SUBMERSIBLE STUDIES OF HYDROTHERMAL ACTIVITY IN BACK-ARC BASINS

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Many back-arc basins are thought to be formed by seafloor spreading similar to that at midocean ridges. Thus, it is expected that hydrothermal circulation is occurring in young back-arc basins as in midocean ridge areas. At the axial parts of midocean ridges, venting of high-temperature fluid was discovered through submersible observation. Detailed heat flow mapping with reference to sea floor structure was also made using submersibles on the midocean ridge flanks. We made geothermal studies with submersibles in two young and active back-arc basins, the Mariana Trough and the Okinawa Trough.

Mariana Trough

The Mariana Trough is the most well investigated active back-arc basin. Geophysical data and DSDP drilling results showed that the spreading started about 6 m.y.b.p. and has continued to the present (e.g. Hussong and Uyeda, 1981). Extensive heat flow measurements using multiple-penetration type probes were made in the off-axis "Mariana Mounds area" at around 18°02'N, 144°17'E with an age of 3 m.y. (Figure 1). The highest value reached about 2000 mW/m^2 and the average was much lower than the theoretical heat flow estimated from the crustal age (Hobart et al., 1983). Such high and variable heat flow, as well as non-linear temperature versus depth profiles in sediment, indicates the existence of hydrothermal circulation.

It is probable that pattern and velocity of such hydrothermal circulation is not temporally stable, though it is difficult to estimate the time scale of variation. Actually, strangely bent temperature profiles observed in this area might result from non-steady-state heat transfer as well as lateral water flow. To investigate possible time variation, we have developed a deep sea long-term temperature monitoring system, modifying a multi-sensor long-term underground temperature recording system which has been used for heat flow measurements on land (Nagao and Uyeda, 1988). It can record temperatures at up to 94 points at a preset time interval in a solid state memory. The system is freely dropped from the surface ship, transported on the seafloor and deployed by a submersible, and retrieved using an acoustic command based pop-up mechanism.

We tested this system when we participated in dive studies with the submersible ALVIN in the Mariana Mounds area in June, 1987. In this experiment, eleven temperature sensors were installed in three 1 m long probes and one sensor was used for monitoring the bottom water temperature. The most significant morphological features found through the ALVIN dives were many small sediment mounds (1 to 2 m high) associated with high heat flow anomalies (Leinen et al., 1987). We set the temperature monitoring system close to one of the high heat flow mound and inserted the probes into the mound, about 5 m apart from the mound, and about 20 m apart from the mound. Temperature was measured every one hour for ten days and the system was successfully retrieved.

Figure 2 shows the time variation of temperatures in the probe inserted into the mound. The temperatures of the lower two sensors gradually decreased with time. It might represent a natural variation of the hydrothermal circulation pattern. It is also possible, however, that insertion of the probe affected the circulation and the effect decayed with time. We need measurements for a longer period to examine various possible causes. In the last part of measurement, a sudden increase in temperature of the lowermost sensor was observed. Temperatures measured with the other probes were very stable for ten days.

From the temperatures recorded just before the retrieval, geothermal gradients on the mound, 5 m from the mound, and 20 m from the mound are calculated to be about 3.7 K/m, 1.2 K/m, and 0.3 K/m respectively. Hence, heat flow is very high on the mound and rapidly decreases with increasing distance from the mound, which is consistent with the results obtained for other mounds with the ALVIN heat flow probe. Such a large horizontal variation indicates that the high heat flow on the mound is supported by advective heat transfer with upward pore-water movement.

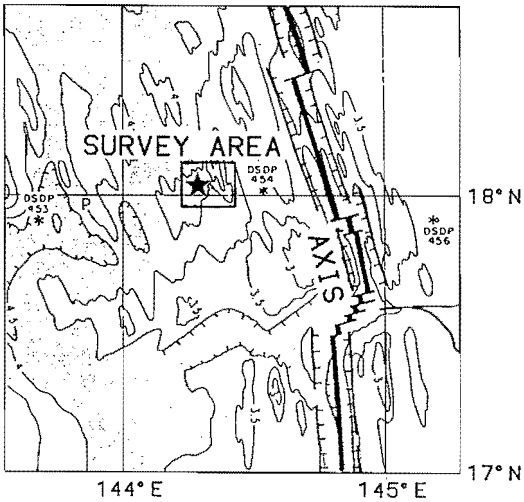

Figure 1
Mariana Mounds area surveyed with the submersible ALVIN. Star represents the station where the long-term temperature monitoring system was deployed.

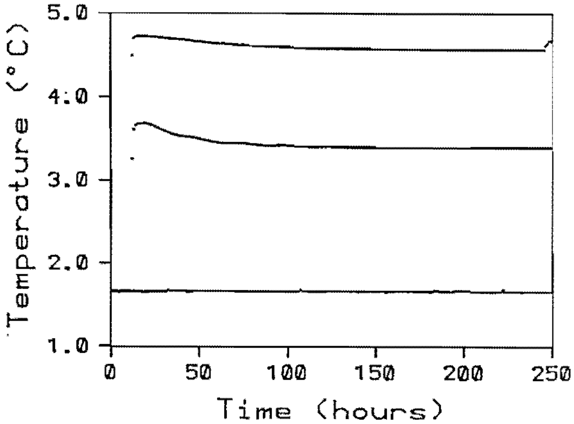

Figure 2
Temperature records obtained by the probe penetrated into the mound. The uppermost sensor was in water.

Okinawa Trough

The Okinawa Trough is also an active back-arc basin under extensional tectonics. There is, however, no clear evidence for seafloor spreading and the trough is thought to be in a very incipient stage of back-arc spreading or rifting of continental lithosphere (e.g. Sibuet et al., 1987). Geophysical and geological surveys made in 1984 revealed the existence of recent or present volcanic activity at the axis of the middle Okinawa Trough (Japanese DELP Research Group on Back-arc Basins, 1986). Anomalously high and variable heat flow, 600 ± 400 mW/m^2, was observed in a small basin in the central rift (Figure 3; Yamano et al., 1986), indicating that hydrothermal circulation is occurring in this area.

Dive studies with the Japanese submersible "SHINKAI 2000" have been carried out in this area since 1984. To investigate hydrothermal activity, we manufactured a 40 cm long probe with two thermistor sensors at an interval of 25 cm. Temperature was measured and recorded using commercial instruments with resolution of 1/100 °C.

In 1986, hydrothermal mounds were discovered on a small knoll just south of the high heat flow basin at 27°34.4'N, 127°08.6'E (Figure 4; Kimura et al., 1988). Shimmering water was observed at several places on the largest mound which is 5 to 6 m high and 15 to 25 m wide. Temperature of the shimmering water was 6 to 7 °C, only 2 to 3 °C higher than the ambient bottom water temperature. Temperature measured by the probe inserted into the mound was much higher and ranged from 20 to 50 °C.

The probe was penetrated into normal sediment about 3 m apart from the foot of the mound. The obtained geothermal gradient was 16 K/m. Assuming that thermal conductivity of the sediment is 0.7 W/m K, heat flow amounts to about 11 mW/m^2.

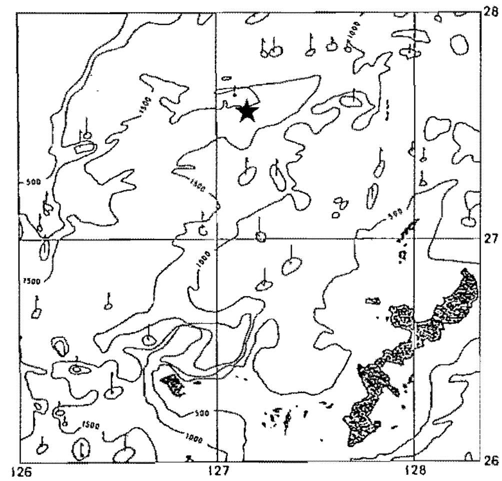

Figure 3
Location of the small basin in the middle Okinawa Trough where extremely high and variable heat flow was observed (star).

Several smaller hydrothermal mounds were observed around the active mound, though ejection of water was not seen on them. Temperature gradient measured near one of these mounds was also high, about 8 K/m. In contrast, temperature gradient was lower than 100 mK/m at a station only 200 m apart from the hydrothermal mounds (Figure 4). These results suggest that hydrothermal activity on this knoll was rather confined in a small area.

We are planning to deploy the long-term temperature monitoring system in the middle Okinawa Trough using "SHINKAI 2000" in September, 1988. Temperature variation will be recorded for about one year.

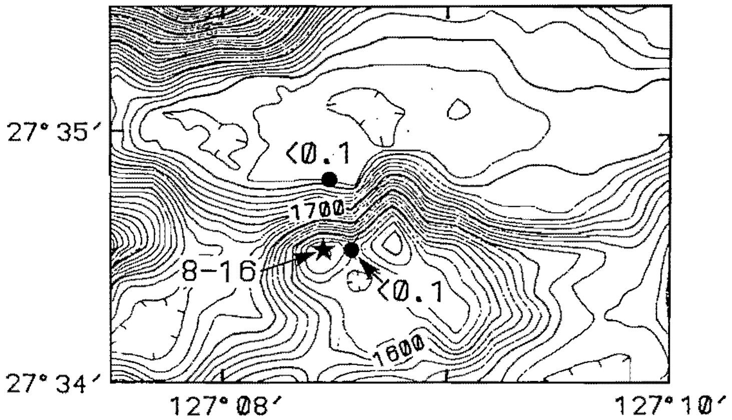

Figure 4 Seabeam bathymetry map around the hydrothermal mound constructed by Hydrographic Department of the Maritime Safety Agency, Japan (contour interval is 10 m) and temperature gradient measured with the submersible "SHINKAI 2000" (in K/m). Star is the location of hydrothermal mounds.

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