

BERICHTE

aus dem MARUM und dem Fachbereich
Geowissenschaften der Universität Bremen

No. 309

Sahling, H.

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R/V POSEIDON CRUISE REPORT POS498

RECOVERY OF OBSERVATORIES AT ATHINA MUD VOLCANO

IZMIR (TURKEY) – CATANIA (ITALY)
18 APRIL – 1 MAY, 2016



Berichte, MARUM – Zentrum für Marine Umweltwissenschaften, Fachbereich
Geowissenschaften, Universität Bremen, No. 309, 63 pages, Bremen 2016

ISSN 2195-9633

Berichte aus dem MARUM und dem Fachbereich Geowissenschaften der Universität Bremen

published by

MARUM – Center for Marine Environmental Sciences

Leobener Strasse, 28359 Bremen, Germany

www.marum.de

and

Fachbereich Geowissenschaften der Universität Bremen

Klagenfurter Strasse, 28359 Bremen, Germany

www.geo.uni-bremen.de

The "Berichte aus dem MARUM und dem Fachbereich Geowissenschaften der Universität Bremen" appear at irregular intervals and serve for the publication of cruise, project and technical reports arising from the scientific work by members of the publishing institutions.

Citation:

Sahling, H., Loher, M., Menapace, W., Voelker, D., Bihler, V., Nowald, N., Seiter, Chr., Leymann, T., Vittori, V., Darilmaz, E., Karaaslan, N.: R/V POSEIDON cruise POS498, Recovery of Observatories at Athina Mud Volcano, Izmir (Turkey) – Catania (Italy), 18 April – 1 May, 2016. Berichte, MARUM – Zentrum für Marine Umweltwissenschaften, Fachbereich Geowissenschaften, Universität Bremen, No. 309, 63 pages. Bremen, 2016. ISSN 2195-9633.

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Recovery of Observatories at Athina Mud Volcano

Izmir (Turkey) – Catania (Italy)
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Cruise sponsored by Deutsche Forschungsgemeinschaft (DFG) through
MARUM – Center for Marine Environmental Sciences

The cruise was performed by
MARUM – Center for Marine Environmental Sciences

2016

R/V Poseidon Cruise Report POS498

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1 Summary

During R/V POSEIDON Cruise POS498 (Figs. 1.1-1.2) two observatories were recovered from the seafloor with the help of the Remotely Operated Vehicle (ROV) MARUM-SQUID. The observatories were deployed during the R/V MARIA S. MERIAN Cruise MSM 35T on 8 February 2014 at Athina Mud Volcano to monitor the activity in terms of fluid flow and mud volcanic eruptions. Athina Mud Volcano is located at ~1800 m water depth in the Anaximander Mountains. One observatory recorded the temperature in the sediments (T-lance). The other observatory recorded the pore pressure at ~2 m sediment depth (P-lance). The P-lance was also equipped with an in-situ porewater sampler driven by an osmotic pump. The observatories were developed within the cross cutting project (CCP 4) *mud volcanic episodicity* at MARUM. The observatories were successfully recovered during two dives with the ROV. The data logger successfully recorded the parameters temperature and pressure during the entire deployment period. While the temperature variations were generally small, the complex pattern of variability in pore pressure supposes considerable changes in the fluid flow through the mud volcano. Detailed analyses of the pressure changes as well as the analytics of the sampled pore water in-situ will be conducted on shore. Due to technical problems, no further dive to the mud volcanoes was possible during the cruise.

The second main objective of the cruise was to recover sediments to study the thermal structure as well as the temporal evolution of the mud volcanoes. In order to achieve this, the gravity corer was equipped with autonomously recording temperature loggers on the outside of the barrel. Sediments and temperature gradients were successfully obtained at Athina and Amsterdam Mud Volcano. On-shore analyses of the comprehensive samples and data will help to better understand the activity of the mud volcanoes with regard to the timing and magnitude of mud eruption and fluid flow during quiescent periods. Planned sediment sampling with a multicorer for undisturbed surface sediments was not successful due to malfunction of the tool. Multibeam echosounder (MBES) data with the hull mounted ELAC swath sounder (SB3050) was acquired in the area of Amsterdam, Athina, and Kazan Mud Volcano in order to increase the quality of the bathymetric maps. Due to the limited resolution of the MBES, the already existing data recorded during the R/V METEOR Cruise M70/3 could only be marginally improved. In order to acquire sound velocity profiles (SVP) for the hydroacoustic equipment ELAC and the underwater subpositioning system GAPS, a memory CTD was deployed several times.

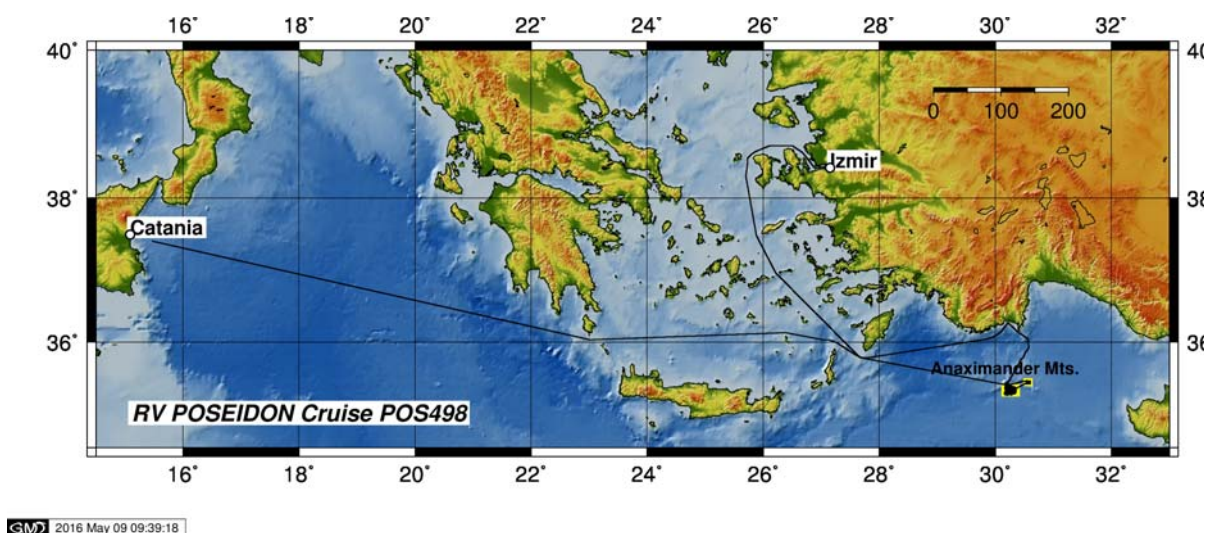


Fig. 1.1: Cruise track of R/V POSEIDON Cruise POS498 (18 April – 1 May 2016, Izmir – Catania).

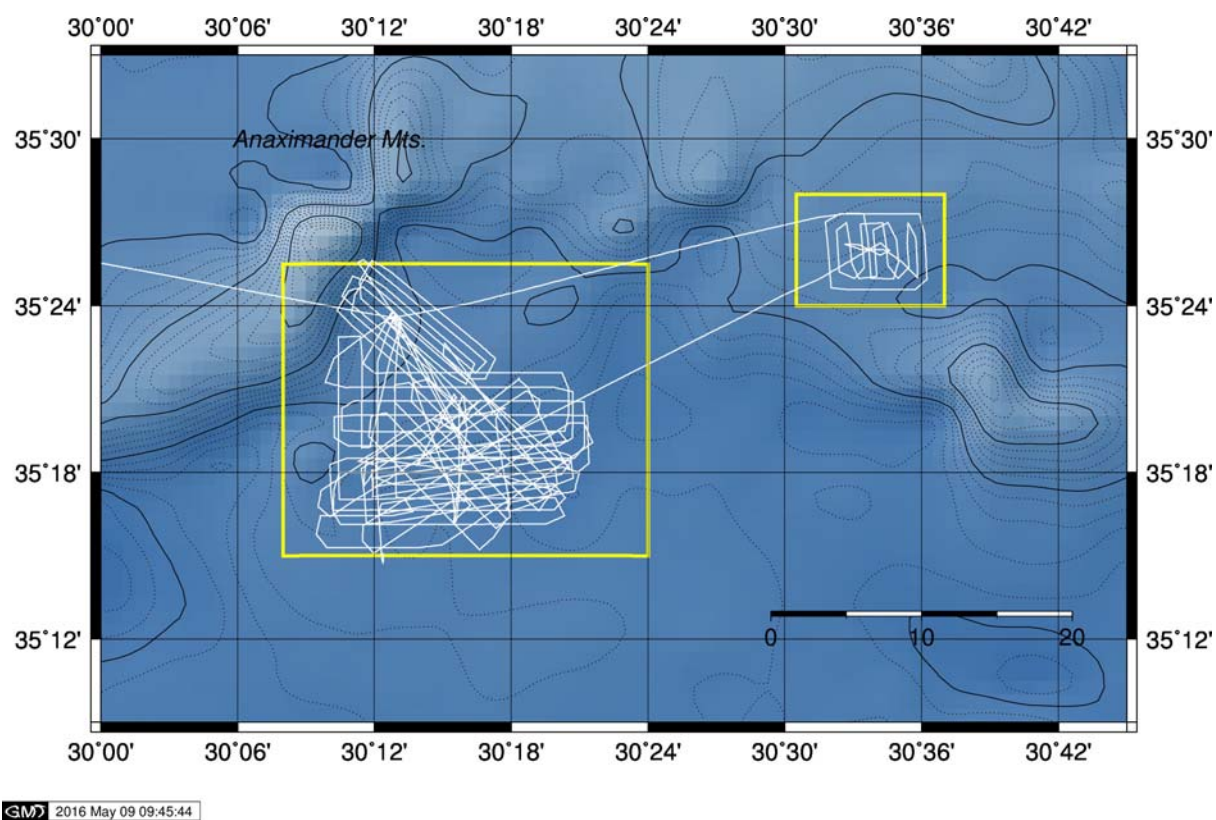


Fig. 1.2: Cruise track of R/V POSEIDON Cruise POS498 (18 April – 1 May 2016, Izmir – Catania) in the working area of the Anaximander Mountains.

2 Participants

Table 1: Scientific crew

Name	Discipline	Affiliation
Sahling, Heiko, Dr.	Chief Scientist	MARUM
Loher, Markus	Sediments	MARUM
Menapace, Walter	Observatories	MARUM
Voelker, David, Dr.	Multibeam	MARUM
Bihler, Viola	Sediments	MARUM
Nowald, Nicolas, Dr.	ROV	MARUM
Seiter, Christian	ROV	MARUM
Leymann, Tom	ROV	MARUM
Vittori, Vincent	ROV	MARUM
Darilmaz, Enis	Observer	DEU
Karaaslan, Nuri	Observer	Turk. Mar.

MARUM Center for Marine and Environmental Sciences, DFG Research Center and Cluster of Excellence, University of Bremen, Postfach 330440, 28334 Bremen, **Germany**

DEU Institute of Marine Sciences and Technology, Dokuz Eylul University, Izmir, **Turkey**

Turk. Mar. Department of Hydrography and Oceanography, Turkish Marine Military, Istanbul, **Turkey**

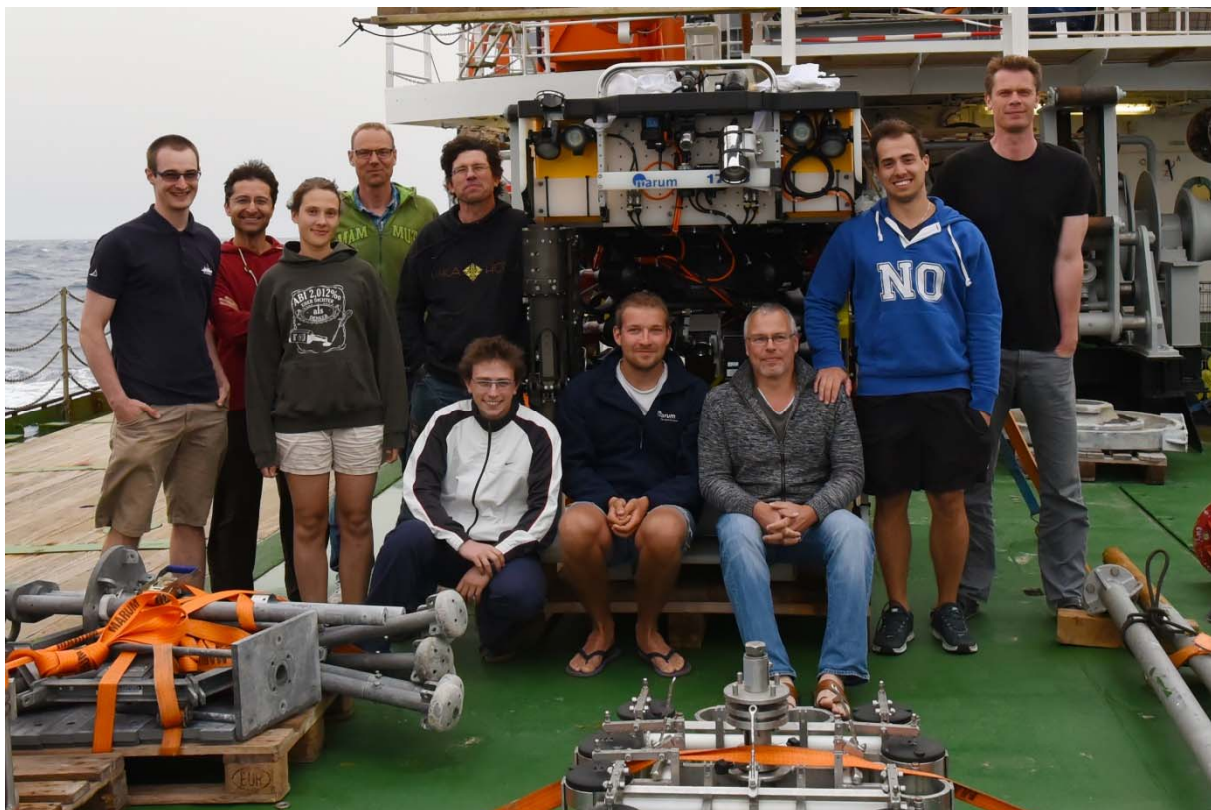


Fig. 2: Scientific crew onboard R/V POSEIDON during POS498.

Table 2: Crew members onboard

Name	Discipline
Günther, Matthias	Master
Griese, Theo	Chief Officer
Pegel, Sebastian	2 nd Officer
Freund, Hans-Jörg	Chief Engineer
Pieper, Carsten	2 nd Engineer
Neitzel, Gerd	Electrician
Engel, Rüdiger	Motorman
Mischker, Joachim	Bosom
Meyer, Felix	Seaman
Mailing, Ralf	Seaman
Rauh, Bernd	Seaman
Kuhn, Ronald	AB
Von Keller, Magnus	AB
Wieden, Wilhelm	Cook
Gerischewski, Bernd	Steward

Shipping operator: Briesse Schifffahrts GmbH & Co KG, Abteilung Forschungsschiffahrt, Hafenstr. 12,
26789 Leer, **Germany**

3 Research Program

Hundreds of mud volcanoes exist in the eastern Mediterranean Sea (Masclé et al., 2014). The mud volcanoes were discovered at the Hellenic Arc in the late 1970s (Cita et al., 1981). However, up to now their activity with respect to mud extrusion during their eruptive phases and fluid flow during quiescent (or dormant) phases is largely unknown. The overarching question of the MARUM-funded cross cutting project (CCP 4) *mud volcanic episodicity* is to better understand how often a mud volcano erupts and what the controlling mechanism on the fluid flow during dormant phases are.

The cruise focused on the mud volcanoes Athina (~1800 m water depth) and Amsterdam (~2030 m water depth) located in the Anaximander Mountains. The Anaximander Mountains comprise a group of three main mountains (Anaximander, Anaximenes, Anaxagoras) between the Cyprus and Hellenic arcs (Fig. 3.1.). They are interpreted as southward rifted blocks of southwest Turkey (Woodside et al., 1997; Woodside et al., 1998). The entire area has undergone complex multi-phase deformation (ten Veen et al., 2004). A kinematic change in the latest Miocene related to the onset of the westward motion of the Anatolian Plate marked the start of different subsidence that resulted in the formation of the Anaximander Mountains (ten Veen et al., 2004). They are currently undergoing a neotectonic deformation phase characterized by strike slip faulting with subsidiary normal faulting and some minor thrusts (Zitter et al. 2004). In general, they are within a zone of accommodation between the westward moving Anatolian Plate and the African Plate (McClusky et al. 2002). Anaxagoras Mountain is a continuation of the ophiolitic Antalya Nappes Complex (ten Veen et al., 2004; Zitter et al., 2005). Mud volcanoes were discovered at Anaximander Mountains during the Dutch ANAXIPROBE project in 1995 and from follow-up surveys in 1996 (Woodside et al., 1997; Woodside et al., 1998).

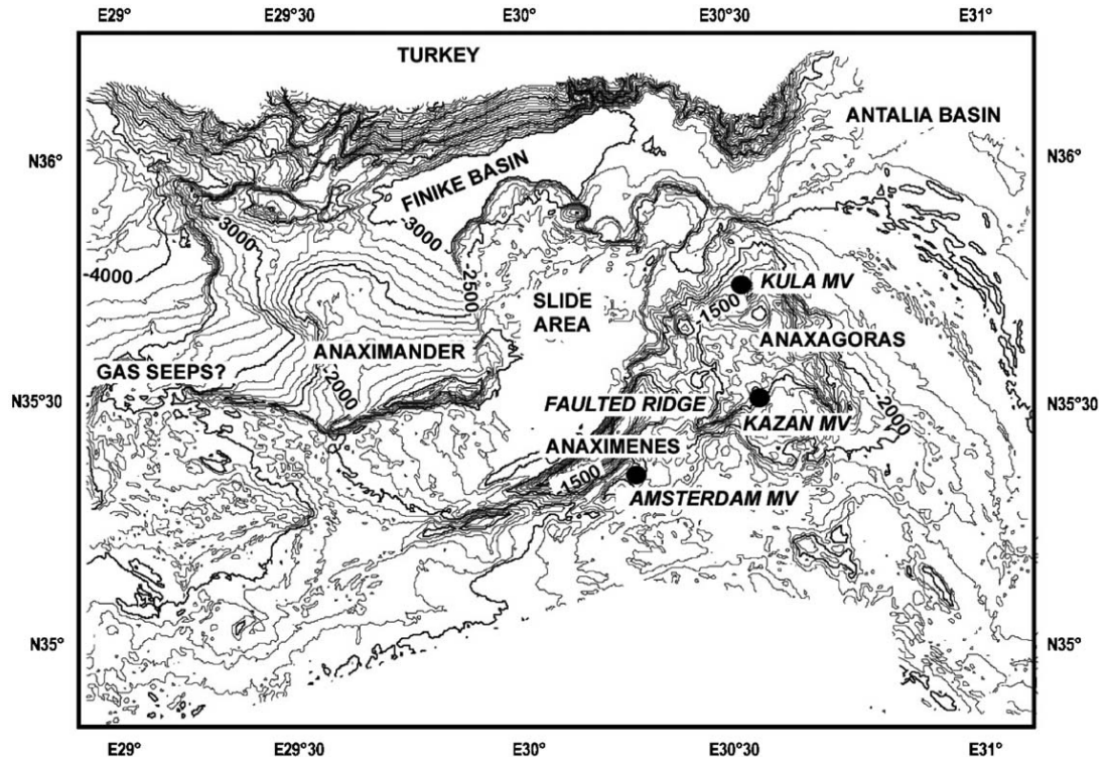


Fig. 3.1: Overview bathymetry of the Anaximander Mountains showing the three ranges Anaximander, Anaxagoras, and Anaximenes as well as selected locations of mud volcanoes (from Charlou et al., 2004).

A wealth of literature exists on the geochemistry of fluids emitted through the mud volcanoes (Charlou et al., 2003; Haese et al., 2006; Haese et al., 2003), the formation of authigenic carbonates

(Aloisi et al., 2002; Aloisi et al., 2000; Aloisi et al., 2004; Himmler et al., 2011), the occurrence of gas hydrates (Lykousis et al., 2009; Lykousis et al., 2004; Pape et al., 2010; Perissoratis et al., 2011), and associated chemosynthetic communities (Olu-Le Roy et al., 2004; Salas and Woodside, 2002). Selected mud volcanoes have been mapped by ship-based multibeam, sidescan sonar, and during ROV dives (Lykousis et al., 2009; Woodside et al., 1998; Zitter et al., 2005).

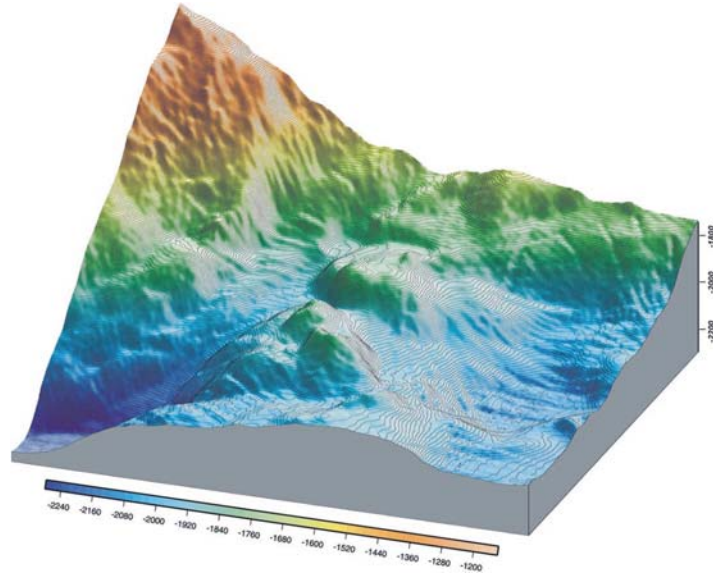


Fig. 3.2: Perspective view on Athina Mud Volcano on based on ship-based bathymetry (from Lykousis et al., 2004).

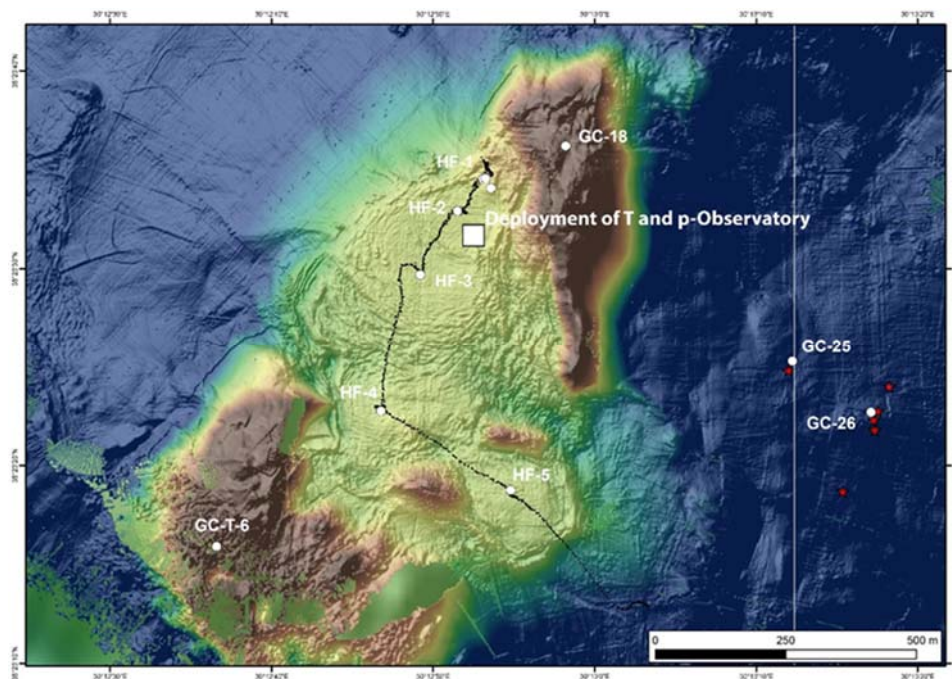


Fig. 3.3: AUV-based bathymetry of Athina Mud Volcano with core locations (GC) and heatflow measurements (HF) as acquired during R/V POSEIDON cruise POS462 (Bohrmann et al., 2014). Indicated are the planned positions of the P- and T-lances deployed during R/V MARIA S. MERIAN Cruise MSM 35T 8 February 2014.

During R/V POSEIDON Cruise POS462, high resolution bathymetric maps were acquired by autonomous underwater vehicle (AUV) MARUM-SEAL 5000 m (Bohrmann et al. 2014), which was a breakthrough in visualization of the mud volcano morphology. While the ship-based bathymetry shows Athina Mud Volcano as a flat-topped conical feature with elevations at the rim of the plateau (Fig. 3.2),

the AUV-based bathymetry shows that the mud flows from a conduit area near the stations HF-1 and HF-2 downslope in a southerly direction (Fig. 3.3). Subsequent heatflow measurements revealed the strongest thermal gradients in the area of the conduit and were therefore selected during R/V MARIA S. MERIAN Cruise 35 T as deployment sites for the observatories. The prime objectives of the observatories were to measure variations in temperature (T-lance) and pore pressure (P-lance) in order to characterize the activity of Athina Mud Volcano with respect to mud and fluid flow.

The prime objective of R/V POSEIDON Cruise POS498 was to recover the observatories employing the remotely operated vehicle (ROV) MARUM-SQUID 2000. The recovery procedure during this cruise was challenging for all involved participants including the ROV operators, the decks crew, and the navigators due to the fact that a second wire was lowered to the seafloor while the ROV was flying at the seafloor. On the lower side of the second wire, a rope with a hook was mounted. It was the challenging task of the ROV pilot to grab the hook with the manipulator and connect it with the observatories that were then pulled out of the sediments and heaved to the ship's deck. Supported by perfect weather conditions, these operations were professionally accomplished. The data loggers recorded for the entire duration of deployment the variations in temperature and pressure. As outlined in the chapter "Preliminary Results", the variations in the temperature were low whereas the variations in the pore pressure indicate considerable changes in the pore-water flow.

A further objective of the cruise was to measure additional temperature gradients and heatflow at Athina mud volcano to complete earlier measurements conducted during POS462 as well as to compare if the thermal structure of Athina Mud Volcano has changed between the years 2013 (POS462) and 2016 (POS498).

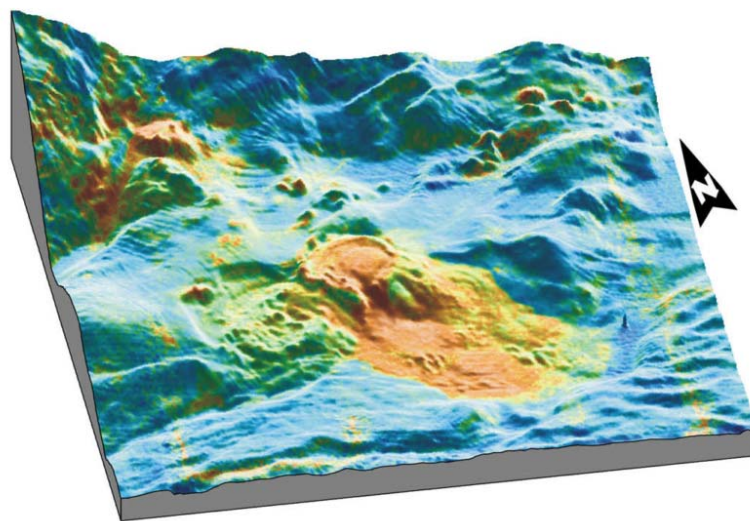


Fig. 3.4.: Perspective view of backscatter (red=high backscatter) draped over bathymetry of Amsterdam Mud Volcano indicating large mud flows several kilometers in length (from Lykousis et al., 2009).

Amsterdam Mud Volcano is a very large circular-shaped mount on the southern flank of Anaximenes Mountain (Fig. 3.4). It is a representative of a pie-shaped mud volcano with indications for large-scale mud flows as indicated by high backscatter (Lykousis et al., 2009). The high backscatter is caused by clasts and mud breccia transported in the mud flows. Mud breccia (Woodside et al., 1998) as well as gas hydrates were recovered from the center of the mud volcano (Pape et al., 2010). In order to study the time when the mud flows deposited, we took the gravity corer to study the sediments that accumulated on top of the mud flows. To recover undisturbed surface sediments it was planned to deploy a multicorer but the tool did not work and failed to recover sediments.

4 Narrative of the Cruise

Research vessel POSEIDON left the port of Izmir, Turkey on **Sunday, 17 April 2016** at 16:00 local time (LT=UTC+3h), in calm and sunny weather. All participants of the expedition arrived safely at the ship. The mobilization of equipment during the port call was accomplished fast, as both containers were already unloaded on Friday, 15 April 2016 thanks to the crew of R/V POSEIDON and the first arriving scientists.

During **Monday, 18 April 2016**, the transit to the working area allowed the ROV team to set-up the equipment needed for the operation of ROV MARUM-SQUID.

The first station (GeoB21101-1) on **Tuesday, 19 April 2016** was a memory CTD (mCTD) to acquire a sound velocity profile (SVP) needed for accurate underwater navigation with the IXSEA GAPS systems, which was mounted on a rod at starboard side of the work deck. During the ROV QUID Dive #17 (GeoB21102-1) the P-lance was successfully recovered (GeoB21102-2; Fig. 4.1). The operation was professionally conducted thanks to the efforts of the ROV team, the decks crew, and the navigators. The P-lance was connected to a second wire lowered via the A-frame of the ship. The operation took place during perfect weather conditions, without wind and waves. During the night, bathymetric data were recorded with the multibeam echosounder (MBES) ELAC mounted on the ship in the area around Amsterdam Mud Volcano (GeoB21103-1).

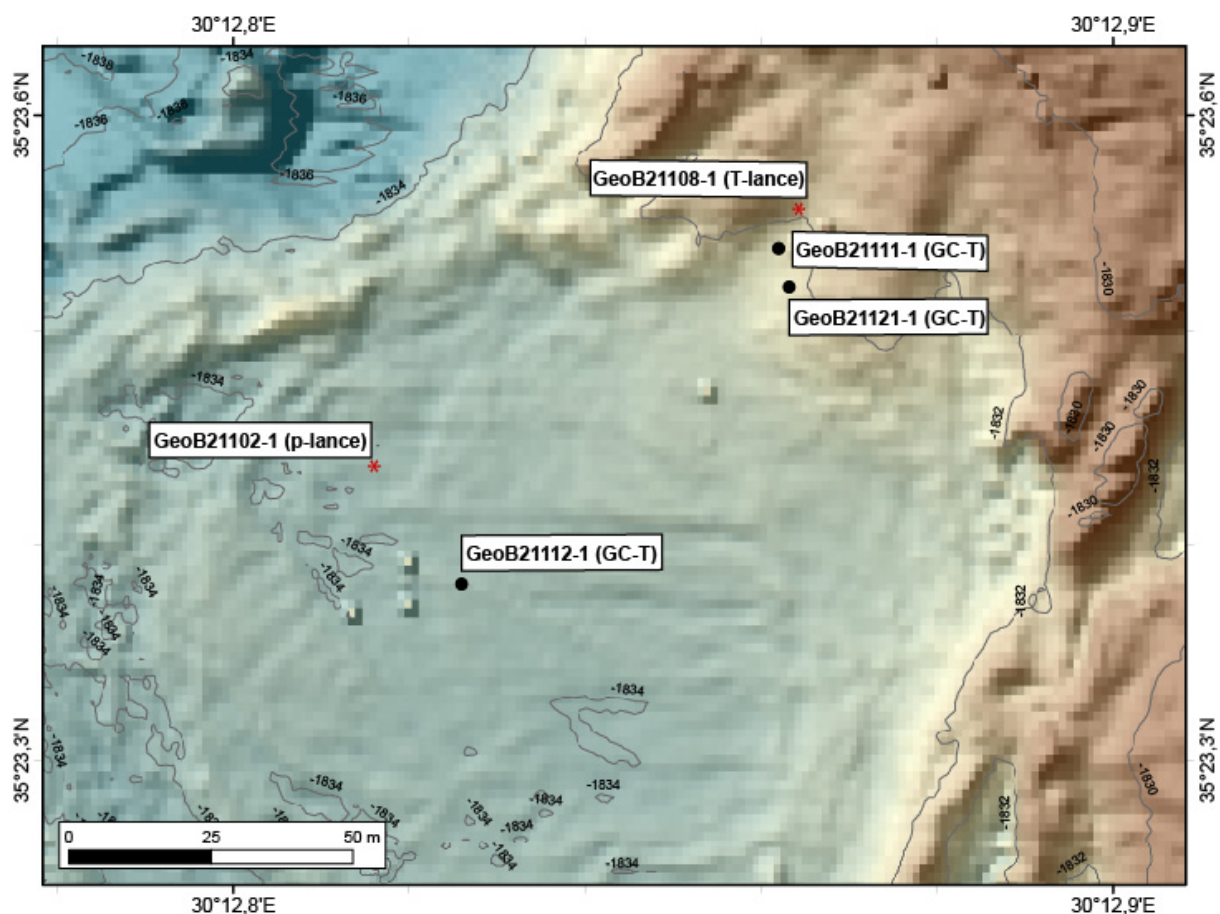


Fig. 4.1: AUV-based bathymetry of the central area of Athina Mud Volcano with the location of the recovered P- and T-lances and additional stations.

On **Wednesday, 20 April** 2016 a ROV dive was planned but abandoned due to problems with the transformer providing power for the underwater vehicle. Instead, the multicorer was deployed four times (GeoB21104-1 – GeoB21106-1) without success. Several modifications were applied to the multicorer set-up but the release mechanisms to close the cores did not operate. A gravity corer (GeoB21106-1) recovered sediments at a reference site and contained several intervals that can be used for event stratigraphy (sapropel and tephra). The night was spent with MBES mapping at Athina Mud Volcano (GeoB21107-1).

Thursday, 21 April 2016, the T-lance (GeoB21108-2) was recovered during ROV SQUID Dive 18 (GeoB21108-1) through a professional operation at perfect weather conditions. While the ROV as well as the T-lance were still in the water, the Turkish coast guard ship brought a second observer who volunteered to take part in the cruise on short notice. The observer from the Turkish Marine Military safely embarked the R/V POSEIDON via rubber boat from the coast guard ship. Thanks to the efficient ROV operation, time allowed the deploying of a gravity corer equipped with thermal probes as outriggers (GC-TL) at Athina Mud Volcano (GeoB21109-1). In the night the wind speed increased to Bft 7, which caused the MBES data recorded at Amsterdam Mud Volcano (GeoB21110-1) to be very noisy.

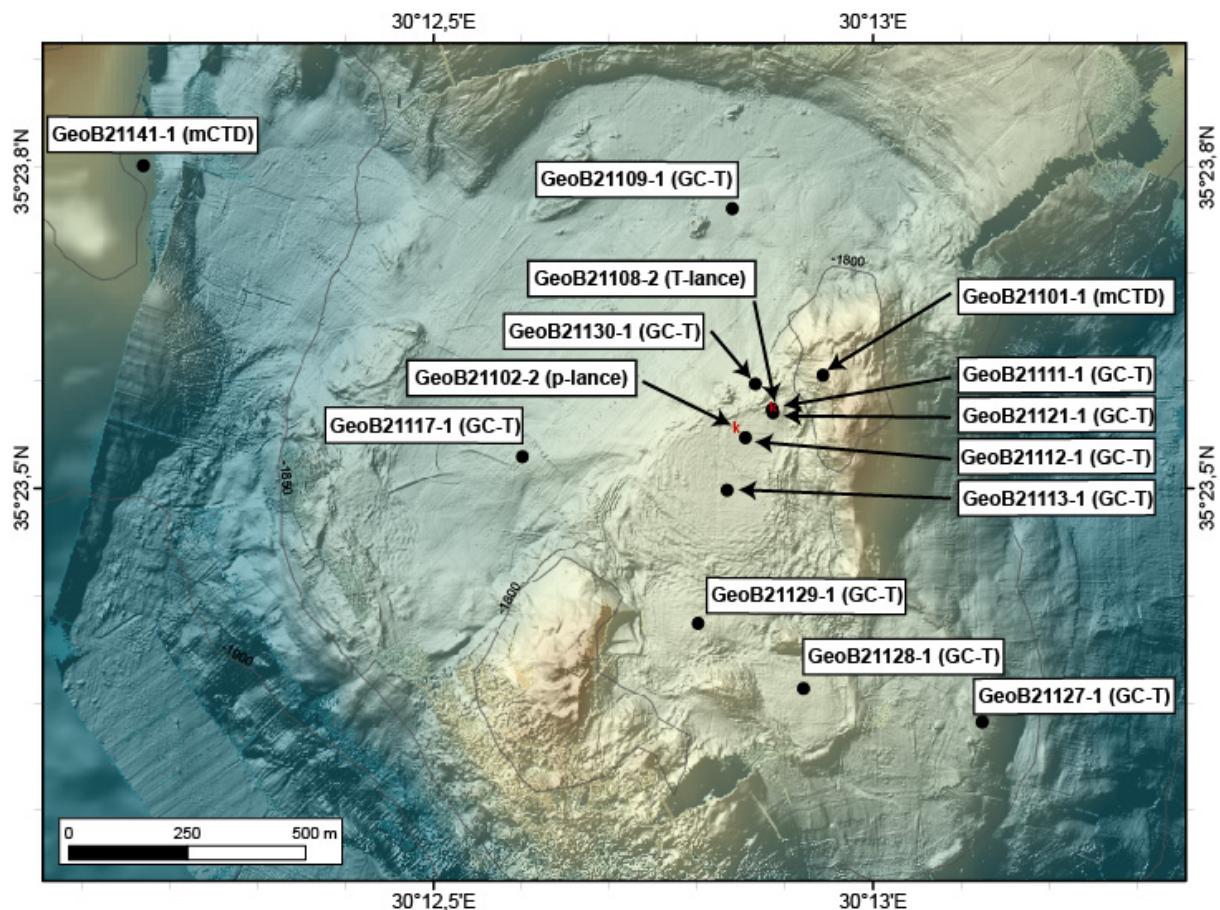


Fig. 4.2: Locations of stations at Athina Mud Volcano shown on AUV-based bathymetry.

As one of the camera systems did not work during Dive 18, the ROV team was busy repairing and, thus, several GC-TL were deployed at Athina Mud Volcano during **Friday, 22 April** 2016. The stations (GeoB21111-1 - GeoB21113-1) combined in-situ measurements of thermal gradients with ex-situ measurements of thermal conductivity on the sediments (Fig. 4.2). Two additional gravity corer (GeoB21114-1 - GeoB21115-1) were deployed that day at Amsterdam Mud Volcano to study the thickness of the hemipelagic drape on top of the mud flows. The mCTD was attached to the cable of

GeoB21114-1 in order to derive a SVP from the data. In the night the still existing swell had deteriorating effects on the MBES data recorded at Amsterdam Mud Volcano (GeoB21116-1).

Saturday, 23 April 2016 started at 06:00 LT with a GC-TL to continue the program at Athina Mud Volcano (GeoB21117-1). Unfortunately, the core barrel was bended when it came on deck. Thanks to the ships deck crew, the steel barrel was cut into two pieces and the core safely rescued. The ROV was in the water at 09:00 LT and on its way down, when the MiniZeus transmission failed. As this is the main HD-camera of the vehicle, Dive 19 (GeoB21118-1) had to be abandoned and the ROV was on deck again at noon. During the afternoon two more tries to deploy the multicorer failed, although modifications were applied to the set-up, such as mounting wood below the feet of the multicorer to prevent it from penetrating too deep into the sediments. In preparation for the next ROV dive, an MBES survey (GeoB21120-1) was conducted at Kazan Mud Volcano. At this site, the occurrence of so-called flares that are indications for gas bubble emissions had been recorded in echosounder data during previous cruises. The MBES survey intended to investigate any current state of activity at the gas bubble emission sites to provide a suitable target for detailed studies with the ROV.

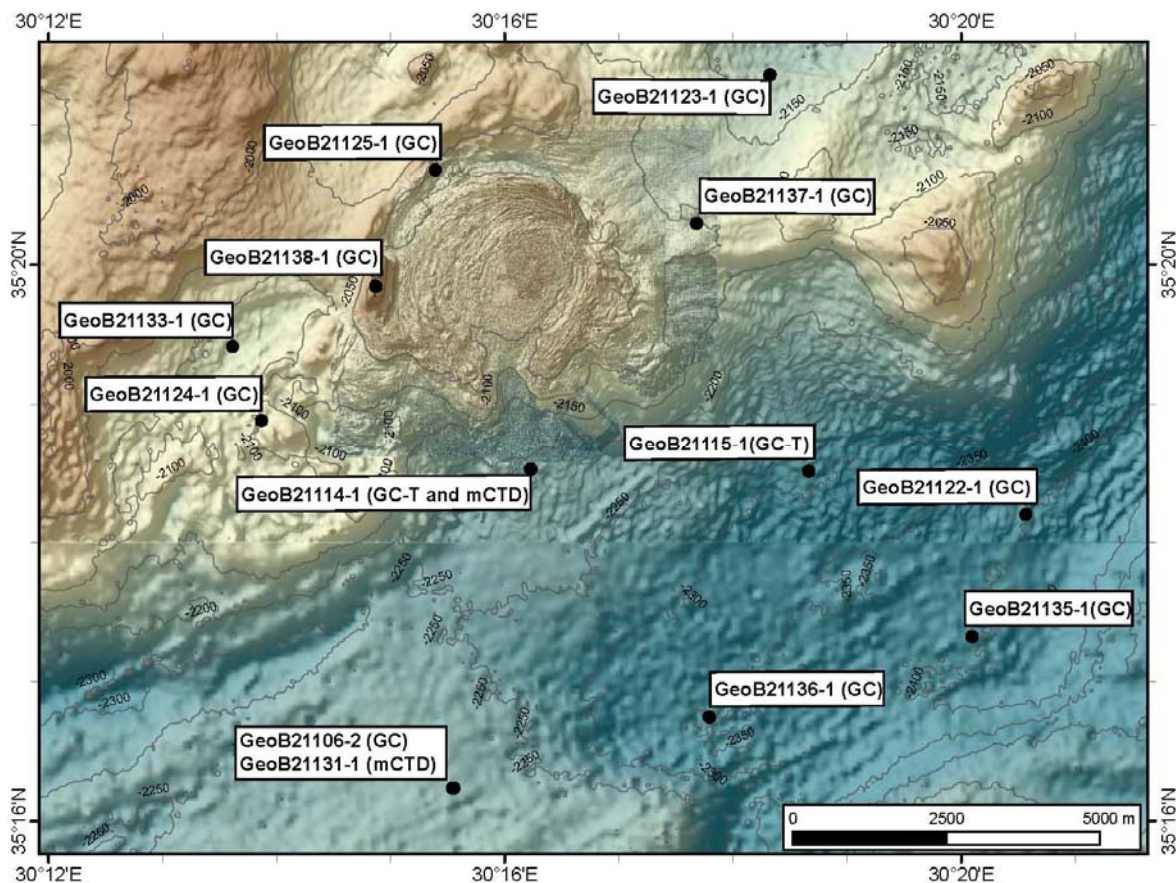


Fig. 4.3.: Locations of stations at Amsterdam Mud Volcano shown on a combination of AUV- and ship-based bathymetry.

In order to collect sediments for lab experiments, a gravity corer with plastic foil instead of a plastic liner was deployed at Athina Mud Volcano (GeoB21121-1) in the morning of **Sunday, 24 April 2016**. The core recovered gas hydrates in the sediments. The planned ROV dive could not take place due to unsolved problems with the data transmission of the MiniZeus camera. During the day, the bad news came, that the ROV cannot be deployed anymore during the cruise. Next to other minor problems, a major problem was diagnosed: the mounting of the depressor on the cable caused damage to the

optical fibres. A further operation of the vehicle in such a set-up is impossible and alternative mounting devices are not available on board ship. The program was followed by additional gravity cores (GeoB21122-1 - GeoB21125-1) taken at Amsterdam Mud Volcano for the purpose of estimating the timing of flow events (Fig. 4.1). In the night, MBES at Amsterdam Mud Volcano was conducted (GeoB21126-1) to increase the data quality.

In the morning of **Monday, 25 April 2016**, the barrel of the gravity corer was closed by a lid. The GC-TL was used similar to a temperature lance by deploying it four times in the sediments by only heaving it 200 m above ground between stations (GeoB21127-1 - GeoB21130-1). Unfortunately, the corer barrel was bended when it came back on deck. With these stations, the planned work at Athina Mud Volcano was accomplished (Fig. 4.2). The multicorer was deployed for the last two times. Thanks to the chief engineer, the friction of moving parts within the multicorer set-up were reduced but without improvement in performance. Further, the damping of the multicorer was reduced but also without success. After eight unsuccessful deployments in total, we decided not to deploy the multicorer again. A gravity corer (GeoB21133-1) was deployed at Amsterdam Mud Volcano. MBES data were recorded at Amsterdam Mud Volcano in the night (GeoB21134-1).

The work at Amsterdam Mud Volcano was finalized during **Tuesday, 26 April 2016** with four gravity corer stations (GeoB21135-1 - GeoB21138-1). Unfortunately, the core GeoB21136-1 was bended when it came up on deck. As we bended now all three 6-m long core barrels that we planned to use during POS498 to POS500, a request to send additional core barrels was sent to MARUM and was organized in the upcoming days accordingly. The remaining time was used to test the MBES to visualize gas emissions in real time during GeoB21139-1 at sites where flares were seen in processed data near Amsterdam Mud Volcano before, but without success. The wind speed increased in the night to Bft 7 and did not allow to record any usable MBES data, therefore, the survey (GeoB21140-1) was abandoned at ~20:00 LT.

Due to the rough sea and wind speed around Bft 6, the gravity corer could not be deployed on **Wednesday, 27 April 2016**. Therefore, the final station was the mCTD deployed together with the temperature loggers used as outriggers on the gravity corer for cross-calibration. The scientific program ended at ~09:00 LT. The ship steamed towards the land to allow one of the observers to be picked up by a coastguard boat near shore, where the waves were calmer. We arrived at Finike Limani at about 16:00 LT and disembarked the observer safely.

During the transit to Catania, the time was used from **Thursday, 28 April 2016** to **Saturday, 30 April 2016** to write cruise report, pack scientific equipment, and open and describe sediment cores. We arrived **Sunday, 1 May 2016** at 09:00 LT at the pilot station. The cruise ended in Catania with the unloading of the ROV equipment and the leaving of the scientific personal.

5 Preliminary Results

5.1 Hydrography

(H. Sahling)

A memory CTD autonomously measuring conductivity, temperature, and pressure was lowered with scientific tools or on the W2 wire over the side of the ship. The probe was a Sea & Sun Technologies Model 48M. The objective was to achieve sound velocity profiles needed for the hydroacoustic equipment, i.e. the ultra-short baseline system (USPL) GAPS as well as the ELAC multibeam echounder (MBES). The derived parameters depth, salinity, and sound velocity were calculated using the software delivered with the Sea & Sun Technology probe. The temperature values displayed are in-situ temperatures (and not potential temperature). No further statistical treatment was applied to the data.

The water column was stable during our investigation in the working area, with a warm upper surface layer, a thermo- and halocline extending to depth of ~500 m underlain by a stable and relatively uniform water body of ~14°C and 38.7°C (Figs. 5.1.1-5.1.2). Considerable variations in salinity were observed in the uppermost mixed layer to depth of 30 m.

In general, the sound velocity profiles were stable over the investigation period. Therefore, only one sound velocity profile was used for the work period (Table 5.1.1).

Table 5.1.1: Sound velocity values used for the hydroacoustic equipment during the cruise.

Depth / m	Sound velocity / m/s	Depth / m	Sound velocity / m/s
0	1525	250	1515
10	1524	275	1514
20	1522	300	1514
30	1520	350	1514
40	1519	400	1515
50	1519	450	1515
60	1519	500	1516
70	1519	750	1519
80	1519	1000	1523
90	1518	1250	1528
100	1518	1500	1532
125	1517	1750	1537
150	1516	2000	1541
175	1516		
200	1515		
225	1515		

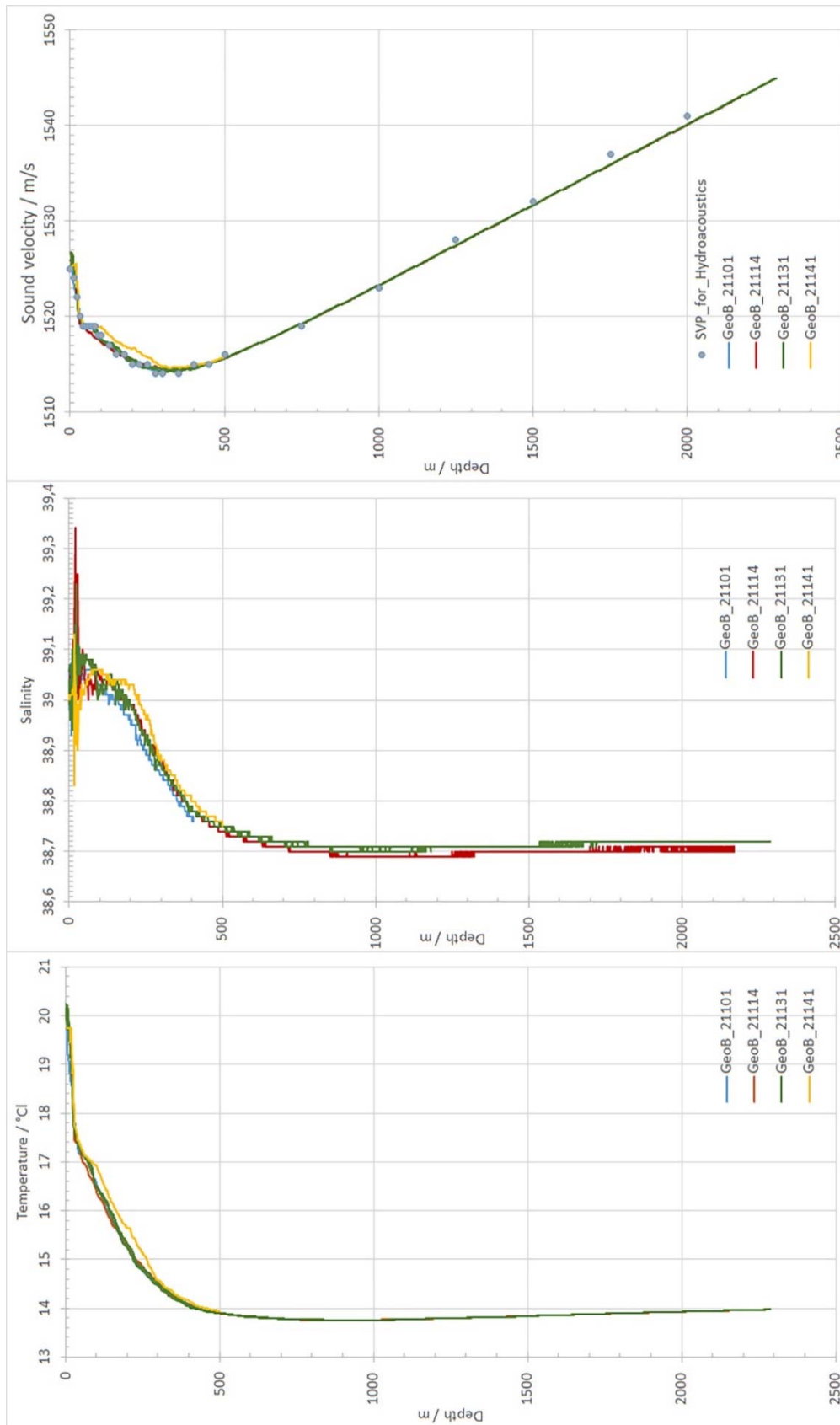


Fig. 5.1.1: Temperature, salinity, and sound velocity plotted versus depth down to 2300 m as measured during four memory CTD (mCTD) deployments as well as the values of sound velocity used for the hydroacoustic equipment (dots in sound velocity profile plot).

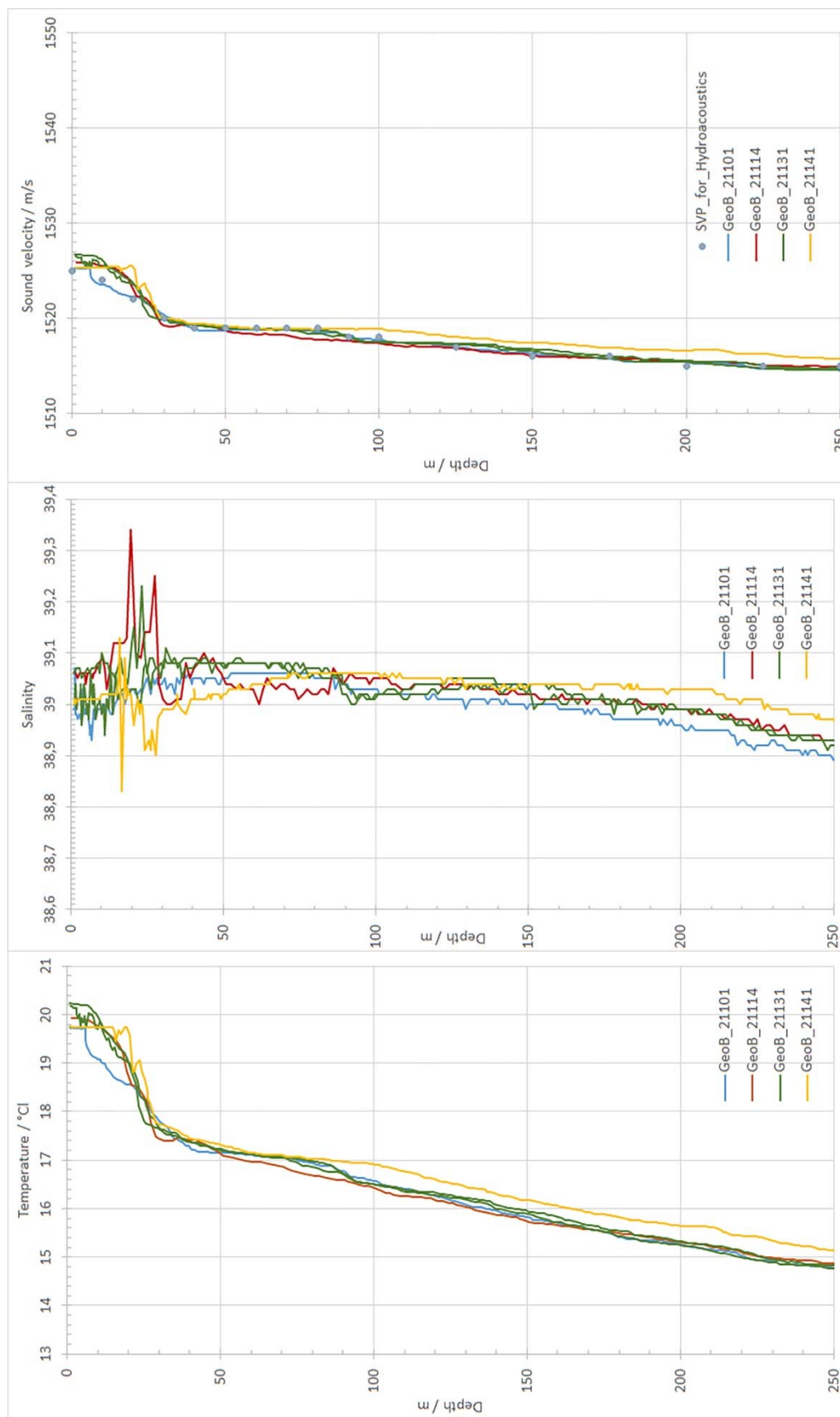


Fig. 5.1.2: Temperature, salinity, and sound velocity plotted versus depth down to 250 m as measured during four memory CTD (mCTD) deployments as well as the values of sound velocity used for the hydroacoustic equipment (dots in sound velocity profile plot).

5.2 Hydroacoustic Mapping

(D. Völker)

Tool and settings: Swath bathymetry mapping of seafloor and of the signal amplitude (sidescan backscatter) was performed with the hull-mounted ELAC SB3050 multibeam echosounder (MBES). It is a 1.5-by-2-degree mid-water MBES operating with a frequency of 50 kHz and a maximum beam number of 384. The swath angle was set to auto and varied mostly between 90 and 70°, thus the maximum swath coverage at the depth ranges between 1200 and 2500 m was between 1.4 and 2-fold of the water depth. The results proved satisfactory given the fact that the water depth was on the verge of the maximum depth range of the SB3050 of 2500 m. Sound Velocity Profiles were calculated from CTD drops roughly every second day, but showed very little variation over the survey (Fig. 5.1.1).

Survey design and outcome: Mapping surveys were run over 7 nights, of which 5 were dedicated to Amsterdam MV, 1 to Athena MV and 1 to Kazan MV (Tab. 5.2.1). Nightly profile tracks were of 60 nm at 5 knots (6PM to 6AM), with a spacing of parallel tracklines of 0.5 and 1 nm, summing up to a total of 400 nm of trackline. Over the first 5 nights, recording profited from very calm seas and results were satisfactory. On the ultimate 2 nights however, data quality degraded from rough sea. Regarding Amsterdam MV, the aim was to get a very dense trackline grid in order to be able to generously discard doubtful pings and to have a detailed backscatter intensity map for core planning (Figs. 5.2.1-5.2.2). Regarding the smaller Kazan and Athena areas this goal was achieved in one night for each target (Figs. 5.2.3-5.2.6).

Data processing: Around 3.5 GB of bathymetric and backscatter data were recorded in the ELAC proprietary xse format (known by MBSysstem as MBIO Data Format ID: 94; Format name: MBF_L3XSERAW) in file units of ~100MB. The data were routinely renamed, analyzed, cleaned from spikes, defective water depths and soundings during ship turns with the help of the MBSysstem tools mbinfo, mbclean and mbprocess (Caress and Chayes, 1995) in a first step. Also the backscatter intensity was normalized with regard to the grazing angle with mbackangle. The second, more time consuming editing step of visual ping-by-ping control of the data with mbedit was done on the ship in a first iteration to eliminate obvious cases of artefacts that passed the first filtering step.

```
#- bash-script used for pre-filtering
#-----
#!/bin/bash
mbioID=94;rawext=xse;rawpath=./raw;workpath=./processed
# save removal of processed files
rm $workpath/*.mb*
rm $workpath/*.pp.mb*
# copy raw files to work-directory, rename to .mb94
rawlist=$(find $rawpath -name "$rawext" -print0 | xargs -0)
for rawfile in $rawlist
do
    echo $(basename $rawfile .xse)
    stripname=$(basename $rawfile .xse)
    cp "$rawpath"/"$stripname"."$rawext" "$workpath"/"$stripname".mb"$mbioID"
done
# change to working dir
```

```

cd $workpath
# produce lists
ls -1 *.mb94 > tmplist
mbdatalist -F-1 -l tmplist > datalist.mb-1
mbdatalist -F-1 -l datalist.mb-1 -N
# autoclean
mbclean -G0.80/1.2 -C3.5 -M1 -S10/3/2 -R1.0 -X5 -l datalist.mb-1
# Backscatter-Intensity normalization depending on grazing angle
mbbackangle -F-1 -l datalist.mb-1 -A1 -V
#process
mbprocess -l datalist.mb-1 -F-1
# cleanup
rm tmplist
#-----

```

Rapid visual control of the data quality was obtained using the MBSys system shellscript `mbm_plot`, while the ultimate gridding into grids of 25x25 m was done with `mbgrid`. The resulting netcdf grid files were transformed to geotiff-layers with the help of the Geospatial Data Abstraction Library (GDAL) tool `gdal_translate` for the easy use in GIS. More thorough processing will be undertaken on land.

Water column data: The SB3050 offers to optionally record water column data in an ELAC- specific format, named `wci`. In this format, each single ping is stored as an individual file, and, owing to the nature of the data, in a single night up to 200 GB of data are being recorded. With the `wci-viewer`, ELAC provides a tool to visualize the data in stacked and/or fan view in playback mode or also in real-time mode. We recorded water column data on 5 nights mainly to check for gas flares that had been described previously on R/V POSEIDON Cruise P462. As an alternative to the `wci viewer`, we preferred FLEDERMAUS FMMidwater for playback visualization because of a more flexible control on the clipping of the shown data, which helps to discriminate weak flares from ambient noise. For doing so, we converted stacks of single `wci` files into larger `gwc` files with the use of the program `wci2gwc` (written by W. Plager / GEOMAR). `Gwc` files can easily be imported into FMMidwater projects.

We were able to track several gas flares at Athena MV at places where they had been observed before, proving a remarkable stability in time. On the other hand, we were unable to trace some of the most prominent flares observed earlier over Kazan MV, but this was at a point where weather conditions deteriorated and the overall data quality was poor. A systematic quest for flares in the total data set is yet to be undertaken.

Problems and suggestions: In total, the system worked reliable over the 7 nights and produced useful data in spite of working at the lower end of its water depth range. This limitation is seen easily by a rapid decrease in data quality if ~2500 m are exceeded. Another major limitation of the system is the dependency of the data quality on wave conditions. The first, very calm nights provided the cleanest data, while waves of 1.5-2.0 m height produced a high level of noise, in particular when the ship's bearing was into the waves. At a wave height of 2.5 m, data quality was poor at a water depth of 2000 m, independent of the ship's course relative to the waves. Some minor issues are that the hard-disk, the water column data are stored on (on the SB3050 processing computer) has a capacity that is exceeded rather quickly (after 3 nights of recording). The software solution for controlling, recording and storing the data, combining four software products is confusing at first, but does its job. We

observed one case of malfunction of the integrated navigation system (F180 unit) by which the heading of the ship in the data diverged from the true heading, resulting in misplaced beams. This malfunction persisted for 10 minutes until the unit corrected automatically.

Table 5.2.1: List of the hydroacoustic surveys conducted during POS498.

Survey No.	Area	Recording interval (UTC)	GeoB No	Comments
01	Amsterdam MV	19.04.16 14:59 - 20.04.16 02:49	21103-1	
02	Athena MV	20.04.16 14:51 - 21.04.16 02:59	21107-1	
03	Amsterdam MV	21.04.14 14:24 - 22.04.16 02:40	21110-1	
04	Amsterdam MV	22.04.16 15:30 - 23.04.16 04:00	21116-1	no wc data recorded
05	Kazan MV	23.04.16 15:40 - 24.04.16 01:30	21120-1	
06	Amsterdam MV	24.04.16 13:03 - 25.04.16 04:18	21126-1	
07	Amsterdam MV	25.04.16 14:28 - 26.04.16 04:26	21134-1	
08	Amsterdam MV	26.04.16 14:18 - 26.04.16 17:11	21139-1-21140-1	Survey prematurely ended (due to wave conditions)

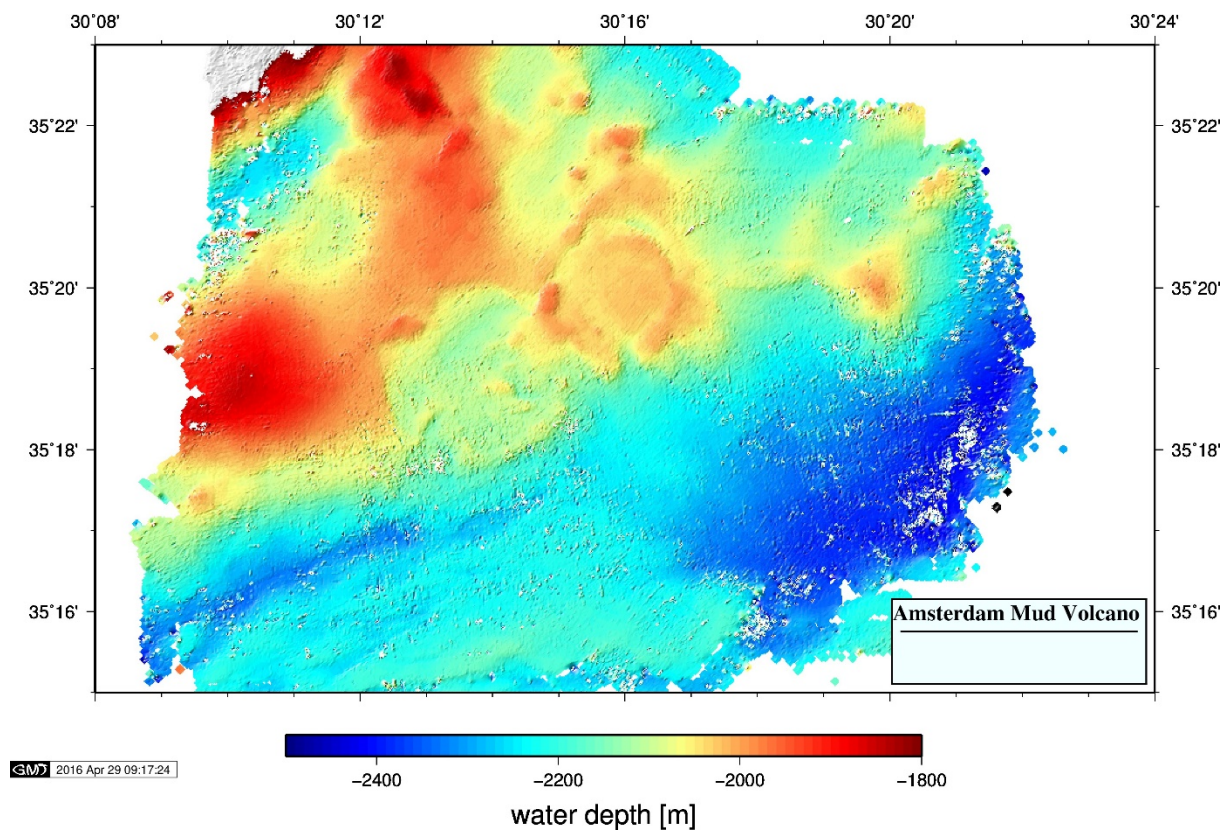


Fig. 5.2.1: Shaded bathymetry map of Amsterdam Mud Volcano, based on a 25x25 m grid after first two stages of data cleaning.

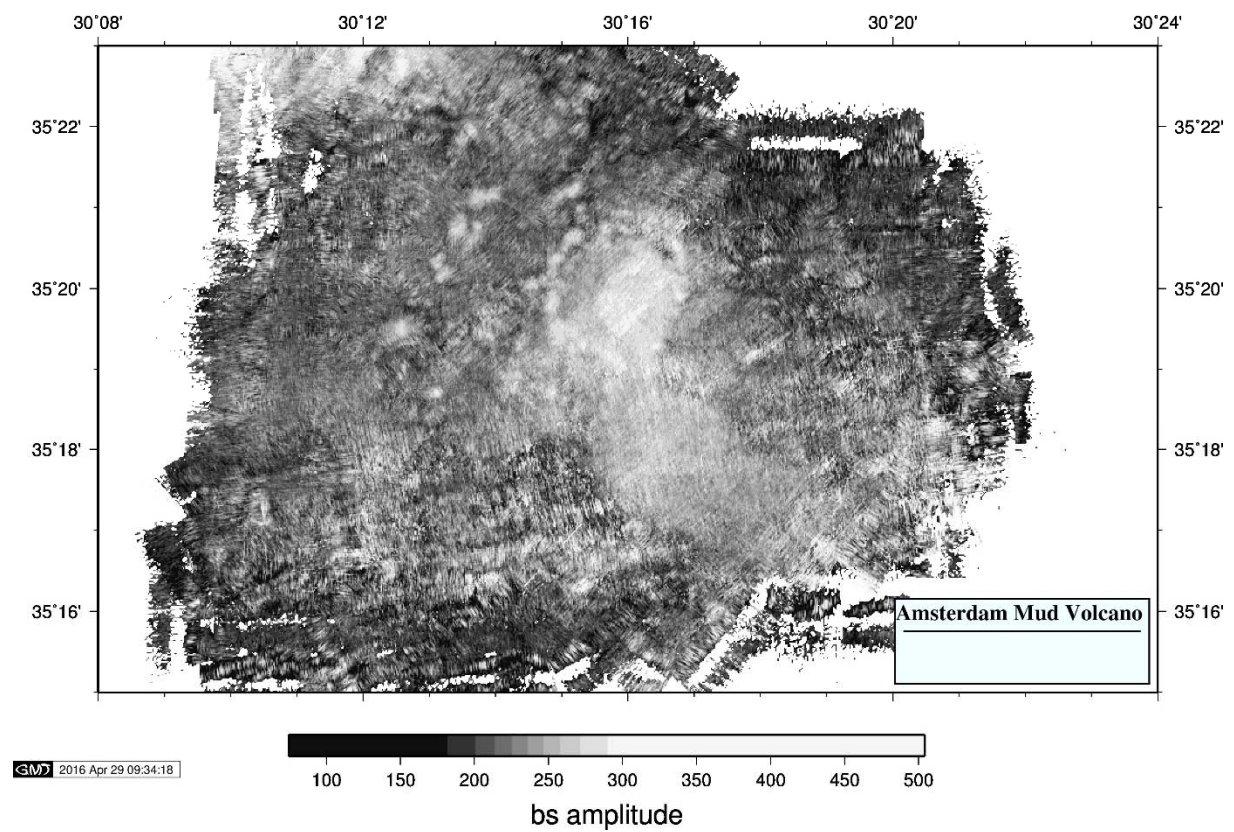


Fig. 5.2.2.: Backscatter intensity map of Amsterdam Mud Volcano, based on a 25x25 m grid.

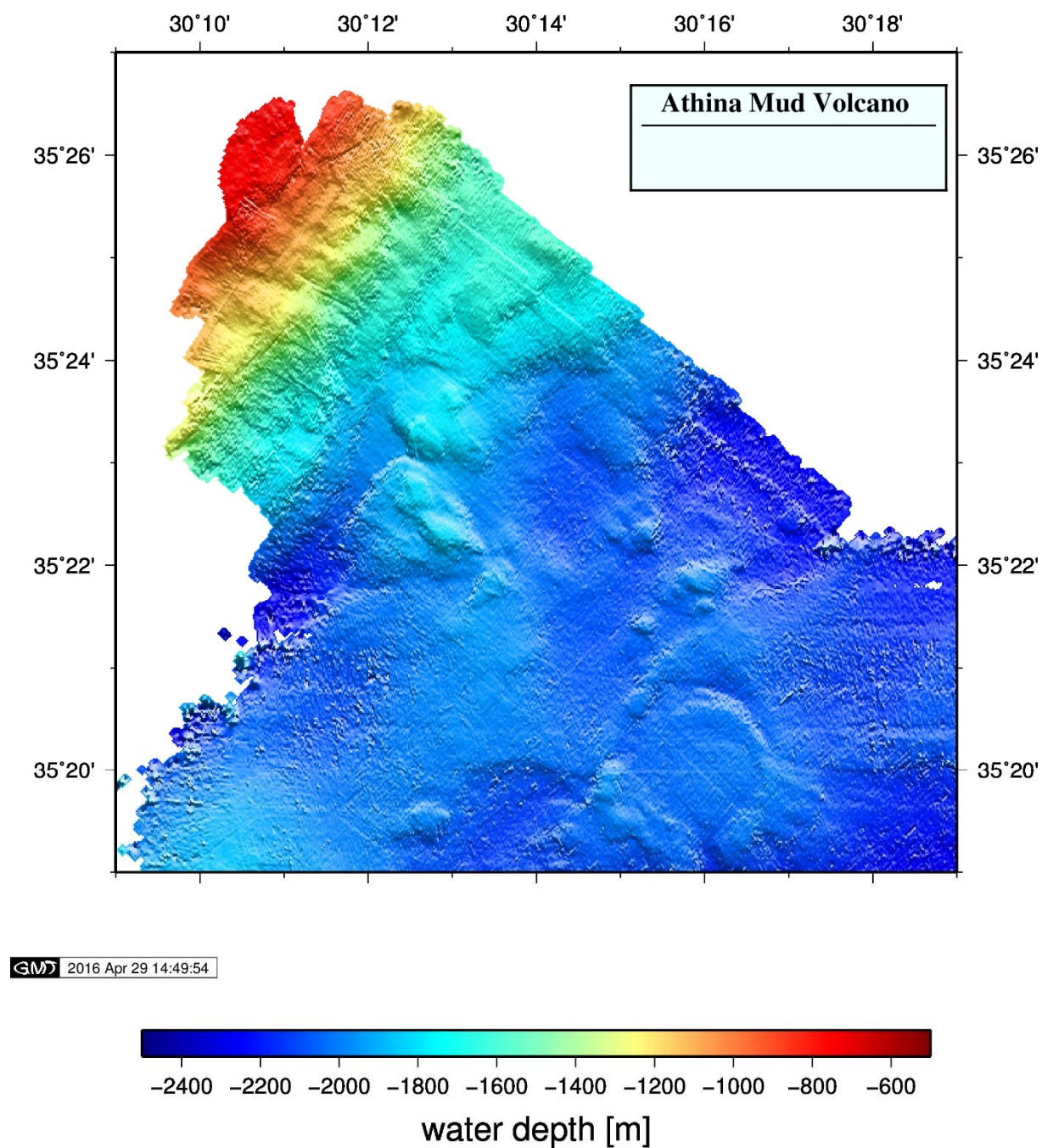


Fig. 5.2.3: Shaded bathymetry map of Athina Mud Volcano, based on a 25x25 m grid after first two stages of data cleaning.

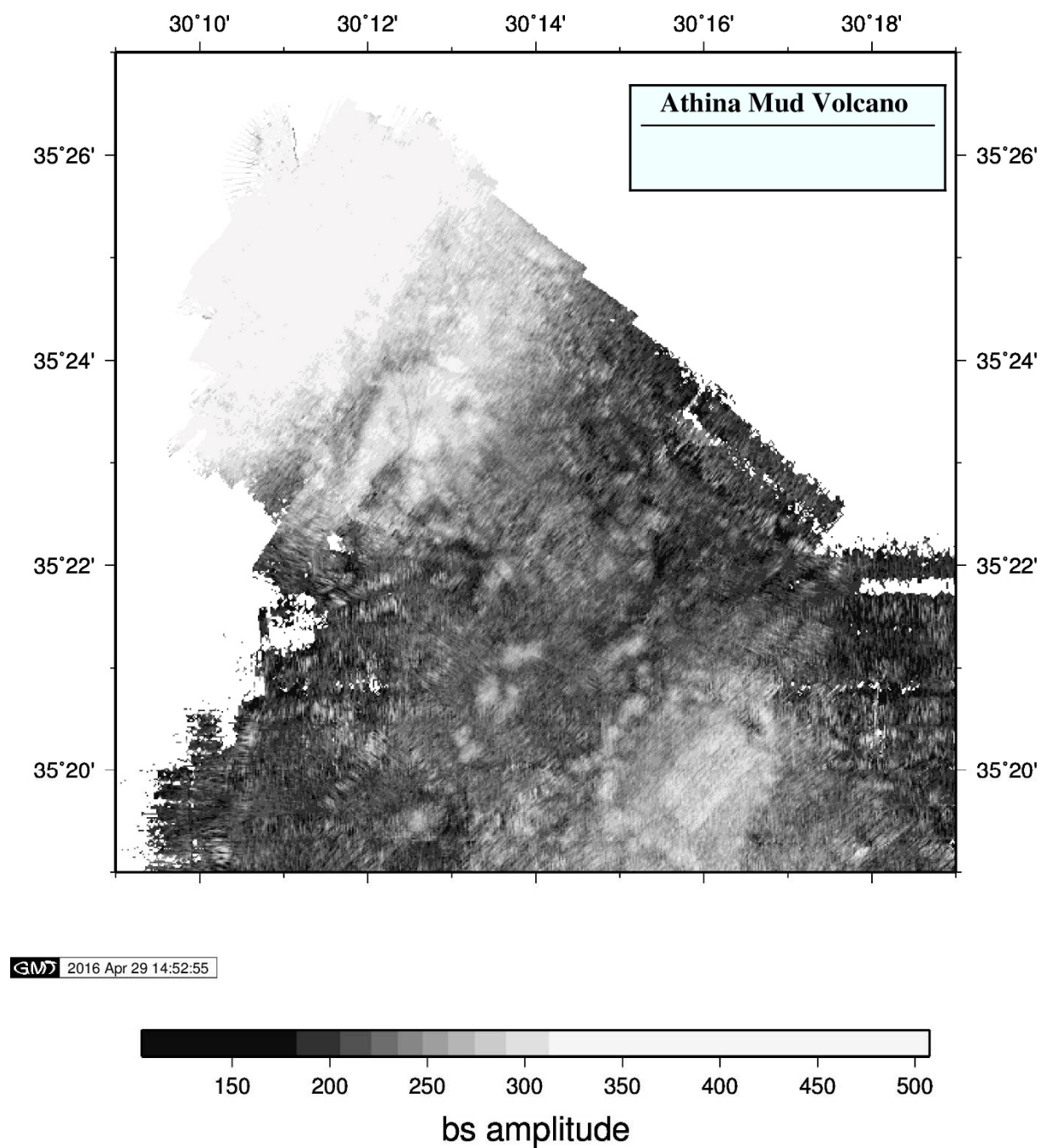


Fig. 5.2.4: Backscatter intensity map of Athina Mud Volcano, based on a 25x25 m grid.

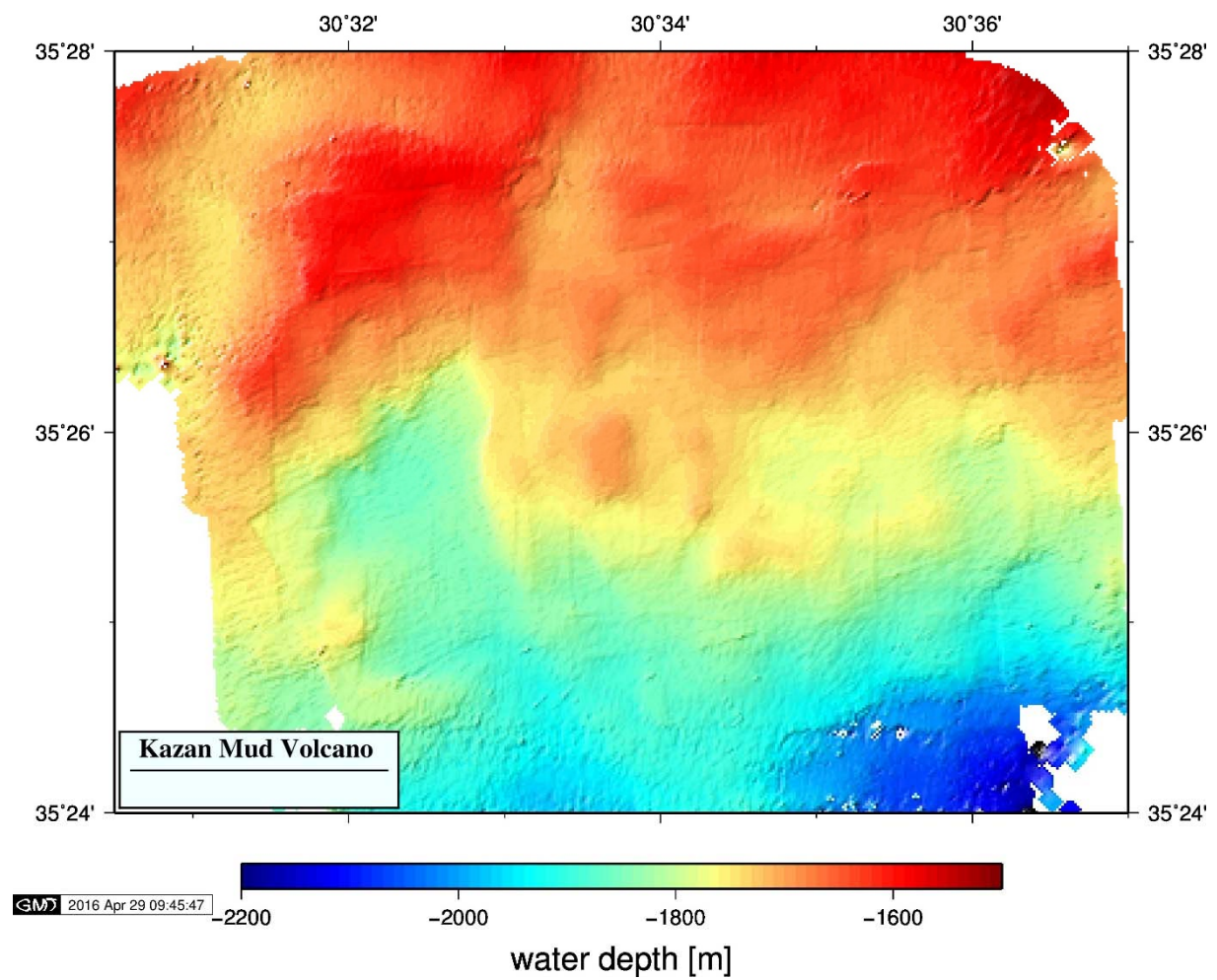


Fig. 5.2.5: Shaded bathymetry map of Kazan Mud Volcano, based on a 25x25 m grid after pre-filtering.

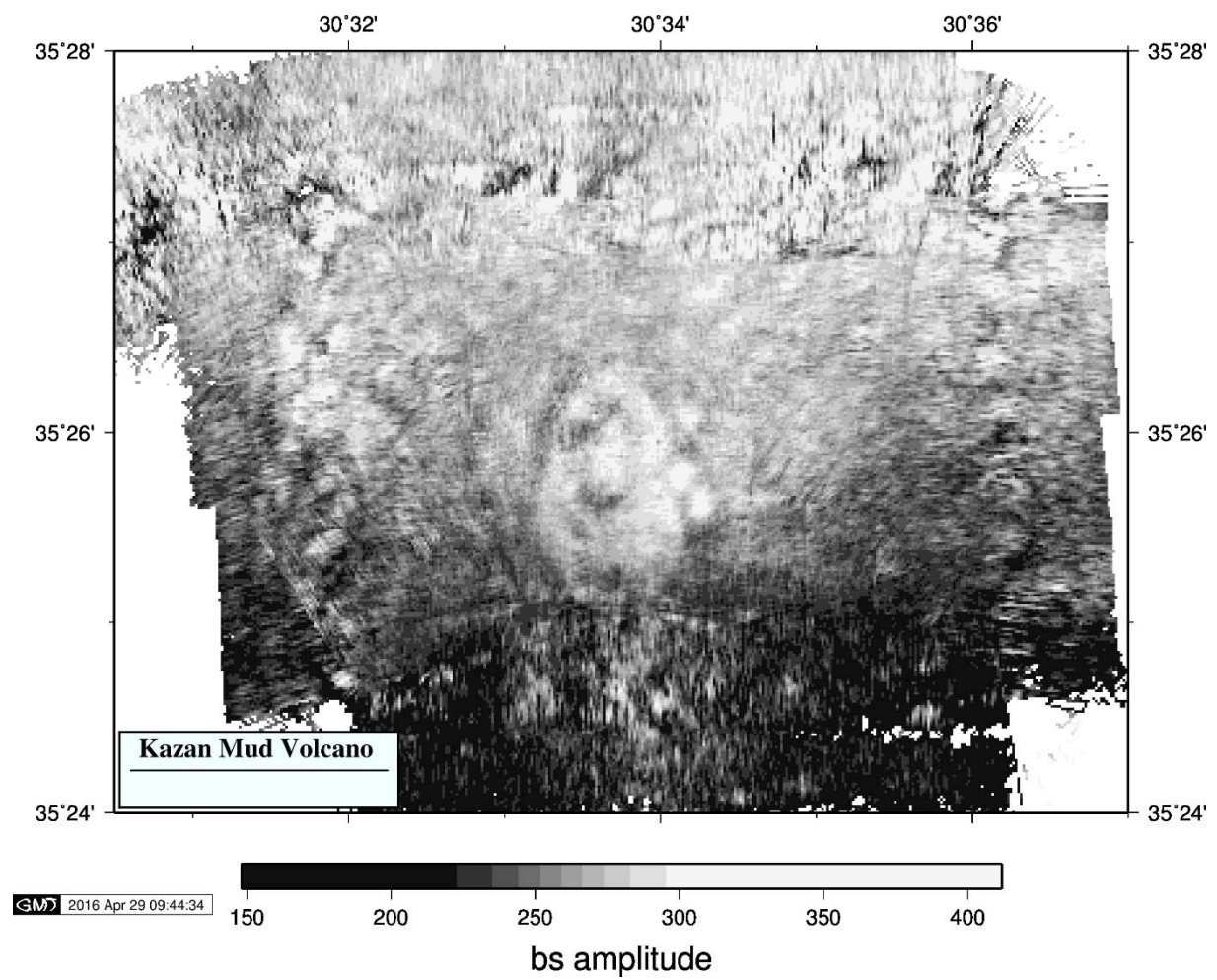


Fig. 5.2.6: Backscatter intensity map of Kazan Mud Volcano, based on a 25x25 m grid.

5.3 ROV MARUM-Squid

5.3.1 Technical Description and Performance

(N. Nowald, C. Seiter, V. Vittori, T. Leyman)

MARUM-Squid is a light work-class ROV manufactured by SAAB Seaeye (UK) for operations down to 2000 m (Fig. 5.3.1). The concept of MARUM-Squid is to provide a powerful ROV for the scientific community, realized on a small footprint at a considerably low weight that can be shipped within 1 x 20" ISO container. The system was adapted for marine research at MARUM and put into service in July 2015. The main objective of the ROV was to recover two seafloor-deployed observatories at Athina Mud Volcano in ~1800 m water depth. For detailed dive statistics see Table 5.3.1.



Fig. 5.3.1: MARUM-Squid during recovery.

5.3.1.1 Mobilization

The system consists of four major components: the vehicle, the winch with ~2400 m supply cable (tether), the topside equipment including power supply, control units and display monitors and the portable ultra-short baseline system (USBL) positioning system GAPS (Ixblue, FR). During mobilization, the winch was placed on the loading hatch of RV Poseidon. The sheave for the tether of the ROV was mounted to a fixing point on the small auxilliary winch of the sliding beam. The main 3kV transformer and the corresponding filterbox were both placed in the chemistry lab of the vessel. Four portable flightcases, containing the devices necessary for vehicle control (e.g. ROV control computer) or video and data recording, were installed in the dry lab, next to the chemistry lab. The GAPS antenna was mounted to a pole on the starboard side of the ship and the GPS antenna on the 1st construction deck above the pole with the GAPS antenna.

5.3.1.2 Vehicle

Dimensions and power

Vehicle dimensions are 2.1 x 1.2 x 1.9 m (L x B x H) and total weight of the ROV is 1.3 t. The transformer on the ROV converts 3kV to 500 V for the thrusters and hydraulics and 24 V for the low power devices such as cameras, Pan and Tilt unit or LEDs. Overall power of the ROV is 45 KW. The vehicle is equipped with a total of 11 thrusters; 8 horizontal thrusters providing a forward bollard pull of ~500 kgf and 3 vertical thrusters

Navigation

The Squid is equipped with a standard navigation sensor package such as a Valeport MiniPS depth sensor and a Tritech PA200 altimeter which measures the height of the ROV above the seafloor. These sensors are used for auto altitude and auto depth hold maneuvers with an accuracy of 10 cm. Furthermore, MARUM-Squid is equipped with two independent navigation devices, the CP16 and the MiniPOS, that can be used in alternation, providing a redundancy in case one of the device fails. The CP16 navigation pod consists of an integrated 3D magnetometer (3D compass) with an embedded processor capable of calculating roll, pitch and yaw in real-time. Using the CP16 navigation pod, Auto Heading as well as Pitch/Roll hold are possible with the ROV. The CDL MiniPOS/NAV3 navigation system provides the same functions as the CP16, but also allows advanced autofunctions like stationkeeping or displacement. Furthermore, the MiniPOS calculates its own position by using all vehicle sensors and an input from any USBL positioning system (see Positioning). The MiniPOS is a fully self-contained Attitude Heading and Reference System (AHRS). It comprises a gyro compass based around a Monolithic Ring Laser Gyrocompass (MRLG). Together with the MRLG, three axis accelerometers make the MiniPOS a full inertial system. The MiniPOS is coupled to a RDI Workhorse Doppler Velocity Log (DVL) which increases the quality of the positioning when the ROV is operating close to the seafloor.

The Tritech Seaking is a dual frequency forward looking sonar operating at 325/675 kHz. The device is installed on the upper porch for 360° obstacle detection/avoidance.

Cameras & Optics

The Squid is equipped with 5 cameras (Fig. 5.3.2). Two PAL DSPL MultiseaCams serve as forward looking and rear looking camera. The latter monitors the orientation of the tether during operation. A vertically, on the front porch mounted DSPL Wide-I is giving a full overview of the area in front of the vehicle. An Imenco Tigersharks stills acquires images at a resolution of 14 megapixel and is mounted on the Pan and Tilt unit of the vehicle. The external flashgun of the stills is installed at a 45° angle on the upper porch. Main working camera is the Insite Pacific MiniZEUS MKII, likewise mounted on the ROVs Pan and Tilt unit. The MiniZEUS is a full HD camera with a resolution of 2.38 megapixel. The MiniZEUS has a hemispherical dome port and a fully corrected optical lens with a 10 x optical zoom. The optical lens corrects for chromatic, geometric and radial distortion that occurs when using optical systems underwater. Two Imenco Dusky Shark line lasers are installed on the Pan and Tilt of MARUM Squid. They project two parallel laser beams at a distance of 30 cm for size measurements of objects on the seafloor.

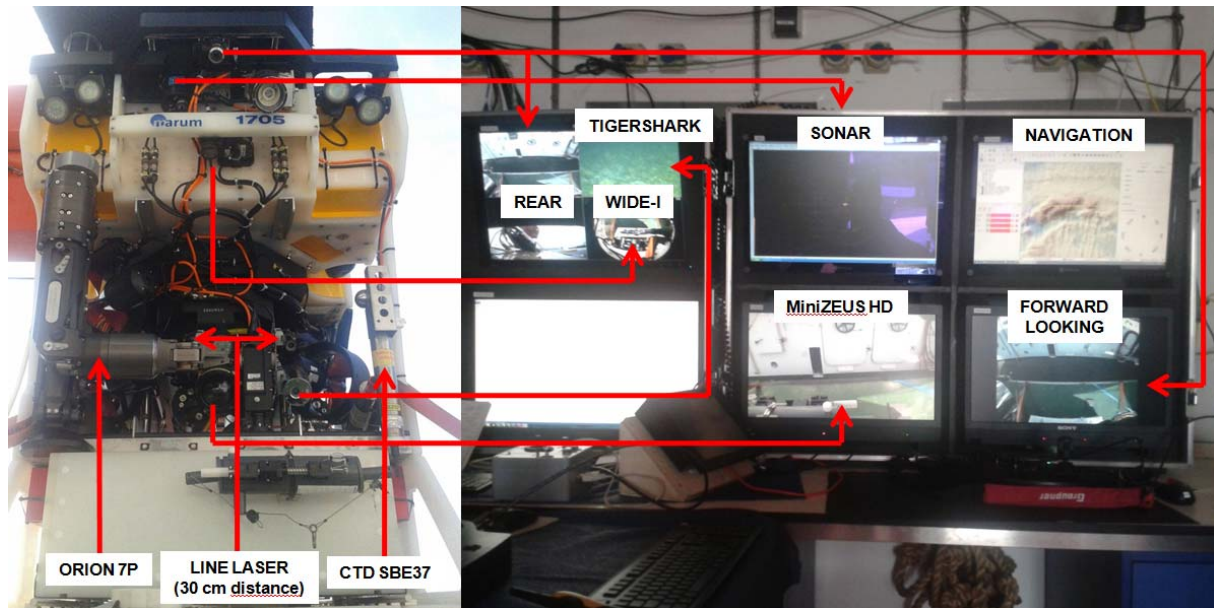


Fig. 5.3.2: Front of MARUM-Squid with its major components and video/navigation displays in the dry lab.

Lights

The Squid comes with 6 x 24V dimmable LEDs at 3520 lumens. One pair is installed on the starboard side and the second pair on the port side of the ROV. The other two LEDs are placed on the Pan and Tilt unit and on the upper porch facing backwards towards the ROV umbilical.

Hydraulics

Onboard the Squid is a hydraulic pump (iHPU) providing a maximum operating pressure of 210 bar. The pump supplies the vehicle's manipulator and the drawer box of the toolskid with hydraulic power.

The Orion 7P manipulator, manufactured by Schilling Robotics, is installed on the starboard side of the vehicle. It is a fully proportional, hydraulic manipulator with 7 degrees of freedom. The reach of the arm is 1.5 m and has a lifting capacity 68 kg. The Orion is remotely controlled via a Master Controller, which is a miniature of the Slave-Arm installed on the vehicle. The movement of the Master Controller directly translates into proportional movements of the Slave Arm, allowing precise operations beyond the centimeter range.

A toolskid is mounted underneath the vehicle's main frame. It carries the MiniPOS and also a sample box (600 x 900 x 320 mm, LxBxH) that can be opened and closed hydraulically. The sample box is used to install scientific gear (e.g. nets) and also to store samples taken during the dive in several compartments.

Vehicle telemetry

The ROV uses a single mode fibre optic telemetry in combination with a Coarse Wave Division Multiplexer (CWDM). The CWDM increases the telemetry capabilities as it splits the light in several wavelength ranges that serve as individual channels for a variety of telemetry boards for video and data. The entire vehicle telemetry runs on one single mode fibre. Solely the MiniZEUS requires a dedicated fibre, due to the large bandwidth of the HD videosignal.

In addition, the Squid has a Small Survey Pod mounted inside the vehicle's frame, for the integration of additional scientific sensors. Six ports for serial communication, a 1 Gigabit Ethernet link for sensors that require a high bandwidth and 2 additional PAL video channels are available.

Positioning

During RV Poseidon Cruise 498, the portable USBL system GAPS (Ixblue, FR) with an accuracy of 0.2 % of the slant range was used for the positioning. In addition to the position provided by the USBL systems, the MiniPOS of the Squid calculates its own position by using all vehicle sensors and the USBL input. Once the inertial system of the MiniPOS is calibrated, the Aided Navigation mode becomes active. When available, the MiniPOS sends precise position updates at a much higher frequency compared to USBL systems. Furthermore, the Aided Navigation allows the vehicle to go into the stationkeep mode, that holds the ROV on position without being displaced in X or Y direction by the currents. While stationkeeping, the vehicle can be shifted in any X and/or Y direction at given distances with an accuracy of 10 cm.

Video and Data

All navigation data from the ROV and the vessel are stored in a separate navigation file. The videos and still images contain a timestamp so they can be geo-referenced using the navigation file. The videos of the MiniZEUS and DSPL Wide-I camera were recorded on harddisk in the MP4 videoformat.

The Squid's navigation software is a Plug-In called Posiview coded for the open source ArcGIS software QGIS. A georeferenced TIFF navigation map is used as the background, displaying the ship's and ROV's heading as well as their position on top of it.

Table 5.3.1: Dive statistics of MARUM-Squid.

Dive#	Date	Launch Time (UTC)	Launch Position	Recovery Position	RecoveryTime (UTC)	Bottom Time (h)	Max. Depth (m)
17	19.04.16	06:15	35°23.54 N 30°12.93 E	35°23.57 N 30°12.72 E	13:50	3.5	1802
18	21.04.16	04:08	35°23.57 N 30°12.89 E	35°23.6 N 30°12.76 E	12:09	4	1808
19	23.04.16	06:10	35°23.62 N 30°12.9 E	35°23.67 N 30°12.57 E	08:00	0	850

5.3.1.3 Winch and Supply Cable

The winch was designed and constructed by Mac-Gregor Hatlapa and weighs 4.7 t including the cable. Overall dimensions are 2.1 x 1.9 x 1.9 m (L x B x H). Maximum Line-Pull is 2.5 t on the lower layer and maximum spooling velocity are 30 m/min. The 19 mm soft umbilical was manufactured by Norddeutsche Seekabelwerke (NSW) and has a total length of ~2300 m. The inner consists of three Aramid layers, resulting in a breaking strain of 120 kN and a safe working load of 20 kN. Three 4² copper conductors supply the ROV with electrical power and 7 drain wires serve as protective earth. A total of 6 loose fitted single mode fibres are available in pairs stored inside three individual metal tubes.

5.3.1.4 Topside Equipment

The topside transformer weighs ~400 kg and its dimensions are 800 x 550 x 1500 mm (LxBxH). The transformer receives 400 V from the ship and converts them to 3000 VAC at 800 Hz to be supplied to the onboard transformer of the ROV. The corresponding filterbox, for compensating unwanted power peaks, weighs 100 kg and has a size of 400 x 600 x 1800 mm (LxBxH).

The devices required to operate the ROV, such as the main computer with the control system, are installed into a double sized 19" flightcase. A second 19" flightcase is equipped with devices for video routing and several computers for video recording and navigation. Two more flightcases with monitors displaying the ROVs cameras, the sonar and navigation map, are part of the topside equipment (see Fig. 5.3.2).

5.3.2 Dive Summaries

5.3.2.1 Dive 17 (Station POSEIDON: 086/1, GeoB21102-1)

Area:	Athina MV
Responsible scientists:	Walter Menapace
Date:	Tuesday 19 April 2016
Start bottom (UTC):	08:51
End bottom (UTC):	12:26
Bottom time:	03:35
Start bottom (Lat/Long/Depth):	35° 23.55' N, 30° 12.87' E, 1833 m
End bottom (Lat/Long/Depth):	35° 23.55' N, 30° 12.87' E, 1833 m

Points of interest:

WP1	35° 23.55' N, 30° 12.87' E	Location of P-lance according to MSM35T
WP2	35° 23.56' N, 30° 12.98' E	Location of T-lance according to MSM35T
WP3	35° 23.556' N, 30° 12.846' E	Retrieval of the P-lance

Scientific purpose:

The main scientific interest in retrieving the P-lance was the recovery of the instruments inside it, which consist in a pore-pressure measuring device and an osmotic water sampler. The instruments, safely brought on deck during the dive, could tell us the evolution of the pore water, as well as the changing in pore-pressure at the Athina MV during the course of more than 2 years. These kinds of long-term measurements are fundamental to comprehend the factors at play in MVs and to really understand the growth and evolution of these dynamic structures.

Summary:

Successful recovery of the pore pressure lance deployed during the cruise MSM35T.

Technical description:

We experienced some small technical difficulties during this dive. The CTD caused a blackout of the vehicle, when turned on during the descent of the ROV, therefore it had been turned off during the whole mission. The general performance of GAPS was bad with jumping positions of the transponder

and a wide scattering of the position fixes. Due to this, we had also troubles locating the cable descending from the ship because the ship signal was unstable, jumping in different spots. In this context, the sonar onboard the ROV helped for the retrieval of the lance. The whole operation was pretty difficult because of the many objects in water at the same time, as explained in Fig. 5.3.3.

Dive description:

As the ROV arrived on the seafloor it was needed to calibrate the MiniPos of the SQUID for a more accurate positioning, hence the vehicle sat on the seafloor for about 50 mins to ensure the positioning was as accurate as possible (Fig. 5.3.3). The P-lance was already located when the ROV was approaching the seafloor, so there has been no need to do an extensive research. For most of the dive, the P-lance was right in front of the vehicle. Its position was about 45 m WNW compared to the original position determined during MSM35T. The shift between the positions is probably due to underwater navigational uncertainties between the different cruises and not the consequence of a possible motion of the P-lance with the mudflows, but in-depth studies need to confirm this. Consequently we waited for the rope from the vessel, which was hard to locate due to the changing GPS signal coming from it, and in the meanwhile we did a photo documentation of the P-lance location (Fig.5.3.4). The seafloor around it seemed to be relatively bumpy, with the presence of different animals as shrimps, crabs, etc., but the P-lance was perfectly deployed in the sediment. At around 10:00 we were able to locate the rope from a sonar signal in front of the ROV, which gave us the possibility to quickly grab it with the manipulating arm and, after few meters, hooking it with the upper part of the instrumentations casing (Fig. 5.3.4). At 11:39 the P-lance was already out of the seafloor, reaching the 150 m depth at 12:26. This last action ended Dive 17, and we subsequently started our ascent to the seafloor. The logger did record pore-pressure successfully. Regarding the Osmo-Sampler, several tubes between the tip of the rood and the sample coil and between the sample coil and the osmotic pump were broken.

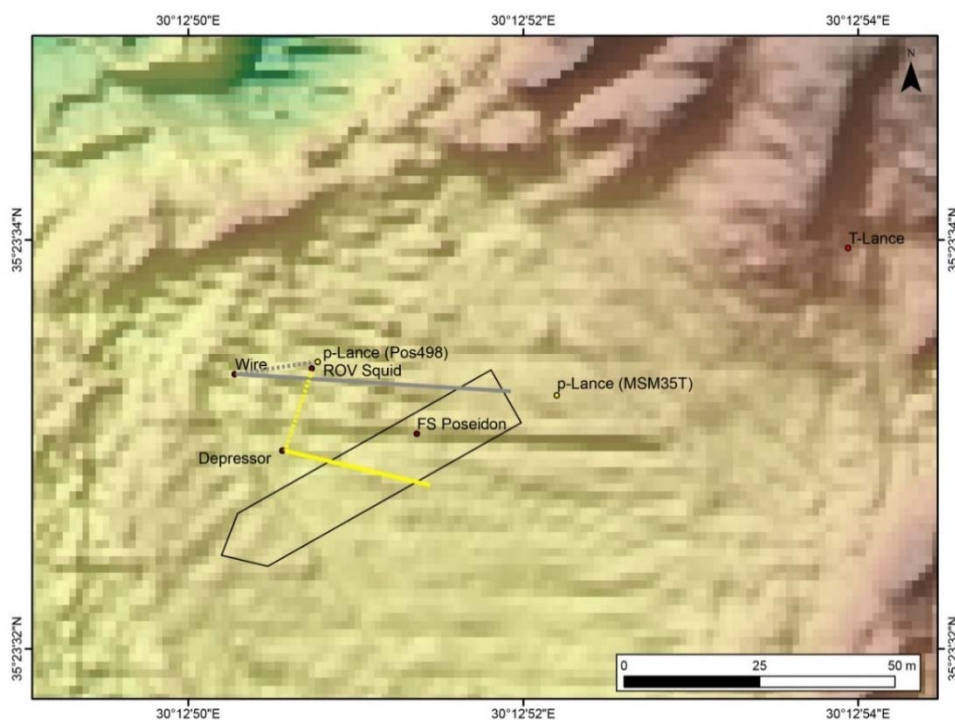


Fig. 5.3.3: The situation when the ROV connected the ship's wire with the P-lance plotted on AUV-based bathymetry during Dive 17. The currents deviated the ROV depressor as well as the wire to the W below the ship.



Fig. 5.3.4: (left) Visual location of the p-lance. (right) Hooking of the p-lance with the cable coming from the ship.

5.3.2.2 Dive 18 (Station POSEIDON: 092/1, GeoB21108-1)

Area: Athina MV
Responsible scientists: Walter Menapace
Date: Thursday 21 April 2016
Start bottom (UTC): 06:44
End bottom (UTC): 10:40
Bottom time: 03:16
Start bottom (Lat/Long/Depth): 35° 23.56' N, 30° 12.88' E, 1800 m
End bottom (Lat/Long/Depth): 35° 23.68' N, 30° 12.86' E, 1800 m

Points of interest:

WP1	35° 23.55' N, 30° 12.87' E	Location of P-lance according to MSM35T
WP2	35° 23.56' N, 30° 12.98' E	Location of T-lance according to MSM35T
WP3	35° 23.556' N, 30° 12.846' E	Retrieval of the P-lance
WP4	35° 23.576' N, 30° 12.887' E	Retrieval of the T-lance

Scientific purpose:

The main scientific interest in retrieving the T-lance was the recovery of the temperature logger placed on top of it, which recorded the temperature through an eight-thermistor string that was placed in the sediment for a length of 5 m. The measurements would tell us the evolution of the temperature at the Athina MV for the last 2 years, highlighting eventual episodes of higher thermal activity. Long-term measurements are the most precise and comprehensive way to elucidate the dynamics of MVs in time, from that the extreme importance of seafloor observatories.

Summary:

Successful recovery of the Temperature-lance deployed during the cruise MSM35T.

Technical description:

The dive was characterized by numerous technical difficulties. The miniPOS calibration did not work properly thus not providing the exact location of the ROV on the seafloor, the pilots could then only

rely on the USBL positioning. The ROV crew was also having troubles locating the depressor, a weight used to stabilize the power cable of the ROV, which position was lost during the descend to the seafloor and never determined accurately afterwards.

Dive description:

The first 20 min of the dive were spent for the MiniPos calibration of the SQUID, which was unfortunately not so successful in providing an exact location. The ROV started then the search for the T-Lance heading first towards the supposed location of deployment (WP2), pausing from time to time to observe the surroundings and scan the seafloor with the sonar. Thanks to an accurate monitoring of the sonar we were able to spot the T-lance that was, in contrast to its unsuccessful deployment, perfectly stuck in the seafloor in a vertical position. We subsequently started a visual inspection of the T-lance and waited for the rope from the vessel. The seafloor around the observatory seemed to be extremely rough with numerous depressions and small reliefs, morphologies typical of a fresh mud flow. At around 09:00 the cable from the ship was located, descending right in front of the ROV and finally, at 09:28, the ROV manipulating arm hooked the cable to the target with an excellent maneuver from the ROV pilots (Fig. 5.3.5). At 10:15 the T-lance was already on deck, with its precious data cargo (Fig. 5.3.5). The Dive 18 ended at 10:40; the temperature logger recorded effectively through all the thermistors chain, for the whole length of the deployment at the seafloor.



Fig. 5.3.5: (Left) Hooking of the T-lance with the cable coming from the ship. (Right) Safe arrival of the T-lance on deck.

5.4 Observatories (Walter Menapace)

5.4.1 Introduction

The main objective of this POS498 cruise was the retrieval of two long-term uncabled seafloor observatories deployed at the Athina MV in February 2014 during Cruise MSM35T. The observatories, installed near the most active center of the MV (according to temperature measurements from the previous expedition POS462 in the area) were aiming to monitor the temporal variability of fluid

seepage, in order to provide insights on the supposed connection between variation of seepage intensity and triggering parameters such as earthquakes at mud volcanoes.

5.4.2 P-lance

The observatories consist of two different stand-alone devices. One of these, the pore pressure lance (P-lance), is composed by two separate parts; a pressure housing measuring different parameters, such as:

- tilting of the instrument
- internal temperature of the instrument housing
- absolute pressure at the seafloor
- differential pressure between the seafloor and 3 m below the seafloor (tip of the P-lance in the sediment)

and an osmotically pumped fluid sampler (OsmoSampler), also connected with the bottom of the P-lance. The OsmoSampler is drawing pore water fluids into a small capillary-like tubing at a very slow velocity, thus allowing long-term sampling. Once opened, this instrument provides milliliter-size samples that can be used to describe the evolution of the dissolved component in water with an incredibly high resolution. Both the devices correctly deployed on the seafloor, were recovered successfully during two consecutive dives with the ROV Squid (see chapter 5.3, Fig. 5.4.1).



Fig 5.4.1: Temperature and pore pressure lances on deck upon retrieval.

The pressure information, recorded with a density of 1 measurement per min, was continuously recorded through the whole time of deployment, thus forming a complete dataset. What is immediately evident also from a rough analysis is the effect of the tides both at the seafloor (Fig. 5.4.2) and at depth (Fig. 5.4.3). Moreover, the differential pore pressure signal appears to respond to earthquakes, either located near the study area or with a high magnitude (Fig. 5.4.4); eventual signs of independent MV activity are not so evident on a first reading of the data and will be further investigated in detail.

The OsmoSampler instead will be opened and analysed onshore due to the lack of the necessary equipment onboard.

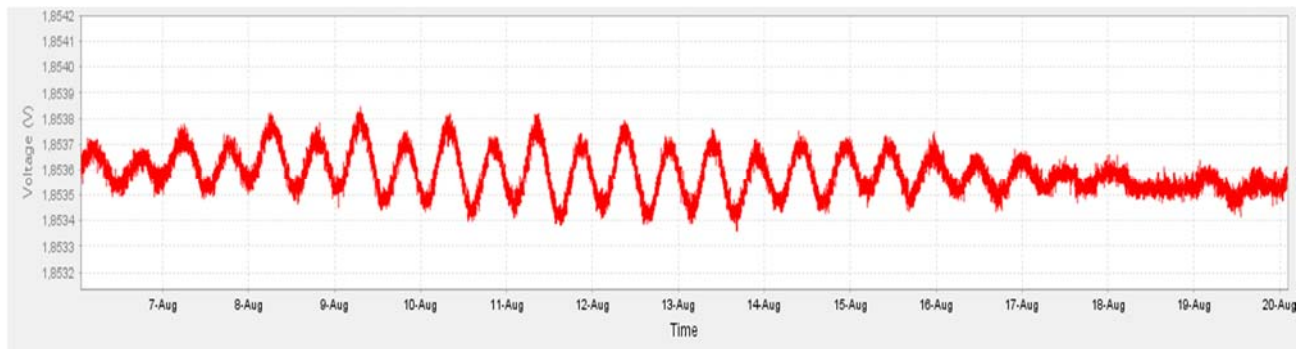


Fig. 5.4.2: Tides signature in the absolute pressure log at the seafloor.

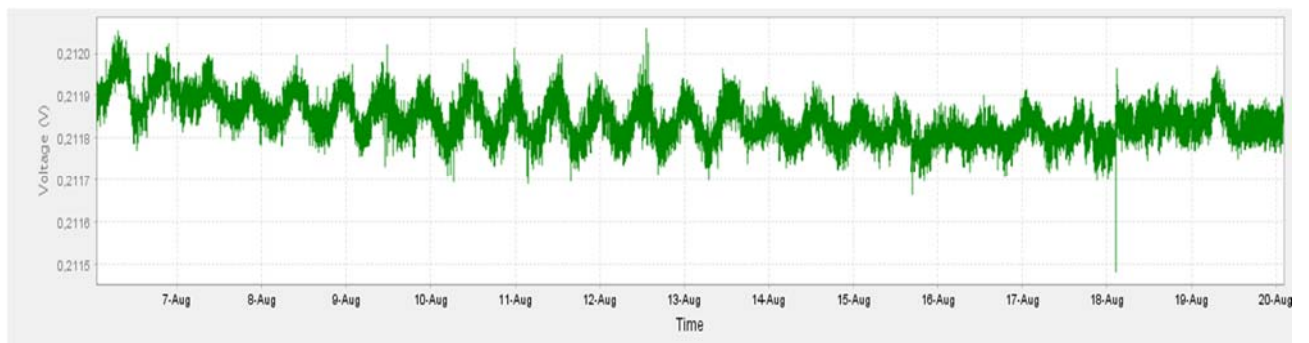


Fig. 5.4.3: Tides signature in the differential pressure log at 3 m depth.

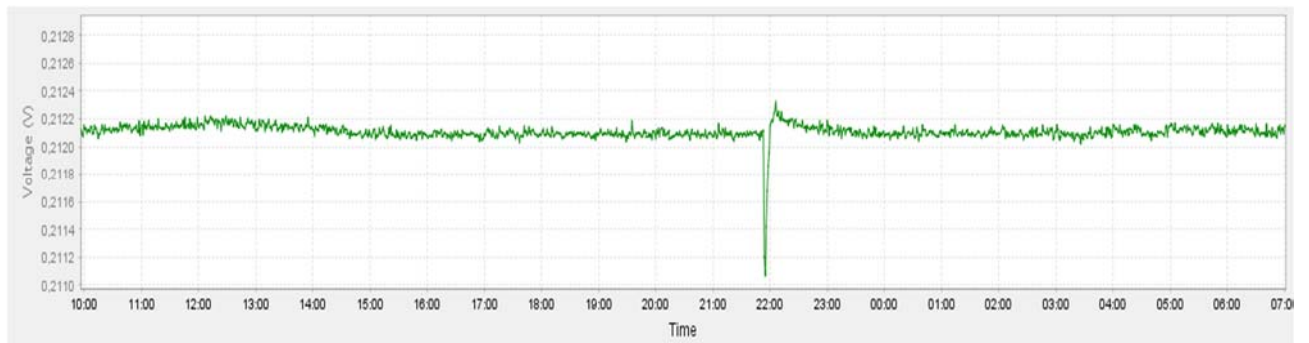


Fig. 5.4.4: Earthquake (M 5.4, offshore Crete, 34 km depth) signature in the differential pressure log.

5.4.3 T-lance

Despite its unfortunate deployment during expedition MSM35T the temperature lance (T-lance) was correctly inserted in a vertical position in the seafloor therefore providing a continuous data series through the whole time of deployment. The T-lance measured the temperature in the sediment down to 5 m depth by means of a thermistor chain mounted violin-bow style on the probe. The data logger has been set up to store the measured temperatures once every 20 minutes.

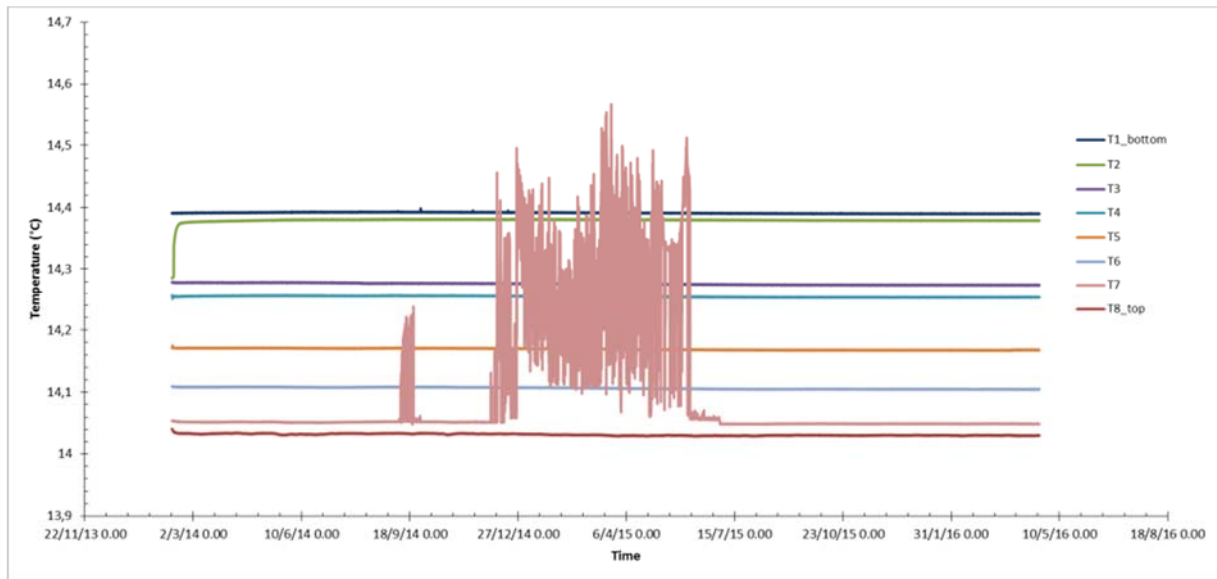


Fig. 5.4.5: Temperature recordings in each one of the thermistors from deployment to retrieval.

As can be observed in Fig. 5.4.5, there is a temperature gradient between bottom and top of the T-lance (around 70°C/km), which suggest a certain degree of activity, definitely higher than the background. The gradient is almost constant for the whole 2 years, showing no particular variations. The exception to this is T7, a thermistor located at about 1 m depth, which is showing unnaturally high temperature variations, with no matches to the other sensors, probably due to malfunctioning. Same as the pressure data, these data will be processed in greater detail once onshore.

5.5 Sediment Sampling and Description

(M. Loher, V. Bihler, E. Darilmaz)

5.5.1. Introduction

During Cruise POS498 a total of 22 gravity cores were successfully deployed at the Athina and Amsterdam Mud Volcanoes of the Anaximander Mountains (Figs. 4.1 – 4.3). A primary scientific aim was the investigation of sedimentological structures resulting from mud volcanism or fluid seepage as well as trying to determine the relative ages of these structures. Furthermore, heatflow measurements were conducted at different areas of the Athina Mud Volcano in order to try and characterize thermal regimes governing mud volcanoes. At the Amsterdam Mud Volcano, results from previous research cruises indicate the presence of fresh mud breccia extrusion, extensive mud flows, compressional mud-ridges, authigenic carbonate crusts and several irregular seafloor areas of unknown origin. Gravity cores specifically aimed for characteristic morphological features or ambiguous backscatter patterns, in order to test whether these structures indicated any sedimentological evidence of mud volcanism or fluid seepage. Of particular interest was the amount of hemipelagic background sediment overlying different mud breccia deposits of the mudflows. Dating of such material can provide insights into the dynamics, rates and ages of mud extrusion events and related fluid flow (Lykousis et al., 2009). The sedimentation rate of the eastern Mediterranean is loosely constrained to range from 2.2 to 4.3 cm/kyr (Mercone et al., 2000) but specific marker horizons such as sapropels (DeLange, 2008; Mercone et al., 2000) or tephra layers (Keller et al., 1987; Narcisi et al., 1999) may help to decipher the age of potential mud flow deposits further (Lykousis et al., 2009).

5.5.2. Gravity Corer (GC) and Multicorer (MUC)

The GC of the MARUM was deployed with a top weight of ca. 2000 kg and either a three or six meter barrel. Further, the barrel could be equipped with a plastic liner (12 cm diameter) for later core storage or with a plastic bag for fast access to the sediments after core retrieval. During Cruise POS498 20 GCs were deployed with the 6 m barrel and plastic liners, one with a 3 m barrel and plastic liner and one with a 3 m barrel and a plastic bag. Sediment cores were extracted from the barrel and cut in 1 m segments on deck. The cores were then labelled according to MARUM standards and stored as whole rounds or D-tubes after opening. Cores were opened with a vibrational saw cutter and manually split. The sediment surface was photographed and a preliminary core description was undertaken (sediment colour following the Munsell colour chart, sedimentary structures, macroscopic estimate of grain size and composition, fossil remains, etc.).

At several stations the core barrel was equipped with up to seven temperature loggers (s. specific chapter 5.6) to measure the temperatures of fresh mud breccia and older mud flow deposits. For this purpose it was possible to seal-off the gravity core barrel with a modified core catcher. This way, several GC deployments were possible without the need for a complete recovery on deck. The vessel could move to a new position with the GC elevated ca. 300 m above the seafloor.



Fig. 5.5.1: MUC head and release mechanism for the lids.

For sampling of surface sediments and in areas where mud breccia deposits might only be covered by a thin layer of hemipelagic drupe, it was planned to use a multicorer (MUC). The working principle of the MUC includes a fixed landing frame and the MUC-head at which up to 12 plastic core liners (60 cm long and 10 cm diameter) and weights up to 250 kg are integrated. Upon setting down the rigid frame on the seafloor, the head of the MUC descends ca. 50 cm relatively to the frame and the liners penetrate the sediments. The descent, driven by the attached weights, is slowed down by a piston which has to displace water out of the piston casing. Ideally, this pushes the liners into the ground in

a relatively slow and controlled manner, without disturbing the topmost sediment layers. Upon heaving on the rope the head of the MUC is lifted off the ground, the lids at both ends of the core liners are released, and clasp shut. This happens via two pins which snap into the upward moving piston, in turn dragging upward a metal ring which unhooks the strings holding the lids open (Fig. 5.5.1).

During POS498 a new MUC of the MARUM was deployed for the first time (manufactured by "Oktopus"). For these purpose, 125 kg of weight was used and 4 liners were attached. Unfortunately, we were not able to successfully recover sediment samples with the MUC. Despite numerous attempts and modifications to the tool, the release mechanism of the lids was never triggered and no sediment was retained within the plastic liners.

On deck the MUC triggered successfully and indicated the basic functionality of the release mechanism. Despite all of the following adjustments the cause of failure for the MUC to not trigger on the seafloor remained elusive. In order to try and improve the performance several modifications were applied:

Use of a small number of liners only

Addition of a hoseclamp underneath the metal ring to reduce the heave necessary for the pins to snap into the piston

Removal of stabilisation rods

Mounting of wooden planks underneath the feet to increase the surface area

Grinding of rough metal surfaces inside the piston in order to reduce the friction

Removal of screw and membrane responsible for the slow settling of the head by water displacement

5.5.3. Gravity Core Analyses

Near the Amsterdam Mud Volcano 11 gravity core locations (Fig. 5.5.2) were selected in order to investigate the general presence and extent of mud breccia deposits. One site (GeoB21106-2) was chosen as a reference site with a sedimentary sequence unaffected by mud volcanism. This core revealed the presence of two very dark and organic rich layers of which the shallower one presumably is the S1 sapropel as described e.g. by Mercone et al. (2000). Several layers of distinct colour and coarse grainsize is indicative of volcanoclastic intervals or tephra deposits.

The study by Lykousis et al. (2009) has documented fresh mud breccia without any hemipelagic drape at the central mound of the Amsterdam Mud Volcano. In contrast, the diverse morphological structures and backscatter patterns in the surrounding of the Amsterdam Mud Volcano are not yet well understood. Whereas recent mud flow activity has been attributed to the main edifice of the Amsterdam Mud Volcano (Lykousis et al., 2009), the age of any surrounding features remains speculative. Mud breccia deposits can be taken as evidence for mud flow activity and by dating overlying, hemipelagic background sediments it is possible to constrain the time of emplacement of a mudflow. Mud breccia deposits have been described for the Amsterdam Mud Volcano to be composed of a clay rich matrix with sand and gravel, containing mud- and rock clasts of up to several cm in diameter (Lykousis et al., 2009).

In most gravity cores mud breccia deposits could be easily identified by the presence of abundant rock or mud clasts. The amount of overlying background sediment ranged from 0 cm (fresh) to a maximum of ca. 380 cm. The potential S1 sapropel interval was encountered in all cores where mud

breccia deposits were buried more than ca. 20 cm. Interestingly, in core GeoB21115-1 (Fig. 5.5.3), the mud breccia seemed to have been emplaced during the sapropel S1 event. Similar to the reference core, tephra layers have been tentatively identified in several cases.

The most active and central part of the Amsterdam Mud Volcano is surrounded by a discontinuous moat and ridge. To the S, this rim is intersected by an apparent breach where extensive mud flows extend in a southward direction. The core GeoB21114-1 (Fig. 5.5.2) documents the occurrence of mud breccia hardly buried by background sediments, suggesting relatively recent mudflow activity through the breach. In the E and W, similar breaches in the mud volcano rim exist and the backscatter map suggests far reaching mudflows extending downslope. Gravity cores such as GeoB21123-1 or GeoB21122-1 reveal that the last mud flow activity through these breaches occurred much longer ago than in the south.

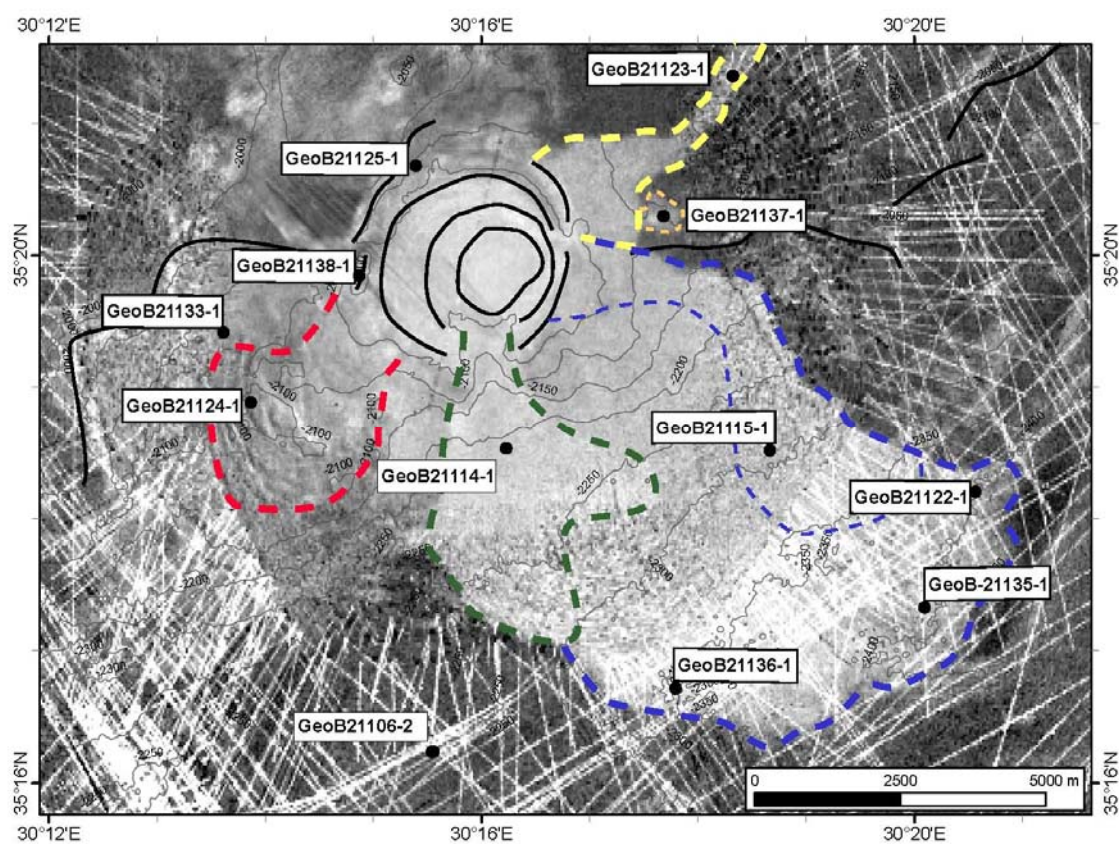


Fig. 5.5.2: Backscatter map (M70-3) of the Amsterdam Mud Volcano with gravity core locations and interpreted mud flow extents (stippled lines) as well as schematic mud volcano structures (black lines).

In the W of the Amsterdam Mud Volcano a large irregular structure is apparent. The two cores taken within this area (GeoB21124-1 and GeoB21133-1) show ca.390 cm of overlying sediments with a gradual transition to mud breccia deposits. The structure is tentatively interpreted as a precursory mud volcano or a collapse structure. Morphologically as well as in the backscatter map (Fig. 5.5.2), a large mud flow seems to extend from the moat of the Amsterdam Mud Volcano down into the precursory structure. The mud breccia encountered in the two cores could represent the emplacement of this mudflow.

In several cores (e.g. GeoB21135-1 or GeoB21136-1) a clear distinction can be made between mud breccia and sand layers (possibly of turbiditic origin). The turbidities are mainly found in cores at distal

positions from the mud volcano but clearly within areas of elevated backscatter attributed to the mud breccia deposits. This observation suggest, however, that a complicated interplay of processes influence sediment transport in the vicinity of the Amsterdam Mud Volcano.

At the Athina Mud Volcano 6 gravity core locations (Table 5.5.1) were selected for sediment sampling and 4 sites where only temperature loggers were attached to the closed-off gravity core barrel. The gravity cores which recovered relatively fresh mud breccia provided sample material for laboratory experiments (s. work by W. Menapace). Hemipelagic sediments overlying mud breccia deposits were not found at any of the sampled locations.

Table 5.5.1: Overview of all gravity core targets for sediment retrieval and general observations; last column indicates from which cores Enis Darilmaz (E.D.) sampled surface sediments (s. chapter 5.5.5.)

GeoB-No.	Mud volcano	Target	Observations	Sampled by E.D.
21106-2	Amsterdam	Reference site	No mud breccia; two sapropel intervals and several ash layers	x
21114-1	Amsterdam	S flow (breach)	Mud breccia at very top.	
21115-1	Amsterdam	E flow (breach)	Mud breccia during sapropel.	X
21122-1	Amsterdam	E flow	Mud breccia intercalated in background sediments (at base of core)	X
21123-1	Amsterdam	NE flow	Mud breccia at base of core	X
21124-1	Amsterdam	SW flow (breach)	Mud breccia at base with diffuse transition to overlying background sediments	X
21125-1	Amsterdam	N-rim	Mud breccia with crust of carbonate	X
21133-1	Amsterdam	Precursory structure	Mud breccia at base with diffuse transition to overlying background sediments	X
21135-1	Amsterdam	E flow	Mud breccia at base of core	X
21136-1	Amsterdam	S flow (distal)	Mud breccia at base with sand and hemipelagic background cover	X
21137-1	Amsterdam	E flow (old)	Patchy mud breccia in deeper sections	X
21138-1	Amsterdam	W rim (block)	Mud breccia with crust of carbonate	X
21109	Athina	N flow	Seemingly fresh mud breccia	X
21111-1	Athina	Top outflow	Unopened during cruise; probably all mud breccia	
21112-1	Athina	First lobe	Only mud breccia (fully sampled by W. Menapace)	X
21113-1	Athina	Second lobe	Unopened during cruise; probably all mud breccia; deepest section fully sampled by W. Menapace	x
21117-1	Athina	W of main flow	Slight drape and mud breccia	X
21121-1	Athina	Top outflow	Fresh mud breccia and gas hydrates (bag); fully sampled by W. Menapace	X

5.5.4. Preliminary Age Interpretations at Amsterdam Mud Volcano

To date the different mudflows around Amsterdam MV, not only the amount of sediment lying on top of the surface of the mud breccia, but also various marker horizons, such as tephra and sapropel layers, which can be observed in most of the taken cores, can be used. Some turbidity events can also be tracked through some of the cores and give hints in terms of the relative age of these cores (Fig. 5.5.3).

The core GeoB21125-1, which was taken at the northern rim of Amsterdam MV, belongs to the youngest sampled mudflows during this cruise. Mud breccia occurs at 5 cm below the surface, which is covered by carbonate crusts, and seems to be mixed with some hemipelagic sediment. No marker horizons can be tracked here. How the carbonate crusts influence the sedimentation at this location needs to be investigated. A similar seep-like structure has been found on top of a block at the western rim of Amsterdam MV in core GeoB21138-1, a bit more distant from the active center. Below the carbonate, a mixture of hemipelagic sediment and mud breccia exists until the depth of 35 cm, which possibly points out higher age of the mud breccia.

The third core without any marker horizon, thus representing a recent event is GeoB21114-1, located close to a breach in the southern area, which can be related morphologically to concentric mud ridges within the central pie shaped mud volcano close to the center. Hardly any hemipelagic sediment is covering the partly oxidized mud breccia. Core GeoB21136-1 was taken to learn more about mud flows which streamed through that breach into the basin southeast of Amsterdam MV. The mud breccia here is slightly older than at the location closer to the breach, and is covered not only by a 10 cm thick sand layer, probably caused by a turbidite, but also by 20 cm of hemipelagic sediment. The sand interval can be related to similar layers in cores GeoB21135-1 and GeoB21122-1, taken within the basin. The mud breccia found in these cores probably belongs to a former breach at the eastern rim. While the two cores in the basin show a sediment coverage of 240 cm and 325 cm, in core GeoB21115-1 the mud breccia occurs already 60 cm below the surface, right below the uppermost sapropel layer. Reasons for the difference in the thickness of overlying sediments are the age differences of the mud flow events and various turbidite layers which create an increased sedimentation. To correct this effect and to create a model of the sedimentation rate of the different areas, two tephra layers and the youngest sapropel event may provide age constraints. They can also be found in cores northeast and southwest of the mud volcano, as well as at the reference site.

A third tephra layer and a deeper occurrence of mud breccia is found in a cored mud flow in the north east (GeoB21123-1) and indicates an even higher age of the last event. The site GeoB21137-1 close to the previous site shows an interesting structure below 320 cm, which seems to be a mixture of hemipelagic sediments, sand layers and mud breccia, which might show a slide or a slump.

The deepest occurrence of mud breccia is found in GeoB21133-1, located in a complicated structure southwest from Amsterdam MV, which might be influenced by former mud flows of Amsterdam MV. The top of the mud breccia is hard to locate, a gradual transition from hemipelagic sediment to mud breccia can be found here. The shallowest sight of clasts was used to set the boundary at about 390 cm. GeoB21124-1 seems to contain a mudflow of more recent times, since mud breccia occurs at a depth of 184 cm. The structure of the gradual boundary resembles that of GeoB21133-1. The swirl-like structure at 268 cm, containing hemipelagic sediment and sapropel, is interpreted as a second surface, caused by a second penetration of the ground by the barrel.

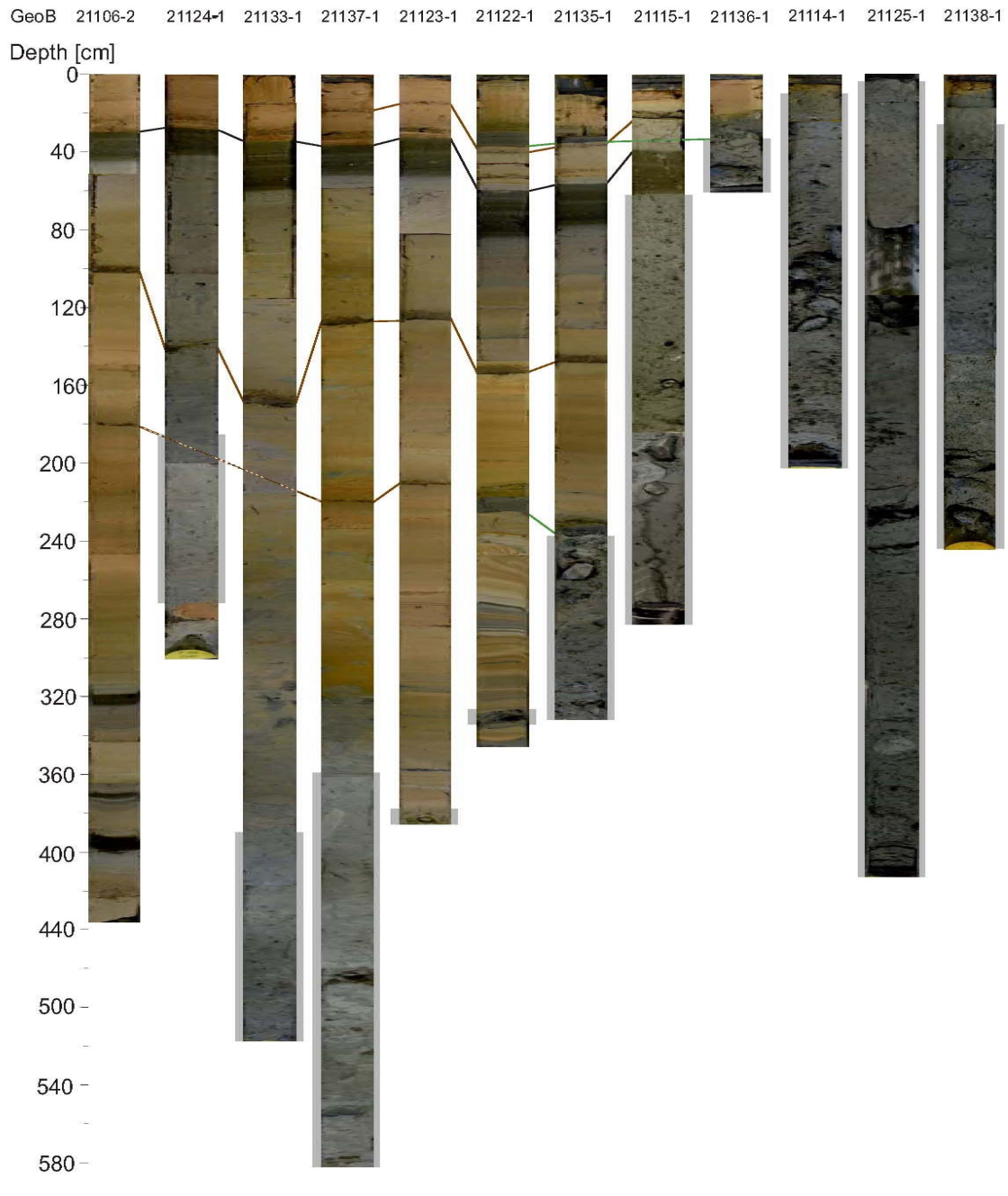


Fig. 5.5.3: Overview over all cores taken at the Amsterdam Mud Volcano. Green lines connect sand layers (possibly turbidites), brown lines connect tephra layers and black lines connect the surface of sapropel 1. The grey highlighted parts contain mud breccia.

5.5.5 Surface Sediment Sampling (E. Darilmaz)

From selected gravity cores (s. table 5.5.1) sampling of the topmost surface sediments was carried out in plastic bags and aluminium foil. The samples were stored at -20°C until analysis. For analysis, the samples will be freeze-dried and then sieved to pass $63\ \mu\text{m}$ (for heavy metals) and $250\ \mu\text{m}$ (for polycyclic aromatic hydrocarbons-PAHs). For heavy metal analysis, sediments are going to be digested

with acid mixture solutions. Heavy metal concentrations of samples will be measured by an atomic absorption spectrophotometer. For PAH analysis, sediments will be extracted using organic mixture solutions. Following initial clean-up treatments, extracts will be fractionated. Quantification will be done by gas chromatography-mass spectrophotometry. Results will be compared with the sediment quality guidelines.

5.6 Heat Flow Measurements (W. Menapace)

5.6.1 Objectives

The episodic activity in and around mud volcanoes can be tested with different in-situ measuring devices (benthic chambers, flow meters, sonars on the seafloor, etc.). During this cruise we measured the heat flow in the sediments of the Athina MV, with the intent of elucidate the seepage rates and the emission pattern of this fascinating seafloor feature. In general, the temperature information provides us not only a direct quantification of the extent of the thermal anomaly on a MV, but could also reveal the depth and size of the gas hydrate stability zone in the area.

5.6.2 Methods

For a correct determination of the heat flow, two parameters are essential: the geothermal gradient and the thermal conductivity of the material where the said gradient has been determined.

In this expedition, the geothermal gradient has been measured by equipping a gravity core barrel with outriggers mounting some miniaturised temperature data loggers (MTLs) from the company ANTARES (Fig. 5.6.1). In some cases, a sediment core was also taken simultaneous to the temperature measurements, while in some others the measurements were performed using a corer barrel with a closed tip. This way, the instrument could be used for multiple penetrations in a row without bringing the device back on deck.



Fig 5.6.1: Pictures of the gravity corer equipped with the MTLs prior to deployment on deck.

The thermal conductivity, in turn, has been determined by using the KD2 Pro, a portable device from the company DECAGON DEVICES. This instrument has a dual-needle sensor which heats the

sediment and records the different thermal parameters, including thermal conductivity. The tool is rated at $\pm 10\%$ accuracy in conductivity measurements.

The MTLs have a resolution of approximately 0.001 K, an accuracy of 0.1 K and they were mounted on a 6 m corer barrel with a spacing of 1 m and a spiral disposition. A seventh logger was installed for bottom water reference on top of the coring device. They were all deployed with a CTD station (GeoB21141-1) for later calibration, which will be done onshore, while the following results derive from intercalibration between the MTLs in the water column, before penetration. The sensors are programmed to continuously record temperature readings at an interval of one second for a maximum of 18 hours.

5.6.3 Preliminary Results

In-situ temperatures were mainly obtained at the Athina MV (Table 5.6.1), with the purpose of measuring, at the distance of two and half years from the last RV POSEIDON cruise in the area, the changes of temperature in those positions already probed during POS462. Moreover the thermal characterization of the Athina MV has been expanded with a transect of measurements perpendicular to the main direction of the mud flows and a denser network of measurements in the center of the MV (Fig. 5.6.2).

Table 5.6.1: List of all heat flow stations conducted on the POS498.

Date	POS Station	GeoB	Target	Lat N	Long E	Depth (m)	Notes
21.04.2016	93-1	21109-1	Athina MV	35°23.760	30°12.840	1785	Liner, 4.18 m core recovery
22.04.2016	95-1	21111-1	Athina MV	35°23.573	30°12.885	1774	Liner, 4.60 m core recovery
22.04.2016	96-1	21112-1	Athina MV	35°23.547	30°12.855	1774	Liner, 5.74 m core recovery
22.04.2016	97-1	21113-1	Athina MV	35°23.498	30°12.834	-	Liner, 5.00 m core recovery
22.04.2016	98-1	21114-1	Amsterdam MV	35°18.526	30°16.227	2179	Liner, 2.23 m core recovery
22.04.2016	99-1	21115-1	Amsterdam MV	35°18.664	30°18.664	2242	Liner, 2.83 m core recovery
23.04.2016	101-1	21117-1	Athina MV	35°23.529	30°12.601	1790	Liner, 1.88 m core recovery, core bended
25.04.2016	111-1	21127-1	Athina MV	35°23.282	30°13.124	1788	Temperature measurements, no core recovery
25.04.2016	112-1	21128-1	Athina MV	35°23.313	30°12.921	1777	Temperature measurements, no core recovery
25.04.2016	113-1	21129-1	Athina MV	35°23.374	30°12.801	1780	Temperature measurements, no core recovery
25.04.2016	114-1	21130-1	Athina MV	35°23.597	30°12.866	1773	Temperature measurements, no core recovery, core bended

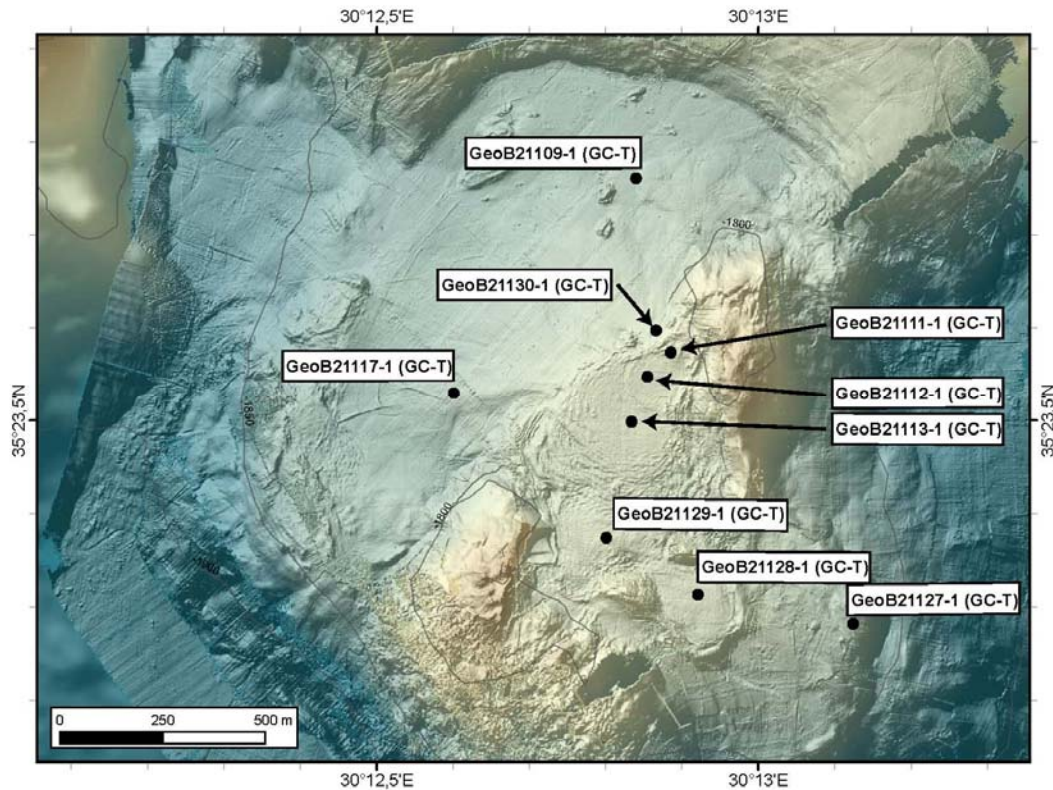


Fig 5.6.2: Map with the locations of the temperature measurements on the Athina MV.

On the Athina MV, the measurements reveal a higher gradient directly in what we believe to be the main emission spot, from where the mud flows are starting. GeoB21111-1 and GeoB21112-1, located close to the northern tip of the MV on one of the freshest mud flows, show gradients between 130 and 180°C/Km, underlining the higher temperature in this central area. Interesting to notice is the presence of gas hydrates in the same zone, also sampled and photographed in GeoB21121-1, which leads to a temperature inversion in the sediment (Fig 5.6.5). With increasing distance from the central area of higher activity, the temperature gradients quickly go down to background values. These values are normally comprised between 15 and 35 °C/km (Fig. 5.6.5). The two measurements on the Amsterdam MV show values similar to background and higher (GeoB21115-1 and GeoB21114-1 respectively).

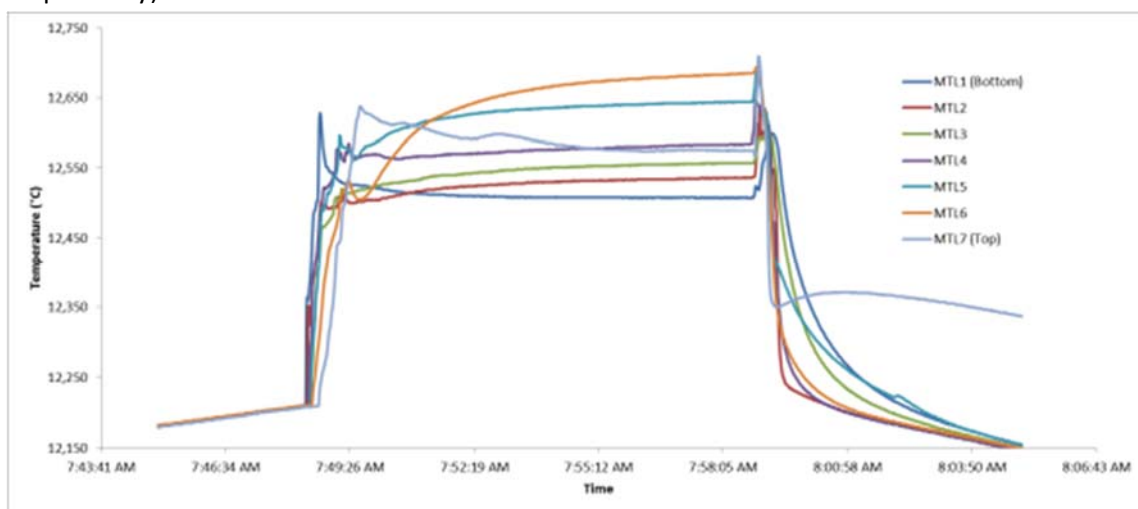


Fig. 5.6.3: Raw data from the GeoB21130-1 temperature measurement, showing thermal cooling probably due to gas hydrates dissociation at depth.

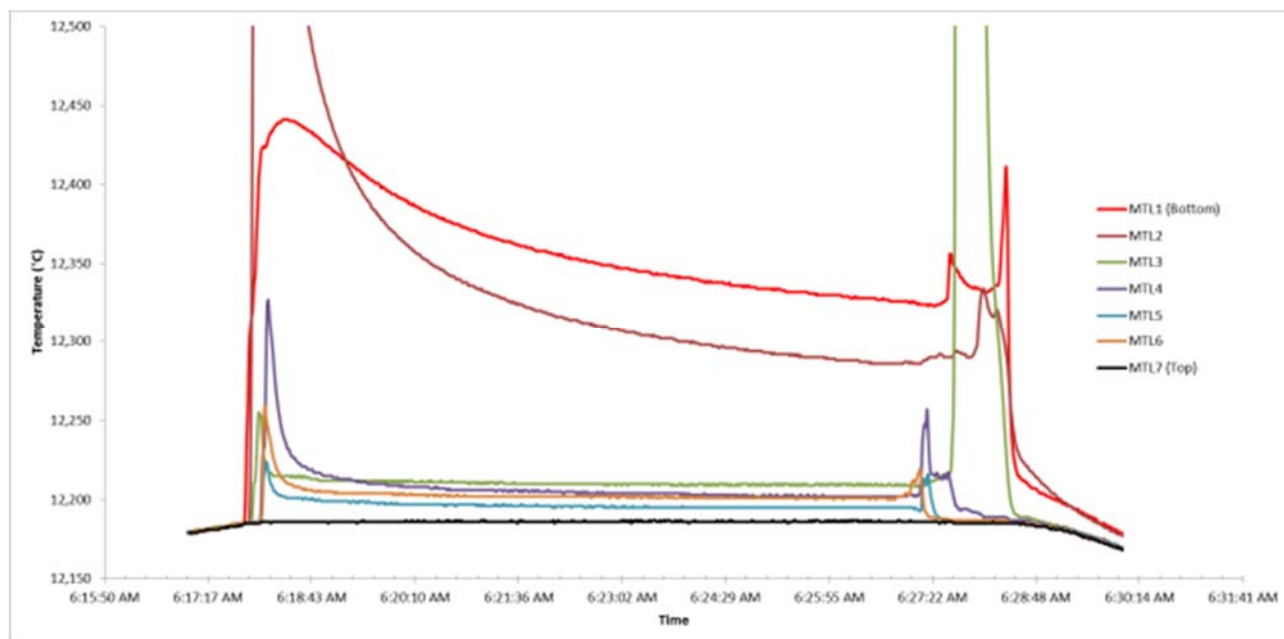


Fig 5.6.4: Raw data from the GeoB21117-1 showing background values.

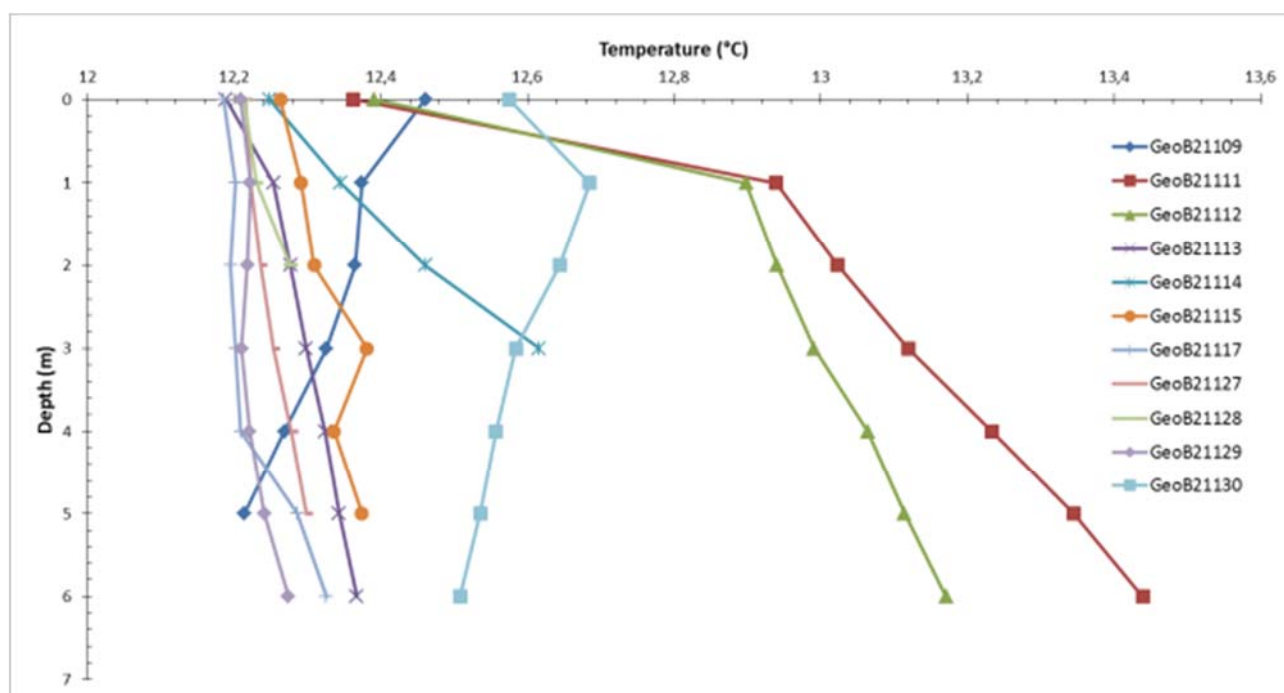


Fig 5.6.5: First calculations of the thermal gradients from all the stations conducted during the POS498.

6 Data and Sample Storage and Availability

Metadata of the cruise as well as the station list will be submitted to PANGAEA immediately after the cruise. Sediment cores are stored at the MARUM GeoB Core Repository. Samples are available upon request.

It is planned to make available all the results of the cruise as scientific publications. Upon publication, it is planned to make available all the data (raw and processed) and samples upon request. In addition, data (raw and processed) will be submitted to PANGAEA along with the scientific publication. All data and samples will be available in two years upon request.

We will prepare a comprehensive cruise report as part of the “Berichte aus dem MARUM und dem Fachbereich Geowissenschaften der Universität Bremen” (available online at: https://www.marum.de/en/Berichte_aus_dem_MARUM_und_dem_Fachbereich_Geowissenschaften_der_Universitaet_Bremen.html). In order to protect the valuable results obtained during the cruise, this report will be freely accessible in two years.

7 Acknowledgements

Work at sea was possible due to the highly professional assistance by the Captain Matthias Günter and the expert crew of R/V POSEIDON. We are grateful for the support of the AUV team. The cruise was coordinated and carried out by MARUM Center for Marine Environmental Sciences at the University of Bremen and we thank all personnel which helped in organization. Financial support was provided by MARUM – Center for Marine Environmental Science.

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9

Appendix

9.1

Appendix 1: Station List

Poseidon 498													
Station List													
Date	St.	Instrument	GeoB	Location	Time (UTC)			Begin/ on seafloor			End/ off seafloor		
2016	No.		St. No.		Begin	on seafloor	off seafloor	Latitude	Longitude	Water depth (m)	Latitude	Longitude	Water depth (m)
19.04.	85-1	mCTD	21101-1	Athina MV	5:10	5:20	-	35°23.605	30°12.943	1774	35°23.633	30°12.961	1780
19.04.	86-1	ROV	21102-1	Athina MV	6:07	8:51	12:31	35°23.540	30°12.929	1770	35°23.560	30°12.780	1770
19.04.	86-2	p-lance	21102-2	Athina MV	-	-	11:37	-	-	-	35°23.566	30°12.846	1800
19.04.	87-1	ELAC	21103-1	Amsterdam MV	14:57	-	-	35°21.060	30°10.490	1980	35°21.010	30°12.890	1982
20.04.	88-1	MUC	21104-1	Amsterdam MV	05:38	6:16	-	35°19.942	30°16.050	1998	-	-	-
20.04.	88-2	MUC	21104-2	Amsterdam MV	06:56	7:23	-	35°19.934	30°16.052	1997	-	-	-
20.04.	89-1	MUC	21105-1	Amsterdam MV	09:07	9:45	-	35°20.701	30°15.854	2039	-	-	-
20.04.	90-1	MUC	21106-1	Amsterdam MV	11:03	11:02	-	35°16.262	30°15.486	2177	-	-	-
20.04.	90-2	GC-6m	21106-2	Amsterdam MV	13:05	13:50	-	35°16.236	30°15.541	2182	-	-	-
20.04.	91-1	ELAC	21107-1	Athina MV	15:20	-	-	35°20.390	30°15.740	1998	35°25.410	30°11.890	1208
21.04.	92-1	ROV	21108-1	Athina MV	04:03	6:44	10:40	35°23.560	30°12.890	1772	35°23.606	30°12.750	1775
21.04.	92-2	T-Lance	21108-2	Athina MV	-	-	9:35	-	-	-	35°23.576	30°12.887	1800
21.04.	93-1	GC-6m+TL	21109-1	Athina MV	12:34	13:10	13:20	35°23.760	30°12.840	1785	35°23.760	30°12.840	1785
21.04.	94-1	ELAC	21110-1	Amsterdam MV	14:40	-	-	35°21.580	30°12.010	1986	35°21.560	30°12.150	1983
22.04.	95-1	GC-6m+TL	21111-1	Athina MV	03:35	4:07	4:17	35°23.573	30°12.885	1774	35°23.575	30°12.889	1779
22.04.	96-1	GC-6m+TL	21112-1	Athina MV	05:30	6:06	6:16	35°23.547	30°12.855	1774	35°23.552	30°12.860	1776
22.04.	97-1	GC-6m+TL	21113-1	Athina MV	07:37	8:09	8:19	35°23.498	30°12.834	1778	35°23.493	30°12.821	1778
22.04.	98-1	GC-6m+mCTD+TL	21114-1	Amsterdam MV	10:03	11:16	11:26	35°18.526	30°16.227	2179	35°18.527	30°16.233	2170
22.04.	99-1	GC+TL	21115-1	Amsterdam MV	12:35	13:20	13:30	35°18.513	30°18.664	2242	35°18.515	30°18.667	2244
22.04.	100-1	ELAC	21116-1	Amsterdam MV	15:32	-	-	35°22.100	30°15.140	2054	35°23.520	30°12.610	1799
23.04.	101-1	GC-6m+TL	21117-1	Athina MV	03:04	4:18	4:26	35°23.529	30°12.601	1790	35°23.529	30°12.601	1783
23.04.	102-1	ROV	21118-1	Athina MV	06:13	-	-	-	-	1770	-	-	1770
23.04.	103-1	MUC	21119-1	Amsterdam MV	10:11	10:53	10:55	35°18.526	30°16.194	2170	35°18.526	30°16.194	2170
23.04.	103-2	MUC	21119-2	Amsterdam MV	12:14	13:01	13:03	35°18.525	30°16.240	2173	35°18.527	30°16.241	2168
23.04.	104-1	ELAC	21120-1	Kazan MV	15:40	-	-	35°24.980	30°31.540	1764	35°27.300	30°33.780	1627
24.04.	105-1	GC-3m	21121-1	Athina MV	03:06	03:36	-	35°23.570	30°12.886	1773	-	-	-
24.04.	106-1	GC-6m	21122-1	Amsterdam MV	05:23	06:03	-	35°18.199	30°20.567	2346	-	-	-
24.04.	107-1	GC-6m	21123-1	Amsterdam MV	07:19	07:58	-	35°21.355	30°18.321	2133	-	-	-
24.04.	108-1	GC-6m	21124-1	Amsterdam MV	09:55	10:32	-	35°18.881	30°13.870	2083	-	-	-
24.04.	109-1	GC-6m	21125-1	Amsterdam MV	11:47	12:20	-	35°20.674	30°15.392	2019	-	-	-
24.04.	110-1	ELAC	21126-1	Amsterdam MV	13:02	-	-	35°20.440	30°15.510	2002	35°19.720	30°11.600	1989
25.04.	111-1	GC-6m+TL	21127-1	Athina MV	03:04	03:33	03:43	35°23.282	30°13.124	1788	35°23.282	30°13.124	1788
25.04.	112-1	GC-6m+TL	21128-1	Athina MV	03:04	04:15	04:25	35°23.313	30°12.921	1777	35°23.313	30°12.921	1777
25.04.	113-1	GC-6m+TL	21129-1	Athina MV	03:04	04:54	05:04	35°23.374	30°12.801	1780	35°23.374	30°12.801	1780
25.04.	114-1	GC-6m+TL	21130-1	Athina MV	03:04	05:49	05:59	35°23.597	30°12.866	1773	35°23.597	30°12.866	1773
25.04.	115-1	MUC+mCTD	21131-1	Amsterdam MV	07:41	08:24	08:26	35°16.235	30°15.556	2180	35°16.240	30°15.551	2178
25.04.	116-1	MUC	21132-1	Amsterdam MV	10:42	11:24	11:26	35°16.984	30°15.983	2197	35°16.981	30°15.983	2197
25.04.	117-1	GC-6m	21133-1	Amsterdam MV	12:38	13:15	-	35°19.412	30°13.615	2086	-	-	-
25.04.	118-1	ELAC	21134-1	Amsterdam MV	15:00	-	-	35°18.340	30°12.020	2045	35°18.140	30°11.420	1985
26.04.	119-1	GC-6m	21135-1	Amsterdam MV	05:09	05:42	-	35°17.325	30°20.092	2343	-	-	-
26.04.	120-1	GC-6m	21136-1	Amsterdam MV	06:58	07:33	-	35°16.713	30°17.791	2300	-	-	-

Appendix 1: Station List continued

Poseidon 498													
Station List													
Date	St. No.	Instrument	GeoB. St. No.	Location	Time (UTC)			Begin / on seafloor			End / off seafloor		
					Begin	on seafloor	off seafloor	Latitude	Longitude	Water depth (m)	Latitude	Longitude	Water depth (m)
26.04.	121-1	GC-6m	21137-1	Amsterdam MV	09:58	10:33	-	35°20.292	30°17.680	2062	-	-	-
26.04.	122-1	GC-3m	21138-1	Amsterdam MV	12:17	12:48	-	35°19.841	30°14.869	1946	-	-	-
26.04.	123-1	ELAC	21139-1	Amsterdam MV	14:20	-	-	35°19.740	30°14.980	2010	35°18.110	30°12.070	2006
26.04.	124-1	ELAC	21140-1	Amsterdam MV	16:32	-	-	35°18.090	30°12.060	2006	35°14.970	30°12.320	2193
27.04.	125-1	mCTD+TL	21141-1	Athina MV	05:22	05:31	-	35°23.800	30°12.170	1826	-	-	-

Instruments

ROV SQUID 2000
 mCTD memory CTD Sea & Sun Technologies 48M
 p-Lance Pore pressure Observatory
 T-Lance Temperature Observatory
 ELAC Multibeam echosounder 50kHz, ELAC Model SB3050
 GC Gravity corer (3 m or 6 m barrel length)
 GC+TL: Gravity corer with temperature logger mounted on barrel
 MUC Multicorer
 mCTD+TL memory CTD with mounted temperature loggers
 SVP Sound velocity profile acquired with mCTD

9.2 Appendix 2: Core Descriptions

Legend for Core Description

Lithology	Fossils	Colours
 Clay	 shell fragments	2.5Y2.5/1 black
 Silty Clay	 pteropod	2.5Y4/1 dark grey
 Fine Sand	 bivalve	2.5Y4/2 dark greyish brown
 Mud Breccia with differently sized clasts	 gastropod	2.5Y4/3 olive brown
 Sapropel	 root/plant debris	2.5Y5/1 grey
 Ash layer	 foraminifera	2.5Y5/3 light olive brown
 Seep structure		2.5Y6/3 light yellowish brown
 gravel		2.5Y6/4 light yellowish brown
 fluid mud filled structures		2.5Y7/2 light grey
 Gap		2.5Y7/3 pale yellow
 sharp boundary		5Y3/2 dark olive grey
 unclear/gradual boundary		5Y4/1 dark grey
		5Y4/2 dark grey
		5Y5/1 grey
		5Y5/2 olive grey
		5Y6/1 grey
		10YR5/1 grey
		10YR3/3 dark brown
		10YR4/3 brown
		10YR5/4 yellowish brown
		10YR5/6 yellowish brown
		10YR6/4 light yellowish brown

Appendix 2: Core Descriptions continued














GeoB21106-2

Site Number: GeoB21106-2
Location: Amsterdam MV

Date: 20.04.2016 Sheet: 1/1

Grid Zone:
Easting: 30°15.541' E
Northing: 35°16.236' N

Logged By: Viola Bihler
Completion Notes:
Reference site

Depth	Lithologie/ Colour	Photo	Description	Fossils
0	10YR5/4		0-23 cm: hemipelagic sediment, light brown	
20				
23			23-30 cm: gradual contact to S1 with interbedded laminars	
30	2.5Y2.5/1		30-44 cm: Sapropel layer, sharp contact, gently grading into hemipelagic sediment	
40			44-100 cm: hemipelagic sediment, grading from light grey to light brown	
60	10YR5/1			
80			100-103 cm: possibly ash layer, sharp boundaries, contains brown, unconsolidated clasts	
100	2.5Y4/1		103-185 cm: hemipelagic sediment, contains mm-sized shell fragments	~
120			185-187 cm: possibly ash layer	
140	10YR5/4		187-326 cm: hemipelagic sediment, contains mm-sized shell fragments, black organic spots (4 mm in diameter)	~
160			326-333 cm: possibly Sapropel layer, sharp contacts, slightly coarser than hemipelagic sediment, presence of wood	~
180	2.5Y4/1		333-345 cm: hemipelagic sediment, laminated	
200			345-374 cm: hemipelagic sediment, contains mm-sized shell fragments	~
220	10YR5/4		374-390 cm: possibly Sapropel layer, gradual contacts, colour varies from light green to dark grey	
240			390-404 cm: hemipelagic sediment:	~
260	2.5Y2.5/1		404-421 cm: possibly Sapropel layer, gradual contacts, shell fragments	
280			421-434 cm: hemipelagic sediment	
300	10YR5/4		434-438 cm: sand layer	
320	10YR5/1		438-449 cm: hemipelagic sediment, presence of shell fragments	~
340	2.5Y2.5/1			
360				
380	10YR5/4			
400	10YR5/1			
420	2.5Y2.5/1			
440	10YR5/4			
440	10YR5/1			

Appendix 2: Core Descriptions continued






GeoB21109-1

Site Number: GeoB21109-1
Location: Athina MV

Date: 20.04.2016 Sheet: 1/1

Grid Zone:
Easting: 30°12.840' E
Northing: 35°23.760' N

Logged By:
Completion Notes:

Depth	Lithologie/ Colour	Photo	Description	Fossils
0	2.5Y2.5/1		0-1 cm: fluid mud, not preserved	
20			1-10 cm: black sediment, laminated, smell of H ₂ S	
40	2.5Y5/1		10-107 cm: grey mud breccia, unconsolidated green, grey, brown clasts up to dm at the top (first 10 cm) only clasts up to 1 cm presence of shells	~
60				
80				
100	2.5Y5/1		107-208 cm: no sediment	
120				
140				
160				
180	2.5Y5/1		208-218 cm: some mud breccia parts, clasts up to cm	
200			218-418 cm: mud breccia, moussy texture, unconsolidated green and brown clasts up to dm	
220	2.5Y5/1			
240				
260				
280				
300				
320				
340				
360				
380				
400				
420				

Appendix 2: Core Descriptions continued

GeoB21114-1

Site Number: GeoB21114-1
Location: Amsterdam MV

Date: 20.04.2016 Sheet: 1/1

Grid Zone:
Easting: 30°16.227' E
Northing: 35°18.527' N

Logged By: Viola Bihler
Completion Notes:

Depth	Lithologie/ Colour	Photo	Description	Fossils
0			0-4 cm: foam, fluid sediment, disturbed by coring, is not preserved	
10	2.5Y2.4/4		4-8 cm: oxidized mud breccia, olive brown, oxidation fronts reach into deeper mud breccia	
20			8-223 cm: olive mud breccia, unconsolidated clasts up to 4 cm, gravel	
30	5Y5/1		90-223 cm: moussy texture	
40			110-140 cm: some cavities, larger unconsolidated clasts, up to 8 cm in diameter	
50				
60				
70				
80				
90				
100				
110				
120				
130				
140				
150				
160				
170				
180				
190				
200				
210				
220				

Appendix 2: Core Descriptions continued

GeoB21115-1

Site Number: GeoB21115-1
Location: Amsterdam MV

Date: 22.04.2016 Sheet: 1/1

Grid Zone:
Easting: 30°18.664' E
Northing: 35°18.513' N

Logged By: Viola Bihler
Completion Notes:

Depth	Lithologie/ Colour	Photo	Description	Fossils
0			0-9 cm: foam	
10	10YR4/3		9-12 cm: hemipelagic sediment, brown	
15	10YR5/6		12-15 cm: hemipelagic sediment, laminated with black	
20	5Y6/1		15-18 cm: hemipelagic sediment, grey	
25	2.5Y4/1		18-22 cm: possibly ash layer	
30	2.5Y5/1		22-37 cm: hemipelagic sediment	
40				
50	2.5Y2.5/2		38-61 cm: sapropel layer, bioturbation Pteropodes/-fragments,	↳
60				
80			61-159 cm: mud breccia, unconsolidated clasts up to cm, many gravel clasts	
100				
120				
140				
160			159-164 cm: Clast with calcite fillings	
180	5Y5/1		159-283 cm: probably same mud flow as before, but less gravel clasts, moussy texture, consolidated and unconsolidated clasts up to dm,	
200			187-198 cm: Clast, metamorph?	
220			209-215 cm: Grauwacke? with fossils	
240			248 cm: green, unconsolidated clast	
260				
280				
300				

Appendix 2: Core Descriptions continued


GeoB21117-1

Site Number: GeoB21117-1
Location: Athina MV

Date: 23.04.2016 Sheet: 1/1

Grid Zone:
Easting: 30°12.601' E
Northing: 35°23.529' N

Logged By:
Completion Notes:

Depth	Lithologie/ Colour	Photo	Description	Fossils
0	10YR6/4		0-10 cm: mud with mm-sized clasts, high portion of clay, shells on top, probably background sediment mixed with mud breccia	~
10	2.5Y5/3			
20			10-18 cm: light olive brown mud breccia, oxidized, clasts up to cm,	
30	10YR5/		18-188 cm: grey mud breccia, unconsolidated clasts up to dm gravel sized clasts	
40				
50				
60				
70				
80				
90				
100	2.5Y5/1			
110				
120			124-137 cm: carbonate rock clast, shell, Pteropodefragment	~ >
130				
140				
150				
160				
170				
180				
190			Core Catcher: coarse grained layer (clay, silt sand, gravel) shells, detritus, gastropodes, Pteropodfragments well defined layer (2-3cm), perhaps cause bending of core tube	> ~

Appendix 2: Core Descriptions continued

GeoB21122-1

Site Number: GeoB21122-1
Location: Amsterdam MV

Date: 24.04.2016 Sheet: 1/1

Grid Zone:
Easting: 30°20.567' E
Northing: 35°18.119' N

Logged By: Viola Bihler
Completion Notes:
SE-flow

Depth	Lithologie/ Colour	Photo	Description	Fossils
0	10YR5/4		0-2 cm: foam, silty fluid on top not preserved	
20	2.5Y4/2		2-25 cm: hemipelagic sediment, yellowish brown, merging to light olive brown	
40			25-30 cm: laminars of thin dark brown fine sand layers	
60	2.5Y6/2		30-38 cm: dark mineral fine sand, clayey matrix, sharp boundaries, grain size increases towards bottom	
80			38-54 cm: light brownish grey hemipelagic sediment, shell fragments	~
100	2.5Y5/1		40-41 cm: possibly ash layer	
120	5/10G		48-52 cm: brownish grey laminars	
140			52-54 cm: dark brown laminars, at bottom orange concretions (Fe)	
160	2.5Y6/3		54-58 cm: hemipelagic sediment, grey	
180	2.5Y5/2		58-83 cm: sapropel, pteropod fragments	~
200	2.5Y5/3		83-106 cm: grey hemipelagic sediment, merging to greenish grey, traces of bioturbation	s
220	5Y5/3		106-207 cm: hemipelagic sediment, light yellowish brown possibly foraminifera, shell&pteropod fragments,	
240	5Y4/1		119 cm: thin greenish fine sand layer	
260	2.5Y5/2		131-133 cm: greenish grey clay, below fs layer	
280	2.5Y5/4		149-154 cm: possibly ash layer, gradual boundary at top	
300	2.5Y6/1		163 cm: thin grey fine sand layer,	~
320	2.5Y5/4		164 cm: greenish clay, below greenish fine sand layer	~
340	[6] 2.5Y7/3		164-207 cm: lighter and darker shades, clasts of upper material in lower parts	
360	[5] 2.5Y7/2		196 cm: thin green fine sand layer, above green clay	
380	[1] 5Y4/2		207-212 cm: silty fine sand layer, top merged with sediment, one unconsolidated clast, 2 cm diameter	
	[2] 5Y7/1		212-222 cm: fine sand layer, homogenous, grey	
	[3] 5Y6/1		222-242 cm: hemipelagic sediments, greyish brown, mottled with grey	
	[4] 2.5Y6/3		235 cm: light olive brown layer, intensity decreasing towards top	
	[7] 10YR6/3		242-246 cm: angled grey layer, clasts up to 1 cm diameter	
	[8] 2.5Y6/3		246-325 cm: finely laminated sediment	
	[9] 2.5Y6/2		246-260 cm: fold structure, light yellowish brown [8]	
			260 cm: angled greenish fine sand layer	
			260-270 cm: pale yellow hemipelagic sediment, laminated, [6] foraminifera,	~
			270-272 cm: light grey, strong HCl reaction [5]	
			272-273 cm: olive grey [1]	
			273-274 cm: light grey, strong HCl reaction, laminated with darker clay [2]	
			274-275 cm: grey, middle to strong HCl reaction [3]	
			275-278 cm: light yellowish brown, laminated with light brown [4]	
			278-283 cm: [3]	
			283-287 cm: 0.5 cm: [2], 0.2 cm: [1], 0.3 cm: [5], 0.3 cm: [4], 0.3 cm: [2], 0.2 cm: [1], 0.4 cm: [5], 1 cm: [6]	
			287-288 cm: pale brown [7]	
			288-290 cm: [4]	
			290-291 cm: [7]	
			291-295 cm: [8]	
			295-296 cm: [6]	
			296-298 cm: [7], followed by silty fine sand layer, grain size decreasing towards bottom, greenish clay below	
			303-305 cm: [7]	
			305-309 cm: [4]	
			309-316 cm: light brownish grey [9]	
			316-325 cm: from the top: [6], [9], [4], [9], [7], [9], [7], [9]	
			225-234 cm: mud breccia, unconsolidated clasts, mainly up to 1 cm, one clast 6 cm	
			234-242 cm: finely laminated	

Appendix 2: Core Descriptions continued











GeoB21123-1

Site Number: GeoB21123-1
Location: Amsterdam MV

Date: 24.04.2016 Sheet: 1/1

Grid Zone:
Easting: 30°18.321' E
Northing: 35°21.355' N

Logged By: Viola Bihler
Completion Notes:
NE-flow

Depth	Lithologie/ Colour	Photo	Description	Fossils
0	10YR5/4		0-2 cm: foam	
20	2.5Y4/2 10YR5/4 10YR3/3		2-14 cm: hemipelagic sediment, yellowish brown 14-16 cm: possibly ash layer 16-33 cm: hemipelagic sediment	ss
40	2.5Y4/3		16-28 cm and 30-33 cm: yellowish brown	ss
60	2.5Y5/1		28-30 cm: dark brown, with very dark brown circle, possibly bioturbation	ss
80	2.5Y6/3		33-53 cm: Sapropel, olive brown, shell fragments, Pteropodfragments bioturbation	
100			53-121 cm: hemipelagic sediment, grey, grading to light yellowish brown	
120	2.5Y4/2		86-89 cm: black organic spots	
140			121-125 cm: possibly ash layer	
160	10YR5/4		125-225 cm: hemipelagic sediment, yellowish brown few traces of bioturbation, possibly foraminifera, shell fragments	s
180				
200			209-210 cm: possibly ash layer	
220	2.5Y4/2			
240	10YR5/4 and 5Y5/2		226-308 cm: hemipelagic sediments, yellowish brown 226-264 cm: more foraminifera, shell fragments than in younger structure	ss
260			264-266 cm: organic layer, light olive brown, gradual boundaries 266-308 cm: Pteropodfragments, shell fragments	
280				
300			308-363 cm: possibly turbidite structure changes between layers of brown hemipelagic sediment and greenish clay, silt, fine sand layers, greenish clay up to 2 cm, fs layers up to 0.4 cm pteropod fragments	
320	2.5Y4/3		355-356 cm: green silt, fine sand layer, regular boundaries	
340				
360	5Y4/1		363-364 cm: calcite layer, fossile fragments, very irregular	
380			375-383 cm: mud breccia, clasts up to 5 cm at the top mixed with hemipelagic sediment, shell fragments	ss

Appendix 2: Core Descriptions continued




GeoB21124-1

Site Number: GeoB21124-1
Location: Amsterdam MV

Date: 24.04.2016 Sheet: 1/1

Grid Zone:
Easting: 30°13.870' E
Northing: 35°18.881' N

Logged By: Viola Bihler
Completion Notes:
precursory structure

Depth	Lithologie/ Colour	Photo	Description	Fossils
0	10YR5/4		0-27 cm: hemipelagic sediment, yellowish brown, 10-15 cm: silt layer, uncontinously 20-23 cm: dark brown 24-27 cm: shell fragments	~
20	10YR3/3		27-39 cm: Sapropel layer, dark olive brown Pteropodfragments, sharp boundaries,	◇
40	5Y3/2		39-184 cm: grey mud, few Pteropods, foraminifera bioturbation	◇ SS ⊗
60	5Y5/1			
80				
100				
120				
140	5Y4/1		135-142 cm: silt, fs layer, irregular boundaries, components up to 0.4 cm, mixing in with grey hemipelagic sediments	
160				
180			184-268 cm: mud breccia, unclear boundary, the deeper the more small unconsolidated mud clasts, mm-sized, foraminifera, pteropods, shell fragments dark grey irregular structures	⊗ ◇ ~
200				
220				
240	5Y5/1			
260				
280			268-300 cm: swirl structure of hemipelagic sediment and sapropel layer, on top of grey hemipelagic mud propably artifact	
300				

Appendix 2: Core Descriptions continued






GeoB21125-1

Site Number: GeoB21125-1
Location: Amsterdam MV

Date: 24.04.2016 Sheet: 1/1

Grid Zone:
Easting: 30°15.592' E
Northing: 35°20.674' N

Logged By: Viola Bihler
Completion Notes:
N-rim block

Depth	Lithologie/ Colour	Photo	Description	Fossils
0	5Y5/1		0-2 cm: foam	
20			2-3 cm: Carbonate crust, shells	
40			3-74 cm: Mud breccia, unconsolidated clasts, mm-cm sized, shell fragments, few pteropod fragments darker and brighter parts	~ ^
60				
80	5Y5/1		74-129 cm: no sediment	
100				
120				
140				
160	5Y5/1		129-264 cm: mud breccia, few mm-sized unconsolidated clasts pteropod fragments, mottled structure, dark/light olive	^
180			223-235 cm: no sediment	
200			242-246 cm: no sediment	
220				
240	5Y5/1		265-414 cm: moussy texture, increase in porosity mm-sized unconsolidated clasts, shell fragments starting at 340 cm: clasts increase in size, up to 5 cm	~
260				
280				
300				
320	5Y5/1		340-350 cm: light olive grey unconsolidated clast	
340				
360				
380				
400				

Appendix 2: Core Descriptions continued


GeoB21133-1

Site Number: GeoB21133-1
Location: Amsterdam MV

Date: 25.04.2016 Sheet: 1/1

Grid Zone:
Easting: 30°13.615' E
Northing: 35°19.412' N

Logged By: Viola Bihler
Completion Notes:
precursory structure

Depth	Lithologie/ Colour	Photo	Description	Fossils
0	10YR5/4		0-34 cm: hemipelagic sediment, yellowish brown	
	10YR3/3		25-32 cm: dark brown mottled, black spots, shell fragments	~
40	10YR4/4		32-34 cm: laminated	
			34-58 cm: sapropel, few pteropod fragments	~
80	2.5Y5/1		58-124 cm: hemipelagic sediment, some black spots, reduce with increase of depth shell fragments, pteropod fragments, fluid mud filled holes	~
120			162-165 cm: possibly ash layer, mixed with hemipelagic sediments	
160			165-244 cm: greenish interlayers, uncontinuously, only few fragments	
200				
240				
280			244-380 cm: mud with black bended structures, mottled, grey, shell fragments	
			290 cm: fine sand layer, uncontinous	
			370-380 cm: Pteropod layer, matrix: green grey mud	
320				
360				
400			380-514 cm: mud breccia, mottled structure, unconsolidated clasts, mm- sized, cm-sized, size and amount of clasts increases with depth, few shell fragments	~
440				
500				

Appendix 2: Core Descriptions continued

GeoB21135-1

Site Number: GeoB21135-1

Date: 26.04.2016 Sheet: 1/1

Location: Amsterdam MV

Logged By: Viola Bihler

Grid Zone:

Completion Notes:

Easting: 30°17.325' E

SE-flow II

Northing: 35°20.092' N

Depth	Lithologie/ Colour	Photo	Description	Fossils
0			0-13 cm: no sediment	
20	10YR6/3 2.5Y4/3 5Y4/3		13-15 cm: brown fluid sediment 15 cm: very thin black fine sand layer 15-26 cm: hemipelagic sediment, brown clasts, unconsolidated, laminated with lighter material, pteropod fragments	
40	2.5Y6/2 2.5Y6/4 2.5Y6/1		26-30 cm: hemipelagic sediment, olive brown, gradual boundary on top	
60	5Y3/1		30-36 cm: fine sand, olive 36-37 cm: hemipelagic sediment, light brownish grey 37-38 cm: possibly Ash layer, mixed in with hemipelagic sediment	
80			38-49 cm: hemipelagic sediment, light brownish grey, shell fragments	
100	5Y5/2		49-53 cm: hemipelagic sediment, light yellowish brown, black spots, orange concretions (Fe)	
120	2.5Y6/4		53-56 cm: hemipelagic sediment, grey, shell fragments 56-78 cm: Sapropel, Pteropods	
140			78-233 cm: hemipelagic sediment, bioturbated, pteropods, foraminifera	
160			99-102 cm: greenish layer, fine sand at the bottom, possibly turbidite,	
180			127-132 cm: greenish clay	
200			146-150 cm: possibly ash layer, mixed with hemipelagic sediments	
220	5Y5/2		166-167 cm: thin green fine sand layers	
240	5Y5/3 Y10GB		180-181 cm: greenish clay 215-216 cm: thin green fine sand layers 227-233 cm: fine sand, gradual boundary at the top	
260			233-238 cm: Turbidite, dark greenish grey, gravel at bottom, grain size decreasing towards the top	
280	2.5Y6/3		238-270 cm: mud breccia, mottled, unconsolidated clasts up to 5 cm in diameter	
300	5Y5/1		252-259 cm: clast with calcite fillings	
320			270-284 cm: clay with clasts up to 1 cm in diameter, interbedded uncontinuous green fine sand layers, shell fragments,	
			281-284 cm: clast, 4 cm in diameter possibly mixing zone between two mudflows	
			284-332 cm: mud breccia, grey, unconsolidated clasts up to 1 cm in diameter	
			322-325 cm: unconsolidated clast, 6 cm in diameter	

Appendix 2: Core Descriptions continued

GeoB21136-1

Site Number: GeoB21136-1
Location: Amsterdam MV

Date: 26.04.2016 Sheet: 1/1

Grid Zone:
Easting: 30°17.791' E
Northing: 35°16.713' N

Logged By: Viola Bihler
Completion Notes:
S-flow

Depth	Lithologie/ Colour	Photo	Description	Fossils
0			0-2 cm: no core, foam	
10	10YR5/4		2-20 cm: hemipelagic sediment, yellowish brown	
20			20-31 cm: medium sand layer, clayey matrix, no or little Quarz, mainly mafic minerals, partly cemented, one clast, 1 cm diameter	
30	5Y4/1		31-61 cm: grey mud breccia, unconsolidated clasts up to 3 cm in diameter, gravel, few unconsolidated clasts up to 8 cm in diameter	
40				
50				
60				

Appendix 2: Core Descriptions continued

GeoB21137-1

Site Number: GeoB21137-1
Location: Amsterdam MV

Date: 26.04.2016 Sheet: 1/1

Grid Zone:
Easting: 30°17.680' E
Northing: 35°20.292' N

Logged By: Viola Bihler
Completion Notes:
E-flow old

Depth	Lithologie/ Colour	Photo	Description	Fossils
0	10YR6/4 10YR5/3		0-2 cm: no sediment, foam	
40	10YR4/3 5Y3/1 2.5Y5/1		2-16 cm: hemipelagic sediment, fluid on top (2-4 cm) light yellowish brown 16-18 cm: possibly ash layer, brown, mixed with hemipelagic sediment 18-35 cm: hemipelagic sediment, the deeper the more shells and pteropods	
80	2.5Y6/3		28-35 cm: darker layers gradual boundary to sapropel 35-51 cm: sapropel, shells and pteropods, very dark grey	~
120	2.5Y5/4		51-318 cm: hemipelagic sediment, light yellowish brown, weak lamination 70-71 cm: pteropod layer 71-97 cm: light yellowish brown hemipelagic sediment, pteropod fragments, gradual change of color, 97-110 cm: mottled texture 121-126 cm: possibly ash layer, unclear boundaries, mixed with hemipelagic sediment	~
160	2.5Y6/3		126-195 cm: hemipelagic sediment, light olive brown, fluid mud filled spaces, 195-218 cm: hemipelagic sediment, light yellowish brown, greenish parts, dark brown layers, shell fragments 218-219 cm: Ash layer, mixed with hemipelagic sediments 233-318 cm: foraminifera	~
200	2.5Y5/3 5Y5/1		318-360 cm: grey clay, mottled structure shell fragments, foraminifera 318-321 cm: green uncontinuous sand layers 360-558 cm: mixture of greenish and grey clay, few clasts, mottled structure, slump? shell fragments, foraminifera 391-408 cm: green fine sand layers 462-465 cm: dark green mud, perhaps sapropel 526-530 cm: fs, ms layer, greenish grey, dark greenish grey at bottom, Biotite	~
240	5Y3/2			
280	6 10GY & 5 10Y			
320				
360				
400				
440				
480				
520				
560				

Appendix 2: Core Descriptions continued



GeoB21138-1

Site Number: GeoB21138-1
Location: Amsterdam MV

Date: 26.04.2016 Sheet: 1/1

Grid Zone:
Easting: 30°14.869' E
Northing: 35°19.841' N

Logged By: Viola Bihler
Completion Notes:
W-rim block

Depth	Lithologie/ Colour	Photo	Description	Fossils
0	2.5Y6/3		0-2 cm: no sediment, foam	
20	5Y5/1		2-7 cm: carbonate crust, light yellowish brown, possibly seep structure, many shells	
			7-35 cm: grey silty clay, vertical, fluid mud filled cavities	ss
40	2.5Y5/1		35-244 cm: mud breccia, grey, unconsolidated clasts up to 1 cm in diameter, a few larger clasts, up to 6 cm in diameter	
60			156-244 cm: higher amount of small clasts	
80				
100				
120				
140				
160	5Y5/1			
180				
200				
220				
240			230-240 cm: clast, 15 cm in diameter	

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