Energy Critical Element and Precious Metal Deportment in Cu-(Fe-) Sulphides from the Bingham Canyon Porphyry Cu-Mo-Au Deposit

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Porphyry copper deposits are predominantly mined for the major commodities Cu, Mo and Au. From some of these deposits, minor (trace) elements are also recovered as by-products (e.g. Ag, Pd, Te, Se, Bi, Zn, Pb). This list will potentially expand with the increasing demand for critical raw materials in modern energy-related technologies. Key components for such technologies are energy-critical elements (ECEs), many of which are classified as credit elements (e.g. Co, Ga, Ge and In). However, even if currently recovered as by-products, their deportment in copper ores and their overall distribution at the deposit scale have received little research attention. This gap in knowledge is limiting more effective recovery of ECEs. The same applies to elements that might incur refining penalties (e.g. As, Cd, Sb and Sn). Characterizing the trace element inventory of host mineral phases contributes to an improved understanding of the distribution of trace metals. By informing geometallurgy, element deportment studies can thus potentially promote economic and ecologic benefits in the form of improving recovery, adding value to ore resources and helping to reduce the dispersion of deleterious metals into the environment.

This study focused on the deportment of ECEs and precious metals in the northwestern high-grade section of the Bingham Canyon Cu-Mo-Au porphyry deposit. Contained Cu-(Fe-) sulphides were characterised with scanning electron microscopy and analysed by laser ablation (LA) ICP-MS for their metal endowment and for their potential use as discriminators of magmatic-hydrothermal processes. The availability of copper (iron) sulfides was found to exert principal control over the chalcophile trace element budget. The abundance of bornite and digenite primarily controls the Bi and Ag- budgets of the overall system and significantly affects variations in Te and Se. Chalcopyrite predominantly controls the Co, Ga and In budgets. By contrast, Ge, As, Cd, Sn, Sb and Au are not significantly controlled by the major sulfides indicating their residence in accessory phases. The presence of electrum and Ag-(Au) tellurides governs the distribution of Au, and most likely also the Te budget.

At the small scale relevant to mineral processing, the Bingham ore shows a particularly interesting phenomenon. Digenite (Cu₉S₅) is invariably present within bornite likely as the exsolution product of a copper-rich bornite solid solution. LA-ICP-MS analyses revealed that the exsolution process has resulted in a redistribution of trace elements, including some ECEs. Trace element partitioning between bornite and digenite is evident in element maps of the complex intergrowths. Silver, Te
and Au strongly partition into digenite, while Se seems to retain its primary homogenous distribution, unaffected by exsolution. Elements that are preferentially retained in bornite (Sn and Bi), or at similar levels between the two sulphide species (In) show more complex zoning patterns in bornite. Zones of lowest concentration in bornite, peripheral around exsolved digenite grains, indicate stress-induced diffusion due to accumulating lattice distortions in bornite during digenite growth. The findings from digenite exsolution in bornite at Bingham show that relatively late, solid-state processes can result in complex deportment of precious metals and ECEs within copper-iron sulphides.