Fluid circulation and heat transport in fractured oceanic crust in the Japan and Kuril trench outer rise regions

*Kouta Sasaki[1], Makoto Yamano[1], Yoshifumi Kawada[2]

1. Earthquake Research Institute, the University of Tokyo, 2. International Research Institute of Disaster Science, Tohoku University

Prominent high heat flow values, higher than that expected for the seafloor age, are pervasively distributed in the outer rise region of the Japan Trench. Overlapping the broad high anomaly, local steep variations at a scale of several kilometers were observed. By contrast, most of the heat flow values measured on the outer rise of the Kuril Trench were normal for the seafloor age (Sasaki et al., JpGU Meeting 2019). Anomaly in the seismic velocity structure of oceanic crust (high Vp/Vs anomaly) was also detected off both trenches. The velocity anomaly indicates high water content in the crust probably due to fracture development associated with bending of the incoming plate. The observed heat flow anomalies may also result from fracturing of the crust, which leads to increase in permeability and allows pore fluid circulation. We examined fluid flow and heat transport processes in fractured oceanic crust through numerical modeling in order to elucidate the relationship between surface heat flow and permeability structure.

The broad high heat flow anomaly observed off the Japan Trench can be attributed to thickening of a permeable layer (aquifer) in the oceanic crust toward the trench (Kawada et al., 2014). The seismic velocity anomaly is reported to be more significant off the Japan Trench than off the Kuril Trench (Fujie et al., 2018). It suggests that the permeability structure of the oceanic crust may be different between the two trenches. We conducted numerical simulations of fluid flow and heat transport for gradual aquifer thickening with various permeability structures. Modeling results for the aquifer with uniform permeability show that a broad high heat flow zone is formed only when the permeability exceeds a certain critical value. In cases where the aquifer permeability decreases with depth, the deeper the high permeability part extends, the more heat fluid circulation pumps up and the broader the high heat flow zone is.

Local heat flow variations are inferred to originate from the heterogeneity in crustal structure or fracturing process. Surface heat flow should increase above a local high-permeability zone formed by intensive fracturing, in which vigorous fluid circulation occurs. Numerical simulations were conducted assuming abrupt development of local high-permeability zones with various shapes and distributions. We found that high-permeability zones with widths of tens to hundreds of meters may yield surface heat flow anomalies extending over several kilometers and narrow high-permeability zones do not necessarily produce high heat flow anomalies.

The results of numerical modeling suggest that higher average heat flow off the Japan Trench than off the Kuril Trench may reflect higher permeability of oceanic crust in the Japan Trench outer rise region. Local heat flow variations indicate that the crustal permeability structure is highly heterogeneous. The width of high-permeability zones could be much smaller than the spatial scale of surface heat flow variations.

Keywords: heat flow, oceanic crust, fluid circulation, Japan Trench, Kuril Trench, outer rise

