Rare earth elements (*REE*) behaviour during gabbro weathering in a tropical rain forest of Southern Venezuela

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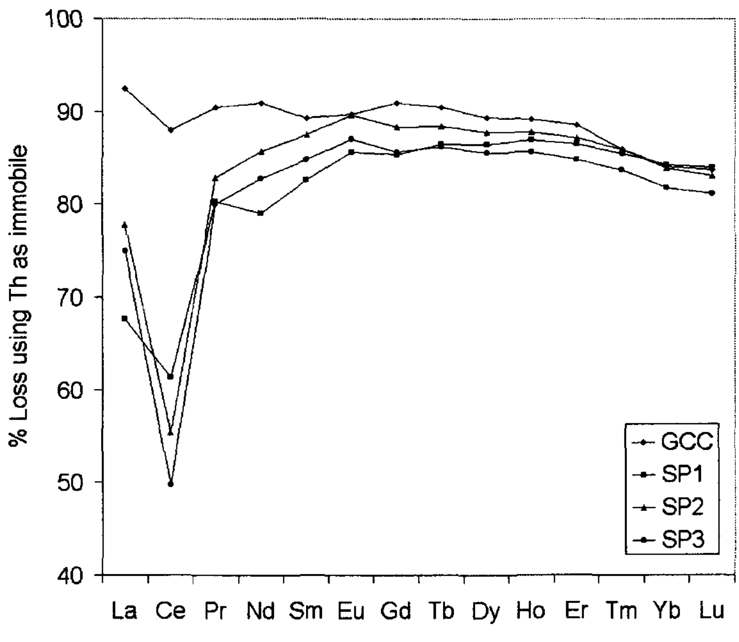
The purpose of this study is to analyse the behaviour of rare Earth elements (*REE*) (and some trace elements) during the weathering of a gabbroic body in a tropical rain forest environment in Southern Venezuela. To perform this analysis, the composition of fresh gabbroic rocks, weathered rock material, and spring waters draining the gabbroic body are taken in account. Three different section along the weathering profile from top (SP1), middle (SP2) to bottom (SP3) were sampled. Also, the weathering crust of an gabbroic rock boulder found at the surface of the weathering profile was sampled. The composition of the spring waters (total Alkalinity, pH, Cl^-, and dissolved organic carbon (DOC)) allows to compute the aqueous speciation of *REE*. Therefore, this information is used to characterize the nature of fluid/rock interaction and *REE* fractionation within the weathering profile.

Mass transfer analysis

Mass balance analysis was performed taking in account the compositions of the fresh gabbro, weathered soil material, and the spring waters draining



.FIG. 1. Calculated *REE* loss using Th as the immobile element (see text). Data points are the *REE* loss in three soil sections along the weathering profile: SP1= top, SP2= middle, and SP3= bottom. GCC= gabbro alteration crust.

the gabbroic body. Application of mass transfer equations considering highly mobile and immobile elements are used to estimate the water/rock mass ratio and the percentage of chemically leached matter. *REE* behaviour was assesed by comparing all *REE* concentrations relative to Th which is assumed to be immobile using the following relation

$$REE \text{ loss} = \left(\frac{\left(\frac{REE}{\mathrm{Th}}\right)_{\mathrm{wr}}}{\left(\frac{REE}{\mathrm{Th}}\right)_{\mathrm{fr}}} - 1 \right) \times 100(1)$$

where *REE* and Th are their corresponding average concentrations in the weathered material (wr) and fresh gabbro (fr), respectively. The *REE* losses along the weathering profile are estimated to reach 90% of the source rock composition (Fig. 1). Such dramatic *REE* loss indicates that no primary or secondary mineral phases hosting these elements survive the weathering process.

REE behaviour

Figure 1 shows that the soils are enriched in light *REE* while the weathered crust on the gabbroic boulders do not show any internal *REE* fractionation. These *REE* patterns are interpreted as distinct weathering conditions between the gabbroic boulders and the soil profile. Light *REE* losses in the gabbroic boulder is consistently higher than those observed in the soils. This is probably a result of the direct contact of relatively acidic fluids (pH 4.5) with the gabbroic boulder rock which has an enhancing effect on mineral solubility. Furthermore, organic-rich solutions prevail in this kind of surficial environments and are able to transport *REE* species more efficiently as organic ligands out of the weathering system. The dominant secondary mineral found in the alteration crust of the gabbro is gibbsite. Adsorption processes on mineral surfaces are minimized by both low pH and oxygen-donors poor surface. *REE* complexation with organic ligands does not result in any significant light/heavy *REE* fractionation. Conversely, at the bottom of the soil profile within the soil-gabbro limit, spring waters are basic (pH 8) and *REE* speciation can be dominated by carbonate and not organo-metal complexes. Mineralogical analysis of these soils show that kaolinite is the dominant secondary clay mineral. These conditions (high pH, carbonate *REE* complexes and O-donors rich phases) increase the adsorption process efficiency particularly for the light *REE*