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Paleoproterozoic Oxygenation Event, Evidence from S and N Isotopes

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Eukaryotes likely originated in the early Paleoproterozoic, with a marked diversification towards the end of the Paleoproterozoic (~1.75 Ga). Ocean oxygenation events pre- and post-date this diversification (e.g., the Lomagundi-Jatuli event; 2.1-1.9 Ga and the Mesoproterozoic oxygenation event; ~1.4 Ga); however, there is little to no evidence for an increase in oceanic or atmospheric O_2 during the Statherian Period (1.8-1.6 Ga), or for a direct link between eukaryotic diversification, nutrient availability, and redox conditions in general during the Paleoproterozoic. Models linking trends in early eukaryotic evolution to shifts in Earth's redox state thus remain controversial. Here, we report geochemical data from newly dated carbonates (~1.78-1.73 Ga) of the Kajrahat Limestone, the basal Semri Group of the Vindhyan Basin, India. A discrete stratigraphic rise in $\Delta^{34}S_{CAS\text{-}Py}$ values (~24‰) along with the 5-to-10-fold increase in U/Th ratios in the Kajrahat Limestone record enhanced oxidative terrigenous weathering and increased metal and sulfate flux to the ocean, providing a quantitative framework for estimating contemporaneous atmospheric O_2 levels. Our estimates suggest O_2 concentrations during deposition to have been in the order of at least 3% of the present atmospheric level, which is sufficient for crown eukaryotes with a derived aerobic metabolism. Regardless, this modest amount of O_2 could have generated a significant amount of nitrate through nitrification, essential for many eukaryotic metabolisms such as amino acid and nucleotide biosynthesis. Although a direct cause for the Statherian Oxygenation Event is difficult to discern, we suggest that the growth of the Nuna supercontinent, several Large Igneous Provinces, and associated enhanced weathering could have together triggered oxygenation that facilitated the early evolution of eukaryotes during the Statherian.