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H_2O storage capacity of the upper mantle and melting atop the 410 km discontinuity

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There is considerable evidence that partial melts are stable in regions of the upper mantle that are deeper than the plausible locus of dry melting of peridotite, and this is widely recognized to mean that volatile-enhanced melting is a common phenomenon in the convecting upper mantle. Among the most enigmatic of these regions are low shear-wave velocity regions atop the 410 km discontinuity, which are widespread regional features. Numerous seismic studies, principally using receiver functions and ScS reverberations, have detected anomalously slow regions in the 20-80 km thick interval above the 410 km discontinuity. Because these regions are commonly 3-8% slow relative to reference models, it is difficult to explain them without the presence of interstitial melt. Alternative explanations, such as enhanced hydration of nominally anhydrous minerals, do not seem to be able to account for the magnitude of the observed anomalies. Many, though not all, of the low velocity zones are associated with regions of present or recent subduction, suggesting that they mark regions of partial melt incited by advection of recycled volatiles into the upper mantle. H_2O and CO_2, alone or in combination, may be capable of inciting partial melting at these depths. Because the convecting mantle is reduced at these depths, and because CO_2 solubility in melts under reducing conditions is very small, CO_2 contributes negligibly to melt stabilization unless the low velocity regions are anomalously oxidized. Thus, hydrous melting is the most likely explanation for the observations.

Hydrous melting atop the 410 km discontinuity can occur if the local concentration of H_2O exceeds the storage capacity of peridotite. The storage capacity is the maximum concentration of H_2O that can be held in the nominally anhydrous minerals at a given temperature and pressure for the chemical system of interest. A critical point, therefore, is that the storage capacity will depend on the diversity and compositions of phases present. The concentrations of H2O that can be stored in olivine at 12-14 GPa along the mantle adiabat approach 0.5 wt.%, but the presence of the full peridotite mineral assemblage stabilizes partial melt at diminished H2O activity and severely reduces the H_2O storage capacity. New experiments conducted at 10-13 GPa indicate that olivine saturated with peridotite and with hydrous partial melt has 500-1800 ppm H_2O. These concentrations are similar to those that might be expected in recycled oceanic lithosphere at TZ depths or in plumes and are consistent with the hydrous melting hypothesis to explain regional observations of LVZ at 410 km. However, they are considerably greater than concentrations in typical convecting mantle sampled at ridges, and are therefore inconsistent with a global layer of melt at 410 km. Remaining challenges include accounting for the unexpectedly great thickness of observed layers, and constructing a petrologically and dynamically consistent explanation for the magnitude of shear wave anomalies, which are not easily reconciled with the fractions of melt that are petrologically likely or dynamically stable.

キーワード: Transition Zone, 410 km discontinuity, hydrous melting
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