

Sulfur and oxygen isotope study of sulfur cycling in a polymictic eutrophic saline lake, Salton Sea, California

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The Salton Sea is a seasonally anoxic and sulfidic lake in the southeastern desert of California. The shallow lake (≤ 12 meters) has an extensive area of approximately 800 km². Due to high evaporation and low riverine input controlled by regional aridity and water policy, respectively, the terminal lake is dominated by evaporation and crystallization. Extensively modified by human activities, the lake sustains high sulfate (SO₄²⁻) and nutrient loading (nitrogen and phosphorus) year-round from agricultural fertilizer runoff, leading to cultural eutrophication and related oxygen deficiencies. High dissolved SO₄²⁻ concentrations (>300 mM) and TDS levels (>60 ppt) have continued to increase over the last century due to largely unregulated input of these agricultural wastewaters. Precipitation of minerals from the evaporitic sequence occurs when high degrees of supersaturation are reached as water evaporates, resulting in extensive evaporitic crusts on the margins. During the summer, mixing of thermostratified surface oxic and bottom sulfidic waters and associated oxidation of hydrogen sulfide result in spontaneous precipitation of gypsum (CaSO₄· $\frac{1}{2}$ H₂O) crystals, averaging 20 microns in diameter, in surface waters 0-3m deep.

This combination of vast SO₄²⁻ availability and seasonal variations in water column redox leads to microbially mediated S cycling in the water column coupled with abiotic processes, all of which remain unconstrained and different from those of other, well-studied permanently euxinic, meromictic lakes (e.g., Mahoney Lake and Fayetteville Green Lake). To better understand the influences of these processes on sulfur isotope compositions, including those driven by humans, and to differentiate between biotic (i.e., dissimilatory sulfate reduction and phototrophic sulfide oxidation) and abiotic (i.e., evaporation) pathways, we analyze the isotopic compositions of sulfate ($\delta^{34}\text{SSO}_4$ and $\delta^{18}\text{OSO}_4$) and sulfide ($\delta^{34}\text{SH}_2\text{S}$) for water column dissolved S, evaporitic crust, suspended gypsum crystals, and pyrite extracted from sediment samples. We provide a stable isotope mixing model with input constraints that include seasonal water column SO₄²⁻ and H₂S concentrations, isotope data, and relevant parameters across the oxic/anoxic/euxinic transition. We use this model to explore controls on rapid SO₄²⁻ reduction and reoxidation as tied to source relationships and associated water mass mixing, redox, seasonal patterns.

