Anisotropy in D″ beneath the Caribbean and Central America from shear wave splitting measurements

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Whilst the majority of the Earth's lower mantle appears to be relatively homogeneous, by contrast the few hundred kilometres above the core-mantle boundary (CMB) are host to a region of probable large chemical and thermal heterogeneity. Seismic observations of this by Lay and Helmberger (Geophys. J. R. astr. Soc., 1983) among others include a large increase in S-wave velocity (the D″ discontinuity) that can vary in depth laterally over distances of less than 100 km —and which may not be present at all in some areas. Also present in many places is significant seismic anisotropy (the variation of wavespeed with direction), which gives rise to the polarisation and subsequent splitting of shear-mode body waves into orthogonal fast and slow components. This shear wave splitting can be quantified by seismic observations of S waves that have traversed the lowermost mantle, and might constrain processes such as slab deformation, mantle phase transformation and thermal upwelling.

The most recent candidate to explain some of the seismic features of the D″ region (including its anisotropy and bounding discontinuity) is the experimentally observed transformation of $MgSiO_3$-perovskite to a post-perovskite structure at near CMB pressures and temperatures. As the phase change has a positive Clapeyron slope, regions where the geotherm is colder than average at the CMB—such as areas beneath long-term subduction—should show evidence of such a discontinuity and, depending on the alignment of mantle minerals or other structure, should also exhibit seismic anisotropy. Studies by, for example, Kendall and Nangini (GRL, 1996) show that the D″ discontinuity is present beneath the Caribbean and that its depth varies between about 250 and 290 km above the CMB.

We study the D″ region beneath the Caribbean and Central America using S and ScS phases from two deep-focus earthquakes with magnitude greater than M_W 5.6 and depths below 550 km. By comparing the splitting parameters of the two phases and thus correcting for anisotropy in the signal introduced in the upper mantle, we obtain measurements of splitting in ScS alone; hence measuring the anisotropy in the lowermost mantle. The S and ScS phases are detected on around 430 seismic stations in Canada and the US, yielding over 250 measurements of anisotropy in D″. The measurements cover an area ~2,000 km square centred on the CMB beneath the Caribbean. They show a small but detectable departure from the expected first-order transverse isotropy with a vertical axis of symmetry (VTI), which may be explained in terms of the same but with a tilted axis of symmetry (TTI). Beneath Central America, the sense of dip of the plane of transverse isotropy is to the east by a few degrees; beneath the eastern Caribbean, the dip is to the west, again by a few degrees. Waveform studies by previous authors agree with our results (for example, Maupin et al., JGR, 2005). Our interpretation (similarly to previous studies) of these features proposes that this is a result of the dynamics of the interaction of slab material with that already present at the base of the mantle, leading to deformation into 'ridges' aligned roughly perpendicular to the direction of palaeo-subduction over short scales (~100 km and less) and the subsequent alignment of the crystals, melt pockets or other features which give rise to the TTI.