Geophysical Research Abstracts
Vol. 16, EGU2014-8674, 2014
EGU General Assembly 2014

Effects of Iron and Aluminum on Phase Boundaries at 600-800 km Depths

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High-resolution seismic studies have reported complex discontinuity structures at 600-800 km depths. However, the origin of the structures have not been well understood. In order to understand compositional effects, we have measured the post-spinel, post-garnet, and post-ilmenite phase boundaries in $MgO-Al_2O_3-SiO_2$ (iron free) and $CaO-MgO-Al_2O_3-SiO_2-FeO$ (iron bearing) systems with pyrolitic oxide ratios. In-situ X-ray diffraction measurements were performed at 20-30 GPa and 1500-2300 K in the laser-heated diamond-anvil cell at the GSECARS and HPCAT sectors of the Advanced Photon Source. We use the Pt and Au pressure scales for the iron-free and iron-bearing compositions, respectively. The Pt and Au scales were calibrated with respect to each other in separate experiments. In most experiments, Ar was cryogenically loaded in the sample chamber as a thermal insulation and pressure transmitting medium, except for a few experiments where a KCl medium was used. At temperatures above 1900 K, the post-garnet transition occurs at higher pressures than the post-spinel transition in both the iron-free and iron-bearing systems. At lower temperatures, while the post-ilmenite transition occurs at nearly same pressures as the post-spinel transition in the iron-bearing system, the post-ilmenite transition occurs at slightly higher pressure (1 GPa) than the post-spinel transitions in the iron-free system. In the iron-free system, akimotoite is stable to much higher temperature (2300 K) than previously thought. In the iron-bearing system, the stability of akimotoite is limited to 2050 K. Our data indicate that Al partitions more into akimotoite than garnet in the iron-free system, which is the opposite to what has been found in iron-bearing systems. The high Al content in akimotoite seems to be responsible for the high-temperature stability of akimotoite in the iron-free system. The Clapeyron slope of the post-garnet boundary is greater by a factor of 2.5 in the iron-bearing system than the iron-free system, while the Clapeyron slopes of the other phase boundaries do not change. Our results suggest that lateral variations in Fe and Al may significantly change the mineralogy in the mantle transition zone. For example, a decrease in iron content will stabilize Al-rich akimotoite even at average mantle temperatures. An increase in iron content will limit the stability of akimotoite and make garnet more important in the mantle transition zone. The large positive Clapeyron slope (5 MPa/K) of the post-garnet boundary in iron-rich regions may allow more vigorous mantle flow across the boundary between the upper and the lower mantle.