Water partitioning between olivine and wadsleyite: Implication to 410-km discontinuity

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We determined stability of olivine and wadsleyite in hydrous Fo90 composition and measured H2O content and partition coefficients of water between olivine and wadsleyite and apply the results to mantle dynamics near 410 km discontinuity.

We used four starting materials in the present experiments. Major charge was an oxide mixture of Fo90 composition. The hydrous composition (15 wt.% H2O) was prepared by adding Mg(OH)2 adjusting the proportion of MgO. Additional charges were: (a) Mg2SiO4; (b) San-Carlos olivine (Fo89) and (c) CaO-MgO-Al2O3-FeO-SiO2 pyrolite. Experiments were carried out using a 1000-tons Kawai-type multianvil apparatus installed at Tohoku University. Polarized infrared spectra were obtained using a micro-FTIR spectrometer in the University of Tokyo. The polished crystals of olivine were 30-70 microns thick and those of wadsleyite were 10-12 microns thick. The OH-concentration was estimated by integration the absorption bands using the calibrations by Paterson (1982) for wadsleyite and Bell et al. (2003) for olivine.

We observed significant broadening of olivine-wadsleyite transformation (OWT) interval by 2 GPa to the lower pressure at 1473 K, whereas no significant broadening of this interval was observed at 1873-2073 K. This result is inconsistent with the data by Chen et al. (2002), who obtained a narrow olivine-wadsleyite transition loop at 1473 K, whereas it supports the calculations by Wood (1995). The IR spectra of olivine are composed of several absorption peaks at 3530-3613 cm-1. Additional weak peaks are observed at 3400-3477 cm-1. The H2O content measured in olivine is 0.14 wt.% H2O at 1473 K and 9.5 GPa, whereas it is increases to 0.42-0.61 wt.% H2O at 1373-1773 K and 12.5-14.0 GPa. The spectra of wadsleyite is composed of a strong peak at 3326 cm-1 and weak peaks at 2500, 3584, 3611, 3643, and 3657 cm-1. The H2O content measured in wadsleyite is 1.6-2.1 wt.% H2O at 1373-1673 K and 0.67 wt.% H2O at 1773 K. The partition coefficients of H2O between wadsleyite and olivine (Dwd/ol) are 4.0 at 1473 K, 2.1 at 1673 K and 1.3 at 1773 K. These values are lower than those obtained in previous studies (Dwd/ol=5-40).

Global topography of 410-km discontinuity indicates admplitude of the depth variations of +/-20 km. Regional studies indicate maximum elevations of 410-km up to 60-70 km. Since influence of water on OWT is comparable with that of temperature, we can suggest that the topography of 410-km discontinuity in some regions may be explained by water in the slabs. Estimates for the width of d410 vary between 4 and 35 km while most estimates suggest 4-6 km width. Frost (2003) reviewed the recent data on OWT along with the new thermodynamic modeling and argued that 4-6 km width of the discontinuity is consistent with OWT in the pyrolite composition. The presence of water has most dramatic effect to broaden the discontinuity. Wood (1995) predicted that the 100 ppm H2O in olivine (with assumed olivine/wadsleyite partitioning as 1:10) would broaden the discontinuity by approximately 3 km. We observed similar broadening in present experiments. Recent observations that 410-km discontinuity is between 20 and 35 km thick beneath Mediterranean (Van der Meijde et al., 2003) may be accounted for by high H2O contents in this region. If the transformation is 35 km thick, the H2O content of olivine and wadsleyite would be 0.21 and 0.84 wt.% respectively according to the model by Wood (1995) and partition coefficients, determined in this work. These estimations are supported by the measurements of electrical conductivity of the upper mantle in this region, which is consistent with 0.1-0.15 wt.% H2O in olivine (Tarits et al., 2004).