

Effects of Al content on water partitioning between Opx and Ol: Implications for lithosphere-asthenosphere boundary

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Most minerals in the Earth's upper mantle contain small amounts of hydrogen (i.e. "water"), structurally bound as hydroxyl. Water has an important influence on the behavior of rock system. This small amount of water has an important influence on the behaviours of rock systems. A large viscosity contrast of more than two orders of magnitude was detected at depths of 70 km to 100 km beneath ocean and was defined as the lithosphere-asthenosphere boundary [1]. The origin of the lithosphere-asthenosphere boundary remains an enigma. The water distribution in the Earth is critical to the nature of the boundary. For example, Mierdel et al. (2007)[2] indicated that a high water solubility in aluminous orthopyroxene among mantle geotherm in the Earth's upper mantle would effectively contribute to a stiffening of the lithosphere. Therefore, precise knowledge on the distribution of water among mantle minerals is very important for understanding the Earth's dynamics. The Earth's uppermost mantle is composed mainly of olivine (Ol), orthopyroxene (Opx), clinopyroxene (Cpx), spinel, and garnet. In particular, Ol accounts for a large proportion (60 vol.%) of the Earth's uppermost mantle. In addition, Opx, which contains significantly more water than does Ol in the mantle xenolith, is the second phase of the Earth's uppermost mantle. The FeO content in mantle Ol shows very limited variation in range, whereas the Al content of Opx in the Earth's upper mantle decreases significantly with increasing pressure [3] Therefore, the variation of Al content in mantle minerals can be important for the solubility of water in mantle minerals.

To investigate the partitioning coefficient of water between Opx and Ol ($D_{(Opx/Ol)}$) under low-water concentrations (3 ~ 387 wt. ppm) similar to the Earth's mantle conditions, high-pressure experiments have been conducted at pressures of 1.5-6 GPa and a temperature of 1573 K. The experiments were performed with Kawai-type multi-anvil and piston-cylinder apparatus by using starting materials of natural Ol and synthetic Opx with various Al contents. The water contents were obtained with a vacuum type Fourier transform infrared spectrometer (Jasco: FT-IR6100, IRT5000). Water content of minerals was calculated based on Paterson's calibration [4]. IR-spectra of Ol and Al-bearing Opx in this study are similar to those obtained by high-pressure experiments [5] and natural rocks [6], respectively. It is believed that broad bands in IR spectra of natural Opx are due to effect of crystal distortion by large Al substitution. On the contrary, IR-spectra of Al-free Opx are not consistent with those reported by Rauch and Keppler (2002) [7] likely because of the large difference of water fugacity. $D_{(Al-freeOpx/Ol)}$ is ~ 1 at all pressure conditions. However, the water contents of Al-bearing Opx are significantly larger than those of Ol at the same conditions. In addition, the effect of Al concentration in Opx on $D_{(Opx/Ol)}$ becomes larger with increasing pressure. The high Al content in Opx significantly increases $D_{(Opx/Ol)}$ and the trend increases with increasing pressure. $D_{(Opx/Ol)}$ drops sharply at the pressure at which the Al concentration of Opx becomes nearly 0 in the Earth's mantle conditions.

These results imply that viscosity of the upper mantle decreases sharply at depths deeper than those in which orthopyroxene contains no Al. The dramatic change of $D_{(Opx/Ol)}$ may explain the lithosphere-asthenosphere boundary beneath oceans and continents.

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Keywords: water partitioning coefficient, olivine, orthopyroxene, viscosity, FT-IR, lithosphereasthenosphere