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Can hydrothermal alteration explain the heavy K isotope signature of seawater?

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Potassium (K) cycle is closely linked to silicate weathering and possible authigenic clay formation (i.e., "reverse weathering")–two processes believed to be fundamental in stabilizing Earth's climate and ocean chemistry over million-year timescales, because K primarily resides in silicate minerals. Stable K isotopes ($^{41}K/^{39}K$ or $\delta^{41}K$) are a novel proxy for the global K cycle, but the first-order observation that seawater has a $\delta^{41}K$ value ~0.6‰ higher than bulk silicate earth (BSE) remains unexplained [1].

Hydrothermal alteration is a major K sink at low temperatures and a major K source at high temperatures, its influence on seawater K isotope composition, however, is poorly constrained. Here we report $\delta^{41}K$ data measured in modern hydrothermal fluids collected from the intermediate spreading Gorda Ridge and fast-spreading East Pacific Rise (EPR) in the Pacific, and the ultraslow spreading Southwest Indian Ridge (SWIR) in the Indian Ocean. Fluid endmember $\delta^{41}K$ values range between -0.15‰ and -0.45‰. Although these values fall between seawater (0.12‰) and basalt (-0.45‰), appearing to be "unsurprising" at first glance, they require either (1) considerably larger K removal than previously believed at the low temperature recharge stage, or (2) K isotope fractionation that enriches heavy K isotopes in altered basalts, when fluid K concentrations are considered. It could be a surprising result if either is tested true. Interestingly, if the latter explanation is correct, the inferred direction of K isotope fractionation would contradict that inferred based on data from altered basalts [2].

The apparent contradiction revealed by data from hydrothermal fluids and altered basalts arises from the difficulty in constraining water/rock ratios in natural samples and the presence of complex, often intangible, processes in hydrothermal systems. We adopted a laboratory approach to elucidate the role of hydrothermal alteration in controlling seawater $\delta^{41}K$. Our preliminary phase separation experiments show limited K isotope fractionation. This implies a dominant role of water-rock interactions on fluid $\delta^{41}K$ values. Low and high temperature alteration experiments are underway, and the results could better address the question if hydrothermal alteration has caused a heavy $\delta^{41}K$ value of seawater.

[1] Wang et al. (2021); [2] Hu et al. (2020).