Structural Controls, 3D Geometry and the Evolution of Vein-Hosted Copper Mineralization at Frontier Mine, Democratic Republic of Congo

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The Central African Copperbelt is world-renowned for its sediment-hosted stratiform copper (SSC) deposits. Throughout the Copperbelt, a series of deposits occur which 1) do not conform to the general SSC style of mineralization and/or 2) are hosted within stratigraphic units other than the Lower Roan Subgroup, the typical host for SSC deposits. One example is the understudied Frontier Mine, a structurally-controlled, vein-hosted copper deposit which is distinct from the majority of the deposits within the Zambian Copperbelt sub-basin.

The successive emplacement of chalcopyrite-quartz-carbonate veins record the interaction between progressive structural evolution of the deposit, documenting northeast-southwest shortening, and associated hydrothermal fluid flow and sodic alteration (albitization). These veins are hosted by greenschist-facies metasedimentary rocks of the Mwashya Subgroup, located in the hinge zone of a first-order, regional-scale, refolded recumbent fold (F1/F2). Veins can be discretised into at least three sets, wherein early bedding/S1-parallel veins (Vein Set 1) formed during layer-parallel shearing and the commencement of recumbent folding (F1). Although relatively poorly mineralized, this vein generation was associated with near-pervasive, bedding-parallel albitization, leading to replacement of the predominantly metapelitic wallrocks. This resulted in reaction-hardening of the wallrock, in turn leading to brittle deformation during subsequent upright folding (F2) and the formation of a second generation of highly mineralized, saddle-reef type veins (Vein Set 2) in the hinges of the folds (F1/F2). The controls and collective geometry of Vein Set 2 defines the overall shoot-like geometry of the orebody, parallel to SE-plunging folds. Vein Set 3 is defined by brecciated textures and a subhorizontal orientation, underlining the formation of these veins under continued northeast-southwest shortening of the brittle wallrocks during the lock-up of the first-order refolded fold. The close relationship between vein sets, alteration and regional folding indicates long-lived, syn-tectonic, multi-phase mineralization during the Lufilian Orogeny.