Fluid-rock interactions recorded by kinetic fractionation of Li isotopes

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Li diffuses relatively rapidly through minerals and fluids and this, coupled with the large differences in diffusivities between its two isotopes (Richter *et al*., 2003), can lead to large kinetic isotopic fractionations parallel to the diffusion pathways. Thus, Li isotopes can be used to trace fluid-rock interaction. Here we summarize three different pluton-country rock settings that illustrate the controls and limits on kinetic Li isotopic fractionation. Lithium diffused over distances of >30 m from the Li-rich Tin Mt. pegmatite into metamorphic country rocks along fluid-filled grain boundaries accompanied by large, kinetically induced isotopic fractionations (>30‰, Teng *et al*., 2006). Li diffused over an order of magnitude further into the country rocks than other fluid-mobile trace elements (e.g., Na, Rb, Cs and Sb), making Li perhaps the most sensitive tracer of fluid-rock interaction amongst the lithophile elements. In contrast, metapelitic country rocks surrounding the Onawa granodiorite are not enriched in Li, reflecting the low Li content of the intrusion (45 ppm) relative to the country rocks (130 ppm) and hence the lack of a chemical potential gradient to drive diffusion. Indeed, Li content of the metapelites decreases by a factor of two adjacent to the pluton, reflecting the loss of Li during metamorphic devolatilization (Teng *et al*., 2007). The constant δ^7Li in the country rocks is consitent with equilibrium fractionation during Li loss via Rayleigh distillation at the temperatures of metamorphism (>500^{o}C). Finally, large, kinetic Li isotopic fractionations are observed perpendicular to the contact between an alkali syenite and granitic country rocks of the Ilímaussaq Complex, Greenland (Marks *et al*., 2007). Here, however, the syenite is barely enriched in Li relative to the country rocks (25 vs. 14 ppm, respectively), and this concentration difference is not large enough to account for the large isotopic fractionations observed over distances of up to 150 m (δ^7Li ≥ -9 in the granite country rocks and $\leq +16$ in the syenite). These large fractionations reflect the circulation of isotopically heavy, Li-bearing fluids adjacent to the syenite-granite contact.

References

Richter, *et al*., 2003, GCA **67**, 3905-3923.
Marks, M. *et al*., 2007, this volume.
Teng, F.-Z., *et al*., 2006, EPSL **243**, 701-710.
Teng, F.-Z. *et al*., 2007, Chem. Geol. **293**, 1-12.

Studies of continent stability using joint petrological and geodynamical models

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Continents are remarkably stable features of our dynamic Earth. Extreme examples of this are Archean cratons, which have resisted erosion by lithosphere delamination and mantle convection for billions of years. However, continents are not stable under all conditions. In fact, delamination of continental lithosphere has been related to intra-plate volcanism and uplift in the absence of shortening. The main goal of this study is to identify and quantifying the key factors that control the stability of continental lithosphere.

To simplify this task we regard lithosphere delamination as a Rayleigh-Taylor instability. Rayleigh-Taylor instabilities have been extensively studied analytically, numerically and experimentally - also with regard to continent stability. It is clear from these studies, that the growth rate of the instability is primarily controlled by the density and viscosity contrast. The density (and viscosity) contrast between the lithosphere and asthenosphere is a complex function of temperature, pressure and, often neglected, chemical and mineralogical composition. Chemical composition can vary significantly among different continents and it may well be that chemical and mineralogical variations determine if the lithosphere is gravitationally stable or not. To test this hypothesis, we use a joint petrological and geodynamical approach. The petrological model is based on a companion study (Simon *et al*. 2007 – this volume), which explores the dependence of mantle density on chemical composition using thermodynamics. The key metamorphic reaction for continental stability is the garnet-in reaction. The location of this reaction in p-T space is strongly dependent on the Cr_2O_3/Al_2O_3 ratio, while the amount of formed garnet mainly depends on the Al_2O_3 content. This suggests that relatively fertile mantle compositions rich in aluminum will tend to destabilize continental roots. To quantify the effect of mantle composition on continent stability, we will integrate thermodynamically computed densities for various mantle compositions into a geodynamic flow model. Using this joint petrological and geodynamic model, we will explore for which mantle composition continents are stable over geological time and define a critical enrichment for which continental lithosphere becomes gravitationally unstable.