Primary Magmas, Mantle Temperatures and Buoyancy Plumes

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The sub-solidus mineralogy and the melting behaviour of lherzolitic upper mantle are experimentally well-determined, including the effects of small quantities of carbon and hydrogen (peridotite-C-H-O). This work established a 'major melting regime' and 'incipient melting regime', approximately above and below the anhydrous solidus respectively. Magmas of possible mantle origin can thus be evaluated with respect to possible pressure, temperature and (SourceÆMagma+Residue) relationships. Intraplate magmas of direct mantle derivation can be identified on the basis of transport of mantle-xenoliths and absence of high pressure fractional crystallisation, i.e. $Mg\#*73$. The experimental study of these magmas determined liquidus phases as functions of P,T, H_2O and CO_2 contents and has established intra-plate magma-extraction as largely within the 'incipient melting' regime of the Peridotite-C-H-O phase diagram. In contrast to these, the constructive plate margin magmas such as picritic N-MORB and E-MORB magmas are shown to have liquidus temperatures at 1 bar of $1325\pm20°C$ and are compatible with lherzolitic residue at 1.4 to 1.9 GPa, 1450-1480°C. Mineralogical and chemical data on Hawaiian picrites from six tholeiitic centres similarly have liquidus temperatures of $1320\pm25°C$ and are partial melts from lherzolitic (Loihi) to harzburgitic residues at 1.5 GPa approximately. The modern mantle has a potential temperature of 1430-1450°C with no deep-seated thermal anomaly associated with, for example, the Hawaiian 'plume'. The buoyancy plume inferred beneath the Hawaiian Swell is primarily compositional, deriving from a major component of refractory harzburgite ($Mg\#_{Ol} = 91-92$, $Cr\#_{70-80}$). The Hawaiian source region probably has a pre-history of 'old subducted slab' and provides a 4-component mixing signature on Hawaiian magmas. [(a) refractory harzburgite; (b) residual pyroxenite and garnet pyroxenite within locally re-fertilised peridotite, from partial melting of subducted oceanic crust; (c) variable addition of incipient melt (olivine nephelinite) from garnet harzburgite/lherzolite at P>2.5 GPa, T~1250-1550 C; and (d) CH_4+H_2O fluid phase from deeper mantle at $fO_2 = IW+1$.] Although a four-component geochemical signature may be discernible in Hawaiian plume magmas, it is emphasised that these processes have produced distinctive harzburgitic to lherzolitic source 'diapirs' or episodic 'plumes' in which the final melt separation leaves a harzburgitic residue. The trace-element and isotopic characteristics of Hawaiian tholeiitic volcanic centres are reflections of the prehistory of their sources and not of the final melt/residue equilibration which fingerprints the major element and petrological characters of the magmas. It is inferred that neutrally buoyant, old, subducted slabs in the sub-asthenospheric mantle provide the locus for melting and initiation of diapirism, initially with melt retention but then with melt segregation and extraction at 1.5 GPa, leaving harzburgitic residues. A dominantly lherzolitic mantle with potential temperature of 1450 C and small contents of carbon and hydrogen, provides rheological and petrogenetic responses consistent with the plate tectonics paradigm and with mid-ocean ridge, intraplate, back-arc and island arc volcanism.