Process Mineralogy of Historical Sn Mine Waste: Recovery of W, In, and Sn from the Herberton Mineral Field, Australia

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Critical metals such as tungsten (W), indium (In), antimony (Sb), and tin (Sn) are essential to modern technologies, including renewable energy, electronics, defence, and advanced manufacturing. With W, In, and Sb listed on global critical minerals lists due to high supply risk and economic importance, secondary sources like historical mine waste from granitoid-related Sn deposits offer a promising, sustainable alternative. However, these materials are often mineralogically complex, necessitating an integrated process mineralogy approach to accurately assess their recovery potential and economic value. This study examines legacy mine waste from the Herberton Mineral Field (HMF), Queensland, Australia, a historic Sn district by combining geochemical (ICP-MS), mineralogical (XRD, MLA, SEM), and trace-element (LA-ICP-MS) analyses from eight spatially distributed sites. Geochemical results reveal significant enrichment: W (1.6–11,650 ppm), Sn (6–81,600 ppm), In (0.004–1,155 ppm), and Sb (0.41–5,200 ppm), with concentrations up to 2,500 times crustal averages. Deportment analysis shows In is mainly hosted in chalcopyrite (4–65%), sphalerite (3–92%), cassiterite (2–26%), tetrahedrite (17%), scorodite (16–59%), and Fe-oxyhydroxides (0.05–56%). Sb occurs in arsenopyrite (3–64%) and secondary phases (1.3–83%). Sn is dominantly hosted in cassiterite (>60%), while W occurs in cassiterite (<28%), pyrite (0.04–4%), schwertmannite (21%), Fe-oxyhydroxides (~4%), and scorodite (0.33–9%). Given the dominance of dense mineral phases (>4.1 g/cm^3), gravity separation was simulated using particle density and size data, with metal recovery modelled via mass balance and multi-mineral equations. Simulated gravity concentration achieved recoveries of ~80% Sn, ~59% In, ~45% W, and ~12% Sb, with overall mineral recovery between 24% and 83%. This study highlights the underutilised reprocessing potential of HMF waste and presents a transferable framework for assessing similar polymetallic mine wastes globally, offering a scalable, data-driven strategy for critical metal recovery and environmental remediation from legacy tailings.