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ARTICLE

Deformation, alteration and implicit 3D geomodelling of deposit-scale controls of vein-hosted copper mineralization of the Frontier Mine, Democratic Republic of Congo

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Abstract
The structurally controlled, vein-hosted copper deposit of the Frontier Mine is distinct from the vast majority of sediment-hosted, stratiform Cu(-Co) deposits of the Zambian Copperbelt. Successively emplaced vein sets document the close interplay between the progressive structural evolution of the deposit, recording northeast-southwest shortening, and associated hydrothermal fluid flow and alteration (albitization). The deposit is hosted by greenschist-facies metasedimentary rocks of the Mwashya Subgroup in the first-order hinge zone of a regional-scale, refolded, recumbent fold (F_1/F_2). Early bedding/S_1-parallel veins (Vein Set 1) formed during layer-parallel shearing and the onset of recumbent folding (F_1). This early vein generation is relatively poorly mineralized, but was associated with a near-pervasive, bedding-parallel albitization and replacement of the mainly metapelitic wall rocks. The reaction hardening process promoted brittle deformation during the subsequent upright refolding (F_2) of the rocks and the formation of a second generation of highly mineralized, saddle-reef type veins (Vein Set 2) in the hinges of particularly upright F_2 folds (F_1/F_2). The controls of Vein Set 2 by fold hinges defines the overall shoot-like geometry of the orebody, parallel to the SE-plunging folds. The subhorizontal orientation and brecciated textures of a subsequent Vein Set 3 underline the formation of veins through continued northeast-southwest shortening of the brittle wall rocks during the lock up of the refolded first-order fold. The overprinting and structural relationships between vein sets, alteration and the regional fold structures signify a syn-tectonic, long-lived, multi-phase mineralization history during the Lufilian Orogeny.

Keywords Lufilian Arc · Zambian Copperbelt · Copper · Vein-hosted · Albitization

Introduction

The Central African Copperbelt, mainly comprising the Zambian and Congolese copperbelts, constitutes one of the world's largest, high-grade resources of copper and cobalt (Cailteux et al. 2005; Selley et al. 2005; Cox et al. 2007). Copper-cobalt deposits are hosted by sedimentary strata that form part of the Lufilian Arc, an arcuate, Pan-African orogenic belt straddling the borders of Zambia and the Democratic Republic of the Congo (DRC). Sedimentary units chronicle early rifting and associated basin formation and sedimentation, to later convergence, inversion and fold-and-thrust tectonics between ca. 880 Ma and 500 Ma (Cailteux et al. 1994; Master et al. 2005; Selley et al. 2005 and references therein). Within the Zambian Copperbelt, the majority of deposits are sediment-hosted, stratiform copper (SSC) deposits within the Lower Roan Subgroup (Cailteux et al. 1994). Host rocks are either a reduced facies argillaceous unit, referred to as the Copperbelt Orebody Member, or a hydrocarbon-rich arenaceous unit (Annels 1979; Selley et al. 2005), termed the hangingwall and footwall deposits. As a result, most genetic models postulate Cu-Co mineralization along the redox interface between oxidized and more reduced formations, thereby denoting stratigraphically defined levels or locales of mineralization (Cox et al. 2007). Geochronological constraints indicate that fluid flow and associated mineralization took place over a

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