In situ spectroscopic study of water intercalation into talc: New features of 10 Å phase formation

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ABSTRACT

The synthesis of 10 Å phase via the reaction of talc plus water at 8 GPa and 500 °C was studied by in situ Raman spectroscopy using a diamond-anvil cell. The initial fast (2 h) incorporation of interlayer H2O molecules into the talc structure is traced by gradual growth of new OH stretching bands at 3592 and 3621 cm–1 and the shift of several framework bands. Further monitoring at HP-HT conditions over 7 h reveals gradual weakening of the 3592 cm–1 band, which can probably be related to the onset of the formation of “long-run” 10 Å phase through the appearance of silanol groups following the model proposed by Pawley et al. (2010), influencing the interlayer hydrogen bonding.

Keywords: 10 Å phase, talc, water transport, subduction

INTRODUCTION

The Earth’s mantle is considered to be an important H2O reservoir in the global water cycle where water can be stored either in hydrous phases or as defects in nominally anhydrous phases (Jacobsen and van der Lee 2006; Kovalc et al. 2012). However, the mechanism of water transport from outer geospheres to the mantle is still debated. In cold subduction zones, hydrous phases avoid dehydration and carry water to mantle depths. The serpentinized peridotite layer that lies just below the igneous oceanic crust constitutes an H2O reservoir in the subducted lithosphere comparative in mass to the oceanic crust (Schmidt and Poli 2014). Although serpentine dehydrates at moderate temperatures (500–700 °C), it can be a precursor for dense hydrous magnesium silicates (DHMS) that are stable at mantle conditions. There are three main scenarios for water behavior in serpentinized peridotite depending on the position of the subduction geotherm (Fig. 1).

1) During “hot” subduction, the release of water from the slab basement is controlled by serpentinite and then chlorite breakdown into anhydrous phases and hydrous fluid. These processes lead to the formation of the lower part of so-called double seismic zones (Dobath et al. 2008).

2) During “cold” subduction a direct transformation of serpentinite into phase A, Mg3Si4O10(OH)2 (Ringwood and Major 1967), is possible with almost no water fluid production (Schmidt and Poli 2014). The retained water can then be transferred even to the lower mantle via the sequence of DHMS phase A → phase E → superhydrous phase B → phase D(G) (Ohtani et al. 2004).

3) As the “normal” subduction geotherm lies above the intersection of serpentine and phase A stability curves (Fig. 1), during “normal” subduction serpentinite decomposes before phase A can be formed. However, experimental studies have shown that the so-called 10-angstrom phase (TAP, 10 Å phase), nominally Mg3Si4O10(OH)2·xH2O, can exist in the low-temperature “dehydration gap” between the serpentine and phase A stability curves (Fig. 1). The corresponding succession of hydrous phases serpentine → 10 Å phase → phase A, where 10 Å phase acts as an intermediate water carrier, can retain about 25% of the initially subducted H2O of the serpentinized peridotite even during “normal” subduction (Schmidt and Poli 2014).

The stability field of 10 Å phase is poorly understood. The position of the 10 Å phase dehydration curve, however, is particularly important because it limits the range of subduction geotherms where H2O can be retained in a slab via serpentine → 10 Å phase → phase A transformations. According to equilibrium experiments of Pawley et al. (2011), the dehydration reaction 10 Å phase → enstatite + coesite + H2O occurs at 690 °C at pressures below 7.5 GPa. In several studies 10 Å phase was obtained at higher temperatures of 700–750 °C (Yamamoto and Akimoto 1977; Pawley and Wood 1995; Dvir et al. 2011), see Figure 1. The latter studies, however, were synthesis experiments and can therefore not be considered as equilibrium. Most significantly, nano-inclusions of 10 Å phase have been found in mantle olivine (Khisina and Wirth 2008), which strongly supports the possibility of its occurrence in nature.

The structure of 10 Å phase is very similar to that of triocahedral mica with 2:1 tetrahedral-octahedral layers parallel to (001), the interlayer space being occupied by H2O molecules (Comodi 2005). The H2O stoichiometry of 10 Å phase is not well constrained and varies, according to different estimations, from 0.6 to 2 H2O molecules per formula unit (Sclar and Carrison 1966; Yamamoto and Akimoto 1977; Bauer and Sclar 1981; Wunder and Schreyer 1992). However, recent structural and thermodynamic studies (Comodi 2005; Pawley et al. 2010, 2011) suggest 1 H2O...