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The Death of Slabs and Segregation of Basalt at the Core Mantle Boundary: Influence of Crustal Thickness, Viscosity and Thermal Conductivity

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Segregation of subducted mid-ocean ridge basalt (MORB) at the CMB has been identified as a potentially important mechanism in the long-term evolution of the mantle and core, which may lead to the accumulation of dense piles that explain seismically-observed LLSVPs. Tackley [2011] presented three-dimensional (3-D) and two-dimensional (2-D) simulations of a compositionally-stratified slab reaching the CMB, which will be summarised and extended here. The goals are to characterise the resulting thermo-chemical-phase structures for comparison with seismic studies, and to quantify the fraction of MORB that is able to segregate and remain near the CMB. Compositional stratification of the slab results in a strong torque due to the relatively high density of basalt and low density of harzburgite, which tends to rotate the slab such that the basalt side faces down. Slab-CMB interaction is characterised by heating up of the slab followed by separation of the basalt and harzburgite layers, with harzburgite rising in vigorous plumes. Plumes form at the edges and sides of slabs at the CMB as well as in their interiors (as previously observed for purely thermal slabs) with plume heads dominated by depleted harzburgitic material (sometimes with small amounts of entrained basalt), while plume tails entrain basaltic material. Segregation of basalt depends strongly on the presence or absence of a preexisting dense layer at the CMB, dimensionality, the thickness of the basaltic layer, and the viscosity and thermal conductivity. Two modes of basalt segregation are observed for slabs that land basalt side-up (i) hot harzburgite extruding from the sides and edges and (ii) hot, harzburgite-rich plumes bursting through the basalt layer (as previously observed in laboratory experiments), whereas for a slab that lands basalt side down (iii) hot basalt can peel off from its underside, displaying fingering instabilities in 3-D. Furthermore, basalt–harzburgite segregation is sometimes observed in slab segments that have already been heated at the CMB and risen a few hundred km, by a folding mechanism. A preexisting dense layer greatly increases the fraction of basalt that segregates from the slab.

New results indicate that slab (basalt layer) thickness, viscosity at the CMB and thermal conductivity have a first order influence on the amount of segregation, with more segregation favoured by a thicker basalt layer, lower viscosity and higher thermal conductivity. A simple scaling law is derived linking these factors to the ability of basalt to segregate. For reasonable deep mantle properties basalt segregation is likely, but the range of uncertainties in these parameters preclude a robust prediction.

Tackley, P. J. (2011) Living dead slabs in 3-D: The dynamics of compositionally-stratified slabs entering a 'slab graveyard' above the core-mantle boundary, Phys. Earth Planet. Inter., doi:10.1016/j.pepi.2011.04.013.