

## Hotspots and large igneous provinces: Excess mantle temperature or mantle fertility?

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Mid-ocean ridge basalt (MORB) ranges in composition from depleted (NMORB) to enriched (EMORB). EMORB composition overlaps that of ocean island basalt (OIB), leading to the assumption that EMORB is the product of plume-contaminated upper mantle. Some ocean islands (e.g. Hawaii, Iceland, Reunion, Galapagos) lie at the ends of long, time-progressive island and seamount chains that are best explained by deep-mantle plumes. Significantly, OIBs from these same islands have the highest  $^3\text{He}/^4\text{He}$  values. Most OIB and EMORB, however, can be produced by passive melting of fertile (i.e. more fusible) blobs within the upper mantle circulation. Enriched components in most OIB need not have been recycled through deep mantle plumes and therefore most "hotspots" need not be hot.

Whether larger fertile blobs in the upper mantle can explain large igneous provinces (LIPs) is central to the current plume debate. Useful insights into this question are provided by a recent study [1] of picrites erupted during the earliest phase of magmatism (~62 Ma) in the North Atlantic LIP. Thick picrite sequences in Baffin Is and W Greenland have compositions that require mantle that is at least 100°C hotter than the upper mantle. The picrites, however, are very similar to MORB in their  $^{143}\text{Nd}/^{144}\text{Nd}$  and incompatible trace-element ratios. NMORB and EMORB types are present in both areas, but they have rather lower absolute abundances of incompatible elements, suggesting higher degrees of melting rather than increased fertility. The picrites have the highest  $^3\text{He}/^4\text{He}$  (up to 50Ra) yet measured in terrestrial basalts, and these high values are found in both N- and EMORB types. The  $^3\text{He}$  source must therefore have been sufficiently He-rich to overwhelm any radiogenic  $^4\text{He}$  in the picrite source, thereby ruling out models of He-isotope evolution in which primitive  $^3\text{He}$  is stored in ancient, depleted mantle. The picrite source differed from upper mantle only in its high temperature and extreme  $^3\text{He}/^4\text{He}$ , suggesting that  $^3\text{He}$  was introduced from a hot reservoir with high  $^3\text{He}/(\text{U}+\text{Th})$ . The Earth's core is a plausible source of both heat and  $^3\text{He}$ , implying that the deep mantle has a similar bulk composition and degree of heterogeneity to the upper mantle.

[1] Starkey *et al.* (2009) *Earth. Planet. Sci. Lett.* **277**, 91-100.

## An experimental study of the effect of sulphate on calcite precipitation rates and CO<sub>2</sub> sequestration

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Calcite precipitation rates are a prerequisite for the understanding of the global carbon cycle, and to optimise the conditions for carbon sequestration and mineralization. One current example of an *in situ* carbon mineralization effort in basalts is currently taking place in Iceland [1]. This process involves dissolution of the basaltic rock and release of divalent cations such as  $\text{Ca}^{2+}$ , which can then precipitate as carbonates [2]. Sulphur is often present in the flue gases of power plants and their disposal also poses an environmental challenge. This study is aimed at exploring if sulphur can be coinjected with  $\text{CO}_2$  during sequestration efforts. Towards this goal the effect of aqueous sulphate on calcite precipitation rates has been measured experimentally.

Experiments were performed in polypropylene mixed flow reactor systems. Calcite was precipitated onto seed crystals from supersaturated inlet solutions comprised of demineralized  $\text{H}_2\text{O}$ ,  $\text{CaCl}_2$  and  $\text{NaHCO}_3$  at 25°C and pH ~ 8.2. Aqueous sulphate in the experiments were varied from 0 to 25 mM.

Preliminary results suggest that sulphate measurably enhances constant saturation state calcite precipitation rates. Calcite solubility, however increases with increasing aqueous sulphate concentration due to aqueous calcium-sulphate complex formation. The degree to which these two effects influence calcite precipitation rates within basaltic rocks during  $\text{CO}_2$  sequestration efforts will be assessed using geochemical modelling codes.

[1] Oelkers, Gislason & Matter (2008) *Elements* **4**, 333-337.

[2] Flaathen, Oelkers & Gislason (2008) *Min. Mag.* **72**, 39-41.