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The behaviour of uranium and lithium isotopes during basalt weathering and erosion

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Physical and chemical weathering rates of basalts are much higher than for many other silicate rocks, and thus basalt weathering exerts a strong control on atmospheric CO_2 (Dessert et al., 2001). Variations in weathering and erosion in response to climatic or tectonic change are likely to affect chemical fluxes to the oceans. Lithium (Li) isotopes potentially provide key information on weathering rates, but their systematics during weathering remain poorly constrained. In particular, understanding of the behaviour of Li in rivers and during estuarine mixing is critical for quantifying the input to the oceans. U-series nuclides can give information on both the weathering process and the timescale over which it occurs. However, under some conditions, U may be strongly affected by association with colloids, in both the riverine and estuarine environment (Riotte et al., 2003). Comparison of U and Li can provide insight as to the processes which govern the geochemical cycles of each element.

This study presents new U and Li isotope data for rivers draining basalt terrains in Iceland (sampled September 2003) and Sao Miguel in the Azores archipelago (October 2004). Both of these islands are monolithologically basaltic, but have different temperature and precipitation ranges. Variations in river chemistry are therefore linked to differences in the weathering environment, rather than to variations in rock type.

Thirty river water samples were taken in Iceland, mostly from the Hvítá catchment in the west of the island, including a transect of the Borgarfjörður estuary, into which these rivers are discharged. A smaller number of samples were also collected from glacier-fed rivers, along with ice samples from the glacier itself. The uranium concentration in the rivers ranges from 0.2 to 20 ng/l, and rises from 3 ng/l to almost 3 μg/l (oceanic value = 3.3 μg/l (Chen et al, 1986a)) in the estuary, showing conservative behaviour in the mixing zone. Lithium concentrations range from 0.02 to 1.05 μg/l in the rivers, and rise to 160 μg/l in the estuary. Li also behaves conservatively in the mixing zone.

Around 20 river water samples were taken from the Azores, along with rain water and samples from an estuarine mixing zone. U and Li river concentrations range from 3 to 212 ng/l and from 0.09 to 3.5 μg/l, respectively. Highest concentrations are linked to hydrothermal input. Both elements attain concentrations close to seawater in the estuarine mixing zone.

Uranium activity ratios (^{234}U/^{238}U) range from 1.13 to 2.14 in Iceland, and from 1.02 to 1.92 in the Azores, showing that silicate weathering can yield a large range of values (down to $\sim$1, which is secular equilibrium). Lowest U concentrations typically correspond to highest activity ratios, especially in glacial rivers. Colloidal fractions in the Icelandic samples were low. However, the Azorean water was ultrafiltered, to separate the colloidal fraction. The activity ratios in the colloidal fraction of the Azorean samples are closer to secular equilibrium than their host waters, indicating that uranium isotopes do not partition equally between the dissolved and colloidal phases.

Li isotope values (δ^7Li) for rivers in Iceland range from 10 to 33 per mil, with low values due to hydrothermal input and high values stemming from superficial weathering in glacial rivers. These data demonstrate that Li isotopes fractionate during weathering of the source basalts (which have δ^7Li $\sim$ 4.5 per mil). Preliminary results of Li isotopes in a saline mixing zone indicate that seawater isotope ratios are already reached by 3500 to 5000 mg/l salinity (seawater has 35000 mg/l salinity).

Chen J. H., Edwards R. L., and Wasserburg G. J. (1986a) ^{238}U-^{234}U-^{232}Th in seawater. Earth and Planetary Science Letters, 80: 241-251

Dessert, C. et al., 2001. Erosion of Deccan Traps determined by river geochemistry: impact on the global climate and the Sr-87/Sr-86 ratio of seawater. Earth and Planetary Science Letters, 188(3-4): 459-474.

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