SHORT CRUISE REPORT

R.V METEOR
Cruise No. M54, Leg 3A

Caldera (Costa Rica) - Caldera (Costa Rica)

10.09.2002 – 29.09.2002

Chief Scientist: V. Spiess

Short Cruise Report M54/3a

During the leg M54/3a we established 6 working areas where extensive sampling and surveys were done; in addition 3 other areas were investigated with only a few stations. The main areas from north to south are: (1) Horst-and-Graben, (2) Mound Culebra, (3) Mound#10, (4) Jaco Scarp, (5) Mound#11 and (6) Mound#12; the minor areas were BGR-slump, mud pie and Cocos Ridge (Fig.54/3a-1).

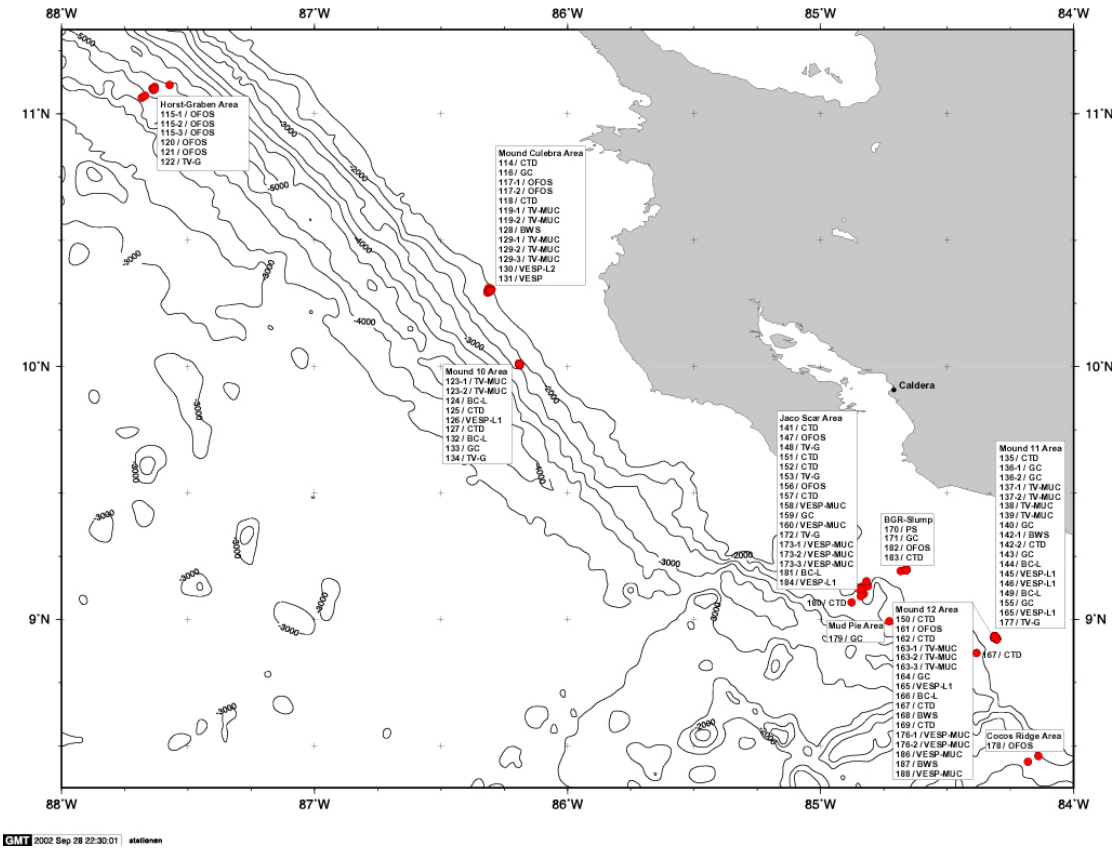

Figure caption: M54/3a-1 Area of investigation with working areas and all of stations occupied in each of these areas.

The events during the week from 09.09.2002-16.09.2002 were as follows: On September 9th we held a very successful reception on board the FS METEOR for guests invited by the local embassy of the Federal Republic of Germany. During the morning there were tours for school classes, as well as interviews with press agents and national television stations, and in the early afternoon the participation exceeded

all expectations with more than 100 guests from local diplomatic, administrative and academic institutions.

The crew's outstanding preparations included not only the elegant buffet, but also help in leading tours of the ship for different groups of guests. Highlights of the occasion were the presentation of our new land-and-offshore 3-D relief map of Costa Rica to various official representatives of the country by the Chief Scientist, as well as the numerous personal contacts with colleagues and employees of relevant scientific institutions. The map was presented in the name of the SFB 574 and Christian-Albrecht-University.

During the whole time of the reception, preparations continued with setting up laboratories and equipment so that the FS METEOR could depart Caldera harbour September 10th, 10:30 local time, with 24 scientific personnel on board, setting course for the furthest northwest field of research, the 'Horst-und Graben' structure offshore Nicaragua.

There, using the OFOS, three of the steep terraces next to the deep-sea trench were investigated at 4020-4350m; 4510-4750m; 4650-4950m. These almost vertically walled terraces showed spectacular exposures of basaltic crust layered over with sediment. It was surprising that the sequence of basalts was thicker than the sediments lying on top. At the bottom of the steep terraces lay strewn widespread heaps of basalt blocks and boulders. The deepest of the steep terraces seemed to be the most eroded and fractured, the middle one showed the best developed contact between sediment and basalt, and the shallowest terrace was similar to the middle terrace but heavily populated by sessile organisms. The contact on the middle terrace showed white precipitates and crusts which were initially interpreted as products deposited from ascending fluids along the contact plane. The TV-grab sampler, however, brought back only pure nanochalk from that contact depth. The precipitates could not be identified. The clear finding is that there is no indication of active fluid emission – either at the deeper end of the seaward-leaning terraces, nor at the contact between sediment and basalt.

The second half of the first week we spent investigating the northern section off Costa Rica, where the EPR-generated crust is subducted. Here two different sites were investigated in more detail. At Mt. Culebra we followed a WNW-trending fault, documented by intensive carbonate formation and populated by colonies of mussels and pogonophorans. A gravity core over an acoustic anomaly („white spots“ on the Parasound recording) showed uniform hemi-pelagic sediment. At a depth of 600 cm, however, clear chloride, CH4- and H2S-anomalies were measured in the pore water, which are an indication of ascending fluids. Several TV-guided MUC operations produced no recovery, either because carbonates prevented penetration or the sediment recovered no indication of fluid movement. These operations became very time-consuming because of the poor quality of the video transmission during the TV-MUCs. It was also difficult to clearly evaluate the nature of the sea floor in vent areas. Several CTD profiles with near-bottom CH4-maxima completed the range of samples around Mt.Culebra

The bottom-water sampler was also deployed very successfully, showing a direct connection between methane contents of near bottom layers and those higher up in the water column. One of the VESP-Landers was deployed during the night of 5/6 September to complete the operations at Mt.Culebra. The VESP-Lander was to record expulsion activity until the end of the expedition.

The second area investigated in detail, alternately with Mt. Culebra, was Mound # 10 situated about 17 sea miles SE, at a depth of 2300 m. From earlier investigations, it was known that there was less contiguous carbonate surface, so the TV-MUC sampling was accomplished more successfully than at Mt. Culebra. This was confirmed by TV-MUC which produced a pronounced enrichment of CH4 and H2S and a decrease in chloride at a core depth of only 4 cm. A gravity core about 400 cm from the top of M#10 showed the highest methane content so far, as well as a strong change in the methane gradient and an increase in sulfide at a depth of about 250 cm; thus ascending fluids can be assumed.

The first deployment of a Benthic Chamber Lander (BC-L) was at Mound #10. Here it was not possible to penetrate the sediment sufficiently, however after 30 hours one of the 4 samplers contained a complete time-series of samples . Two others did not

function properly and a third was damaged during recovery. In the area around Mound #10 there had as yet been no CTD-survey of methane distribution in the water column. Two depth profiles, one above the top, the other at the western edge, resulted in identical patterns of methane distribution identical in the near-bottom water. This distribution confirmed all previous observations on CH_4-maxima directly at the bottom and a continual decrease upwards. This is to be interpreted as a fluid source and not as bubble transport of the methane.

After completing the station work, we transited to the southern area of investigation around Mounds #11 and #12. From here, all other areas could be reached within a few hours, so several investigative goals were worked on alternately. The sea was exceedingly calm so far; the temperature of 28°C and the high air humidity was not everyone´s cup of tea, but this did not dampen the good spirits.

The events during the week from 17.09.2002-23.09.2002 were as follows: We spent time investigating the southern section offshore Costa Rica where the Galapagos-generated crust is subducted. We worked alternately in two areas 32 nm from each other: the Jaco Scarp and the Mounds #11 and #12. The scarps and mounds emit various types of fluids from different depths; the mechanism responsible for the fluid-movements seems to be respectively different as well. Therefore, the comparison of mounds and scarps is of high scientific priority.

Mounds #11 and #12 are gentle morphological elevations at 1000 m depth offshore Quepos, with a relief of maximum 30 m at the middle slope. Earlier OFOS observations had documented active fluid venting based on carbonate formations and vent communities. During leg M54/2 the mounds were identified as mud volcanoes with a more or less contiguous carbonate platform on top. Gas hydrates were also found about 200 cmbsf on the southern flank of Mound #11, a mound characterized by high heat flow. At the beginning of the week several gravity cores were taken at the position of the gas hydrates and in the center of the mounds. All of them terminated at about 200 cmbsf because penetration failed when they encountered compact layers of gas hydrate. Regrettably, we were not able to sample any of the gas hydrate.

All cores contained either layers of volcanic ash of different thickness (1-20 cm) cemented by carbonate, or layers of different types of carbonate concretions. TV-guided multi-corer deployments at those stations where the gravity cores failed or at positions with bacterial mats allowed an exact delineation of the pore water-concentration gradients near the surface. In general, the chloride contents decreased significantly to as low as 250 mol/L. Methane, hydrogen sulfide, and alkalinity increased significantly caused by ascending low-salinity fluids. Freshening may, however, also be caused by dissociation of gas hydrate. Both types of chloride decrease were measured.

The deployment of the BC-L was a remarkable success. Near bacterial mats at Mound #11, it recorded a 30-hour continuous decrease of oxygen and nitrate to values less than half those of the bottom water, with a simultaneous increase in methane. The sediment enclosed in the chamber was sampled for high-resolution pore-water chemistry. A detailed OFOS-survey of Mound #12 showed that active venting is presently taking place on the southwestern flank. Bacterial mats and carbonate-edifices (irregular chimney formations found with venting communities) are present here. Continuously younger carbonate formations extend from the top down the southwestern flank.

Platy crusts of interrelated carbonates build up the top of Mound #12. Fractures between the carbonate plates are extraordinarily densely occupied by Bathymodiolus colonies (vent shell) whose margins are discolored by bacterial mats. Along the downward edge of the slope fewer carbonates and more vent-organisms were observed; i.e. fragmented pieces of carbonates with dense fields of living mussels grading into fields of empty shell debris, followed by single clams and bacterial mats at the western margin of the active field.

The highest solute concentrations of pore water were obtained from sediments sampled by TV-guided multi corer at bacterial mat sites. Approximately 20 mMol/L hydrogen sulphide were measured at a depth of only 20 cmbsf; alkalinity, chloride and methane were likewise extremely high. The BC-Lander and the VESP-Lander were positioned on Mound #12 and we continued taking water column samples by using CTDs and the in situ pump. Particulate matter was collected with the in situ

pump to isolate biomarkers. These are expected to be characteristic of vent-activities. Between 10-15 cm off the seafloor at Mound#11 an exceedingly high methane content of 120 mMol/L was measured as well as strong gradients. In this way we succeeded in documenting the continuous transition of the methane concentrations between the measurements of the CTD-rosette and the bottom water sampler.

Jaco Scarp represents the best-defined and, with its bathymetry, the most outstanding feature generated by seamount subduction. .Along this feature a volcanic seamount originally situated on top the Galapagos-generated crust plowed into the slope sediments. Such features open up routes for fluid- and gas-emission and by this means contribute to the dewatering of subduction zones. Jaco Scarp extends from its upper edge at a water depth of 1000m down to 2300m. Inside the semi-circular scarp face there is an apron of debris and boulders which, after the passage of the seamount, were loosened from the sides and the head wall. Above 1900m the sediments of the slope are exposed and free of debris, forming several abrupt steps up to almost 1000m of water depth. From earlier investigations, we know that here fluid venting is active as shown by methane anomalies in the water column and by the presence of vent communities. Based on these results observed between 1700-1900 m, at the lower end of the exposed layers , the entire width of the caldera was searched and sampled for vent phenomena. The results indicate that venting is restricted to the center of the exposed head wall with the most active spot between 1760-1840 m. Here fluids exit horizontally from the exposed indurated layers of mud stones and support a shrubbery of pogonophoran colonies which stick out of the vertical wall. At several spots we observed caves where these colonies prosper even more than at the walls. Vent shells (Calyptogena) are found in the colonies as well. They are restricted to debris aprons and narrow ledges at the base of the vertical wall, primarily at a depth of about 1800 m but also around 1700m. Only at these ledges did we succeed in sampling by using the TV-grab. The material consisted mainly of mud-stone pebbles with a bit of sediment mixed in. In spite of their high permeability, and therefore the possibility of considerable admixing of bottom water, chloride values of 440 mM/L —considerably lower than seawater-- were measured in the pore water of these sediments. The TV-MUC could not be used here because of the rubble, however two locations were found where the Lander could be deployed.

This week once again the sea was calm, with air temperatures decreasing slightly compared to the week before. Also strong and frequent showers combined with thunderstorms, mostly at night, made temperatures more bearable.

The events during the week from 23.09.2002-29.09.2002 were are follows: First, following a Parasound survey, we sampled a gravity core from a small slide area on the upper slope (BGR-slump). A reflection seismic profile of the slide area showed a chaotic development of the BSR, which suggested possible methane degassing. The 320 cm core showed 50 cm of recent sediment deposited above an erosive discontinuity of older and much more consolidated sediments below. This superposition enables us to obtain an exact dating of the slide phenomenon. At the same time, the physical characteristics of the exposed deeper sediment might allow a reconstruction of the circumstances of the slide.

Following this the older VESP-sampler modified to carry a timed sequence of 5 water samplers on a cable, took 3 profiles along the steep slope of the scarp which was colonized by abundant pogonophora. Due to the inaccessible morphology of the fluid- and gas expulsion sites on the flank, the deployment of our usual bottom equipment was not possible. Nevertheless, in this manner described above with the modified device we obtained a composite deep profile over the whole area of expulsion. The data showed increasing methane concentrations from top to bottom of ca. 400-1.700 nMol/L. These values exceeded all the contents measured thus far during the expedition and verified the high activity of this vent site. Also a higher radon activity could be confirmed in these vent waters. A TV-grab sampler brought up large pieces of chemoherm carbonate from the flat 'roof' of the Jaco Scarp, thereby increasing the already large extent of our collection of vent carbonates.

The following day the Benthic Chamber Lander and the VESP-Lander were retrieved at Mound #12, One was placed directly in an anoxic vent field with mussel fragments and bacterial mats. The methane and hydrogen sulfide discharge and the oxygen consumption gave a consistent picture of venting. These deployments were followed by VESP-MUCs along a profile on the active SW corner of Mound #12.

The first deployment was in an active Bathymodiolus field and yielded high methane contents; the second, over a bacterial mat, but missed its target and showed only a moderate methane increase during deployment time. Finally, a TV-G deployment on Mound #11 to attempt again to recover some gas hydrate produced only mud with carbonate concretions and cemented sediment. .

The following night, an extended OFOS-survey was carried out beyond the deep-sea trench on the oceanic plate. Here, on the flank of the Cocos Ridge, the previous leg had measured an extremely high heat flow value but nowhere along the way was there the slightest indication of fluid expulsion. After discontinuing the profile, we returned to Mound #12. However, local fishermen had laid out long lines in our working area and we could not begin. Instead we steamed to the
ca. 0.5 nm diameter 'mud pie' structure, identified in the Side Scan Sonar at 2000 m depth, to obtain a gravity core. This core contained a highly carbonate cemented layer at its deepest part with shell debris and peculiar brecciated material. This fabric was overlain by hemi-pelagic sediment, which suggested a currently inactive methane vent site.

The BC-Lander was then deployed for a short station (12 hrs.) first at a narrow ledge with extended populations of vent mussels on Jaco Scarp followed by the VESP-Lander at the same site for a longer period, maximum 7 days. The deployment went smoothly, thanks to the ship's exceptional navigation skill and detailed knowledge of the steep slope that had been acquired. In the course of the day we steamed back to Mound #12 to take up the work we had not been able to carry out the previous day. The modified VESP-MUC was deployed again at a carbonate platform densely colonized with Bathymodiolus mussels. Here methane contents were of the same order of magnitude as at the active vent off the Jaco Scarp. This deployment was, however, mainly for measuring radon, which had also shown a slightly increased activity. Deployment of the bottom water sampler was followed early the next morning with the last instrument: The VESP-MUC; the survey of the unknown part of Mound #12 was unspectacular, but toward the end of the profile in the SW section, the device could be deployed for the first time on top of a pogonophoran colony associated with mussels. This site turned out

to be the most active one found yet for fluid venting and dewatering. The opportunity of having sampled a 'pure' end-member type vent fluid promises exciting results for budgeting considerations of the total dewatering process in this area.

After this successful conclusion, FS METEOR set course for the position >150 nm distant to the NW to recover the VESP-Lander on Culebra Mound which had been deployed there for 10 days. This transit was a welcome change from the continuous and very extensive work for the laboratory- and equipment groups. The VESP-Lander was successfully recovered on the evening of the 27th; all systems had functioned without problems. In the early morning hours of 28th of September, all science work had ended and FS METEOR set course for Caldera. At 1230 hrs. local time the pilot came aboard and shortly thereafter at 1300 hrs FS METEOR tied up at the pier in Caldera. Thereby Leg M54/3A came to a successful end, after 17 unusually productive days. A large number of samples, analyses, measurements, and observations were collected whose evaluation will bring us a good deal closer to the central goals of SFB 574.

SHORT CRUISE REPORT

R.V METEOR
Cruise No. M54, Leg 3B

Caldera (Costa Rica) - Willemstad (Curacao)

30.09.2002 – 11.10.2002

Chief Scientist: E. R. Flüh

R.V METEOR, Cruise No. M54, Leg 3B

Caldera (Costa Rica) - Willemstad (Curacao) 01.10.2002 – 11.10.2002

Report written by the Chief Scientist of the cruise: E. R. Flüh
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Cruise M 54, leg 3B of the research vessel METEOR started on 30. September 2002 at 04:30 p.m. when the vessel left the harbour of Caldera, Costa Rica. The multinational/ multi-institutional science team included researchers from GEOMAR, SFB 574 of CAU Kiel and ICE, San Jose, Costa Rica.

The working area of M54/3B was located on the Pacific margin of Costa Rica, where a 23 element seismological array was to be recovered, serviced and redeployed. In addition, a lander had to be recovered. During the transits to and from the working area, i.e. after leaving the three nm zone of Costa Rica and up to entering the shallow waters of Panama on 7 October, RV Meteor's Hydrosweep System was in continuous operation.

At 16:30 on September 30 METEOR left the port of Caldera and steamed towards the research area offshore Pacific Costa Rica, the Jaco Scar seismological network that was to be retrieved. This network comprised 23 ocean bottom stations which were deployed in May 2002 during cruise SO163-2 from RV SONNE (Weinrebe and Flueh, 2002). After maintenance, these stations were to be redeployed for another seismological network, the Quepos network to the southeast of Jaco Scar. When a waterdepth of 200 m was reached, the bathymetric data from the hydrosweep System were digitally recorded. The first instrument was reached after three hours transit, released and safely recovered at 20:30 on September 30. Subsequently, on average every two hours another instrument was recovered.
After the first ten instruments were picked up, the route was made such that five instruments (OBH301 to 305) were deployed in the Quepos network on October 01, before we continued to pick up further instruments from the Jaco network. Stations in shallow water were released using the ships hull transducer, while for instruments in deeper waters the ship stopped several miles ahead of the instrument and an active transducer was lowered on starbord side to send acoustic release commands. The operation went smoothly, and all stations responded almost instantaneously to the release commands.
On October 02 at 17:00 the VESP Lander, that was deployed during the previous leg from METEOR, was released and safely brought back to the ship. The remaining stations from the Jaco network were picked up and after service redeployed in the Quepos area. All except two stations recorded good data. One of the two tiltmeter stations was damaged, apparently a lithium battery had exploded during the recording period. Data recording had stopped on August 17, and the instrument could not be repaired on board for a redeployment.
After deployment of the last station (OBH323) station OBS305 was recovered to check the amplification of the seismometer. This station was placed at 1000 m waterdepth, and analysis of the data recorded in the first two days indicated that the amplification on the two horizontal components was rather high. This was changed to a lower gain and the instrument was redeployed. This terminated the planned work for this short leg, and since no problems were encountered, time was available for some bathymetric profiles to extend the coverage of high resolution bathymetry on the Pacific waters off Costa Rica. The main activity was centered on the northern end of the Panama fracture zone off the Burica Peninsula.

On October 05 at 18:00 METEOR left Costa Rican waters, and headed towards Balboa, Panama, for refuel and Panama canal passage. Some scientists left the vessel in Balboa. The canal passage was completed October 08 by 01:00, and the final destination of this cruise, Curacao, was reached October 10 at 23:00, where cruise M54 terminated.