Acoustic velocities across the olivine – wadsleyite – ringwoodite transitions and the seismic signature of the 410 km mantle discontinuity

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Abstract

The phase changes of olivine (Mg,Fe)2SiO4 to its high pressure polymorphs, wadsleyite and ringwoodite, have long been associated with the seismic discontinuities observed at 410 and 520 km depth in the Earth's mantle. The position and thickness of these discontinuities potentially provide basic constraints on the temperature, chemical composition and water content of the mantle. A common practice is to infer these properties by comparing seismic observations with modeled velocities from equilibrium phase relations and elastic moduli of the individual phases. Here, we directly measured the evolution of velocities across the olivine phase changes in order to investigate the transient, *i.e.* time-dependent, processes of the transformation. We developed an experimental method that combines *in situ* X-ray diffraction and ultrasonic interferometry to follow the elastic wave velocities as a function of reaction progress, with a time resolution of _˜ 30 s. The experiments were carried out on the 1000 t multi-anvil press of the ID-13D beamline of the APS synchrotron (Chicago, USA). Samples were sintered polycrystalline powders of olivine with XFe=0.10 and XFe=0.52 composition, that have been reacted in the stability field of wadsleyite or ringwoodite at 7-12 GPa and 1000-1200 K. Measurements show an unexpected decrease in shear waves velocity at the onset of reaction, followed by a steady increase that correlates with the percentage of transformation. This velocity anomaly is coupled with an increase in attenuation as observed from amplitudes of S-waves echoes. We relate this softening at the early stage of transformation to the presence of the intermediate spinelloid phase, as observed in the pseudo-martensitic

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reaction mechanism. This velocity profile may help to explain the sharpness ($<$ 6 km) and reflectivity of the 410 km discontinuity that have long been difficult to interpret from phase equilibria alone.