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Ferropericlase layering as potential cause for seismic anisotropy in Earth's lower mantle?

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Seismic anisotropy in the Earth is indicative of regions where significant deformation takes place and usually reflects the presence of crystallographic or shape preferred orientations (CPO and SPO) of crystals induced by strain. The lower mantle is considered to be a quasi-isotropic medium for the propagation of seismic waves, and seismic anisotropy seems to be restricted to its lowermost portion, known as the D"-layer. The cause of this anisotropy is a matter of debate. In "cold" regions above the core-mantle boundary (CMB) it has been shown that the development of CPO of both postperovskite (pPv) and ferropericlase (Fp) may cause significant VSH>VSV shear wave splitting.

The modeling of D" anisotropy, based on the preferred orientation of these phases and their respective single crystal elastic properties, usually considers the effect of each mineral separately. However, it has been shown on crustal rocks that, in polymineralic aggregates with pronounced rheological contrast between the phases, the weakest phase tends to accommodate most of the strain. In regions of high strain, this can cause solid-state layering. Ferropericlase appears to be the weakest phase in a typical lower mantle assemblage and thus could form "channels" in regions of very high strain in the D"-layer. To test the effect of potential solid-state ferropericlase layering in a matrix of Perovskite (Pv) or pPv on seismic observables, we have applied differential effective medium (DEM) modeling based on recently reported elastic constants of Pv, pPv and Fp. The DEM modeling is based on the introduction of a fluid or solid inclusion as an elastic medium in a homogeneous background. Here, we consider a background of spherical random crystals of Pv/pPv and inclusions of ferropericlase with varying amounts of iron and different aspect ratios varying from 2:2:1 to 50:50:1. For a typical lower mantle assemblage that consists of 80% perovskite and 20% ferropericlase, where the ferropericlase contains 20-30% of Fe, an aspect ratio of about 10:10:1 is required to produce a shear wave splitting of about 1-1.5%, consistent with seismological observations. However, if ferropericlase is enriched in iron as proposed for "hot regions" (low velocity zones) at the CMB, the aspect ratio of the layering needed to produce visible seismic anisotropy is significantly reduced. In a deformation environment that is dominated by horizontal flow, such as the cold D" regions, this layering could be parallel to the CMB. The resulting shear wave splitting would be of a VSH>VSV type, consistent with seismic observations. In regions that are dominated by vertical flow, such as plumes, the ferropericlase grains would be orientated vertically, inducing a more complex seismic pattern characterized by azimuthal anisotropy.