Bimodal delivery of deep-sourced, volatile-rich mantle plume material to the global ridge system

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Deep-sourced volatile-rich material is delivered to the global mid-ocean ridge (MOR) system via mantle plumes and accounts for the short wavelength variability (over 10's of km) in geochemistry and bathymetry that is superimposed on the much larger (many 100's of km) region of plume-influenced MOR. A striking feature is that mid-ocean-ridge basalts with exceptionally-high volatile contents correspond to the intersections of long-lived, linear, plume-related, volcanic ridges. Examples include: Galápagos (the Wolf-Darwin lineament), La Réunion (Rodrigues Ridge), Discovery (Discovery Ridge), and numerous smaller ridge-like structures associated with the Azores and Easter-Salas y Gómez hot spots.

We use new joint models for rare-earth element inversion and mineral-melt volatile element partition coefficients to constrain depths of volatile extraction during mantle melting. We show that depletion of volatiles is rapid and occurs deep in high temperature mantle plume stems. Our models reveal that the most H_2O-rich basalts on global ridges contain up to 15% of these "deep", small-fraction volatile-rich melts. We propose these are transported directly to nearby MOR segments via pressure-induced, highly-channelized flow in sub-lithospheric channels -- expressed at the surface as volcanic lineaments and ridges -- and that these "tube-like" channels constitute a primary delivery mechanism for deep hydrous melts formed deep in plume stems to nearby MORs.

Our findings have significant implications for cycling of volatiles between Earth's deep interior and surface, since approximately one-third of the 65,000 km long global MOR system is affected by nearby mantle plumes. This enhanced ridge volcanism, together with that at the associated islands and seamounts, involves significant volatile (CO_2, H_2O) outgassing from the mantle. We estimate that low-viscosity volatile-rich melts, transported in channels embedded in laterally-spreading solid mantle plumes (Gibson & Richards, 2018), contribute ~20% of the global ridge H_2O flux whereas conventional solid-state lateral flow of 'background' plume material represents ~30% of the ridge H_2O flux (3.3×10^{13}g/yr; Hirschmann, 2018). We anticipate similar plume-ridge fluxes of deep-sourced CO_2.