Multiple sulfur isotopic insights into 2.7 Ga sulfur cycle

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Multiple sulfur isotopes have been proved as a robust tool to interpret the Archean environments. Previous studies have suggested that the global changing atmospheric chemistry of 2.7 Ga mainly controls the multiple sulfur isotopic signature (i.e., $\Delta^{36}S/\Delta^{33}S$) instead of local events (Mishima et al., 2017). To testify this hypothesis, we carried out high-resolution in-situ analyses of multiple sulfur isotopes by SIMS and major and minor elements by EPMA on pyrite nodules from the 2.7 Ga Nimbus deposit (West Australia) and Joy Lake sequence (Superior province, Minnesota., USA).

Primary sulfur isotopic compositions of diagenetic pyrite are carefully identified from both localities based on isotopic and elemental comparisons with local metamorphic pyrite disseminated in hydrothermal quartz veins. The Joy Lake pyrite nodules yield a $\Delta^{33}S/\delta^{34}S$ slope of -0.23 and a $\Delta^{36}S/\Delta^{33}S$ slope of -1.25, and the Nimbus pyrite nodules yield a $\Delta^{33}S/\delta^{34}S$ slope of -0.73 and a $\Delta^{36}S/\Delta^{33}S$ slope of -0.91. The Joy Lake pyrite sulfur isotope data can be well explained by the felsic volcanic array, which is a result of arc volcanic eruption (Li et al., 2017). Although the Nimbus pyrite nodules show similar $\Delta^{33}S$-$\delta^{34}S$ relationship to the Joy Lake pyrite nodules, the environmental control on the Nimbus pyrite nodules could be more complicated. The core and rim of Nimbus pyrite nodule have distinct sulfur isotopic compositions, which are better explained by two stages of pyrite formation with two different sulfur reservoirs, rather than continuous growing process. The core of pyrite was derived from seawater sulfate reservoirs; however, the rim of nodule was derived from elemental sulfur reservoirs. Two reservoirs were modified by mass-dependent fractionation process (e.g., microbial sulfate reduction, abiotic S reduction). Furthermore, a positive shift in $\Delta^{33}S$-$\delta^{34}S$ at the rim of pyrite is observed, which implies a third reservoir from elemental sulfur is added in pore water at the last stage of Nimbus pyrite formation. This study has demonstrated that the Archean environment's variability can occur in very short time scale and can also reflect over the growth of single pyrite grain.

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Mishima K, Yamazaki R, Satish-Kumar M, Ueno Y, Hokada T, Toyoshima T (2017) Multiple sulfur isotope geochemistry of Dharwar Supergroup, Southern India: Late Archean record of changing atmospheric chemistry. *Earth and Planetary Science Letters*, **464**, 69-83.