Modeling the observed heat flow variation along the Nankai Trough between the Muroto and Kumano transects

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Gradual decrease in heat flow with a spatial scale of several tens of kilometers is observed between the Muroto and Kumano transects of the Nankai Trough, which are located 150 km apart [Yamano et al., 2013, JpGU]. The average heat flow on the trough floor is twice as that of model predicted value around the Muroto transect, whereas that is comparable to model predicted value around the Kumano transect. In this study, we construct a series of numerical models including hydrothermal heat transport within the oceanic crust in order to explain the observed gradually decreasing heat flow.

The first model considers a three-dimensional domain using enhanced thermal conduction within the aquifer [Spinelli and Wang, 2008, Geology], which mimics hydrothermal heat transport by a simplest manner. With a gradual decrease of basal heat flow along the trench axis corresponding to the age difference between the Muroto and Kumano transects, the resulting heat flow gradually varies along the trench axis but is too gradual to account for the observation. With a sharp contrast of the aquifer permeability, i.e., high permeability at the Muroto transect and low permeability at the Kumano transect, hydrothermal heat transport at the Muroto transect does not affect the Kumano transect, and this is also inconsistent with the observation. We expect that the difference in the aquifer permeability as well as the difference in the basal heat input is required to account for the observed heat flow contrast between the Muroto and Kumano transects.

The second model considers the effect of trench-parallel heat and fluid transport, using a two-dimensional computational domain parallel to the trench axis covering the area between the trough floor of the Muroto and Kumano transects. Referring to the result of the first model, in which hydrothermal heat transport occurs along the trench axis, we include an internal heating in a half of the aquifer corresponding to the Muroto transect. In cases of no or weak hydrothermal circulation, for example the permeability is of the order of 10-12 m2, square-sized convection cells are formed within a 500 m thick aquifer, which transport heat vertically through the aquifer and result in a sinusoidal heat flow pattern. The increase in the aquifer permeability results in an elongated convection cell across the heating and non-heating areas. Heat flow above the elongated cell gradually decreases with the spatial scale of the cell. The spatial scale is several tens of kilometers using the permeability of the order of 10-10 m2. This high permeability is consistent with the condition for along-aquifer hydrothermal heat transport to occur.

We construct two end-member models that can qualitatively explain the observed heat flow: (1) three-dimensional heat upwelling involving in the Muroto and Kumano transects and (2) two-dimensional heat upwelling along the Muroto transect and along-trench heat transport of the upwelled heat below the trough floor from the Muroto to Kumano areas. The first model assumes that heat transport pervasively occurs throughout the aquifer between the two transects. The second model, in contrast, assumes that the heat is mined below the Muroto transect, and a part of which is transported along-trench direction below the trough floor. The area involved and the intensity of heat upwelling are different between these models. More heat flow observations, especially on the landward crust between the Muroto and Kumano transects, are required to distinguish these two end-member models.

Keywords: heat flow, numerical modeling, pore fluid flow, Nankai Trough, Muroto transect, Kumano transect

