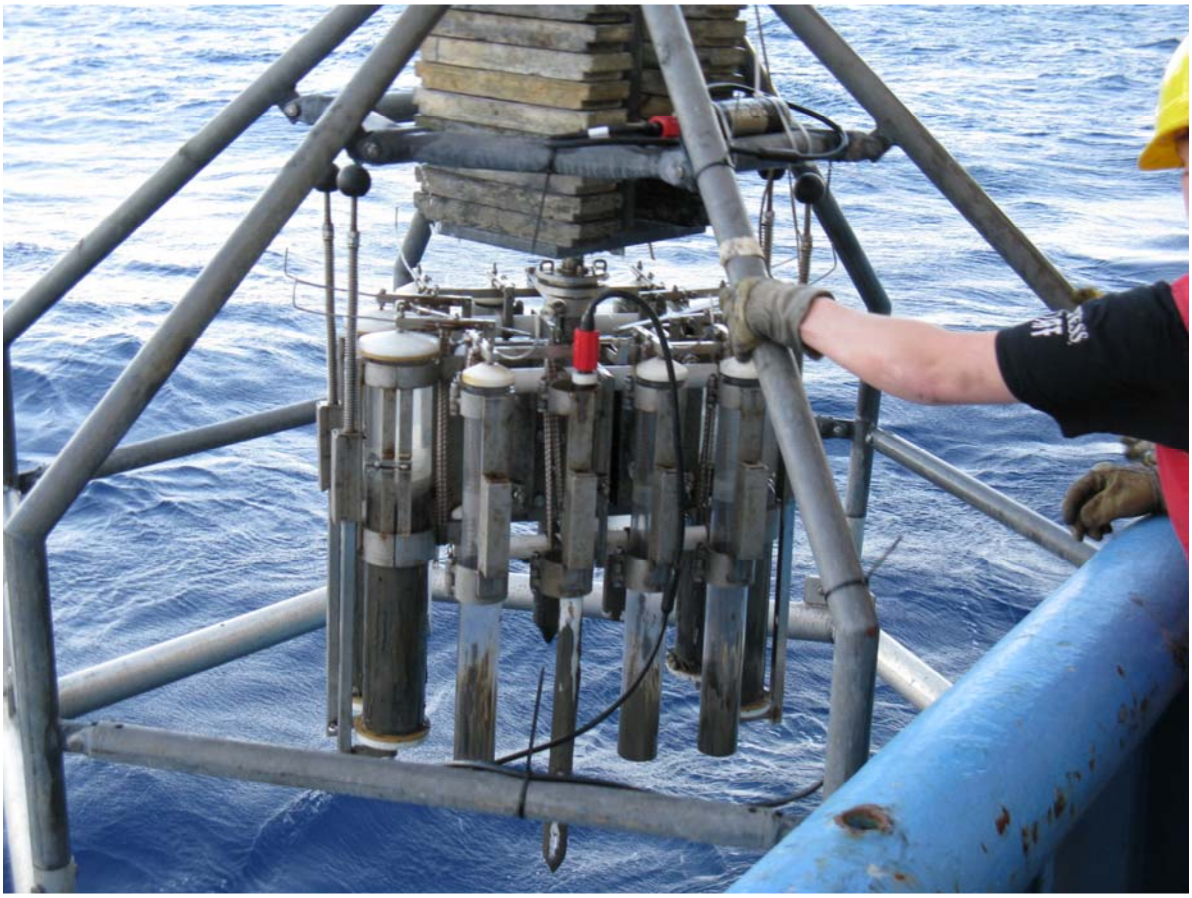


Figure 6.4.2.3: Temperature probe mounted on a MUC.

6.4.3. TEMPERATURE OBSERVATORY

To investigate the temporal variability of mud volcano activity, a temperature observatory was installed at each mud volcano. As illustrated in Fig. 6.4.3.1, each observatory consists of a 6-m-long solid steel lance with a concrete weight at the top, which is connected to a buoy. A thermistor chain with 7 temperature sensors is attached to the lance so that it enters the sediment when the lance penetrates the seafloor and records changes in the vertical sediment temperature profile. Bottom water temperature and the pressure at the position of the observatory are recorded by additional sensors mounted between the concrete weight and the buoy. Additionally, there is a second thermistor chain consisting of 24 temperature sensors, evenly distributed over an active length of 92 m. Following the winch-controlled deployment of the observatory, this thermistor chain is laid out on the seafloor away from the lance to provide information about the spatial extent of seepage events.

The main components of the observatory are integrated into the buoy. Each thermistor chain is recorded by a separate data logger which controls the measurements and stores the readings. The data loggers were synchronized and programmed to a sampling rate of 30 minutes. Each data logger mirrors the recorded data to an underwater serial port connected to an acoustic modem, which stores a copy and transmits the data to a surface vessel on demand.

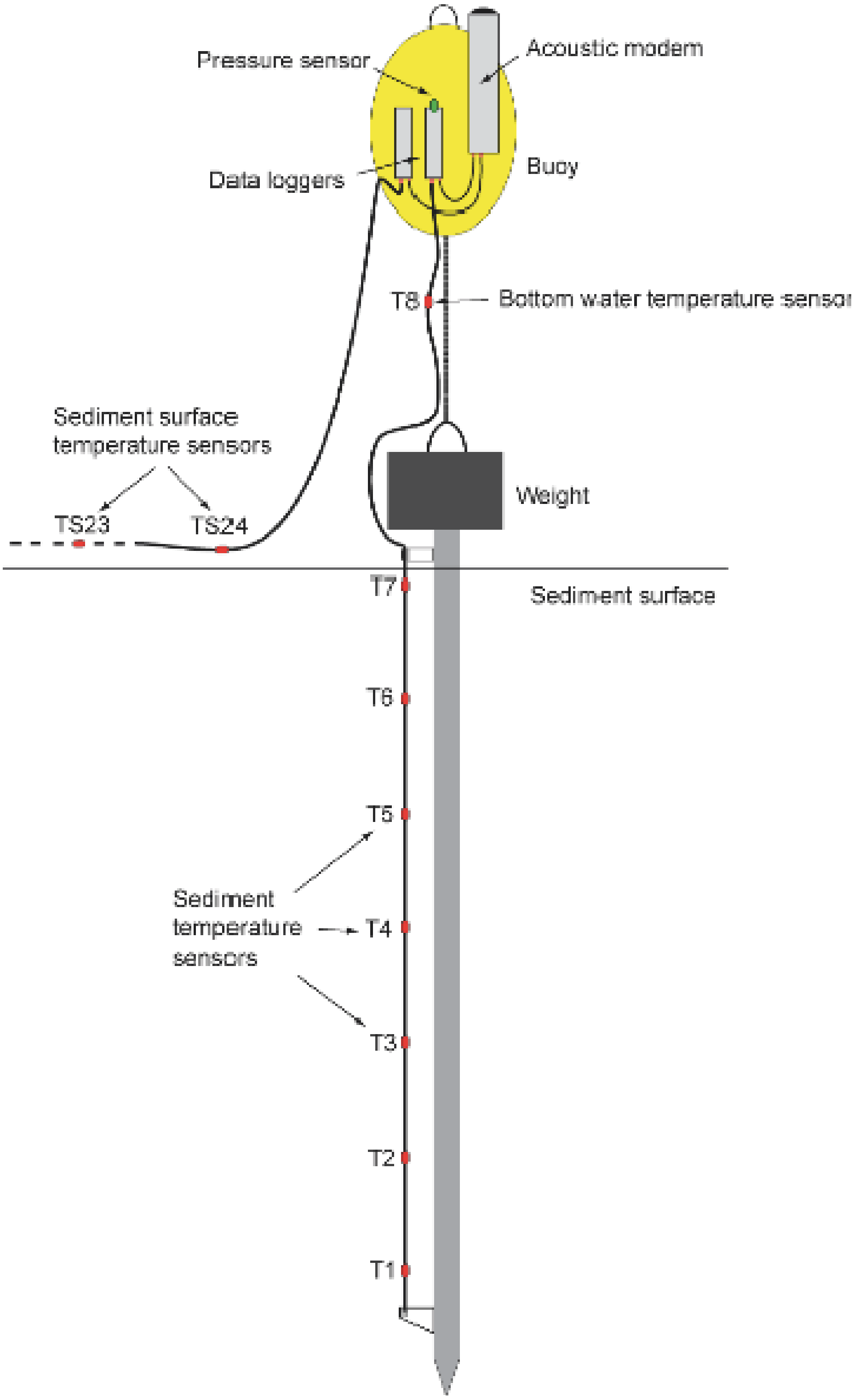


Figure 6.4.3.1: Design of the long-term temperature observatory.

6.5. CAT METERS

During cruise 64PE298 a total of 7 CAT meters were installed on North Alex mud volcano (6) and Giza mud volcano (1) to determine fluid flow rates at specific locations, for example in bacterial mats. Two types of CAT meters were installed, the only difference being the mode of recovery: three instruments were deployed without a releaser system, three with an integrated release system, one was attached to a releasable tiltmeter OBMT. The locations of deployments and specific targets are tabulated at the end of this section.

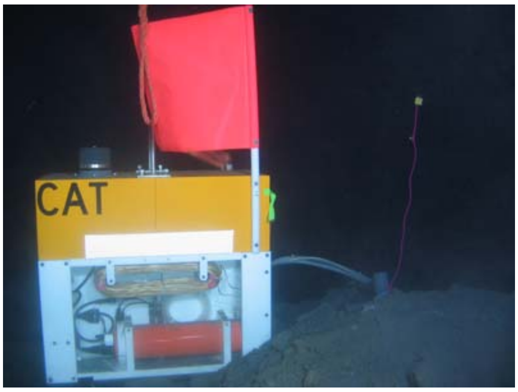


Figure 6.5.1: CAT meter with acoustic release system

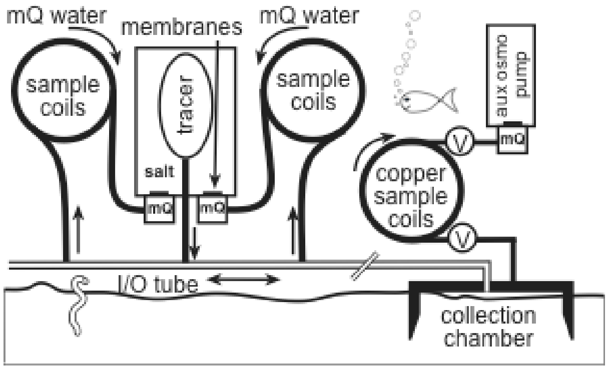


Figure 6.5.2: CAT meter schematic

6.5.1. RELEASE SYSTEM

The Chemical and Aqueous Transport (CAT) meter (Fig. 6.5.1) [Tryon et al., 2001] is designed to quantify both inflow and outflow rates on the order of 0.01 cm/yr to 100 m/yr. At high outflow rates, a time series record of the outflow fluid chemistry may also be obtained. These instruments have been in use since 1998 and have been very successful in monitoring long-term fluid flow in both seep and non-seep environments. The CAT meter uses the dilution of a chemical tracer to measure flow through the outlet tubing exiting the top of a collection chamber (Fig. 6.5.2). The pump contains two osmotic membranes that separate the chambers containing pure water from the saline side that is held at saturation levels by an excess of NaCl. Due to the constant gradient, distilled water is drawn from the fresh water chamber through the osmotic membrane into the saline chamber at a rate that is constant for a given temperature. The saline output side of the pump system is rigged to inject the tracer while the distilled input side of the two pumps is connected to separate sample coils into which fluid is drawn from either side of the tracer injection point (Fig. 6.5.2). Each sample coil is initially filled with deionized water. With two sample coils, both inflow and outflow can be measured. A unique pattern of chemical tracer distribution is recorded in the sample coils, allowing for determination of a serial record of the flow rates. Upon recovery of the instruments the sample coils are subsampled at appropriate intervals and analyzed using a Perkin-Elmer Optima 3000XL ICP-OES. Both tracer concentration and major ion concentration (Na, Ca, Mg, S, K, Sr, B, Li) are determined simultaneously. A subset of these instruments are equipped with an auxiliary osmotic pump connected to copper coils and high pressure valves so that they can be returned to the surface at ambient pressure, maintaining the gas composition of the fluids for analysis.

As explained in Tryon et al., 2001, diffusion in the sample coils is negligible. Typical sample sizes are 25-75 cm of tubing, many times the characteristic diffusion length for typical seawater ions at ocean bottom temperatures. Previous data have shown that typical resolutions are ~0.5% of the deployment time in the latest portions of the record and ~2% in the oldest portion for deployments of a year. At this time, there are no quantitative data with regards to long-term He diffusion in the copper coils, however, since the diffusion coefficient (D) of He is ~7x10-5, and that of typical seawater ions is ~1-3x10-5. The characteristic diffusion length (∝D1/2) for He should only be about twice that of the other species we analyze for (45 cm for a year at 25°C and much less at ocean bottom temperatures). The copper coils used here are a smaller diameter than the plastic coils and thus our samples are typically twice the length, offsetting any difference in diffusion length.

6.5.2. TYPES OF CAT METERS USED

Basic hand-held CAT
Dimensions: 50 x 46 x 55 cm (base x base x height)
Weight in air: 36 kg
Weight in water: 15 kg

The instrument housings and structures are PVC, the switching valves are made of PVC, while all other hardware is 316 stainless steel: the top handle is a 316 stainless steel - standard Alvin T-handle. The dissolved gas system is made of copper refrigeration tubing with brass couplers and valves.

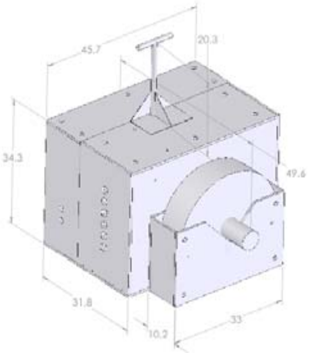
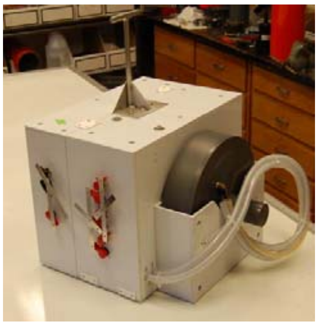
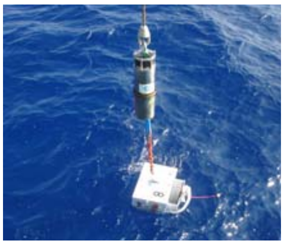
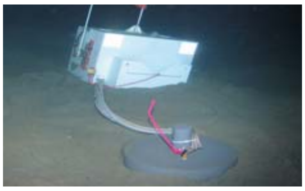
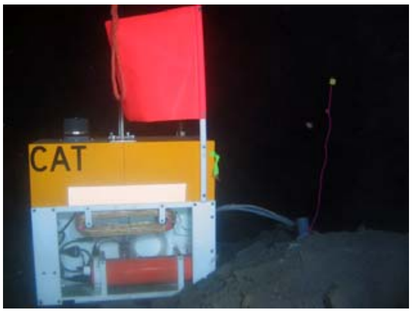
 a	 b	 c
 d	 e	 f

Fig. 6.5.3 a-f: Standard CAT meter design, deployment and installation on the seafloor.

<u>Acoustically releaseable CAT</u>
Dimensions: 80 x 38 x 91 cm (base x base x height)
Weight in air w/ ballast: 138 kg
Weight in air w/o ballast: 110 kg
Weight in water w/ ballast: 12 kg
Weight in water w/o ballast: -15 kg

The instrument consists of the basic CAT as described previously and the frame, releaser and floatation. The frame is made of high-density polyethylene, the hardware is 316 stainless steel, the top handle is a 316 stainless steel hoop. The floatation is syntactic foam rated at 50 MPa (Syntech AM-37). The acoustic release electronics are in a 7075 Aluminum housing rated at 50 MPa and certified to 4500 meters for use with manned submersibles (safety factor of 1.5).
All other components are solid, oil- or water-filled: There are no other implodeable volumes.

a



b

c

Fig. 6.5.4 a-c: Releaser-equipped CAT meter, deployment (a) and installation (b) on the seafloor, standard CAT meter attached to OBT-1 (c)

References

Tryon, M., K. Brown, L.R. Dorman, and A. Sauter, (2001), A new benthic aqueous flux meter for very low to moderate discharge rates, *Deep-Sea Research Part I-Oceanographic Research Papers*, *48*, 2121-2146.

6.6. ROV

The Remotely Operated Vehicle (ROV) "Genesis" held by the Renard Centre of Marine Geology (RCMG) of Ghent University (Belgium) was acquired in 2006 thanks to an Impulsfinanciering of the Special Research Fund of Ghent University. It is a fully-electric driven CHEROKEE ROV from Sub-Atlantic company, depth-rated up to 2000 m with a maximum payload of 60 kg for extra instrumentation.

The ROV can be operated in 2 modes: 'live boating' or 'TMS'. The 'live boating' mode is a deployment of the ROV 'over the side' with a tether of 500 m. The second operation mode is with the Tether Management System (TMS). In this mode, the deck container with winch (1600 m of fibre-optic umbilical) is used to lower the ROV from the ship's deck to 20-30 m above the seafloor within the TMS cage. The ROV can then freely survey the seafloor connected to the TMS with a tether cable of 200 m. The latter operation mode was used during the survey from RV PELAGIA. All ROV operations were conducted from the control unit in the deck container.

Fig 6.6.1: Deck-container with winch and the control unit, also used for storage of boxes and the TMS + ROV during transport.

The standard instrumentation of the ROV consists of:

- Forward-looking black-and-white camera, forward-looking color camera, forward-looking color stills camera (with flashgun), a rear-looking black-and-white camera and a TMS-mounted black-and-white camera.
- Three Q-LED lights in the front and one in the rear
- Altimeter (also on TMS)
- Depth meter
- Pan- and tilt-meter
- Compass
- Forward-looking "Super Seeking Sonar System" (325 or 675 kHz) for object detection
- a 5-function manipulator arm
- CTD 90M probe from SST (extra sensors Turbidity, Fluorometer, Oxygen)
- Drawer for storage of retrieved samples or extra equipment (e.g. Niskin bottle)

Figure 6.6.2: Front of the GENESIS ROV.

Figure 6.6.3: GENESIS control unit.

Among the instruments used during this survey, there was a coring device from the University of Bremen.

An additional skid for CSEM measurements designed by IFM-GEOMAR was placed under our ROV (replacing the usual ROV drawer skid). Electrical power for this experiment was provided by the ROV.

During deployments of the ROV all cameras were displayed on monitors in the control unit. An additional monitor displayed the color camera with overlay. This overlay informs the pilot with information about depth, altitude ROV and TMS, heading ROV, P/T of camera, Pitch/Roll ROV. Two video channels, a normal color camera with overlay and a front-looking B/W camera were recorded on DV-tapes

Positioning on a meter-scale and navigation of the ROV was achieved with an IXSEA GAPS system and ROV-mounted and TMS-mounted transponders. The calibration-free Global Acoustic Positioning System (GAPS) is a portable Ultra Short Base Line (USBL) with integrated Inertial Navigation System (INS) and Global Positioning System (GPS). The GAPS was attached and deployed from an over-the-side pole on the port side of the vessel. It used the GPS signal from a Simrad GN33 DGPS system. Six additional transponders were used for the positioning of different CSEM stations and MUC or Heat flow-probe deployments.

Real-time positions of the ship, ROV and TMS were displayed on screen using OFOP software. This software also served to make additional transponders on different stations or deployments visible.

6.7. GEOCHEMISTRY

6.7.1. MULTICORER MUC

Multicorer sediment cores taken for biogeochemical analysis were used for (1) sediment solid-phase sampling, (2) pore water squeezing , (3) microbial turnover rate measurements, (4) flow-through experiments, and (4) sampling of active sediments. For sediment solid phase sampling, the first five centimeters of the sediment core were sliced into 1-cm sections. Below five centimeters, the core was sliced at 2-cm intervals. Each depth section was sub-sampled for further chemical and molecular analyses (Table 6.7.1.1). The pore water core was sliced into 2-cm intervals. Pore water was recovered using a nitrogen gas pressure squeezer at three bars. Sub-sampling of the collected pore water was done according to Table 6.7.1.1. Alkalinity was measured on board. The titration procedure for measuring alkalinity is described in detail on the IFM-GEOMAR web page. Microbial turnover rates of methane and sulfate were measured in three parallel sub-cores (i.d. 26 mm), respectively, by radiotracer techniques. Fifteen µl of ^{14}C-methane tracer (activity 2 kBq) and 6µl of the ^{35}S-sulfate tracer (activity 200 kBq) were injected into the sediment, respectively, in 1-cm intervals. After an incubation time of 24 hours the reactions were stopped by slicing the cores into 1-cm intervals and transferring the sediment into 2.5% (w/w) sodium hydroxide and 20% (w/w) zinc acetate, respectively (Table 6.7.1.1.). One sub-core (i.d. 60 mm) was taken from a multicorer core for sediment flow-through experiments in the home laboratory. The core liner was specifically designed to be installed into a flow-through system enabling biogeochemical studies under controlled fluid flow parameters. Active sediments for in-vitro studies were taken from one to two multicorer cores per station. The cores were sliced into the depth sections 0-2, 2-5, and 5-10 cm. The sediments were transferred into glass bottles, sealed with a rubber stopper, and cooled.

6.7.2. PUSH CORES

Push cores taken by the ROV were principally sampled by the same scheme as applied to multicorer samples (except for the sampling of the flow-through core and active sediments). All sediments were sliced in 1-cm intervals. If the material was not sufficient, the programme was reduced to rate measurements, sulfate and methane concentrations, porosity, RNA/DNA, as well as FISH sampling (see Table 6.7.1.1.).

Table 6.7.1.1. Subsamples taken from the sediment solid phase, pore water squeezing, and microbial turnover rate cores.

Parameter	**Chemicals**	**Sample Volume (ml)**	**Storage**
Sediment solid phase			
Methane	5 ml 2.5% NaOH	2 ml sediment	room temperature
FISH	1.5 ml 4% formaline	0.5 ml sediment	stored in PBS/Ethanol at –20°C after washing two times in 1x PBS
RNA/DNA	-	ca. 3 ml	-80ºC
AODC	9 ml 2% formaline	1 ml sediment	cooled
CNS, BioMarkers	-	ca. 30 ml	-20ºC
Pore -water squeezing			
Porosity	-	~1 teaspoon sediment	cooled
IC/Nutrients	-	>2 ml porewater	-20ºC
Sulfate/Sulfide	1 ml 5% ZnAc	1 ml porewater	cooled
ICP	10µl HNO_3 per ml sample	2 ml porewater	cooled
Alkalinity	on board titration	1 ml porewater	N/A
Delta ^{18}O	-	1 ml porewater	cooled
DIC	3µl HgCl	3 ml porewater	cooled
Microbial turnover rate measurements			
AOM	20 ml 2.5% NaOH	ca. 5 ml sediment	room temperature
Sulfate Reduction	20 ml 20% ZnAc	ca. 5 ml sediment	room temperature

7. WORK PERFORMED: NORTH ALEX

7.1. SEISMICS

7.1.1. MCS SEISMICS

During cruise 64PE298 of R/V PELAGIA, a dense grid of active seismic profiles was acquired across North Alex mud volcano (Fig. 7.1.1.1, Tab. 11.3). Airgun shots were fired every 7 seconds by means of a GI airgun with a 105 cinch generator and a 105 cinch injector volume. A set of 25 profiles was collected, providing a good 3-D coverage above the central part of the mud volcano.

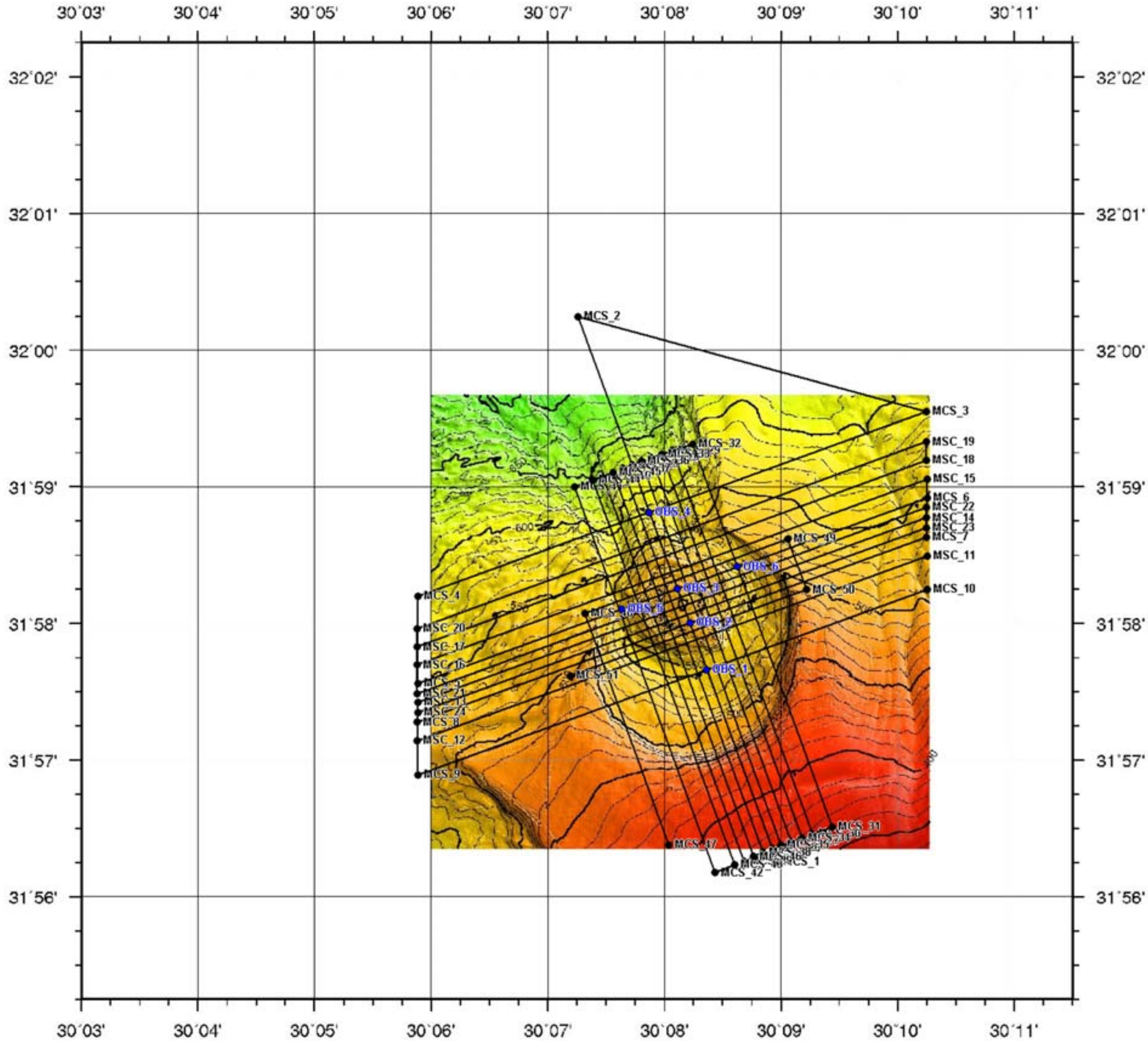


Figure 7.1.1.1: Map of seismic lines across North Alex mud volcano.
Blue points indicate positions of OBS stations.

The single channel seismic section of profile 15 (Fig. 7.1.1.2) shows the good data quality achieved. A bandpass filter (10 Hz to 150 Hz) and a 200-ms long AGC were only applied during preliminary data processing. Clear sediment reflections can be detected until the arrival of the multiple event. Major structural features like the deep-cutting fracture in the SE of the mud volcano, the mud volcano itself as well as numerous minor faults and fractures within the several layers can easily be detected even in this raw data set. With the dense line offset of about 250 m the data set will provide a good data base to image the tectonic setting of the North Alex mud volcano.

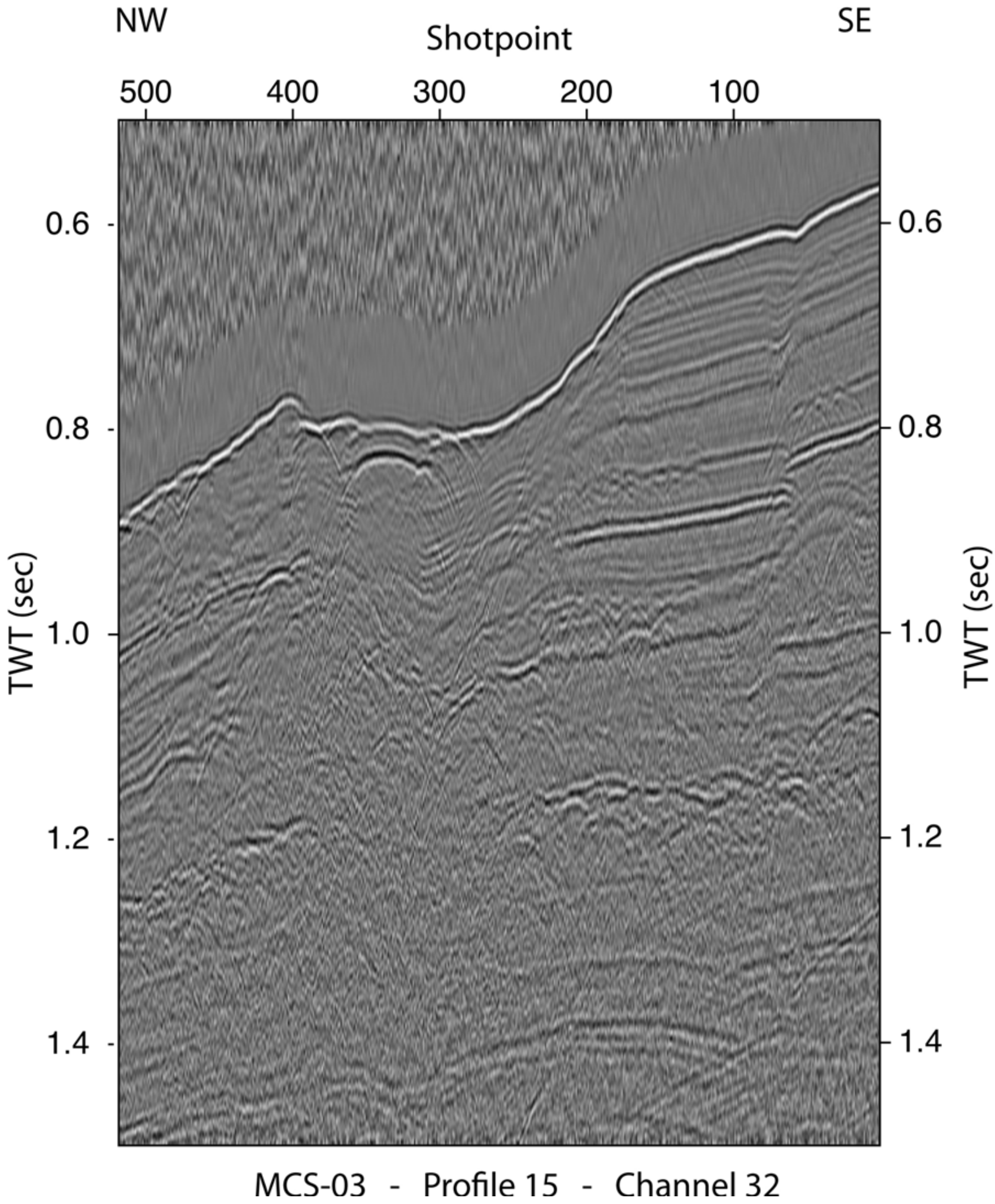


Figure 7.1.1.2: Single channel section of profile 15

7.1.2. OBS DEPLOYMENTS

Six Ocean Bottom Seismometers (OBS) – each equipped with a 4.5-Hz three-component seismometer as well as a hydrophone – were deployed as part of the active seismic experiment (Fig. 7.1.1.1, Tab. 11.2).

The OBS are designed to record seismic waves induced by the airgun, which is towed behind the vessel and thus acts similar to the streamer sections, which are towed behind the vessel as well. The important difference is that the streamer – always at the same distance to the airgun – records seismic rays that travel at one particular angle of incidence. This angle allows to image reflectors, but hardly allows vor construction of a model for the seismic velocities beneath the seafloor. This can only be done by using the seismic travel time records from the OBS, which include data from seismic rays that travel at various angles due to constant change of the distance between the source (airgun) and the receiver (OBS). Crossing rays can be used in inversion schemes to produce seismic velocity models. A combination of OBS and streamer data makes it possible to determine the depth of reflectors.

The data logger of OBS #4 stopped about 3 hours after deployment for an unknown reason. All other instruments recorded all shots. Without further processing, applied reflection events could be observed with a T_0 time of up to 4 sec traveltime (Fig. 7.1.1.3). Due to the GI airgun application ony minor bubble effects are observed in the direct wave arrival. Later deconvolution processing will sharpen this event and allow identification of most shallow events.

Therefore, not only 2-D inline observations might be used for the development of a velocity-depth model but all 3-D observations as well. Pre-Stack Depth Migration processing of the OBS data will allow for using the wide-angle observations, which will include the central part of the mud volcano. The benefit of this data is that due to an “undershooting” geometry, reflection images are provided from an area where standard near-vertical streamer seismics fail due to the high reflectivity of uppermost gas-saturated layers.

All six OBS have been deployed a second time and will not be recovered before August ’09. Until then, they will record seismic events close to the mud volcano, i.e. events generated by fluid movements (passive seismic experiment). The aim is to determine the exact location of any seismic event in the study area. It is difficult to determine such locations from their arrival times at the OBS stations alone, since the latter depend not only on the location but also on the velocity model. This is known as the coupled-hypocenter-velocity-problem. However, by determining the velocity structures during the active seismic experiment, the problem is reduced to a simple location inversion.

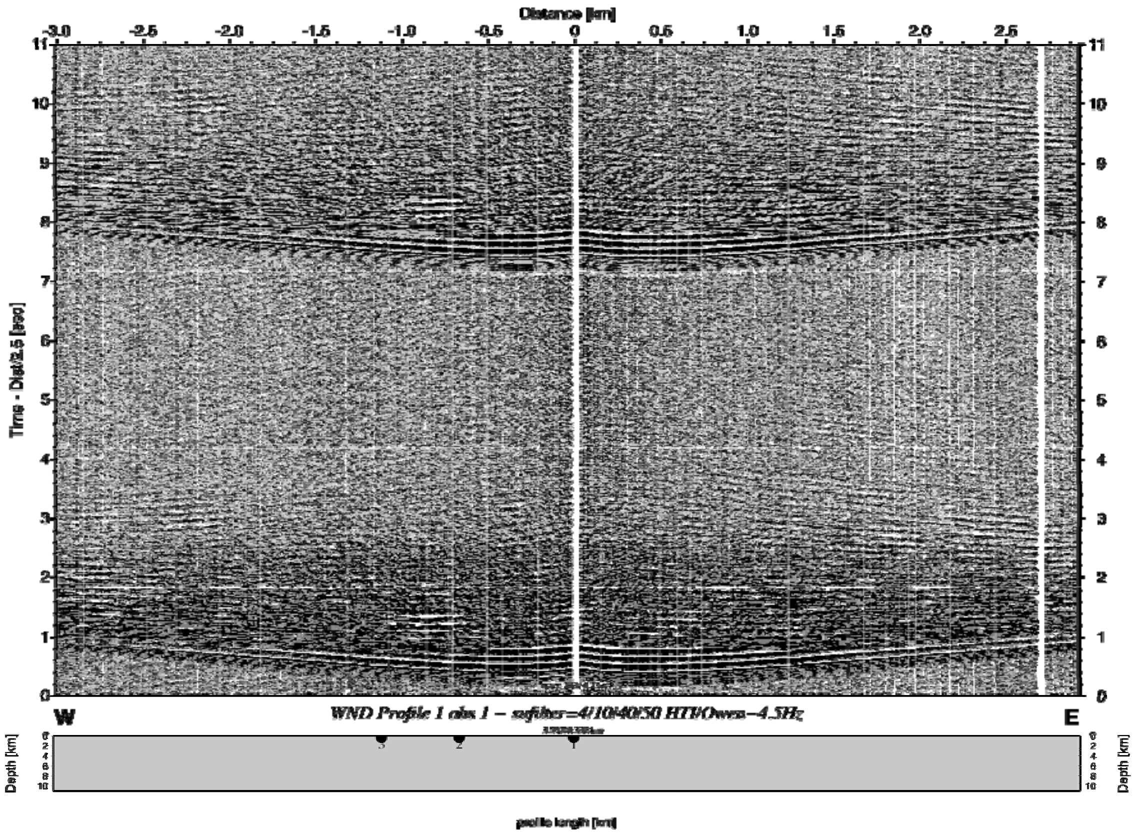


Figure 7.1.1.3: Record section from OBS1 HTI/Owen-4.5 Hz, Profile 1.

7.2. MARINE ELECTROMAGNETICS

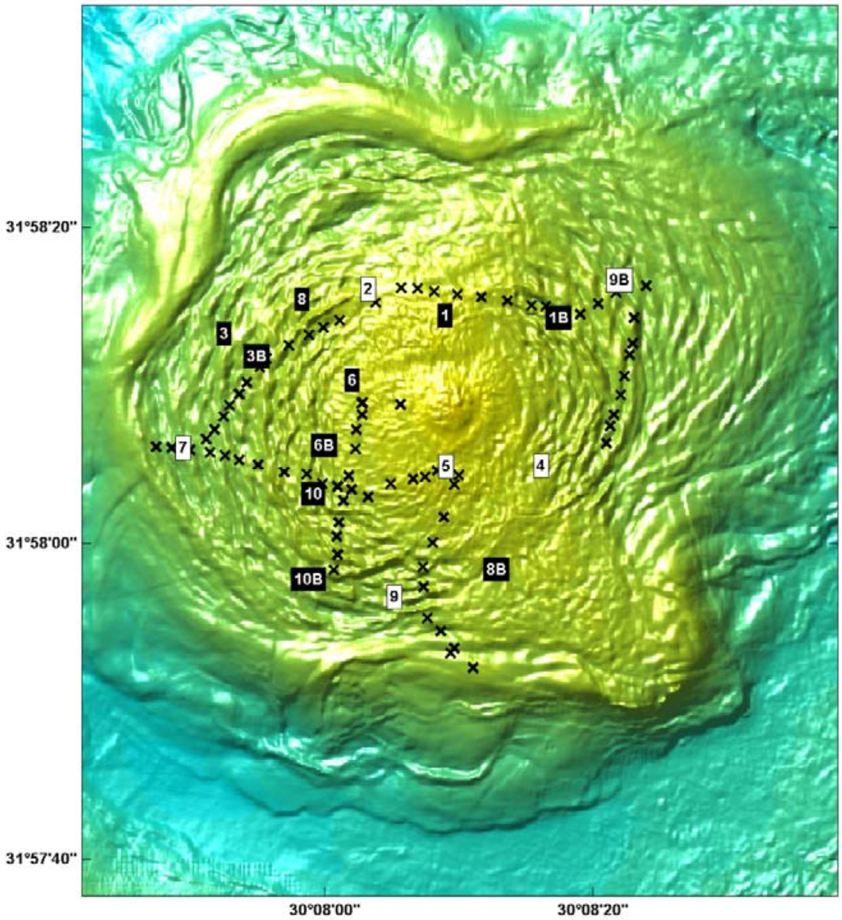


Figure 7.2.1: White rectangles: OBMT receiver locations (stations 2,4,5,7,9 and 9B). Black rectangles: Electric dipole receivers (stations 1, 3, 6, 8, 10, 1B, 3B, 6B, 8B and 10B). Black crosses: transmission stations of electric dipole mounted on ROV.

7.2.1. RECEIVER DEPLOYMENTS

Figure 7.2.1 (Tab. 11.4) shows the distribution of the five hybrid OBMT instruments (white squares) and five electric dipole receivers (black squares). A first deployment of 5 OBMT instruments (stations 2, 4, 5, 7 and 9) was performed on 10 November, followed by a deployment of 5 E-dipole instruments on 11 November (stations 1, 3, 6, 8 and 10). One receiver of each type was recovered to check on signal level after active source transmission and was redeployed on 15 November. While signal levels were good at the OBMT stations, slight modifications had to be done on the E-dipole instruments. The remaining 4 E-dipole stations were subsequently recovered, modified and redeployed in the night of from 16 November to 17 November (stations 1b, 3b, 6b, 8b and 10b). the final recovery of the electric dipole receivers and OBMT stations took place on 21 November and 22 November, respectively.

7.2.2. PASSIVE SOURCE EM EXPERIMENT

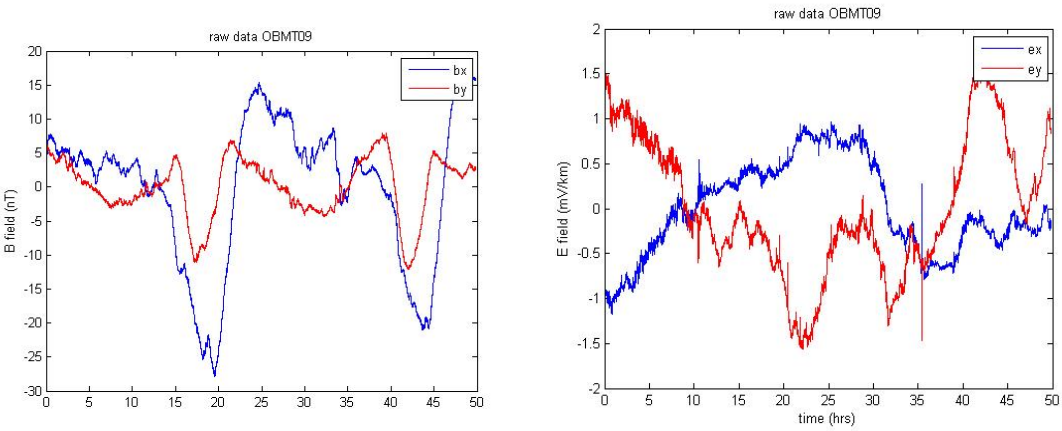


Figure 7.2.2.1: Magnetic (left panel) and electric (right panel) variations at station 9 for a period of 50 hours.

The passive source EM signal has been continuously recorded by 5 OBMT stations. Figure 7.2.2.1 shows 50 hours of raw data recorded at station OBMT9.

7.2.3. ACTIVE SOURCE EM EXPERIMENT

Electromagnetic waves were actively transmitted on a total of four ROV dives. A first dive on 13 November had to be aborted since one of the glass fibre transmitter arms broke during descent to the seafloor. On 14 November a second dive of approx. 5 hours covered the southern part of the transmission points (crosses) shown in figure 7.2.1. To check on data quality and signal levels, one of each type of receivers was brought up to the surface and redeployed on Nov. 15th. The tests showed that data on the hybrid stations were of good quality, yet some minor adjustments had to be made in the electric dipole receivers.

A third 6-hour ROV dive on 16 November was used to transmit towards hybrid stations in the south. In the night from 16 November to 17 November, the remaining 4 electric dipole receivers were recovered, modified and deployed again. A final fourth dive of 9 hours covering the western and northern part of the mud volcano took place in the night of the from 17 to 18 November.

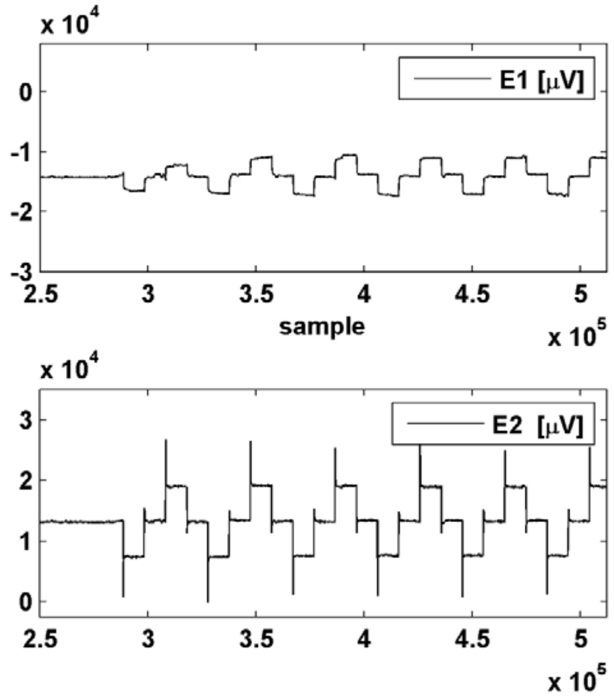


Figure 7.2.3.1: Raw data showing the received bipolar transmitter wave at station 9.

At each transmission station the ROV was placed on the seafloor and a 20 A bipolar wave with a period of 4 seconds was transmitted for 1 minute. Subsequently, the ROV and with it the electric dipole transmitter were turned by 90 degrees and the procedure was repeated. All stations were visited except station 4, which allowed us to determine the position of the station with a precision of ca 2 m and note the heading of the electric receiver dipole antennas. In order to measure the phase delay in the signal, It is vital for the measurements that time is kept accurately. While on the receiver as well as the transmitter time is kept by highly accurate clocks, a direct transmission of electromagnetic energy at a distance of less than 15 meters was performed in order to give additional constrains on tje time drift of the receiver and transmitter clocks.

An example of the raw data received at station 9 during dive 3 is shown in figure 7.2.3.1. The bipolar wave is clearly visible in both electric field components. Raw data from each transmission cycle will be stacked to obtain a single noise-reduced bipolar wave, and subsequently they will be inverted to a resistivity sounding.

7.3. TEMPERATURE AND HEAT FLOW

The heat flow probe was deployed on North Alex MV three times, resulting in a total of 38 successful in-situ sediment temperature measurements which are listed in table 10.5. Preliminary analyses of the collected data confirm that seepage is focussed at the center of the mud volcano, where temperatures of more than 50° C above bottom water temperature were found 4 m below the seabed (Fig. 7.3.1).

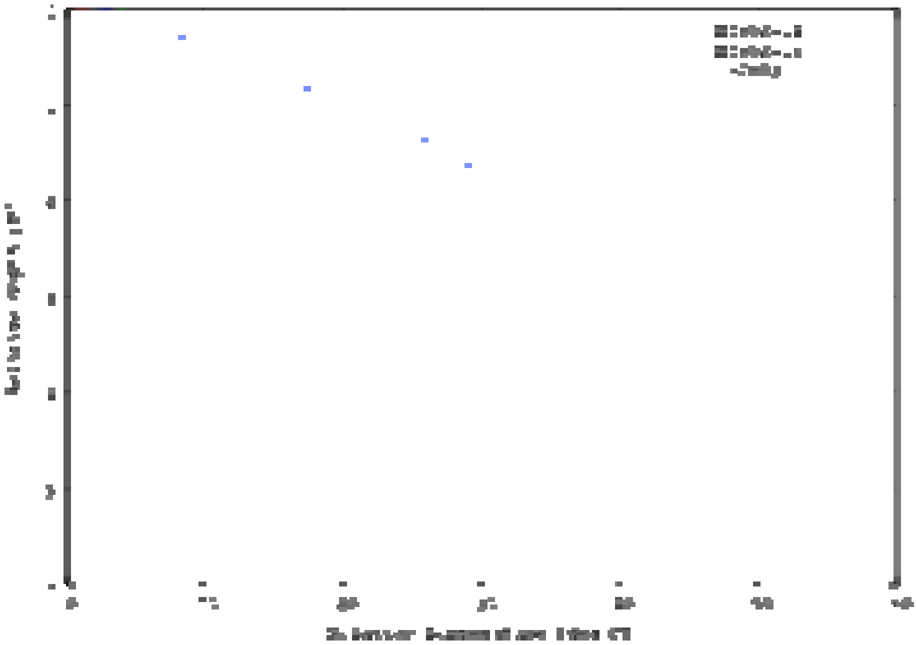
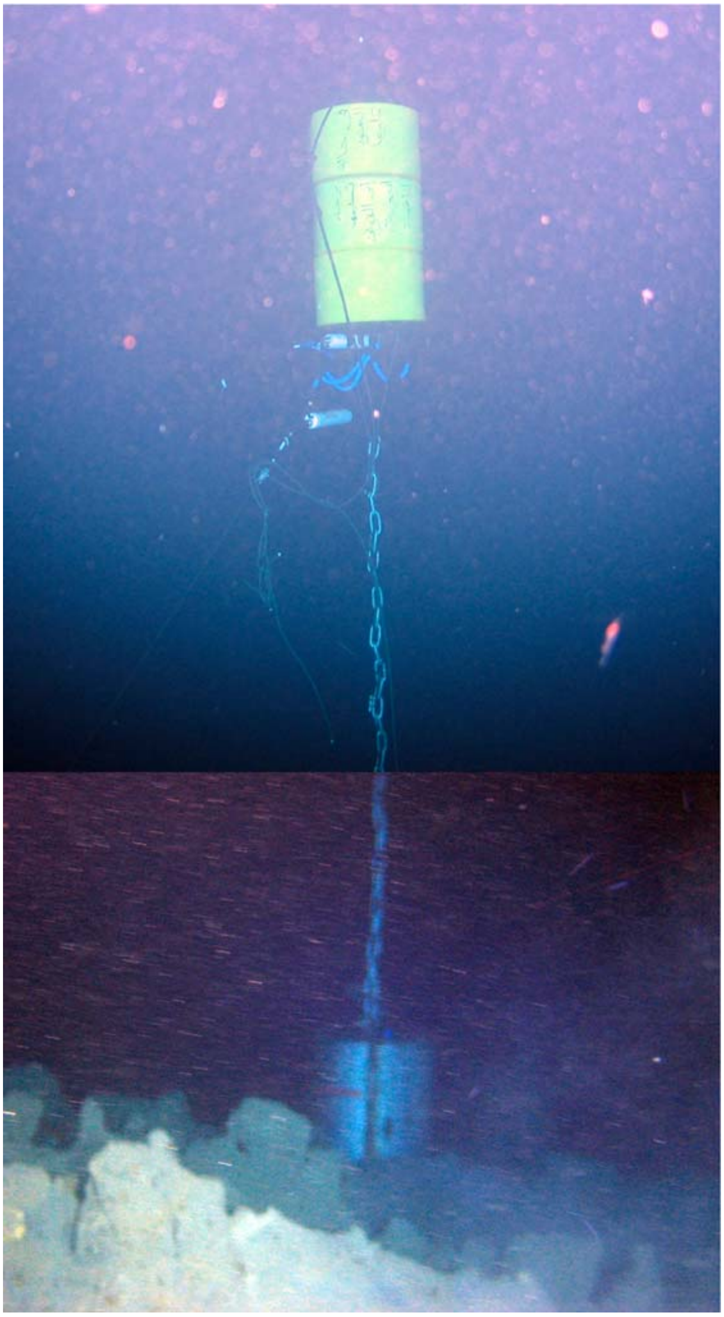


Figure 7.3.1: Temperature profiles recorded at North Alex mud volcano

Using the short temperature lance, shallow in-situ sediment temperature profiles were recorded at three locations during ROV dive 06 and on 5 deployments of the multicorer (MUC-20 through MUC-24). Bottom water temperature measurements were recorded during three dives of the ROV Cherokee.

The temperature observatory was installed approximately 50 m SE of the center, and the second thermistor chain was laid out across the center of the mud volcano. As shown in figure 7.3.2, the lance fully penetrated the seabed. Unfortunately, the connection between the data logger controlling the 100-m thermistor chain and the acoustic modem was damaged during the ROV operation so that only the vertical temperature profile data can be transmitted.



Firgure 7.3.2: ROV photograph of the temperature observatory

7.4. CAT METERS

A total of 6 CAT meters were successfully deployed on North Alex Mud volcano (Fig. and Tab. 11.6). The instruments were lowered to the seafloor by wireline and released from the wire by an acoustic releaser from a height of 30m above the seafloor. The exact locations were recorded by a GAPS transponder. In all cases, the instruments landed on the seafloor in an upright position. During the following ROV dives the instruments were deployed right next to the desired locations, the collection chamber placed on top of the seafloor feature and gently pushed into the sediment (Fig. 6.5.3e and f). In some instances it was not possible to push the chamber in all the way as required due to stiff sediments. e.g. in the center of North Alex MV.

One CAT meter was deployed together with OBT-1 at the rim of North Alex MV for measuring background fluid outflow at this site (Fig. 6.5.4c).

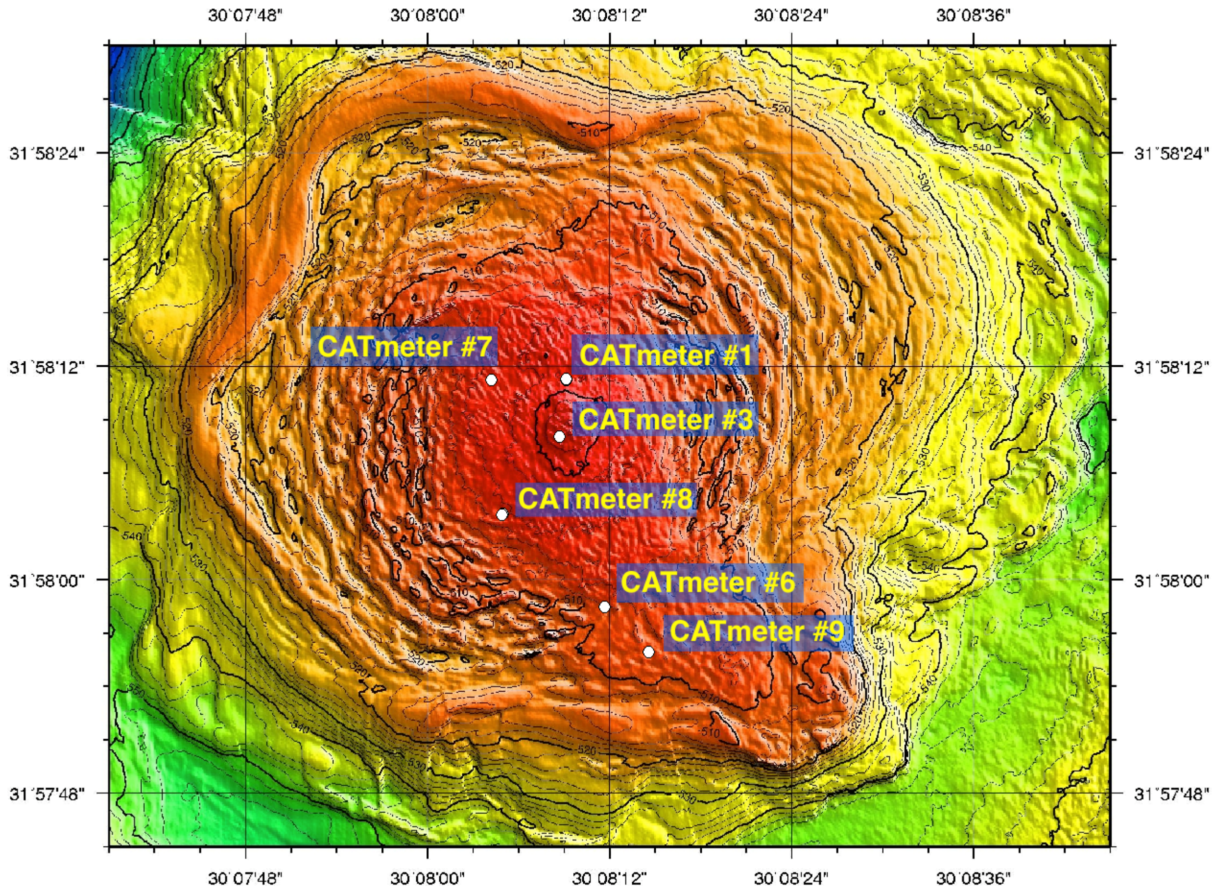


Figure 7.4.1: CAT meter deployment positions on North Alex-

7.5. GEOCHEMISTRY

The aim of this study was to understand the connection between fluid/methane discharge, biological processes, and geochemical reactions at the North Alex mud volcano. Microbial anaerobic oxidation of methane (AOM) with simultaneous sulfate reduction leads to precipitation of authigenic carbonates and accumulation of hydrogen sulfide in the sediment. Chemoautotrophic communities (free sulfur bacteria or symbiont clams and tube worms) utilize sulfide to gain energy for primary production.

At North Alex, several indications of chemoautrotrophy, which could be based on methane discharge, were found. The center of the mud volcano appeared to be most active with respect to methane flux and AOM. Here, free sulfur bacteria (*Beggiatoa* spp.) and symbiont clams (*Calyptogena* spp.) were found at the sediment surface (Fig. 7.5.1). Sediment cores from the center showed a completely dark gray to black color (indicating the presence of iron sulfides), a strong smell of hydrogen sulfide, a foamy consistency from degassing methane, and nuggets of authigenic carbonates (Table 11.7., Fig. 8.5.2 and 8.5.3, MUC 4-10, 20, 21, ROV 1). One sediment core harbored sub-surface symbiont clams (most likely *Acharax* spp., Fig. 7.5.1), which live in a U-shaped burrow inside the sediment and mine for sulfide in deeper parts.

Sediment cores taken in the south-east of the mud volcano, inside or close to a tubeworm field (Fig. 7.5.4), are most likely to represent slightly lower methane fluxes and AOM rates compared than at the center. Here, dark gray sediments were covered by a gray-greenish top layer, i.e., methane had probably already been oxidized in the deeper sediment parts (Table 7.5.1., Fig. 7.5.2, MUC 18 and 19, ROV 17). Tube worms (Fig. 8.5.1) are able to reach deep hydrogen sulfide sources via the long roots of their tubes, which extend into the sediment. The clam *Lucinoma* spp. (Fig. 7.5.1), which was found in association with the tube worms, is described to be independent from its sulfide-oxidizing symbionts in times of low sulfide availability by switching to a normal feeding behavior. This is another indication that methane flux might be lower or infrequent in this area. Sediments taken directly from the tube worm field exhibited coarse carbonate nuggets.

The lowest or even no methane flux and AOM can be expected at locations sampled in the north-east of the mud volcano (Table 11.7, Fig. 7.5.2, MUC 18 and 19). The sediments from these parts showed no indications for sulfide production via methane oxidation in the top 40 cm, i.e., they were completely gray-greenish, without any dark color, sulfidic smell or carbonates. All cores revealed signs of bioturbation (burrows of several centimeters in depts left by unknown animals).

Biogeochemical data and a confirmation of the organisms' ID are not yet available. The samples taken at North Alex will be processed and identified in the home laboratory.

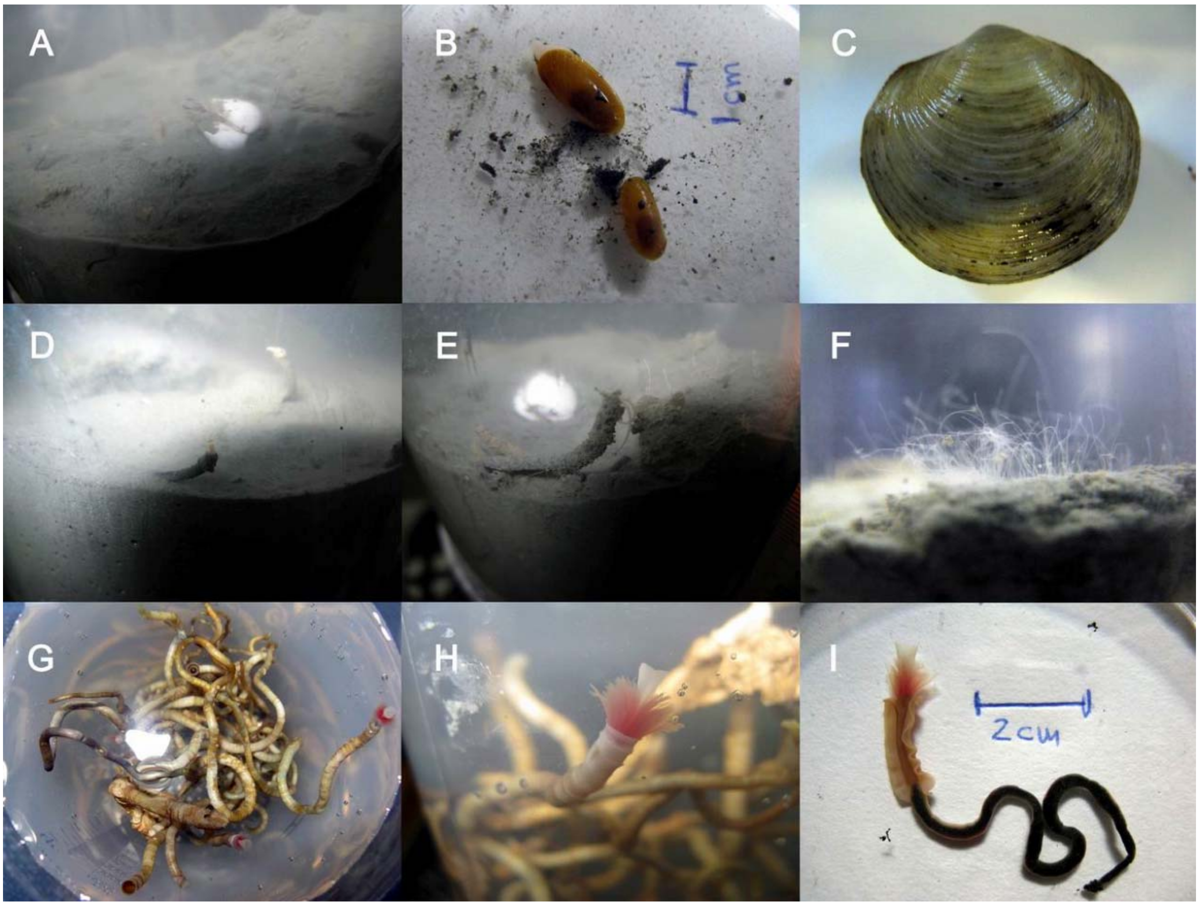


Figure 8.5.1: Organisms sampled at North Alex:
(A) symbiotic clam *Calyptogena* spp., MUC 4,
(B) symbiotic clam *Acharax* spp., MUC 21,
(C) symbiotic clam *Lucinoma* spp., ROV 17,
(D) Polychaetes, MUC 4,
(E), Polychaetes, MUC 4,
(F) filaments of the sulfur-bacteria *Beggiatoa* spp., ROV 1,
(G-I) symbiotic tubeworms *Lamellibrachia* spp., ROV 17.
Species ID's are preliminary and need to be confirmed.

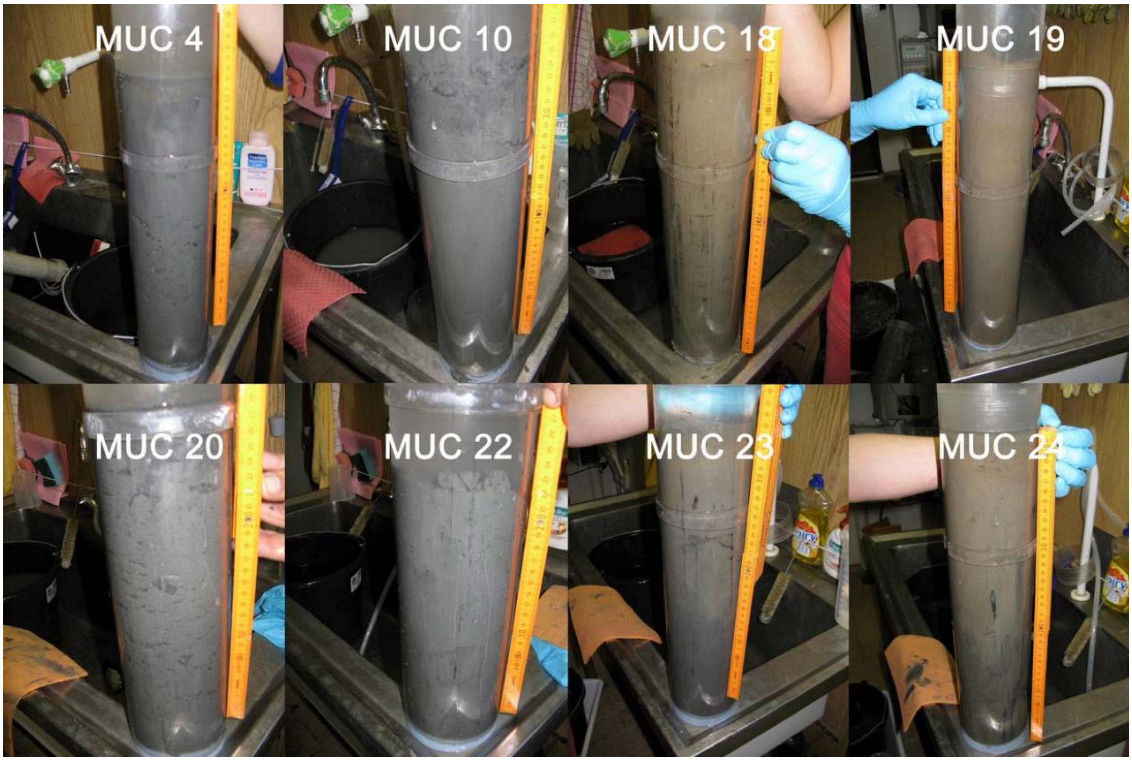


Figure 8.5.2: Selection of sediment cores retrieved by multicoring. A dark sediment color (most likely from iron sulfides) indicates cold-seep related microbial activity (anaerobic oxidation of methane coupled to sulfate reduction).

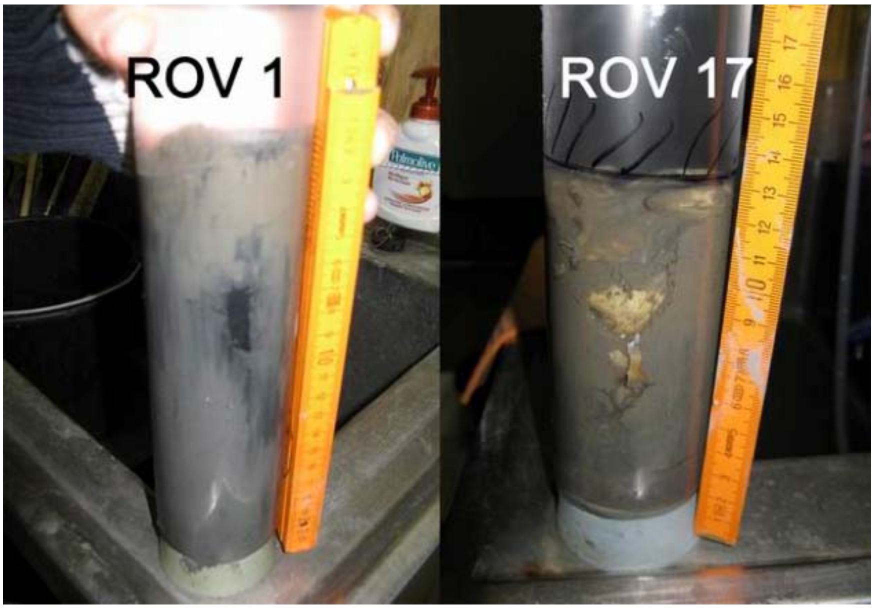


Figure 8.5.3: Selection of sediment cores retrieved by the ROV. The ROV 1 core was covered by a small *Beggiatoa* mat (free sulfur bacteria). The ROV 17 core had clams (possibly *Lucinoma* spp.), tubeworm remains, and carbonates.

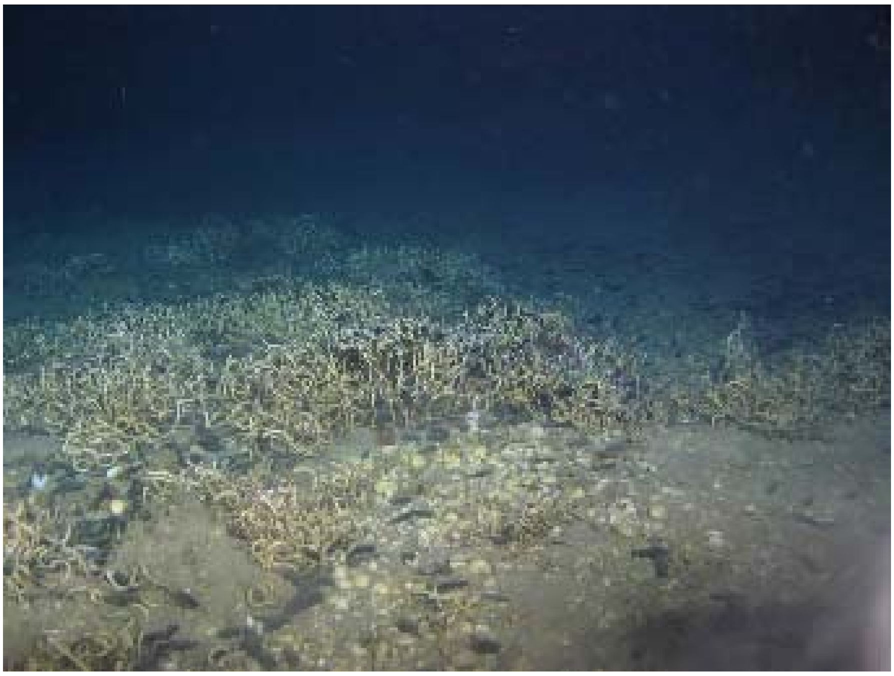


Figure 7.5.4: The tube worm seep area sampled during ROV dive 17. Tube worms form bush-like structures, which are used as nursery ground by rays (black-brown spots in the pictures were ray eggs). Around and between the tube worms, dead and living clams (probably *Lucinoma* spp.) were visible. The picture was taken by the ROV Cherokee.

8. WORK PERFORMED: GIZA

8.1. MCS SEISMICS

During cruise 64PE298 of R/V PELAGIA a grid of seven active seismic profiles was acquired across Giza mud volcano (Fig. 8.1.1, Tab. 10.8). Airgun shots were fired every 7 seconds by means of a GI airgun with a 105 cinch generator and a 105 cinch injector volume.

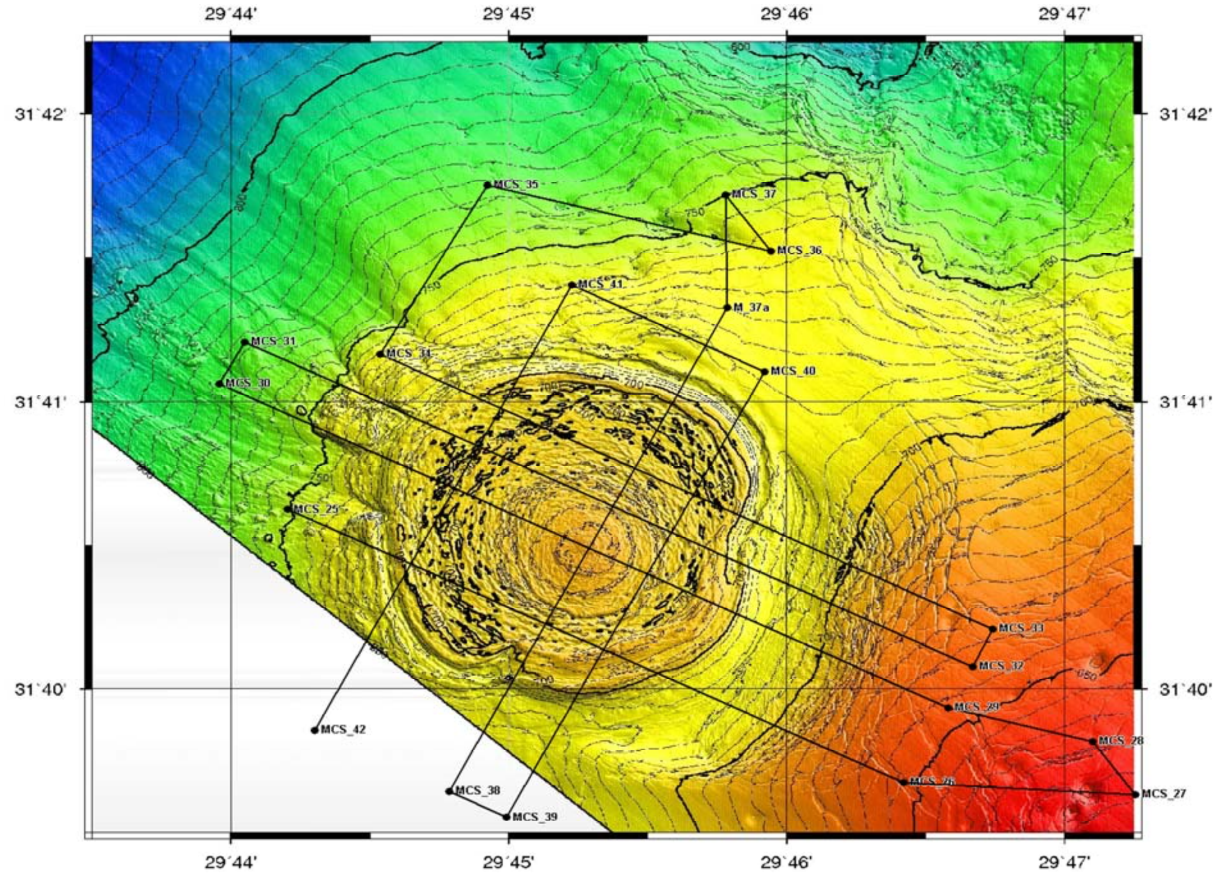


Figure 8.1.1: Map of seismic lines across Giza mud volcano.

The single-channel seismic section of profile 31 (Fig. 8.1.2) shows the good data quality achieved. A bandpass filter (10 Hz to 150 Hz) and a 200-ms-long AGC were only applied for preliminary data processing. Clear sediment reflections can be detected until the arrival of the multiple event. The prominent feature of the mud volcano is clearly visible in the center of the line. Some weak events at later travel times between shotpoint 100 and 300 suggest that more details will be achieved after migration and stacking processes have been applied. An interesting feature is found in the form of an inverted reflection to both sides of the mud volcano at about 1.2 s TWT. This might be an indication for a gas front as this event is interrupted in the vicinity of a pockmark depression at the seafloor (shotpoint 25).

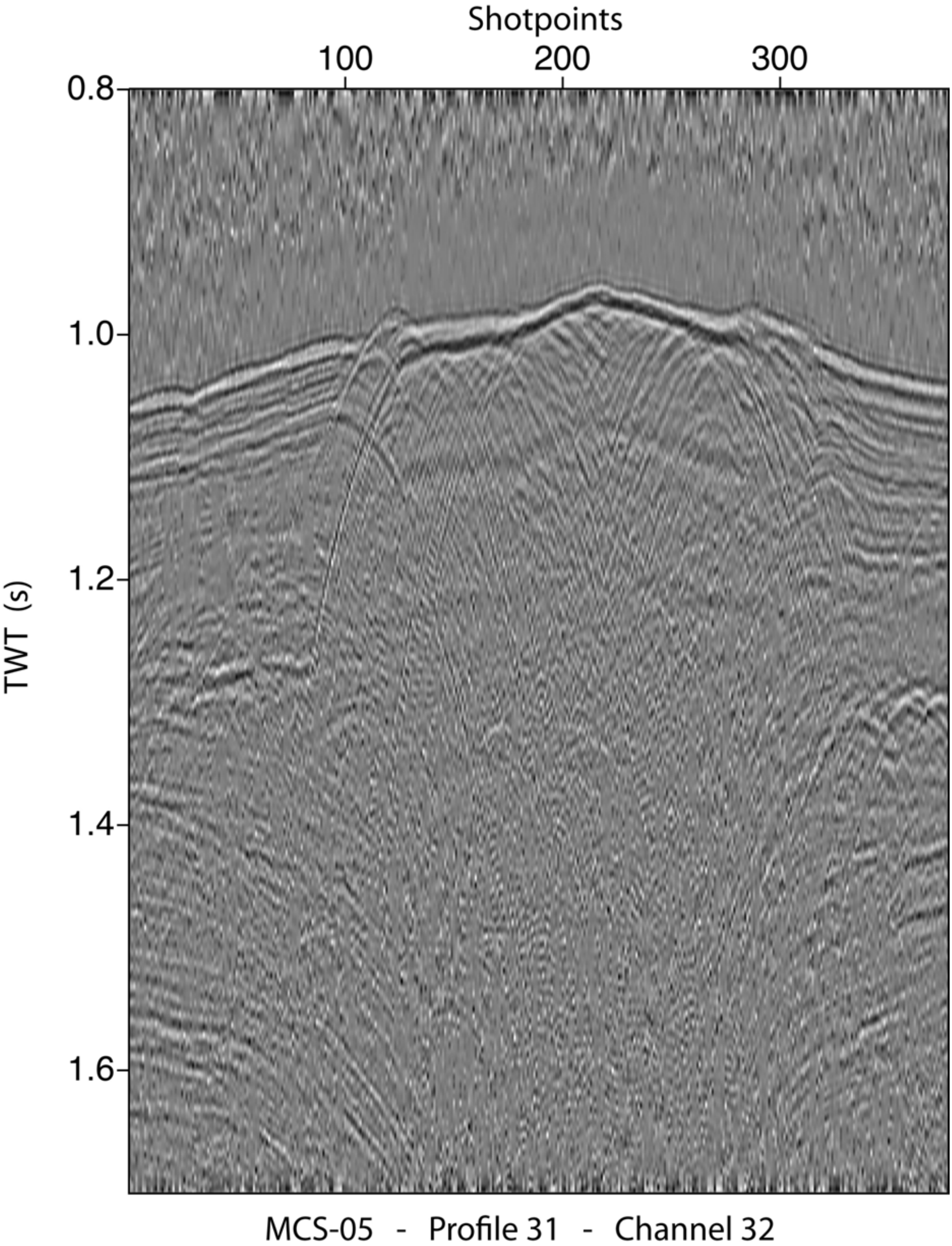


Figure 8.1.2: Single-channel section of profile 31

8.2. TEMPERATURE AND HEAT FLOW

There was only one deployment of the heat flow probe at Giza MV, resulting in 21 successful in-situ sediment temperature measurements at selected locations on the mud volcano. All stations are listed in table 10.9. Preliminary analyses of the collected data suggest that Giza MV has been inactive since it was last probed on cruise P362/2 of R/V Poseidon in February 2008. The highest temperatures (around 17° C above bottom water temperature) were found at the center of the mud volcano at 6 m below the seabed (Fig. 8.2.1). Bottom water temperature measurements were taken during one dive of the ROV Cherokee.

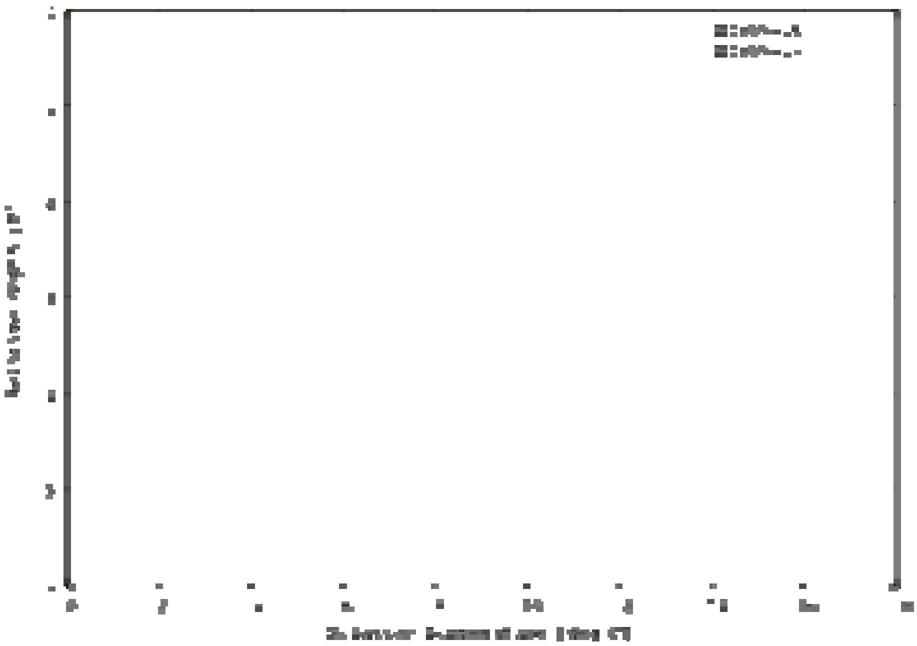


Figure 8.2.1: Temperature profiles measured at Giza mud volcano.

The temperature observatory was installed close to the center of the mud volcano and the second thermistor chain was laid out on the seafloor away from the center to the position of the CAT-meter. Figure 8.2.2 shows that only the lower part of the lance penetrated the sediments.

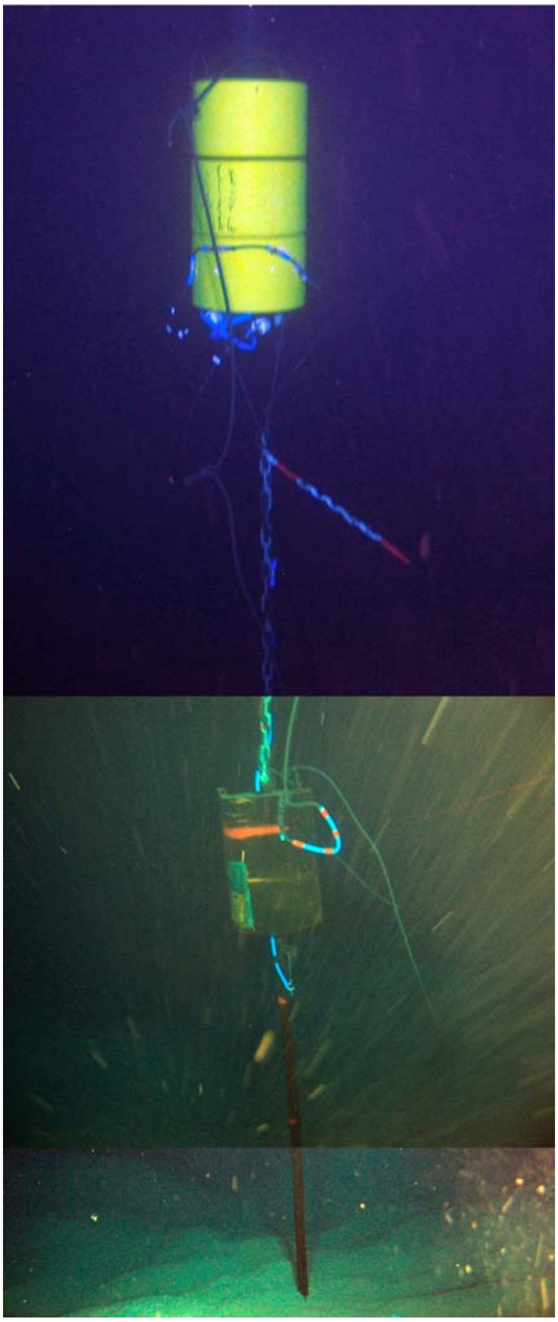
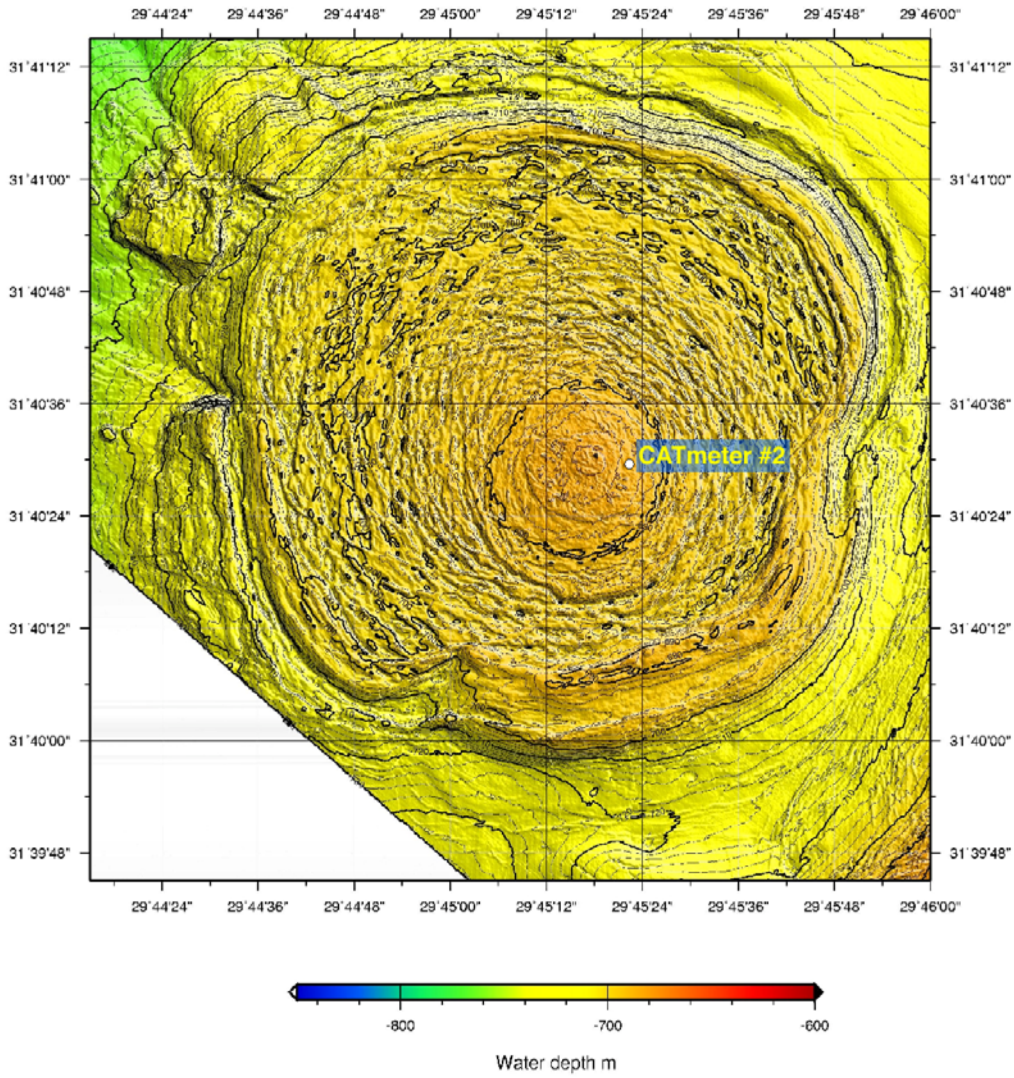


Figure 9.2.2: Photograph of the Giza mud volcano long-term temperature observatory

8.3. CAT METERS

Only one CATmeter with release system was deployed at the center of Giza MV (Tab. 10.10). This decision was prompted by the apparent lack of activity at Giza and the need to focus our observation work on one mud volcano, i.e. North Alex.



9. ACKNOWLEDGEMENTS

Our thanks go to the captain and crew of R/V PELAGIA. It is because of their outstanding support throughout the entire cruise that all investigations could be completed with great success. We thank RWE/Dea for funding this project and for their support during the permitting process.

10. APPENDIX

Tab. 10.1: List of all long-term installations deployed on cruise 64PE298.

Instrument	Latitude N	Longitude E	Height above seafloor	Remarks
CAT Meter #8	31:58.062	30:08.083	1 m	
CAT Meter #1	31:58.188	30:08.153	1 m	
CAT Meter #9	31:57.932	30:08.243	1 m	
CAT Meter #3	31:58.134	30:08.145	1 m	
CAT Meter #6	31:57.974	30:08.195	1 m	
CAT Meter #7	31:58.187	30:08.070	1 m	On frame of OBT #1
CAT Meter #2	31:40.492	29:45.372	1 m	
Temperature #1	31:58.109	30:08.167	5 m	Acoustic modem with float
Temperature #1b	31:58.155	30:08.148	0.5	Seafloor sensor
Temperature #2	31:40.497	29:45.313	5 m	Acoustic modem with float
Temperature #2b	31:40.492	29:45.366	0.5 m	Seafloor sensor
OBS #7	31:58.552	30:07.312	1.5 m	
OBS #8	31:58.793	30:08.765	1.5 m	
OBS #9	31:58.181	30:08.116	1.5 m	
OBS #10	31:57.839	30:09.197	1.5 m	
OBS #11	31:57.545	30:07.290	1.5 m	
OBS #12	31:56.950	30:08.341	1.5 m	
OBT #1	31:58.189	30:08.067	2 m	With CAT Meter
OBT #2	31:58.177	30:08.218	2 m	
OBT #3	31:58.075	30:08.118	2 m	

Any reports or findings of instruments washed ashore please report to:

Leibniz Institute for Marine Science
IFM-GEOMAR
Dr. J. Bialas / Dr. W. Brueckmann
East Shore Building
Wischhofstr. 1-4
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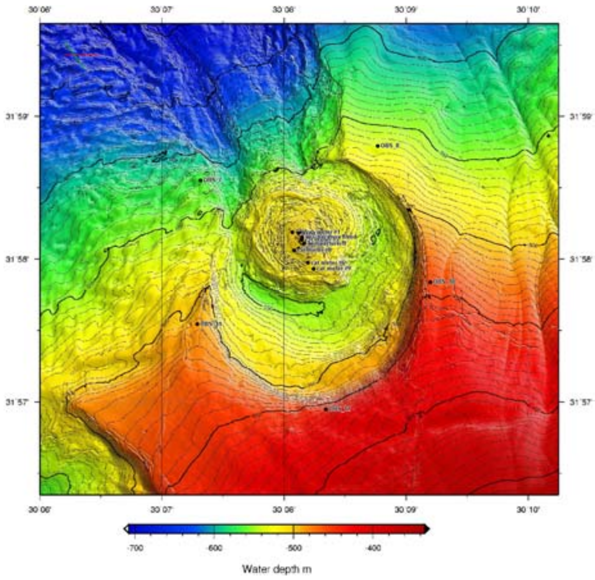
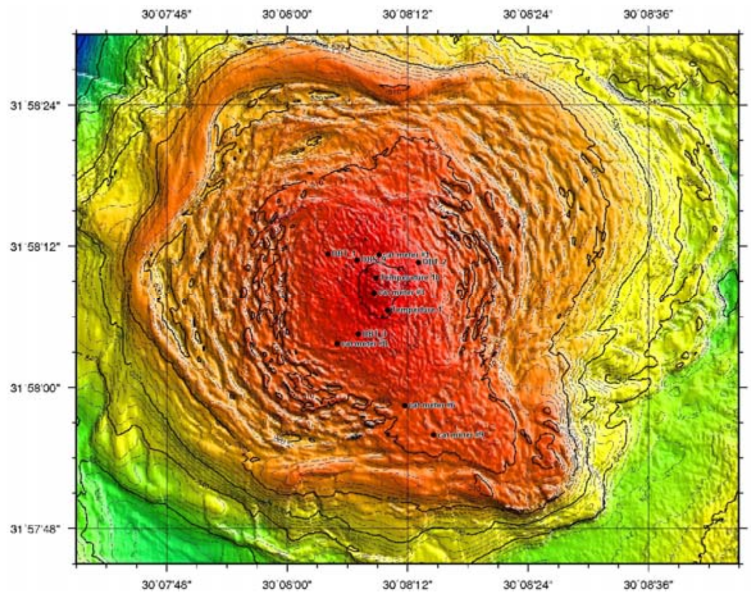
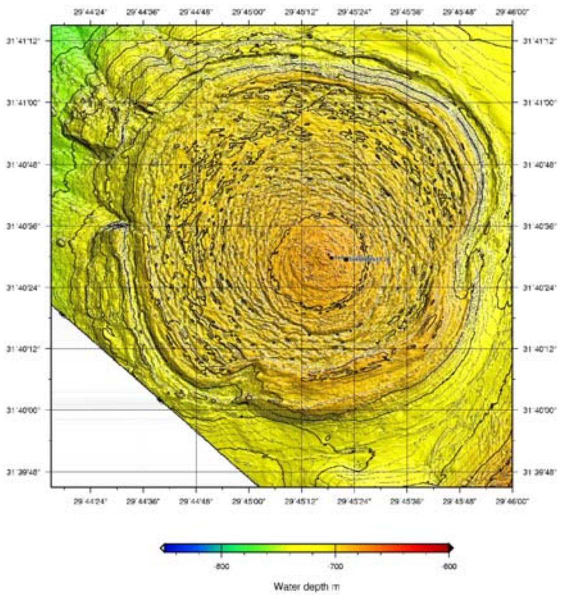
Map of North Alex mud volcano with installations:





Map of Giza mud volcano with installations:

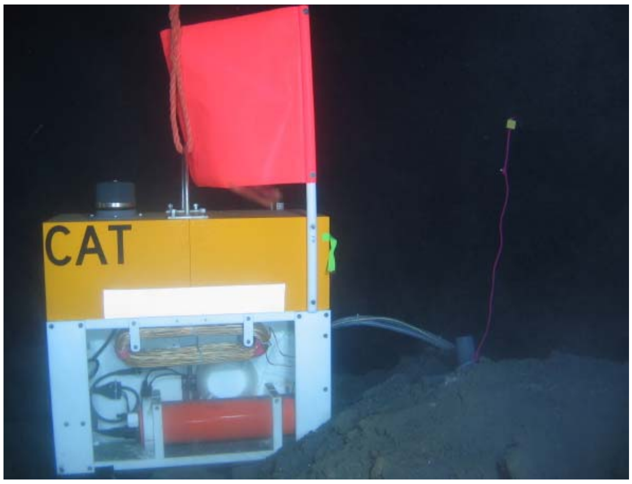


Picture of an OBS instrument:

Picture of an OBT instrument deployed at the seafloor:

Picture of a Temperature station at the seafloor:

Picture of a CAT Meter at the seafloor:



Tab 10.2: Short-term OBS deployments (10th Nov. – 16th Nov. 2008)

Date	Time (UTC)	Lat (N)	Lon (E)	Depth (m)	
10.11.2008	09:26:55	31.96110	30.13928	544	OBS-1
10.11.2008	12:09:30	31.96667	30.13683	500	OBS-2
10.11.2008	13:09:00	31.97060	30.13565	495	OBS-3
10.11.2008	14:17:16	31.98017	30.13115	575	OBS-4
10.11.2008	14:53:01	31.96845	30.12697	532	OBS-5
11.11.2008	07:00:56	31.97358	30.14362	532	OBS-6

Tab. 10.3: MCS profiles at North Alex

Tab. 10.4: CSEM Stations and profiles at North Alex

Table 10.5: Heat flow probe stations on North Alex MV

Series	Pen.	Date	Time UTC	Lat			Lon			Comment
H0802	1	09.11.2008	21:15	N	31°	57.736'	E	030°	8.396'	
	2	09.11.2008	21:54	N	31°	57.886'	E	030°	8.316'	
	3	09.11.2008	22:16	N	31°	57.966'	E	030°	8.261'	
	4	09.11.2008	22:45	N	31°	58.038'	E	030°	8.208'	
	5	09.11.2008	23:07	N	31°	58.100'	E	030°	8.200'	
	6	09.11.2008	23:27	N	31°	58.154'	E	030°	8.155'	
	7	10.11.2008	00:12	N	31°	58.185'	E	030°	8.163'	
	8	10.11.2008	00:29	N	31°	58.223'	E	030°	8.124'	
	9	10.11.2008	00:51	N	31°	58.316'	E	030°	8.095'	
	10	10.11.2008	02:22	N	31°	58.441'	E	030°	7.994'	
	11	10.11.2008	03:24	N	31°	57.990'	E	030°	7.900'	with conductivity measurement
	12	10.11.2008	04:22	N	31°	58.029'	E	030°	8.010'	failed
	13	10.11.2008	04:45	N	31°	58.103'	E	030°	8.121'	failed
	14	10.11.2008	05:11	N	31°	58.139'	E	030°	8.162'	
	15	10.11.2008	05:33	N	31°	58.138'	E	030°	8.175'	
H0803	1	10.11.2008	17:41	N	31°	58.143'	E	030°	8.167'	
	2	10.11.2008	18:16	N	31°	58.155'	E	030°	8.199'	
	3	10.11.2008	18:34	N	31°	58.170'	E	030°	8.249'	

H0804	1	17.11.2008	11:54	N	31°	58.092'	E	030°	8.080'
	2	17.11.2008	12:15	N	31°	58.101'	E	030°	8.103'
	3	17.11.2008	12:31	N	31°	58.113'	E	030°	8.131'
	4	17.11.2008	12:45	N	31°	58.126'	E	030°	8.147'
	5	17.11.2008	13:17	N	31°	58.142'	E	030°	8.178'
	6	17.11.2008	13:34	N	31°	58.152'	E	030°	8.202'
	7	17.11.2008	13:50	N	31°	58.157'	E	030°	8.222'
	8	17.11.2008	14:12	N	31°	58.168'	E	030°	8.241'
	9	17.11.2008	14:29	N	31°	58.179'	E	030°	8.269'
	10	17.11.2008	15:00	N	31°	58.222'	E	030°	8.357'
	11	17.11.2008	15:26	N	31°	58.268'	E	030°	8.452'
	12	17.11.2008	15:48	N	31°	58.319'	E	030°	8.563'

Table 10.6: CAT meter installations at North Alex

CAT#	Longitude E	Latitude N	ROV-Dive #	Time of chamber installation GMT	Site description
1	31° 58.1877	30° 08.1528	5	15.11.2008@13:20	North Alex MV, background flow site
8	31° 58.0616	30° 08.0829	5	15.11.2008@15:00	North Alex M, near small bacterial mat patch in very rough topography
3	31° 58.1340	30° 08.1450	8	17.11.2008@07:45	North Alex MV, bubble site near surface temperature cable
6	31° 57.9740	30° 08.1950	8	17.11.2008@06:15	North Alex MV, near a black bacterial mat

9	31° 57.9320	30° 08.2430	8	17.11.2008@05:15	North Alex MV, near pogonophara field
7	31° 58.1870	30° 08.0700	15	19.11.2008@21:15	Nort Alex MV, with OBT-1 tiltmeter w/o gas sampler, background site

Table 10.7: Multicorer (MUC) and ROV/push core (PC) stations at North Alex. MUC 1-3, 5-7, 11-17, and 22 were empty. MUC 20-24 were deployed for 7 minutes for temperature measurements with an attached temperature probe.

Station	**Date**	**Time (UTC)**	**Lat (N)**	**Long (E)**	**Depth (m)**	**North Alex Location**
MUC 4	11.11.2008	17:13	31:58.148	30:08.173	492	Center
MUC 8	13.11.2008	13:05	31:58.148	30:08.190	492	Center
MUC 9	13.11.2008	13:31	31:58.172	30:08.173	492	Center
MUC 10	13.11.2008	14:10	31:58.186	30:08.167	493	Center
MUC 18	14.11.2008	11:30	31:58.294	30:08.190	500	North West
MUC 19	14.11.2008	12:10	31:58.306	30:08.183	500	North West
MUC 20	17.11.2008	8:40	31:58.152	30:08.161	492	Center
MUC 21	17.11.2008	9:20	31:58.160	30:08.182	492	Center
MUC 23	20.11.2008	12:45	31.57.945	30:08.244	502	South East
MUC 24	20.11.2008	13:31	31:57.942	30.08.237	503	North Alex, South East
ROV 1, PC 1	11.11.2008	21:18	31:58.078	30:08.138	502	Center

ROV 17, PC 1-3	22.11.2008	8:27	31:57.9551	30:08.2388	497	South East

Table 10.8: MCS profiles at North Alex.

Table 10.9: Heat flow probe stations on Giza MV.

Series	Pen.	Date	Time UTC	Lat			Lon			Comment
H0805	1	18.11.2008	07:53	N	31°	40.292	E	029°	45.909	
	2	18.11.2008	08:20	N	31°	40.344	E	029°	45.741	
	3	18.11.2008	08:43	N	31°	40.418	E	029°	45.522	
	4	18.11.2008	09:02	N	31°	40.447	E	029°	45.422	
	5	18.11.2008	09:22	N	31°	40.472	E	029°	45.364	
	6	18.11.2008	10:00	N	31°	40.537	E	029°	45.181	
	7	18.11.2008	10:25	N	31°	40.585	E	029°	45.042	
	8	18.11.2008	10:57	N	31°	40.674	E	029°	44.743	
	9	18.11.2008	11:30	N	31°	40.769	E	029°	44.523	
	10	18.11.2008	12:06	N	31°	40.836	E	029°	44.183	
	11	18.11.2008	13:37	N	31°	40.046	E	029°	44.899	
	12	18.11.2008	13:58	N	31°	40.173	E	029°	44.997	
	13	18.11.2008	14:25	N	31°	40.292	E	029°	45.109	
	14	18.11.2008	14:45	N	31°	40.399	E	029°	45.197	
	15	18.11.2008	15:08	N	31°	40.453	E	029°	45.240	
	16	18.11.2008	15:24	N	31°	40.488	E	029°	45.270	
	17	18.11.2008	16:14	N	31°	40.493	E	029°	45.270	
	18	18.11.2008	16:36	N	31°	40.534	E	029°	45.302	
	19	18.11.2008	16:53	N	31°	40.594	E	029°	45.358	
	20	18.11.2008	17:18	N	31°	40.710	E	029°	45.449	
	21	18.11.2008	17:38	N	31°	40.827	E	029°	45.448	

Table 10.10: CAT meter installations at North Alex

CAT#	Longitude E	Latitude N	ROV-	Time of chamber	

			Dive #	installation GMT	Site description
2	31° 40.4920	29° 45.3720	12	19.11.2008@17:45	Giza MV, near white bacterial mat next to end of surface temperature cable

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No.	Title
1	RV Sonne Fahrtbericht / Cruise Report SO 176 & 179 MERAMEX I & II (Merapi Amphibious Experiment) 18.05.-01.06.04 & 16.09.-07.10.04. Ed. by Heidrun Kopp & Ernst R. Flueh, 2004, 206 pp. In English
2	RV Sonne Fahrtbericht / Cruise Report SO 181 TIPTEQ (from The Incoming Plate to mega Thrust EarthQuakes) 06.12.2004.-26.02.2005. Ed. by Ernst R. Flueh & Ingo Grevemeyer, 2005, 533 pp. In English
3	RV Poseidon Fahrtbericht / Cruise Report POS 316 Carbonate Mounds and Aphotic Corals in the NE-Atlantic 03.08.–17.08.2004. Ed. by Olaf Pfannkuche & Christine Utecht, 2005, 64 pp. In English
4	RV Sonne Fahrtbericht / Cruise Report SO 177 - (Sino-German Cooperative Project, South China Sea: Distribution, Formation and Effect of Methane & Gas Hydrate on the Environment) 02.06.-20.07.2004. Ed. by Erwin Suess, Yongyang Huang, Nengyou Wu, Xiqiu Han & Xin Su, 2005, 154 pp. In English and Chinese
5	RV Sonne Fahrtbericht / Cruise Report SO 186 – GITEWS (German Indonesian Tsunami Early Warning System 28.10.-13.1.2005 & 15.11.-28.11.2005 & 07.01.-20.01.2006. Ed. by Ernst R. Flueh, Tilo Schoene & Wilhelm Weinrebe, 2006, 169 pp. In English
6	RV Sonne Fahrtbericht / Cruise Report SO 186 -3 – SeaCause II, 26.02.-16.03.2006. Ed. by Heidrun Kopp & Ernst R. Flueh, 2006, 174 pp. In English
7	RV Meteor, Fahrtbericht / Cruise Report M67/1 CHILE-MARGIN-SURVEY 20.02.-13.03.2006. Ed. by Wilhelm Weinrebe und Silke Schenk, 2006, 112 pp. In English
8	RV Sonne Fahrtbericht / Cruise Report SO 190 - SINDBAD (Seismic and Geoacoustic Investigations Along The Sunda-Banda Arc Transition) 10.11.2006 - 24.12.2006. Ed. by Heidrun Kopp & Ernst R. Flueh, 2006, 193 pp. In English
9	RV Sonne Fahrtbericht / Cruise Report SO 191 - New Vents "Puaretanga Hou" 11.01. - 23.03.2007. Ed. by Jörg Bialas, Jens Greinert, Peter Linke, Olaf Pfannkuche, 2007, 190 pp. In English

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