Elasticity and Thermally-induced Seismic Heterogeneity of Ferropericlase in the Earth's Lower Mantle

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Ferropericlase, the second most abundant mineral in the Earth's lower mantle, can contain up to 20% of iron in its lattice under lower mantle conditions. The partitioning of iron in lower-mantle minerals can cause both chemical and seismic heterogeneities in the deep Earth. Deciphering the chemically-induced from thermally-induced seismic heterogeneity has been one of the major challenges in understanding the chemical, dynamic, and seismic structures of the deep mantle. However, experimental elasticity study on single-crystal ferropericlase at relevant simultaneous pressure-temperature conditions of the lower mantle remains lacking. In this study, the single-crystal elastic properties of high-spin ferropericlase $(Mg_{0.94}Fe_{0.06})O$ were measured by Brillouin spectroscopy up to 40 GPa and 900 K with an externally-heated diamond anvil cell. At 300 K, the elastic properties are in excellent agreement with those reported from the sample containing 6% of iron (Jackson et al., 2006). High pressure and high temperature Brillouin data were fitted using third-order finite-strain equation of state, yielding temperature and pressure derivatives of single-crystal elastic constants, which allow us to extrapolate the data to representative geotherm conditions by using thermoelastic modelling. Our modeled results show that from 660 km to 2000 km, V_P anisotropy is enhanced from 4% to 9.7%, shear anisotropy increases from 9% to as high as 22.5% in the Earth's lower mantle. Thermally induced lateral heterogeneity ratio $R_{S/P} = \partial \ln V_S / \partial \ln V_P$ of ferropericlase was calculated to be 1.48 at 0 GPa and 1.43 at 40 GPa along a geotherm. Incorporating with reported data of bridgmanite (Li and Zhang, 2005), thermally induced lateral heterogeneity ratio of the simplified pyrolite model which consists of 80% bridgmanite and 20% of ferropericlase was modeled and compared with major seismic models, which show consistency above 1500 km, but disagreement at the depth of the mid-lower mantle.

The discrepancy in heterogeneity ratio is likely due to a contribution from chemically-induced lateral heterogeneity, or an effect from iron spin transition in the Earth mid-lower mantle.

Reference:

Jackson, J. M., S. V. Sinogeikin, S. D. Jacobsen, H. J. Reichmann, S. J. Mackwell, and J. D. Bass (2006), Single-crystal elasticity and sound velocities of ($Mg_{0.94}Fe_{0.06}$) O ferropericlase to 20 GPa, *Journal of Geophysical Research*, *111*

Li, B., and J. Zhang (2005), Pressure and temperature dependence of elastic wave velocity of MgSiO3 perovskite and the composition of the lower mantle, *Physics of the Earth and Planetary Interiors*, *151*(1–2), 143-154