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Sound velocities of polycrystalline $MgSiO_3$-orthopyroxene to 10 GPa at room temperature

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ABSTRACT

A polycrystalline sample of $MgSiO_3$-orthopyroxene was hot pressed at a pressure of 4 GPa and temperature of 975 °C in a multi-anvil apparatus. The recovered specimen has a bulk density within 1% of the X-ray density and compressional and shear wave velocities within 1% of the Hashin-Shtrikman averages of the isotropic velocities calculated from the single-crystal elastic moduli. Compressional and shear wave travel times were measured at pressures up to 10 GPa at room temperature using the phase comparison method of ultrasonic interferometry in a 1000 ton uniaxial split-cylinder apparatus (USCA-1000). The velocities and elastic moduli monotonically increase with pressure; discontinuous behavior is not observed. Both the compressional velocity and bulk modulus, however, exhibit pronounced non-linear dependence on pressure. Fitting a fourth-order Eulerian finite-strain equation of state yield values of the bulk modulus and its first and second pressure derivatives, $K_0 = 104(2)$ GPa, $K_0' = 10.9(5)$, and $K_0'' = -1.6(2)\ \mathrm{GPa}^{-1}$. In contrast, the shear velocity and modulus are linear with pressure, yielding values of $G_0 = 74.9(1.5)$ GPa and $G_0' = 1.6(1)$, when fit to a third-order finite-strain equation of state. A P-V trajectory calculated from these continuous measurements of K vs. P to 8 GPa is in agreement with extant static compression data for this material, without requiring a discontinuous change in K at 4 GPa. The velocities of $MgSiO_3$-orthopyroxene increase more rapidly with pressure than those for Mg_2SiO_4-olivine (especially for P-waves), such that these two mineral phases are virtually indistinguishable in their velocities at 200 km depth, unless the velocity-temperature dependence of the two phases is dramatically different.