Abschlußbericht

für das Projekt

SEAMOUNTFLUX

Effiziente Abkühlung junger ozeanischer Kruste durch Zirkulation von Meerwasser durch Seamounts (Guatemala Becken, Ostpazifik)

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Prof. Dr. H. Villinger

Prof. Dr. T. Pichler

Fachbereich Geowissenschaften

Universität Bremen

Bremen

1.0 Scientific Background and goal of the project

The scientific goal of the project "SeamountFlux" was to investigate the exchange of matter and energy between the ocean and the upper lithosphere in the vicinity of unexplained circular depressions in the sediment cover of the Cocos Plate (see Figure 1), previously already described in the literature. Bekins et al. (2007) hypothesize that these 'hydrothermal pits' are possibly responsible for the plate-wide cooling of the oceanic crust of the Cocos Plate. They presented a possible model how these pits are formed: warm, diffuse outflow of hydrothermal fluids within the pits dissolve the calcium carbonate ($CaCO_3$) minerals in the sedimentary cover and create hereby the depressions observed in the bathymetry. The discharging warm fluid is probably entering the upper crust at seamounts, heats up and escapes at the pits. If such a process is going over geological time scales it will affect the thermal structure in and around the pits as well as the geochemistry of the pore water inside the pits. The goal of the investigation was to test this hypothesis by mapping the pits acoustically (swath bathymetry, Parasound sediment echo sounding and reflection seismic), measure heat flow inside and outside of pits and collect pore water from sediment cores also from inside and outside of the pits.

2. Sequence of activities within the project

2.1 Scientific work during expedition SO207

Ms. Schmidt-Schierhorn (MSc Marine Geosciences) and Mr. Becke (Dipl. Geol.) were contracted at the beginning of the project to start with the preparations for expedition SO207. This included technical preparation such as collecting relevant data and publications. A summary of published papers on the working area and the scientific background of the cruise were handed out to all cruise participants. Maps and seismic profiles of the working areas were printed out to serve as a working base on board.

Expedition SO207 took place from 21st of June to 13th of July 2010, approximately 360 nautical miles off Costa Rica (East Pacific, ca. 8°N and 90°W). Figure 1 shows the location of the working area. On board of the German research vessel SONNE were scientists from the University of Bremen and one Scientist from the University of Bern.

During cruise SO207 we mapped the pits in three working areas (Figure 1 Figure 1 and Figure 2) with acoustical methods (bathymetry, sediment echo sounding and single channel seismic). Seismic lines crossed ODP/IODP sites 844 and 1256 in order to calibrate the seismic records and to correlate prominent reflectors with dated horizons in the boreholes. Heat flow measurements were always done on seismic lines to allow later the calculation of basement temperatures. Gravity cores provided the samples for pore water and sedimentary analysis.

Seismic profiles (Figure 2) with an overall length of 400 km and more than 5600 km² of obtained bathymetry data provide detailed acoustical surveys of the pits and their surroundings. The acoustic mapping showed that most hydrothermal pits are about 100 to 150 m deep with a diameter of about 1 km. Heat flow measurements (140 in total on 9 profiles) around seamounts confirm that they act as pathways for cold seawater which leads to a large cooling effect in the vicinity of the seamount where heat flow values as low as 10 mW/m^2 were measured. All heat flow values inside the pits show values up to five times higher than background values around the pits.

Sediment was collected with a gravity corer with a total recovery of 191 m. From these cores we extracted 451 pore water samples which were analyzed in Bremen.

Overall, the cruise was extremely successful as we got the data needed to support or reject the scientific hypothesis and to investigate the role of the hydrothermal pits.

Directly after coming back from the expedition, the cruise report was prepared and printed in mid-October 2010. It contains all detailed information with respect to location of profiles, location of gravity cores and location of heat flow measurements. All measured data was given to Dr. Grobe (Alfred-Wegener-Institut für Polarforschung, Bremerhaven) for adding it to the database Pangaea.

2.2 Processing and interpretation of the collected data

3.0 Results

In the following we will summarize the main results of the geophysical and the sedimentological and geochemical investigations and discuss the main results of the three working areas. Additional figures and tables can be found in the two appendices, one for Sediments and Pore Water (abbreviated as Appendix SPW) and the other one for Geophysics (abbreviated as Appendix G).

3.1 Geophysics

3.1.1 Processing of geophysical data

After finishing the cruise report, the geophysical data were processed in detail. This included the following:

- Bathymetry
  - Clearing up the raw data
  - Generate consistent maps for each working area
  - Generate detailed maps for specific regions
- Parasound
  - Re-play all Parasound profiles
  - Generate maps with Parasound profiles and navigational information
- Seismic
  - Draw up geometry and calculate shot point navigation
  - Determine ideal filter parameters
  - Stacking of CDPs
  - Migration
  - Generate maps with seismic profiles and shot point navigation
  - Calculate sediment thickness with data from next ODP site and draw result in a map
- Heat flow measurements
  - Consistent post processing of all heat flow measurements
  - Combining seismic sections with heat flow profiles.

- Calculate temperature at the sediment-basement boundary based on measured heat flow and sediment thickness.

3.1.2 Results of the geophysical survey

Summary of the most important results:

- Hydrothermal pits are easily identifiable in the detailed bathymetry. Most of them have a depth between 50 and 100 m and a diameter of about one kilometer.
- The seismic profiles show that the sediment thickness is significantly smaller inside the pits than in the surrounding area. The reason for this is a slight basement elevation inside the pits but obviously also a missing sediment section, compared to the sediment section outside of the pits.
- The well layered sedimentary structure outside of the pits is highly disrupted inside the pits. Therefore a direct correlation of layers inside and outside is difficult if not impossible.
- Sediment thickness was calculated on all seismic profiles calibrated with core data from ODP site 844 in WA 1 and ODP site 1256 in WA 3.
- Heat flow measurements inside the pits show values which are up to 5 times higher than the surrounding values outside the pits. This increase is not fully explainable by the smaller amount of sediment lying in the depressions.
- All heat flow measurements in the vicinity of seamounts show low values of even less than 10 mW/m². These results support the hypothesis that cold seawater enters the upper crust through permeable seamounts and hereby cools down the surrounding of the seamount up to distances of 10 km or more. This large-scale cooled down zone suggests a strong and efficient circulation system which had been active over possibly millions of years.
- Calculated basement temperatures based on measured heat flow show that temperature at the sediment-basement boundary is not isothermal, which is a strong indication that the circulation in the upper crust cannot be very vigorous.

3.1.2.1 Working area 1

We surveyed WA 1 with bathymetry, seismics and sediment echosounding (Parasound) on twelve profiles (see profiles in the Appendix G). In the southern part of WA 1, there is a high seamount of about 400 m height just about 10 km south of ODP site 844. A series of hydrothermal pits is clearly visible in the bathymetry and on seismic profile ‘a’ (see Figure 7). Three heat flow profiles complete the measurements. Profile ‘a’ and ‘b’ cross over the largest pit in the working areas (see detailed map in Figure 29), while Profile ‘c’ is measured towards the seamount. Figure 3 to Figure 8 show the results from WA 1.

Profile ‘a’ (see Figure 3) and ‘c’ show significantly higher heat flow in within the hydrothermal pit. Profile ‘c’ starting at ODP site 844 and runs towards the seamount shows extremely low heat flow an indication that the seamount acts as recharge site.

A detailed look at the sedimentary structure inside the largest pit in all three working areas (Figure 5 and Figure 6; called The Pit in the following) shows that the upper sediment layer of about 50 to 60 m is continuous across the pit but underneath this top layer the layering is very