R/V Meteor

Cruise 72-2 MICROHAB

Istanbul (Turkey) – Istanbul (Turkey)
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Short Cruise Report

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Objectives

The Black Sea is the largest anoxic basin on earth and provides unique conditions for the study of microbial habitats and controls on key anaerobic microbial processes in the element cycles. In the focus of expedition MICROHAB M72/2 were in situ measurements of fluxes and turnover of methane and sulfur at seep systems of the Black Sea, as well as the investigation of the microbial diversity of subsurface sediments in permanently anoxic settings associated with fluid flow and gas seepage. Currently, the global inventory of fluid seeps at passive continental margins is growing rapidly, but geological, chemical and biological processes operating at those fluid seeps remain poorly understood. In the Northern Black Sea, a large variety of active methane seeps have been identified at depths from 100-3000 m, including actively gas emitting mud volcanoes, and unique microbial reefs. The main objectives of MICROHAB are to map specific microbial habitats at high resolution, to quantify the composition, distribution and development of microbial communities in the permanently anoxic Black Sea, to and to obtain insight in element cycling and export at different types of fluid seeps in the Black Sea.

These goals will be achieved by the detailed near-field videographic mapping of selected habitats, followed by detailed geochemical in-situ measurements and specific sampling of mud, fluids, carbonates and biota along geochemical gradients. Sampling and in-situ measurements was mainly performed with the German ROV QUEST and gravity coring. The expedition MICROHAB contributes to the GEOTECHNOLOGIEN program MUMM II by studying the microbiology and biogeochemistry of methane and sulfur turnover by in situ technologies, as well as to Work Package 4 “Anoxic microbial habitats” of the EU FP6 Integrated Project HERMES which deals with the biodiversity of hot spot ecosystems at Europe’s continental margins.

Two target areas were selected:
1) “Crimean Seeps”:
In the northwestern Black Sea, hundreds of active gas seeps occur along the shelf edge west of the Crimea peninsula at water depths between 35 and 800 m. At some of the shallow Crimean seeps, massive microbial mats were found associated with isotopically light carbonates. Aspects of the microbiology, sedimentology, mineralogy, and selected biomarker properties of these deposits were recently described. Strong 13C depletions indicated an incorporation of methane carbon into carbonates, bulk microbial biomass, and specific lipids. Large structures are formed by up to 10-cm-thick microbial mats that are internally stabilized by carbonate precipitates. From holes in these structures, streams of gas bubbles emanate into the water column. Apparently, the cavernous structure of these precipitates enables methane and sulfate to be transported and distributed throughout the massive mats. Smaller microbial structures and nodules from nearby areas were of the same morphology, with compact mat enclosing calcified parts and cavities. The development and structure of such reef systems is not yet understood and requires detailed analysis. During MICROHAB we mapped different reef fields, carried out detailed in situ analyses of fluid transport across reef chimneys, and sampled the reefs for microbiological analyses.

2) “Sorokin Trough”
This area is characterised by diapiric structures and compressional tectonics, which facilitate fluid migration to the seafloor. Abundant mud volcanoes and near surface gas hydrate occurrences were identified in this area at water depths between 800 and 2000 m. The mud volcanoes have diameters of up to 2.5 km and heights of up to 120 m above the surrounding sea floor. We focused on the Dvurechenskii mud volcano, a flat-topped and very active mud volcano in the Sorokin Trough. A number of indicators for recent methane emission were investigated: temperature anomalies, the presence of gas hydrates in surface sediments, highly gassy sediments, strong sulfidic smells of surface sediments, authigenic carbonate crusts, the presence of microbial precipitates. We identified the hot spot on the mud volcano with regard to the temperature gradient in the center, and carried out transects across the mud volcano to investigate the relationship between fluid flow and microbial methane turnover.

Cruise diary

R/V Meteor left Istanbul on February 23 at 9 a.m. local time. It took a while to pass the Bosporus because of strong fog. We steamed to the first site NW of the Crimean Peninsula at 44° 48' N and 31° 57' E to start with multibeam mapping, followed by ROV and AUV work. Unfortunately the transit was quite uncomfortable for the crews working on depth with temperatures below the freezing point and strong winds. We arrived in the evening of the 24 Feb on site. Due to technical problems with the ROV we changed the working plans and started instead with a series of TV-guided multicorers across the oxic-anoxic boundary from 120 m water depth down to 170 m. The search for benthic life at oxygen depletion is an objective of the new HERMES partner, the Ukrainian Institute of Biology of the Southern Seas (IBSS). Katya Ivanova from the Benthos Ecology Department looked for changes in meio- and macrofauna composition with regard to oxygen availability. The night was used to complete a multibeam survey around the wider sampling area of the first site (Fig. 1); and in the early morning we carried out a couple of tests on the weight of the payload shuttle. In the morning of the 25 February the weather improved considerably and we planned the first dive of the AUV AsterX (Ifremer) carrying the multibeam echosounder Simrad EM2000 (Geosciences Azur) (Fig. 2). It was planned to dive above the gas seeps in 150-300 m water depth on the slope of the Crimea peninsula. The aim was to map the famous carbonate reefs formed by methanotrophic microorganisms in this region. Unfortunately it was discovered already during the first dive that the AUV had severe technical problems, including water leakage into the hull and dysfunctional propulsion. Instead we worked with the ship based Kongsberg EM 710 Multibeam to prepare the first ROV dive (Dive 146) to the microbial reefs. The task was to do video-mosaicking and sampling of the METROL and GHOSTDABS microbial reef fields focusing on their organic and inorganic geochemistry and geobiology. Due to the continuing technical problems with ROV QUEST (MARUM) the video-mosaicking had to be canceled, but we obtained very interesting push cores from between a chimney field showing various forms of subsurface mats and microbial biofilms, and quite gassy sediments. The dive was terminated before midnight. We then steamed in the early hours of the 26 February to the Dvurechenskii mud volcano (DMV) in the Sorokin Trough, NE of Crimea (44° 17' N and 34° 59' E). The Sorokin Trough area is known for its many active mud volcanoes, which have been previously studied by the TTR program (IOC/UNESCO) and during METEOR expedition M52 "Margasch". We made plans for the first ROV dives on the DMV, a flat-topped and very active mud volcano in the Sorokin Trough. Unfortunately, the repairs took on and neither AUV nor ROV could dive 26-28 February. Instead we mapped the mud volcano with the EM120 to plan the dives, and carried out a series of gravity corers equipped with in situ temperature probes as well as multiple corers (Fig. 3). As part of the HERMES program, Tom Feseker of IFREMER/AWI is studying the in situ temperatures of the surface and subsurface muds in relation to the morphology and chemistry of the mud volcano for a better idea of the fluid flow and its causes and effects. Thanks to the ship's own multibeam system, we were able to discover a small elevation in the NE center of the mud volcano which proved to be the temperature hot spot as indicated by the gravity cores. We had to stop the coring program for 6 hours in the night of the 27-28 February due to problems with the ships winch.

The first ROV dive on the 2000 m deep DMV was realized around noon of 28 February (QUEST dive 147). After consulting with the company and their home base the ROV QUEST team had agreed to carry out dives without the auto-piloting function in a fully manual mode. Also, the problems with the manipulator could not be fixed and resulted in loss of several samples. Dive 147 was dedicated to videographic mapping of the DMV in the western and northern direction from its center. We could confirm by in situ measurements that the subsurface temperature gradient is highest where relatively fresh mud flows are visible and free gas is escaping when the seafloor is touched by the ROV or our instruments. The ROV dive lasted to the morning of the 1 March. We continued with 3 multiple corer stations close to Odessa MV for the IBSS biodiversity survey, and later in the afternoon with 3 stations on DMV for geochemical and microbiological sampling. The night of the 1-2 March we used for multibeam and parasound mapping of the Sorokin Trough (Fig. 4). On 2 March we carried out two more tests on the AUV with the repaired propulsion. Unfortunately, the problem with the water leakage remained. In the evening of the 2 March, the ROV team was ready for another dive. The shuttle system was launched to an area close by the center. Dive 148 was dedicated to in situ sampling with profiler and chamber, and to the deployment of an RCM current meter. Unfortunately, the ROV dive 148 had to be cancelled due to electrical problems with the ROV. Struck by bad luck, we could not retrieve the shuttle system by its acoustic release. We decided to wait for the other day to carry out a rescue dive with the ROV, to give the ROV team some sleep as they had been already on watch with repairs for 18 hrs. During the night of the 2-3 March we continued with gravity coring. For our high resolution porewater and gas sampling, we carried out 3-4 replicate gravity cores at 4 different stations in the center, the west, south of the DMV, and in addition at a reference station to the north. We are analyzing the biogeochemical signatures of various microbial and geochemical processes in sediments connected to methane turnover within and outside of the mud volcano. In the morning of the 3 March we started the rescue dive. We found the shuttle deeply buried with its feet in the soft mud of the DMV. Unfortunately, the release had not worked, but also the removal of mud from the feet did not result in mounting of the shuttle, which obviously was too heavy. We had to decide for a winch-based recovery operated by ship and ROV. The operation went smoothly, using a hook and a weight from the ship to pick up the shuttle and lifting it up. We used some remaining hours at the seafloor for water sampling, the ROV was back on deck in the evening.

The night of the 3-4 March and the following day we used for gravity coring according to our sampling scheme. Dive 150 was planned for the evening of the 4 March until the morning of the 5th. It was foreseen to carry out several profiler measurements in connection to in situ temperature profiling. However, during the dive, winds picked up within a few hours from Beaufort 4 to Beaufort 9. In the morning of the 5th March, the QUEST team leader decided to avoid a recovery procedure at these very bad weather conditions and waves > 4m. Hence, the 150th dive of QUEST broke several records at once: it lasted 32 hours and 20 minutes, resulted in 72 microsensor profiles, 23 in situ temperature probe measurements and 10 pages Alamer dive report. This unwanted change of the station plan resulted in a beautiful data set on geosphere-biosphere interaction: One of our main scientific questions on the MICROHAB cruise is as to the influence of subsurface fluid flow velocity on microbial activity, especially with regard to consumption of the greenhouse gas methane. We use temperature and sediment geochemistry as indicators of fluid flow rates. With temperature probing and microsensor deployments (measuring sulfide as a product of microbial methane consumption), we carried out a transect from the active warm summit across the geographical center of the mud volcano to its Western Rim and back to the summit. At the summit of the DMV the strong temperature anomaly indicates high upward flow rates of sulfate-depleted, warm fluids suppressing the formation of gas hydrates at 2000 m water depth, and also microbial consumption of methane. This is the reason why the central summit of the DMV is loaded with free gas bubbles, which are released upon minor pressure changes.

The ROV was recovered in the night of the 5-6 March. We continued with gravity coring in the morning of the 6 March. We deployed successfully a long-term subsurface temperature observatory (Fig. 5) similar to the one previously deployed by the fluid flow-working group of IFREMER-AWI at Haakon Mosby mud volcano. One temperature logger was already retrieved by the working group of Gerhard Bohrmann (RCOM Bremen) during M72/3, another one will be retrieved when we return in 2009 or 2010 with the HOMER expedition. Another long-term experiment was deployed on the 6^{th} March, namely a wood colonization experiment for the future observation of its microbial degradation under anoxic conditions. We will compare this with the animal-microbe mediated degradation in oxic deep-sea habitats where the wood often attracts a high diversity of unique species – but also relatives of chemosynthetic animals like those found at vents and seeps (project DIWOOD). The AUV was further tested, but any attempts to find and stop the water leakage were unsuccessful. The last dive at DMV (dive 151) started in the morning of the 7 March and was dedicated to checking the mooring of the long term temperature observatory, and carrying out chamber measurements as well as getting a few more push core samples for the geochemists. The ROV was retrieved in the evening of the 7 March, and followed by another multibeam and parasound transect, before we left for site 1 NW of the Crimean peninsula.

The last 4 days of the cruise were dedicated to in situ measurements of sulfide fluxes and methane consumption in the microbial reefs at the gas seeps on the Crimean shelf. We managed 3x12 hour dives with QUEST and worked both at the GHOSTDABS field discovered by scientists of the University Hamburg in 2001 as well as at the close-by METROL field discovered by the EU project METROL in 2004. The sidescan sonar of ROV QUEST was used to map the fields and the distributions of chimneys, which reach from a few cm above bottom to 4 m in height. The microbial reefs are the largest and densest accumulations of microbes known on earth and consist of methanotrophic archaea and a variety of associated bacteria. Anaerobic methane consumption does not result in a large energy yield. Hence, growth of microbes is extremely slow. A rough estimate suggests that the large chimneys may be a few 1000 years old. Unfortunately, large areas of these unique microbial reefs have been destroyed, probably by benthic trawling, which makes one wonder about the establishment of marine protected areas even for microbes. We arrived on site in the evening of 8 March. Dive 152 was focused at sediment and water sample retrieval and chamber measurements close by and away from the seeps (Fig. 5). Sampling and moving from station to station was extremely difficult due to an enormous bottom current. The dive was stopped in the early hours of the 9 March. A final attempt for an AUV dive was canceled a few minutes after the AUV was launched because of the strong water leakage. During the day we continued the TV

MUC coring for the IBSS biodiversity program. Dive 153 was planned around the use of a new in situ instrument, the horizontal microsensor profiler. We looked for a microbial mat chimney to carry out in situ profiling with H2S and pH sensor to reveal the hotspot for methane turnover in the mat (Fig. 5). Furthermore we carried out sidescan sonar, acoustic sonar and videographic mapping of the two reef areas. The ROV was retrieved in the morning of the 10 March. During the day we completed the final multibeam mapping as well as TV MUC coring program (Fig. 6). Unfortunately, the ROV dive planned for the evening of the 10 March was canceled. The night was used for an extensive multibeam mapping of the wider Crimea slope. The last ROV dive 154 of the expedition MICROHAB started in the morning of the 11 March and was dedicated to chamber measurements, water and gas sampling as well as high-resolution videography with the new HDTV camera. We ended dive 154 in the evening of the 11 March. After a few more hours of multibeam and parasound measurements, we concluded the sampling program of expedition M72/2 in the night of the 12 March and steamed back to Istanbul.

When we arrived in the early morning of the 13 March, the entry of the Bosporus was closed because of construction works. Unfortunately we lost 1 harbor day with waiting for the permission to enter Istanbul harbor, which finally happened in the evening of the 13 March. 25 members of the scientific crew were exchanged in Istanbul and the AUV and shuttle as well as our laboratory equipment were unloaded.

Summary

Despite many technical difficulties and bad weather conditions, the cruise M72/2 allowed for high-resolution geochemical, microbiological and biological studies of anoxic microbial habitats associated with methane seepage on the NW and NE slope of the Crimea peninsula. We completed over 60 ship stations. In total we carried out 8 ROV dives, 21 gravity corer, 19 multiple corer deployments, 3 deployments of long term experiments, as well as 9 multibeam/parasound transects with a length of 250 nm.

We would like Captain Pahl and his team for excellent support with work at sea, and the ROV, AUV and shuttle teams for their efforts with repairs.

Fig. 1 Ship track and working areas during MICROHAB M72/2

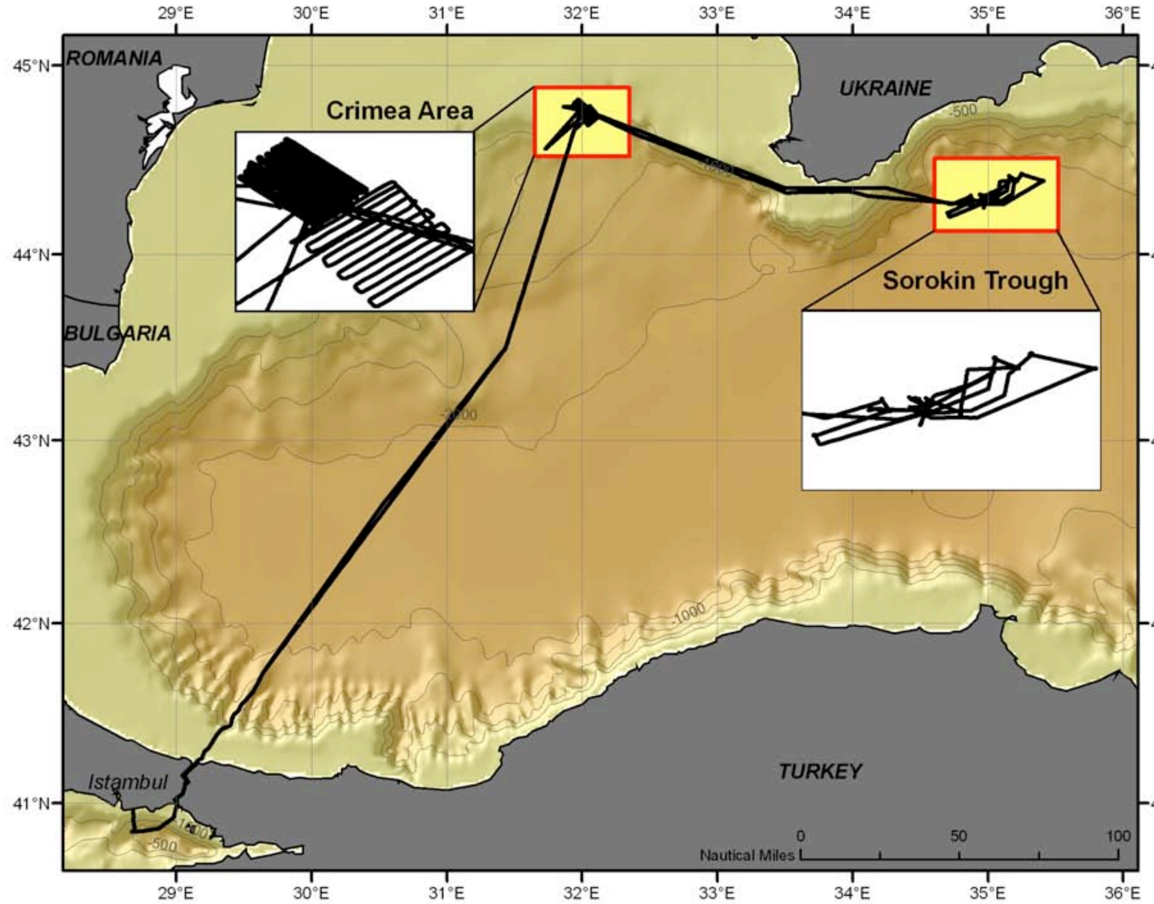


Fig. 2 Main technologies of expedition MICROHAB – left: ROV QUEST (MARUM), right: AUV Aster^{x} (IFREMER) and ROV shuttle (MPI/RCOM)

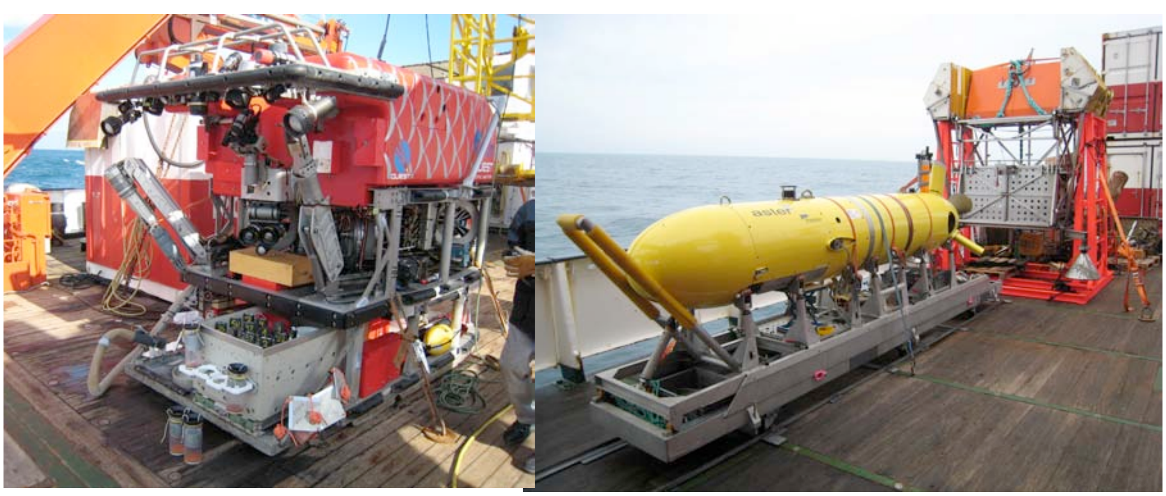


Fig. 3 Ship-based (EM120 multibeam of METEOR) with gravity corer and multiple corer positions

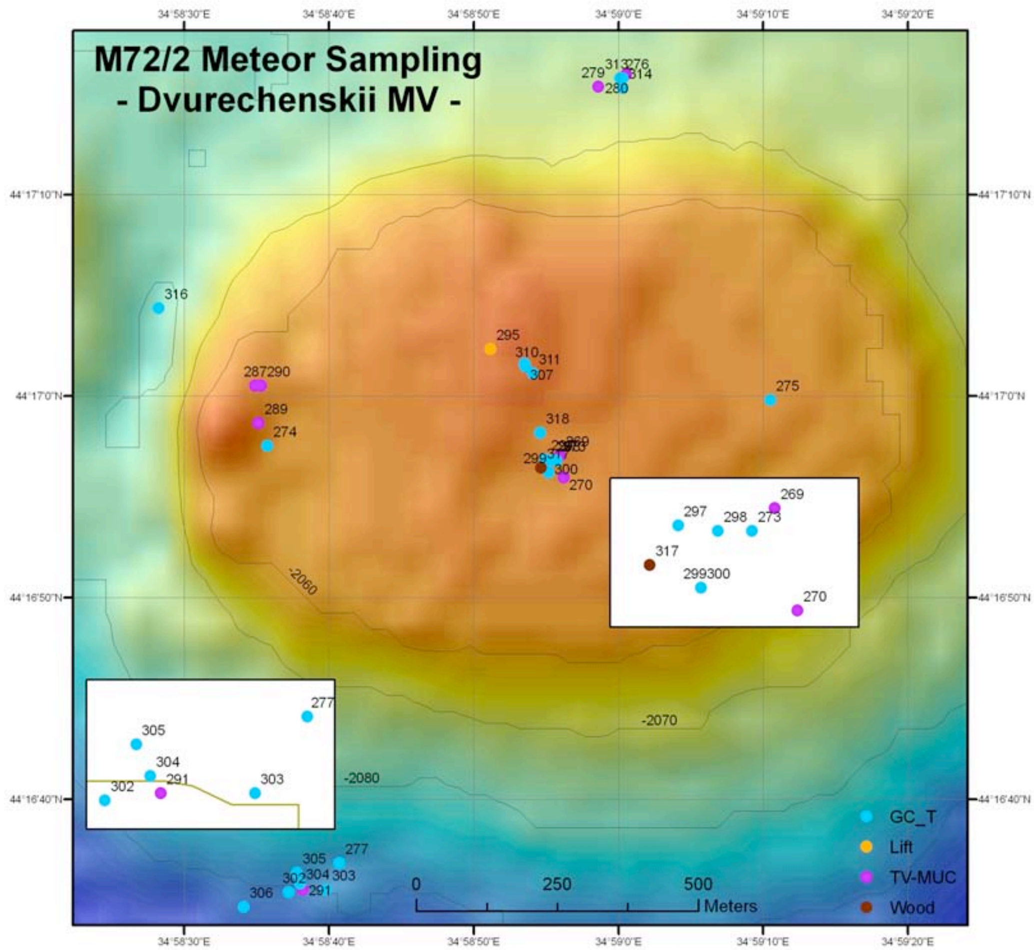


Fig. 4 Further mapping of the the Sorokin Trough with the EM120

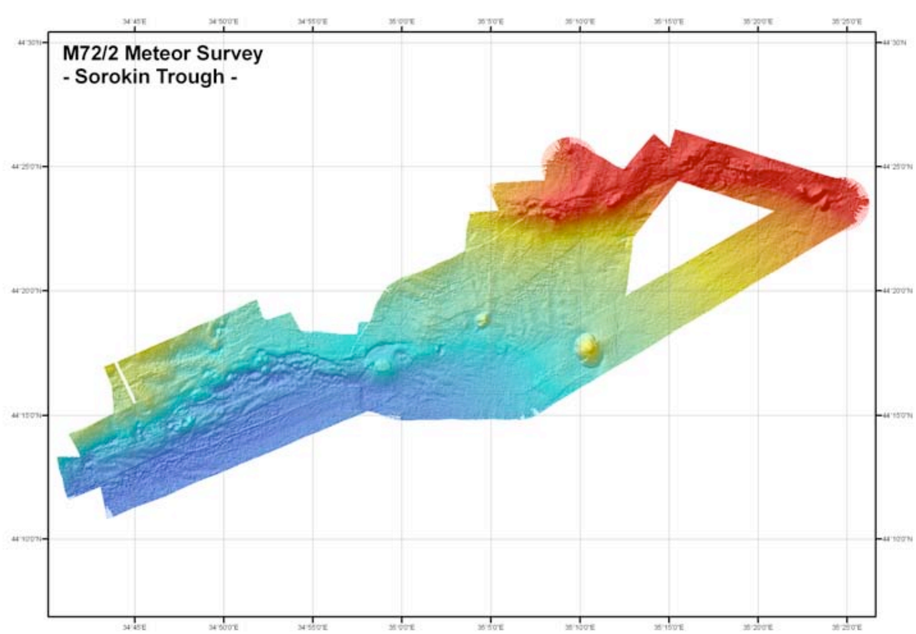


Fig. 5 In situ instrumentation to measure biogeochemical processes at the seafloor. Upper left: benthic chamber measuring methane fluxes, Lower left: horizontal microprofiler. Upper middle: temperature loggers on the mooring buoy. Lower middle: in situ temperature probe; Right: long term temperature observation system

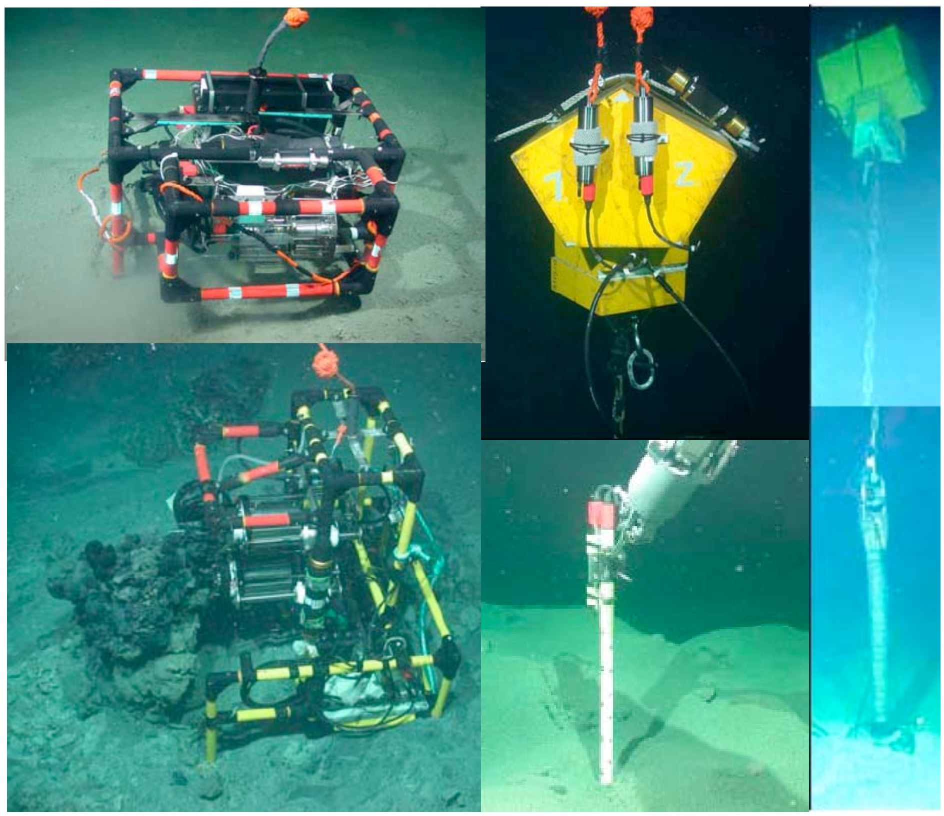
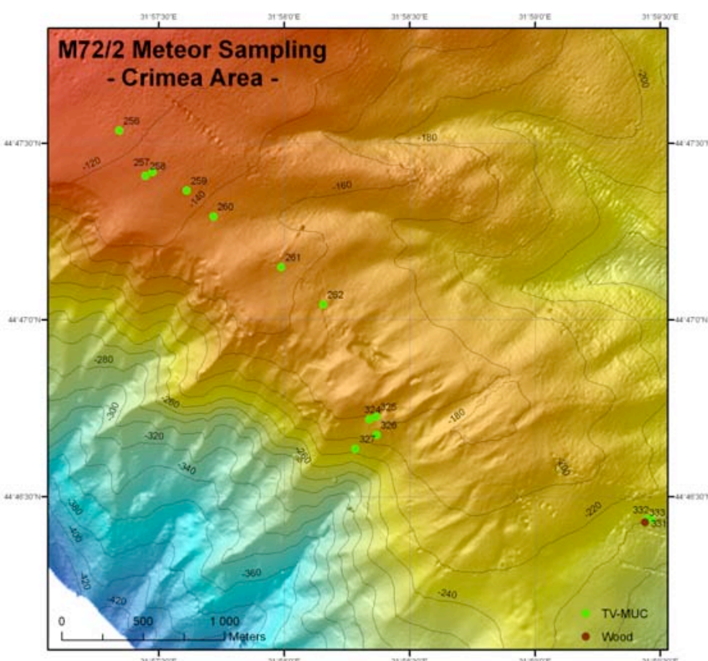


Fig. 6 TV-MUC stations on the NW Crimean slope



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