Thermal models, magma transport, and velocity anomaly estimation beneath southern Kamchatka

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ABSTRACT

A finite-element method is applied to model the thermal structure of the subducted Pacific plate and overlying mantle wedge beneath the southern part of the Kamchatka peninsula. A numerical scheme solves a system of 2D Navier-Stokes equations and a 2D steady-state heat transfer equation.

A model with isoviscous mantle exposed very low temperatures (~800 °C) in the mantle wedge, which cannot account for magma generation below the volcanic belt. Instead, a model with strong temperature-dependent viscosity shows a rise in the temperature in the wedge. At a temperature of more than 1300 °C beneath the active volcanic chain, melting of wedge peridotite becomes possible. Although the subducting slab below the Kamchatka peninsula is rather old (ca. 70 Ma), some frictional heating (m = 0.034) along the interface between the subducting oceanic slab and the overlying Kamchatka peninsula lithosphere would be enough to melt subducted sediments. Dehydration (>5 wt% H_2O release) occurs in the subducting slab because of metamorphic changes. As a consequence, hydration of the mantle wedge peridotite might produce melt, which may rise to the base of the continental crust as diapirlike blobs.

Considering that melting processes in the subducting plate generate most of the volcanic material, we developed a dynamic model that simulates the migration of partially melted buoyant material in the form of blobs in the viscous mantle wedge flow. Blobs with diameters of 0.4–10.0 km rise to the base of the continental lithosphere within 0.002–10 m.y. depending on blob diameter and surrounding viscosity.

The thermal structure obtained in the model with temperature-dependent viscosity is used to estimate seismic compressional wave (P-wave) velocity anomalies (referenced to the Preliminary Reference Earth Model) associated with subduction beneath Kamchatka. A low-velocity zone (~–7% velocity anomaly) is obtained beneath the volcanic belt, and a high-velocity anomaly (~4%) is obtained for the cold subducted lithosphere. These results agree with seismic tomography results from P-wave arrivals.