

Compositional discontinuities in the Horoman peridotite: a nonlinear effect of melt percolation in partially molten mantle?

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The Horoman peridotite is well known for its well-developed compositional layered structure. It was emphasized that the compositional variation is gradational and continuous (Obata and Nagahara, 1987). There are some places confirmed in the peridotite mass, however, where whole-rock composition changes rather abruptly and discontinuously. We review the data of such a place (Bozu section) and propose a model by which such a discontinuity may be produced by melt percolation.

In the Horoman peridotite, in a 100 meter measured section, harzburgite, lherzolite, and plagioclase lherzolite occur in this sequence forming a layered structure (Takazawa et al., 2001). Important features are (1) that these rocks define a single collinear trend in compositional space in terms of whole-rock major element composition and (2) that there are several compositional gaps between the rock types. The observed compositional collinearity is best explained by the partial melting and melt extraction model but the compositional jump cannot be explained by any conventional model. The observed compositional jump may imply some discontinuous behavior of melt percolation in the upper mantle.

We then consider melt percolation for partially molten mantle. Permeability is an important parameter of partially molten rocks that controls the readiness of migration of partial melts along grain boundaries of partially molten rocks. Theoretically the permeability is the function of porosity (or melt fraction) and geometry of the pores (microstructure) of the partially molten rocks. In the upper mantle high-temperature conditions, textural equilibrium is believed to be maintained or to be closely approached, with the microstructure being controlled by the balancing of the surface energies between the melt and the solids. Several models have been proposed for the permeability function on the basis of experiments and theoretical consideration for a simple and idealized geometry. All the previous models, however, assumes one-to-one relationships between the permeability and the porosity for a given grain size in the matrix. This may be valid only when the melt is not in motion and when the melt pressure is equal to the solid pressure. However, in a dynamic situation where melt is in motion with respect to the solid framework, the melt pressure may deviate from the solid pressure. This inequality of the melt and the solid pressures may affect the geometry of the pore and thus the microstructure and thereby affect the permeability of the rocks even if the melt fraction is kept constant. Quantitatively, in a dynamic situation, a small imbalance in pressure that is generated between the melt and solid may be adjusted through a local recrystallization by the variation of the average curvature between the melt and solid interface, which in turn affect the melt connectivity and thus the permeability function. We point out a possibility that a discontinuous topological change may occur at some critical melt fraction, which causes a sudden jump of permeability function. Such a discontinuous change of permeability may cause an abrupt motion of the intergranular melt. The abrupt change of composition observed in some orogenic lherzolite mass may be the products of such an abrupt behavior of melt percolation in the upper mantle.