

Supergene Overprint in a Metamorphosed VMS Deposit: Insights From the Hawiah Deposit, Arabian Shield

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Volcanogenic massive sulfide (VMS) deposits are widespread across the Arabian Shield; however, the development and expression of supergene modification affecting metamorphosed VMS ore bodies, particularly under arid climatic conditions, remain poorly constrained. This study investigates the Hawiah deposit, southwestern Saudi Arabia, to characterize the mineralogical, geochemical, and geophysical signatures associated with supergene processes overprinting a VMS ore deposit metamorphosed to greenschist facies.

The deposit is hosted by chlorite-actinolite-clinzoisite bearing metavolcanic schists intruded by post-mineralization granodioritic to gabbroic dikes. Integrated ore petrography, QEMSCAN, X-ray diffraction (XRD), SEM-EDS, and whole-rock geochemistry define a vertically organized weathering profile developed primarily within the massive sulfide mineralization. Three main zones are recognized. The upper oxidized cap is dominated by goethite-limonite with quartz, carbonates, and locally secondary copper carbonates and clay minerals. This horizon transitions downward into a redox-controlled enrichment zone where covellite and bornite partially replace chalcopyrite along grain boundaries and microfractures. At greater depths, the fresh massive sulfide zone is characterized by pyrite-dominated frameworks with subordinate sphalerite, chalcopyrite, and pyrrhotite.

Downhole geochemical trends show near-surface Pb enrichment accompanied by Cu-Zn depletion, Cu-Ag maxima at the cementation front, and progressively increasing Zn concentrations with depth. Gold occurs as native grains near the oxidation boundary but becomes increasingly inclusion-bound downward, with persistent Au-As associations suggesting partial incorporation within arsenian pyrite.

Self-potential correlation imaging expressed as charge occurrence probability (COP), together with induced polarization (IP) chargeability, delineates a focused subvertical sulfide corridor beneath the oxidized cap and constrain the geometry of the mineralized system. These results demonstrate that late-stage supergene weathering can generate well-preserved and diagnostically recognizable profiles within massive sulfide mineralization of metamorphosed VMS deposits in the Arabian Shield, providing practical exploration vectors for identifying similar systems in arid terranes.