Estimates of mantle temperatures based on olivine phenocrysts and olivine-melt equilibria

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The magnitude of the temperature differences between oceanic islands and mid-ocean ridges is crucial to the identification of thermal plumes. Green et al. (1999) have noted that maximum forsterite (Fo) contents of olivines from several MOR segments match or exceed maximum Fo values at Hawaii, and use estimated MgO contents to infer that mantle potential temperatures are nearly equal at Hawaii and MOR's. However, a re-consideration of olivine saturation temperatures, using the approach of Roeder and Emslie (1970) and Langmuir and Hanson (1981), indicates that very high Fo content crystals need not imply high mantle temperatures. A comparison of the highest Fo contents from the Hawaiian Islands and several mid-ocean ridge localities appears to require higher melting temperatures in the Hawaiian source region by approximately 250 K, when observed FeO contents (rather than calculated MgO contents) are used as model input. This analysis is in contrast to that of Green et al. (1999) in that by using FeO as input, greater amounts of MgO in primitive Hawaiian liquids (20 wt. %) are implied. In contrast, the methods of Green et al. (1999) underestimate FeO at Hawaii. The present calculations also utilize a higher value for the Fe-Mg exchange coefficient for ol-liq (0.35); this higher value is likely more appropriate for equilibration at the pressures appropriate to the base of the Hawaiian lithosphere (Herzberg and O'Hara, 1998). If melt fractions are similar at Hawaii (8-15%; Feigenson et al., 2003) and MOR's (6-18%; Kinzler & Grove, 1992), then decompression at Hawaii yields a smaller value for the difference in mantle potential temperatures: about 220 K, similar to estimates required by geodynamic models for mantle thermal upwellings. It thus seems unnecessary for mantle plume advocates to require that high Fo content olivines at mid-ocean ridges are disequilibrium xenocrysts, completely unrelated to melting or crystallization phenomena.

Magmatic segmentation of the East Pacific Rise

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Competing models for what controls the intensity of ridge crest processes are at odds on the scale of magmatic segmentation of the mantle and crust. One popular and long held view is the magma supply hypothesis, wherein mantle melt is centrally injected into a ridge segment bounded by long-lived tectonic discontinuities and ridge parallel flow of magma over distances of 10's of kilometers gives rise to along-axis variations in ridge crest processes. In this view, the scale of mantle melting at depths of 30 to 60 km is thought to govern the scale of magmatic segmentation of the mid-ocean ridge. Axial variations in volcanic, tectonic and hydrothermal activity are attributed to waxing and waning episodes of melting events. Where magma supply is high, greater amounts of volcanic and hydrothermal activity are predicted. Where the ridge is `starved' of magma, tectonic activity predominates. Recent studies at the East Pacific Rise, however, bring up several challenges to the magma supply hypothesis and an alternative model which we refer to as magma plumbing. The two essential features of the magma plumbing hypothesis are the scale of along-axis segmentation of shallow mantle upwelling and the vertical (mis)alignment of the mantle and crustal magmatic systems. In this view, magma injection from the mantle to the crust occurs at more-or-less equally spaced intervals within a ridge segment bounded by tectonic discontinuities and the cross-axis offset between a center of mantle upwelling and an axial volcano regulates the intensity of ridge crest processes. When the mantle and crustal plumbing systems are aligned, the ridge crest is more volcanically and hydrothermally active. Conversely, when the mantle and crustal plumbing systems are misaligned by many kilometers, the intensity of extrusive volcanic and hydrothermal activity is less, while tectonic activity is increased. As a consequence, even at constant magma supply (or mantle temperature) the intensity of seafloor processes can be fundamentally different because of magma plumbing. We will show that the magma plumbing model can successfully predict along-axis variations in axial depth, major element basalt chemistry, crustal thickness variations and gravity anomalies. We will also discuss several implications, including the liklihood of active upwelling in the shallow mantle (<30 km depth), the effects of ridge migration on the secular evolution of ridge crest processes and the formation of replacive dunites along interfaces sub-parallel to the Moho.