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Revisiting the mid-Proterozoic Marine Oxygenation Event at ~1.1 Ga

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Co-evolving marine redox and ecosystem dynamics have acted synergistically to regulate long-term habitability over much of Earth history. Despite their early rise, eukaryotes did not play an ecologically significant role throughout the mid-Proterozoic. This evolutionary stasis was likely due to widespread anoxia and coupled limitations in nutrients. Importantly, however, a growing body of evidence suggests dynamic ocean redox conditions over the mid-Proterozoic characterized by multiple oxygenation events, including one at ~1.1 Ga. However, the present body of supporting data are still scarce and inclusive, demanding that we explore this purported oxygenation further.

Here, we are interrogating a set of well-preserved shale records (Atar/El Mreiti Group) from the Taoudeni Basin, Mauritania—the same sediments previously interpreted to have recorded the transient marine oxygenation at ~1.1 Ga. Our iron speciation data suggest that the local redox state was dynamic, shifting between oxic, ferruginous, and euxinic. Unexpectedly, even in the euxinic intervals, concentrations of redox-sensitive trace metals are low, inconsistent with rising oxygen levels in the global marine realm. A possible explanation for this inconsistency is that Taoudeni Basin was hydrologically (semi)-restricted, thus with a limited connection with the open ocean. The redox dynamics were likely controlled by time-varying degree of connectivity linked to sea-level changes—with high-stands corresponding to elevated nutrient supplies replenished from the open ocean and resulting anoxia, in contrast to low-stands associated with limited nutrients and resulting oxic conditions. To further illuminate the basin's hydrological features, we will explore thallium isotope (ε^{205}Tl) systematics. In modern restricted basins, Tl isotope compositions recorded by sediments underlying euxinic water columns are similar to those of the Tl inputs to the basins (ε^{205}Tl = -2) rather than open seawater. If showing this relationship, our results will be consistent with basin restriction, and thus the data from this basin cannot be used to infer the global redox landscape. However, we cannot rule out the possibility that the basin was instead connected to the open ocean, and the global oceans were characterized by prevailing anoxic conditions with minimal burial of manganese oxides. Regardless, both possibilities appear to challenge the suggestion of a transient oxygenation at ~1.1 Ga.