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Chemical Weathering Fluxes Underestimated in Erosion Hot-Spots due to the Hidden Riverine Flux of Adsorbed Cations

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Mountain ranges are hot-spots for erosion, physical weathering, chemical weathering, and carbon transfer between the atmosphere, biosphere, and solid-earth [1]. Estimating the rate of carbon transfer from silicate and carbonate weathering requires knowledge of the total mobile ion flux in rivers deriving from mineral dissolution reactions. Recent work has demonstrated that fluxes of ions adsorbed to mineral surfaces (the exchange pool) can account for a significant proportion of the total mobile ion flux, and that exchange reactions with uplifted marine sediments bias estimates of CO_2 drawdown by silicate weathering [2].

We present a two-year time-series of samples spanning the entire discharge and suspended sediment concentration ranges of two major Himalayan rivers (Kosi & Sun Kosi), including several episodic high sediment discharge events. The adsorbed phase was extracted from the sediment using two separate chemical extraction methodologies, with results agreeing within 10%. Radiogenic strontium isotopes confirm an exchange equilibrium between the dissolved and adsorbed phases.

We demonstrate that the annual adsorbed fluxes of calcium and strontium account for 20-30% of the total mobile flux (dissolved & adsorbed). Large seasonal variations in the fraction of total mobile fluxes transported by the exchange pool are primarily controlled by suspended sediment concentrations. Up to 85% of the total mobile calcium, 82% of the mobile strontium, and 100% of mobile barium, can be transported in the adsorbed phase. Furthermore, episodic extreme sediment flux events (such as glacial lake outburst flood events) transport substantial fractions (up to 7% for calcium) of the total annual mobile element budgets, in the adsorbed phase, within a matter of hours to days.

Despite the increase in the total mobile flux, estimates of CO_2 drawdown by silicate weathering using conventional methods, without accounting for cation exchange, are 20-30% too high, assuming Ca-Na exchange with an old sedimentary exchange pool. Our results stress the need to include the adsorbed ion flux in chemical weathering budgets of rivers with high suspended sediment concentrations.

[1] Hilton & West (2020), Nature Reviews Earth & Environment 1, 284–299.

[2] Tipper et al. (2021), Proceedings of the National Academy of Sciences, 118.