Maria S. Merian Cruise 1 leg 3

Last report: 10. 05. - 18. 05. 2006

In the last week our activities were split geographically between Captain Arutyunov MV (CAMV) in the north, Meknes MV in the south and Mercator MV with the adjacent Vernadski Ridge and Renard Ridge/Pen Duick Escarpment in between. Geochemical work focussed on Meknes MV and Mercator MV whereas coral mound investigation was more concentrated to the ridges. The biogeochemistry group further focussed on CAMV with additional lander deployments, BBL water sampling and multiple corer sampling. We retrieved more gas hydrates from about 20cm sediment depth and found substantial gas flares with the 12kHz echo sounder extending up to 400m above the sea floor on top of CAMV. We deployed the Pore Water Pressure Lance Lander (PWPL) for long-term observation at the gas hydrate field on top of CAMV and the Deep Sea Observatory Lander (DOS) on a coral mound at Renard Ridge. Both long-term observatories will be retrieved with FS Meteor in August this year. At o2:00h on Thursday (18.05.) we finished station work and started our voyage to Lisbon where we will arrive on Friday morning (19. 05).

The geochemistry group investigated six mud volcanoes, Bonjardim, Porto, Carlos Ribeiro, Captain Arutyunov, Mercator, and Meknes, with a total of 48 cores. These structures cover the range from 3800 m to 360 m water depths. The objective was to determine the origin of the fluids expelled into the overlying water column and to quantify the present day activity of the mud volcanoes.
At all mud volcanoes, the geochemical concentration-depth profiles are influenced by anaerobic methane oxidation. The depth of this reaction front strongly depends on the upward advection rate of deep-sourced fluids pushing the AOM zone close to the sediment surface (< 1m). In many places, data from the top few centimetres of the sediment show the effectiveness of the benthic filter at the sediment surface, e.g. pogonophora, in changing the composition of these fluids and thus preventing H_2S- and CH_4-rich fluids to escape into the water column. A good example is given by the data of a multi corer from CAMV (Fig. 1). The sediments contained finely dispersed gas hydrates below a sediment depth of 20 cm. Upon core retrieval the decomposition of the hydrates could be followed with the camera mounted to the MUC. No solid hydrate pieces survived until the gear was secured on deck. The respective pore water profiles show the irrigation of bottom water into a sediment depth of 10 cm, most likely due to pogonophorans and polychaetes. This sulphate-rich pore water then reacts with the upward advecting methane-rich fluid from below. As a consequence, a very narrow AOM zone was observed around 1 cmbsf, accompanied also by steep gradients in sulphide and total alkalinity.
The fluid regime of the six MVs can be divided into 2 general groups according to their salinity. The deep fluids from Bonjardim, Porto, Carlos Ribeiro and Meknes carry a low chloride signature with concentrations as low as 200 mM, whereas the fluids of CAMV and Mercator are enriched in Cl^- with extreme values (> 8700 mM) at Mercator MV. Low chlorinities are usually due to mineral dehydration processes in several kilometres depth. High chloride contents, on the contrary, are often related to dissolution of salt deposits. Further studies of the pore water composition will provide the respective answers.
Overall, highly active sites appear to be of small size and are often indicated by gray patches with clam shells or pogonophora colonies at the sea floor. A quite good correlation of the fluid flow activity and temperature and salinity anomalies can be measured with CTD mounted to the OFOS, suggesting that the OFOS-CTD data might be suitable for a

spatial quantification of the activity on these mud volcanoes. Preliminary estimates of fluid flow rates applying numerical transport-reaction models at a couple of sites suggest moderate to low advection rates at the investigated mud volcanoes.

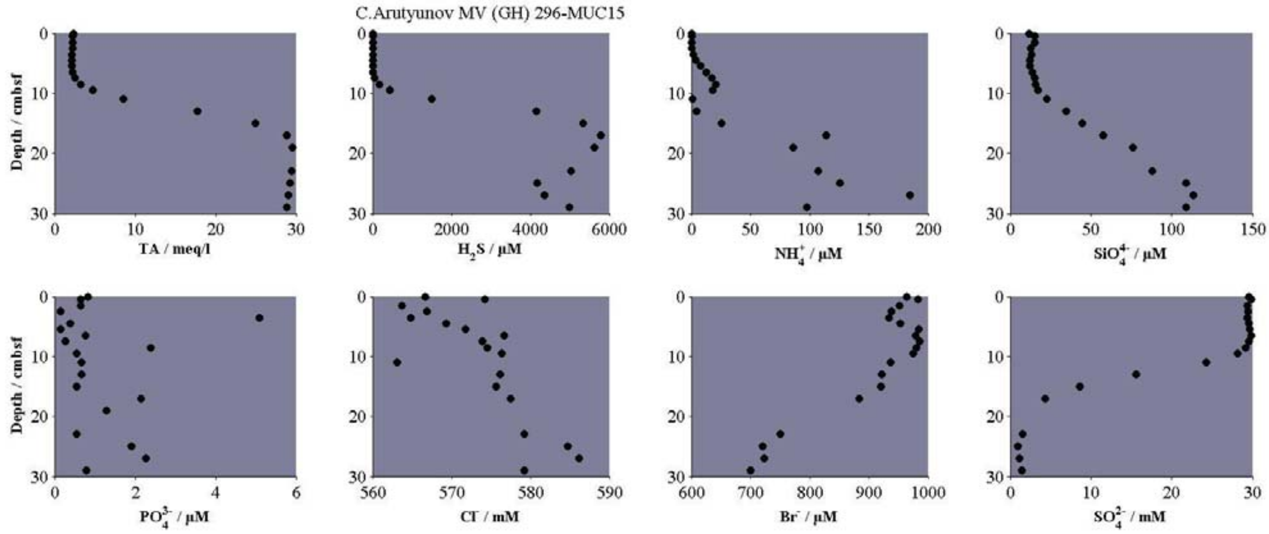

Fig. 1: Porewater profiles of a multicore at Captain Arutyunov MV with near surface gas.

The presence of numerous carbonate mounds, in the close vicinity of mud volcanoes (Gemini MV, Fiuza MV, Don Quichote MV, etc), and overlaying large faults (Pen Duick escarpment, Renard Ridge), suggests a possible relationship between carbonate mound distribution and fluid migration through the sea floor. A previous coring of a carbonate mound in this area (Privilege cruise- R/V Marion Dufresne) showed that mounds were indeed the place of an enhanced flux of methane, bearing a sulphate to methane transition zone at 3.5 m below the mound surface. At this depth, ^{13}C depleted carbonate as well as sulfide are released in the sediment column, suggesting an active zone of anoxic methane oxidation. Hence, a possible relationship between focused fluid flow and the carbonate mound distribution at Renard Ridge has been hypothesized.
One aim of this cruise was to confirm or infirm this hypothesis, by sampling several other carbonate mounds along the Renard Ridge, including the Pen Duick Escarpment and examine if they all show the same trend. We cored in total seven carbonate mounds, and measured on-board several geochemical parameters such as methane, sulphate, sulphide and alkalinity. We determined the sampling position according to the numerous topographic elevations in the form of knolls, present all along the ridge. In each case, we could recover long cores (around 5m) containing coral rubbles from bottom to top. It is therefore most likely that every single knoll on the Renard ridge is a coral carbonate mound, and that the entire ridge has been massively colonized by cold water coral over a long period.
Similar to the previous results, every carbonate mound sampled during this cruise shows a decrease of sulphate with depth, suggesting the presence of a methane oxidation zone in the deeper sediment. However, the penetration of the traditional gravity core was insufficient to reach the sulphate to methane transition zone.
According to the first measurements, methane migration seems to be of greater importance in the carbonate mounds at the south-eastern part of the ridge (Pen Duick II and Pen Duick III mounds), whereas the sulphate gradient becomes weaker toward the center of the ridge. Furthermore, the “no-name structure”, a carbonate mound sampled during the SONNE cruise 175, and located at the noth-western part of the ridge was the place of an significant methane flux. Measures of bacterial activity showed a zone of anoxic oxidation of methane at 2.5 mbsf. Hence, this part of the ridge is again subject to fluid flux.

In the context of carbonate mound studies, the Renard ridge is of particular interest, and constitutes the first case of co-occurrence of fluid flow, microbially mediated oxidation of methane, and cold-water corals. However, further studies on these mounds would require the use of alternative coring or drilling facilities, to be able to reach the methane zone and the base of the mounds to determine the eventual role of fluid flux in the initiation stage of carbonate mounds.

The intense sampling of CAMV by the biogeochemistry group with different gears revealed a highly diverse environment with a distinct fauna of pogonophoran tube worms and bivalves of the genus Thyasira both harbouring chemosynthetic endosymbionts, thus indicating an active mud volcano. We retrieved sediment samples which obtained gas hydrates, buried about 20cm below the sediment surface with a multiple corer (MUC 15). During the heaving of the gear back through the water column, gas bubbles were observed escaping at the base of the corer liners. A single beam echo sounding record (12khz), revealed that bubble development in the sediment cores of MUC 15 coincided with the limit of the gas hydrate stability zone. Although gas release from gas hydrates created a big void in the sediment column (Fig. 2) the surface of the sediment overlying the gas void remained surprisingly intact and remained apparently relatively gas tight. This observation is completely different to sediment cores retrieved at Hydrate Ridge, where gas release from gas hydrates completely disturbed the surface sediments in multi corer tubes. Hydrate Ridge sediments appear to be more permeable enabling sulphide to diffuse up the sediment surface, inducing the formation of dense bacterial mats of *Beggiatoa*.

Fig. 2: Gas void in a sediment core retrieved by MUC deployment 15.

The sediment retrieved by MUC#15 was densely populated by pogonopharan tubeworms, furthermore empty shells of thyasirid bivalves and living polychaete worms were found. Methane concentrations in the uppermost 6 cm were below 2µmoll^{-1}sediment. As hypothesized in the fourth weekly report the pognophoran tubeworms are apparently perfectly adopted to "bridge" the gap between well oxygenated zones at the surface of the sediment and deeper sediment strata with higher methane and sulphide concentrations to nourish its endosymbionts. Figure 3 impressively shows that these massive occurrence of pogonophorans which are able to exploit the methane derived energy (Fig. 4) for their metabolism and growth.

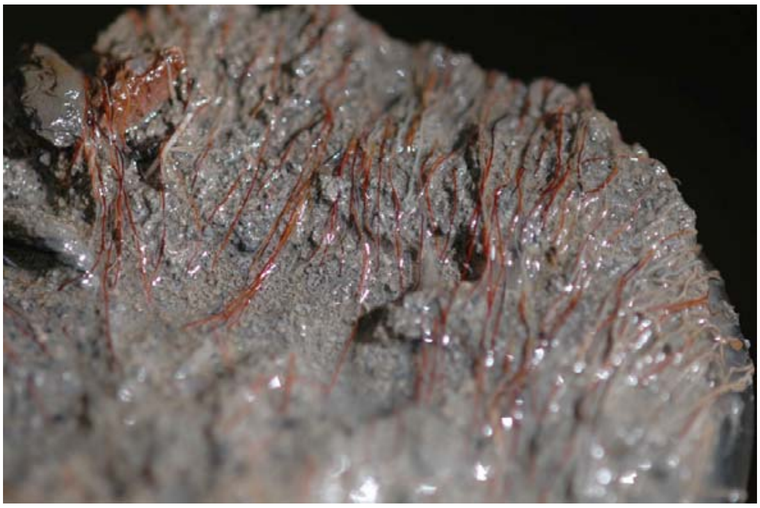

Fig. 3: Dense populations of pogonophoran tubeworms (red tubes) in sediments above shallow gas hydrates.

Fig. 4: After gas samples have been taken for isotope analyses the remaining gas was enlighted.

A major scientific objectives of leg MSM 1/3b was related to the investigation of framework-constructing cold-water corals in terms of distribution patterns, community analysis, physical environment and geology in the southern Gulf of Cadiz off Morocco. Special attention was paid to the interaction of active fluid flow and mud volcanoes with the spatial occurrence of scleractinian corals. This thematic priority links the objectives of the COMET project with the aims of the HERMES project and the recently launched ESF-MICROSYSTEMS project.
The areas surveyed for cold-water corals with the OFOS were Mercator MV and its adjacent ridge structure, the Vernadski Ridge, the Pen Duick Escarpment, the Renard Ridge and the Meknes MV with its surroundings. In addition, corals were mapped and collected along the deep slopes of CAMV which is the only site being affected by the Mediterranean Outflow Water.

We could confirm observations from previous cruises that framework-building coral communities were almost dead. We could not find any live *Lophelia pertusa*, *Madrepora oculata* or *Dendrophyllia cornigera*, *D. cornucopia*, *D. alternata* (Fig. 5). Careful analysis of box corer collected coral sites yield evidence of living *Stenocyathus vermiformis* that use the fossil framework as substrate. Presumably the „freshest“ *Lophelia pertusa*

frameworks were collected on the CAMV at 1400 m water depth. The morphotype of *Lophelia* is a dwarfed form with thin calcified, slender corallites as they characteristically occur elsewhere in the NE Atlantic in areas where this species comes close to its ecological limits. This is in contrast to the growth form of the fossil *Lophelia* remains from the sites in the southern Gulf of Cadiz, where thick calcified morphotypes are dominating. However, their preservation is poor due to bioerosion and chemical dissolution.
Box-coring from coral sites in the southern Gulf of Cadiz reveals a similar down core alternation of framework-constructing corals. The surface sedimentary units are dominated by *Dendrophyllia* spp. and *Stenocyathus vermiformis* with the clam *Spondylus gussoni* attached to the coral skeleton. Further down core, this assemblage becomes replaced by *Madrepora oculata* and increasingly by *Lophelia pertusa*. The latter is associated with *Desmophyllum cristagalli* and *Caryophyllia sarsiae* or *C. calveri*.

Fig. 5A: *Dendrophyllia cornigera* represents the youngest framework-producing coral community in the area studied. **B** Thin-calfied and tubular morphotype of *Lophelia pertusa* sampled at 1400 m depth from Captain Arytunov MV. Scale bars = 1cm.

The richest coral grounds were found on the Renard Ridge and Pen Duick Escarpment. This prominent structure is characterised by a series of elongated up to 40m-high elevations and knolls measuring about a half a kilometre in length. OFOS surveys, box- and gravity-coring confirms their nature as carbonate mounds. The life in and between the dead but exposed coral framework is very rich. Gorgonians and redbrown isidid colonies form important constituents of the megafauna. Current rich mound areas are indicated by masses of unstalked crinoids. The macrofauna and microfauna consists of bryozoans, serpulids, brachiopods, molluscs, hydroids, foraminifers and komokiaceans. Further down slope of the individual carbonate mounds, fine-grained deposits increasingly bury the fossil coral framework and the fauna changes to a soft-bottom community dominated by current aligned *Isidella elongata* (Fig. 6), whip corals, rare in antipatharians but rich in Lebensspuren and burrows. The surface sediment is a silty clay and it has to be analysed in the lab, how much of aeolian contribution has been accumulated in the recent past. Stochastically in the *Isidella* Facies but much more common in the coral mounds, boulder fields and outcropping rocks are a prominent feature. Especially the carbonate rocks are colonised by large sponges (Fig. 7).

Concerning the question about the interaction of scleractinains with active fluid flow it becomes clear that the framework-generating stone corals were not found in close vicinity to fluid flow sites. For instance, one of the most actively gas emitting mud volcanos, the CAMV, shows a clear spatial separation between chemosymbiotic communities on its top and oxygen-demanding coral communities along the lower slopes. However, we find several lines of evidence for a scleractinian coral with affinities to gas seeping - the solitary coral *Caryophyllia* sp. that lives in between the pogonophoran forests on CAMV and on Mercator MV.

The overall question remains: What caused the widespread decline of framework-building cold-water corals in the southern Gulf of Cadiz? Viewing along the NW European continental margin and the Mediterranean slopes, the most vivid zones of coral reef growth are confined to the higher latitudes from the Porcupine Seabight to the southern Barents Sea. On the contrary, coral ecosystems in the Mediterranean and off Mauretania were in decline since the beginning of the postglacial period. The wide occurrence of dead cold-water corals in the wider Gulf of Cadiz calls for more suitable environmental conditions allowing even coral mound formation in the recent geological past. We have to check with a couple of datings of coral skeletons when this decline happened and what does the change of framework-building coral species means. We were quite sure that the regional extinction of the coral reefs is not related to the emission of methane by the abundant mud volcanoes. Instead, the fertility of the surface waters must have been much more productive to sustain rich coral life fuelled by bentho-pelagic coupling. Can we relate the vanishing savanna condition of the Sahel zone with the increasing desertification and surplus of aeolian transport with the decline of the coral ecosystem in the southern Gulf of Cadiz? Fascinating new scientific questions arise on the screen. This cruise is going to fill an important biogeographic gap to better understand the (paleo)-ecology of cold-water coral ecosystems as a mirror of climate change.

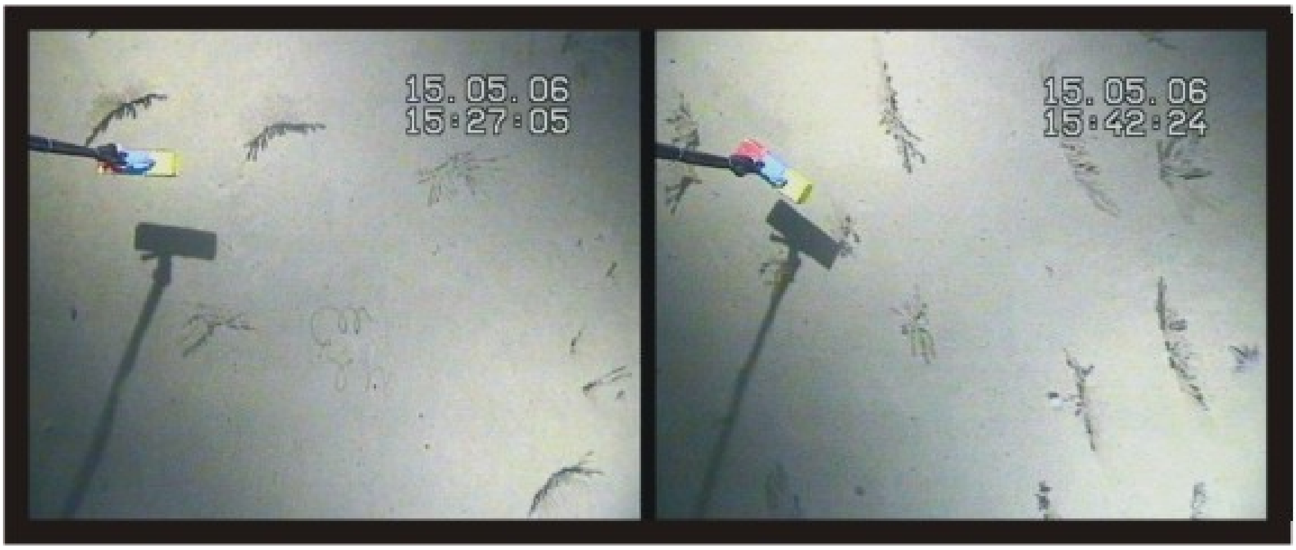

Fig. 6: OFOS images from the *Isidella* Facies on Renard Ridge. The octocoral colonies are oriented perpendicular to the current.

Fig. 7: Slabs of isolated boulders which are intensely colonised by sponges, hydroids and other sessile organisms, Renard Ridge.

Merian ends her maiden voyage with her arrival at Lisbon on May 19th. Her first expedition lead from the ice covered Bothnian Bay to the deep sea of the Gulf of Cadiz. Leg 3 encompassed all major oceanographic disciplines and had very ambitious goals with respect to sea floor sampling on decimetres scales under video control. Besides the A-frame we used all winches, cranes and pushing beams intensively at 233 working stations from 3800m to 360m water depth. Like with all major building sites we had to fight with initial technical difficulties which still need adjustment and fine tuning. However, we regard our achievements as excellent and are impressed by the technical potential of the ship. Maria S. Merian represents a major step towards the development of a new generation of multi purpose research vessels fit for multidisciplinary marine earth system research. The construction, propulsion system and technical installations appear to be trend setting for future constructions of German research vessels e.g. R/V SONNE replacement.

The success of this expedition was not possible without the dedicated and professional performance of captain von Staa and his crew which is acknowledged gratefully by us.

An Bord sind alle wohlauf.
Es grüssen.

O. Pfannkuche und alle Fahrtteilnehmer