Now you see it, now you don't: Seismic signals of an iron spin transition in the lower mantle

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Unambiguous seismic detection of an iron electron spin pairing transition in (Mg,Fe)O ferropericlase (Fp) would yield an important constraint on lower mantle composition because the presence of Fp requires that (Mg+Fe)/(Si-Ca)>1 (e.g., as required for pyrolite or harzburgite). The absence of a clear signal of this transition in global seismic profiles could be taken to mean that (1) a substantial portion of the lower mantle is Si-enriched relative to pyrolite, (2) seismological resolution is insufficient, and/or (3) the predictions of mineral physics are inaccurate. After years of double-checking (2) and (3) we are seemingly left with option (1). Nevertheless, we also have a variety of evidence that subducted lithospheric slabs penetrate into the lower mantle and at least some of this material is later recycled back to the shallow mantle. Slabs are harzburgite sandwiches and should contain enough Fp to manifest a detectable spin transition, so we focused our efforts on interrogating the characteristics of fast velocity anomalies in the lower mantle. We found that S wave tomography models resolve fast material continuously with depth but P wave models have a drop-off in detection of strong fast anomalies at the range of depths expected for the spin change, consistent with predictions of a spin transition in Fp. When we looked at slow mantle we found a more subtle feature similar to that in fast regions. On the other hand, we have been unable to detect any clear decoupling between S and P behavior in ambient (moderate seismic velocity) mantle. The sum of these observations suggests that the lower mantle has strong lateral variability in (Mg+Fe)/(Si-Ca), and this might explain why the spin change is absent in global models because average mantle is relatively Si-rich and contains to little Fp to produce a clear signature. Our findings are broadly consistent with the proposal that large highly viscous regions called bridgmanite-enriched ancient mantle structures (BEAMS) stably reside in the mid-lower mantle and organize the pattern of deep mantle convection over billions of years. An important remaining question concerns the origin of large scale Si-concentration variations and connection (or lack therefore) with isotope anomalies.