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Hydrothermal alteration and multiple sulfur isotope chemistry of Kayad Zn-Pb deposit, Ajmer, Rajasthan, western India: Implications for ore genesis

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The Kayad Zn-Pb deposit in Ajmer, Rajasthan is a Proterozoic SEDEX deposit located in the Aravalli-Delhi fold belt of western India. The ore mineralization comprising predominantly of sphalerite and galena and subordinate chalcopyrite and pyrrhotite occurs in quartz mica schist (QMS), calc-silicate, quartzite and pegmatite, of which QMS hosts the majority of it. Other minerals such as arsenopyrite, lollingite and sulfosalts such as pyrargyrite, gudmundite and breithauptite are commonly associated with the massive ores in QMS.

The mineralization occurs as dissemination in calc-silicate and quartzite, in veins intruding pegmatite or on the wall rock of pegmatite, and occurs as lamination and massive ores in QMS. The laminated ores conform to the schistosity whereas the coarse, massive ores disrupt and overprint the metamorphic fabric. The massive sphalerite and galena (\pm chalcopyrite and pyrrhotite) ores are commonly associated with one or more of the hydrothermal minerals such as prehnite, Al-pumpellyite, albite and allanite replacing K-feldspar and plagioclase which indicates episode of Ca-Na metasomatism. On the other hand, pyrrhotite and chalcopyrite are mostly associated with chamosite, albite and potash-feldspar replacing other minerals in the host rock suggesting Fe-Na-K metasomatism. Sphalerite, galena, and arsenopyrite have been analysed by the SHRIMP SI ion microprobe for $\delta^{34}\text{S}$ while multiple sulfur isotope (^{32}S , ^{33}S , ^{34}S , and ^{36}S) study has been attempted on pyrrhotite and chalcopyrite. $\delta^{34}\text{S}$ of chalcopyrite (+6.4 to +8.8‰), pyrrhotite (+6.1 to +11.3‰) and arsenopyrite (+7.1 to +9.4‰) are relatively compact and consistent while sphalerite shows a larger variation from +2.7‰ to +8.9‰ across host rocks. Galena, however, shows the highest $\delta^{34}\text{S}$ values ranging from +7.8 to +24.3‰. Such high variations for both sphalerite and galena can result partly from crystal orientation effect during analysis. Average $\Delta^{33}\text{S}$ and $\Delta^{36}\text{S}$ of pyrrhotite are $-0.01 \pm 0.06\text{‰}$ (2 S.D.) and $0.03 \pm 0.02\text{‰}$ (2 S.D.) respectively that show no MIF-S signatures. However, in the case of chalcopyrite, a few $\Delta^{33}\text{S}$ values deviate up to 0.33‰ from the mean of 0.11 ± 0.15 (2 S.D.)‰.

Various microscale and mesoscale textures in massive sulfides, like attenuation of fold limbs of QMS and accumulation of sulfides at fold hinges, discrete blebs of galena and chalcopyrite in a matrix of sphalerite and extremely low dihedral angles among them, and prominent durchbewegung textures indicate the ores have been mobilized. Mineralogy (presence of

sulfosalts) and geochemical analysis of the massive sulfides show enriched concentrations of low chalcophile elements like Ag, Sb, As, Bi, Se, Tl which indicate metamorphism-induced sulfide melting might have been an important process in migration of pre-existing ore. However, presence of hydrothermal alterations in close proximity with the mobilized massive ores suggests that fluid-mediated chemical mobilization also played a crucial role in such remobilization. Consistently high positive values of $\delta^{34}\text{S}$ hint at a thermochemical reduction of seawater sulfate during SEDEX mineralization and recycling of the sulfur during remobilization that formed massive ores.