Decoding deformation history of upper mantle peridotites recorded in Cr-Al spinel

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Chromian spinel is a minor phase in peridotite, but is present in almost all peridotites. It provides us useful information on various mantle processes, such as melting and deformation. We have examined morphology, internal strain, grain size, and Cr-Al zoning of spinel in harzburgite and dunite of the Horoman peridotite complex, Hokkaido, northern Japan, in addition to lattice preferred orientation and grain size of olivine, to clarify the link between deformation and P-T history of the complex. Spinel in harzburgite of the Horoman complex shows morphological diversity, which can be represented by roundness parameter DR (degree of roundness). The roundness of spinel from the middle of each harzburgite layer tends to increase from the bottom to the top of the complex. It shows good correlation with internal strain and Cr-Al zoning in spinel but no correlation with Cr/(Cr + Al) at the core. Rounded spinel with high DR has minor internal strain and tends to have concentric Cr-Al zoning, and is common in the Upper Zone of the Horoman complex. Irregular spinel with low DR has significant internal strain exhibited by many grain and subgrain boundaries and Cr-Al multi-polar zoning along the internal grain boundaries with both Cr and Al maxima along grain boundaries side by side. The Cr maxima tend to occur on the rim nearly parallel to the foliation and Al maxima on the rim in the direction of lineation. This type of spinel is restricted in the Lower Zone. These features in spinel may reflect diversity in deformation mechanisms and conditions. The irregular outline and internal strain characterized by many subgrain boundaries of spinel are attributed to dislocation creep. The Cr-Al multi-polar zoning is attributed to diffusion creep (Ozawa, 1989), whereas the concentric Cr-Al zoning in rounded spinel grains is due to reactions with surrounding minerals upon cooling (Nagata et. al. 1983). There are rounded spinel grains showing Al-Cr multi-polar zoning that is obscured by the overlapping of concentric zoning from the outermost rim, suggesting that the concentric zoning of rounded but elongate spinel in the Upper Zone had experienced diffusion creep before or during the final ascent and cooling through the crust. The absence of subgrains in such spinel with few rare cases indicates insignificant dislocation creep during the cooling stage. Multi-polar zoning in irregular spinel is not superimposed by subgrain boundaries, indicating that irregular spinel in the Lower Zone had experienced dislocation creep before diffusion and dislocation creeps were operated concurrently during the final ascent and cooling of the Lower Zone. The inferred deformation history is supported by variation of grain size, texture, and lattice preferred orientation (LPO) of olivine in the Horoman complex. The olivine from the Upper Zone shows coarse-grained polygonal texture and [100](010) LPO pattern, which is in contrast to olivine of the Lower Zone showing porphyroclastic texture with finer neoblasts and [100](0kl) LPO pattern. These features of olivine and spinel indicate that the Upper Zone and the Lower Zone experienced high temperature (above 1100 deg. C) and low temperature (below 1000 deg. C) deformation, respectively.