SEG 2024 Conference: Sustainable Mineral Exploration and Development

Indium in Mine Wastes: Geochemistry, Mineralogy, and Microbiology

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Indium (In) plays an essential role in transitioning to a low-carbon economy, primarily because it serves as a key component in solar panels. Understanding the (bio)geochemistry of indium in surface environments is essential for developing effective extraction strategies. This study aims to understand indium cycling and mobility in two distinct geologic mine-waste environments, serving as an essential first step toward designing a remining process. We collected solid and aqueous mine waste samples from the Mt. Morgan (Au-Cu VHMS deposit) and Baal Gammon (Sn-Cu granite-related deposit) mines in Queensland, Australia, and subjected them to geochemical, mineralogical, and microbiological analyses. At Baal Gammon, waste rock exhibited indium concentrations above 350 ppm, with sphalerite, chalcopyrite, and stannite-kësterite identified as primary In-bearing minerals. The highest concentrations of indium are at micro- and nano-features in grain and mineral dislocation boundaries. Acidic waters contained up to 73 μm/L In, alongside elevated fluoride levels. In contrast, indium concentrations at Mt. Morgan reported indium up to 3.5 ppm in waste rock, with sphalerite and chalcopyrite as the predominant In-bearing minerals. Acidic waters here contained up to 5 μm/L In, with moderate-low fluoride levels. In both sites, indium displayed positive correlations with Cu and Ag in waste rocks, As in sediments, V in precipitates, and Pb, As, and fluoride in acidic waters. The study identified Baal Gammon as the indium-rich sulfidic waste system, along with a wide range of In-rich secondary minerals, including biogenic precipitates associated with *Alicyclobacillus fastidiosus* and *Ferroacidibacillus organovorans*. Indium cycling involves a complex interplay of anthropogenic and (bio)geochemical processes dictating its distribution and mobility. Findings suggest strategies such as selective flotation followed by leaching, prioritising As, Pb, and V removal, alongside a stepwise Fe precipitation process. Further research into the microbial communities is imperative to assess the potential for biomining and/or bioremediation of indium.