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Experimental and modeling constraints on the seismic structure of oceanic lithosphere

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Seismological techniques provide different views of the structure of the oceanic upper mantle. Surface waves can not resolve sharp changes in velocities with depth, but provide absolute velocities. Receiver functions are sensitive to sharp changes, but these steps in velocities have to be reconciled with absolute velocities. Experimental measurements of seismic properties can be used to translate velocities into a physical state and to explore possible mechanisms for sharp changes. Current experiments at elevated pressures and temperatures are designed to resolve the onset of the deviation from elastic behavior at temperatures above 600°C. Initial experiments with copper jackets, which avoid the interference from phase transitions in mild steel, confirm the existence of a plateau in dissipation in olivine that is due to the grain-scale process of elastically accommodated grain boundary sliding. As this mechanism is solely due to temperature it occurs everywhere in the thermal boundary layer, although the sharpness will depend on the temperature gradient.

Forward modeling of seismic velocities with the experimentally determined properties predict velocity gradients in the thermal boundary layer that are not sharp enough to generate receiver functions. However, particularly for younger oceanic lithosphere these gradients only need to be enhanced by a relatively small amount by other factors. Possible mechanisms include the presence of melt and/or volatiles. For older oceanic lithosphere small scale convection may steepen the temperature gradient beneath the lid. We are currently conducting numerical models with experimentally derived rheological parameters with the aim to determine the thermal structure and calculate seismic velocities from it. If operative, small scale convection may also lead to cooling of the whole upper mantle as a function of age.

In the upper part of the lithosphere seismologic observations imply a constant, high velocity lid. This contrasts with decreasing velocities required by the increasing temperature in the thermal boundary layer. In more detail, the top of the high velocity lid is slower than predicted based on olivine elastic parameters. A possible explanation is a significant proportion of plagioclase in the top of the lid which decreases with depth to counter the effect of temperature.