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Upper-mantle discontinuities and gradients: Their origin, seismic expression and geodynamic significance

S. Lebedev (1)
Utrecth Univ. (sergei@geo.uu.nl)

Phase transformations within the Earth's upper mantle give rise to a number of relatively sharp increases in density and seismic velocities with depth. Different phase transformations occur over different depth intervals, from a few kilometers wide to a few tens of kilometers and more. The properties of these gradients are inferred primarily from observations of seismic waves that scatter at them. Seismic waves at different periods, however, sample the same gradients differently: what is a reflector (apparent discontinuity) for a long-period wave can be a transparent, gentle gradient for a short-period one. And, thus, the catalogue of discontinuities thought to be present in the upper mantle may vary from one worker to another depending, in part, on the period range that they use.

Yet, the depth interval of a phase transformation will have an unambiguous effect on the flow in the mantle. A downwelling or upwelling feature of a few tens of kilometers across is likely to interact differently with a gradient zone that is as thick as the feature itself and with a gradient zone that is much thinner. This motivates us to review recent evidence for the occurrence of global discontinuities and gradients.

Sharp, global discontinuities occur near 410 and 660 km depths, most likely due to phase transformations in olivine structure. Sightings of signal from multiple discontinuities near 660 km depth in receiver functions have been reported and attributed to the low-temperature transformations from garnet to ilmenite to perovskite. The signal from conversions at these hypothetical discontinuities, however, is conspicuously absent in the waves arriving from within the cold NW-Pacific slab beneath NE China. This suggests that the various reflectors commonly observed below 660 km in subduc-

tion zones indicate small-scale heterogeneity, possibly brought about by subduction, rather than global or subduction-zone-scale discontinuities. As for the ilmenite phase transformation, they are likely to occur over broad depth intervals of many tens of kilometers, in agreement with lab measurements. The depth interval of the garnet-perovskite transformation is also broad, comparable to the thickness of a subducting slab.

In the shallow mantle, the Hales discontinuity near about 80 km depth has been postulated and attributed to the transition from spinel peridotite to garnet peridotite. The increase in seismic velocities with depth at 50–120 km depth is confirmed by surface-wave observations. No sharp discontinuity, however, is required by any seismic data, suggesting that a "Hales gradient" may be present instead, influencing lithospheric dynamics of oceans and young continents.