

Femtosecond-LA-ICP-MS Mapping of Chalcogenide Minerals: Implications for Geology and Geometallurgy

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Laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) trace element analyses of chalcogenides have been increasingly favored for studies of ore deposit mineral chemistry and geometallurgy, especially given the heightened focus on critical elements hosted by these minerals. However, these analyses remain affected by issues such as lack of matrix-matched reference materials (RMs), and the beam-induced melting and elemental fractionation associated with widely used nanosecond laser ablation (ns-LA) systems. Moreover, given that trace elements may be physically hosted with chalcogenide minerals on a spectrum ranging from intra-lattice substitutions to host phase-controlled inclusions or exsolutions, the spatial bias of commonly performed spot analyses precludes accounting for many potential trace element hosting mechanisms. Our work addresses all three issues through quantitative, spatially resolved trace element mapping via femtosecond laser ablation (fs-LA) ICP-MS combined with multi-RM calibration and fs-LA fluence-scaling to accommodate non-matrix-matched RMs, an approach made feasible by the demonstrably athermal nature of fs-LA. This technique was used to analyze a compositionally and genetically diverse suite of chalcogenide minerals and assemblages, including selenides, tellurides, and uncommon sulfosalts rarely examined in the LA literature, spanning porphyry-related (including skarn, cordilleran vein, and carbonate-replacement), epithermal, polymetallic, and 5-element-suite type deposits. Acknowledging a tradeoff between mapping resolution and detection limits, criteria-based pixel-pooled averages offer a flexible approach to zoned or inclusion-rich host chalcogenides. Pixel-pooled averages are amenable to the same statistical treatment as spot analyses, though agreement with electron microprobe values can vary due to a variety of factors related to each technique, which we explore. Femtosecond-LA-ICP-MS maps are particularly valuable for geometallurgical deportment studies performed by SEM-EDS Mineralogy systems (e.g. QEMSCAN, TIMA), where the spatial associations of trace elements can be used for improved trace element accounting strategies across multiple phases. This LA-ICP-MS mapping method overcomes key limitations for accurate, spatially-resolved chalcogenide trace element analysis.