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Oscillatory and expanding marine oxygen oases in the runup to the Great Oxidation Event

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Multiple lines of evidence support the hypothesis that molecular oxygen (O_2) accumulated in surface oceans beneath an essentially O_2-free Archean atmosphere 4.0 to 2.5 billion years ago (Ga) [1,2]. Yet the temporal and spatial distribution of these environments, referred to as “oxygen oases”, remains under-constrained. To constrain the tempo and extent of marine oxygen oases, we measured authigenic thallium isotopic compositions ($e^{205}Tl_A$) in black shales from the Jerrinah Formation, Western Australia (~2.65 Ga) and the Nauga and Klein Naute Formations, South Africa (~2.6–2.5 Ga).

Lower-than-crustal $e^{205}Tl_A$ values (< –2) are frequently observed in shales from the ~2.65 Ga Jeerinah Formation and the ~2.50 Ga Klein Naute Formation. Particularly low $e^{205}Tl_A$ values are found at ~2.50 Ga when a pronounced “whiff” of O_2 occurred [5]. These data are best explained by pronounced seafloor Mn oxides burial, which requires persistent penetration of bottom water O_2 into marine sediments beneath regionally extensive marine oxygen oases. By contrast, near-crustal $e^{205}Tl_A$ values from the ~2.6–2.5 Ga Nauga Formation (South Africa) shales imply an intervening period of muted seafloor Mn oxide burial.

The Tl isotope data from the Jeerinah Formation extend evidence of regional marine bottom water oxygenation on continental shelves backward by ~150 million years. The low $e^{205}Tl_A$ values of the ~2.50 Ga Klein Natue Formation (South Africa) corroborate the previous finding of at least regional water column oxygenation evidenced by the broadly coeval Mt. McRae Shale (Western Australia). Integrating our data with previously published datasets (the 2.6–2.5 Ga Mount McRae Shale) [3,4], we paint congruent pictures of a dynamic marine oxygen oases during the runup to the Great Oxidation Event.

[1] Crowe et al. (2013) *Nature*, 501, 535-538. [2] Planavsky et al. (2014) *Nat. Geosci*. 7, 283-286. [3] Ostrander et al. (2019) *Nat. Geosci*. 12, 186-191. [4] Ostrander et al. (2022) *Front. Earth Sci.* 10, 833609. [5] Anbar et al. (2007) *Science*, 317, 1903-1906.