Local heat flow variations seaward of the Japan Trench: Implications for development of fractures in the oceanic crust

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Anomalous heat flow values, higher than that expected for the seafloor age, are pervasively observed on the seaward side of the Japan Trench (Yamano et al., 2014). Appreciably high values were obtained within about 150 km of the trench axis, indicating that the anomaly is related to deformation of the incoming Pacific plate associated with subduction. The broad high heat flow zone seaward of the trench can be attributed to efficient vertical heat transport by pore fluid circulation in a permeable layer in the oceanic crust which thickens toward the trench through fracturing due to plate bending (Kawada et al., 2014). Overlapping the broad anomaly, local variations at a scale of a few kilometers were detected through concentrated measurements at some sites. Such short-wavelength anomalies cannot have their origin deep in the plate and may arise from heterogeneity of the oceanic crust.
For investigation of the nature and the origin of the local anomalies, we conducted dense heat flow surveys around 39°N in 2014 and 2015. Most of the measurements were made along an E-W pre-existing multichannel seismic survey line (JAMSTEC SR101), perpendicular to the trench. A detailed heat flow profile was obtained around 60 to 80 km from the trench axis, in the region where immature horst and graben structures are found with no significant surface displacement. Heat flow values along this 20 km transect range from 60 to 110 mW/m^2 and show prominent sawtooth-like variations at a scale of 3 to 5 km. Heat flow variation in the N-S direction, parallel to the trench, was also examined by closely-spaced measurements along a short line crossing the E-W transect at one of the heat flow peaks. The values obtained along the 5 km N-S line has a very high average, about 100 mW/m^2, with a lateral variation as large as the variations along the E-W line. It suggests that high anomalies in this region have elongated shapes extending in the direction parallel to the trench.
The local heat flow variations may have resulted from heterogeneous development of fractures in the oceanic crust. We conducted numerical modeling of heat transport by pore fluid circulation and found that local development of fractures, i.e. sharp lateral variation in the thickness of the permeable layer, would yield heat flow anomalies at the scale of km, with elevated heat flow above more developed fractures. The observed heat flow distribution may therefore indicate that there exist a series of N-S extending well-fractured zones with spacing of several km. Two-dimensional survey of the heat flow distribution on the outer rise would provide information on fracturing process in the oceanic crust.

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