Goldschmidt 2022 Abstract
https://doi.org/10.46427/gold2022.12186

The Archean seawater sulfate isotopic signature determined from VMS deposits

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The sulfur isotope signature of Archean seawater sulfate is key to understanding the evolution of the Earth's hydrosphere. Unfortunately, due to the lack of evaporite preservation in the Archean sedimentary record, the seawater isotopic composition remains poorly constrained. However, seawater composition can also be tracked through its massive circulation in seafloor hydrothermal systems that has occurred throughout Earth's history, and preserved in Volcanogenic Massive Sulfide (VMS) deposits. These deposits are known from Archean to modern times, and several studies show that part of the sulfur comes from the reduction of seawater sulfate whose isotopic signature is then preserved in massive sulfides. Analysis of sulfur isotopes from Paleoproterozoic to Modern VMS deposits, shows that the proportion of seawater sulfate incorporated into VMS remains relatively constant, between 5 and 30% regardless of the age of the deposit. Here, we analyze the S isotope signature of Neoarchean VMS deposits and their associated exhalites of similar age (around 2.7 Ga) which are well-preserved, weakly to moderately metamorphosed, from the Noranda camp and the McLeod Deep mine in the Matagami camp, Abitibi, Canada. The latter corresponds to a sub-seafloor replacement VMS deposit which is analyzed to determine the isotopic signature of magmatic sulfides as minimal incorporation of seawater sulfate is expected here. The Noranda camp VMS are interlayered with pillow-lavas, suggesting precipitation of massive sulfides near the seafloor, whereas Noranda exhalites directly formed on the seafloor, implying an important seawater sulfate influence (probably more than 75%). Therefore, the McLeod Deep mine signature is considered as the magmatic VMS signature, and the exhalites as the near seawater isotopic signature. They act as end-members, while Noranda's VMS make it possible to precisely calculate the signature of the seawater sulfates. By cross-checking these different pieces of information, it is possible to calculate that the sulfur isotope signature of the sulfates in Archean seawater to yield a $\delta^{34}S$ around +7‰ and a negative $\delta^{33}S$ around -1‰. This study opens up new opportunities to decipher the composition of Archean seawater and its role in hydrothermal interactions on the seafloor, which are likely key in understanding the early appearance of life.