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A double magmatic heat pump at the core-mantle boundary

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ABSTRACT

Gigantic silicate magma chambers have been postulated to account for seismically inferred ultra-low-velocity zones at the base of the mantle, acting to modulate heat transport out of the core and into plumes. In the core, rising plumes of liquid metal and light elements pump the latent heat outward from the inner core boundary by compositional convection. The outer core thus pumps heat to the core-mantle boundary (CMB), and the giant magma chamber pumps heat into the mantle to act as a plume source. Magmatic action at the CMB depends critically on the balance between melt composition, compressibility, and temperature. A stably resident magma above the CMB must be denser than the mantle crystals, mostly silicate perovskite (pv) and magnesiowüstite (mw). Dense melts should form at the CMB, where they must be saturated with Fe and FeO from the core. Given normal Mg-Fe partitioning, mw will be denser than pv, and melts from pv + mw + iron = liq should also be intrinsically dense relative to the bulk crystal assemblage. Such melts may become superheated to overcome the compositional density, and rise upward in the magma chamber, assisted by turbulent mixing. Cooled melt sheds dense metal and metal oxide crystals, and growth of these crystals releases light solute that quickly transports heat upward toward the chamber roof, where it melts the mantle. Near the roof, dense melt grows from the heat transported upward by compositional convection, and sinks. Excess heat and occasionally some melt escapes to feed plumes in the mantle. CMB magmas must be among the most Fe-rich in the Earth.