Elasticity measurements on magnesium silicate perovskite and the chemical composition of the lower mantle

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The only rigorous method for determining the composition of the Earth's lower mantle is to compare experimental estimates for the S and P wave velocities of potential lower mantle assemblages with seismic observations. The dominant mineral of the Earth's lower mantle is likely to be magnesium-silicate perovskite. If the lower mantle has the same composition as the upper mantle, then silicate perovskite should also contain significant concentrations of Fe and Al. In addition evidence for lateral heterogeneities in the mantle could potentially arise from either chemical or thermal anomalies. If chemical anomalies exist these are most likely to arise from variations in the Fe and Al content of the mantle.

In this study simultaneous Brillouin spectroscopy and X-ray diffraction measurements have been performed in the diamond anvil cell to determine the densities and transverse and longitudinal acoustic phonon velocities of $(Mg,Fe)SiO_3$ and $MgSiO_3$ perovskite single crystals. Helium or neon was used as the pressure transmitting medium and experiments were performed in the pressure range from ambient to 31 GPa. Using data from two crystals of each composition with different non-specific orientations it is possible to obtain all 9 independent Cij elastic constants for orthorhombic symmetry at different pressures. Above 31 GPa the P wave signal from the sample becomes obscured by the diamond Vs peak. We compare these results with additional data on the elasticity of polycrystalline $MgSiO_3$ perovskite plus samples of the same phase containing Fe and Fe and Al obtained using ultrasonic interferometry in the multianvil. These measurements were performed up to 25 GPa and 1200 K. The results of both types of study have been integrating into a single model to interpret seismic wave velocities in the lower mantle in terms of temperature and composition.