Title: Evaluating the Role of Iron-Rich (Mg,Fe)O in Lowermost Mantle Heterogeneity

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Abstract:

The core-mantle boundary is a region of great complexity, where extreme contrasts in material properties promote the persistence of multiscale structural heterogeneities. The thermo-elastic variations at the lowermost mantle play a dominant role in the evolutionary history of the Earth through regulation of heat flow and consequent influence over the dynamics of both the mantle and the core. Despite the centrality of this region in the development of the solid Earth system, many open questions remain regarding the characteristics, origins, and dynamical interactions of observed heterogeneities such as large thermochemical piles, ultralow-velocity zones, subducted slab material, and small seismic scatterers. Improvements in seismological observation over the past several decades have revealed large variations in the elastic properties, locations, and structural geometries of ultralow-velocity zones (ULVZs), leading to the development of a variety of proposed explanations for their causes, origins, and dynamics. Increased attention in recent years has been given in particular to the hypotheses of partial melt and iron enrichment in the (Mg,Fe)O solid solution. However, limited quantitative constraints on possible seismic signatures of such features and a lack of systematic comparisons against seismic observations have created significant difficulty in rigorously evaluating the likelihood of proposed explanations.

As part of developing a more comprehensive understanding of the potential role of iron-rich (Mg,Fe)O in lowermost mantle heterogeneities, with this study we measure the compressional behavior of $(Mg_{0.06}Fe_{0.94})O$ in a helium pressure medium at ambient temperatures using synchrotron x-ray diffraction at beamline 12.2.2 of the Advanced Light Source. We produce a well-constrained isothermal equation of state for this material and, with thermo-elastic information from previous studies, calculate the densities and velocities of iron-rich (Mg,Fe)O compositions at CMB pressure-temperature conditions. Using the most up-to-date measurements of other major lower mantle phases, we calculate properties of mineral assemblages containing iron-enriched (Mg,Fe)O in order to demonstrate the range of velocity and density space that can be reproduced by the presence of this mineral. In addition, we build a linear mixing model that combines uncertainty estimates from both seismology and mineral physics to give best-fit concentrations of iron-rich (Mg,Fe)O for individual ULVZ observations and apply this process to a diverse selection of ULVZs. Our work demonstrates the viability of iron-rich (Mg,Fe)O in accounting for a variety of ULVZ observations and, in doing so, develops a framework for systematic and rigorous evaluation of proposed hypotheses for lowermost mantle heterogeneity.