Elastic wave velocities of Fe- and Al-bearing akimotoite by means of ultrasonic measurements

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Abstract

The Earth's transition zone between 410 and 660 km depth marks a region of transitional seismic wave velocities that increase rapidly with depth between the upper and lower mantle. Models for the mineralogy at the base of the transition zone, using a peridotitic mantle bulk composition, propose the stability of ringwoodite and majoritic garnet. However, by using the elastic properties of these two minerals to estimate the seismic wave velocities, the resulting longitudinal and shear wave velocities are much lower than those actually observed globally for this region. Larger wave velocities may be obtained if the temperatures at the base of the transition zone were lower than expected due to the presence of stagnating cold slab material. Lower temperatures, however, imply the possible presence of akimotoite, a MgSiO3 polymorph stable between 22 and 24 GPa and 1100 to 1700 ∘C. The elastic properties of the MgSiO3 endmember recently have been studied, however, no data are available for compositions relevant for the Earth's transition zone, i.e. containing some Fe and Al substitution. If it can be demonstrated that assemblages containing akimotoite reproduce the transition zone velocity structure, then this would have important implications for the thermal structure and consequently for the dynamics of the Earth's mantle. Three well-sintered polycrystalline akimotoite samples containing 10 mol% of Fe, 20 and 25 mol% of Al were synthesized in a multianvil apparatus at 25 to 27 GPa and 850 ∘C from glassy starting materials. All samples were double-sided polished and inserted into a modified 10/4 multianvil cell assembly equipped with a Re heater and a D-type thermocouple suitable to perform ultrasonic measurements. High pressure and temperature experiments were performed at 13 ID-D (APS) using an ultrasonic system to collect longitudinal and shear wave velocities of the different akimotoite compositions at different pressure and temperature points up to the actual stability conditions of akimotoite of 25 GPa and 1200 ∘C. Synchrotron radiation has been used to measure the exact sample length in-situ employing X-ray tomography and to determine the density of the akimotoite samples. The effect of Fe and Al substitution on the wave velocities of akimotoite will be discussed and compared to seismic reference models.

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