

Geodynamics and Formation Conditions of Porphyry Copper Ores in the Kounrad District, Balkhash–Ili Volcanic Arc

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Many decades of mineral exploration across the Balkhash-Ili volcanic arc in Kazakhstan have confirmed that the Kounrad district hosts a Cu-Mo porphyry cluster. Two key technical questions remain central for district-scale targeting: (i) why Cu mineralization is concentrated within the NW Kounrad-Borly trend, and (ii) which combinations of alteration characteristics and structural features provide reliable vectors for extending targeting from known centers to adjacent and more distal prospects in the arc.

The Kounrad, Borly, and Karabas Cu-(Mo) porphyries occur within a compact area in the NW Balkhash region and align along a regionally persistent fault system associated with the Kounrad-Borly trend. Repeated reactivation of this structure is interpreted to have controlled magma ascent and the siting of intermediate to felsic porphyry intrusions, and later focused hydrothermal fluid flow. The intrusions, dominated by granodiorite and quartz monzonite porphyries, cut Carboniferous volcanic, tuffaceous, and sedimentary rocks, indicating emplacement into a mature volcanogenic-sedimentary succession.

Alteration shows a consistent district-scale architecture. Propylitic assemblages (chlorite-epidote-calcite) dominate peripheral domains, whereas more intense phyllic assemblages (quartz-sericite-clays) strengthen toward the core of the mineralized system. Alteration intensity peaks at structural nodes formed by fault intersections and local dilation, where dense quartz stockwork veining and hydrothermal brecciation indicate transient high-permeability domains and focused fluid discharge.

Taken together, these relationships are consistent with a three-part framework for ore formation in Late Paleozoic arc settings: (1) arc magmatism supplies heat, metals, and volatiles; (2) system of faults and their intersection zones create and sustain permeability, localizing discharge and prolonging fluid-rock interaction; and (3) ore-grade mineralization develops where alteration gradients and stockwork-breccia domains coincide with these nodes.