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Heat flow measurement in shallow seas through long-term temperature monitoring

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Terrestrial heat flow is a product of the temperature gradient and the thermal conductivity. In deep-sea areas where the bottom water temperature is stable, the temperature gradient is measured by penetrating a several meters long probe with multi temperature sensors into sea floor sediment. In shallow-sea areas, the sub-bottom temperature profile may be significantly affected by the bottom water temperature variation (BTV), which makes it difficult to determine the temperature gradient by the conventional method for deep-sea measurements. As a result, few heat flow data have been obtained in shallow seas.

We may be able to remove the effect of BTV for determining the heat flow in shallow seas, using a long-term record of the temperature profile in surface sediment and the bottom water temperature. Pop-up type long-term temperature monitoring instruments have been developed for this purpose (Matsubayashi and Yamano, 2001) and we could obtain temperature data at four stations with water depths from 1040 to 2026 m landward of the Nankai Trough, including the longest record for 223 days at a station off Kochi with a water depth of 1040 m (Hamamoto et al., 2001 Japan Earth Planet. Sci. Joint Meeting). At other three stations, sub-bottom temperature data for 30 to 96 days and bottom water temperature data for 155 to 238 days were obtained.

We calculated the effect of the observed BTV at the four stations and estimated what temperature gradient values would be measured with a conventional deep-sea temperature probe. The results indicate that we need at least 4 to 5 m penetration to determine the reliable temperature gradient at all the stations. However, it is usually difficult to attain such large penetration and long-term temperature monitoring is necessary for heat flow measurement in the studied area if the water depth is shallower than about 2000 m. We also examined how the temperature variation propagated through sediments based on the sub-bottom temperature data. At the 1040-m station off Kochi, it was found that the temperature variation recorded by each sensor originated from the BTV and the heat transfer between the sensors was purely conductive. At other stations, however, similar analyses could not be made since the temperature profiles were significantly disturbed by the BTV before the measurement periods.

The data at the 1040 m station were then analyzed for heat flow determination. We estimated the effective thermal diffusivity between the topmost sensor and other sensors and corrected for the effect of BTV on the temperature of each sensor. Using the average of the corrected temperature, the undisturbed temperature gradient is determined to be 55 +- 3 mK/m. The thermal conductivity measured on a core sample from a nearby station is 0.94 +- ? W/m/K and the heat flow is calculated to be 52 +- 5 mW/m^2. This value is consistent with the heat flow estimated from the depth of gas hydrate BSR (bottom simulating reflector) in the vicinity of this station, 53 mW/m^2 (Ashi et al., 1999), though BSR heat flow may have an error of 10 to 20 %.

This result at the 1040 m station demonstrate that we can remove the effect of BTV and determine the heat flow in shallow-sea areas through long-term temperature monitoring with a pop-up type instrument, while the temperature records for up to 96 days at the other stations were not long enough for heat flow determination. We are improving the analysis method so that we can use information on the BTV before the measurement period contained in the initial part of the sub-bottom temperature record. It may allow us to take account of components of the BTV with lower frequencies and to obtain heat flow values from shorter temperature data.

We will also report on new data obtained with a pop-up type instrument at a station in Kumano Trough with a water depth of 2081 m (from August 2001 to February 2002).