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Tracking the spatial extent of ocean redox variability in the Mesoproterozoic ocean

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Emerging geochemical evidence suggests that the redox state of the Mesoproterozoic (1.6 – 1.0 billion years ago, Ga) ocean was more dynamic than previously recognized. However, spatial and temporal variability in ocean redox conditions through this time interval, particularly in relation to quantitative estimates of the extent of different modes of anoxia, are still poorly constrained. Uranium isotopes ($\delta^{238}U$) have emerged as a promising proxy for reconstructing ancient marine redox conditions based on isotopic fractionation occurring during the reduction process. In this study, we present a new $\delta^{238}U$ dataset for siliciclastic rocks from the 1.4 Ga Xiamaling Formation, deposited on the North China Craton. A combination of iron speciation and redox-sensitive trace element concentration data indicate a gradual transition from oxygenated bottom waters to dominantly ferruginous conditions in the middle part of the succession, with the subsequent development of euxinia up section, followed by mixed oxic-anoxic conditions towards the top. Our $\delta^{238}U$ data for oxic samples exhibit similar isotopic compositions to upper continental crust, demonstrating a dominant detrital U signal, as expected under such conditions. Organic-rich samples deposited under euxinic conditions record the highest authigenic $\delta^{238}U$ isotopic fractionations, which fluctuate within a narrow range. By contrast, authigenic $\delta^{238}U$ compositions for samples deposited under ferruginous conditions span a much wider range, generally spanning an interval between the euxinic and oxic end-members. These data provide support for the independent redox interpretations based on iron speciation and trace metal concentrations, and provide new insight into the redox structure of the Mesoproterozoic ocean. We combine our U isotope data with previously published Mo isotope data, and utilize a mass balance model to constrain the spatial extent of anoxia and euxinia in 1.4 Ga oceans.