High temperature phase transitions and the origin of the upper mantle low velocity zone

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The low velocity zone (LVZ) is a widespread seismologic feature of the oceanic upper mantle that has been often interpreted as a partially molten zone. Significant melt fractions are required to account for anomalously low shear velocities, large attenuation and low viscosities in this region. Alternative models imply attenuation through dissipative mechanisms such as viscous creep or melt flow at grain boundaries. However, seismic observations suggest that it is difficult to reconcile the magnitudes of anelastic shear wave speed reduction and attenuation with such mechanisms Some mineralogical models have shown that LVZ can be accounted for by elasticity of dry rocks along geotherms away from the mid-oceanic ridges. These models did not take into account high temperature phase transitions in orthopyroxene. We use in situ Brillouin and Raman spectroscopy to show that enstatites undergo phase transition or pre-transitional behavior at high temperature. Pre-transitional behavior induces a large softening of the elastic and low frequency modes, resulting in a large decrease of sound velocities in hot zones of the upper mantle. Elastic softening of orthopyroxene softening should therefore significantly contribute to the LVZ in seismic profiles. A simple model is constructed to evaluate possible elastic softening effects on the upper mantle seismic properties. Results depend much on the poorly constrained pressure and compositional dependence of the phase transition boundary. Within the tested range of parameters, orthopyroxene softening may contribute to LVZ in the oceanic upper mantle down to 300 km, and is likely to affect the seismic properties of shallow mantle rocks (down to 100 km) near mid-ocean ridges and hot spots.

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