Sulfur Isotopes Establish a Context for Early Life: Insights from > 3.7 Ga Metasediments (Isua, Greenland)

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Sulfur isotopes (^{32}S, ^{33}S, ^{34}S, ^{36}S) have proven to be a powerful tool for uncovering details of Earth's past surface conditions, as well as the nature of early microbial communities. For instance, the termination of mass-independently fractionated (MIF) sulfur at ~3.2 Ga is widely regarded as evidence for the oxygenation of Earth's atmosphere. Similarly, numerous sulfur isotope studies of ~3.47 Ga rocks from the Pilbara Craton offer compelling evidence that sulfur metabolizing microbes were active by that time. It is sensible, then, to expand the search for environmental changes and microbial activity – using sulfur isotopes as a proxy – even earlier into Earth's history. However, well-preserved Eoarchean (4.0-3.6 Ga) rocks are rare, and the existing S-isotope record from that era is similarly scarce. Here we present bulk-rock $\delta^{34}S$, $\Delta^{33}S$ and $\Delta^{36}S$ measurements from an ~80m core of minimally-altered, >3.7 Ga metasediments from the Isua Supracrustal Belt, SW Greenland. Some of the most striking results are found in $\Delta^{36}S/\Delta^{33}S$ plots, where two discrete clusters of data are found: one cluster that lies on a slope of -1, and another at -5. Some of the $\Delta^{36}S$ values (-7‰) are among the lowest values measured in the Archean. Oscillations between these bizarre $\Delta^{36}S/\Delta^{33}S$ values are observed, and point to broad swings between at least two stable atmospheric/oceanic modes. Conversely, $\delta^{34}S$ values are as negative as -6.3‰ (diverging from the Archean array by ~8‰), and only serve as ambiguous evidence for microbial processing. In total, our sulfur isotope data portray the Eoarchean as a period of volatile atmospheric and oceanic changes, establishing a context under which some of Earth's earliest life-forms may have evolved.