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Fingerprinting nickel and cobalt supply chain using trace elements and sulfur isotopes signatures

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Nickel (Ni) and cobalt (Co) are critical raw materials due to their essential role in key industries (e.g., stainless steel and rechargeable batteries) and their supply risks. As the global demand for Ni and Co continues rising, the ability to identify the origin of these metals and trace them along the supply chain is crucial to ensure their responsible and sustainable sourcing. However, due to complexity of the supply chain and lack of transparency this objective cannot be reached with current traceability systems.

This study explores a traceability approach for Ni-Co sourced primarily from magmatic sulfide deposits, using coupled information of trace elements and sulfur isotopes signatures as a fingerprinting tool. We collected representative ore samples from magmatic sulfide deposits worldwide, as well as processed samples along the supply chain—mineral concentrates, Ni-Co matte, and Ni sulfates from a known source. These samples underwent different processing stages including mineral processing, pyrometallurgy, and hydrometallurgy. To characterize trace element compositions, ore and mineral concentrate samples were analysed *in-situ* using electron probe microanalysis (EPMA) and laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) on key minerals (e.g., chalcopyrite, pyrite, pyrrhotite, pentlandite, and cobaltite). Samples after pyrometallurgy and hydrometallurgy processes were ground into fine powders, compressed as pressed pellets, and analysed *in-situ* using LA-ICP-MS for bulk trace element composition. Sulfur isotopes were analysed with LA-MC (multi-collector)-ICP-MS. Multivariate analysis of the trace element dataset showed that different ore sources can be spatially discriminated based on their bulk and single-mineral (e.g., pentlandite) trace element compositions and specific elemental ratios. Notably, some trace element ratios (e.g., Ni/Co and Cr/V) remain stable during the Ni extraction process, making them possible 'fingerprints' for tracing material provenance. Bulk sulfur isotopes ratio stays robust through mineral separation, pyrometallurgy and most hydrometallurgy processes. This study demonstrates the feasibility of using combined information of trace elements and sulfur isotopes as a fingerprinting tool for Ni and Co raw materials traceability along the supply chain.

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