The low-P cooling history of the Horoman peridotite complex: Constraints from the olivine-spinel geospeedometry

Kazuhiro Iwasaki[1], # Kazuhito Ozawa[2], Hiroko Nagahara[3]

[1] Earth and Planetary Sci., Univ Tokyo, [2] Univ. Tokyo, EPS, [3] Dept. Earth Planet. Sci., Univ. Tokyo

Quantification of upwelling processes of magmas or mantle peridotites is crucial for understanding the evolution of the Earth. It is difficult to constrain the processes on the basis of natural rocks, and a forward approach is a common way, though it inevitably requires a physical model by assuming relevant initial and boundary conditions. Geospeedometry based on diffusional transfer of elements in crystals is one of the practical ways to obtain thermal history if the thermochemical parameters and diffusion data are properly determined.

Olivine-spinel geospeedometry developed by Ozawa (1984) is a powerful tool for the analysis of upwelling history of mantle peridotites because the minerals are two of the most important constituent minerals in mantle peridotites and because the partition coefficient of Mg-Fe2+ between them has strong temperature dependence. Ozawa (1984) applied the speedometer to a peridotite from the Horoman peridotite and estimated the cooling rate. However, the peridotite mass is shown to have a wide range of P-T conditions in the garnet and spinel stability fields (Ozawa and Takahashi, 1995; Ozawa, 2001). It is, therefore, imperative to clarify up to at which depth the whole complex took different ascent histories. Application of the geospeedometry to peridotites from various horizons in the Horoman complex may answer this issue. In the present study, olivine-spinel geospeedometer is applied to 9 peridotites from the Horoman complex after evaluating available olivine-spinel geothermometers, which is the critical element in the speedometry, by using two samples from the same locality.

Spinel in examined samples from the Horoman complex shows a wider range of Cr/(Cr+Al) ratio (=Cr#) (0.15-0.8), which is intimately related to Mg# (=Mg/(Mg+Fe)) of the coexisting olivine. Because of the strong Cr# dependence of olivine-spinel geothermometer, the variability of Cr# must be carefully evaluated for wide applicability of the geospeedometry. We evaluated the thermometers of Fabries (1979) and Sack and Ghiorso (1991) by comparing calculated temperatures of many olivine-spinel core pair in two samples with significantly different Cr# of spinel and from the same locality (within ~10 m apart).

The overall relationship between grain-size and temperature calculated after Fabries (1979) for 9 samples apparently suggests a consistent cooling history for the Horoman complex. However, the size-temperature relationship is significantly different for two samples with different Cr# of spinel, although they are from the same locality. The Cr-rich sample gives a higher temperature than the Cr-poor one. On the contrary, application of Sack and Ghiorso (1991) gives completely opposite relationship. The overall trend is widely scattered, but two samples from the same locality gives rather consistent trend. We doubted that the thermometry of Fabries had a problem in its Cr# dependence because it is based on natural peridotite sample, which experienced cooling process maintaining zoning particularly in Cr-rich spinel. Mg-Fe diffusion in spinel with higher Cr# is much slower than that of aluminous spinel (Ozawa, 1984), and Cr-rich spinel grains tend to retain higher temperature information than aluminous ones.

The geothermometer was recalibrated by optimizing parameters in the Fabries' themometer by matching size-temperature relations for two samples with different Cr# spinel. It was then applied to estimate the thermal history of the Horoman complex. The results manifest a strong Cr# dependence and are very similar to those obtained by applying Sack and Ghiorso (1991). The resulted large scatter is attributable to strong Cr# dependence of Mg-Fe diffusion in spinel. Samples with similar Cr# shows that the Horoman complex cooled at a consistent cooling rate of 10-4 - 10-5C/year at temperature of ~700C regardless of horizons in the complex.