Super-weak asthenosphere in light of plate motions and azimuthal anisotropy

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Plate motions and azimuthal seismic anisotropy from surface waves are consistent with a strong, oceanic lithosphere that is predominantly dragged by slabs, and weakened upon subduction. Plates are underlain and sustained by a moderately weak asthenosphere, as expected from the temperature and pressure dependence of olivine viscosity for the upper mantle. However, recent observations from active source seismology, magneto-tellurics, body wave anisotropy, and postseismic surface deformation can be interpreted to imply the existence of a very weak channel of low viscosity material, potentially decoupling plates, not unlike a plume-fed asthenosphere scenario in several ways. Here, I explore the implications of such a decoupling channel for plate driving forces as well as observations of seismic anisotropy. The thickness and viscosity reduction of the channel are expected to trade off with each other, and plate motions are sensitive to the lateral extent of this super-weak asthenosphere. While there is some ambiguity of plate motion metrics with the strength of slabs, seismic anisotropy is expected to be sensitive to how shear is localized with depth. The overall good fit of azimuthal anisotropy patterns to flow model predictions brakes down for a number of the more extreme lateral and depth-dependent viscosity scenarios. This may imply that weakening mechanisms may not apply globally under plates, but are rather limited to isolated regions, perhaps associated with melt-rich pockets that have limited connectivity.

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