How marine eukaryote evolution could have caused Neoproterozoic-Paleozoic oceanic oxygenation events

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A 'Neoproterozoic oxygenation event' is widely invoked as a causal factor in animal evolution, and often attributed to abiotic causes such as post-glacial pulses of phosphorus weathering. However, recent evidence shows a series of transient oceanic oxygenation events ~660-520 Ma [1], which do not fit the simple model of a monotonic rise in atmospheric oxygen (pO_2). Hence we consider mechanisms by which the evolution of marine eukaryotes, coupled with biogeochemical and ecological feedbacks, potentially between alternate stable states [2], could have caused changes in ocean carbon cycling and redox state, phosphorus cycling, and atmospheric pO_2.

We argue that the late Tonian ocean ~750 Ma was dominated by rapid microbial cycling of dissolved organic matter (DOM) with elevated nutrient (P) levels due to inefficient removal of organic matter to sediments. We suggest the abrupt onset of the eukaryotic algal biomarker record ~660-640 Ma [3] was linked to an escalation of protozoan predation, which created a 'biological pump' of sinking particulate organic matter (POM). The resultant transfer of C and P to sediments was strengthened by subsequent eukaryotic innovations, including the advent of sessile benthic animals and mobile burrowing animals [4].

Thus, each phase of eukaryote evolution tended to lower P levels and oxygenate the ocean on $\sim 10^4$ year timescales, explaining the abrupt onset of oceanic oxygenation events. However, by decreasing $C_{organic}/P_{total}$ burial ratios, each oxygenation event sowed the seeds of its own demise, by tending to lower atmospheric pO_2 and thus deoxygenate the ocean again on $\sim 10^6$ year timescales. This hypothesis can help explain the transient nature and $\sim 10^6$ year duration of oceanic oxygenation events through the Cryogenian-Ediacaran-Cambrian. Their increasing frequency could be linked to a long-term ($\sim 10^7$–10^8 year) increase in atmospheric pO_2 and/or a long-term decrease in ocean P inventory.

[1] Sahoo *et al.* (2016) *Geobiology* **14**, 457-468.
[2] Handoh & Lenton (2003) *Glob. Biogeoch. Cyc.* **17**, 1092.
[3] Brocks *et al.* (2017) *Nature* **548**, 578-581.
[4] Lenton *et al.* (2014) *Nature Geoscience* **7**, 257-265.