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Probing asthenospheric double-layered melt structure using basaltic Y/Yb ratios

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Partial melts in the Earth's convecting mantle influence its physical and chemical state, particularly the plasticity of the asthenosphere and the dynamics of plate tectonics. Basaltic melt compositions change systematically with the depth of mantle melting. Experimental and theoretical studies find that Yttrium (Y) and Ytterbium (Yb) are concentrated in garnet at pressures of <10 GPa, and garnet/melt ($D_{Y,Yb}^{garnet/melt}$) and clinopyroxene/melt ($D_{Y,Yb}^{cpx/melt}$) partition coefficients for Y and Yb decrease with pressure (and temperature)[1,2], but both show nearly identical geochemical behavior with negligible Y/Yb fractionation during planetary differentiation, mantle degassing and rock alteration[2]. It was also noted that, with increasing depth, the lower Y/Yb bulk partition coefficient leads to melts with increasing Y/Yb[2]. A quantitative link between basaltic Y/Yb ratios and LAB/LVZ depth were established by compiling Y/Yb ratios of basaltic lavas from both oceanic and continental settings and published estimates of geophysically determined depths of the lithosphere-asthenosphere boundary (LAB) or low velocity zone (LVZ). The depth of mantle melting can thus be estimated by basaltic Y/Yb ratios. The estimated depth using our approach agrees well with the method reported by Sun and Dasgupta[3], who used the newly developed liquid composition-based thermobarometer and primary melt correction scheme. Using our established relationship between basaltic Y/Yb ratio and the depth of LAB/LVZ, we find that a bimodal Y/Yb distribution is widespread in oceanic and continental basalts, consistent with two distinct depths of melt accumulation in the asthenosphere (80–110 km and 140–165 km, respectively). This suggests that a double-layered melt structure may be more widespread in the asthenosphere than previously thought, particularly in areas of active or passive mantle upflow.

References

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