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A 550-million-year record of the concentration and isotopic composition of lithium in seawater

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Earth's climate, eustatic sea-level, and the major-ion composition of seawater have co-varied on ~100 million-year timescales throughout the Phanerozoic. These long-term oscillations are commonly attributed to plate-tectonic processes associated with supercontinent assembly and breakup, including variations in seafloor spreading, arc volcanism, continental uplift and the geographic distribution of mafic and ultramafic terrains that modulate hydrothermal and weathering fluxes. More recently, a rapid rise in the lithium isotopic composition of seawater (δ^7Li_{SW}) reconstructed from bulk marine carbonates has been interpreted as evidence for a state change in the global silica and carbon cycles during the Paleozoic, linked to biological innovations such as the radiation of land plants or shifts in the marine silica cycle [1].

Here, we present the first coupled record of seawater lithium concentration ($[Li^+]_{SW}$) and δ^7Li_{SW} spanning the past 550 Ma, reconstructed from fluid inclusions in marine halite from a global suite of Phanerozoic and Neoproterozoic evaporite basins. These samples were previously used to document secular variations in the major-ion, trace-element, and Mg-isotope compositions of seawater over the past 550 Ma. Negligible Li isotope fractionation (<1‰) during halite precipitation [2] and the conservative behavior of Li during seawater evaporation and halite precipitation [3] make fluid inclusions in marine halite a robust archive for reconstructing δ^7Li_{SW} and $[Li^+]_{SW.}$

Our results show that $[Li^+]_{SW}$ and δ^7Li_{SW} co-vary with major-ion chemistry and long-term climate states. Hothouse intervals are characterized by elevated $[Li^+]_{SW}$, low Mg/Ca ratios, and lower δ^7Li_{SW}, whereas icehouse climates exhibit lower $[Li^+]_{SW}$, higher Mg/Ca ratios, and elevated δ^7Li_{SW}. Mass-balance modeling incorporating experimental constraints on Li partitioning into marine clays demonstrates that these trends can be explained by modest (~2×) variations in the global carbon cycle (e.g., seafloor spreading, hydrothermal exchange, and silicate weathering) associated with supercontinent cycles, without invoking a Paleozoic state change in the global carbon–silicon system. Reconstructed Paleozoic–Mesozoic seawater $[Li^+]$ values were >5–10× higher than modern seawater, suggesting that evolved evaporite basins of these ages may represent an important and underexplored lithium resource.

[1] Kalderon-Asael et al., 2021, Nature 595, 394–398; [2] Li et al., 2024, Chem.Geol. 668, 122326; [3] Shalev et al., 2018, GCA 241, 164–179