Meso-Scale Imaging and Whole-Rock Quantification of Indium in Mine Waste from a Granite-Related Deposit Using Laser-Induced Breakdown Spectroscopy (LIBS)

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Laser-Induced Breakdown Spectroscopy (LIBS) is a rapid, in-situ, semi-quantitative analytical technique based on the spectroscopic analysis of atomic emissions from laser-induced plasmas. In this study, LIBS was applied for meso-scale geochemical mapping using the ECORE benchtop system on centimetre-scale slabs of indium (In)-rich waste rock from the Baal Gammon mine, a granite-related deposit in Australia. Selected samples were further used to develop LIBS-based calibration models for quantifying indium in whole-rock pressed powder discs, using both benchtop and handheld LIBS instruments.

A range of elements were detected alongside indium, including those relevant to prospectivity (e.g., copper, tin, silver) and environmental monitoring (e.g., arsenic). Elemental imaging of the ~451 nm indium emission line revealed detailed spatial patterns of indium enrichment, including high intensities along chalcopyrite grain boundaries, within lamellar textures, at mineral interfaces—particularly between sulphide–sulphide and magnetite–sulphide contacts—and as micro-inclusions. In terms of relative abundance, LIBS signal intensities were highest in sphalerite, followed by stannite and chalcopyrite, with pyrrhotite showing the lowest response. These trends were consistent with mineral-specific indium concentrations obtained through correlative LA-ICP-MS analysis.

LIBS-based indium calibration models demonstrated high predictive accuracy for whole-rock sulphidic matrices. For the benchtop system, the models achieved an R^2 of 0.99, a root mean squared error of prediction (RMSE-P) of 73 ppm In, and a limit of detection (LOD) of 4 ppm In. The handheld prototype yielded an R^2 of 0.98, an RMSE-P of 102 ppm In, and a LOD of 28 ppm In. Optimal performance of the handheld instrument was achieved by restricting data processing to high-stability regions, and avoiding pre-ablated areas. Baseline correction was essential, whereas smoothing algorithms proved ineffective for trace-level elements such as indium.

This study highlights LIBS as a promising, high-throughput, and spatially resolved technique for rapid geochemical imaging and quantification of critical elements in complex mine waste matrices.