Rheological transition during progressive antigorite serpentinization of peridotite

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Antigorite is inferred as a major hydrous phase in forearc mantle. A degree of serpentinization in mantle wedge differs depending on age, thermal state and location of the subduction zone. Under progressive serpentinization, antigorite-bearing peridotite consisting of olivine and antigorite is substantially important and is expected to have significant roles in the geodynamic processes. It is generally accepted that an increase of antigorite reduces strength of mantle above a plate interface resulting in slab-mantle decoupling. The idea of lubricant serpentinite is developed based on geological observations of serpentinite mélange that encloses high-P tectonic blocks. However, convincing evidence constraining rheological behaviours of antigorite is not found from structural and experimental works.

This study focuses on olivine and antigorite coexisting in partially serpentinized peridotite that is expected to have information of the relative strengths of these important minerals. Microstructural observations and crystallographic analyses of naturally deformed antigorite peridotite in the Higashi-akaishi ultramafic body revealed transitions of deformation mechanism of olivine during progressive antigorite serpentinization. Before serpentinization, in wet conditions, coarse olivine has deformed in dislocation creep regime and olivine neoblasts were dominated by dislocation-accommodated grain boundary sliding (DisGBS). In the early stage of serpentinization, fine grains of olivine deformed by both DisGBS creep and dissolution precipitation creep (i.e. grain boundary diffusion-controlled creep). Observations of higher dislocation densities in olivine grains adjacent to antigorite indicate that antigorite blades were rigid to keep higher local stress than those at olivine-olivine boundaries. With increasing degrees of serpentinization at lower temperature, proportion of smaller grains of olivine increases so that dissolution precipitation creep becomes dominant. The mechanism is supported by elongation to a-axis parallel to stretching direction and shortening parallel to b-axis. In the latest stage, crack-filling antigorite characteristically occurs in olivine grains, suggesting that olivine became rigid and antigorite has controlled the strain of rocks.

At the three stages of progressive serpentinization (associated with characteristic deformation) in the Higashi-akaishi body, dislocation microstructures, grain shape and CPO of olivine are consistent with deformation mechanism map based on experimentally determined flow laws for wet olivine. This indicates that these rheological equations determined at high temperature conditions (> 1000 ˚C) can be extrapolated to low temperature conditions of serpentine stability. Observations of the antigorite peridotite suggest that crystal plasticity of olivine exceeds that of antigorite. Antigorite-rich layers in highly serpentinized rocks acted as weak layers at deformation conditions of 500-600 ˚C although the deformation mechanism of antigorite is unclear. The strain rates of antigorite peridotite estimated for the early and later stages ($10^{-14\sim-16}$) are not sufficient to form a thin weak layer to cause slab-mantle decoupling. If rheological strength of antigorite schist is not largely reduced by intercrystalline displacement, alternative material should be considered as an explanation for a cause of ‘cold nose’ in mantle wedge such as talc and brucite.