Silicate weathering in kinetically limited weathering environments: Constraints from Li isotopes in Himalayan rivers

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Chemical weathering of silicate rock consumes atmospheric CO_2 and supplies the oceans with cations, thereby controlling both seawater chemistry and climate. The rate of CO_2 consumption via weathering and the rate of CO_2 outgassing from the planetary interior are related by a negative feedback loop essential to maintaining an equable climate on Earth. Considerable attention has been drawn to the possible links between weathering, erosion and climate as being important drivers of this negative feedback.

To illustrate the controls on silicate weathering this work considers the Li isotopic composition of river waters and sediments in the headwaters of the Ganges. Dissolved Li is primarily derived from silicate minerals and the large fractionation of its isotopes in the Earth surface environment make Li a sensitive tracer for silicate weathering processes.

The rivers in the headwaters of the Ganges show a wide range in their Li isotopic composition in both waters and sediments, covering much of the observed global riverine variation. These variations are a consequence of the pronounced gradients in climate (rainfall and temperature), and erosion rates across the river basin, typical for rivers transecting the Himalayan range.

In such mountainous ‘kinetically limited’ weathering environments chemical weathering occurs along a range of groundwater flow paths in fractured saprolite and rock. The evolution of the Li isotopic composition along individual flow paths is modelled using a simplified one-dimensional reactive transport model. The model considers the input of Li from rock dissolution, removal due to secondary mineral formation, and the advective flux along subsurface flow paths. In the model Li isotopic variations are described by two dimensionless variables; (1) the Damköhler number, N_D, which relates the silicate dissolution rate to the fluid transit time, and (2) the net partition coefficient of Li during weathering, K_{net}, describing the partitioning of Li between secondary clay minerals and water. The response in N_D and K_{net} is tested for a range of climatic and erosional settings across the basin, providing a nuanced view of the controls on Li isotope fractionation, and by extension silicate weathering, in kinetically limited weathering environments.