Modeling the impact of the evolution of the biological pump on the shelf sea and ocean nutrient and redox state

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At the Neoproterozoic-Paleozoic transition, the marine ecosystem evolved from one dominated by bacteria to a eukaryotic food web, with profound consequences for the biological carbon pump [1]. In the same period, data show a series of transient oceanic oxygenation events (~660-520 Ma) and evidence for an overall rise in atmospheric oxygen. With the present study, we investigate what could have caused such abrupt changes in the redox state of the ocean. We use a newly developed ocean-atmosphere box model that resolves the coupled nutrient (P) and oxygen (O) cycles and the processes driving the dynamics of the biological carbon (C) pump. Through changes to the model's representation of the biological pump, such as changes in the sinking speed, remineralization rates and coagulation/fragmentation dynamics of the organic matter pools, we explore the impacts upon the ocean redox state, and P 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 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, and the role of coagulation and fragmentation of particles in the relative shelf and open sea budgets. Our results show how the evolution of the biological pump, connected to drastic changes in nutrient P levels, provides a plausible explanation for the sporadic oxygenation of shelf seas during the Neoproterozoic-Paleozoic.

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