Seafloor hydrothermal deposits: Modern analogues for Precambrian iron formations

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The biogeochemical cycling of iron (Fe) is determined primarily by the redox conditions of the local environment. Under modern surficial conditions, Fe occurs predominantly in the form of sparingly soluble Fe-oxyhydroxide minerals. In contrast, the abundance of iron formations (IFs) during the Archean and Paleoproterozoic suggests that the deep oceans were widely anoxic and Fe-rich. However, mechanisms by which oxidation of ferrous Fe occurred in ancient oceans and the interplay among oceanic, tectonic, and biological processes in controlling Fe redox cycling are still debated.

Here we present a comparison between ancient and modern seafloor metalliferous deposits. Discussed are geochemical and Fe-isotope signatures of (1) hydrothermal Fe-oxide deposits and microbial mats from the Loihi Seamount hydrothermal field; (2) hydrothermal plume fall-out deposits from modern and Paleoproterozoic (e.g. Jerome jaspers, AZ) settings; and (3) Paleoproterozoic and Archean IFs.

The Fe-isotope composition (δ^{56}Fe) of microbial mats at Loihi displays a large range between -1.2 to +1.6 ‰, which is considerably greater than the range of δ^{56}Fe values for Proterozoic to Phanerozoic plume fall-out deposits (-0.4 to +1.0 ‰). These results indicate that the Fe isotope composition of Fe-rich microbial mats is most sensitive to oxygen levels in the local environment, and controlled less by abiotic vs. biotic processes. Our extensive survey of δ^{56}Fe values of Precambrian IFs allows a first-order assessment of the Fe isotope mass balance of Earth's early oceans. We propose that both positive and negative δ^{56}Fe values of IFs record redox-driven, water-column processing of hydrothermally-delivered Fe accross a chemocline.

This comparative approach provides a mechanistic constraint on the origin of Fe isotope fractionation in IFs. The rise of atmospheric O_2 led to the contraction of marine environments where active Fe redox cycling produced large Fe-oxide deposits, on the scale of oceanic basins in the Archean, and restricted to microbial mats in modern seafloor hydrothermal systems.