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Effect of structural water on the elasticity of orthopyroxene

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Abstract

As a major nominally anhydrous mineral (NAM) in the Earth's upper mantle, orthopyroxene could host up to several hundred parts per million H_2O in its crystal structure and transport the H_2O to the deep Earth. To study the effect of structural H_2O on the elasticity of orthopyroxene, we have measured the single-crystal elasticity of $Mg_{1.991}Al_{0.065}Si_{1.951}O_6$ with 842–900 ppm H_2O and 1.64 ± 0.20 wt% Al_2O_3 at ambient conditions using Brillouin spectroscopy. The best-fit single-crystal elastic moduli (C_{ij}s), bulk (K_{S0}), and shear (G_0) modulus of the hydrous Al-bearing orthopyroxene were determined as: C_{11} = 235(2) GPa, C_{22} = 173(2) GPa, C_{33} = 222(2) GPa, C_{44} = 86(1) GPa, C_{55} = 82(1) GPa, C_{66} = 82(1) GPa, C_{12} = 75(3) GPa, C_{13} = 67(2) GPa, and C_{23} = 49(2) GPa, K_{S0} = 111(2) GPa, and G_0 = 78(1) GPa. Systematic analysis based on the results presented in this and previous studies suggests that the incorporation of 842–900 ppm H_2O would increase C_{13} by 12.0(7)% and decrease C_{23} by 8.6(8)%. The effects on C_{11}, C_{22}, C_{33}, C_{44}, C_{66}, K_{S0}, and V_P are subtle if not negligible when considering the uncertainties. The C_{55}, C_{12}, G_0, and V_S are not affected by the presence of structural H_2O. Although laboratory experiments show that Fe,Al-bearing orthopyroxenes can host up to 0.8 wt% H_2O in its structure, future high-pressure-temperature elasticity measurements on orthopyroxene with higher H_2O content are needed to help better quantify this effect.

Keywords: Elasticity, orthopyroxene, structural water, seismic velocities