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Tracing Riverine Sulfate Sources Using Stable Strontium Isotopes

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Chemical weathering of rocks is a fundamental component of the long-term carbon cycle, influencing atmospheric CO_2 over geological timescales. While silicate weathering serves as a major CO_2 sink, weathering of carbonate rocks has a more complex role. Carbonate weathering by carbonic acid is CO_2-neutral, whereas reactions with sulfuric acid, primarily derived from the oxidative weathering of pyrite (OWP), result in CO_2 release [1,2,3]. Quantifying the extent of OWP is therefore essential for understanding the role of carbonate weathering in the global carbon fluxes. Existing estimates rely on riverine sulfate concentrations, but a key challenge lies in distinguishing sulfate derived from OWP from that originating from the dissolution of evaporite rocks.

It has been shown that sulfate evaporites are characterized by a uniquely heavy stable strontium isotope composition ($\delta^{88/86}Sr$) compared to carbonates and silicates [4]. This study explores whether stable Sr isotopes can reliably trace Sr sources and help identify sulfate origins in river systems. We present new stable Sr isotope data from small catchments in Eastern France mostly underlain by carbonate and evaporite rocks ($\delta^{88/86}Sr$: 0.17‰–0.54‰), along with Sr isotope data from natural Triassic evaporites (0.39‰–0.54‰). A simple mixing-reaction model is developed and applied to these rivers, estimating that 0–50% of their Sr originates from gypsum dissolution. When extended to large rivers worldwide, the model suggests evaporite-derived Sr contributions of 0–70%. Upscaling these results, we estimate that OWP contributes approximately 16–48% of the global riverine sulfate flux, with an associated carbon flux of ~15 TgC/yr (ranging from 7 to 21 TgC/yr). Our findings demonstrate the potential of stable Sr isotopes as a promising tool for tracing sulfate sources in riverine environments. Refining the chemical characterization of local weathering endmembers, improving constraints on secondary carbonate precipitation, and integrating additional proxies for sulfate source quantification would further advance the development of this approach and strengthen its reliability.

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