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The Boron Isotopic Composition of Streams as a Tracer of Forest Nutrient Cycles

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Forest ecosystems, which are essential for the regulation of Earth's climate, depend on a variety of essential nutrients derived from mineral sources. A variety of (bio)geochemical processes cause measurable fractionation between the stable isotopes of nutrients, creating fingerprints for the pathway of these elements through the critical zone. The micronutrient boron (B) offers particular utility as a tracer of ecosystem nutrition. At the catchment scale the isotope signature of B reflects multiple sources and processes such as chemical weathering, atmospheric deposition, incorporation into clays and biological recycling. This can lead to significant isotopic fractionation of B between Critical Zone compartments. In particular, here we explore how the B isotope signature of streams, relative to underlying bedrock mineralogy, can be leveraged as an indicator of nutrient cycling in the catchment.

We present B-isotopic data from two long-term instrumented Critical Zone Observatories within the French OZCAR network. Stream, springs, groundwater and unsaturated porewater solutions from the Quaraze watershed on Mt. Lozère (Southern France) were analysed and compared to data from stream water and springs in the Strengbach in Vosges (Eastern France). Both sites are mature forests underlain by granite bedrock but they experience distinct climates and host different tree species assemblages. The Quaraze stream is characterised by high $\delta^{11}B$ values. Depending on the season, its outlet is at least 8‰ higher in $\delta^{11}B$ than underlying groundwaters and it displays more than 10‰ higher $\delta^{11}B$ values than the Strengbach outlet. The Quaraze stream displays a gradient in $\delta^{11}B$ from the source to the outlet with differences above 5‰ in summer, while the source and outlet are identical within the analytical error in fall. Groundwater and porewater solutions from the unsaturated zone vary more than 15‰ in $\delta^{11}B$. Vegetation cycling should play a key role in generating the elevated stream $\delta^{11}B$ as recycled B is characterised by high $\delta^{11}B$ levels, whereas the $\delta^{11}B$ gradient in the stream may be caused by mixing waters from a range of flow paths. This work contributes towards establishing the chemistry of streams as a sensor of the nutritional status of the ecosystems they drain.