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Boron isotopes profile in temperate forest granitic soils: a clue for exploring past and present weathering conditions

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In the present study, we tested the sensitivity of B isotopes to conditions of soil forming in the case of a forest soil developed after a multi-phases alteration sequence: from an ancient hydrothermal alteration of the bedrock (380 Ma) to the quaternary soil development. We focused on two soil profiles collected in the Strengbach basin (Vosges Mountains, Eastern France), which have developed on granitic bedrock differently affected by a gradual intensity of hydrothermal alteration. The B chemical and isotopic profiles analyzed along the two soils clearly point the sensitivity of this element to distinct weathering histories and soil forming reactions. The model of the B mobility during weathering reactions we propose in this study leads to the conclusion that the ancient hydrothermal alteration induced the formation of 10B enriched fine-grained minerals and the departure of a complementarily 11B enriched component (most likely a dissolved B in the hot percolating fluid). As a result, the distribution of B isotopes within altered bedrock samples and coarse particles from soil horizons reflects the intensity of this ancient hydrothermal event. The lower the δ11B value of the coarsest grains is, the more intense the hydrothermal alteration was. This scenario, the simplest one we conceive being able to enrich the remaining altered bedrock in 10B also implies that the bedrock evolved as a rather confined system with very limited B supply from an external source.

Additionally, examination of B and δ11B in the finest particle size and bulk soil samples greatly helps understanding the weathering reactions operating during pedogenesis. In particular, the distribution of B isotopes within particle size fractions is consistent with the mineralogical and chemical observations pointing to a hydrolysis behavior of the soil developed on the most intensively altered granite by opposition to a complexo-hydrolyzing behavior shown by the soil developed on the less intensively altered granite. In the latter soil, the finest particle size fraction (clay minerals) shows systematic 11B enrichment in the uppermost soil layers by comparison with deeper ones revealing a significant and measurable contribution of boron originating from pore fluids and possibly recycling of the vegetation cover.

In this study, B isotopes from bulk soil and separate particle size fractions helped reconstructing a complex and multi-phases history of water/rock interaction as well as identifying the contribution of the vegetation cover as a source of element during pedogenesis. These conclusions are mostly held by the large B mobility and the large B isotopic fractionation generated by its partial transfer between mineralogical and hydrological reservoirs. In particular, the soil solutions are such enriched in 11B compared to any other mineral pool that make their contribution to B in secondary phases easy to trace. Because any pristine crystalline bedrock generally has δ11B spanning over a limited range of values, we expect that variations of the bedrock at a regional or even continental scale may be overshadowed by the B isotopes redistribution induced by water/rock interactions. If this turns to be validated, analyses of B isotopes in minerals (bedrock, soil minerals or even suspended particles in rivers and lake sediments) may reveal the nature and intensity of weathering reactions that have led to their formation.