

New insights into the metallogeny of MVT Zn-Pb deposits: A case study from the Nayongzhi in South China, using field data, fluid compositions, and in situ S-Pb isotopes

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ABSTRACT

The newly discovered Nayongzhi Zn-Pb deposit (>20 Mt ores at 1.11–15.65 wt% Zn and 0.59–0.97 wt% Pb) in NW Guizhou province, South China, is hosted by late Ediacaran and early Cambrian carbonate rocks. The ore body is structurally controlled by a kilometer-scale reverse fault-anticline system and occurs as stratiform, lenticular, or steeply dipping vein structures. Its geological feature is comparable to that of the Mississippi Valley-type (MVT) Zn-Pb deposits. $\delta^{34}\text{S}$ values (+11.8 to +33.0‰) of sulfide minerals determined by NanoSIMS have a larger range than those determined by conventional bulk analysis ($\delta^{34}\text{S} = +18.12$ to +24.79‰). This suggests that S isotopes determined by in situ analysis can reflect the nature of fractionation involved in mineralization. Furthermore, cores of sulfide crystals have higher $\delta^{34}\text{S}$ values (+26.1 to +33.0‰) than their rims (+11.8 to +24.5‰). This implies a mixture of multiple S reservoirs or a Rayleigh fractionation of S isotopes occurred during ore formation process. Additionally, both S isotopic compositions determined by in situ and bulk analyses reflect the enrichment of ^{34}S in hydrothermal fluid ($\delta^{34}\text{S}_{\text{fluid}} > +11.8\text{\textperthousand}$), a typical characteristic of marine sulfate-derived S. Such S isotopic signatures also show that thermochemical sulfate reduction (TSR) is the dominant mechanism for the incorporation of S^{2-} from SO_4^{2-} . Pb isotopic ratios of galena obtained by femtosecond LA-MC-ICPMS plot in the field that overlaps with the Pb evolution curve of upper crust contributed to the orogeny and the field of modern lower crust, and can be compared to the Proterozoic metamorphic rocks. This means that the majority of Pb metal is sourced from the basement rocks. Although $\delta^{13}\text{C}$ values (−4.1 to +0.5‰) of calcite separates and corresponding fluids are similar to both fresh limestone (−1.7 to +1.3‰) and typical marine carbonate rocks, the $\delta^{18}\text{O}$ values (+12.4 to +14.1‰) are significantly lower than both limestone (+24.1 to +25.5‰) and marine carbonate rocks. Such C-O isotopic characteristics suggest that the source of C is ore-hosting carbonate rocks, whereas O has a mixed source of metamorphic fluids and carbonate rocks resulting from water/rock (W/R) interaction. This study demonstrates that (1) fluid mixing caused rapid sulfide precipitation, resulting in significant fractionation of S isotopes; and (2) both the W/R interaction and CO_2 degassing controlled local carbonate cyclic process of dissolution → re-crystallization, which provided metastable physical and chemical conditions for giant sulfide mineralization. These two processes are crucial in forming MVT deposits.

Keywords: In situ S-Pb isotopes, fluid mixing, buffer of carbonate, MVT deposits, South China