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EPMA, Raman spectroscopy and EBSD analysis track physiochemical changes during hypogene to supergene mineralization in the Lubambe-Mingomba Cu-Co deposit

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Lubambe-Mingomba (formerly Lubambe extension) is a supergiant sediment-hosted Cu-Co deposit in the Zambian Copperbelt (ZCB). Hypogene and supergene ores are hosted in Lower Roan sediments of the Neoproterozoic Katangan Supergroup. Petrographic analysis of ore-bearing intervals reveals several generations of Cu minerals hosted in disseminated stratiform sulfides, bedding-parallel and irregular sulfide-bearing veins. Supergene fluids caused in-situ alteration and replacement of earlier-formed hypogene chalcopyrite, bornite (bn), and chalcocite (cc) by supergene cc phases and covellite (cov). Electron probe micro-analyzer (EPMA), raman spectroscopy and electron back-scattered diffraction (EBSD) measurements were carried out on these sulfide phases to provide insights into the transition from hypogene to supergene mineralization conditions in the ZCB.

$Cu_{2-x}S$ sulfide generations show clear variations in Cu:S ratios ranging between 1.92 ± 0.05 and 1.10 ± 0.10. Raman spectroscopy of hypogene phases reveal systematic phonon shifts (measured in cm^{-1}) for increasing x in $Cu_{2-x}S$, decreasing from a phonon shift of 302 cm^{-1} for milkish-white supergene cc (1.98 ± 0.12), 305 cm^{-1} for whitish-blue hypogene cc (1.88 ± 0.10) to 310 cm^{-1} for light-blue altered hypogene cc (1.70 ± 0.10). Similar trends are seen for dark blue supergene phases, with $Cu_{2-x}S$ values of 1.60 ± 0.09 (shift of 271 cm^{-1}) and 1.00 ± 0.05 (shift of 266 cm^{-1}). Supergene altered cc and bn phases are identified by sharp stretch bands in the Raman spectra at 472-475cm^{-1}, interpreted to be due to the appearance of S-S bonds. EBSD mapping of these phases confirms that differences in crystal symmetry coincide with chemical variation, allowing for further distinction of sulfides formed under hypogene-supergene conditions.

Our results also show that spectroscopic techniques have the capacity to accurately distinguish between various hypogene and supergene sulphide phases. In summary, supergiant Cu-Co deposits such as Lubambe-Mingomba are formed and upgraded by multiple generations of hypogene and supergene Cu(+Fe)-Co sulfides.