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Copper Mineralization in Siliciclastic Sediments of Southern Jordan: Mineralogical and Geological Insights from Abu Khusheiba Sandstone Formation

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Abstract

Copper mineralization in the Lower Cambrian sandstones of Wadi Abu Khusheiba, southern Jordan, represents a significant epigenetic Cu occurrence along the Wadi Araba segment of the Dead Sea Transform Fault. It has been mined by the Nabateans around 200BC and 100 AC. Field mapping and petrographic investigations reveal that Cu is concentrated in laterally discontinuous lenses and seam-like horizons that occur concordantly and discordantly within permeable siliciclastic units. The mineralized zones are strongly influenced by the region's structural architecture, particularly N–S and NW–SE trending faults that facilitated fluid migration and Cu redistribution.

Mineralogical analyses identify atacamite as the dominant Cu mineral, accompanied by clinoatacamite, paratacamite, malachite, bornite, and cuprite. These minerals occur as stratified seams, disseminations, micro-veins, pore-filling cements, and well-developed Cu-rich concretions exhibiting distinct mineralogical zonation. The gangue assemblage consists mainly of quartz, orthoclase, fluorapatite, dolomite, clay minerals, and localized pyrolusite. Textural relationships—such as cross-cutting micro-veins, discordant mineralization, and replacement textures—confirm both syn- and epigenetic stages of Cu enrichment.

The spatial variability of Cu grades (0.07–11 wt%) correlates strongly with the regional tectonic regime, reflecting NE–SW and NW–SE fault systems that controlled fluid pathways and Cu re-mobilization. Integration of lithology, petrography, geochemistry, field mapping, and spatial analyses outputs supports a genetic model in which oxidized (brine) fluids leached Cu from nearby late Precambrian porphyritic volcanic rocks and precipitated it within reduced permeable Cambrian sandstones. Structural focusing and repeated fault reactivation provided conduits for metal-bearing fluids and localized the formation of Cu-rich lenses and discontinuous seams and nodular concretions.

The results have important implications for exploration. They highlight the importance of structural corridors, proximity to Cu-bearing volcanic sources, and host-rock permeability in future exploration. Areas adjacent to Precambrian porphyries especially where major structural trends intersect permeable sandstone horizons. constitute the most prospective targets for discovering remobilized or stratified Cu mineralization in southern Jordan and analogous siliciclastic basins.