Structure and dynamics of the lowermost mantle from seismic anisotropy

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The lowermost mantle (a.k.a. D") is an enigmatic and important region of the Earth. As the interface between the core and the mantle its properties place significant boundary conditions on the dynamics and evolution of the two systems. Among the lowermost mantle's anomalous seismic properties are large velocity heterogeneity, the observation of reflected S- and P-wave energy, and strong - in places complex - anisotropy. Recent years have seen a stepwise improvement in the imaging of these features. This is driven by a number of factors, including the vast new resources of data that are available. Improved observational data is being matched by new constraints from experimental and computational mineral physics.

For nearly two decades the anisotropy of this region has been studied using shear-mode body wave phases. The most common technique applied is the measurement of shear-wave splitting. Until recently this was done primarily by measuring differential travel times between radial and transverse components of phases such as S, ScS and Sdiff. For this to be valid, the anisotropy must be assumed to be transversely isotropic (TI). This has been fairly successful in mapping broad anisotropic structure in D". More recently some groups have developed techniques of to allow for more general forms of anisotropy (e.g., Garnero et al, Science, 2004; Wookey et al, GJI, 2005). These techniques have also had to address the issue of anisotropy in upper mantle overprinting that from D", which is generally done using a reference phase which does not transit the lowermost mantle (for example, differential S-ScS splitting; Wookey et al, GJI, 2005). This also permits the use of shallow events. These studies have found anisotropy which, to various degrees, differ from simple TI. The dynamical inferences possible from these studies, however, is limited as they only image the lowermost mantle from a single azimuth. New studies, however, image regions where more than one data azimuth is available (Wookey and Kendall, EPSL, 2008; Nowacki et al, AGU, 2009). These allow the accurate resolution of tilted-axis transverse isotropy (TTI), and potentially even more general symmetries. Both these regions show a dipping anisotropy (30-40 degrees, assuming a TTI mechanism). The strike of the dip in both cases is well correlated with structure observed in tomographic images of the regions. These structures have been postulated to be associated with the presence of palaeosubducted material at the core mantle boundary, an explanation which provides plausible anisotropy mechanisms in the presence of post-perovskite or melt. These results show the potential for the inference of dynamics using seismic anisotropy. Future work will involve applying these techniques to a much more global, long-period dataset (Houser et al, GJI, 2008).

Images of the D" discontinuity have also radically improved. In many places rather than a discrete discontinuity, complex packages of reflectivity are observed (e.g., Van der Hilst et al, Science, 2007; Hutko et al, Science, 2009). Continuing experimental work has suggested that when elements like Fe are considered the perovskite to post-perovskite phase boundary is broadened to seismic invisibility (Catalli et al, Nature, 2010). One possible way around this is the suggestion that reflectivity is enhanced by the texturing of D" minerals. Velocity models inferred from ab initio calculated elasticities show that discontinuities in the texturing of post-perovskite effect significant reflectivity in both P- and S-waves; equivalent to those associated with isotropic phase changes. Preliminary results (Thomas et al, AGU, 2009) from beneath the Caribbean and beneath Eurasia show amplitude variation compatible with these models. If this is the case, the apparent structure and dynamics of the lowermost mantle may be more intimately connected that we have hitherto suspected, and multiazimuth studies of reflectivity might provide another dataset to probe dynamics and mineralogy of the base of the mantle.