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Beyond $\delta^{18}O$: Triple oxygen isotope constraints on Archean ocean conditions from the cherts of the Daitari Greenstone Belt, Singhbhum Craton, India

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Physicochemical conditions in the Archean ocean defined critical boundaries for the development and emergence of life on Earth. Seawater temperatures and their spatial variation, from surface to deep water and across hydrothermal zones, are key factors for pinpointing regions that may have supported life in early oceans. Traditionally, $^{18}O/^{16}O$ ratios measured in chemical sediments such as cherts, carbonates, and phosphates have served as proxies to infer ancient ocean temperatures and $\delta^{18}O$ values. However, interpretations of monotonically decreasing $\delta^{18}O$ sediment trends with age have varied widely, from models proposing cold, $\delta^{18}O$-depleted oceans to scenarios of isotopically modern-like seawater with temperatures up to 80 °C.

We present new oxygen isotope data from well-preserved 3.4 Ga banded cherts of the Tomka formation in the Singhbhum craton (India), exhibiting some of the lowest $\delta^{18}O$ values (down to 7.5‰) reported in the Archean record. If interpreted only via $\delta^{18}O$ systematics, these data would suggest ancient seawater was either much hotter or more isotopically depleted than current thermodynamic and geodynamic (i.e., high-versus low-temperature alteration balance) models allow. Our results demonstrate that $^{18}O/^{16}O$ ratio approaches are insufficient for robust paleo-environmental reconstruction in these complex sedimentary archives.

Triple oxygen isotope ($\Delta'^{17}O$) analyses reveal that the cherts were not in equilibrium with seawater during their formation or final isotopic imprint. Instead, they record a multifaceted oxygen isotope signature, reflecting diagenetic evolution, changes in pore fluid oxygen isotope composition, and seawater temperatures, that can only be unravelled by examining all three stable isotopes together. This holistic approach offers deeper insights into Archean ocean conditions and cautions against oversimplified interpretations derived from conventional $^{18}O/^{16}O$ isotope ratios.