High-pressure high-temperature single-crystal elasticity of iron-bearing wadsleyite: Reappraising the water sensitivity of seismic observables

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Abstract

The Earth's deep water cycle carries hydrogen into the mantle by subduction processes entailing the potential formation of deep hydrogen reservoirs throughout Earth's history. At depths between 410 km and 660 km, large amounts of water can be stored by the nominally anhydrous minerals wadsleyite and ringwoodite. Low seismic velocities are commonly accepted as an indicator for hydration as suggested by previous mineral physics experiments. The detection of hydrated regions within the transition zone by seismology, however, led to contradicting results. We present simultaneous sound wave velocity and density measurements on iron-bearing wadsleyite single crystals at high pressures supplemented by first experiments at combined high pressures and high temperatures. Direct comparison of our results with earlier work shows that both P-wave and S-wave velocities of anhydrous and hydrous iron-bearing wadsleyite converge at high pressure to become seismically indistinguishable at conditions of the transition zone. As a consequence, seismic tomography might be unsuitable to map water in the shallow transition zone. We further modelled velocity, density, and acoustic impedance contrasts across the 410-km seismic discontinuity and found that velocity contrasts change only slightly on hydration. Instead, our results suggest that impedance contrasts are more sensitive to hydration and hence that the reflectivity of the 410-km discontinuity might serve as a more reliable indicator for water in the transition zone.

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