

Phase transitions and mineral chemistry in pyrolite at 1600-2200C across 660-km seismic discontinuity

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It is widely accepted that pyrolite is a model rock which represents the chemical composition of the Earth's upper mantle. Because the post-spinel transition in pyrolite occurs at about 23 GPa along mantle geotherm (e.g. Litasov et al. 2005), it has been accepted that the transition is responsible for the seismic 660-km discontinuity. Slow velocity anomalies by global seismic tomography which may indicate mantle upwelling have been found in the transition zone and the lower mantle, and these regions are higher in temperature than average mantle. To elucidate the origin and dynamics of the mantle plume, informations on phase relations in pyrolite are essential. However, few investigations on phase relations in pyrolite have been made at hot-plume temperatures (1800-2200C) (Hirose, 2002; Nishiyama and Yagi, 2003). In this study, we demonstrated detailed phase equilibrium experiments in pyrolite composition at hot plume conditions.

The starting material was prepared as the oxide mixture in pyrolite composition after McDonough and Sun (1995) excluding minor components (MnO, K₂O and P₂O₅). Quench experiments were made at about 20-28 GPa and 1600-2200C for 2-10 hours using a Kawai-type 6-8 multianvil high-pressure apparatus at Gakushuin University. The starting material was packed with pressure calibrants (MgSiO₃ and pyrope) in a Re multi-sample capsule. A LaCrO₃ heater and a W5%Re-W26%Re thermocouple were inserted in a Cr₂O₃-doped MgO pressure medium. Phases of recovered samples were identified with microfocus-Xray diffractometer and SEM-EDS.

The mineral assemblages of MgSiO₃-rich perovskite (Mpv) + magnesiowustite (Mw) + garnet (Gt) + CaSiO₃-perovskite (Cpv) and Mpv + Mw + Cpv at 1600-2200C are stable at pressure range of 22-24 GPa and above 24 GPa, respectively. The mineral assemblage of ringwoodite (Rw) + Gt + Cpv at 1600C changes to that of Rw + Mw + Gt + Cpv at 1800-2000C, and Rw disappears perfectly above 2200C. From mass balance calculation of analyzed compositions of the phases, we found that Gt content increases with increasing temperature before and after formation of Mpv. We also calculated the densities in pyrolite at each temperature. The density of average pyrolite mantle (1600C) is higher than pyrolite plume (1800-2200C) across 660-km discontinuity due to increase in Gt content with increasing temperature. Therefore, we conclude that hot-plume ascending nearby 660-km discontinuity has positive buoyancy by the phase transitions.

Keywords: post-spinel transition, 660-km seismic discontinuity, mantle plume, pyrolite, post-garnet transition