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High-pressure single-crystal elasticity measurements of Al-Fe-bridgmanite

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The chemical composition of Earth's lower mantle can be constrained by combining seismological observations with mineral physics elasticity measurements. However, the lack of laboratory data for Earth's most abundant mineral (Mg,Fe,Al)(Al,Fe,Si)O_3 bridgmanite has hampered any conclusive result. Here, we report single-crystal elasticity measurements on Al-Fe-bearing bridgmanite $(Mg_{0.9}Fe_{0.1}Si_{0.9}Al_{0.1})O_3$ to pressures above 40 GPa. The experimetns were conducted using in-situ high-pressure Brillouin spectroscopy and x-ray diffraction combined with advanced sample preparation that allows for the simultaneous loading of two single-crystals with different crystallographic orientations. Our measurements show that the elastic behavior of Fe-Al-bearing bridgmanite is markedly different from the behavior of the $MgSiO_3$ endmember reported previously.

Values and uncertainties of K_0, K_0', G_0 and G_0' as well as the elastic constants C_{ij} and absolute pressure values for all experimental points were derived using a global fit of all our experimental data, combining the usually employed Christoffel equation that relates elastic constants and density to direction-dependent acoustic wave velocities with the finite strain formalism.

We employ our data to model seismic wave velocities in the top portion of the lower mantle, assuming a pyrolitic mantle composition and accounting for depth-dependent changes in iron partitioning between bridgmanite and ferropericlase. We find excellent agreement between our mineral physics predictions and the seismic Preliminary Reference Earth Model down to at least 1200 km depth, indicating chemical homogeneity of the upper and shallow lower mantle. A high Fe^{3+}/Fe^{2+} ratio of about 2 in shallow lower mantle bridgmanite is required to match seismic data, implying the presence of metallic iron in an isochemical mantle. Our calculated velocities are in increasingly poor agreement with those of the lower mantle at depths $>$1200 km, possibly indicating a decrease in the ferric iron content of the lower mantle that has potential implications for geochemistry and geophysics.