Application of the novel large area SEM imaging module "Atlas 5" in combination with nano-scale HRTEM studies to enhance mineral exploration and mining efficiency.

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Mineral exploration is an exceedingly expensive endeavor for mining companies. Any tool that routinely increases exploration or extraction efficiencies has the potential to create economic returns of millions of dollars. The *in situ* characterization of minerals associated with ore zones and geochemical anomalies is one such tool. The knowledge of how gold occurs within sulphide minerals (e.g., in the lattice or as nano-particles) is of great importance to mineral exploration and mining companies in order to define effective exploration and extraction methods. Bulk rock and microprobe analyses alone lack the spatial resolution and sensitivity necessary to accomplish the required level of characterization. We present a suite of advanced SEM, FIB and TEM techniques that can be applied sequentially and quickly. Samples from two major Canadian gold deposits (Timmins-Porcupine gold camp and the Kirkland lake gold/copper deposit, Ontario) were analyzed using high-resolution large area SEM imaging, TEM specimen preparation in the FIB-SEM microscope, and subsequent high-resolution TEM (HRTEM) characterization. The gold hosting mineral in the Timmins-Porcupine gold deposit is primarily pyrite that contains free gold as inclusions, as fracture filling, and along grain boundaries as well as "invisible" gold in arseno pyrite. The gold in the Upper Beaver deposit from Kirkland Lake is also associated with pyrite grains. The samples were imaged in a Carl Zeiss Sigma HD field emission SEM using the "Atlas 5" large area imaging module. Overview image mosaics were aquirred with the backscatter electron detector at a resolution of 100 nm/pixel. Selected areas that contained gold, pyrite, and arsenopyrite mineralizations were additionally imaged at 15 nm/pixel, and regions of interest for FIB foil extraction were identified. High-resolution TEM analyses of the extracted FIB sections from the Timmins sample show the complexity of the zoned pyrite crystals. High angle annual dark field (HAADF) images reveal areas with complex zonation patterns in the arsenian-pyrite. Zones with copper-rich inclusions alternate with As-rich zones consisting of multiple bands of about 50 to 400 nm in width with varying proportions of As. Electron Dispersion X-ray (EDX) line scans across the arsenopyrite inclusions revealed the presence of Au. TEM lattice-fringe images or HAADF images do not show any features of gold nanoparticles, which suggests that gold is bound to the crystal lattice of the arsenopyrite. The sequence of techniques used in this study enabled quick and systematic characterization of gold mineralizations from a micro to the nanometer scale in a reasonable time.