Redox evolution in deep geological time revealed by trace element enrichments in Precambrian iron formations

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Résumé

Iron oxyhydroxide minerals have precipitated directly from seawater throughout geological time. While such occurrences today are generally restricted to settings strongly influenced by hydrothermalism, during the Precambrian (prior to 541 Ma) iron oxyhydroxide muds accumulated over large areas of the ocean floor to be preserved as iron formation (IF). The Precambrian IF record is extensive, spanning every continent and dating as far back as Earth's oldest known sedimentary deposits. As nearly pure chemical sediments, the precipitates that formed IF captured elemental and isotopic signatures of evolving ancient seawater by sorption and co-precipitation reactions, rendering IF a rich record of ancient Earth's evolving marine geochemistry. That record is explored here using a database of $>$ 3000 chemical and isotopic analyses of IF compiled from literatures sources as well as new analyses. Emerging trace element proxies for the redox evolution of the ocean-atmosphere system, chromium (Cr) and uranium (U) in particular, appear to track with high temporal precision the onset, peak, and aftermath of Earth's earliest oxidative weathering ca. 2.5-2.0 Ga, the so-called Great Oxidation Event (GOE). In the case of Cr, muted Cr isotopic fractionations suggest that the GOE was characterized by an enhanced supply of Cr in reduced (Cr(III)) form. We suggest that only the oxidation of an abundant and previously stable crustal pyrite reservoir by aerobic-respiring, chemolithoautotrophic bacteria could have generated the degree of acidity required to solubilize reduced Cr from ultramafic source rocks and residual soils; in other words, Earth's first acid rock drainage. These emerging trace element proxies will also be discussed in the context of recent studies suggesting free atmospheric oxygen on the early Earth well before the ca. 2.5 Ga Great Oxidation Event.

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