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The Role of Cu- and Co-rich Potassic Brines in Zambian Copperbelt Mineralisation

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The Central African Copperbelt is the largest repository of sediment-hosted copper and cobalt on Earth. The criticality of these elements in battery technology and electricity transmission establishes them as fundamental components of the carbon-free energy revolution. As such, understanding the processes through which they are sourced, transported, and precipitated in sedimentary basin environments is fundamental to securing future supply. In the Central African Copperbelt, the relative timing of mineralization, and the nature and origins of fluids involved, is controversial. As essential components of the mineral system, constraining these characteristics is central to developing an understanding of the unique metal endowment of the region.

Microthermometry, scanning electron microscopy, and Laser Ablation ICP-MS analysis of an extensive suite of barren and mineralized vein-hosted fluid inclusions indicate that base metal concentrations vary by 1 to 2 orders-of-magnitude between "barren" and "ore" fluids, with concomitant distinctions in the major salt chemistry of fluids.

Across three deposits in the Zambian Copperbelt (Nkana-Mindola, Nchanga, and Lumwana), anomalously high temperature-salinity brines characterised by K/Na ≥0.8 host elevated metal concentrations (10^2 to 10^3 ppm Cu and Co) within mineralised pre- to syn-kinematic veins. Conversely, lower temperature and salinity fluids, characterised by K/Na ≪0.8 are typically barren, and occur as primary fluids within post-kinematic veins as well as secondary inclusions in all vein types.

Crush-leach analysis of fluids from several Central African Copperbelt deposits indicates that early potassic ore fluids were bittern brines with an advanced evaporitic origin, whereas many later sodic fluids represent halite-dissolution brines which interacted extensively with evaporites hosted within the Katangan stratigraphy.

A model invoking high-temperature, potentially sulfate-deficient, metalliferous and ultra-potassic bittern brines residing at sub-salt levels correlates with pervasive potassic metasomatism, where K-feldspar and phlogopite are intimately associated with Cu-Co-sulphides. From the onset of halokinesis through basin closure, lower temperature, halite-undersaturated fluids interacted with evaporites, forming structurally-controlled sodic metasomatism.

These new data suggest that the extended residence of potentially sulfate-deficient, ultra-potassic bittern brines within a high temperature depocenter was a critical factor in mobilizing anomalous concentrations of base metals in the Central African Copperbelt.

Figure 1: Scanning electron microscope images of fluid inclusion cavities. Net intensity element maps display the relative masses of various solid daughter phases using backscattered electron imagery. A-C) Intergrown halite and sylvite forming anhedral salt masses in primary fluid inclusions hosted by two mineralized, syn-kinematic veins from the Nchanga Upper Orebody. D) Primary inclusion in a mineralized, pre- to syn-kinematic vein from the ore shale at Nkana. Sylvite and halite form the primary solid phases, with a minor Ba(CO3?) phase (left).