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Cobalt enrichment in the De'erni UM-VMS Deposit, NW China: From Seafloor Exhalative Sedimentation to Early Cretaceous Hydrothermal Overprinting

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The De'erni Cu-Co-Zn deposit in the East Kunlun orogenic belt represents a rare example of an ancient ultramafic-hosted volcanogenic massive sulfide (UM-VMS) system [1]. While recent studies have documented the occurrence of cobalt within complex sulfides [2], the precise mechanisms driving significant cobalt enrichment remain poorly understood. This study integrates in-situ pyrite trace element geochemistry and hydrothermal apatite U–Pb geochronology to unravel the underlying cobalt enrichment mechanism.

Analytical results define a two-epoch cobalt mineralization model. During the Late Paleozoic seafloor exhalative-sedimentary epoch, early-stage serpentinization facilitated the extensive leaching of metals from the ultramafic host rocks [2]. Pyrite formed during this initial alteration (Py1) exhibits highly variable Ni, Co, and Cu contents. Governed by their specific geochemical behaviors [3], Co and Cu were preferentially partitioned into circulating hydrothermal fluids relative to Ni. These fluids subsequently precipitated during the main exhalative stage, forming massive sulfides dominated by Py2, which shows marked Co-Cu enrichment and significant Ni depletion.

Driven by the far-field effects of Neo-Tethyan evolution, the East Kunlun Orogenic Belt transitioned into an intracontinental extensional regime during the Early Cretaceous, triggering a major hydrothermal overprinting event at the De'erni deposit. LA-ICP-MS U–Pb dating of hydrothermal apatite from late-stage carbonate-chalcopyrite±cobaltite-siegenite veins yields an age of 125.28 ± 0.87 Ma. The apatite displays distinct positive Eu anomalies (Eu/Eu* = 8.94–16.28) and weak negative Ce anomalies (Ce/Ce* = 0.50–0.63), indicating precipitation from relatively oxidized fluids. Circulating along reactivated deep crustal faults under this extensional setting, these oxidized fluids drove the dissolution and remobilization of early sulfides. Pyrite formed during this overprinting stage (Py3) is notably depleted in Co, Cu, and Ni, reflecting the efficient extraction of these metals to form discrete Co-Ni-Cu minerals, such as cobaltite, siegenite, and chalcopyrite. Consequently, the significant cobalt enrichment at De'erni resulted from early seafloor exhalative pre-enrichment combined with intense Early Cretaceous hydrothermal reworking.

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