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Peering into the Cradle of Life: multiple sulfur isotopes reveal insights into environmental conditions and early sulfur metabolism some 3.5 Ga ago

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During the early stages of Earth's evolution, environmental conditions were much different from today. The early atmosphere was reducing with abundant carbon dioxide and methane, but largely devoid of oxygen, while the ocean was anoxic [1]. Hence, life emerged and evolved under inhospitable environmental conditions.

This multinational and multidisciplinary ICDP project aims at investigating which environmental conditions existed when life emerged and evolved on our planet. A systematic and comprehensive multiple sulfur isotope (^{32}S, ^{33}S, ^{34}S, and ^{36}S) study is pursued in order to trace early metabolisms on Earth as well as characterizing the prevailing environmental conditions and the redox conditions in particular. Samples stem from the 3.55–3.23 billion years old Barberton Greenstone Belt in South Africa, one of the oldest well preserved rock successions from the earliest part of Earth history. Specifically, ICDP drill core BARB5 was obtained from the Barite Syncline, and preliminary results are reported for samples from the Mapepe Formation, Fig Tree Group. The lowest part is mostly composed of carbonaceous shale, the middle part of sandstone and conglomerate, the upper part of volcanoclastic rocks. Total sulfur abundance ranges between 0.01 and 3.03 wt.% (avg. 0.29 wt.%; n=72), while total carbon abundances vary between 0.15 and 10.29 wt.% (avg. 3.16 wt.%; n=72).

The carbonaceous shale displays a sulfur isotopic composition ($\delta^{34}S$) between -0.09 and 2.21‰ (avg. 0.88‰; n=33); volcanoclastic rocks show a $\delta^{34}S$ values ranging from -6.57 to 2.32‰ (avg. -2.19‰; n=9); sandstone and conglomerate are characterized by a $\delta^{34}S$ composition between 1.51 and 2.11‰ (avg. 1.84‰; n=3). Similar to the $\delta^{34}S$ values, $\Delta^{33}S$ values are different for each lithofacies. Samples from the carbonaceous shale yielded a range between 0.41 and 2.33‰ (avg. 0.97‰, n=33), so values are positive, while volcanoclastic rocks show values between -0.32 and 0.20‰ (avg. -0.10‰, n=9) and sandstone and conglomerate between 0.14 and 0.61‰ (avg. 0.50‰, n=3). Furthermore, samples show a linear negative correlation between the $\Delta^{33}S$ and $\Delta^{36}S$ values with a slope of -0.8, typical for Archean sedimentary sulfides.

Some preliminary conclusions can be drawn with these first results. Each lithofacies is characterized by a different isotopic composition. Clearly, $\Delta^{33}S$ values in carbonaceous shale reflect mass-independent sulfur isotope fractionation, hence an atmospheric signal while volcanoclastic rocks signal display mass-dependent fractionation. This could represent a biotic signal, but alternatives have been proposed [2].

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References:

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