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Fluid evolution and silver enrichment in the giant Yindonggou Ag-Pb-Zn deposit, South Qinling orogen: insights from sphalerite and apatite texture and composition

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The processes controlling silver enrichment in epithermal ore systems, particularly the triggers for its efficient precipitation, remain debated. Traditional investigations into silver in such deposits primarily rely on Ag-hosting minerals like galena and Sphalerite, However, their composition is highly variable and susceptible to multiple factors influence, making it difficult to trace subtle fluid evolution. Thus, we use apatite, newly identified in the Yindonggou deposit, as a complementary proxy. By integrating geochemical data from coeval sphalerite and apatite from the same paragenetic stage, we reconstruct a detailed fluid evolution.

The giant Yindonggou Ag-Pb-Zn(-Au) deposit (2000t Ag @ 178 g/t, 20t Au @ 1.79 g/t) is the largest silver deposit in the South Qinling Orogen. The genesis of Yindonggou deposit, including the nature of the ore-forming fluids, and the source of metallogenic materials remains contentious. Its clear vertical zoning, exhibiting a transition from Pb-Zn to Ag mineralization, makes it an excellent object for investigating fluid evolution in large-scale Ag-Pb-Zn systems. The mineralogical expression of this zoning is distinct: the Pb-Zn stage is dominated by sphalerite and galena; the Ag-Pb-Zn stage features the appearance of minor silver minerals; and the Ag-rich stage is characterized by abundant native silver, argentite, and stromeyerite.

The systematic geochemical data from coeval sphalerite and apatite across the paragenetic stages, which record a systematic fluid evolution. The early Pb-Zn mineralization stage (~250℃) is characterized by Fe-Mn-Co enrichment in sphalerite and Sr-Y-REE-rich apatite; In contrast, during the later Ag mineralization stage (167-229℃), sphalerite shows Zn-Cu-Ag enrichment, while coeval apatite exhibits positive Eu anomalies and high F/Cl ratios, and distinct core-rim textures. Collectively, these data indicate that the observed zonation resulted from the progressive of a single hydrothermal fluid. We propose that the transition from reducing to oxidizing conditions during fluid cooling was a critical trigger for silver precipitation. The comparative analysis of sphalerite and apatite enables a more accurate reconstruction of fluid evolution and a clearer understanding of silver enrichment mechanisms in hydrothermal systems.