Notes on the possible uncertainties in heat flow estimation from BSR depths

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The Hyuga-nada is the site of the subduction of Kyushu-Palau Ridge. We proposed a scientific ocean drilling to clarify the relationship between the subduction of seamounts and the slow earthquakes. Also, in order to estimate the temperature and hydrological state, which play an important role for characterization of the seismogenic zone, we measure and analyze the heat flow through the seafloor. Heat flow can be estimated from the depth to the BSR (several hundred meters below the seafloor) obtained from the seismic reflection data. This method can obtain continuous values along seismic lines and can grasp the heat flow from depth without being affected by seafloor topography and bottom water temperature fluctuations. Seismic structure surveys have been conducted off the Hyuga-nada offshore Kyushu, and new heat flow data have been obtained along the BSR. In this study, the uncertainty of the heat flow estimated from the BSR was investigated.
Assuming a one-dimensional, steady-state heat conduction state, heat flux (Q) is constant regardless of depth. It can be calculated from the BSR depth (z), the temperature T(z) and the thermal resistance (obtained from the thermal conductivity). If the thermal conductivity can be taken as constant l independent of depth, it can be simply calculated as Q=l(T(z)-T(0)). Where there are drilling expeditions, the measured thermal conductivity and P-wave velocity are related to each other, and the P-wave velocity model from the seismic survey can be converted to thermal conductivity to determine the heat flow. T(z) can be estimated from the BSR phase equilibrium curve determined experimentally (Maekawa et al., 1995) if the BSR depth is known. The uncertainty of the BSR depth depends on the velocity model estimated in the seismic data processing; in this study, we simply evaluate it as the deviation of the BSR depth near the intersection of two intersecting survey lines. We found that the difference in BSR depth between the crossing lines was up to 20%, partly because BSRs were not necessarily located close enough to each other.
Since there is no drilling in the Hyuga-nada, thermal conductivity was estimated from the velocity model obtained from the seismic survey line (HYU01) conducted in 2020. P-wave velocities were first converted to porosity using the equations of Erickson and Jarrard (1998) and Hoffman and Tobin (2004), and then converted to thermal conductivity from porosity and thermal conductivity of the solid part (2.7 W/m/K in this case), using a geometric mean model that represents well the thermal conductivity of sediments (A). Since different velocity models are used for other survey lines, or velocity model is not available, we used the average thermal conductivity from the seafloor to the BSR depth obtained from the HYU01 survey line (B, here we used 1.3 W/m/K). A comparison of the heat flow using the method A and B along HYU01 shows a difference of up to 5 mW/m^2 (~10%). The average thermal conductivity was greater than 1.3 at the low heat flow locations due to the deeper BSR, making the B results underestimate (up to 5%), but conversely overestimate (up to 10%) at the high heat flow locations. This level of uncertainty was found to be comparable to the uncertainty in converting P-wave velocity to porosity in method A.
If drilling data (thermal conductivity, P-wave velocity, porosity) and seismic structure data (velocity model) are available, it is useful to make full use of them to minimize uncertainties of heat flow. In the absence of drilling data, we assess that the overall uncertainty increase trough using the average conductivity, but not significantly because the conversion from Vp to conductivity also has a large uncertainty.

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