Phase transition of wadsleyite-ringwoodite in the Mg$_2$SiO$_4$-Fe$_2$SiO$_4$ system

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**ABSTRACT**

The Fe-bearing wadsleyite-ringwoodite phase transition loop under dry conditions in a temperature range of 1473 and 1873 K was determined by in situ X-ray diffraction experiments at the synchrotron facility SPring-8. Pressure at high temperature was precisely determined within a 0.23 GPa error using in situ X-ray diffraction of MgO as a pressure standard. Under dry conditions, assuming an equilibrium chemical composition of wadsleyite and ringwoodite coexisting with garnet in a pyrolite model and an adiabatic temperature gradient with a potential temperature of 1550–1650 K, the phase transition depth and effective width of the seismic discontinuity were found to be 500–514 and 20–22 km, respectively. This effective width, which is three times greater than that of the olivine-wadsleyite phase boundary, can reflect a seismic wave of approximately 0.25 Hz. The wider transition loop between wadsleyite and ringwoodite could create a broad seismic discontinuity. Considering wet and oxidized conditions, the depth of the wadsleyite-ringwoodite phase boundary could be greater than 520 km assuming the small temperature dependency on water and oxygen fugacity effects. Variation in the depth of seismic anomaly may be attributed to water content or oxygen fugacity of the transition zone.

**Keywords:** Mantle, wadsleyite, ringwoodite, phase boundary loop, in-situ experiments

**INTRODUCTION**

Various seismic discontinuities in the Earth’s interior have been globally determined by various seismic studies (e.g., Dziewonski and Anderson 1981). Phase transitions in the major constituent minerals are believed to cause such global discontinuities in the Earth’s mantle. According to the velocity model (IASP91) proposed by Kennett and Engdahl (1991), an increase in P- and S-wave velocities by 3.6 and 4.1%, respectively, can be explained by the olivine-wadsleyite phase transition at 410 km seismic discontinuity. The post-spinel phase transition accounts for the 660 km seismic discontinuity characterized by seismic discontinuity. The post-spinel phase transition is explained by the olivine-wadsleyite phase transition at 410 km depth. In some cases, the phase boundary between wadsleyite and ringwoodite produces velocity increases of only 1% or less (Helffrich 2000). Although several seismic studies using long period seismograms have suggested that the 520 km seismic discontinuity is a global feature (e.g., Shearer 1990, 1991; Flanagan and Shearer 1998), recent seismic studies demonstrated that this discontinuity is not a ubiquitous feature and is lacking in some regions (Gossler and Kind 1996; Deuss and Woodhouse 2001). In some cases, two discontinuities at approximately 500 and/or 560 km depths were detected rather than the 520 km seismic discontinuity (Deuss and Woodhouse 2001). Therefore, to understand the nature of the 520 km seismic discontinuity, it is important to accurately determine the phase boundary between wadsleyite and ringwoodite as a function of temperature, pressure, and chemical composition.

Temperature is among the key parameters that constrain the structure and composition of the Earth’s interior. Although geophysical observations allow for the precise determination of depth, and hence, pressure, it is difficult to determine the temperature at a given depth without knowledge of mineral physics. The combined studies of potential temperature (e.g., McKenzie and Bickle 1988), phase boundary depth of constituent minerals, and depth of seismic discontinuities (Akaogi et al. 1989; Katsura et al. 2004) have made it possible to estimate a temperature profile of the Earth’s mantle. The phase boundary binary loop between wadsleyite and ringwoodite is among the most important interfaces of the major predicted phase transitions used to constrain the mantle geotherm.

Using in situ X-ray diffraction at a synchrotron facility, Morishima et al. (1994) and Katsura et al. (2004) determined the olivine-wadsleyite phase boundary in the Mg-end-member and Fe-bearing systems, respectively. The phase boundary between wadsleyite and ringwoodite has only been determined in the Mg-end-member system by in situ studies (Inoue et al. 2006; Suzuki et al. 2000), while the phase boundary loop of wadsleyite-ringwoodite in Fe-bearing systems has only been estimated through thermodynamic calculations (Akaogi et al. 1989; Frost 2003) and quench experiments (e.g., Katsura and Ito 1989). In this study, we determined the precise pressure of the phase boundary loop between wadsleyite and ringwoodite at various temperatures under dry conditions via in situ high-pressure experiments. We also discuss the origin of the 520 km seismic discontinuity based on the wadsleyite-ringwoodite phase transition.

**EXPERIMENTAL methods**

In situ X-ray diffraction experiments were conducted using a Kawai-type multi-anvil apparatus SPEED-1500 installed at the beamline BL04B1 of the synchrotron facility SPring-8 (Utsumi et al. 1998). The pressure medium was an...