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How Neoproterozoic-Paleozoic evolution of the biological pump affected shelf sea and ocean nutrient and redox state

Elisa Lovecchio, Stuart J. Daines, and Timothy M. Lenton
Earth System Science Group, College of Life and Environmental Sciences, University of Exeter, Exeter, UK

Profound changes to the plankton and the biological carbon pump took place during the Neoproterozoic and earliest Paleozoic Eras. The marine ecosystem evolved from one dominated by bacteria to a eukaryotic food web. In the same period, data show a series of transient oceanic oxygenation events ∼660-520 Ma, which get more frequent over time, and other evidence for an overall rise in atmospheric oxygen, suggesting the interaction of processes on multiple timescales.

Here we set out to model what could have caused abrupt changes in the redox state of the ocean. Towards this aim, we combine the use of a simple 2-layer box model for a stratified shelf sea with the use of a more complex 1D shelf sea model, both including a representation of the nutrient, oxygen and organic matter cycles. Through changes to the model's representation of the biological carbon pump, coupled with biogeochemical and ecological feedbacks, we explore the impacts upon the ocean redox state, carbon (C) and nutrient cycling.

We start with a dissolved organic matter (DOM) dominated ocean with rapid microbial cycling, to reproduce ecological conditions representing the late Tonian ocean ∼750 Ma. We show how the inefficient removal of organic matter to sediments supports elevated nutrient (P) levels. Next we explore the effect of the onset of eukaryotic algae, as indicated in the biomarker record ∼660-640 Ma. We study the impact of the efficient transfer of C and P to deeper waters and sediments on the oxygen and nutrient availability both on the short and on the long term. Our results show how the evolution of the biological pump, connected to a drastic change in the nutrient P levels, provides a plausible explanation for the oxygenation of shelf seas during the Neoproterozoic-Paleozoic.