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Experimental constraints on the crystallography and seismic velocity of calcium perovskite

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The Earth's mantle extends from the base of the crust all the way to the core-mantle boundary, some 2,891 km beneath our feet. Mantle convection and geodynamics, the driving force behind crustal recycling and degassing, have facilitated the evolution and maintenance of Earth's habitability over geological time. However, there are a dearth of direct samples from the deep mantle, such that we must instead interpret geophysical observations to gain insights into deep mantle properties. Arguably the most promising route to understanding the extent of chemical heterogeneity in the mantle is via careful comparison of observed seismic velocities with those predicted from mineralogical models of materials at the conditions of the Earth's deep interior. However, our available mineralogical models are simply not yet up to the task.

One issue in current mineralogical models are the lack of measurements constraining the seismic velocities of calcium silicate perovskite (Ca-Pv), which is the lower mantle's 3rd most abundant phase and comprises 5-30 vol.% of common rock assemblages. The main reason for this stems from the unrecoverable nature of perovskite-structured $CaSiO_3$, which undergoes spontaneous amorphisation during room-temperature decompression. In attempt to fill this gap we performed synchrotron-based experiments in the large-volume press that simultaneously measured the crystal structure and acoustic velocities of end-member, and Ti-bearing, Ca-Pv samples. Our results revealed that Ca-Pv samples undergo one, or two, symmetry reducing phase transitions upon cooling from high to low temperature conditions at high-pressure. Concurrent velocity measurements, collected using pulse-echo ultrasonic interferometry, revealed these phase transitions are associated with large anomalies in sample elasticity, large enough to create observable velocity anomalies if they were to occur in natural Ca-Pv. Additionally, when combined with literature data, our results imply that suggest that Ca-Pv has slower seismic velocities than predicted previously. In particular Ca-Pv has significantly slower velocities than those in the most widely adopted thermodynamic mineralogical datasets used by geophysicists. Ultimately the slow velocities of Ca-Pv mean that the seismic properties of the LLSVPs are consistent with long-lived piles of recycled oceanic crust material sitting upon the core-mantle boundary.

Core Mantle Coevolution

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