PRIMARY MAGMAS AT MID-OCEAN RIDGES, 'HOT-SPOTS'AND OTHER INTRAPLATE SETTINGS: CONSTRAINTS ON MANTLE POTENTIAL TEMPERATURES

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The melting regime for mantle-derived basaltic magmas from intraplate settings (kimberlites, olivine melilitites, olivine nephelinites, basanites, alkali-olivine basalts) requires the presence of carbon and hydrogen (dissolved ($CO_3^{=}$) and (OH^-) in the melt phase. Magma genesis in intraplate settings can be understood in terms of the lherzolite+(C-H-O) system. Magmas are derived from an "incipient melting" regime which lies at temperatures below the volatile-free lherzolite solidus – marking entry to the "major melting" regime. Experimental petrology and observations of natural magmas concur in defining magma segregation at deep levels and magma transport within channels with only limited wall-rock reaction. In the intraplate settings, the role of an "incipient melting" field in lherzolite + (C-H-O) at depths of >90 km to ? <200 km creates conditions in which both depletion (from N-MORB to D-MORB sources) and enrichment (from N-MORB to E-MORB sources); occur by migration of a 1-2 % melt fraction.

These relationships are summarized in a specific model for a petrological lithosphere [below the silicate solidus for lherzolite +(C-H-O)] and asthenosphere (above the silicate solidus) The proposed model is used to explain production of specific primary magmas in the P,T field between the regionally applicable conductive geotherm and adiabatic upwelling of mantle with potential temperature (T_p) □1430°C (FIG. 2).

In many earth models, Mid-Ocean Ridge magmatism is attributed to decompression melting of upwelling upper mantle/asthenosphere at normal mantle temperature and melting has been considered to occur in the absence of significant volatiles (C-H-O). Nevertheless, primitive MORB have water and carbon contents which are not negligible but rather are very low because of relatively high degrees of melting of a source with low carbon and hydrogen contents. Most importantly, primitive mid-ocean ridge basalts have remarkably restricted compositions compatible with saturation with olivine, orthopyroxene, minor clinopyroxene and Cr-Al spinel at pressures around 2 GPa. Processes of melt migration by porous flow may have occurred at deeper levels but at 2 GPa equilibrium between melt and lherzolite mineralogy is indicated. Primary magmas move from this depth through dykes or channels without significant modification by wall-rock reaction, to sub-ridge magma chambers or sea-floor eruption.

In the 'hot-spot' setting, combinations of geophysical arguments (the buoyancy implication beneath the Hawaiian Swell) and geochemical arguments (thicker crust, "garnet signature" on REE implying deeper melting if the anhydrous solidus is used) have been used to infer higher temperature in the mantle, in comparison with the Mid-

Ocean Ridge setting. The comparison of magma and phenocryst compositions between MOR and Hawaiian primitive basalts is a way of testing for evidence for such temperature contrasts, argued in some models to be of the order of 200^{o}C.

The composition of olivine phenocrysts in Hawaiian picrites and in Mid-Ocean Ridge picrites vary up to $Mg^{\#}_{91.3}$ and $Mg^{\#}_{92.1}$ respectively. The compositions and liquidus temperatures of the magmas crystallizing the most magnesian phenocrysts can be estimated and anhydrous liquids temperatures (at 1 bar pressure) of Hawaiian tholeiitic picrites average 1365^{o}C, and for MOR picrites average 1335^{o}C. Water contents of the magmas decrease in the order Hawaiian picrites, E-MOR picrites to N-MOR picrites, and consideration of liquidus depression by these water contents leads to the conclusion that all primitive magmas had liquidus temperatures of approximately 1325^{o}C at □ 1 bar. The data from primitive magmas suggests that the temperature contrast between “Hot-Spot” and MOR primary magmas is $\leq$ 20^{o}C. Application of information from partial melting studies of model (pyrolite) source compositions and of the liquidus phases of the Hot-Spot and MOR picrites leads to the conclusion that both “Hot-Spot” and MOR primary basalts are derived from mantle with potential temperature T_p □ 1430^{o}C. Insofar as primitive magmas may be used to infer the potential temperature of their sources, there is no evidence for a temperature contrast of Δ T_p = 100-250^{o}C between “Hot-Spot” or “Deep Mantle Plume” sources and ambient (MOR source) asthenospheric mantle.

Although magma temperatures are similar, the residual mantle compositions for Hawaiian picrites are refractory harzburgites, more refractory (including Cr/Cr+Al ratio) than the lherzolite to harzburgite residue from MOR picrite extraction. It is argued that the buoyancy plume and geophysically anomalous mantle beneath the Hawaiian Swell is due to compositional and not temperature contrasts in the upper mantle. The four-component mixing identified in the Hawaiian source is attributed to interaction between old subducted lithospheric slabs, buoyant or suspended in the upper mantle, and surrounding ambient mantle at T_p =1430^{o}C. A cartoon representing the model is presented in Figure 1.

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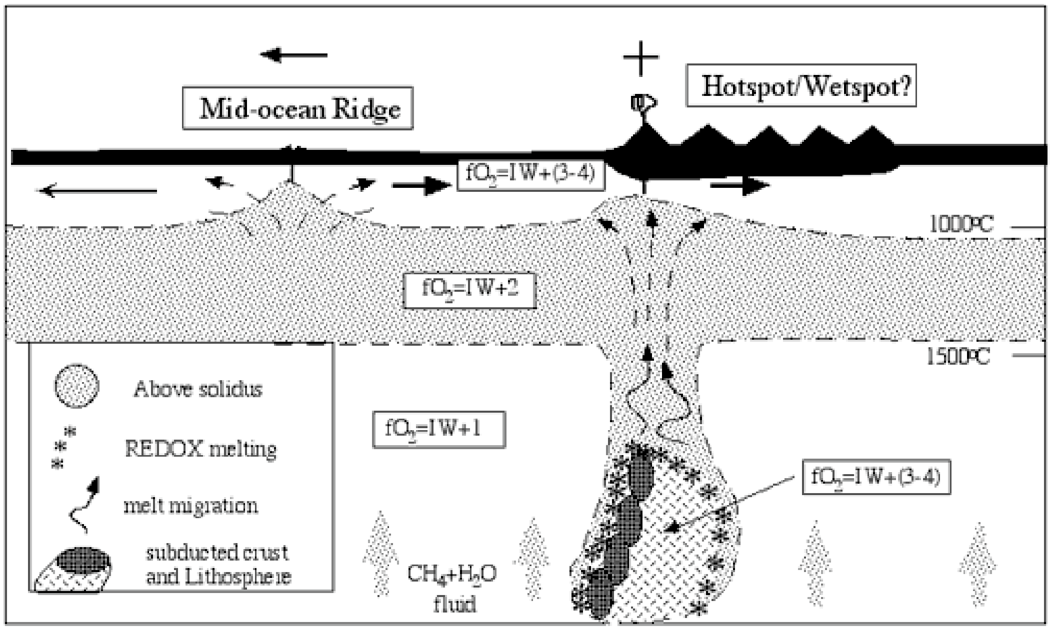
Mid-ocean Ridge
Hotspot/Wetspot?
fO2=IW+(3-4)
1000ºC
fO2=IW+2
1500ºC
Above solidus
REDOX melting
melt migration
subducted crust
and Lithosphere
fO2=IW+1
fO2=IW+(3-4)
CH4+H2O
fluid

Figure 1