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DENSITY AND COMPOSITIONAL ASPECTS OF MANTLE PLUMES

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Places of Irruption of Much Magma (PIMMs) like Iceland, Hawaii and many other postulated surface expressions of hypothetical mantle 'plumes' may be much less 'productive' than MORs - the PIMM source is not *required* to be volumetrically more 'fertile' than MORB mantle (not true of LIPs, however). Eruptives at PIMMs typically have lower eruption temperatures than MORB, hence it may be misleading to think of PIMMs as either '*particularly hot spots*' or even '*much heat spots*'.

At any fixed temperature within the earth's upper mantle, depleted (residual) peridotite is always less dense (higher Mg#, less spinel or garnet) than fertile peridotite and much less dense than eclogite. If any *solids* are going to ascend adiabatically *within* the upper mantle, they should be depleted peridotite rather than fertile peridotite, and certainly not eclogite. 'Solutions' invoking higher temperature in the fertile peridotite or eclogite are prone to encounter the solidus before buoyancy sets in; those invoking patches or veins of fertile peridotite, pyroxenite or eclogite entrained within ascending residual peridotite require large volumes of ascending and spreading peridotite, for which there is little direct evidence; solutions invoking plumes from the lower mantle 'pushed' through the transition zone encounter negative buoyancy because of the effect of lower Mg# on the phase changes, and pay an enthalpy and temperature toll as olivine is formed at the transition zone/upper mantle boundary.

The model of a 'plume' of hot, fertile peridotite floating through depleted asthenosphere and possibly lithosphere also, and partially melting because of its adiabatic decompression, leaves unanswered at least four questions:- Why do trace element features apparently require small mass fractions of partial melting, when the local abundance of irrupted products apparently requires high mass fractions of partial melting or alternatively an exceptionally large source region? Why is there so little evidence of hot, low density residual peridotite spreading away from the surface expression of a 'plume'? How is the need for buoyancy in the model to be reconciled with the density of fertile peridotite? Where does the enthalpy of melting of basalts come from and how is it concentrated, given that conduction of heat through the solid will be slow and would proceed down-temperature, out of the allegedly hot plume?

Partial melting in the upper mantle produces solid residue and partial melt liquid, both less dense than the fertile peridotite they replace. If the enthalpy source is external, both products are also as hot as or hotter than the unmelted fertile peridotite, further enhancing buoyancy. An alternative model envisages ascent and adiabatic decompression of mantle materials commencing because they have already partially melted. This could result from a heat flow out of the lower mantle and an intersection between the geotherm and a cusp on the mantle solidus at the transition zone-upper mantle boundary. The liquids might escape by cracks and conduits (with much modification en route) to form PIMM volcanoes while the solids of very different rheology might rise (with further partial melting) somewhere else than at the site of the PIMM. Partial

melting is, however, likely to be concentrated in the uppermost part of the Transition Zone, when the presence of an increased abundance of Mg_2SiO_4 -spinel will render the residues denser than the fertile source mantle.

Small mass fractions of nearly isobaric partial melting of a vast and diversified source region are then permitted; following melt removal that source region automatically replenishes itself by gravity controlled subsidence of upper mantle into the partial melting zone, facilitating fertile mantle and eclogite participation; the relative density problems of fertile 'plumes' vanish; enthalpy is concentrated at PIMMs by flow of partial melt, not by flow of heat; location of the PIMM is controlled by tectonics and is not required to be fixed; and the peridotite most directly associated with the PIMM would be adjacent to the conduits in the form of hot ultramafic cumulates formed from the ascending melts - a mass of the same order of magnitude as, rather than ~ 10-20 times greater than, that of the erupted magma at a PIMM.

The petrogenetic environment underpinning PIMMs would then be one of progressive partial crystallisation throughout the upper mantle, of an originally ultramafic partial melt, capped by substantial low pressure partial crystallisation in a thick volcanic superstructure. This is radically different from the regime underpinning MORs, where picritic or olivine basaltic parental liquids form at high levels by adiabatic decompression melting continuing and advancing until close to the Moho, capped again by substantial low pressure crystallisation in a thinner volcanic superstructure.

The geochemical versatility of the partial crystallisation processes that might be operating, especially in RTMXC-SPC-EPC and RMTXC-SPC-EPC magma chambers, has been seriously underestimated in conventional interpretations. Processes there and in the process of melt separation from crystals in the conduit can produce effects which many would unhesitatingly ascribe to differing but small mass fractions of partial melting of heterogeneous sources.