SHORT CRUISE REPORT

METEOR cruise M74/3

Dates: 31 October - 27 November, 2007

Port calls: Fujairah – Male

Chief scientist: Prof. Gerhard Bohrmann

Institutions:

RCOM: Research Center Ocean Margins, University Bremen, Germany
AWI: Alfred-Wegener-Institute for Polar and Marine Research, Germany
MPI: Max-Planck Institut für Marine Mikrobiologie, Bremen, Germany
NIO: National Institute of Oceanography, Karachi, Pakistan
NOC: National Oceanographic Centre, UK

Objectives:

Investigations on fluid venting at Makran subduction zone (Continental slope of Pakistan) were planned. The expedition was strongly related to the previous cruise of METEOR M74/2, during which geophysical investigations on fluid seepage were conducted in the same area. Both cruises were planned together as part of research area E of the DFG research center ocean margins at the University of Bremen (RCOM). Fluid and gas seepage (cold seeps) at the sea floor is of global importance and leads to a major material exchange between sediments of the ocean, the hydrosphere and/or the atmosphere. Scientists of RCOM are currently working on various types of cold seeps to understand the mechanisms of fluid and gas exchange as well as to measure and estimate the amount of seafloor emissions and to learn about the influence of emissions to the environment. The RCOM scientists had been limited so far to the study of the cold seeps at passive margin sites. During this cruise our research activities took place at an active margin where fluid and gas circulation of the sediments is characterized by the compression tectonic regime of the plate convergence. Thus in the investigation area the Arabic plate, and/or a micro plate is pushed under the continental slope of Pakistan, whereby very thick sediments in the collision zone are squeezed and should produce an intensive fluid and gas circulation at the continental slope.

Cruise narrative:

RV METEOR sailed from the pier in the harbour of Fujairah (United Arab Emirates) at 7 p.m. local time on Tuesday 30 October. After 2.5 days in the port of Fujairah during which scientists and scientific devices were exchanged and R/V METEOR started his cruise. The new device on board, the ROV QUEST4000, represents the main instrument of our cruise. A 30-hour transit began towards the area of activity in the south of Pakistan. After a 10-hour bathymetric survey at the proto-deformation front the first dive with ROV QUEST began on Friday 2 November on nascent ridge, a small ridge south of the first accretionary structure. Due to the brilliant result obtained during the cruise before, a place of free gas emanation was immediately found by the ROV. The site was characterized by one of several acoustically detected plumes in the water column which were found in sidescan-sonar (TOBI) and the Parasound system. We have been very lucky to find an active seep field just right at the beginning of the cruise. Beside numerous discharge positions of gas bubbles the seep area was characterized by a grey colour of the sediments of the bottom as well as by a settlement of small tube worms in the centre and chemosynthetic shells at the edge. A gas and a push core sampling, as well as temperature measurements in the very fine-grained sediment performed the program of analyses, before we unfortunately had to break off the dive for technical reasons. In the evening we tried to sample the seep area by means of the gravity corer. We succeeded the entire gravity core was filled with gas hydrates which had formed near the surface within the seep environment from ascending free gas. After a bathymetric survey during the night a second gravity core was taken for a detailed geochemical examination in the seep area. Afterwards we began in advance with a special sampling program for the investigation of the oxygen minimum zone, since further ROV dives had to be cancelled for a longer repair work time.

On Sunday 4 November we used the time during the repair work of the ROV QUEST to accomplish our sampling program of the oxygen minimum zone (OMZ) along a transect over the margin. The water column was sampled using the CTD and hydro casts, and the sediments were sampled with multicorer and gravity corer at 660 m, 995 m, 1425 m and 1586 m water depth. The scientists will examine the samples and study the effects of the different oxygen concentrations on preservation of certain organic particles and substances, e.g. dinoflagellate cysts and biomarkers. The investigations are used for the evaluation of individual marine microfossils, as well as biogeochemical and geochemical proxies, so that their use for palaeoceanographic studies will be tested. Biogeochemical work on the organic material will be performed as well as pore water investigations of the sediments.

On Monday 5 November, the daily ROV dive began, and up to Saturday evening 7 dives were successfully performed. The dives examined scientifically spectacular and exciting information and samples. The fluid and gas seeps were dominantly characterized by bacterial mats in the OMZ. Other chemosynthetic organisms in addition appeared sometimes and their presence seemed to be related to small changes in oxygen content. This was especially the case at the lower boundary of the OMZ. On the crest at gas seep No 7 in 1600 m water depth where a large area (300 x 1000 m) of high backscatter signals in the side-scan sonar measurements were found, we could observe widespread seep areas. The entire crest was covered by carbonate crusts several decimetre to several centimetre thick explaining the presence of high backscattering in the map. Large fields which are colonised by *Bathymodiolus* mussels (Fig. 2) and which usually are interrupted by tube worm colonies at the more active seep sites were particularly impressing. In several places we could repeatedly observe emanation of free gas, and with the pressure tight gas sampler we could analyse both, the gas flux and the gas composition. Detailed observations with the ROV showed that the tube worms root with their tubes underneath the carbonate crust, where they can find sufficient hydrogen sulphide for their symbiotic bacteria. In contrast, the *Bathymodiolus* mussels were sitting on the carbonate plate, and so far it is not clear which reduced substances are used by their symbionts and how is the mechanism of their transport.

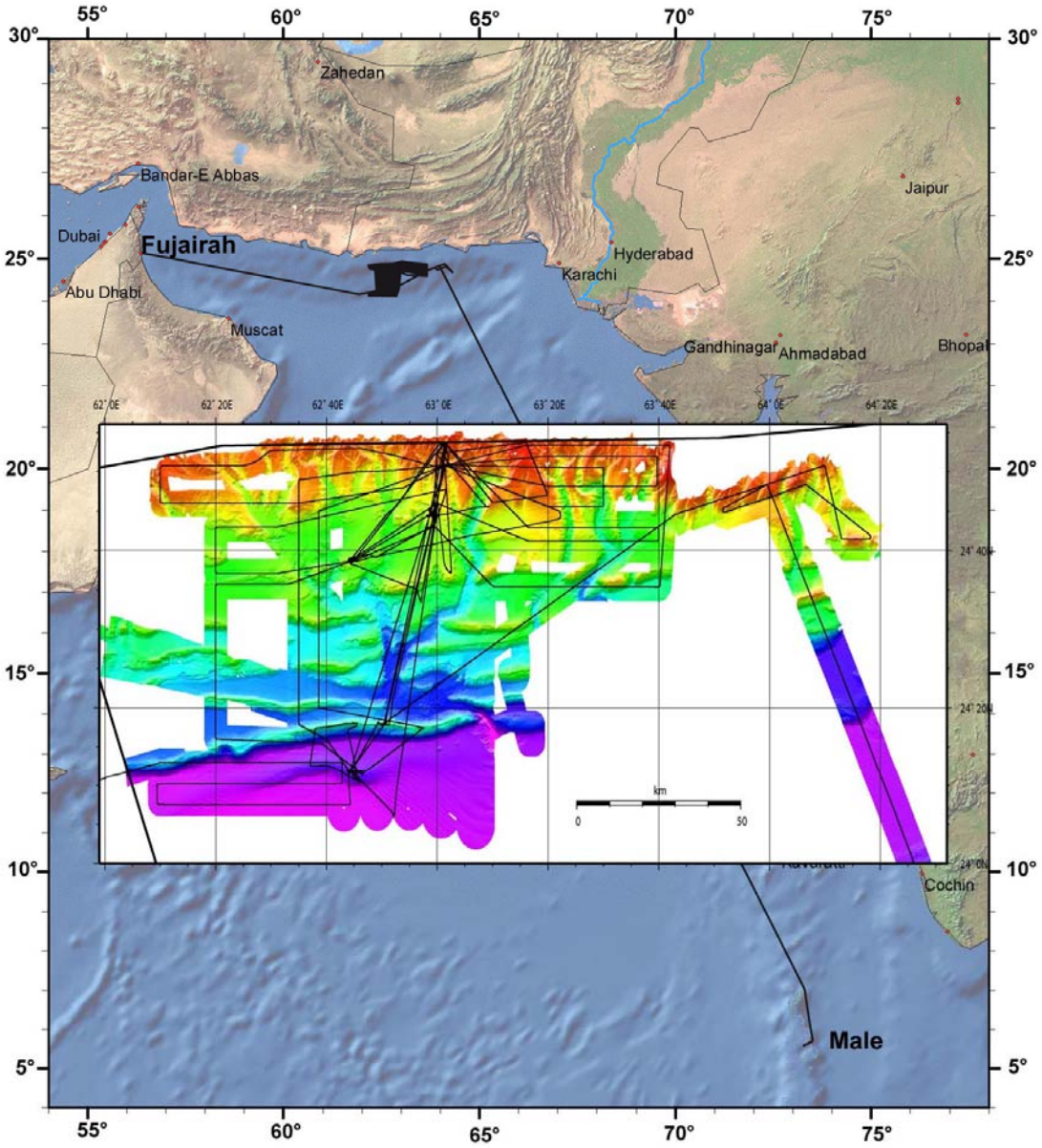
As before, the third week was characterized by ROV QUEST dives during the day, whereby in the early morning and late evening gravity corer, multicorer and CTD stations were performed. At the night locations with acoustically proven gas emanations were pre-examined with the TV-sled for potential ROV dives, or geologically interesting places were explored by the Parasound for further acoustic gas plumes. Thus we could find 5 well defined gas flares in addition to the 7 flare positions found during previous cruise M74/2. This mode of day and night shifts was productive and gave the scientists also sufficient time to work on their samples. This schedule also allowed the ROV pilots to accomplish their small repair work in the evening hours. On each morning after 2-hour preparation ROV QUEST was ready for the next dive. By support of the ROV dives we could understand clear differences of the fluid and gas discharge through the oxygen minimum zone (OMZ). The OMZ is characterized by oxygen concentrations of less than 0.05 ml/L between 150 - 1200 m water depth. In the environment of Flare No. 1 at 570 m water depth filaments of sulfure bacteria (very probable *Thioploka*) arose directly around the gas emission site. We have examined approximately 8-10 oval patches of white bacterial mats, often with orange coloured in the centre. Each of these patches had several holes where gas in various intensity bubbled out. Settlements by other benthic organisms were not to be proven, and are not to be expected due to the very small oxygen concentrations in the water. The seeps of Flare No. 2 at 1020 m water depth however showed clearly more benthic live, which appeared nevertheless very small-sized. So vesicomyide clams and other animals were found in clear distance to the gas discharge positions surrounded by bacterial mats. Such gradients in biological zonal colonization are well-known from other areas, where different hydrogen sulfide concentrations lead the chemosynthetic organisms to colonize according to their individual acceptance in H_2S concentrations. H_2S-content is probably very high around the gas discharge position due to the high rate of anaerobic methane oxidation which might be toxic

for clams. In a greater distance however the H_2S-concentration is surely smaller, so that clams find ideal conditions to life. This clear zoning around the actual gas bubble sites was found in 1000 m several times.

On Thursday, 15 November we accomplished two short dives. The first dive in the morning was performed at Flare No. 2 in order to quantify gas bubble emanation using the newly-developed bubblemeter. The principal aim of the equipment is an illumination which produces light over an area of 30 x 30 cm with a homogeneous intensity corresponding to the 1,5-fold of the sun exposure during a sunny day in Bremen. Ascending gas bubbles in front of this screen were recorded by a camera with very high resolution rate, so that most of the gas bubbles could be determined with the help of a computer program. Both, the handling of the equipment, and the somewhat unusual adjustment to the ROV QUEST, worked very well, so that this dive could be finished around midday. The second dive was started within the area of Flare No. 3 in 1500 m water depth, but had to be terminated after short time due to a short-circuit of the electrical system of the ROV.

On Sunday 18 November the video mosaicing was completed at Flare No. 2. Furthermore the in-situ pore water sampler was deployed, gas was sampled by pressure tight gas sampler and push cores have been taken. At Flare No. 2 we obtained the most complete data set and sample set of the cruise. The dive performed during the following day at Flare No. 11 was very exciting. As at many seeps in these water depths of 1500 m mytilide mussels were predominantly to find, which settled on hard substrates, predominantly above authigenic carbonates. Enormous large surfaces were settled by a dense population of galatheide crabs. Sampling of the water column directly above the discharge positions and sampling of the carbonates as well as the clams finished this fascinating dive. The dive on Tuesday examined an area of the first accretionary ridge, where backscatter anomalies have been found during the TOBI survey. This ridge is the youngest and tectonically most active ridge of the subduction zone. After an investigation with the video-sled during the night there were sufficient signs for active seepage, so that the dive on the crest of the very narrow ridge in 2000 m water depth was performed. The ridge has a very steep flank to the south of more than 1000 m height. So a constant slipping of rocks and sediments is expected related to the tectonic folding. Many extensive fresh outcrops were observed at this southern flank, which probably constantly rebuild very fast, so that they are not settled at all by organisms. Thus, we found our indicators for fluid seepage, the chemosynthetic organisms, only direct on top of the crest in small protected depressions. Again and again we searched along the steep southern flank, until we found very small holes at the bottom where fluids expulsions have been observed. Smallest differences in the density of the fluids showed us that these fluids mix with the bottom water very fast and then cannot be traced anymore.

The very small expulsion sites of less than a half cm in the diameter were to be seen only with the HD camera, which can be driven very near to the bottom. Since all other seeps which we examined so far on the cruise were characterized by free gas expulsion, here we could document a fluid outflow without free gas. The depths of the accretionary wedge from which the fluids ascend, will be clarified by the geochemical analyses of water samples which were taken by the KIPS sampler. The last dive (no. 18 of this cruise) was accomplished on Wednesday at a new location within the oxygen minimum zone (OMZ) at 750 m water depth. This diving work considerably extended our past spectrum of the OMZ seeps, since we could sample valuable carbonate chimneys at gas discharge positions, which develop as a precipitate of biogeochemical methane transformation around the gas bubble sites. Beside the diving program we daily sampled with the gravity corer, multicorer and CTD. The station work was terminated in the night from Wednesday to Thursday, and the 5-day transit to the south began. On Tuesday we entered the port of Malé in the morning, where our scientific cruise ended.



Track lines of R/V Meteor during cruise M74/3

Scientific work/station work during M74/3:

ROV dives	18 dives
Push cores	68 stations
Gas bubble sampler	18 stations
Temperature-stick	09 measurements
In-situ pore water sampler	06 deployments
Osmo-sampler	01 deployment
Bubblemeter	02 deployments
Gravity corer	31 stations
CTD/hydrocast	25 stations
TV-sled	06 profiles
Multicorer	08 stations
Parasound and swath bathymetry mapping	3300 km