

Distribution of stable isotopes in soil: A clue to discriminate between lithogenic and biogenic fluxes

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It is still poorly understood whether the biological activity in soil promotes or inhibits the weathering processes and what are the nature and mechanisms of the feedbacks. Amongst the processes that control the element distribution in soil, it is then important to distinguish the reactions or fluxes that are related to the transformation of mineral from those related to the biological cycling. Here, we couple multi-isotopic and numerical approaches with a view to model the relative contributions of the vegetal recycling and the mineral weathering on the soil solution chemistry.

We choose to use B and Li isotopes in a temperate forested soil (Strengbach, Vosges, France, <http://ohge.u-strasbg.fr/indexuk.html>) because of their geochemical complementarity in characterizing sources and reactions involved in both mineral and biological processes. The B and Li isotopic systems are of particular reliability because of their great sensitivity to water/rock interaction and the contrasted role played by the vegetation in their respective geochemical behavior. At the watershed scale, it is estimated that the amount of B being cycled each year through the vegetation is about 4-5 times larger than the amount of B exported at the outlet of the basin. This observation leads to the conclusion that any change in the biological activity should significantly affect the B geochemical signature in soil. Moreover, recent analyses have demonstrated that the B isotopic composition of the vegetation is far from any other B pool in soil offering a real opportunity to trace B biogenic fluxes. In contrast Li isotopes are known to reflect almost exclusively water/rock interactions with very little, if not negligible, contribution of the biological activity. Analyses of B and Li isotopes in soil solutions and solids along depth-profiles at different locations have demonstrated the presence of a highly reactive zone at shallow depth (5-15 cm) in soil that is characterized by a mass transfer between the solids and solution at a seasonal scale. At deeper depth in soil (below 40-50 cm), the soil solution chemistry only reflects a mixture between an averaged biogenic input and weathering flux from which it is then straightforward to calculate the relative contribution of mineralogy and biology to the net mass transfer.

Lithium isotope fractionation along a weathering chronosequence

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Understanding the mechanisms of silicate weathering is a fundamental interest in understanding the past and present climate, the flow of elemental fluxes from the continents to the oceans, and soil formation. The BigLink project aims at a detailed understanding of incipient rock weathering by a multidisciplinary study of a young soil chronosequence located in a glacier forefield in the Swiss Alps. The fresh rocks are exposed due to glacier retreat and young soils formed on the basal moraine. This project offers a unique opportunity to develop new tools for the study of geochemical weathering, such as new isotopic tracers.

As Li is concentrated in the silicate rocks and its isotopes fractionate during weathering reactions, it seems like an ideal proxy for silicate weathering. Experimental studies have established that Li isotope fractionate during secondary clay formation while other studies have focused on large basins or on weathering profiles. In this study, we analyzed the isotopic composition of lithium in stream waters in rocks and in soils along the glacier forefield chronosequence using the high resolution Nu 1700 ICP-MS.

The isotopic composition of Li (⁷Li/⁶Li) in soils decreases from the youngest to oldest soil and can be linked to the removal of cations. This clearly shows preferential release of ⁷Li during alteration. As noted previously in the literature, ⁶Li should be preferentially coprecipitated into secondary weathering minerals. In contrast, Li isotopic composition in stream waters increases from the glacier front onward. This suggests the contribution of an increasingly fractionated pool of Li as water-interaction proceeds in the watershed.

These remarkable trends clearly demonstrate the potential of lithium isotopes to trace the initial weathering reactions at the scale of a small watershed.