High-temperature phase relations of hydrous aluminosilicates at 22 GPa in the AlOOH-AlSiO$_3$OH system

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**ABSTRACT**

The stabilities of the minerals that can hold water are important for understanding water behavior in the Earth's deep interior. Recent experimental studies have shown that the incorporation of aluminum enhances the thermal stabilities of hydrous minerals significantly. In this study, the phase relations of hydrous aluminosilicates in the AlOOH-AlSiO$_3$OH system were investigated at 22 GPa and 1400–2275 K using a multi-anvil apparatus. Based on the X-ray diffraction measurements and composition analysis of the recovered samples, we found that the AlSiO$_3$H phase Egg forms a solid solution with δ-AlOOH above 1500 K. Additionally, at temperatures above 1800 K, two unknown hydrous aluminosilicates with compositions Al$_{2.03}$Si$_{0.97}$O$_{6.03}$H$_{2.03}$ and Al$_{1.11}$Si$_{0.88}$O$_{6.11}$H$_{2.11}$ appeared, depending on the bulk composition of the starting materials. Both phases can host large amounts of water, at least up to 2275 K, exceeding the typical mantle geotherm. The extreme thermal stability of hydrous aluminosilicates suggests that deep-subducted crustal rocks could be a possible reservoir of water in the mantle transition zone and the uppermost lower mantle.

**Keywords:** Water, hydrous phase, mantle transition zone, phase Egg, phase transition; Physics and Chemistry of Earth’s Deep Mantle and Core

**INTRODUCTION**

Recent experimental studies have suggested that mantle materials can hold an amount of water exceeding that stored in the ocean (e.g., Fu et al. 2019; Inoue et al. 1995; Litasov et al. 2003). However, the actual storage capacity and the detailed distribution of water remain unclear. The mantle transition zone can be a major water reservoir because ringwoodite and wadsleyite, the dominant minerals, can retain up to 2–3 wt% water in their crystal structures (e.g., Inoue et al. 1995; Kohlstedt et al. 1996). The discovery of hydrous ringwoodite in diamond implies that the transition zone is wet, at least locally (Pearson et al. 2014). In contrast, water solubility in the lower-mantle minerals, such as bridgmanite and magnesiowüstite, is considerably lower (e.g., Liu et al. 2021; Fu et al. 2019; Bolfan-Casanova et al. 2002). Because of the contrast in water capacity, mantle convection to the lower mantle across the transition zone causes a release of water, resulting in dehydration melting, producing seismic low-velocity anomalies (e.g., Liu et al. 2018; Nakajima et al. 2019; Schmandt et al. 2014). Thus, the stabilities of the minerals that can hold water are important for understanding the water behavior in the Earth’s deep interior.

The storage capacity of water in the cold plate subducted into the mantle is much larger than that of the surrounding mantle because dense hydrous magnesium silicates (DHMSs) can be stabilized there (e.g., Nishi et al. 2014; Ohtani et al. 2014). Although these hydrous minerals may deliver water to the mantle, most of the hydrous minerals are stable only in extremely cold regions in the subducted plate. Furthermore, recent experimental studies have shown that the incorporation of aluminum enhances the thermal stabilities of DHMSs significantly (e.g., Panero and Caracas 2017; Xu et al. 2021). For instance, the aluminum end-member of Al$_2$SiO$_3$H$_2$ phase D can endure without dehydration within mafic rocks at temperatures at least up to 2000 °C at 26 GPa, suggesting the potential of a hydrous phase as the host for water under the typical mantle geotherm (Pamato et al. 2015). This finding suggests that water released from DHMSs in ultramafic rocks could be re-trapped in aluminous hydrous minerals in the Al-rich mafic crustal section in the deep mantle.

Many high-pressure hydrous phases have been found in the Al$_2$O$_3$-$SiO_2$-$H_2$O ternary system. Among them, δ-AlOOH (Suzuki et al. 2000), phase Egg (Eggleton et al. 1978), and aluminous phase D (Pamato et al. 2015) are stable under the pressure and temperature conditions corresponding to the mantle transition zone and the uppermost lower mantle (Abe et al. 2018; Fukuyama et al. 2017). These phases are the key minerals for understanding the Earth’s deep water cycle because they have been found as inclusions in superdeep diamonds (Kaminsky 2017; Wirth et al. 2007). In this study, we investigated the high-temperature stability of hydrous aluminosilicates at 22 GPa using a multi-anvil apparatus. We found...