Petrological interpretation of deep crustal intrusive bodies beneath oceanic hotspot provinces

Mark Richards[1], Eduardo Contreras-Reyes[2], Carolina Lithgow-Bertelloni[3], Mark Ghiorso[4], Lars Stixrude[3]

[1]University of California, Berkeley, USA, [2]Universidad de Chile, Santiago, Chile, [3]University College, London, UK, [4]OFM Research, Seattle, USA

E-mail: Mark_Richards@berkeley.edu

Seismic refraction studies of deep-crustal and upper mantle structure beneath some oceanic hotspot provinces reveal the presence of ultramafic bodies with P-wave velocities of Vp 7.4-8.0 km/s lying at or above the Moho, e.g., Hawaii, the Marquesas, and La Reunion. However, at other hotspot provinces such as the Galapagos, Nazca Ridge, and Louisville the lower crust is intruded by large volumes of gabbroic (mafic) rocks (Vp 6.8-7.5 km/s). Ultramafic primary melts formed beneath mature oceanic lithosphere at pressures of 2-3 GPa (60-90 km depth), and ponded at the Moho due to their relatively high density, can explain the observed ultramafic deep-crustal bodies. By contrast, plume melts formed at depths of 15-30 km beneath thin lithosphere crystalize assemblages that are more gabbroic. The velocity and density gradient is particularly strong in the pressure range 0.6-1.3 GPa due to the replacement of plagioclase by olivine as melts become more MgO-rich with increasing pressure (and degree) of melting. This anomalous density gradient suggests a possible filtering effect whereby plume melts equilibrated at relatively shallow depths beneath very young and thin oceanic lithosphere may be expected to be of nearly gabbroic (mafic) composition (6-10 wt. percent MgO), whereas ultramafic melts (MgO 12-20 wt. percent) formed beneath older, thicker oceanic lithosphere must pond and undergo extensive olivine and clinopyroxene fractionation before evolving residual magmas of basaltic composition sufficiently buoyant to be erupted at the surface. A survey of well-studied hotspot provinces of highly-varying lithospheric age at the time of emplacement shows that deep-crustal and upper mantle seismic refraction data are consistent with this hypothesis. These results highlight the importance of large-volume intrusive processes in the evolution of hotspot magmas, with intrusive volumes being significantly larger than those of the erupted lavas in most cases. Pyrolite melting can account, to first order, for the total crustal column of magmatic products, whereas alternative models such as selective melting of pyroxenite blobs probably cannot.