

The geologic history of marine dissolved organic carbon from iron oxides

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Dissolved organic carbon (DOC) is the largest reduced carbon reservoir in modern oceans. Its dynamics regulate marine communities and atmospheric CO₂ levels, whereas ¹³C compositions track ecosystem structure and autotrophic metabolism. However, the geologic history of marine DOC remains entirely unconstrained, hindering our ability to mechanistically reconstruct coupled ecological and biogeochemical evolution. To address this, we developed and validated the first-ever direct proxy for past DOC signatures using co-precipitated organic carbon in iron ooids, and we applied this to 26 marine iron ooid-containing formations deposited over the past 1650 million years. Predicted DOC concentrations were near modern levels in the Paleoproterozoic then decreased by 90-99 % in the Neoproterozoic before sharply rising in the Cambrian. We interpret these dynamics to reflect three distinct states: (i) small, single-celled organisms combined with severely hypoxic deep oceans; (ii) larger, more complex organisms and little change in ocean oxygenation; (iii) continued organism growth and a transition to fully oxygenated oceans. Furthermore, modern DOC is significantly ¹³C-enriched relative to the Proterozoic, possibly due to changing autotrophic carbon-isotope fractionation driven by biological innovation. Our results reveal previously undiscovered connections between the carbon cycle, ocean oxygenation, and the evolution of complex life.