Dynamics of mantle upwelling and outflow during Galapagos plume-ridge interaction

Sally A Gibson[1], Dennis J Geist[2], Mark A Richards[3]

[1]University of Cambridge, UK, [2]University of Idaho, USA, [3]University of California, Berkeley, USA

E-mail: Sally@esc.cam.ac.uk

The compositions of basalts erupted in the Galapagos archipelago and adjacent Galapagos Spreading Centre provide important constraints on the dynamic processes involved in transfer of deep-mantle-sourced plume material to mid-ocean ridges. Galapagos Islands are unusually widespread for such a tectonic setting and offer a unique broad aperture into mantle processes. Of particular interest are recent basalts from central and northeast Galapagos that are more isotopically depleted, and have lower volatile contents, than those at the nearby ridge. Paradoxically, these depleted basalts have higher Sm/Yb ratios than those on the adjacent ridge. We infer from this and also regional variations in isotopic ratios that the compositional differences of basalts erupted during plume-ridge interaction are influenced by factors other than lithospheric thickness variations and mantle heterogeneity.

We use published surface wave data (Villagomez et al., 2007) to calculate temperatures in the Galapagos mantle, at sub-anhydrous peridotite solidus depths. A depth slice at 100 km reveals a 200 km wide channel of highest-temperature (TP=1400 oC) mantle extending from the postulated plume stem towards the nearest section of ridge. Further independent support for this region of high-temperature mantle is provided by coincidence of its predicted intersection with the eastern Galapagos Spreading Centre with the location of the most enriched basalts, greatest crustal thickness and elevated topography. We propose that at this section of ridge (east of the 91 oW transform fault), combined plume-driven deep volatile-rich melting and plate-limited shallow anhydrous melting generate relatively large volumes of more enriched basalts than elsewhere on the Galapagos Spreading Centre. We further note that ridge-ward flow of plume mantle is unaffected by variations in lithospheric thickness of the Nazca Plate and suggest that these are too small to capture and cause confinement of Galapagos plume material flowing to the ridge.

Our geochemical and geophysical observations for Galapagos require a model that involves narrow channelling of highest temperature, low-viscosity mantle from the plume stem to the nearest section of the Galapagos Spreading Centre at depths below the anhydrous peridotite solidus (>80 km), together with sub-axial rather than radial plume flow. The physical parameters and styles of mantle flow that we have defined for Galapagos are poorly constrained for other well-known sites of plume-ridge interactions, such as Easter Island in the Pacific, the Azores, St Helena and Tristan in the mid-Atlantic, and Amsterdam in the Indian Ocean. In many of these cases the presence of a mantle plume is contested. Our findings permit realistic parameters and boundary conditions to be used in dynamical models of global plume-ridge interactions and therefore aid understanding of what drives the most currently active volcanism on the surface of the Earth.