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REE Fractionation During Granite Weathering and Removal by Waters and Suspended Loads

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Several geochemical and isotopic studies have been performed on suspended and dissolved river loads in order to provide information about their origin (Sholkovitz, 1992; Allègre et al., 1996). However, very few studies deal with REE (rare earth elements) mobility within the system atmosphere-soil-soil solution-stream water. In this study, we try to characterize the fractionation and the migration of the REE in a granite derived soil system located in a small catchment of the Vosges mountains (France). Sampling site and methods

The Strengbach forested catchment covers 80 ha on the eastern part of the Vosges mountains. The bedrock is a 320 My base-poor leucogranite that has been affected by post-intrusive hydrothermal events. The soils are rather deep, sandy and stony and belong to the brown acidic to ochreous podzolic soil series. The mean annual stream discharge reaches 20 l/s. ICP-MS and TIMS measurements were performed on both solid samples ("fresh" granite, different soil samples of three soil profiles and suspended load of the stream) and surface waters (rainwater, throughfall, soil solutions, spring and stream water) in order to determine their respective REE concentrations as well as Sr and Nd isotopic compositions. A liquid-liquid extraction technique using HDEHP as organic solvent has been applied to enrich the REE by a factor of at least 100 in water samples. The same extraction technique has been used to obtain sufficient Nd for isotope determination (Tricca et al., 1999).

Results and discussion

The PAAS normalized REE pattern of the bedrock is characterized by a strong depletion in HREE (heavy REE) and a negative Eu anomaly (0.46). Similarly, the granite normalized REE distribution patterns of the soil samples of the different soil profiles show HREE depletion which become more important with decreasing depth. The correlative behaviour between P_2O_5, Th and REE with depth indicates that besides apatite other phosphate minerals like monazite are most important phases controlling the Th and REE budget in the soil. This is in accordance with other mineralogical and geochemical studies in such a soil (Probst et al., 2000). On the other hand, at greater depth, zircon seems to be another important mineral phase controlling especially the HREE enrichment as shown by the positive relationship between Zr content and the Yb/Ho ratio. Different grain size fractions show similar REE distribution patterns and are only weakly fractionated compared to bulk soil sample. However, the finest fraction (0-20 µm) is more enriched in Sr and REE suggesting a stronger concentration of REE carrying minerals in this fraction. The suspended and dissolved load of the stream show as a whole an enrichment in HREE if compared to the granite or to the different soils samples. However, compared to the uppermost soil samples the suspended load is significantly more enriched in HREE than compared to the deepest soil sample or the "fresh" granite. Thus, most probably the REE of the suspended load originate from a source with REE characteristics found in the deep soil horizons. This source might have been situated in the uppermost soil profile which is actually REE depleted. The weathering process can be compared with a leaching experiment where the waters correspond to the leachate and the soil to the residual phase of the granite. As shown by the Sr isotope data, the suspended load would originate from the finest soil fraction. The Sr and Nd isotopic data of the suspended load suggest that it contains up to 3% Sr and Nd from apatite and up to 97% from feldspar (Figure 1). On the opposite, a great part of the Sr and Nd in the waters would originate from apatite leaching or dissolution, although apatite only represents 0.5% of the total granite. But also the atmospheric contribution to the REE budget of the drainage water may be of importance as indicated by similar REE distribution patterns of rainwater, throughfall and soil solutions. Nd isotope determination on these waters shall help to quantify the atmospheric contribution.

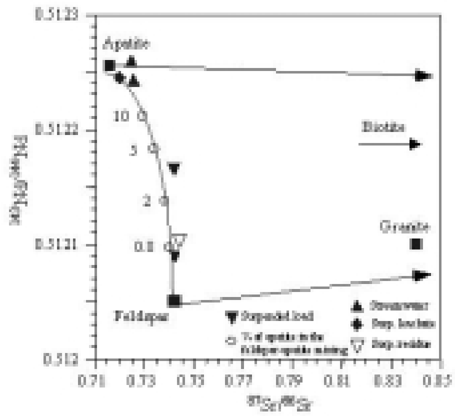

Figure 1: Mixing model explaining Sr and Nd isotopic composition of suspended and dissolved loads (% are in terms of the weight fraction of apatite)

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