Thermal & petrological structure of lithospheric mantle deciphered from xenoliths from Ichinomegata, NE Japan.

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Mantle xenoliths are important sources of information on thermal and petrological structure of lithospheric mantle and its temporal variation. Extraction of such information from xenoliths in arc settings is critical to understand evolution of wedge mantle. However, our knowledge on arc lithosphere is limited because of lack of reliable geobarometers for plagioclase- and spinel-peridotites. We have conducted geothermobarometry on carefully selected pairs of minerals and their chemical compositions, and successfully gained reasonable pressure estimates. This allows us to construct reliable thermal and petrological structure and its temporal variation of the mantle beneath NE Japan arc.
Ichinomegata volcano is a latest Pleistocene maar in Oga peninsula, NE Japan. Peridotite xenoliths occur as inclusion in basaltic to dacitic pyroclastic rocks (Katsui et al. 1979). The MOHO depth beneath Ichinomegata is estimated as 28 km (Zhao et al. 1992), and the depth of lithosphere-asthenosphere boundary (LAB) was estimated to be close to that of Japan Sea (ca. 60 km; Zheng et al. 2011). Eight lherzolite and one wehrlite samples were examined. Three samples contained plagioclase and/or pyroxene-spinel symplectite after plagioclase (Takahashi, 1986), and six samples were spinel-peridotite. They are also grouped into two types: equigranular samples with etching pits on void surfaces indicating a fluid phase, and porphyroclastic samples with interstitial glass suggesting a melt phase.
We analyzed chemical zonings of orthopyroxene and clinopyroxene using EPMA to pinpoint compositional pairs where equilibrium conditions are preserved. Four patterns of the chemical zonings of Ca, Al, and Cr due to temperature (T) changes are distinguished. They indicated 1) simple and gradual T decrease, 2) gradual T decrease followed by rapid and weak T increase, 3) gradual T decrease followed by rapid and strong T increase, 4) faint T increase. The prograde zonings observed in (3) are referred "preheating" in Takahashi (1980). On the basis of the zoning patterns and consideration on diffusional time scale, the most appropriate pairs of chemical compositions and minerals preserving pressure and temperature information just before xenolith extraction were identified for geothermobarometry.
The essential strategy in the choice of geothermobarometers is based on the fact that Al and Cr effects on geothermobarometries are very difficult to evaluate which is actually included in several thermobarometers (e.g. Lindsley 1983; Tayler 1998; Nimis and Taylor 2000; Putirka 2008). This is because response of the solubility of Al and Cr in pyroxene to pressure and temperature changes is different for plagioclase, spinel, and garnet peridotites (Gasparik 2003). We thus used T_{BKN} and $T_{Ca\text{-}in\text{-}Opx}$ (Brey and Köhler 1990), since the effects of Al and Cr contents are less important.
The estimated pressure ranges from 0.7 to 1.6 GPa, which correspond to a depth range from 28 to 54 km (± 6 km), and the estimated temperature ranges from 831 to 1084 ˚C (± 9 ˚C). The pressure values are well within the range of lithosphere, and the temperature values are consistent with those of previous studies (e.g. Takahashi 1980; Takahashi 1986; Abe and Arai 2005).
According to the pressure estimate, we can construct thermal and petrologic structure beneath Ichinomegata. Samples derived from the deeper level (1.1-1.6 GPa) were "preheated" (up to 1016-1084 ˚C), and samples from the shallower depth (0.7-0.9 GPa) stayed at low temperature (832-905 ˚C) without such "preheating". Systematic depth variations of various features of the xenoliths are identified: the change of Al-phases from plagioclase to spinel, the change of interstitial phases from fluid to melt, and change of microstructure from equigranular to porphyroclastic textures. The consistent depth dependent transitions might correspond to those expected in the thermal and rheological boundary

layers near LAB controlled by wet-solidus.

Keywords: wedge upper mantle, thermal structure, rheological structure