The Eastern Rift Zone through time: A record of plume pulsing or magma plumbing evolution?

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Lavas from Öræfajökull volcano, SE Iceland, exhibit isotopic compositions distinct from normal Icelandic enriched mantle, attributed to the presence of recycled sediment in their source [e.g.1, 2]. This distinctive source has recently been recognized in postglacial Eastern Rift Zone (ERZ) lavas [3], indicating the source is more widespread, as well as in the East Iceland Tertiary lavas (~13 Ma) [4], indicating that it is also long lived.

A comprehensive suite of lavas from the ERZ; Siđa and Fljótshevrfi Groups (0.7 - 3 Ma) and Tertiary lavas from Skaftafell (3-5 Ma) have been analysed for Sr-Nd-Pb isotopic ratios along with major and trace elements. Whilst both Skaftafell and ERZ lavas lie on correlations trending towards an enriched end-member similar to the Öræfajökull source, the Skaftafell lavas trend to an end-member which has lower $^{143}Nd/^{144}Nd$ for a given $^{87}Sr/^{86}Sr$ and more positive $\Delta^{207}Pb$ and $\Delta^{208}Pb$. This suggests a temporal change in the composition of the enriched mantle source in the past 5 Ma. Further, the Siđa and Fljótshevrfi lavas (0.7 - 3 Ma) show more depleted and less variable isotopic compositions suggesting the transition was not gradual, but that there was a distinct break in the supply of enriched mantle at ~3 Ma. Possible mechanisms for this could be: 1. Supply of discreet blobs of enriched mantle from the plume [4], 2. Changes to the magma plumbing regime resulting in a reduced contribution from the enriched source and greater homogenisation of melts between 3 and 0.7 Ma.

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Fluids, subduction, and deep carbon

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Studies of the deep carbon cycle have concluded that the mantle is gaining C because more carbon is subducted than is degassed by volcanism [1]. This relies on the assumption that all CO_2 lost from slabs is degassed at arc volcanoes, which is problematic because arc crust is permeable [2] and arc magmas may attain deep fluid saturation [3]. Support has also been drawn from models showing that slab fluids possess low X_{CO2} [4]. But new theoretical and experimental results show that C solubilities are likely higher than these models predict. Total dissolved carbon depends on the solubilities of all C species (e.g., CO_{2aq}, HCO_3^-, CO_3^{-2}, etc), which are controlled by pH, fO_2, halogens, and dissolved cations. Controls on these variables in subduction zones are likely to combine to elevate carbonate mineral solubility. For example, the calculated pH of model slab mineral assemblages of jadeite, white mica and quartz [5,6] along the top of the Costa Rica slab [7] indicate that the $CaCO_3$ solubility is higher at mineral-buffered pH than at the more alkaline pH of otherwise pure H_2O saturated only in $CaCO_3$, or than in molecular mixing models. Carbonate solubility is also enhanced by salts. At a given P-T, calcite solubility increases in proportion to the square of NaCl mole fraction [8]. Our studies in KCl, LiCl, and their mixtures have similar form and, at fixed P, T and X_{salt}, solubility decreases as LiCl > NaCl > KCl, consistent with Pearson Hard-Soft Acid-Base rules. Metal-carbonate ion pairing and reduction of carbonate or CO_2 to CH_4 during mantle-wedge serpentinization will further increase solubility. Models including the above effects yield ≥1 wt% total C in some slab fluids. C carried by subduction-zone fluids and deep degassed magmatic volatiles likely play important roles in the deep carbon cycle, and must be taken into account in assessing the gain or loss of carbon by the mantle.

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