Geometallurgy of a Complex Ore: Lappberget Zn-Pb-Ag-(Cu-Au) Deposit, Garpenberg Mine, Sweden

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Complex ores, which contain three or more metals along with additional precious and penalty elements, pose significant challenges for successful production forecasts due to the large number of variables that must be accounted for during the multi-stage separation process. In this study, geometallurgical characterization was conducted to understand the variability in the process performance of a complex and variable ore and to quantify the impact of geology on the metallurgical response and metal recovery processes. The approach is divided into five stages: (1) geological characterization, (2) ore classification, (3) grinding and flotation tests, (4) development of prediction models, and (5) geometallurgical domaining. Qualitative and quantitative mineralogical and textural investigations were performed on geological samples and flotation products using various analytical techniques, including scanning electron microscopy (SEM), automated mineralogy (i.e., QEMSCAN), electron microprobe analysis (EPMA), and laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS).

The study revealed the mineralogical, textural, and chemical variations of the sulfides within the deposit, reflecting the complex ore-forming conditions and tectono-metamorphic processes that have affected the deposit. Different generations of sulfide minerals (i.e., sphalerite, pyrite, galena, and chalcopyrite) were identified based on their distinct mineral chemistry, trace-element signatures, texture, and host rock associations. The study identified seven geometallurgical domains that were characterized by their specific mineralogical, chemical, and textural features, which were found to have a significant impact on the grinding and flotation performance. Mineral deportment of precious and penalty elements (Ag, Au, As, Bi, Hg, Mn, Mg) and potential by-products (Ga, Ge, In, Sb, Cd) were also investigated. A comprehensive and systematic approach for characterization was proposed to optimize data collection from both geological and process performance perspectives, towards a smart and future-oriented mining value chain.