28 Trust but Verify: a spot check for the new stratified model of upper mantle anisotropy beneath North America

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28.1 Research Summary

A newly developed 3D model of radially and azimuthally isotropic shear wave velocity beneath the North American continent (Yuan et al., 2011; referred to as YR11 hereafter) resolves a long-standing argument regarding the provenance of seismic anisotropy (e.g., Silver, 1996; Vinnik et al., 1984) with directional dependency of wave speed placed into both the lithosphere and the asthenosphere. As YR11 shows, the anisotropy domain of the North American continent is strongly stratified; large amplitude anisotropy domains are observed in both lithosphere and asthenosphere, suggesting that contributions to the core-refracted shear wave SKS splitting come from both lithosphere and asthenosphere.

Due to the continent-wide coverage, the new model has lateral resolution on the scale of 500 km and is expected to average, and thus possibly misrepresent, the structure in regions with abrupt lateral changes in properties. One such region is the New England Appalachians, where rifting and paleo-ocean closure have significantly reworked the passive continent margin (e.g., Thomas, 2006). The local tomography studies suggest a thin lithosphere (∼100km) in the region (e.g., Li et al., 2003). This view is also supported by the P and S receiver function (RF) studies (e.g., Abt et al., 2010).

On the other hand, azimuthal anisotropy in this region in YR11 shows in general a two-layered upper mantle (Fig. 2.52): a thick upper layer (>150 km; with peak around 80 km) with the anisotropy direction at high angle to the plate motion (APM; Gripp and Gordon, 2002); and a deeper layer (>200km) whose anisotropy direction appears APM parallel (Fig. 1). This two-layered fast axis direction pattern is consistent with one of the earliest cases for stratified anisotropy built on data from this part of North America (Levin et al., 1999), however the lithosphere thickness inferred from the abrupt depth dependent anisotropy is thicker than other studies.

We conduct two-layer single station shear wave splitting modeling at station HRV, and anisotropy P-receiver function analysis at the stations. Compared to the long period surface waveform modeling, these techniques have complementary sensitivity to the upper mantle anisotropy structure, therefore can provide high-quality constraints on the vertical and lateral variation in attributes of anisotropy. We compare (and contrast) these constraints with structure predicted for this location by the YR11 model. Our goals are both to test the new model in one place, and to develop a strategy for such testing.

![Figure 2.52](image-url) 1D azimuthal anisotropy strength (top left) and anisotropy angular difference with respect to the APM, averaged from model nodes (green dots) in the maps below, which shows the two-layer equivalent apparent fast axis directions (blue sticks) predicted from YR11 model: lithosphere, lower left; and asthenosphere, lower right. Red arrow shows the APM.

28.2 Results and Conclusions

We find ample evidence for sharp gradients in anisotropy within the upper mantle beneath northeastern North America. The depths where these gradients occur are consistent with the region of abrupt vertical change in anisotropic parameters of the new 3D model. Orientations of the symmetry axes suggested by polarity changes in receiver functions (Fig. 2.53) also agree with the model. Individual measurements of splitting in SKS phase from HRV vary with backazimuth, forming a characteristic π/2 pattern (Fig. 2.54) that is well represented by two layers of anisotropy. This result confirms Levin et al. (1999) results with vastly larger amount of data. We find it very gratifying that parameters of anisotropy within the layers generally agree with both the new model and the old study. Orientations of fast anisotropic axis at ~100 km depth suggested by the two methods are in good agreement as well: 100SE from SKS (Fig. 2.55) and 110-130 from RFs (Fig. 2.53).

We can thus infer that the fabric below~100 km is indeed aligned with plate motion, and that the transition from this fabric to another is abrupt. This transition may indicate a shallow LAB in the region, as evidenced by the negative velocity gradient following the orogenic trends.
Figure 2.53: Receiver function azimuthal stacks at station HRV. Left radial component; right transverse component. Note change of polarity occurs around 10 sec (circled).

Figure 2.54: Model prediction (red curves, YR11) and data measurements for individual events, plotted against event back-azimuth. Measurements from Levin et al. (1999) model synthetic waveforms are plotted for comparison.

and the hotspot track shown in the updated shear-wave model of YR11 (Fig. 2.56).

28.3 Acknowledgements

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28.4 References


Silver, P. Seismic anisotropy beneath the continents; probing the depths of geology, Annu. Rev. Earth Planet. Sci., 24, 385-432, 1996.


