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Characterization of energy critical elements in ore resources and associated waste tailings: Implications for recovery and remediation

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The occurrence of Energy Critical Elements (ECE) in primary ore minerals and their subsequent enrichment in waste tailings is of great metallurgical interest. Recovery of many ECEs, in particular In, Ge, and Ga have come chiefly as a by-product of base-metal production (smelting and refining); these elements are found only at very low levels in the Earth's crust and do not typically form economic deposits on their own. As the ECEs become more important for a growing number of technological applications, it is critical to map the distribution of these elements in ore and waste (gangue) minerals to optimize their recovery and remediation.

The characterization and beneficiation of ECEs is best illustrated for Zn-rich ore systems, where a mineral such as sphalerite (ZnS) will concentrate a number of major (Fe, Mn) and important trace elements (Cd, Se, In, Ge, Te, Sn, Bi, Sb, Hg). Interestingly, the mineral chemistry of sphalerite will often differ between different styles of mineralization (i.e. granite-hosted veins versus volcanic-hosted massive sulfides) and can even exhibit considerable variability within a deposit in response to metal zonation across hydrothermal facies. This has significant metallurgical implications for the blending of ore resources, the efficient production of Zn concentrates, and their ultimate value during the smelting and refining stages. Gangue minerals transferred to waste tailings may also exhibit significant enrichment in ECEs and precious metals; including Au in pyrite-arsenopyrite, and rare earth elements in a range of carbonate and phosphate minerals.

In situ micro-analytical techniques are ideal for the quantitative measurement of trace elements in ore minerals as well as associated gangue materials. Recent advances in ICP-MS and ICP-OES technology coupled with newer classes of UV Excimer lasers (native 193 nm light) have allowed for more discrete analyses, permitting micro-chemical mapping at small scales (<10 microns). Further improvements in spatial resolution and detection limits has allowed for the development of 3D micro-chemical maps of mineral grains as well as heterogeneous ore concentrates. These techniques will continue to have important applications in the petrology of ore forming systems, their beneficiation, and in resolving metallurgical issues associated with the inclusion and substitution of energy critical elements in principal ore minerals and tailings.

Keywords: Energy-Critical-Elements, Trace-Elements, Sphalerite, Laser-Ablation ICPMS, Sulfides.