Important influences of depth-dependent lower-mantle properties on the formation of a plume-fed asthenosphere in the upper mantle

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Asthenosphere is an old geological concept based on uncanny intuition of Reginald Daly in the 1920's. to explain surface geological observations with underlying mobility in mind.

The idea of a plume-fed asthenosphere has been around for a few years due to the ideas of Phipps-Morgan and his father Jason Morgan. Basiclly this calls for a dynamically induced mechanism instead of partial melting or a mineralogical phase change. Using a two-dimensional Cartesian code based on finite-volume method, we have investigated the influences of lower mantle physical properties on the formation of a low viscosity zone in the upper mantle in regions close to a large mantle upwelling. The rheological law is Newtonian and has both temperature- and pressure-dependences. An extended Boussinesq model is assumed for the energetics and both the spinel to perovskite and perovskite to post-perovskite phase transitions are considered. We have compared the differences in the behavior of hot upwellings passing through the transition zone in the mid-mantle for a variety of models, starting with constant physical properties in the lower-mantle and culminating with complex models which have the post-perovskite phase transitions and depth-dependent properties of both the thermal expansion coefficient and the thermal conductivity.

We found that the formation of the asthenosphere in the upper mantle in the vicinity of large upwellings is only possible in models where both depth-dependent thermal expansivity and thermal conductivity are included. The constant thermal expansivity and costant thermal conductivity models fail to deliver a hot low viscous zone, resembling the asthenosphere. Our findings argue for the potentially important role played by lower-mantle material properties on the development of plume-fed asthenosphere in the oceanic upper-mantle.