During cruise M54/2 sedimentological and water column samples were taken for geochemical investigations along the Central American margin. In addition an extensive heat flow-measurement program was performed, to complement to the water and sediment data. The working area was located at the trench west of Nicaragua and spans approx. 500km to the southeast down to southern Costa Rica. The scientific work began in the northwest of the study area and was continued with stations to the southeast along the central American subduction zone the southern most locations being on the Cocos Ridge. The main areas from the northwest to the southeast were

1. Faulted outer-flexural bulge area off northern Nicaragua,
2. the area around Mound Culebra to the west of the northern Nicoya Peninsula,
3. the deep-sea slope and trench off western Nicoya,
4. the potential vent sites at Jaco Scarp,
5. Mound Quepos,
6. Mound 12
7. Mound 11
8. and the northern part of the Cocos Ridge.

RV Meteor departed from Caldera harbor on Aug. 13 for a 15h transit to the first working area, the faulted outer-flexural bulge. The faults occur mainly in the northern part of the Cocos Plate and are orientated parallel to the subduction trench. Seismic investigations indicate existence of echelon faults, ranging very deeply through the crust into the mantle. This could result in serpentinization along these faults through in-flowing seawater, which then causes a) the production of methane in great depths and b) heat release through an exothermal chemical reaction.

Within the first six days samples were taken and measurements performed at 15 stations in this area, among them 6 gravity cores (GC), most of them equipped with a Miniature Temperature Logger (MTL), 4 heat flow profiles (HF) and 4 conductivity-temperature-depth sensors (CTD). While the CTD measurements onboard Meteor didn't show the expected increase in methane concentration in the lower part of the water column, and hence no indication for venting in these areas, the HF profiles yielded very interesting results. The values were significantly lower than expected, which led to the conclusion, that the heat flow from the basin doesn't take place in a conductive way, but rather uses convection as a mechanism, which should result in an active fluid circulation pattern within the basaltic oceanic crust. This circulation might be driven by the retained heat of the 20 million year old crust, or by an exothermal chemical reaction due to serpentinization. However, active fluid venting could not yet be confirmed in this location.

In addition a GC profile was drilled off Nicaragua, recovering sediments from shelf, slope and trench areas. Within these sediments 12 different ash layers could be distinguished, allowing us to reconstruct the history of explosive volcanism in Nicaragua, one of the important goals of the SFB. Pore water examinations yielded insight into diagenetic processes taking place within the sediments. Sulfide and methane contents indicate a more intensive diagenesis in trench sediments, compared to slope or shelf sediments. Measurements of chloride and alkalinity showed an increased influence of freshwater at the base of the gravity cores, which could be due to groundwater outflow. In situ measurements done by American colleagues also point in this direction.

On Aug. 19 the ship left the area off northern Nicaragua and steamed south to Mound Culebra, a structure approximately 1,1km^2 in size. It lies in a water depth of about 1600m, where it stands up about 100m over the surrounding seafloor. The top of the mound is covered with carbonates. Based on the morphology Mound Culebra had previously been interpreted as a mud volcano, however investigations using the Ocean Floor Observation System (OFOS) during cruise Sonne 163 (SO163) revealed, that there was no indication for mudflows on the mound. The observations rather showed, that it is covered with the same terrigeneous sediments found on the surrounding seafloor. In addition various vent faunas like mussel banks were identified, which indicate outflow of methane- and sulfur-rich fluids. High methane concentrations measured in the bottom water supported this assumption.

The investigations performed by M54-2 between Aug. 19 and 22 were done to approve, whether Mound Culebra is indeed a mud volcano, or what other possibilities exist to describe the development of this seafloor feature. Altogether on Mound Culebra 11 gravity cores were recovered, as well as 3 CTD stations, 2 HF profiles and 1 multicorer (MUC). While the GC's at the base of the mound contained mainly homogeneous clays, the sediments at the flank and on the top were deformed showing signs of upward mudflow from the deep. Beneath a thin layer of clay, clasts of claystone and carbonate cemented claystone up to approx. 10 centimeters in diameter were found. Most of the clays were overconsolidated, indicating an origin from greater depth. An alternation of layers containing very few clasts in some places or very many clasts in others indicates, that mudflows added material to build up the mound. Many carbonate /marl layers of various thickness and clay content as well as small carbonate “chimneys” were found as well in sulfide and methane rich cores showing evidence for high diagenetic rates in these muds. Since the sediment cover on the summit is only approximately 40 cm thick, it can be estimated, that the mud volcano has ceased to deliver mud from the deep, but is merely releasing fluids and gas to the surrounding environment for the last few thousand years.

With the exception of one station the porewater data shows, that the muds at Mound Culebra contain water carrying a signature very similar to that of the seawater. Only in one location at the summit an increased sulfur and methane concentration could be measured, however nutrients were still very low. This is probably due to methane in a gas phase being delivered to the top, while the nutrient enriched fluids stay in greater depths.

The heat flow measurements on Mound Culebra show a similar picture, with values significantly lower than the general background. Slightly higher values were only obtained from stations at the foot and the lower part of the slope. This could mean that a continuous flow of sea water goes through the whole top of Mound Culebra while salt depleted warmer fluids are escaping from the lower regions. The heat flow measurements at the location showing higher methane and sulfur concentrations had an exceptional form in that it had a clearly visible peak on the surface of the seafloor, decreasing to a minimum at approx. 1m depth. This could be due to heat produced by microbial activity oxidizing sulfide and methane.

Methane measurements in the water column at Mound Culebra confirmed, that much methane is discharged into the bottom water at this site. In contrast to measurements performed during SO163 the methane content varied dramatically within relatively small depth ranges.

We continued sampling at the western Nicoya continental slope and trench from Aug 21-24, where numerous HF profiles were measured and 6 GC’s and 1 MUC taken. The heat flow profiles are in the north offshore Nicaragua as well as further south in the working areas of ODP legs 170 and 205. The results of the northern profiles show a good consistency with the models for conductive heat transport calculated for the subducted plate, while the southern profiles showed far too low values. In the northern areas approx. 90-120 mW/m^2 were measured over the subducted plate and approx. 40 mW/m^2 over the continental margin, while the values in the south were only 10 mW/m^2 and 20 mW/m^2 accordingly. Since the distance between the profiles is only about 20 nm, it may be speculated, that lateral fluid flow within the subducting plate accounts for the reduced heat flow in the southern profiles.

From Aug. 24 to 28 extensive sampling was done at Jaco Scar, interrupted by nighttime shifts of heat flow profiles on the Costa Rica continental margin. Jaco Scar is a very interesting feature located in approx. 800-2400 m water depth on the continental margin off Costa Rica. It's a scarp scratched into the uplifted continental plate caused by a subducted seamount. This results in a mound on the continental side and a very steep slope on the oceanic side of the margin where blocks of sediment slide downward as the seamount carves into the overlying plate. Due to the high pressures involved as well as the intense faulting in this area highly active venting can be expected. Indeed the methane concentrations at the crest are many magnitudes higher than the background value and actually much higher than anywhere else in Central America.

The very intensive measurements in the water column in this location allowed us to precisely locate the depth horizons at the slope releasing methane into the seawater, however we were unsuccessful obtaining sediments and fluids from those areas. Several tries to recover sediments with gravity corers yielded only few relatively hard claystones without cutting through into deeper layers. Deployments were more successful on the top of the feature, where methane- and sulfide-rich sediments could be recovered as well as very much nutrient depleted, indicating a similar dilution mechanism like on Mound Culebra. The observed heat flow pattern showed lateral changes in the faulted zones on the top of Jaco Scarp, probably influenced by fluid flow in this area.

On Aug 29. the ship moved south to Mound Quepos, where several GC, MUC and CTD stations were visited during daytime until Aug. 31, while heat flow profiles were still measured during the nightshifts. Mound Quepos is a very small structure in approx. 1400m water depth, only 200m in diameter and about 40 m high. During SO163 widespread venting was observed on this location. During this cruise we were unsuccessful to push through the massive carbonate layers covering the known active venting areas on the summit of Mound Quepos. In the marginal areas several cores were taken, containing anoxic H_2S-rich sediments. The bottom water did contain an increased amount of methane, documenting the still active venting. In addition it was possible to demonstrate a clear decrease in chloride in a gravity core from the top to the bottom. The detailed analysis of the recovered salt-depleted fluids will surely help to determine the origin of these waters, and whether they are actually originating from the sediments of the subducted plate. We didn't find any indication for active mud flows, hence it is still uncertain, whether Mound Quepos is actually a mud volcano, like Mound Culebra, or built up by other processes.

The heat flow measurements in the vicinity of Mound Quepos revealed a major thermal anomaly with values approx. 4 times higher than expected. The anomaly could be traced down into the deep sea trench. It indicates, that the increased heat flow could be influenced by fluids ascending originating from the subduction zone.

The cruise continued with a short transit to the southwest, where two small submarine mounds labeled 11 and 12 were sampled from Sept. 1 until Sept. 5, again interrupted by several heat flow profiles off the Costa Rica Margin and trench, as well as 4 stations at the Quepos slide. Similar to Mount Quepos, Mounds 11 and 12 are two small submarine features which are only 1 km away from each other. They lie in about 1000m waterdepth off the Costa Rica coast. Each of these mounds is about 100 m in diameter and 40m high. Cruise SO163 detected rich vent faunas and carbonates on these mounds, indicating active discharge of fluids into the ocean.

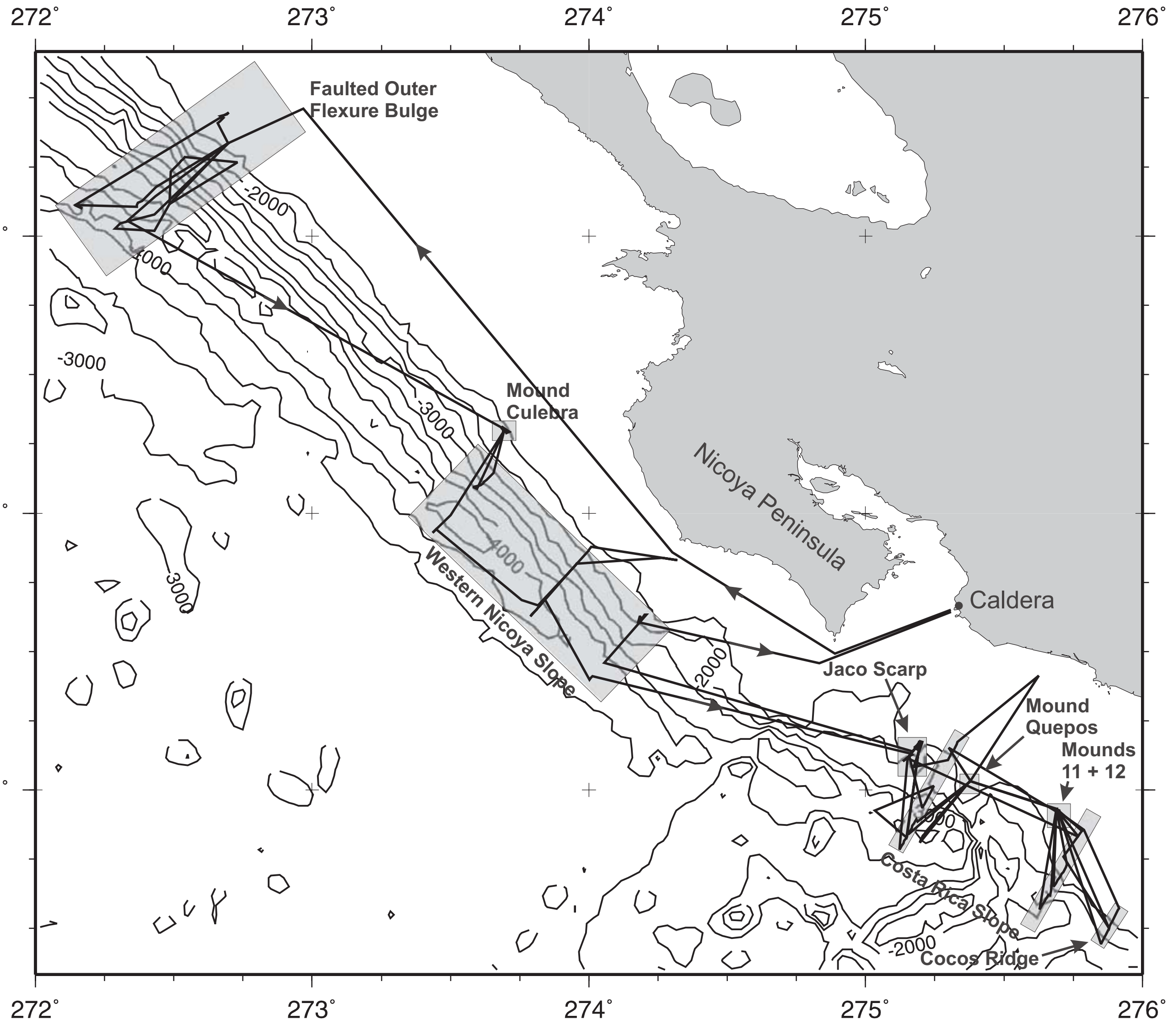
At Mound 12 eleven stations were visited for gravity coring, of which seven yielded excellent sediment cores. Many of the sediments had chaotic structures and big clasts of scaly clays were evidences for active mud volcanism. In one of the sediment cores the salinity dropped significantly with depth to values of about 360mM chloride, which is about 40% lower than that of the surrounding seawater. The high freshwater content could be an indicator for the very deep source of the uprising fluids, which originates from diagenetic and metamorphic processes of the subducted sediments. It is very likely that our isotope studies will shed more light on the precise source of these waters.

Mound 11 was a central area for the heat flow investigations. A 16 station 2-D grid was lain out and measured, to gain a full 3-D picture of the heat flow from Mound 11. The picture showed a maximum within an oblonged area stretching through the middle of the mound.

Hence the last gravity core from the cruise was decided to be taken from this area hoping to find an area of uprising fluids. With great excitement and surprise we discovered, that in depths below 2m this core was filled with large chunks of massive gas hydrate, several centimeters in size. Indeed the sediment there was embedded within a matrix of gas hydrate, while the upper layers contained the same muds found elsewhere, with very low salinity pore waters. Hence Mound 11 can be regarded as a mud volcano, delivering methane saturated fluids from the very deep parts of the subduction zone to the surface, resulting in gas hydrate formation at the sediment/water boundary. The presence of gas hydrates indicates a very high methane delivery rate to prevent sulfur reducing microorganisms to oxidize the methane before it forms hydrate. This peculiar feature made Mound 11 a spectacular and unique site during our cruise ensuring that further investigations will be performed here by later cruises.

On Sept. 5 and 6 the cruise continued to the southernmost region on the Cocos Ridge, to measure 2 heat flow profiles. The profiles measured yielded an extremely high temperature gradient of approx. 1000 °C/km, leading to the assumption, that warm hydrothermal fluids circulating through the crust are massively releasing heat to the ocean in this area.

Finally on Sept 6, the ship steamed north to visit the last stations at Jaco Scar again, to measure a heat flow profile and to allow the rest of the party to pack up containers, laboratories and prepare for departure in Caldera harbor. Caldera was reached on schedule on the morning of Sept. 7, where most of the scientific party left the ship to make room for many of the already waiting participants of the following leg M54-3a. A very successful cruise came to an end, blessed by very good weather conditions, excellently working equipment and an exceptional hard working crew and scientific party who was rewarded with many truly extraordinary and thrilling scientific results.



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