Heat flow distribution of Kumano Knoll No.4, Kumano Basin

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Mud volcano is a surface expression of mud diapir, which over-pressured unconsolidated sediment has been intruded into the overlying sediment column. There are many mud volcanoes in subduction zones over the world. Mud diapir is important in material transport in subduction zones. Mud volcano provides information on the process of material transport and physical and chemical conditions in a deeper part without a deep drilling.

Kumano Knoll No.4 (KK4) is one of the mud volcanoes in the Kumano Basin, where several mud volcanoes were found by side-scan sonar survey and deep-tow survey in the Kumano Basin east of Kii Peninsula [Kuramoto et al., 1998; Ashi et al., 2003]. The diameter and height above the basin floor are 800 m and 100 m, respectively. The summit area has bumpy surface with pits whose diameter are several meters. There are living and dead clam colonies in the area.

In order to survey thermal and hydrological characteristics of KK4, we deployed a long-term temperature monitoring system (LTMS) at the top of the mud volcano on August 9, 2002. This system is composed of a stainless frame, a titanium pressure case containing a data-logger and battery, and two probes (760 mm in length and 13.8 mm in diameter). Each probe contains six thermistors at intervals of 10 cm. One probe (Probe-2) was penetrated into sediment within a pit with a dead clam colony that suggests the existence of cold seepage in the past. The other (Probe-1) was installed in the outside of the pit where there was no expression of cold seepage. LTMS was recovered on May 28, 2003.

It is well known that in Kumano Basin, there is bottom-water temperature variation (BTV) of various periods with large amplitude [Hamamoto et al, 2005]. Measured bottom-water temperature shows long-period variation with short-period variation. As a result of Fourier analysis, the predominant periods of BTV measured in this study are 48.5 days, 9.4 days, 29.7 hours and 12.3 hours. Measured sub-bottom temperatures show similar variation to the bottom-water temperature variation but its amplitudes decay and the phases delay with increasing sub-bottom depth. By comparing amplitude and phase of BTV and sub-bottom temperature variation, we can identify whether there is vertical fluid migration in sediment [Goto et al, 2005]. For sub-bottom temperatures measured in the outside of the pit, we could explain that the effects of BTV propagated into sediment by conduction only. By correcting the effects of BTV from the sub-bottom temperatures, we estimated heat flow value as 14 mW/m^2. On the other hand, sub-bottom temperatures measured within the pit could be better explained by a model with upward water flow at a rate of 10^{-7} m/s order, than by conduction only. Heat flow combined conduction and this upward water flow was estimated as 60 mW/m^2, about four times the heat flow values in the outside of the pit. Our results indicate that there was cold seepage activity in KK4.

We conducted 11 heat flow measurements with two small heat flow probes 60 cm in length (SAHF) along a survey line from west to east just before the recovery of LTMS. Using bottom-water temperature data measured with LTMS, we removed the effects of BTV from temperature profiles measured with SAHF. The cross-section of corrected heat flow values indicates three characteristics: (1) high heat flow values higher than 70 mW/m^2 was measured on the base of the mud volcano, (2) low heat flow values (20-30 mW/m^2) were measured on the western slope, and (3) heat flow increases to ˜60 mW/m^2 on the top of the mud volcano. Preliminary analysis by numerical computation indicates that to interpret this heat flow distribution, we need consider not only advective heat supply to KK4 but also topographic effects of KK4 on the subsurface thermal structure.