Geophysical Research Abstracts
Vol. 21, EGU2019-7567-1, 2019
EGU General Assembly 2019

Seismic observations of upper mantle discontinuities, and their petrological and dynamical interpretation

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The transition zone discontinuities at 410 and 660 km separate the upper mantle from the lower mantle. Their characteristics determine the style of mantle convection in the Earth and can be used to infer mantle temperature and composition. Here, we study the seismic signature of the transition zone discontinuities by stacking large collections of seismic SS, PP, P'P' and Pds phases. The long period SS and PP precursors are sensitive to wide discontinuities and velocity gradients, while short period P'P' can only detect sharp discontinuities. Converted Pds phases (or receiver functions) can be studied at a large range of frequencies. In general, we find that seismology and mineral physics agree on the level of complexity at the transition discontinuities: a simple 410, a more complicated 520 and a highly complicated 660-km discontinuity are consistently found in both disciplines.

We find that the 410 km discontinuity is seen in most long period SS, PP and Pds data types, but becomes more difficult to observe in short period P'P' data. This might be due to the influence of water which broadens the olivine to wadsleyite phase transition, which in some cases also makes the 410 invisible in long period Pds data. The 510 and 660 km discontinuity show much more complexity, which is due to combined garnet and olivine phase transitions leading to seismic observations of multiple discontinuities. The garnet phase transitions also change the traditional expectation of a thin transition zone in hot regions and a thick transition in cold regions.

Additional discontinuities are also seen in the upper mantle. The Lehmann discontinuity at 220 km depth appears to be related to a change in deformation mechanism from dislocation to diffusion creep and might be related to the lithosphere-asthenosphere boundary in some continental regions.