Post-spinel Phase Transformation in Dry and Hydrous Peridotite Mantle

Konstantin Litasov[1]; Eiji Ohtani[2]; Asami Sano[3]; Akio Suzuki[4]; Ken-ichi Funakoshi[5]

[1] Inst. Mineral. Petrol. Econ. Geol.,

Tohoku University; [2] Institute of Mineralogy, Petrology, and Economic Geology, Tohoku University; [3] Inst.Mineral. Petrol.& Econ. Geol., Faculty of Sci.,Tohoku Univ; [4] Faculty of Science, Tohoku Univ.; [5] JASRI

The 660-km seismic discontinuity in the Earth's mantle is identified with the transformation of ringwoodite ((Mg,Fe)2SiO4-spinel) to (Mg,Fe)SiO3-perovskite and (Mg,Fe)O-ferropericlase. It was suggested using quench experiments that the transformation boundary has significant negative Clapeyron slope (-3 MPa/K, Ito and Takahashi, 1989) responsible for depressions and elevations of the 660-km discontinuity in subduction zones and hot mantle plumes. Recent in situ X-ray diffraction studies in Mg2SiO4 system indicate that negative slope of the boundary is much gentler (-0.4 to -1.3 MPa/K) (Katsura et al., 2003; Fei et al., 2004). Therefore there must be the other factors resulting in significant depth variations of the 660-km discontinuity. In this study, we present the phase relations in dry and hydrous pyrolite by in situ X-ray diffraction measurements to examine the influence of compositional variations and water on post-spinel transformation.

Experiments were carried out using Speed-1500 multianvil apparatus installed at BL04B1 at synchrotron radiation facility 'SPring-8' (Hyogo, Japan). Starting materials were synthetic glass representing CaO-MgO-FeO-Al2O3-SiO2 -pyrolite. In the hydrous runs 2 wt.% H2O was added as Mg(OH)2 adjusting the proportion of MgO. Graphite, AgPd and Pt capsules were used as a sample container. Co-doped MgO was used as the pressure medium and a cylindrical LaCrO3 heater was used as the heating element. Temperature was measured with a WRe thermocouple. Different equations of state for Au and MgO were used for pressure calibration.

The phase relations were determined at 20-25 GPa and temperatures up to 2300 K. In the anhydrous pyrolite system we observed easy nucleation of Mg-perovskite and ferropericlase from ringwoodite-bearing assembly in the temperature range of 1600-2200 K. The obtained post-spinel phase boundary (appearance line of Mg-perovskite) can be expressed as P (GPa) = -0.0005 T (K) + 23.54 using pressures calibrated by Au scale (Tsuchiya, 2003) and P (GPa) = -0.0008 T (K) + 24.42 using pressures calibrated by MgO scale (Speziale et al., 2001). Our experiments demonstrated that variations of chemical composition in pyrolite relative to Mg2SiO4 do not affect the post-spinel phase transformation boundary.

In hydrous pyrolite we observed that the post-spinel phase boundary shifts to higher pressures by 0.6 GPa at 1473 K relative to the anhydrous system. No significant shift was observed at 1873 K. The resulting linear equation for appearance of Mg-perovskite may be expressed as P (GPa) = -0.002 T (K) + 26.3 and applicable for the temperature range 1200-1800 K. However, we should note a possibility that the transformation boundary deviates from linear trend and the phase boundary can be shifted by more than 2.5 GPa at 1000 K.

The displacement of the post-spinel phase transition boundary in hydrous pyrolite corresponds to about 15 km on the depth scale and may account for a half of 30-40 km depressions of the 660 km discontinuity in the subduction zones at the temperature around 1473 K. Moreover, recent quench multianvil experiments showed clear evidence of shift of the olivine-wadsleyite phase transition boundary (responsible for the 410 km seismic discontinuity) to lower pressures by 1-2 GPa if we add water (Smyth and Frost, 2002; Litasov and Ohtani, 2003). Combining these data we can suggest that water, if present, may have crucial contribution to elevation of 410 km and depression of 660 km in the subduction zones and the effect of water may be stronger than that of temperature. Since the Clapeyron slope of the post-spinel transformation boundary in anhydrous pyrolite is very gentle, we can not explain depressions of the 660 km discontinuity only by the temperature effect. Thus, if our data are correct, a large depression of the 660 km discontinuity can be considered as a direct evidence for existence of water in the transition zone.