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Sulfur sourcing at Mars-relevant lakes informs controls on magnesium sulfate precipitation

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The surface of Mars underwent a dramatic episode of drying ~3.7-3.5 billion years ago, indicated in part by the presence of magnesium sulfate ($MgSO_4$) minerals recently confirmed by the Curiosity rover at Gale crater [1]. Yet naturally forming $MgSO_4$ remains poorly understood, along with possible constraints it could provide for the habitability of ancient Mars.

Analog environments on Earth can provide an empirical framework within which to interpret $MgSO_4$ on Mars. Hundreds of evaporative lakes are scattered across the Fraser Plateau in British Columbia, Canada, and among them are rare sites with active $MgSO_4$ precipitation (e.g., epsomite [$MgSO_4 \cdot 7H_2O$]). Such settings result from a chemical divide scenario where SO_4^{2-} concentrations outstrip Ca^{2+}, leaving Mg^{2+}, SO_4^{2-}, and Cl^- as the predominant ions in solution. Basque Lake 2 serves as an ideal example. Importantly, lakes proximal to Basque follow different chemical divide pathways. These include the phosphorus-rich Last Chance and Goodenough systems, which are low in dissolved Mg^{2+} and do not precipitate $MgSO_4$. Investigating these Fraser Plateau lakes may reveal how relatively fine-scale differences in the weathering environment and ecological setting can impact the likelihood of $MgSO_4$ precipitation.

Here we present sulfur stable isotope data ($\delta^{34}S$) in tandem with dissolved ion concentrations from three lakes: Basque Lake 2, Last Chance Lake, and Goodenough Lake. The geologic source of sulfur appears distinct at each setting. Basque Lake 2 presents low sulfate isotope values ($\delta^{34}S$ = -6.2 to -6.8‰), possibly indicative of sulfide weathering despite lake water pH of ~8. Sulfate $\delta^{34}S$ is significantly higher at both Last Chance ($\delta^{34}S$ = 20.9 to 25.0‰) and Goodenough (33.9 to 73.0‰). Additionally, the uniformity of Basque sulfate isotope data (σ = 0.2‰) does not indicate microbial sulfate reduction (MSR) in the shallow sediments, while Goodenough exhibits a positive, MSR-signifying shift of >30‰ across the sediment-water interface. Taken together, these data indicate that (1) the absence of a biological sulfate sink near the sediment-water interface and (2) a weak relationship between sulfide weathering and lake water pH represent potential controls on lacustrine $MgSO_4$ formation.

[1] Chipera et al. (2023) *J. Geophys. Res. Planets*, 128(11), e2023JE008041.