Ferruginous versus euxinic: Elucidating the fundamental controls on the redox state of the Precambrian ocean

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Eukaryotic life evolved in a shallow oxygenated surface layer overlying an ocean that was largely anoxic. In the absence of oxygen, the ocean interior should have been either iron-rich ('ferruginous'), sulphide-rich ('euxinic'), or a spatially segregated mix of the two, an inference supported by the geologic record. These contrasting redox states can exert profound and very different controls on nutrient concentrations and cycling, and hence supply to the surface; iron-rich conditions have been proposed to limit oceanic phosphate concentrations, while high sulphide can limit trace element availability such as of iron. Changing ocean redox conditions and hence nutrient limitation have thus likely played a central role in the evolution of marine life. Currently however, we do not understand why and how the earth switched between these two states and most of this uncertainty stems from the lack of a quantitative description of the ancient ocean.

We have updated an Earth system model (cGEnIE) with a fully coupled Fe-S cycle. We then used this model to explore the three dimensional redox structure of the Precambrian ocean, and identify factors that might drive an ocean to a predominantly ferruginous or euxinic state, namely changes in the relative Fe and S fluxes and changes in biological productivity and changes in the carbon export from the surface zone. Our results show that regardless of the iron or sulphur flux, other factors – like surface productivity and carbon export – can keep the ocean in a ferruginous state and from becoming predominantly euxinic. This suggests that the Precambrian ocean chemistry was primarily controlled by marine ecology and the biological carbon pump in the ocean, rather than a difference in the relative fluxes of iron and sulphur from the crust.