Trace Element signatures and Formation Conditions of Sphalerite from the Zgounder Epithermal Ag-Hg (Zn±Pb±Cu) Deposit (Anti-Atlas, Morocco)

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Résumé

The Zgounder Ag-Hg deposit (Siroua Massif, central Anti-Atlas) is hosted within Neoproterozoic metasedimentary rocks of the Saghro Group (ca. 630–600 Ma). In addition to the Ag-Hg ore, the deposit hosts significant Zn±Pb±Cu hydrothermal vein-type mineralization (_˜550 Ma), dominated by sphalerite. Textural observations, combined with EPMA and μXRF, reveal that sphalerite occurs in three distinct generations: Sph I consists of Fe rich coarse grains (Feavg: 5.6 wt%, Mnavg: 0.04 wt %) exhibiting chalcopyrite exsolution and commonly displays recrystallization and annealing textures. Sph II displays rhythmic growth zoning, with light-color bands enriched in Zn and Cd. Late-stage Sph III is colorless, associated to Ag-sulfosalts and strongly enriched in Cd (up to 0.7 wt %) and Cu (up to 0.69 wt %), but highly depleted in Fe (0.5 wt%) and Mn (0.01 wt%). Trace element incorporation in sphalerite occurs via simple and coupled substitutions, primarily through $Zn^2 \leftrightarrow Fe^2$, Mn^2 in Sph I–II, and $Zn^2 \leftrightarrow Cd^2$ in Sph III. Mn and Cd effectively discriminate deposit types, while the highest Mn concentrations occurs within sphalerites of Magmatic-hydrothermal origin. Mn–Fe and Cd/Fe–Mn plots, along with Zn/Cd ratios (92–708; avg. 227), position Zgounder sphalerites within the epithermal field, overlapping several deposits such as Xinling (Liaodong Peninsula) and Cisma; Roșia Montană (Romania). Sphalerite geothermometry indicates progressive cooling from 299∘C (Sph I) to 262∘C (Sph II) and 236∘C (Sph III). Given the thermometer's application limit (_˜240∘C), Sph III temperatures are likely lower, supported by high Fe/Zn ratios (up to 6644; avg. 2114), suggesting crystallization below 150∘C. Sulfur fugacity (fS) averages are indicating intermediate sulfidation state during sphalerite formation. Chlorite geothermometry yields consistent results, with average temperatures of _˜295∘C and a minimum temperature of 169∘C. These results define Zgounder as an epithermal system evolving from moderate-temperature, reduced magmatic-hydrothermal fluids toward lower-temperature basin brines fluids , with Cd enrichment primarily controlled by fluid Zn/Cd ratios rather than cooling.

Mots-Clés: Zgounder deposit, sphalerite geochemistry, trace elements, epithermal system, EPMA

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