The water transportation into the deep mantle along the hot subducting slab by humite minerals

Yusuke Yachi[1]

[1] Grad. Sch. Sci. Tech., Kumamoto Univ.

The water transportation and dehydration of subducting slab are key processes in understanding arc magmatism, metamorphism, origin of the earthquake, and global water cycle. Dense hydrous magnesium silicates (DHMS), which are composed of alphabet phases and humite minerals, may play an important role in the transport of water.

The experimental studies of MgO-SiO2-H2O (MSH) system (e.g. Wunder, 1998) reveal that an invariant point located at approximately 6 GPa and 600 C separates two different regions: a colder region where H2O is preserved in the solid assemblage (phase A + enstatite), and a hotter region where H2O is not preserved in the solid assemblage (forsterite + enstatite + H2O). This suggests that subduction of water into the deep mantle is restricted to the coldest area of the subducting slab.

Stalder and Ulmer (2001) found that small amounts of F increase the stability field of clinohumite ((F-OH) chu) + forsterite (fo) + enstatite (en) + H2O, compared to that of the assemblage in pure MSH system. This assemblage can contain water at the conditions in the hotter region. This suggests that (F-OH) humite minerals solid solutions may transport water into the deep mantle through hot subduction process. In this study, I construct thermodynamic model of (F-OH) humite minerals, and calculate stable assemblages and water content of F-bearing hydrated mantle along the subducting hot slab geotherm.

I adopted the heat capacity function and equation of state for end member minerals of Holland and Powell (1998) and the subregular solution model for (F-OH) solutions of Duffy and Greenwood (1979). Standard-state entropies, heat capacities, volumes, and parameters of equation of state for F, OH end members are derived from experimental studies or estimated following Helgeson et al. (1978). Using the least square regression, I determined standard-state enthalpies of formation for F, OH end members and excess parameters for (F-OH) solutions from the experimental phase equilibrium data (Wunder, 1998; Duffy and Greenwood, 1979). The derived thermodynamic properties are internally consistent with the thermodynamic properties of minerals of Holland and Powell (1998).

The computed stability field of (F-OH) chu + fo + en + H2O and compositions of (F-OH) chu of the assemblage are consistent with experimental phase equilibrium data (Stalder and Ulmer, 2001). These results show validity of this thermodynamic model.

Using the free energy minimization algorithm of de Capitani and Brown (1987), I computed the stable assemblages and water content of F-bearing hydrated mantle (serpentine + F 0.1 wt. %) at the P-T conditions along the subducting hot slab geotherm (Peacock, 1991). Although, significant dehydration due to the breakdown of serpentine occurs under forearcs (depths about 60 km), the assemblage (F-OH) chu + fo + en still contains small amounts of water at deeper conditions. At the maximum depths of this calculation (about 300 km), the assemblage contains about 0.5 wt. % water (this value depends on F content of hydrated mantle). This calculation result shows that (F-OH) humite minerals in a system containing small amounts of F can transport water into the deep mantle (at least 300 km) along the subducting hot slab.