A Mesoarchean Microbial Iron Shuttle.

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In the search for extraterrestrial life, an understanding of Earth's early biosphere is useful. One deeply rooted microbial metabolism that holds great astrobiological potential is Dissimilatory Iron Reduction (DIR). This metabolism occurs in both archea and bacteria, Fe the electron donor is ubiquitous in the solar system, and DIR produces Fe isotope anomalies. This project focuses on Fe isotope compositions of proximal to distal shelf sedimentary rocks from the well-preserved Mesoarchean (~3 Ga) Witwatersrand Supergroup. Iron isotope analyses of microdrilled pyrite and whole rock samples define a trend of iron enrichment with δ^{56}Fe depletion from the proximal shelf to the deep distal basin (See Figure 1). This negative correlation between δ^{56}Fe and Fe bulk-rock concentration is indicative of a benthic Fe shuttle, where DIR produces isotopically light iron which escapes from the shelf and is transported and trapped in a deeper anoxic basin setting—resulting in lighter Fe isotope ratios and Fe enrichment in distal depofacies. While modern marine systems have proposed the operation of a benthic iron shuttle on small scales, this data demonstrates, for the first time, that DIR had a major footprint in the early Earth environment [1]. Besides informing us about the Archean biosphere, a benthic iron shuttle implies the presence of a water-column redox boundary, since the expression of a benthic Fe shuttle requires a redox boundary in the water column in order to trap the reactive Fe. This has important implications for the redox evolution of early Earth, further substantiating the hypothesis of an ephemeral Mesoarchean oxidation proposed by Se concentrations in pyrite and Cr and Mo isotopes [2, 3, 4].

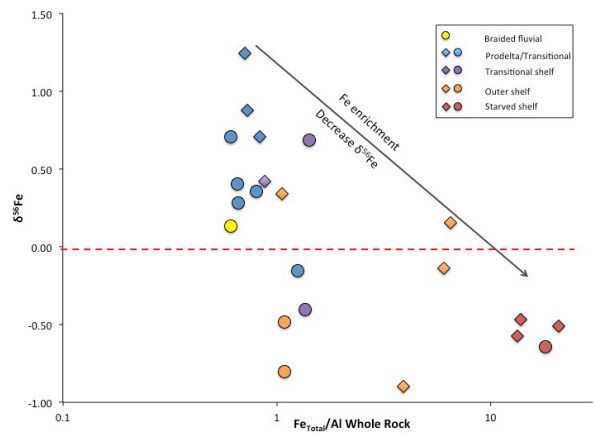

Figure 1.
Plot of whole rock (circles) and microdrilled pyrite (diamonds) δ^{56}Fe values versus bulk rock total Fe/Al ratio. The red dashed line represents the δ^{56}Fe value of hydrothermal Fe, which is similar to average crustal Fe. Braided fluvial, Prodelta, and Transitional depofacies are proximal, while outer shelf and starved shelf depofacies are distal.

References:

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