

Constraints on fluid-mixing during formation of sediment-hosted stratiform sulfide deposits by using Fe and S isotopes

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Sedimentary exhalative (SEDEX) deposits represent anomalous accumulations of base metals and reduced sulfur in marine strata, whereas whether mixing of hydrothermal metalliferous brines with S-rich fluids is a dominant ore depositional mechanism still remains ambiguous. Here we conducted a case study of the combined Fe and S isotope systematics in various sulfides from the Dongshengmiao strata-bound orebodies and their host rocks in the economically significant Agulugou Formation (late Paleoproterozoic Zhaertai Group; North China). Our results show that disseminated pyrite grains that preceded hydrothermal mineralization are characterized by markedly positive $\delta^{56}\text{Fe}_{\text{IRMM}}$ values (mean = +0.55‰; $n = 32$), implying partial Fe-[oxyhydr]oxides drawdown, whereas vein-type to massive sulfide ores at Dongshengmiao have largely negative $\delta^{56}\text{Fe}_{\text{IRMM}}$ values (mean = -0.83‰; $n = 111$), indicating a typical stratiform hydrothermal replacement origin. Hydrothermal sulfide ores yielded exclusively highly positive $\delta^{34}\text{S}$ values (mostly +15.0 to +40.0‰) and have even slightly higher range and similar deposit-scale stratigraphic variations with those non-hydrothermal sedimentary-diagenetic pyrites (+17.5‰ to +37.1‰), suggesting that the origin of the dominant ore sulfur was also from contemporaneous near-seafloor seawater sulfate, rather than from significantly older evaporites in the hydrothermal fluid-flow path. The existence of two separate reservoirs for ore sulfur and metals, rather than a model based on single brine which introduces sulfur and the metal cations, is further evidenced by the systematic Fe-S isotope decoupling of ore sulfides at deposit scale: variable Fe isotope values within the analyzed ore sulfide coincide with rather constant S isotope values and vice versa. The incomplete fluid-mixing of hydrothermal metal- and diagenetic S-end members in such a hydrothermal-diagenetic system from deep to shallow environment could result in a gradual increase in S availability relative to Fe and transition from Fe- to S-excess through the Agulugou Formation, which could account for the changes of major mineral types from pyrrhotite (Fe-rich sphalerite) to pyrite (barite) and their decoupling Fe-S isotope evolutions. Overall, our study demonstrates that Fe and S isotope compositions and their spatial trends can speak to the mechanisms of SEDEX deposits and provide a new tool for constraining the processes of fluid mixing in the complex physicochemical system.