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# Nutrient feedbacks on interglacial oxygenation during the Great Oxidation Episode

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The permanent rise of atmospheric oxygen above the threshold for production and preservation of mass-independent sulphur isotope fractionation in the sedimentary record occurred over a protracted period (from ~2.43 to 2.22 billion years ago) during the Great Oxidation Episode (GOE). The GOE was characterised by major fluctuations in atmospheric oxygen levels linked to extreme climatic instability, and these perturbations drove changes to both chemical weathering and oceanic redox conditions, which likely greatly impacted the bioavailability of key nutrients such as phosphorus. As it is the ultimate limiting nutrient for primary productivity on geological timescales, phosphorus bioavailability likely exerted a strong, but unresolved, control on the dynamics of the GOE. Here, we investigate the behaviour of phosphorus across the final two glaciations of the GOE, as documented by marine sediments from the Transvaal Supergroup, South Africa. Following an enhanced weathering-induced influx of bioavailable P that stimulated oxygenation in the aftermath of the third glaciation, phosphorus phase partitioning demonstrates that the extent of sedimentary P recycling was controlled by feedback-driven fluctuations in oceanic redox state. We then employ a biogeochemical box model to test the impact of phosphorus recycling on atmospheric and ocean oxygenation, demonstrating that under the non-steady state, the self-limiting rise of atmospheric oxygen was a combined consequence of nutrient availability and extreme climatic fluctuations.