

Pyrite as a Host of Critical Metals in Porphyry Systems: Distribution Patterns and Exploration Vectoring Insights from LA-ICP-MS

Jose Carbajal Ronces¹, Simon Jowitt¹, Andrew Martin², Dalton Pell², Jorge Crespo¹

¹Ralph J. Roberts Center for Research in Economic Geology, Nevada Bureau of Mines and Geology, University of Nevada, Reno, Reno, United States, ²Department of Geoscience, University of Nevada Las Vegas, Las Vegas, United States

Modern standards of living and the global shift toward lower-carbon economies have sharply increased the demand for metals, particularly those classified as critical, meaning new sources of these commodities are required. Porphyry deposits are among the largest mineral systems and serve as the primary source of Cu globally. Pyrite is the most abundant sulfide in porphyry deposits, and can host metals in inclusions and in the lattice. However, its contribution to the critical-metal budget of porphyry systems remains unclear, suggesting it may represent an under-recognized recoverable resource within porphyry systems. Systematic trace element patterns in pyrite may also serve as effective vectoring tools in porphyry exploration. Here, we present a global LA-ICP-MS and EPMA dataset of 4,531 pyrite analyses from 49 deposits worldwide, combining global data compilation and statistical analyses to identify geochemical trends and average critical-metal concentrations. Pyrites from porphyry Au and Cu-Au deposits are enriched in base metals (Cu, Zn, Pb), precious metals (Au, Ag, Pt, Pd, Rh), and semi-metals (As, Sb, Bi) relative to other porphyry systems. At deposit level, the concentrations of Co, Ni, Se, Ge, and V decrease from potassic to argillic alteration zones, whereas concentrations of As, Te, Pb, Bi, and Sb increase from potassic to argillic and to propylitic zones, reflecting phase separation, temperature, redox, and pH changes within the mineralizing systems. In porphyry Cu-Au systems, Se vs Co distinguishes pyrite from K-silicate, sericitic, and argillic alteration zones, representing the most robust discriminator for this deposit type. In comparison, As vs Ni variations in porphyry Cu-Mo(-Au) systems can clearly discriminate between pyrite from different alteration zones. Our findings show that recognizing pyrite as a critical-metal source expands the metal endowment of porphyry deposits. Consistent concentration trends further indicate that pyrite is an effective vectoring tool in porphyry exploration.