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# Redox structure of the Tonian ocean and its implication for early eukaryote diversification

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The early Neoproterozoic witnessed a transition from prokaryote-dominated marine ecosystem to one characterized by the proliferation of eukaryotes. This fundamental change has generally been attributed to evolving marine redox states. Conventionally, the Proterozoic ocean is thought to be characterized by oxic surface waters, with anoxic and sulfidic waters in middle depths along productive continental margins and anoxic and ferruginous deeper waters. This surface-to-deep redox structure is suggested to have persisted until the Ediacaran or even early Paleozoic. Previous studies also suggest a transition from sulfidic to ferruginous mid-depth ocean waters toward the earliest Neoproterozoic, leading to a pervasively anoxic and ferruginous subsurface ocean. This redox structure transition may detoxify ocean marginal settings and allow for eukaryote diversification following a prolonged evolutionary stasis during the Boring Billion. The global ferruginous conditions could result in ocean phosphorous limitation, decreased primary production, and low atmospheric oxygen levels during the early Neoproterozoic. To better understand the ocean redox structure in the early Tonian, we carried out sedimentological and geochemical analyses for the Huainan, Feishui, and Huaibei groups in the Xuhuai basin of the North China craton, mainly based on a complete drill core section together with three short outcrop sections. Multiple redox proxies show consistent water depth-dependent variations across the Xuhuai basin, i.e., mudstones were deposited in oxic/suboxic mid-depth slope environments, while carbonate rocks were deposited in persistently anoxic and ferruginous shallow-water settings. We propose that a shallow-water oxygen minimum zone sandwiched between the oxic/suboxic surface layer and mid-depth water masses occurred in the oligotrophic Xuhuai basin, which is analogous to, but much shallower than modern oxygen minimum zones. Ba proxy data indicate spatial variations in primary productivity which ultimately control basinal redox structures. Future work is needed to test the duration of this proposed redox structure and its potential global distribution. If the shallow-water oxygen minimum zone that occurred in the early Tonian Xuhuai basin is confirmed to be a global phenomenon, such marine redox architecture may benefit the maintenance of a stable bioavailable nitrate reservoir in the ocean, foreboding the subsequent expansion of eukaryotes.