Microbial transport through rock and its importance for microbially-induced mineral precipitation

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Emerging bio-technologies offer natural, minimally invasive and cost-effective methods for dealing with environmental remediation and engineering problems. Microbially-induced mineral precipitation could become one of these innovative technologies as it has shown great potential for soil stabilisation, solid-phase capture of pollutants and porosity sealing to control leakage at nuclear waste depository and CO_2 storage sites. Critically, deployment strategies for microbially-induced processes are heavily dependent on the movement, homogeneous distribution and viability of micro-organisms over long injection distances. Problematically, we have little understanding of how microorganisms are transported in subsurface rock environments.

Initial data on bacterial transport through sandstone clearly showed that bacteria get easily immobilised in rock compared to packed sand [1] (Figure below). This is a significant problem as most previous bacterial transport studies have been undertaken on homogeneous packed sand; data which clearly cannot be used reliably to predict bacterial transport through rock. Furthermore, the subsurface is inherently heterogeneous, leading to preferential flow paths, and this will greatly affect bacterial transport behaviour.

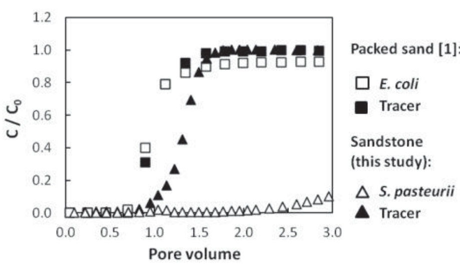

Figure: Breakthrough curves for bacteria (10^8 cells/ml) and a conservative tracer (0.3 mM NO_3).

Here, Breakthrough Curve (BTC) analyses were extended to quantify the effect of rock composition, heterogeneity and injected bacterial density on bacterial transport through porous and fractured rock. BTC data was modelled using colloidal filtration theory to obtain information about the dispersivity and sticking efficiency of injected microorganisms. This data was then used to develop and test improved injection strategies for the application of microbially-induced mineral precipitation to seal subsurface rocks. For this, different rock cores were subjected to repeated cycles of ureolysis-driven calcite precipitation until a significant decrease in permeability was measured. The spatial distribution of the produced calcite fill, and thus the effectiveness of the applied injection approach, was quantified using scanning electron microscopy.

[1] Liu et al. (2011) *EST* **45**, 3945–3951.

Involvement of recycled silica-rich pyroxenite in continental intraplate magmatism: Evidence from alkaline basalts in NW Kyushu, SW Japan

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Abstract

Recycled silica-rich materials such as pyroxenite (eclogite) are important sources of mantle-derived magmas not only in oceanic magmatism but also in continental intraplate magmatism [1]. Here, we show an evidence for presence of the silica-rich pyroxenite in the continental intraplate magmatism by using major and trace elements and Sr-Nd-Pb-Hf isotopes for Miocene alkaline basaltic lavas from northwestern Kyushu, SW Japan. The alkaline lavas, defined by silica versus total alkali contents, are mostly normative hypersthene. In contrast, alkali basalts with normative nepheline are scarce. Their primitive mantle-normalized trace element patterns show strong enrichment in incompatible elements and remarkable negative spikes in B, Pb and Li, and some of the alkaline lavas show slightly weak depletions in high-field strength elements (HFSE). The isotopic compositions in the alkaline lavas significantly correlate with major elements (e.g. SiO_2, MgO, CaO, Na_2O and CaO/Al_2O_3) and trace element ratios (e.g. Nb/U, Zr/Hf and Sr/Nd). These correlations cannot be explained either by shallow-level magma chamber processes such as fractional crystallization and in situ crustal assimilation, or variable degree of partial melting of a homogeneous mantle source. Instead, constraints from coupling between the major element compositions and those of partial melts of the silica-rich pyroxenites from high pressure experiments (e.g. [2] and [3]), and the negative correlation of $^{176}Hf/^{177}Hf$ versus Zr/Hf, these indicate the involvement of the recycled silica-rich pyroxenite within an asthenospheric upwelling that triggered the continental intraplate magmatism. The correlations between the isotopic compositions and trace element ratios further suggest that the recycled silica-rich pyroxenite was derived from oceanic basaltic protoliths metasomatized by overlying sediment. It is thus inferred that the recycled pyroxenite and its peridotite matrix were major sources of the normative hypersthene melts and the normative nepheline melts, respectively. Mixing between their melts derived from lithologically and chemically distinct end-members would have taken place at low pressures in melt conduits and magma chambers. The involvement of crustal recycling might be closely linked with tearing of subducted stagnant slab beneath the East Asia.

[1] Sobolev *et al.* (2007) *Science* **316**, 412-417. [2] Pertermann & Hirschmann (2003) *J. Petrol.* **44**, 2173-2201. [3] Spandler *et al.* (2008) *J. Petrol.* **49**, 771-795.