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Isotopic constraints on Fe biogeochemical cycling in the Precambrian

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A growing database of isotopic data for natural samples and experimentally determined fractionation factors constrain the sources for ferrous Fe that may have been in equilibrium with Fe-rich low-temperature minerals from Archean and Proterozoic sedimentary sequences. Magnetite from sedimentary rocks, including Banded Iron Formations (BIFs), appears to reflect a mixture of Fe(II) sources that were produced by dissimilatory Fe(III)-reducing bacteria and Mid-Ocean Ridge (MOR) hydrothermal sources. In contrast, siderite from BIFs and other sedimentary rocks appear to have not formed through dissimilatory Fe(III) reduction but instead reflect direct precipitation from MOR hydrothermal sources of Fe(II). In some cases, these Fe(II) sources appear to have moderately high ⁵⁶Fe/⁵⁴Fe ratios, possibly indicating an unusual hydrothermal composition as compared to modern MOR vent fluids. Ferric oxides from Archean and Proterozoic rocks generally have high ⁵⁶Fe/⁵⁴Fe ratios, as expected from abiotic and biologic experimental studies where incomplete oxidation of aqueous Fe(II) sources occurred, suggesting that there was likely to be significant inventories of aqueous Fe(II) in the oceans during the Archean and Early Proterozoic. Oxidation of Fe(II) under abiotic conditions in the presence of an oxygenated atmosphere is one explanation for the data, but anaerobic photosynthetic Fe(II) oxidation can also explain the data.

Weathering in the Archean has produced bulk clastic material that is isotopically indistinguishable from igneous rocks and modern clastic sediments, indicating that the continents had Fe isotope compositions similar to those of today. Mass-balance models suggest that little change in the Fe isotope composition of bulk sediment is expected under either oxic or anoxic atmospheric conditions. Dissolved riverine Fe input in oxic atmospheric conditions may have very low ⁵⁶Fe/⁵⁴Fe ratios, and may be a significant flux of isotopically distinct Fe to the modern oceans, but would have no influence on the Fe isotope composition of an Fe(II)-rich Archean ocean.

The entire range of Fe isotope compositions measured in Precambrian rocks may be found in modern microenvironments where large redox gradients exist, but the extensive record of such variations in Precambrian sedimentary rocks suggests that redox cycling of Fe by bacterial and abiotic pathways in the Archean and Early Proterozoic was far more extensive than today.

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WSSC: An initiative to study Earth's weathering engine

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At the Earth's surface, a complex system of grinding, dissolution, biological interaction, mineral precipitation, and transport define the engine that transforms bedrock into soil. Earth's weathering engine provides nutrients to nourish ecosystems and human society, mediates the transport of toxic components within the biosphere, creates flow paths for water that carve and weaken bedrock, and contributes to the evolution of landscapes at all temporal and spatial scales. At the longest timescales, the weathering engine sequesters CO₂, controlling climatic evolution. Despite the importance of soil, we know very little about the primary controls on its formation. Our knowledge is limited because the weathering zone forms a complex ever-changing interface, and because scientific approaches and funding paradigms have not promoted integrated research agendas to investigate such complex interactions. No initiative has promoted a systems approach to investigation of weathering science across the broad array of geology, soil science, ecology, and hydrology. We will discuss the need for such a program, a Weathering System Science Consortium (WSSC), and describe a platform on which to build the initiative to answer the following question: *How does the Earth weathering engine chemically and physically break down rock to nourish ecosystems, carve terrestrial landscapes, and control carbon dioxide in the global atmosphere?*