Two-billion-year-old-evaporites capture Earth's great oxidation

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Increasing oxidation dramatically changed Earth's surface environments during the Paleoproterozoic, but few quantitative constraints exist on this important transition. The disappearance of large-magnitude mass-independent fractionation (MIF) of sulfur isotopes at 2.4–2.3 Ga shows that the atmosphere exceeded a redox threshold of ~1 ppm pO_2; however, this limit reflects only a tiny fraction of the potential surface oxidant budget. Today, marine sulfate constitutes one of the largest surface oxidant reservoirs, equivalent to almost twice the modern atmospheric O_2 inventory and a key part of the coupled biogeochemical cycles of sulfur, oxygen, and carbon. We present a new quantitative constraint on marine sulfate concentrations at ~2.0 Ga derived from the sedimentology, mineralogy, and geochemistry of a remarkably preserved two-billion-year-old and ~800 meter-thick evaporite succession from the Onega Basin in Russian Karelia. The deposit consists of a basal unit dominated by halite and bearing bittern salts (~100 meters) followed by anhydrite-magnesite (~500 meters) and dolomite-magnesite (~200 meters) units. Analysis of the evaporite stratigraphy and calcium isotope ratios provides a robust constraint that marine sulfate concentrations were at least 10 mmol/kg at ~2.0 Ga, representing an oxidant reservoir equivalent to over 20% of the modern ocean-atmosphere oxidizing capacity. These results show that substantial amounts of surface oxidant accumulated during this critical transition in Earth's oxygenation. By extending the record of marine evaporites by almost a billion years, this unique deposit provides a window into marine conditions and redox balance in the aftermath of the initial rise of oxygen on Earth.