

Stability and substitution mechanism of Al-bearing superhydrous phase B at the mantle transition zone and the upper most lower mantle

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Water is the most abundant and important volatile component in the deep mantle. Water is transported into the Earth's deep interior by hydrous minerals in a cold subducted slab. However, all Mg-Si endmembers of dense hydrous magnesium silicates break down at temperatures close to the typical mantle geotherm. Recent studies suggest that incorporation of Al increases the high-temperature stability of these hydrous minerals. Al-bearing phase D breaks down at approximately 1600 °C and 24 GPa, which is approximately 200 °C higher than that of Mg-end member phase D (Ghosh and Schmidt, 2014). Moreover, Al-end member phase D (Al-phase D, $\text{Al}_2\text{SiO}_4(\text{OH})_2$) is stable at a temperature of over 2000 °C and pressure of 26 GPa (Pamato et al., 2015). In the case of phase H, it can form a solid solution with δ -AlOOH (Nishi et al., 2014) and this solid solution is stable even along a typical mantle geotherm (Ohira et al., 2014). On the other hand, phase A cannot contain Al. Instead, Al is included in 23 Å phase ($\text{Mg}_{11}\text{Al}_2\text{Si}_4\text{O}_{16}(\text{OH})_{12}$), which has stability region similar to phase A (Cai et al., 2015). However, the effect of Al on the stability of superhydrous phase B is not known. To clarify the stability of Al-bearing superhydrous phase B in the mantle transition zone and the uppermost lower mantle under a typical mantle geotherm, we conducted high-pressure and high-temperature experiments using a multi-anvil apparatus. Here, we report the stability of Al-bearing superhydrous phase B and the tendency of its chemical composition, and we will also discuss a mechanism of water transport to the lower mantle.

The high pressure and high temperature experiments were conducted using a multi anvil high pressure apparatus (ORANGE-2000) installed at the Geodynamics Research Center, Ehime University, Japan. The starting materials for these experiments were powdered mixtures of MgO, Al_2O_3 , SiO_2 , $\text{Mg}(\text{OH})_2$, and $\text{Al}(\text{OH})_3$ with 6 different compositions. The experiments were performed at 20 and 24 GPa at 1400 and 1600 °C. Water content of the selected samples was quantified using a SIMS installed at Hokkaido University, Japan.

Superhydrous phase B contained significant amounts of Al_2O_3 , from 15-33 wt%, and Al-bearing superhydrous phase B remained stable, even at 1600 °C and pressures of approximately 20-24 GPa. Moreover, two types of superhydrous phase Bs with different chemical compositions coexisted at 20-24 GPa and 1600 °C. The Al_2O_3 and H_2O contents increased, and the MgO and SiO_2 contents decreased as the pressure and temperature increased. The maximum H_2O content of Al-bearing superhydrous phase B is 11.1(3) wt%, which is ~1.9 times larger than that of the Mg-endmember. The substitution mechanism of Al and H can be described as $2\text{Mg}^{2+} + \text{Si}^{4+} \rightarrow 2\text{Al}^{3+} + 2\text{H}^+ + \text{Vc}$ (cation vacancy). The crystal structures of the two coexisting superhydrous phase Bs are expected to be slightly different from each other. The present results indicate that Al-bearing superhydrous phase B can be stable in a subducted slab with a high Al content at temperatures typical of the mantle transition zone and lower mantle. Thus, water can be transported to the lower mantle by Al-bearing superhydrous phase B in a subducting slab, even at the typical mantle geotherm.

Keywords: superhydrous phase B, dense hydrous magnesium silicates, hydrous mineral, stability, substitution mechanism