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Composition and Structure of Earth's Lower Mantle from Elasticity and Rheology Measurements

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In this contribution, we present results of two novel experimental data sets on the elasticity and rheology of lower mantle minerals and discuss how the results contribute to our understanding of the composition, structure and dynamics of the shallow lower mantle.

(1) We report first high-pressure single-crystal elasticity data on Al-Fe-bearing bridgmanite (Mg0.88Fe0.12Si0.89Al0.11)O_3, the dominant phase in Earth's lower mantle, using high-pressure Brillouin spectroscopy and x-ray diffraction on focused ion beam (FIB) cut samples in a novel self-consistent approach. We combine our elasticity data with previous experimental measurements of the phase assemblages and element partitioning in a pyrolitic mantle and present a mineral-physics based seismic profile of the uppermost lower mantle. Within the resolution of our model, we find excellent agreement of our mineral physics prediction with the seismic Preliminary Reference Earth Model up to at least 1000 km depth, indicating chemical homogeneity of upper and shallow lower mantle.

(2) We present results from synchrotron radial x-ray diffraction measurements on the deformation behavior of (Mg0.8Fe0.2)O ferropericlase, the second most abundant mineral in the lower mantle, at high-pressures and temperatures of up to 1400 K. From our data, we calculate the flow strength of ferropericlase, which we find to increase at pressures >20 GPa. Modelling based on our experimental data indicates a strong increase of viscosity around subducting slabs in the upper 900 km of a lower mantle with a pyrolitic composition. This viscosity increase takes place in the shallow lower mantle without the need for a compositional change with depth or a phase transition. It can therefore provide a plausible mechanism to explain the stagnation of sinking slabs in the shallow lower mantle as observed by seismic tomography that is consistent with the compositional constraints from our elasticity measurements on bridgmanite.