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Lithospheric Structure from Combined Seismological and Experimental Models

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Combining global shear velocity and attenuation models with forward calculated properties based on experimental data can provide a powerful tool to investigate the physical state of the upper mantle. On the experimental side we have extensively re-calibrated our assembly for measurement of shear modulus and dissipation at high temperatures and seismic frequencies. The improved resolution at low levels of attenuation reveals a plateau in attenuation at temperatures below 1000ºC, which may be attributed to elastically accommodated grain boundary sliding.

Forward modeling of the experimental results to construct velocity-depth profiles for geotherms calculated from from surface heat flow measurements and crustal and lithospheric heat production does not produce discontinuities which could explain the sharp velocity contrasts inferred from receiver functions in stable continental interiors. Moreover, at a depth of about 100 km at which the discontinuities are observed, shear velocities in excess of 4.6 km/s require temperatures below 1000ºC. As anelastic and viscous processes are closely related at the grain scale, and both are strongly temperature dependent, such low temperatures imply viscosities commonly associated with lithospheric plates. Velocity-depth profiles as well as global models therefore indicate that the thermal/mechanical LAB for continental interiors should be significantly deeper, below 200 km for cratons.

A possible resolution of the seemingly conflicting interpretations of receiver function and surface wave models for cratons maybe related to the volatile content of the lithosphere and the resulting phase diagram. Green and coworkers have shown that amphibole is stable to pressures corresponding to about 100 km depth at temperatures below 1000ºC. According to their work, in the amphibole stability field water is partitioned into amphibole. The shear modulus of amphibole is somewhat lower than that of olivine, but a significant amount is required to affect the shear velocity of the bulk rock. At the depth of amphibole breakdown, the bulk rock water storage capacity is sharply reduced, leading to the occurrence of a volatile rich fluid phase for water contents above about 100 ppm. This may cause a relatively sharp, local decrease in velocity for a smooth geotherm, imaged with receiver function studies, but not seen by the much lower resolution of surface wave studies. This velocity contrast then is internal to the lithosphere (mid-lithospheric discontinuity) as defined by temperatures inferred from surface wave and attenuation models.