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Comparative in situ X-ray diffraction study of San Carlos olivine: Influence of water on the 410 km seismic velocity jump in Earth's mantle

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Abstract

A comparative study of the equation of states of hydrous (0.4 wt% H_2O) and anhydrous San Carlos olivine (<30 ppm H_2O) was conducted using synchrotron X-rays up to 11 GPa in a diamond anvil cell (DAC) at ambient temperature. Both samples were loaded in the same high-pressure chamber of the DAC to eliminate the possible pressure difference in different experiments. The obtained compression data were fitted to the third-order Birch-Murnaghan equation of state, yielding a bulk modulus K_0 = 123(3) GPa for hydrous olivine and K_0 = 130(4) GPa for anhydrous olivine as K_0' is fixed at 4.6. Therefore, 0.4 wt% H_2O in olivine results in a 5% reduction in bulk modulus. Previous studies reported bulk modulus reduction by water in olivine's high-pressure polymorph (wadsleyite), to which the transformation from olivine gives rise to the seismic discontinuity at 410 km depth. The new data results in a reduction in the magnitude of the discontinuity by 50% in v_P and 30% in v_S (for 1:5 water partitioning between olivine and wadsleyite) with respect to anhydrous mantle. Previous knowledge of the influence of water on this phase transition has been in opposition to a large amount of water [e.g., 200 ppm by Wood (1995)] existing at 410 km depth. Calculation of the seismic velocities based on newly available elasticity data of the hydrous phases indicates that the presence of water is favorable for the mineral composition model (pyrolite) and seismic observations in terms of the magnitude of the 410 km discontinuity.

Keywords: High-pressure studies, equation of state, XRD data, hydrous olivine, San Carlos olivine, 410 km discontinuity, hydrogen, compressibility measurements