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Thermal subduction-zone model including hydrothermal circulation in an aquifer that thickened toward the trench axis

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To clarify the mechanism of high-heat-flow anomalies observed at the Nankai Trough offshore of Muroto, Japan and the Japan Trench, we construct a thermal subduction-zone model including parameterized hydrothermal circulation within an aquifer, the uppermost part of subducting oceanic plates. We aim to obtain the relationship between the observed heat flow and the intra-plate temperature structure within subduction zones.

In the model of Spinelli and Wang (2008), parameterized hydrothermal circulation within a constant-thickness aquifer in a subducted plate produces high-heat-flow anomaly near trench axes. Heat is pumped up along the aquifer from deeper part of the subducted plate to the location around the trench axis, thereby it significantly lowers the temperature at depth, 100^{o}C at most. However, in order to explain the observed magnitude of high-heat-flow anomalies with a 500 m thick aquifer, which is typically observed in bore holes (Fisher, 1998), the aquifer permeability should be as high as that near the spreading axis, 10^{-9} m^2.

Alternatively, we model an aquifer that is thickened toward the trench axis, based on a detailed mapping of seismic velocity near the Japan and Kuril trenches, in which a high V_p/V_s zone in the uppermost part of the oceanic plate is thickened toward the trench axis (Fujie et al., 2012, 2013). We assume a 500 m thick aquifer 150 km seaward of the trench axis is linearly thickened to 3000 m at the trench axis. Calculations show that this thickened aquifer induces two kinds of hydrothermal circulation. First, upward vertical hydrothermal heat transport occurs in the aquifer being thickened, which pumps up heat vertically below the aquifer. The magnitude of high-heat-flow resulted by this hydrothermal circulation depends on the rate of aquifer thickening, but not on the permeability. The temperature is decreased below the aquifer being thickened and increased above it, but not influenced within the subducted plate. More importantly, this circulation can account for the observed high-heat-flow even if the aquifer permeability is as low as a typical value for the oceanic plate, 10^{-12} m^2. This type of hydrothermal heat transport can account for the high-heat-flow anomaly observed at the Japan Trench (Yamano et al., 2008). Second, in especially with young plates, along-aquifer hydrothermal heat transport of Spinelli and Wang (2008) occurs at a low permeability around 10^{-12} m^2, because the subducted aquifer is thick. This type of heat transport can explain the high-heat-flow observed at the Nankai Trough (Yamano et al., 2003). This model overcomes the deficit of Spinelli and Wang's (2008) model, which requires extremely high permeability.

Keywords: heat flow, temperature structure, subduction zone, oceanic plate, seismogenic zone, hydrothermal circulation