

MENEZKART

RV POSEIDON Cruise No. 402

30.07. – 10.08.2010, Ponta Delgada – Ponta Delgada (Portugal)



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Table of Content

	Page	
1	Summary	3
2	Participants	3
3	Research Program	4
4	Narrative of the Cruise	4
5	Preliminary Results	6
5.1	Bathymetric Mapping	6
5.1.1	System Overview	7
5.1.2	Sound velocity Profile	9
5.1.3	Calibration	9
5.1.4	Data Processing and Preliminary Results	10
5.2	AUV Operations	12
5.2.1	System Overview and data Processing	12
5.2.2	Status of AUV	14
5.2.3	Dive 38	14
5.2.4	Results	15
5.3	ROV Operation	15
5.3.1	System Overview	15
5.3.2	ROV dives	17
5.4	Geology	22
5.4.1	Geology of Menez Gwen	22
5.4.2	Geological Mapping	23
5.5	CTD Measurements and Sampling for Methane Concentrations in the Water Column	24
5.5.1	Methods	24
5.5.2	Results	25
5.6	Plume Mapping with CTD/MAPR Tow-yows	26
5.6.1	Methods	26
5.6.2	Results	26
6	Station List	31
7	Data and Sample Storage and Availability	31
8	Acknowledgements	32
9	References	32

1 Summary

Menez Gwen is a ridge-centred seamount with neovolcanic and hydrothermal activity at 37°N on the Mid-Atlantic Ridge (MAR). Menez Gwen was discovered 1994, and although it was visited by submersible dives in subsequent years it remains one of the least investigated hydrothermal vent fields on the northern MAR. The Menez Gwen hydrothermal vent field was chosen as a key study site for interdisciplinary geological, chemical and biological studies within the Research Area F “Lithosphere – Biosphere Interactions” of the MARUM Cluster of Excellence. This cruise served as a base line study for a follow up cruise with RV METEOR and the ROV Quest and focused on two major questions: 1) What is the volcanic activity at Menez Gwen? and 2) Are there more active vent sites than previously described and did the hydrothermal activity on the young volcano in the rift graben change since 1997? To achieve these goals we followed two strategies: High resolution bathymetric mapping using ship based and AUV based echosounders and tracking of the neutral buoyant hydrothermal plume with CTD/MAPR profiles.

Zusammenfassung

Menez Gwen ist ein bei 37°N zentral auf der Spreizungsachse des Mittelatlantischen Rückens (MAR) gelegener, neovulkanisch und hydrothermal aktiver Seeberg. Menez Gwen wurde 1994 entdeckt und war in den darauf folgenden Jahren Ziel wissenschaftlicher Expeditionen mit Tauchbooten. Trotzdem ist Menez Gwen bis heute eines der am wenigsten untersuchten Hydrothermalgebiete am nördlichen MAR. Das Menez Gwen Hydrothermalfeld wurde als ein Kernuntersuchungsgebiet für interdisziplinäre geologische, chemische und biologische Untersuchungen innerhalb des Forschungsbereichs F „Lithosphere– Biosphere Interactions“ des MARUM-Exzellenzclusters ausgewählt. Die Forschungsfahrt POS 402 diente zur Vorbereitung einer nachfolgenden Reise mit FS METEOR und dem ROV Quest und sollte die folgenden Fragen beantworten: 1) Wie ist die vulkanische Aktivität von Menez Gwen? und 2) Gibt es mehr aktive vent sites als die bisher beschriebenen und hat sich die hydrothermale Aktivität des jungen Vulkans im Rift-Graben seit 1997 verändert? Um diese Ziele zu erreichen sollte das Gebiet mit Fächerecholoten vom Schiff und von einem AUV aus hoch auflösend bathymetrisch kartiert werden. Weiterhin sollte die schwebende hydrothermale Plume mit CTD/MAPR-Profilen kartiert werden.

2 Participants

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Thal, Janis	Geology	MARUM
Wintersteller, Paul	Bathymetry	MARUM
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3 Research Program

Menez Gwen is a ridge-centred seamount with neovolcanic and hydrothermal activity at 37.5°N on the Mid-Atlantic Ridge (MAR). Its summit harbors the Menez Gwen hydrothermal vent field which was discovered 1994 and remains one of the least investigated vent fields on the northern MAR. It was chosen as a key study site for interdisciplinary geological, chemical and biological studies within the Research Area F “Lithosphere – Biosphere Interactions” of the German MARUM Research Cluster of Excellence. The proposed cruise focused on the major questions: 1) What is the volcanic activity at Menez Gwen – has it changed since the last explorations in the late 1990s? 2) Are there more active hydrothermal vent sites than previously described?

The main purpose of this cruise was to answer the above questions as a preparation for a research cruise with RV METEOR and the MARUM ROV Quest in September/October 2010 that was dedicated to a detailed geochemical and biological research program at the hydrothermal vents. The scientific program of POS 402 included initial mapping with a ship-based 50 kHz multi-beam echosounder to provide maps of the entire Menez Gwen seamount. In a next step it was planned to create more detailed bathymetric maps of identified sites of special interest in the summit area by AUV-based swath bathymetry surveys (200 kHz). Such micro-bathymetry can give indications for additional hydrothermal activity. The 1000-m depth rated ROV Cherokee was used for detailed video observations, geological mapping and geological sampling in selected locations of the Menez Gwen summit area. Micro-bathymetry and ROV surveys should serve as a basis for the selection of suitable dive sites for geochemical and biological sampling and experimentation with the ROV Quest during the following RV METEOR cruise.

The existence of additional hydrothermal vents and the extension of the neutral buoyant hydrothermal plume was investigated by CTD casts and tow-yos with Miniaturized Autonomous Plume Recorders (MAPR). These instruments can “sniff” turbidity and reduced volatiles introduced into the water column by hydrothermal input, while water samples collected with the Rosette sampler were analyzed for methane concentrations.

4 Narrative of the Cruise

27th – 29th August: An advance group started with installing the mobile Elac multibeam echosounder and setting up the AUV Seal. The Cherokee ROV was still on board and ready to use since the preceding cruise POS 400. The remaining scientific group entered the ship in the

morning of 29th August and continued setting up scientific equipment and laboratories. This day served for a multibeam echosounder calibration daytrip to off the southwest coast of São Miguel. Return to Ponta Delgada at 17:00.

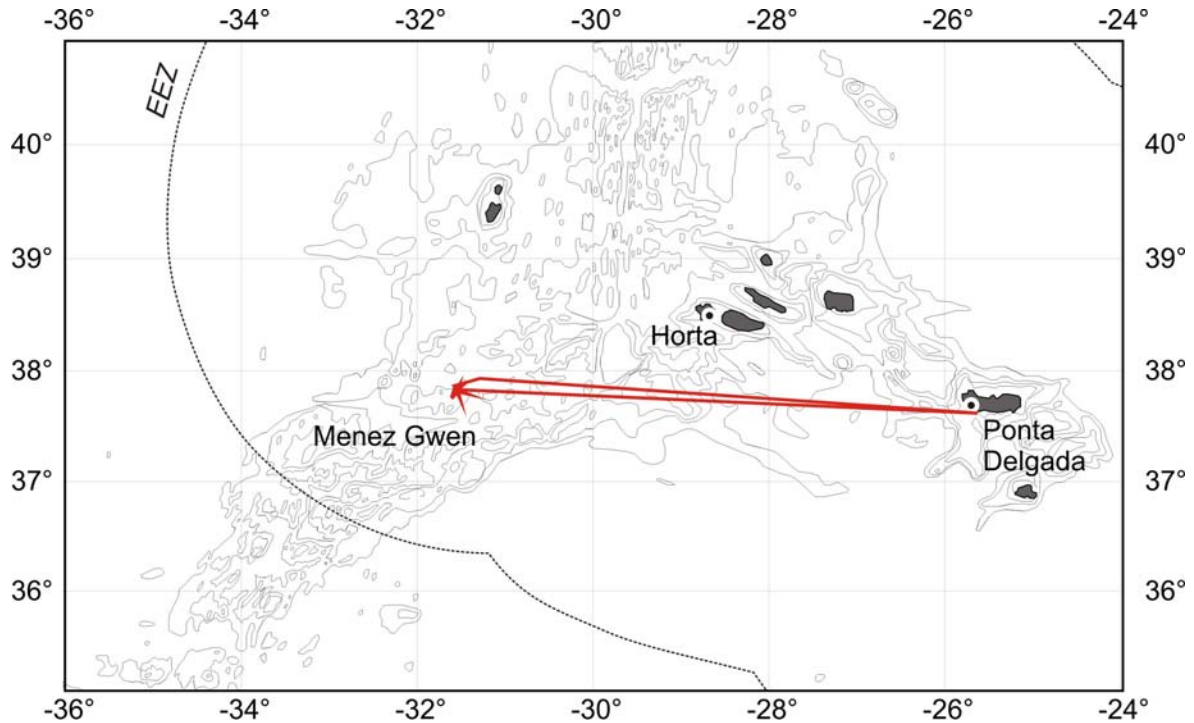


Fig. 1 Track chart of RV POSEIDON Cruise 402 Ponta Delgada - Menez Gwen – Ponta Delgada.

30th August. We left Ponta Delgada 09:00 and started transiting to the Menez Gwen working area. Wind E, 4.5 – 7 m/s

31st August. 15:15 AUV balance trim test on sea surface at 37°56.74' N, 32°43.99' W with AUV hooked to crane. Wind N-E, 4.5 – 6 m/s, waves ~1.5: too rough for proper evaluation of trim. 16:10 first CTD cast at same position for background values. Arrival in the research area late at night.

1st September. Between 01:50 and 08:00 first multibeam echosounder profiles starting at 37°52.74' N, 32°26.48'. In the morning (08:00), wind from ENE is increasing from 3.8 to 6.5 m/s, waves still ≥ 1.5 m, i.e. too rough for AUV deployment. During the day, two CTD casts and the first ROV dive at 37°50.63' N, 32°29.13' W on the NW slope of the young small Menez Gwen volcano in max. 865 m water depth. Purpose: search for known Menez Gwen vent sites, deploy wood colonization experiments. After 20:30 multibeam echosounder surveys (start 37°48.56' N, 32°25.45' W).

2nd September. 07:00: wind ENE up to 9.1 m/s. 07:30 – 16:30 ROV Cherokee dive no. 2 around 37°50.54' N, 32°27.80' W on outer flank of E volcano wall. Purpose: search for active chimneys mentioned in MOMAR database. 17:40 – 04:00 first CTD/MAPR tow-yo N to S along the Menez Gwen rift valley.

3rd September. 04:50 multibeam echosounder profiling. 08:00 wind ENE around 7 m/s, therefore continue echosounding. At 12:00, wind is around 5 m/s but waves are still too high for AUV deployment. Therefore continue searching for active chimneys on outer flank of E volcano wall with ROV dive no. 3 on 37°50.96' N, 32°26.57' W. 18:20 CTD cast and 20:30 multibeam echosounding.

4th September. 00:56 CTD/MAPR tow-yo southward along the rift valley as a continuation of the previous. 08:00 wind between 8 and 10.5 m/s, therefore continue with ROV dive no 4; purpose: explore top of young volcano above vents located during dive 1 and deploy wood colonization experiments next to vents at 37°50.67' N, 31°31.15' W. Further program: 12:00 multibeam echosounding. 19:00 CTD cast, 20:50 CTD MAPR tow-yo on same profile as tow-yo no. 1.

5th September. Wind and waves had calmed down to <5 m/s and 1 m, respectively, and we could do the first AUV mission with the purpose to map the small young Menez Gwen volcano at the northern end of the rift valley. Start 09:00. The vehicle began the mission but aborted after a short time at depth and surfaced again. Adjustment of the minimum distance-to-bottom threshold without recovery of the vehicle and restart of the mission – aborted again after short time at depth. A third attempt ended similar and we decided to recover the vehicle for a thorough failure analyses. This revealed later that the vehicle to keep minimum distance to bottom in this rough terrain. As this failure could not be eliminated aboard ship, it was decided that the vehicle should not be used again during this cruise. Continue with a CTD cast (17:45) and multibeam echosounding (19:40).

6th September. Wind speed again up to 7 m/s. 09:45 ROV dive no. 5 at 37°50.54' N, 32°28.65' W, purpose: search for known vents on the southern slope of the small young volcano and explore the young rift valley. 16:20 CTD cast, 18:00 CTD/MAPR tow-yo across the rift valley some 1.5 km south of the small young volcano.

7th September. 00:10 multibeam echosounding. 08:00: wind speed had calmed down to ≤ 2.1 m/s, waves 0.5 - 1 m. Further program of the day: 2x CTD cast, 1x CTD/MAPR tow-yo across the rift valley at the southern margin of the small young volcano (start 09:25) and multibeam echosounding during the night.

8th September. Wind speed 4 m/s, waves <1 m. Cherokee dive no. 6 purpose: deploy wood colonization experiment next to vents at 37°50.67' N, 31°31.15' W, explore small young valley on top of the small young volcano. With the end of this dive at 15:10, we stopped the scientific program and headed back to Ponta Delgada.

9th September. On transit, wind at 08:00 ENE around 6 m/s.

10th September. Arrival in port at 08:00. Unloading of equipment was completed around noon time.

5 Preliminary Results

5.1 Bathymetric Mapping

(P. Wintersteller)

The Menez Gwen area had been visited by earlier research cruises, but good quality maps of the summit region were not available (Fig. 2). A major aim of this cruise was therefore to produce

good quality maps with ship based and AUV based multibeam echosounders serving for the preparation of a follow up cruise with RV METEOR and the ROV Quest (Marum, Bremen) dedicated to research on the geochemistry and biology of the Menez Gwen hydrothermal vents.

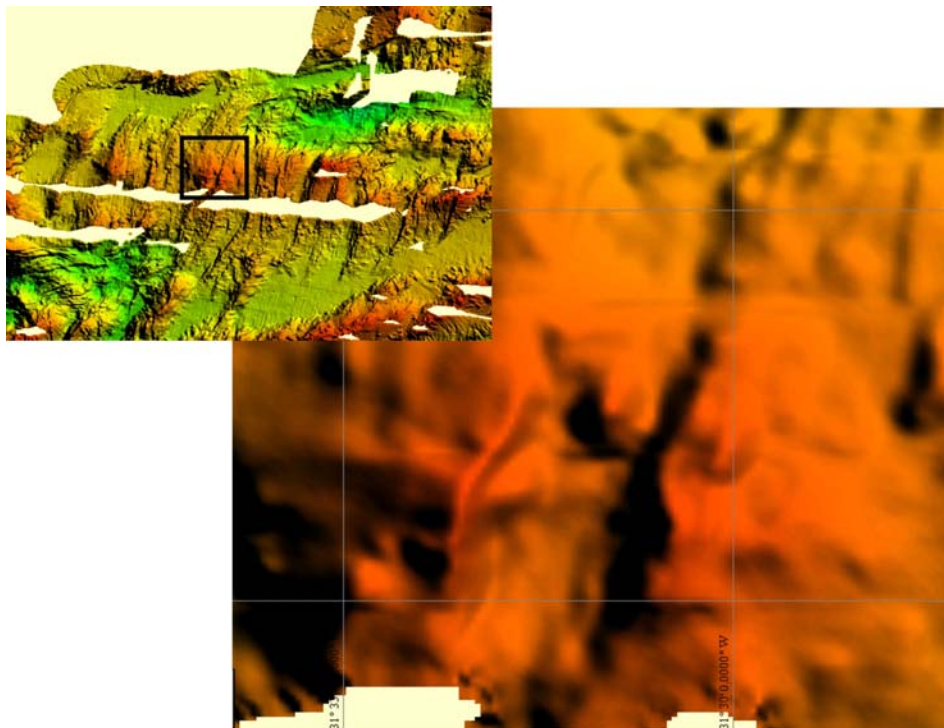


Fig. 2 Bathymetric maps of the Menez Gwen area were only available low resolution (100 m grid, source: Sismar/Ifremer)

All devices used during POS402 were tracked by a Trimble DGPS owned by MARUM. The Trimble SPS351 receiver uses RTCM DGPS corrections either broadcast freely by IALA Beacon stations, from SBAS (Satellite Based Augmentation Systems) or via an external radio or Internet connection from a DGPS reference station. The GPS-Antenna was installed at the rear star port side of the vessel, next to IXSEAs GAPS acoustic antenna array. The portable pre-calibrated Global Acoustic Positioning System (GAPS) combines ultra-short baseline (USBL), inertial navigation system (INS) and GPS technologies. This system is known as the most accurate USBL in its category because it works well from deep to very shallow water depths and in difficult environments. The accuracy is given as 0.2% of the slant range.

5.1.1 System Overview

The L3 ELAC Nautik multibeam echosounder SeaBeam 1050D was used during this cruise to map a total of almost 600 km² of the Menez Gwen segment. It consists of the following units:

- 2 x Ultrasonic Transducer Arrays (LSE 237)
- 1 x Transmit/Receive Unit (SEE 30)
- 1 x Roll, Pitch and Heave Sensor (IXSEA Octans3000)
- 1 x Data Acquisition System (19" industry PC)

- 1 x DGPS-System (Trimble SPS351 see above)
- 1 x Sound Velocity Probe (SEA&SUN CTD48M)
- 1 x Postprocessing Hardware (Lenovo ThinkPad W500)

Installed in the moon pool of RV POSEIDON, the system collects bathymetric data in shallow to medium water depths with a swath width of 120 degrees. Two narrow beam width transducer arrays are pinging quasi-simultaneously into 14 directed sectors with a high acoustic transmission level. The receiving beamformer generates 3 narrow beams within each sector (a so-called subfan) with a beam width of 1.5° (Phase calculator) and a spacing of 1.25° . A complete fan comprises three subfans, i.e. there are 14 sectors x 3 beams x 3 subfans = 126 beams in total. The relatively high operating frequency of 50 kHz together with special small size transducers offers the two advantages of high coverage and narrow beam width. The application of preformed beams guarantees extremely good side lobe suppression and a very low error rate.

Both frequencies of 50 and 180 kHz are powered by only one sonar processor. During POS402 we used only the 50 kHz transducers. As written above the mounting angle at RV POSEIDON allows a swath width of 120 degrees, thus 108 instead of 126 beams were formed. One needs to take this into account during post processing with e.g. *CARIS HIPS*.

A disadvantage of the system is the time consuming procedure for the complete fan that lowers the data density. Accommodating this circumstance we changed our survey planning following two coils shifted by a distance of less than 1km. Figure 3 shows all the track lines inside the survey area.

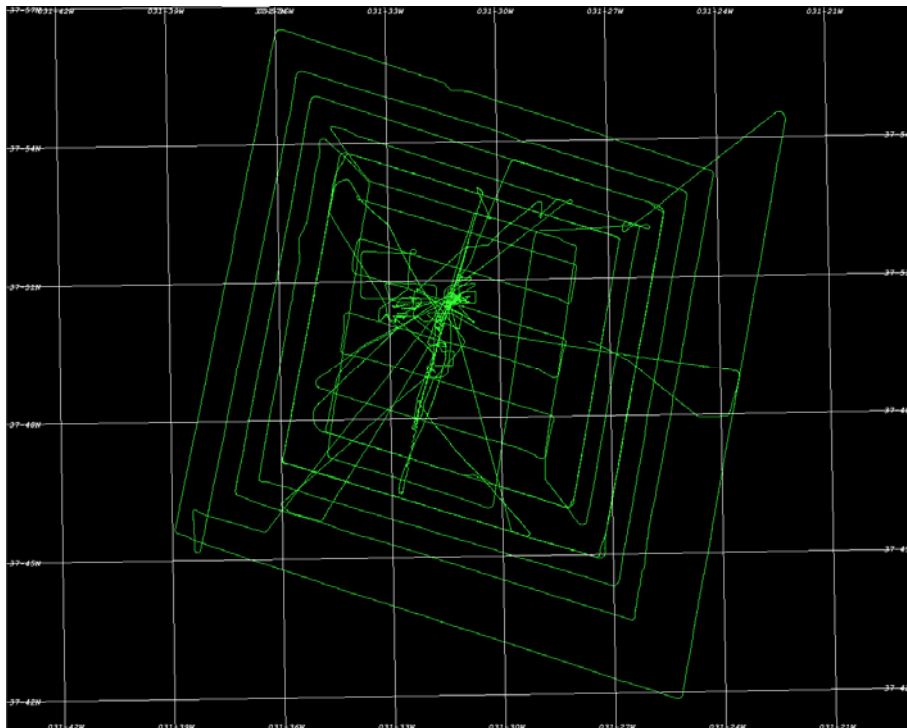


Fig. 3 Track lines in the survey area of Menez Gwen

5.1.2 Sound Velocity Profile

The influence of the sound velocity profile (SVP) on the sound beam propagation in water is taken into account by using ray tracing algorithms based on the measured actual SVP. Thus correct depth and position data are calculated. One SVP has been taken with the *SEA&SUN* probe for the calibration survey, off the island of Sao Miguel at 37°45.131'N, 25°45.923'W. In the survey area of Menez Gwen a SVP was taken with the onboard CTD from IOW at 37°56.6712'N, 31°16.1520'W.

5.1.3 Calibration

Since the multibeam system is mounted temporarily in the moon pool of RV POSEIDON a calibration of the system is mandatory. For roll calibration a shallow area of max. 100m water depth is sufficient. We found the area next to the harbor of Ponta Delgada between 37°45.969'N, 25°47.241'W and 37°44.735'N, 25°45.281'W. Our calibration survey started at 29th July afternoon and took about 5 hours.

A flat ground is needed for roll calibration whereas an obstacle in evidence is used for a pitch and yaw calibration. Figure 4 shows that the two structural conditions were given in the research area.

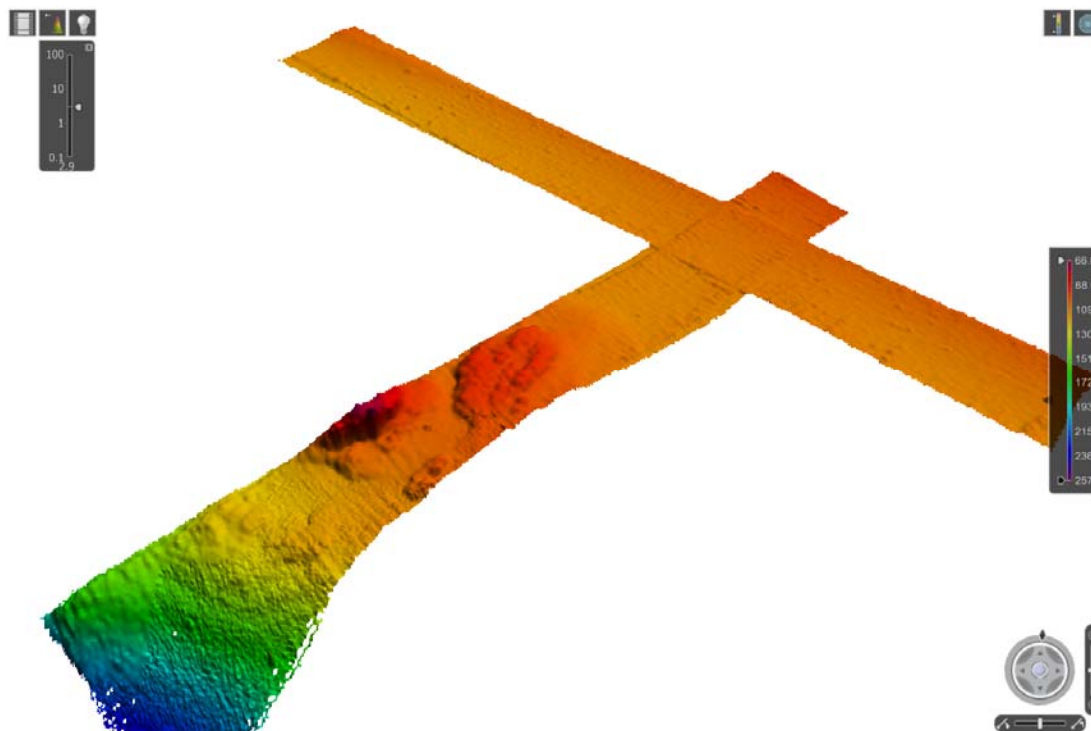


Fig. 4 The lines in the figure are shown without calibration offsets.

The ELAC software package *HDP* is used for post processing and calibration. The obtained values were also checked with *CARIS HIPS* and entered in the so called SHIP-File of the acquisition software *Hydrostar* (ELAC).

5.1.4 Data Processing and Preliminary Results

Post processing has been done with CARIS HIPS and SIPS. Since the motion data (roll, pitch and heave values) looked quite good, no automatic filtering or smoothing of the sensor data has been applied. Single outliers were manually removed. The DGPS navigation information is very good therefore only minor outliers in terms of speed/distance were removed manually. The major part of post processing was the editing of single beams and swath. Due to body noise of the vessel that causes a very weak signal to noise ratio for water depths below about 1000m lots of artifacts were recorded. Cleaning this data was time consuming since most has to be done manually. During the first two days of the survey we realized that the vessels navigators used the normal steering gear with actually partly damaged hydraulic cylinders. Major parts of these surveys have been repeated due to the very bad data quality. Later on the vessels auxiliary steering gear was used and signal to noise ratio improved a lot. The result of about 300nm of surveying is a 30m grid shown in Fig.4.

Summarizing the facts:

- Surveys of about 715 km have been acquired.
- The average speed was 2.8 kn, taking curve speed into account.
- An area of about 600km² was covered in total.

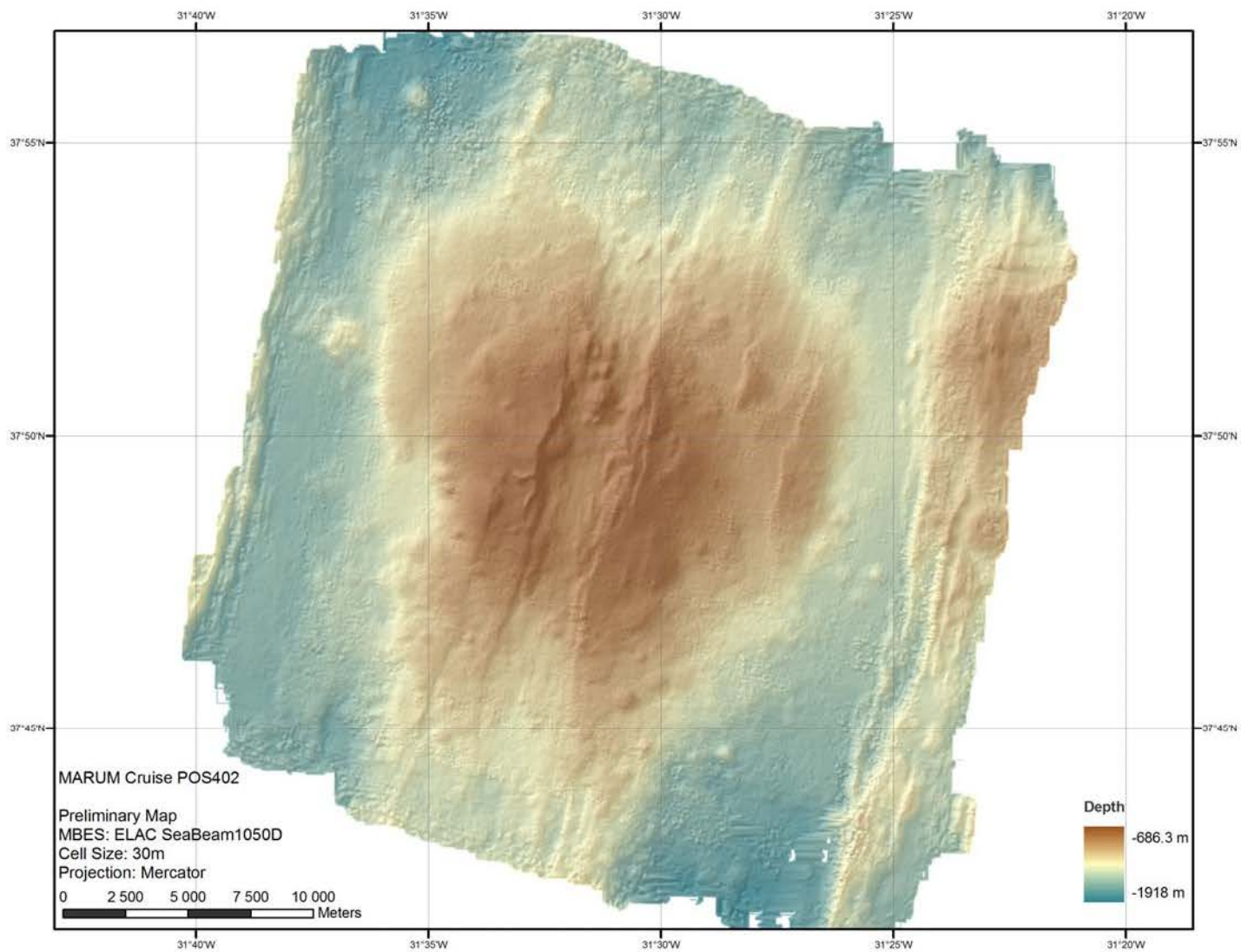


Fig. 5. 30 m grid resolution of the mapped area of Menez Gwen.

5.2 AUV Operations

(G. Meinecke, J. Renken)

5.2.1 System Overview and Data Processing

AUV SEAL is No. 5 of the Explorer-AUV series from the company I.S.E., delivered in 2007 to MARUM. The AUV is nearly 5.75 m long, with 0.73 m diameter and a weight of 1.35 tons. The total system is mobilized with 2x20" container, one operation and one transport van. The AUV consists of a modular aluminum atmospheric pressure hull, with installed lithium batteries, spare room for additional "dry" payload electronics and the main vehicle control computer (VCC). The VCC is based on industrial electronic components and compact-PCI industrial boards. The software is built QNX 4.25 – a licensed UNIX derivative, to large extend open for user modifications. In addition, the inertial navigation system PHINS and the RESON multibeam-processor are located in the pressure hull. The tail and the front section, build on GRP-material, are flooded wet bays. In the tail section the motor, beacons for USBL, RF-radio, Flash light, IRIDIUM antenna, DGPS antenna and the pressure-sensor are located. In the front section the Seabird SBE 49 CTD, the Sercel MATS acoustic modem, the DVL, KONGSBERG forward sonar and the RESON MBES 7125 are located.

For security aspects, several hard- and software-mechanisms are installed on the AUV to minimize the risk for malfunction, damage and total loss. More basic features are dealing with fault response tables, up to a emergency drop weight, either released by user or completely independent by AUV itself.

On the RV POSEIDON, the counterpart to the VCC is located on the surface control computer (SCC), running with same QNX and a Graphic User Interface (GUI) to control and command the SEAL AUV. Direct communication with the AUV is established by Ethernet-LAN, either by hard-wired 100mb LAN cable plugged to AUV on deck, or by Ethernet-RF-LAN modem once vehicle is on water. The typical range of RF-communication is around 1 – 2 km distance to vehicle. Within this range the user has all options to operate the AUV in Pilot-Mode, e.g. to manoeuvre the AUV on water or change settings. Once the AUV is under water, all communication links were shut down automatically and the AUV has to be in Mission-Mode, means it is working based on specific user-defined mission.

Mission-Mode

The AUV as dedicated autonomous vehicle has to be pre-defined operated under water; once it dives, it will loses communication and therefore must be "on mission". Simplified, an AUV mission is a set of targets, clearly defined by its Longitude, Latitude, and a given depth the vehicle should reach/keep by a given speed of AUV in a distinct time. The AUV needs to be in a definite 3-dimensional underwater space to know exactly its own position over mission time in order to actively navigate on this. To achieve this basic scenario, the AUV is working at sea surface with best position update possible, e.g. DGPS position. Once it dives, it takes the actual position as starting point of navigation, looks for its own heading and the actual speed and calculating its ongoing position change based on the last actual position, e.g. method known as dead reckoning. To achieve highest precision in navigation, a combination of motion reference

unit (MRU) and Inertial Navigation System (INS) is installed on the SEAL AUV – the PHIINS inertial unit from IXSEA Company. Briefly, the MRU is “feeling” the acceleration of the vehicle in all 3 axis (x,y,z). The INS is built on 3 fibre-optic gyro’s (x,y,z) and gives a very precise/stable heading, pitch and roll information, based on rotation-changes compared to the axis.

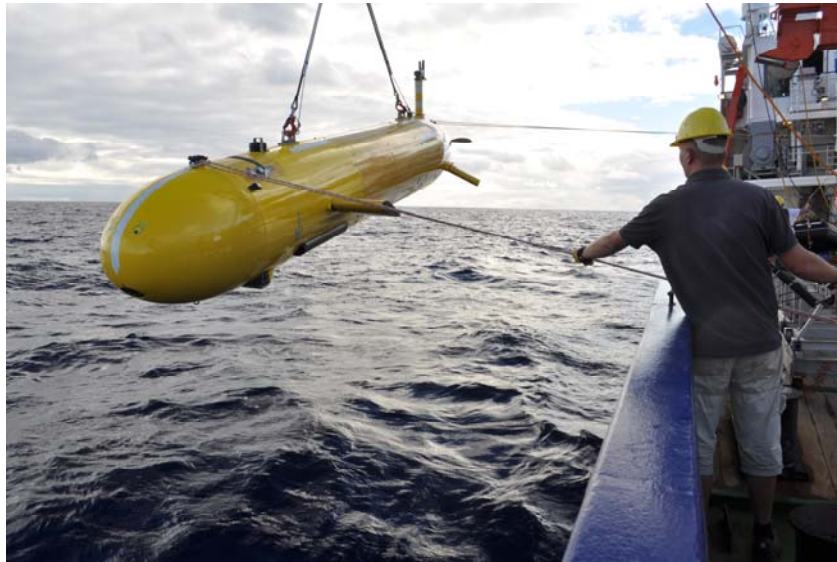


Fig 6. Deployment of AUV over the side of RV POSEIDON

Mission planning

A graphical planning tool is used for the mission planning on AUV SEAL. The MIMOSA mission planning tool, developed by IFREMER, is specially designed to operate underwater vehicles (AUVs, ROVs). The main goal of this software is to plan the current mission, observe the AUV once it is underwater and to visualize gathered data from several data sources and vehicles. MIMOSA is mainly built on ArcView 9.1 (Graphical Information System, GIS) and a professional Navigation Charting Software. In order to plan a mission the user has to work on geo-referenced charts with a given projection (MERCATOR), either user-defined GIS-maps, raster-charts, S-57 or C-MAP commercial electronic navigational charts (ENCs).

Mission observing/tracking

The MIMOSA planning tool is also used to monitor the vehicle at sea surface, more interesting under water. The MIMOSA software is client based, means one dedicated server is used for planning, while the others are in slave/client mode, picking up actual missions. Therefore, position data strings from the AUV are being sent to local network and fed into the MIMOSA software to display actual vehicle position, e.g. DGPS signal once it is on sea surface. During dive the AUV can be tracked via ship based installed ultra short baseline systems (USBL), e.g. IXSEA GAPS or POSIDONIA, using the on-board AUV installed USBL transponder beacon (deliver position where the vehicle “actually is”). In addition to this independent position source vehicles own position can be displayed also (deliver where the vehicle “believes” it is).

Summary of data display in tracking mode:

- position of support vessel
- position of AUV (either DGPS on surface or underwater position based on PHINS INS)
- USBL position (GAPS or POSIDONIA)

5.2.2 Status of AUV

The AUV Seal was sent directly from the former MSM 15 field cruise, terminated at Greece, towards Ponta Delgada. During the MSM cruise the AUV worked well, but severe trimming problems occurred. The reason for trimming problems have been found in dis-arranged battery package. The battery package is new and was implemented short before the MSM cruise. During the MSM cruise, a work-around was found in some additional trim weights in order to run the AUV.

Finally, the hydro-dynamic behavior of AUV was not perfect, but working for smooth environment. On the last dive at MSM cruise, the AUV failed at the end of the mission on a rough and steep structure, due to a low altitude alarm on AUV. The alarm is a given fault response in order to avoid crash with sea bottom and strictly end up in a mission abort. Actually, the fault limit is set to 20 m altitude.

5.2.3 Dive 38

Main goal of the AUV dive no. 38 was to map the northern part of central area at Menez Gwen location. Here, a separate mount structure is visible. Based on ship-borne MBES data, the expected topography should be steep and complex.

The mission was planned to start 2 km south of the internal mount and to spiral down to approx. 1000 m water depth, because the terrain is more flat at that spot. Afterwards, the AUV should head to 10° N and fly up the hill and to start the survey grid on top the mountain. The given altitude for AUV was 50 m, by a line spacing of 80 m.

The AUV was deployed on sea surface and the very basic trimming was acceptable in order to bring the AUV into mission mode. The AUV managed to spiral and headed to the mount and flew up the mountain. After five lines on top of the seamount the vehicle stopped the mission autonomously and ascended to surface (Fig. 7). A check of the log files at surface revealed a low altitude fault indicating that the vehicle had approached the seafloor closer than the 20 m safety distance. After a re-commission the vehicle descended to the top of mountain. Again, after 4 lines on top of mountain, the AUV stopped mission mode and ascended to surface. Review of log files have shown the same result as before, the AUV bounced out of mission due to low altitude fault. A third attempt on the eastern part of mountain ended directly in low altitude fault due to stronger drift affects on spiral down. A fourth attempt again on top of mountain also ended in low altitude fault some minutes on track of AUV and the AUV ascended again to surface.

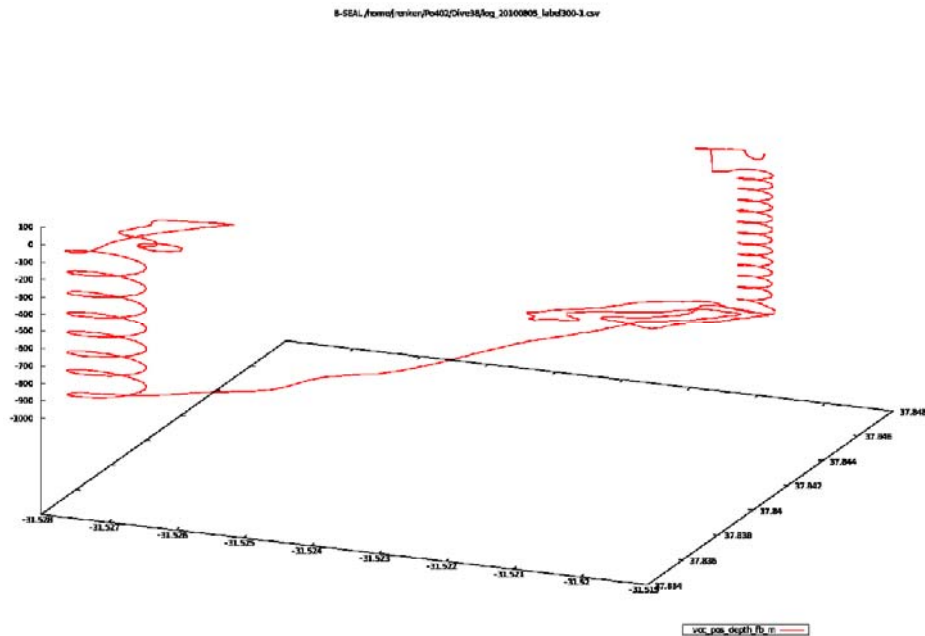


Fig. 7 First attempt of AUV dive 38. The vehicle descended in a spiral (left) and approached the young volcano with N-heading. After five lines on top of the young volcano the vehicle ended the mission because of a low altitude fault and ascended to surface.

5.2.4 Results

From beginning of AUV operation it was clear, that the AUV was not trimmed well. Analysis of the log files revealed three results:

1. the AUV was working well, all functions are in good conditions
2. the AUV hits 4 times the low altitude fault criteria
3. the AUV was as close as 6 m above sea-floor on attempt 3

The explanation for this result was that “bottom-avoid maneuvers” are started when there is a risk to hit the sea-floor, but the AUV could follow in time with the necessary movements. The disarranged battery mass was followed by a very slow maneuver reaction of AUV. This response time was far too slow for the actual very complex and steep contour at the internal mountain. Due to this AUV behavior, the risk to severely damage the AUV was too high. Therefore, no additional dive was performed.

5.3 ROV Operations

(N. Nowald, G. Ruhland)

5.3.1 System Overview

The Cherokee ROV is a commercially available, mid-size inspection class ROV, manufactured by SUB-ATLANTIC, Aberdeen. It is operated by MARUM since 2001 and was adapted for scientific purposes. The vehicle was involved in many different research programs and cruises

with a total of 117 dives up to now.

The system consists of three major components: a spooling winch, the surface control units and the vehicle itself. Vehicle dimensions are 120x80x100cm (LxBxH) with a weight of ~450kg. Cherokee has a payload for scientific equipment of approximately 10 kg. The ROV is electrically propelled by four axial thrusters (440 VAC) and total power of the entire system is 12kW. Cherokee can operate in depths down to 1000m.

The vehicle is equipped with a high resolution colour zoom PAL video camera and a 5 megapixel digital still camera mounted onto a pan and tilt unit. Two additional video cameras are mounted for overview/navigational purposes to the front and the back area of the vehicle. Three lasers on the pan and tilt unit can be used for size calibration of objects on the seafloor. Light is provided by four 240V/250W dimmables. A compass and other sensors provide navigational data such as heading and depth. A scanning sonar generates images of objects or structures in the water column or on the seafloor within an effective range of 50 m. The sonar transmits its data directly to the control racks where an online image is displayed. Cherokee is equipped with a hydraulic, 5 function manipulator and a sample box on a tool skid. Both allow the collection of objects from the seafloor and/or the operation scientific tools such as push cores, nets, etc.



Fig. 8 Recovery of ROV Cherokee after a dive on the western flank of the small Menez Gwen volcano.

The surface control units consist of three control racks, in which video signals and navigational data are displayed. A data acquisition computer collects data from the ship and the ROV. Video, navigational ship and ROV data are all time referenced and stored on DV video tapes and hard disk or as ASCII files respectively, for further processing. The winch is electrically powered and bears the 1000 m umbilical cable. The umbilical contains several electrical conductors for electrical power and basic telemetry. Four optical fibres are provided for video transmission (4 channels) and additional telemetry channels (4xRS232).

Cherokee uses the USBL (Ultra Short BaseLine) positioning system GAPS. The system consists of an antenna which is located on the ship and an acoustic beacon on the vehicle. The GAPS antenna is mounted to a pole on the starboard side of the ship and is lowered prior to the deployment of the vehicle. The four hydrophones of the antenna receive acoustic pings from the

beacon on the vehicle, calculating the absolute position of the ROV with an accuracy of two meters.

5.3.2 ROV Dives

(C. Borowski)

The vehicle was deployed on six stations in the center and eastern flank of the small Menez Gwen volcano with a total bottom time of ~22 hours (Tab. 1, Figs 9, 10, 11, and 12). The main purpose of the dives was to locate fluid vents and suitable positions for the deployment of a tool elevator for the upcoming METEOR M 82/3 cruise.

Tab. 1 Station list of ROV dives

Dive#	Ship station	Date	Sart time (UTC)	Lat	Lon	Bottom time	Recover (UTC)
1	POS 402-384	01.08.2010	10:30	37°50,58N	31°30,84W	5h 09min	17:30
2	POS 402-387	02.08.2010	09:15	37°50,46N	31°32,94W	5h 40min	17:00
3	POS 402-391	03.08.2010	13:00	37°50,1N	31°32,82W	3h	17:30
4	POS 402-395	04.08.2010	08:45	37°50,64N	31°31,14W	0h 40min	11:00
5	POS 402-402	06.08.2010	09:40	37°50,52N	31°31,32W	4h 10min	15:15
6	POS 402-410	08.08.2010	07:00	37°50,64N	31°31,08W	6h 40min	15:15

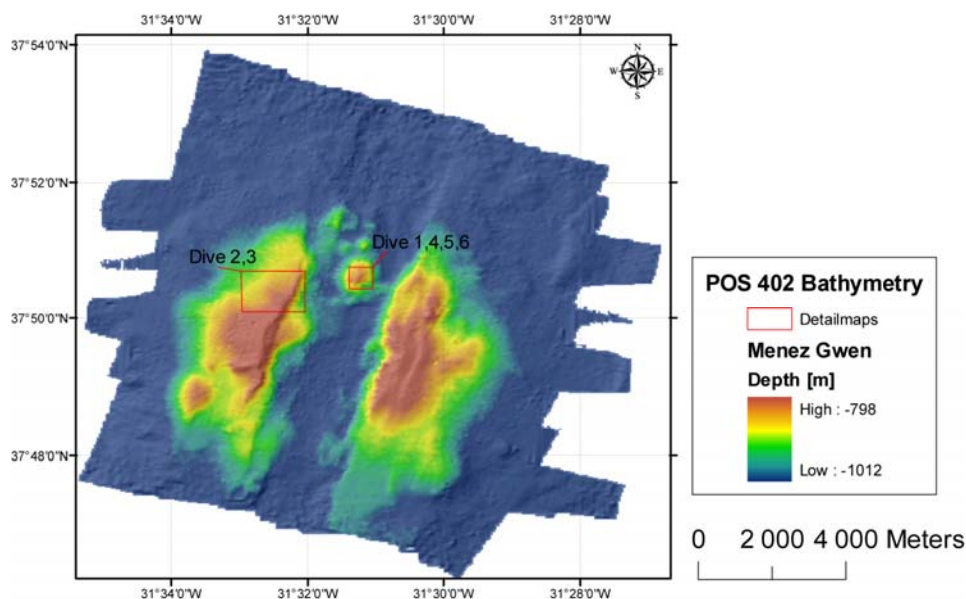


Fig. 9 Overview on ROV dive station on the small young volcano and on the outer flank of the Western graben wall.

Dive 1 started 01.08.2010 at 12:04 37°50.58' N, 31°30.84' W in 795 m water depth on the top of the small volcano (Figs. 10 and 11). After short orientation, the ROV headed northwards upslope, crossed crest in 783 m a crest and descended a steep wall until it reached bottom of a graben at 793 m (Fig. 13). After turning to east and crossing again the crest, we descended the

volcanic slope until the maximum wire length was reached at 843 m water depth (13:40) and then searched for vent sites by westwards meandering upslope. Another turn in 787 m water depth (15:25), descend westwards to 828 m water depth and start of another meandering search.

Hydrothermal fluid flow was first encountered around 16:20 in 823 m water depth at (37° 50.66870' N, 31° 31.15403' W (“Fluid vent” in Tab. 2). This site was characterized by diffuse flow and thick bacterial mats on lava rocks (Fig. 14A). Three other hydrothermal sites were encountered a few meters upslope (Vents 2-4, Tab. 2, Fig 14B-F). Vent 2 was characterized by diffuse fluid flow and a few *Bathymodiolus* mussels on lava rocks. Vent 3 was located on a steep slope and consisted of a couple of prominent and up to 70-cm high chimneys discharging white hot fluids, diverse emanations of diffuse fluid and extended mussel beds on rocky walls around the chimneys. Vent four was characterized by an extended area of white precipitates with a prominent white inactive chimney in its center, diverse diffuse fluid emanations and surrounding rocks covered by mussels. This site was chosen for the deployment of biological colonization experiments: A total of 5 wood parcels fixed to passive markers were deposited to attract wood boring bivalves. The wood experiments should be recovered with RV METEOR cruise in October 2010 (Fig. 14).

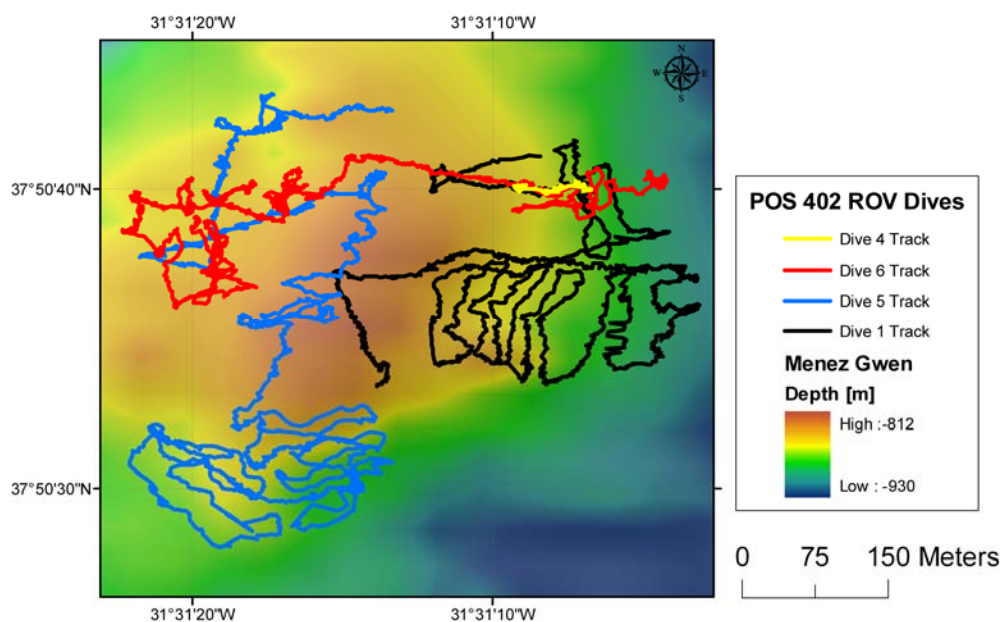


Fig. 10 Dive tracks of dives 1, 4, 5 and 6 on the small young volcano.

Dives 2 and 3 (02./03.08. 2010) lead to the western slope of the outer wall of the Menez Gwen rift valley around 37° 50' 26.9880" N, 31° 32' 38.4000" W because this position had been marked as an active chimney site in data base (Figs.9 and 12). However, we did not find any trace of hydrothermal activity.

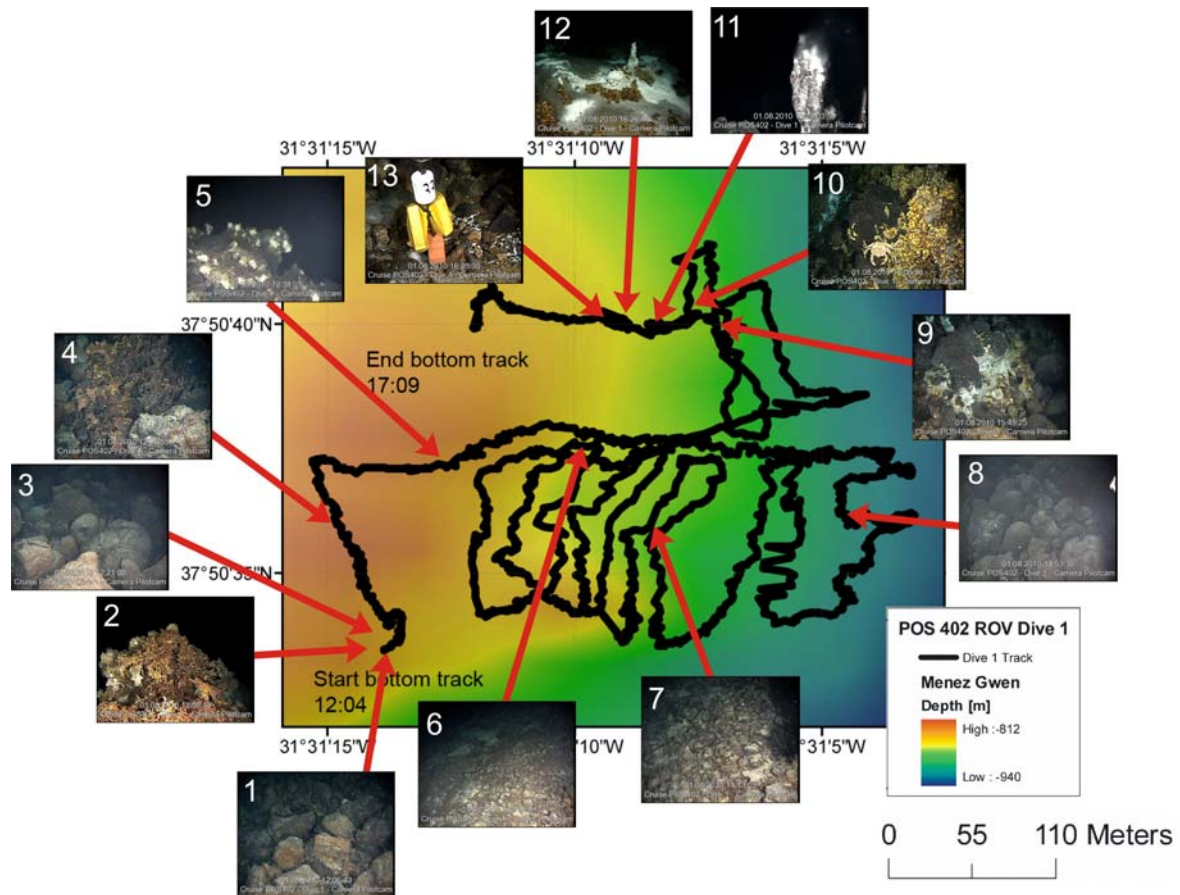


Fig. 11 Dive 1, track and screenshots of the pilot camera: 1 – broken pillows; 2 – dead and live corals; 3 – pillows; 4 – dead corals; 5 – live corals; 6 – talus; 7 – broken pillows; 8 – large pillows; 9 – diffuse hydrothermal fluid flow, bacterial mats and scattered mussels; 10 – diffuse fluids and dense mussel beds; 11 – chimney expelling hot gaseous fluids; 12 – dense bacterial mats and chimney; 13 – deposited marker with wood colonization panels.

Tab. 2 Electronic markers set during dive 1

Marker name	Latitude	Longitude
Rope 1	37° 50.62800' N	31° 31.15173' W
Vent 4 Bacterial Mats	37° 50.66870' N	31° 31.15403' W
Vent 2	37° 50.66888' N	31° 31.12832' W
WP 2	37° 50.61804' N	31° 31.18302' W
Vent 3	37° 50.66551' N	31° 31.13994' W
Wp 1	37° 50.59200' N	31° 31.24100' W
WP 3	37° 50.61759' N	31° 31.13078' W
WP 4	37° 50.61804' N	31° 31.08020' W
WP 5	37° 50.58815' N	31° 31.07965' W
WP 10	37° 50.64036' N	31° 31.18330' W
WP 6	37° 50.58748' N	31° 31.12938' W
WP 7	37° 50.58637' N	31° 31.18302' W
Rope 2	37° 50.61804' N	31° 31.16408' W
WP 8	37° 50.63575' N	31° 31.08093' W
Rope 3	37° 50.62176' N	31° 31.17123' W
WP 9	37° 50.63664' N	31° 31.13011' W
Vent 1	37° 50.66869' N	31° 31.12072' W

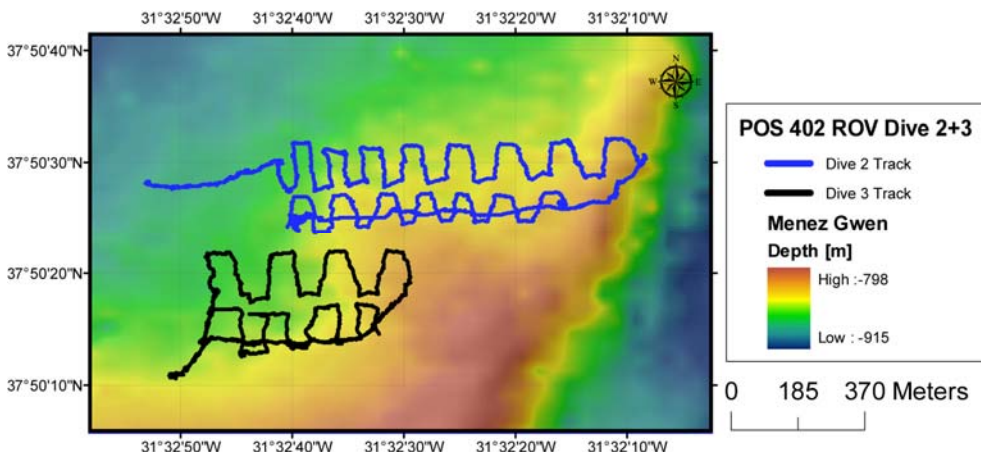


Fig. 12 Dive tracks of dives 2 and 3 on outer flank of the western graben wall.

Dive 4 (04.08.2010) was short (Tab. 1). Its purpose was to confirm the positions of the active vents encountered during Dive 1 and for making photographs (Figs. 10, 15).

Dive 5 (06.08.2010) was used to search for hydrothermal vents on the southern flank of the small Menez Gwen volcano and to explore the young rift valley on its top. The dive started at 07:00 with a meandering course upslope. Without finding any vents we entered the rift valley from the south, climbed up its eastern wall, crossed the valley between 12:44 and 13:24 and ended the dive by exploring the western outer slope of the young volcano (Figs. 10 and 13). This dive did not find hydrothermal vents.

Dive 6 (08.08.2010) was used for geological mapping of the mountain top and the young rift valley. It started at the vents on the eastern flank, crossed the rift valley and ended on the western flank (Fig. 10).

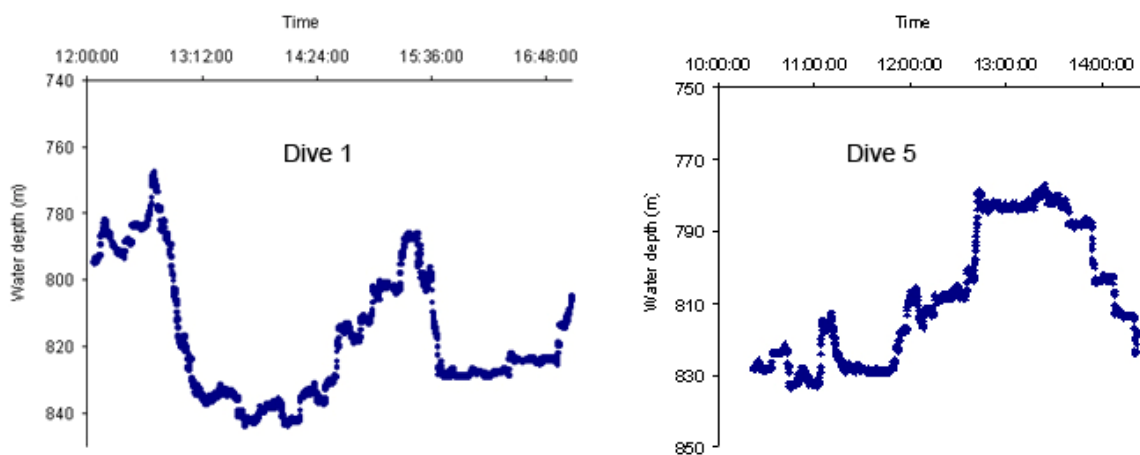


Fig. 13 Depth profiles of ROV Cherokee Dives 1 and 5.

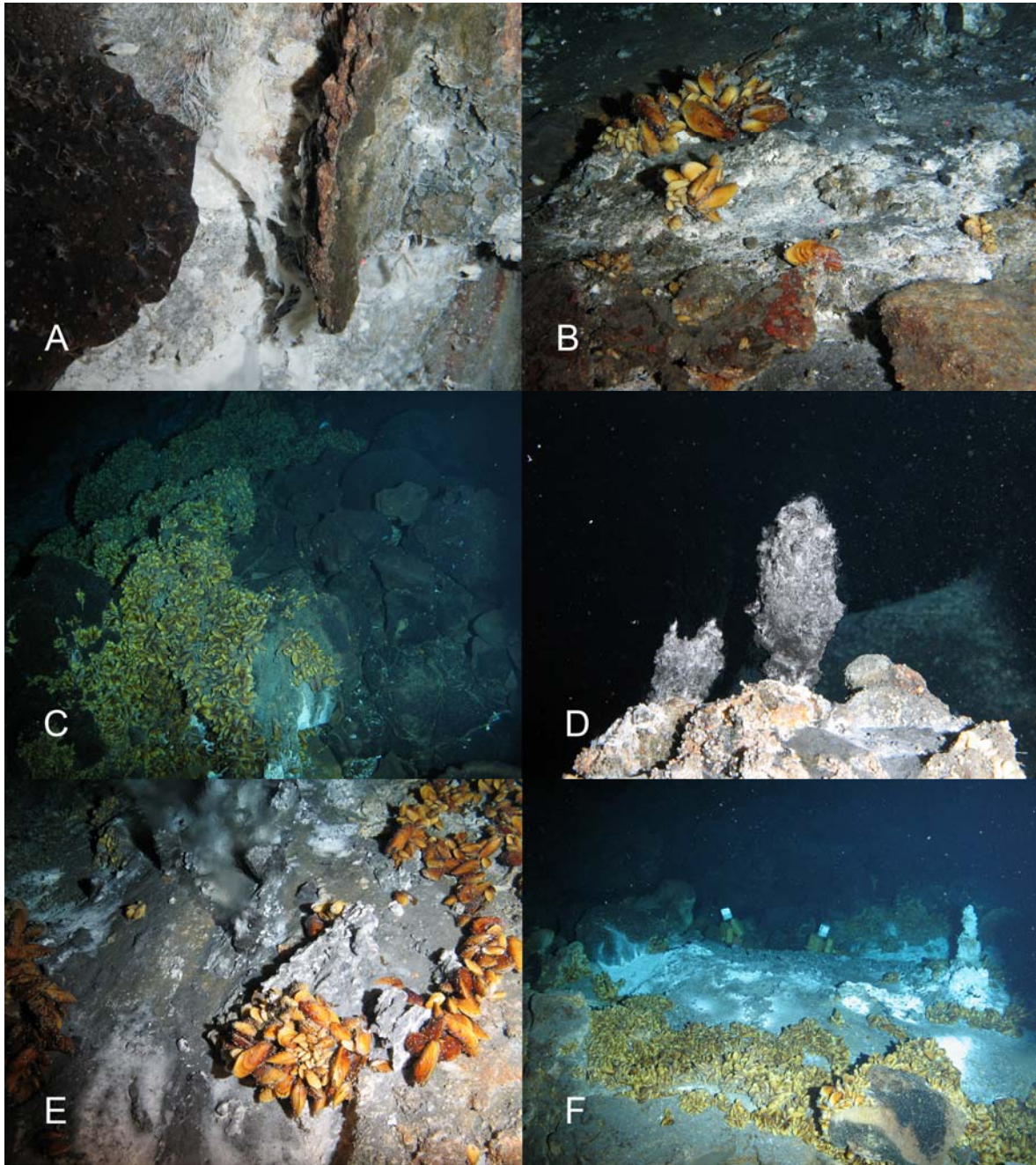


Fig. 14 Hydrothermal vents at the eastern flank of the small Menez Gwen volcano. A. Vent 1, white bacterial mats on rocks; B. Vent 2, scattered mussels and white precipitates; C: Vent 3, extended mussel beds on rocks; D: Vent 3, chimneys discharging hot fluids; E: vent 3 mussels next to hot fluid flow; F: Vent 4, white precipitates, chimneys, diffuse fluid flow and mussels on rocks; in the background passive markers with wood deployments.

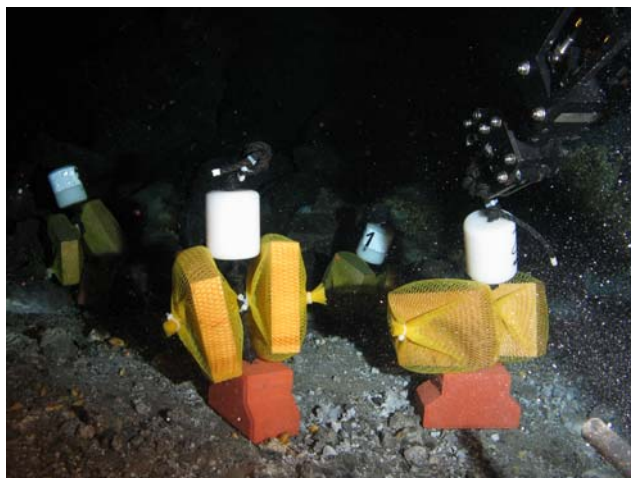


Fig. 15 Colonization experiments for wood boring bivalves deposited at “Vent 4”.

5.4 Geology

5.4.1 Geology of Menez Gwen

(J. Thal)

South of the Azores Islands, close to the Azores triple junction, the slow spreading Mid Atlantic Ridge (MAR) consists out of several volcanic segments. One of them is the Menez Gwen segment that extends from 37°35' to 38° N. It is about 55 km long, lacking a central rift valley and hosts a circular, ~700 m high volcano with a diameter of ~17 km in the central area.

A 6 km long, 2 km wide and maximum 350 m deep axial graben oriented N20 splits the top of the volcano into two parts. Ondréas et al. (1997) found at the base of the eastern and western wall of the graben massive lava flows that are topped by 300 m of layered volcanic ejecta, indicating explosive volcanism. In the central part of the graben, where water depth is greatest (1045mbsl), a lava lake with very fresh lava is developed next to fresh lobate lava flows (Fouquet et al., 1994; Charlou et al., 2000). At the northern end of the graben is a sediment-free, 120-m high small volcano with a diameter of 600 m. The main hydrothermal vent field of Menez Gwen lies at the southern slope of this young volcano where anhydrite chimneys grow on top of pillow lavas. The site covers an area of about 200 m² with barite-rich mounds (Fouquet et al., 1994). Sulfides are not abundant, indicating that hydrothermal activity at Menez Gwen may have started just recently. A second discharge site, dominated by diffuse venting of clear fluids with only a few small chimneys, is located on the eastern slope.

Based on the low Si concentrations of the ~ 285°C hot vent fluids feeding the Menez Gwen hydrothermal field, Charlou et al. (2000) estimated a shallow extent of the hydrothermal convection cells.

Two geochemically distinct types of basalt, both highly plagioclase-phyric, have been identified from inside the graben. Marques et al. (2009) explain the difference in rock composition with melting-induced mixing of a two-component mantle.

5.4.2 Geological Mapping

(J. Thal, P. Wintersteller)

The geological mapping conducted in the course of cruise POS402 produced significant new insights on the morphology and geological structures of the young volcano inside the Menez Gwen graben. The AUV-map in Fig. 16 is a result of AUV- dive nr. 38. Post processing has been realized with RESON software PDS2000. The final geo-referencing is validated with the help of several transects from the ROV. Horizontal accuracy is now in the range of GAPS accuracy, about 3m. The map clearly shows a previously unrecognized rift valley crossing the entire top of the seamount. The valley strikes N-S with a 38° steep western slope and a 25° eastern slope that fades into a terrain dominated by small volcanic ridges.

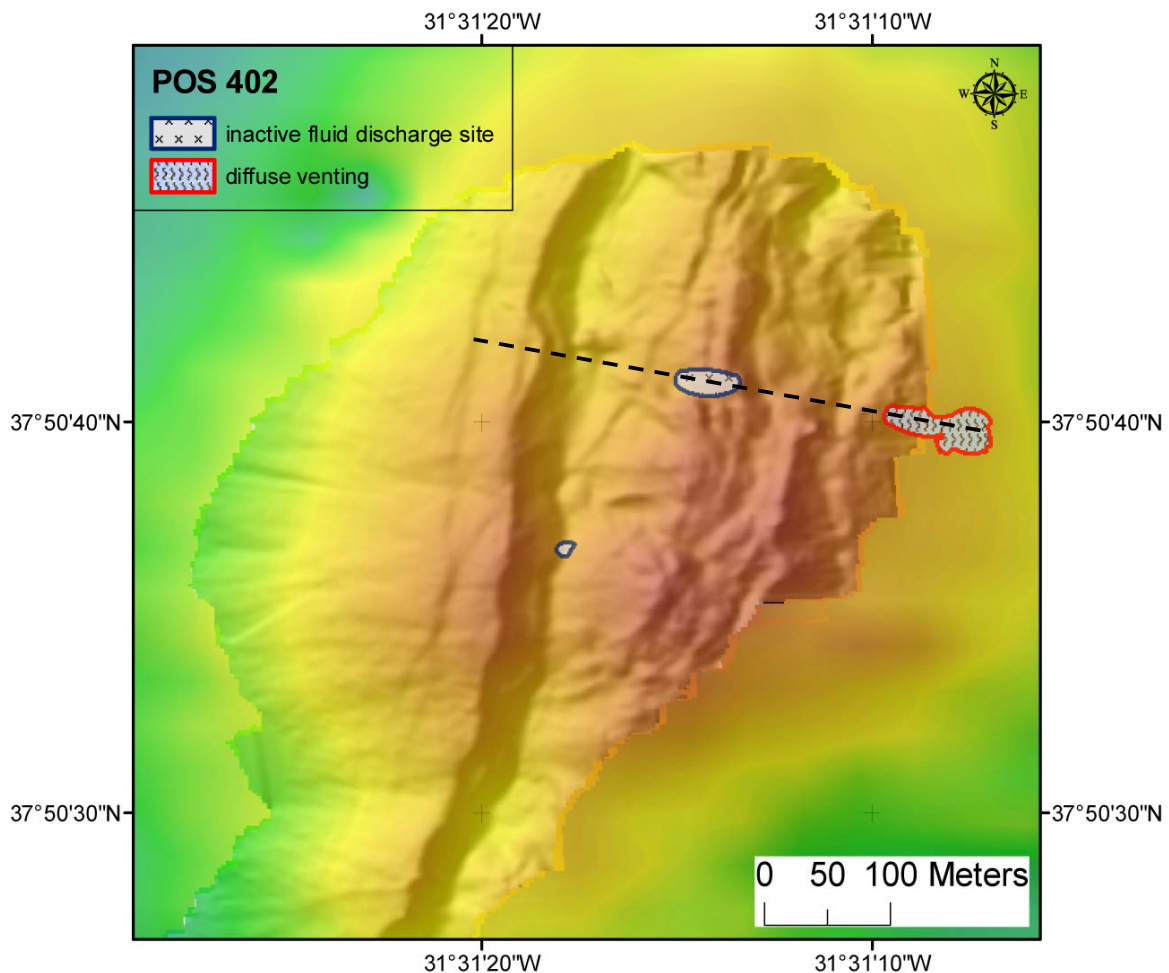


Fig. 16 AUV-bathymetry of the young volcano shows the new rift valley and active (red border) and inactive (blue border) vents. The dashed line indicated the profile of Fig. 10 crossing the young volcano.

Hydrothermal activity was only observed down-slope on the Eastern slope of this terrain within the young volcano. This site was visited during three ROV dives that showed that the area of fluid discharge is limited in general to a ~10 m narrow stripe expanding for 70 m in East-West direction. The entire young volcano is mainly made of pillow lava and talus. The hydrothermally active field is in an area dominated by volcanic talus. In-situ lava was found only on top of small ridges.

Five rock samples were collected; all are highly plagioclase-phyric basalts similar to what has been described from Menez Gwen by Marques *et al.* (2009).

Dive 387ROV and 391ROV were carried out on the western slope of the main Menez Gwen volcanic edifice. Except for a small area close to the edge of the central graben, where rusty pillow lava was found, the whole slope consists of flat, slightly sedimented terrain that is probably underlain by volcanic ejecta (Fig. 17).

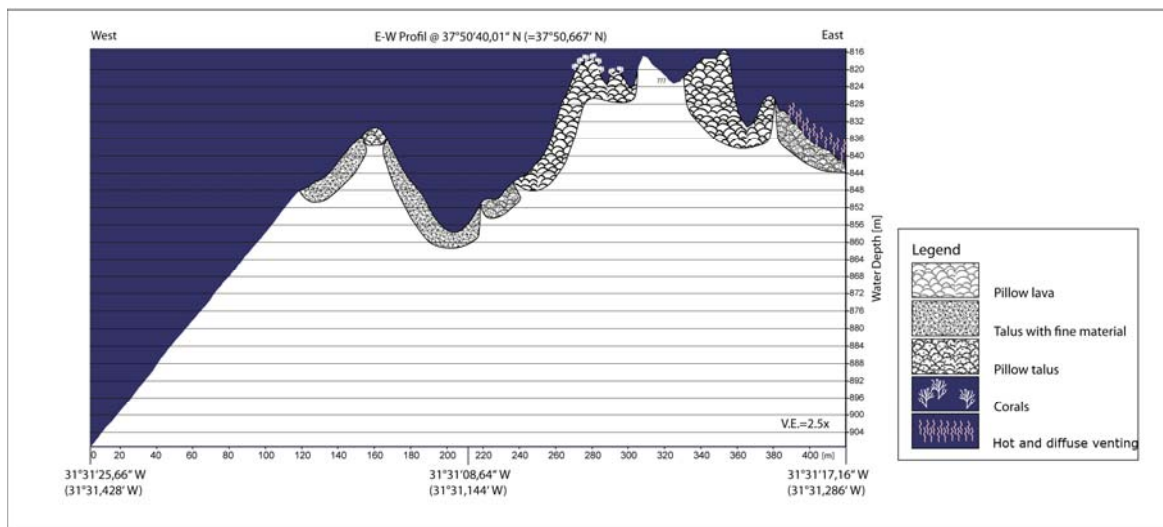


Fig. 17 Mapping of geological surface structures along a profile across the summit and rift valley of the young Menez Gwen volcano.

5.5 CTD Measurements and Sampling for Methane Concentrations in the Water Column

5.5.1 Methods

(J. Wendt)

The Organic Geochemistry group was in charge of the on-board measurement of methane concentrations in the water column in order to map the hydrothermal plumes. Expected concentrations were between <1 and 100 nmol/L Seawater according to data available from previous cruises.

Water samples were taken from the CTD (12 x 10 L Niskin bottles) with a 50 ml syringe directly connected to the Niskin bottle by a short tube with a manual valve. During the sampling the tube and valve were first flushed with water from the Niskin bottle in order to avoid contamination from previous samples and then 10 ml of sample were taken (each bottle was sampled in duplicate). The samples were transferred through needles into 20 ml serum vials that had been previously flushed with helium. Due to overpressure in the vial after the 4th station we decided to evacuate the vials with a vacuum pump prior to the sample transfer.

Methane concentration was performed by gas chromatography coupled to a flame ionization detector (GC-FID). Methane was casted out of the samples with a helium flow and transferred through a system of loops and valves to a trap (Chemipack C18 80/100 Mesh) where the

methane was trapped with liquid nitrogen. After 10 minutes the container with liquid nitrogen was retrieved and exchanged by a beaker with hot water releasing the methane into the GC column.

For the calculations we used a linear calibration performed with methane standards in different concentrations (100 ppm and 1 %) and using several sample loops (100 μ l, 1 ml and 5 ml).

CTD casts were performed along transect in N-S direction across the young volcano which corresponded to the assumed prevailing direction of tidal currents through Menez Gwen Rift Valley. Eight CTD/Rosette casts were analyzed for methane concentrations with 12 samples per station and 1-3 replicate measurements per sample (Fig. 18).

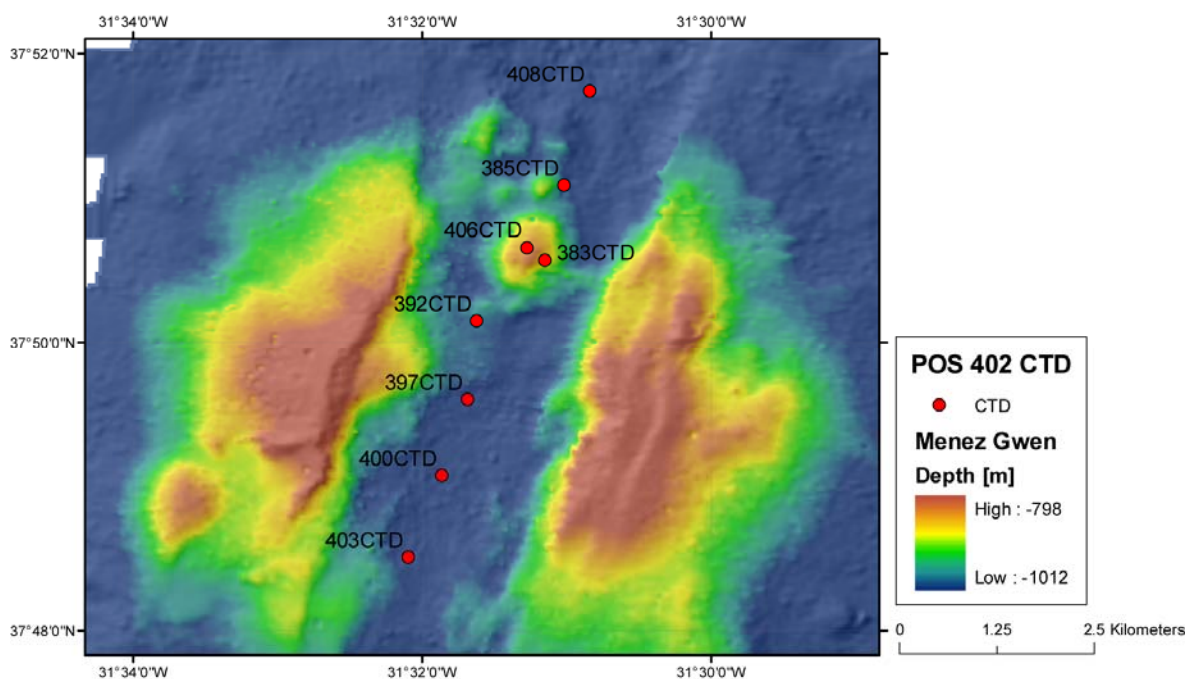


Fig. 18 CTD stations in the Menez Gwen working area.

5.5.2 Results

Methane concentrations ranged between <1 and $426.3 \text{ nmol L}^{-1}$ seawater and there was a general trend for increasing concentrations up to $200 \text{ nmol L}^{-1} \text{ CH}_4$ towards the seafloor (Fig. 12). A prominent exception was found at CTD station 397 at 2 km S of the young volcano in which CH_4 peaked in 600 m water depth. Above the Menez Gwen hydrothermal vent fields on the young volcano, all analysed water depths contained methane well above background level and there was a steep incline between 700 and 800 m depth (Fig. 19; 406 CTD). Similar steep incline was observed 2 km north and 1 km south of the young volcano close to the seafloor in around 1000 m water depth (408 CTD and 392 CTD). In contrast, 3 km and 4 km away from the Menez Gwen vents, the methane profiles showed rather constant slopes and concentrations decreasing with distance from the Menez Gwen vents suggested mixing in the water column

(400 CTD, 403 CTD). These observations may imply different explanations. Methane exiting from the Menez Gwen vents on top of the young volcano is possibly transported north and south by deep tidal currents that follow the seafloor morphology. In this case, we would not expect a considerable buoyant hydrothermal plume rising above the young volcano. Alternatively, additional outflow of methane in the rift valley next to the young volcano could also explain increasing methane concentrations close to seafloor and the high peak in 600 m water depth at 2 km south of the Menez Gwen vents may indicate a neutrally buoyant hydrothermal plume. We hope that additional data collections during the upcoming cruise with RV METEOR will elucidate this question.

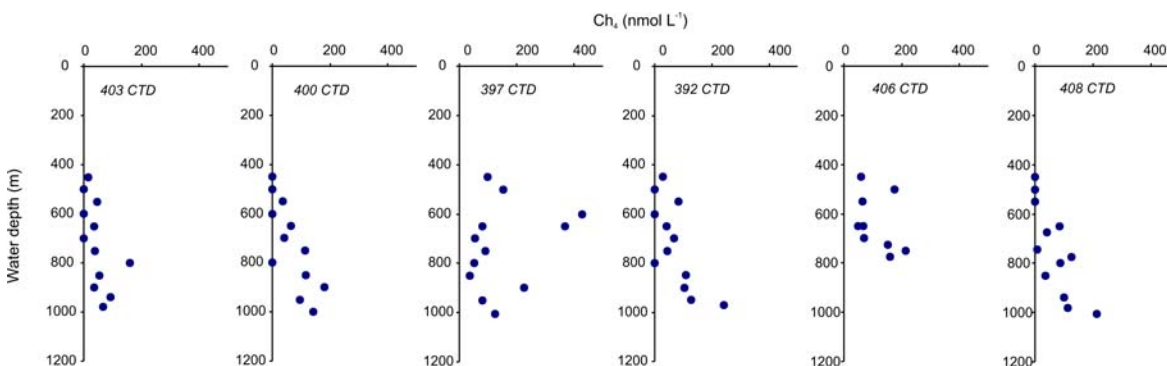


Fig. 19 Methane concentration profiles from CTD/Rosette casts in the Menez Gwen rift valley.

5.6 Plume Mapping with CTD/MAPR Tow-yows

(C. Borowski)

5.6.1 Methods

The buoyant hydrothermal plume in the Menez Gwen rift valley was mapped by tow-yows with the CTD/rosette and Miniaturized Autonomous Plume Recorders (MAPR, provided by E. Baker, NOAA/PMEL, Seattle, USA) attached to the CTD cable (Fig. 20). MAPRs logged the distribution profiles of temperature, pressure, turbidity and oxygen redox potential (ORP) in the water column at 5 s intervals. The yo-yo range was approximately 30-500 above ground and the tow speed was 0.3-0.5 knots. The tow-yows were performed along and across the in the Menez Gwen Rift valley (Fig. 21).

5.6.1 Results

Due to the low particle load of the white smoker fluids, we did not expect prominent turbidity signals and concentrated on ORP. Tow-yo 388 started at the northern end of the Menez Gwen rift valley, crossed the small young volcano and ended near the southern opening of the rift valley. As expected, this tow-yow produced a strong ORP signal on top and at the southern end of the small young volcano in ca. 820 m water depth (Figs. 22, 23). This corresponds very closely to the depth of the vents visited with the ROV dive on the eastern flank of the young volcano indicating that the buoyant hydrothermal plume does not rise significantly from the bottom into the water column. This plume signal was reaching ca. 1 km to the north and 2 km

downstream of the volcano indicating primarily southerly distribution of the buoyant

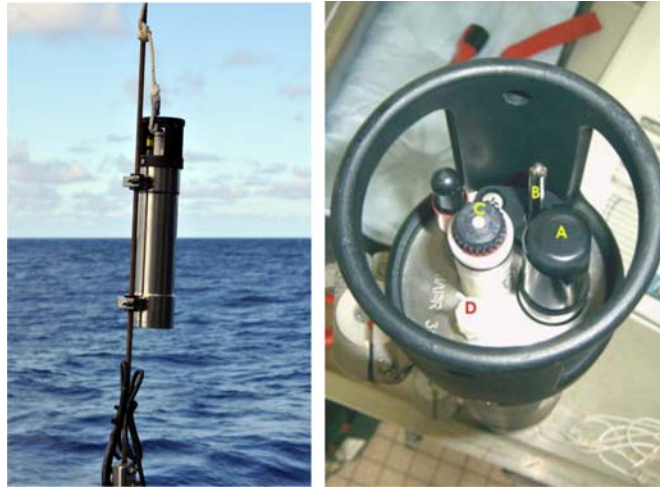


Fig. 20 NOAA/PMEL MAPR. Left: MAPR attached to the CTD cable 1 m above the rosette. Right: MAPR sensors. A: nephelometer, B: pressure sensor (0-6000 psi gauge sensor), C: OPR sensor, D: temperature sensor.

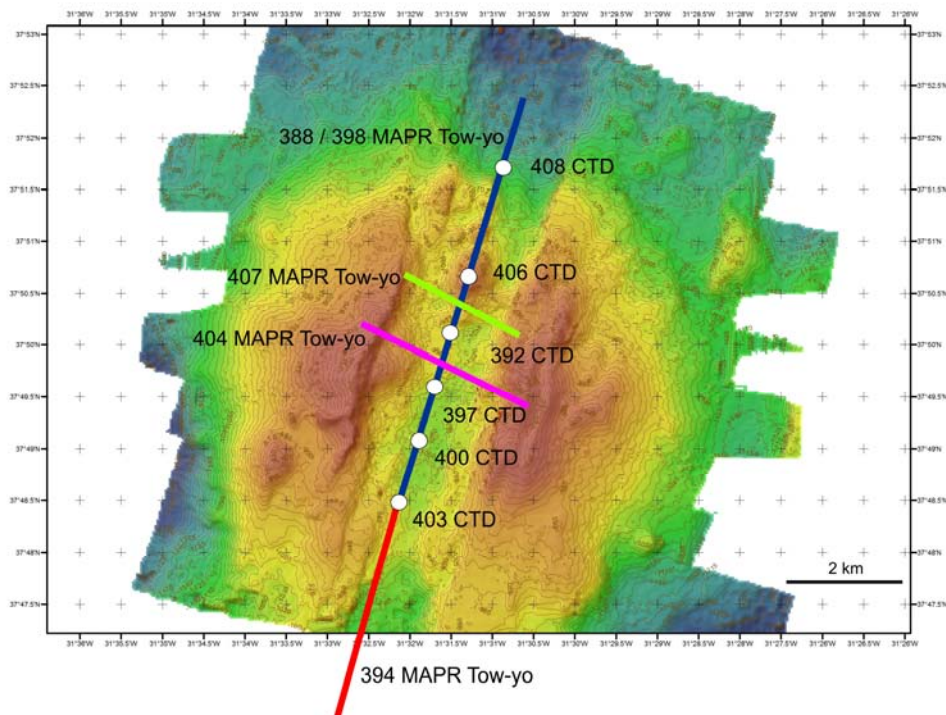


Fig. 21 CTD/MAPR Tow-yos along and across the Menez Gwen rift valley. 388 Tow-yo went along the CTD profile through the rift valley. 398 Tow-yo repeated the same track.

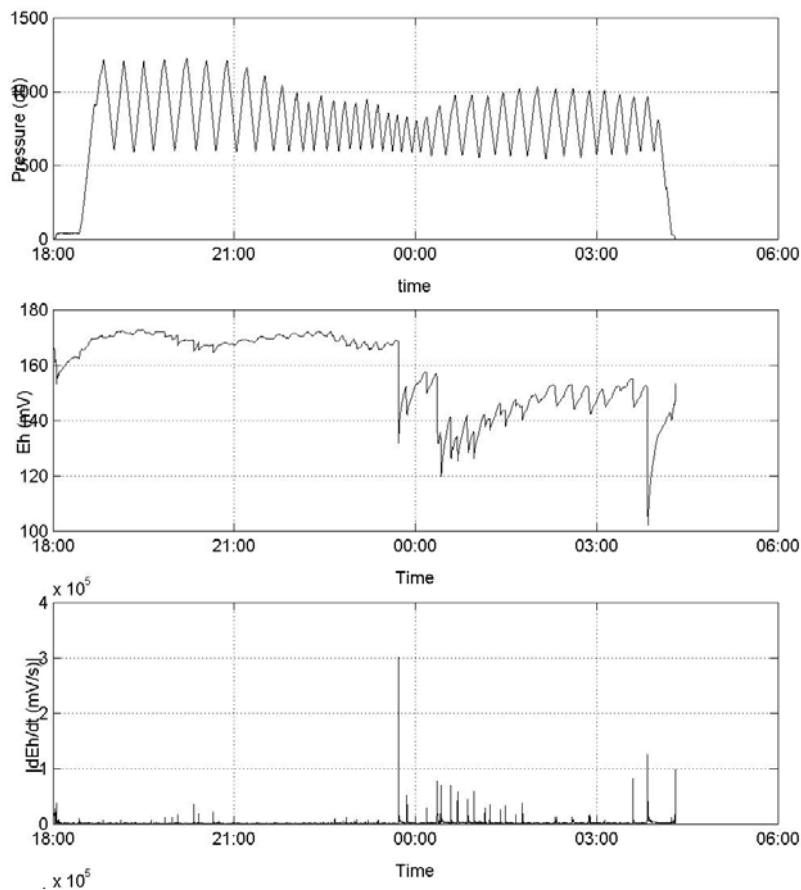


Fig. 22 388 Tow-yo. Top panel: Depth profile expressed as pressure (db). The lowering started 18:10 north of the Menez Gwen rift valley. The young volcano was reached around 21:15 and it was passed around 01:00. Middle panel: Strong ORP signals on top and south of the young volcano indicate the presence of buoyant hydrothermal plume originating from the vents on the eastern and southern flank of the young volcano. Another large ORP signal at the end of the tow-yo suggested the presence of an additional source of hydrothermal plume. Lower panel: Differential ORP signal (dEh/dt). Small peaks north of the young volcano suggest additional sources of hydrothermal plume at a certain distance from the tow-yo.

hydrothermal plume. Small peaks of ORP and differential ORP in the beginning of the tow-yo indicated the presence of another buoyant hydrothermal plume at 750 m water depth (Figs 22, 23). This signal was weaker and the fact that it was recorded at shallower water depth than the signals from the small volcano suggested that it probably originated from another source which might be further away from the tow-yo track, possibly on top of one of the rift valley walls.

An unexpected strong ORP signal occurred shortly before the end of 388 Tow-yo, and it was not clear at first if this signal was produced by real ORP or if it was an artifact (Figs. 22, 23). To clarify this, 398 Tow-yo was performed two days later on the same transect, but the strong signal at its end could not be reproduced. 403 Tow-yo connected to the southern end of tow-yo profiles 388 and 398. This tow-yo did also not reproduce the southern peak of 388 Tow-yo, but it showed another clear ORP signal approximately 5 km south of the young volcano. Because this signal was deeper and not connected to that of the young volcano and because of its strength this ORP signal strongly suggested the presence of a source hydrothermal plume source at the southern end of the Menez Gwen rift valley (Figs 23, 24).

404 Tow-yo showed weak ORP signals at the beginning of the profile which could suggest that there is another hydrothermal source on the western wall of the rift valley (Fig. 25). 407 Tow-yo did not show any signals.

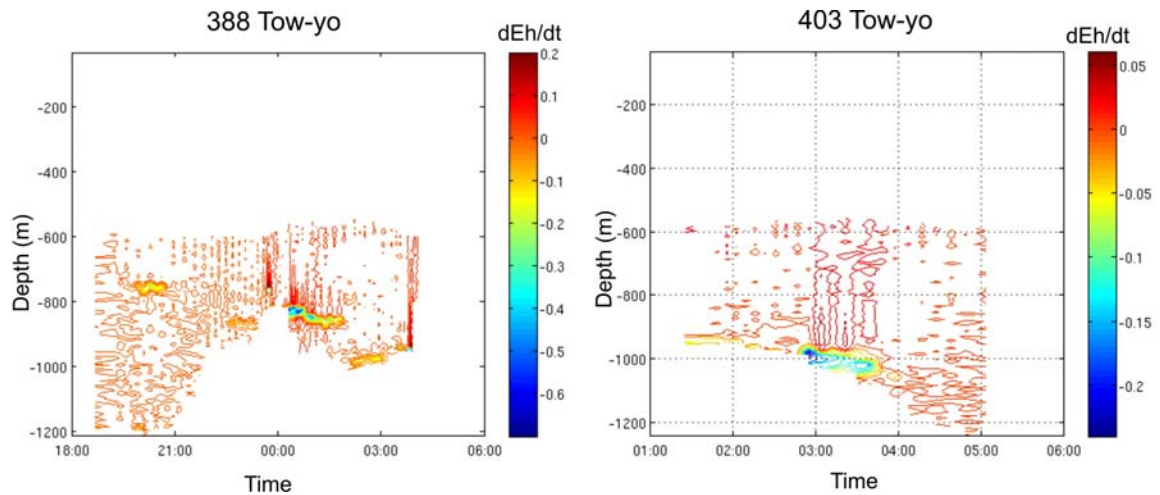


Fig. 23 Contour plots of differential ORP signals of Tow-yo 388 and 403 (orientation: N = left, S = right).

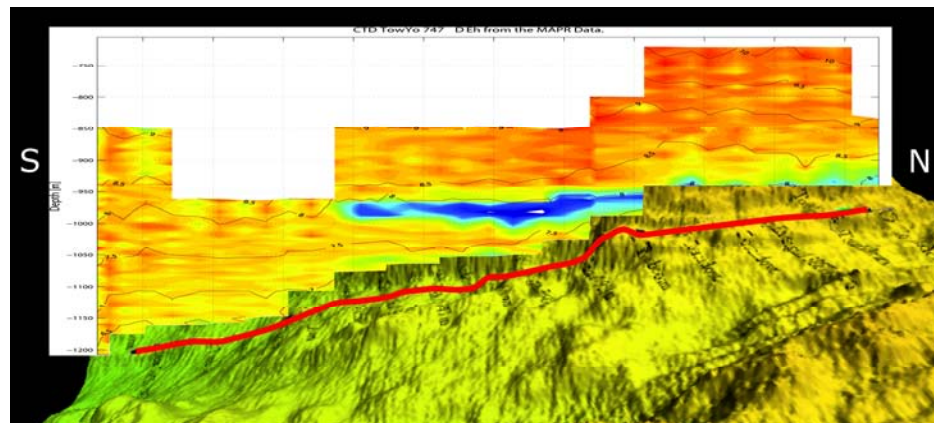


Fig. 25 403 Tow-yo. Reconstruction of the ORP signal over bathymetric contours at the southern end of the Menez Gwen rift valley.

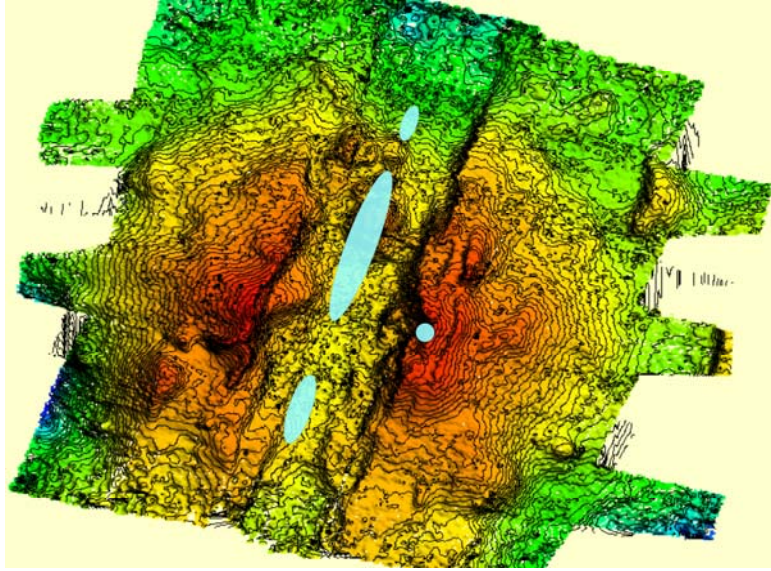


Fig 25. Interpretation of buoyant hydrothermal plume dispersal along the Menez Gwen rift valley.

6 Station List POS 402

Station No. / Event label	Date	Gear	UTC	Latitude At station begin	Longitude	Remarks
POS 402-380	31.07.2010	AUV Seal	15:15	37°56.738'N	32°43.988'W	Trim test
POS 402-381	31.07.2010	ROS/CTD	16:09	37°56.671'N	32°43.848'W	Background
POS 402-382	01.08.2010	Multibeam EL-3	01:56	37°52.735'N	32°26.476'W	
POS 402-383	01.08.2010	ROS/CTD	08:54	37°50.614'N	32°28.876'W	
POS 402-384	01.08.2010	ROV Cherokee	10:45	37°50.629'N	32°29.133'W	NE vents on s mall young volcano
POS 402-385	01.08.2010	ROS/CTD	18:19	37°51.075'N	32°29.01'W	
POS 402-386	01.08.2010	Multibeam EL-3	20:38	37°48.557'N	32°25.445'W	
POS 402-387	02.08.2010	ROV Cherokee	07:35	37°50.535'N	32°27.799'W	Outer E flank of large valley wall
POS 402-388	02.08.2010	CTD/MAPR Tow-yo	17:49	37°52.901'N	32°29.61'W	Along rift valley
POS 402-389	03.08.2010	Multibeam EL-3	04:53	37°48.158'N	32°27.868'W	
POS 402-390	03.08.2010	Multibeam EL-3	08:34	37°47.739'N	32°25.179'W	
POS 402-391	03.08.2010	ROV Cherokee	12:15	37°50.961'N	32°26.567'W	Outer E flank of large valley wall
POS 402-392	03.08.2010	ROS/CTD	18:21	37°50.149'N	32°28.392'W	
POS 402-393	03.08.2010	Multibeam EL-3	20:38	37°50.149'N	32°28.392'W	
POS 402-394	04.08.2010	CTD/MAPR Tow-yo	00:56	37°48.283'N	32°27.826'W	Extension of profile stat. 388
POS 402-395	04.08.2010	ROV Cherokee	08:59	37°50.663'N	32°28.865'W	NE vents on small young volcano
POS 402-396	04.08.2010	Multibeam EL-3	12:10	37°45.436'N	32°30.564'W	
POS 402-397	04.08.2010	ROS/CTD	18:51	37°49.62'N	32°28.318'W	
POS 402-398	04.08.2010	CTD/MAPR Tow-yo	20:54	37°52.899'N	32°29.61'W	Repetition of profile stat. 388
POS 402-399	05.08.2010	AUV Seal	08:59	37°49.965'N	32°28.29'W	Small young volcano
POS 402-400	05.08.2010	ROS/CTD	17:46	37°49.087'N	32°28.135'W	
POS 402-401	05.08.2010	Multibeam EL-3	19:42	37°45.864'N	32°24.833'W	
POS 402-402	06.08.2010	ROV Cherokee	09:44	37°50.539'N	32°28.65'W	S slope small young volcano explore small rift valley
POS 402-403	06.08.2010	ROS/CTD	16:23	37°48.509'N	32°27.89'W	
POS 402-404	06.08.2010	CTD/MAPR Tow-yo	18:06	37°49.437'N	32°29.414'W	Across rift valley
POS 402-405	07.08.2010	Multibeam EL-3	00:10	37°48.206'N	32°36.294'W	
POS 402-406	07.08.2010	ROS/CTD	08:12	37°50.667'N	32°28.76'W	
POS 402-407	07.08.2010	CTD/MAPR Tow-yo	09:25	37°50.094'N	32°29.305'W	Across rift valley
POS 402-408	07.08.2010	ROS/CTD	12:43	37°51.742'N	32°29.164'W	
POS 402-409	07.08.2010	Multibeam EL-3	16:00	37°52.673'N	32°31.812'W	
POS 402-410	08.08.2010	ROV Cherokee	07:04	37°50.667'N	32°28.901'W	

8 Data and Sample Storage and Availability

The chief scientist is responsible for data processing. Long term storage of processed and quality checked data will be in the Pangaea database

9 Acknowledgements

RV POSEIDON cruise POS 402 was a research activity on the geology and geochemistry of the Menez Gwen hydrothermal vent field at 37°N on the Mid-Atlantic Ridge within the Research Area F “Lithosphere – Biosphere Interactions” of the MARUM Cluster of Excellence. The cruise was planned and coordinated by MPI-Bremen, with the help of the involved institutions. The cruise was financed in Germany by the German Research Foundation (DFG). The shipping operator (Briese Schifffahrt GmbH & Co, Leer) provided technical support on the vessel in order to accommodate technical challenges required for sea-going operations. We would like to especially acknowledge the Master of the vessel, Klaus Ricke and his crew for their continued contribution to a successful research program and a pleasant and professional atmosphere aboard RV POSEIDON.

10 References

Marques, A.F.A., Scott, S.D., Gorton, M.P., Barriga, F.J.A.S., Fouquet, Y., 2009. Pre-eruption history of enriched MORB from the Menez Gwen (37°50'N) and Lucky Strike (37°17'N) hydrothermal systems, Mid-Atlantic Ridge. *Lithos* 112, 18-39.