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Insights into paleoproxy behavior from a redox-stratified lacustrine system

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Lakes represent a key segment of the land–ocean continuum with the potential for selective trace-element retention and isotope signal modification, thereby altering downstream fluxes. Lakes are also valuable as modern analog systems for biogeochemical proxy validation, particularly for redox proxy systematics, as lakes encompass a broader range of redox regimes (e.g., iron and sulfur availability) than marine settings. Redox-sensitive trace elements such as molybdenum (Mo) and chromium (Cr) are widely used as proxies for reconstructing redox conditions of ancient aquatic environments. Robust interpretation of their sedimentary enrichment patterns and isotopic compositions, however, requires a detailed understanding of the processes governing their cycling and isotope fractionation within the water column, as well as how these paleoredox signals are transferred to and preserved in sediments.

This study focuses on Lake Zug (Switzerland), a deep lacustrine system (to ~200 m) that develops persistent anoxia below ~130 m and is characterized by manganese-rich, iron- and sulfide-poor waters representing a rare ‘manganous’ redox regime. Preliminary results suggest that both Cr and Mo are removed from the dissolved phase in the anoxic zone. A progressive decrease in dissolved $\delta^{53}Cr$ from 1.53‰ at mid-depths above the oxic–anoxic transition to ~0.70‰ in deep waters indicates substantial internal fractionation within the water column, consistent with reported observations from other modern anoxic basins [e.g., 1, 2]. $\delta^{98/95}Mo$ values change from 1.12‰ at the surface to ~1.30‰ at ~100 m and remain invariant below. Bottom-water Mo concentrations exhibit pronounced seasonal variability, with lowest concentrations coinciding with transiently observed dissolved sulfide in the deepest waters during the most reducing conditions, suggesting possible seasonality to Mo removal due to formation of particle-reactive thiomolybdate species. The observed isotope offset between $\delta^{98/95}Mo$ of the bulk anoxic water and the underlying sediments ($\Delta^{98/95}Mo_{sed\text{-}water}$) is approximately -1‰, similar to ferruginous and sulfidic sediments underlying non-sulfidic marine waters [3]. The results will be discussed in the context of existing data from other anoxic systems and their implications for paleoproxy application.

[1] Janssen et al., 2022. *Geophysical Research Letters.*
[2] Mallick et al., 2025. *Applied Geochemistry.*
[3] Scholz et al., 2017. *Geochimica Cosmochimica Acta.*