Redox-Sensitive Trace Elements in Apatite: Insights into Porphyry Copper Mineralization Environments

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Apatite readily incorporates numerous ions in its crystal structure, enabling it to record physicochemical conditions and trace the composition of parent melts or fluids. Its ubiquity in ore deposits makes apatite an ideal indicator mineral, particularly in porphyry systems that lack zircon.

We studied apatite from six porphyry deposits in British Columbia (BC), from silica-undersaturated Cu-Au Galore Creek to silica-saturated Cu-Mo Camp Creek. Apatite from the unmineralized silica-undersaturated Zippa Mountain suite was also analysed as a baseline. Apatite grains were identified and texturally characterised using petrography, micro-XRF, SEM-EDS, and cold cathodoluminescence (CL). Major and trace element compositions were quantified using EPMA and LA-ICP-MS.

Euhedral to anhedral apatite occurs in the groundmass and as inclusions in mafic phenocrysts, exhibiting complex cold CL zoning in brown, yellow, green and purple hues. Most grains are fluorapatite (0.6-0.8 F apfu) with < 0.05 Cl apfu. Apatite from Galore Creek has the highest average concentrations of redox-sensitive elements (~3000 ppm S, ~250 ppm V, ~150 ppm As). Similar enrichments and elevated Sr concentrations (>1000 ppm) occur in other deposits in BC that are associated with silica-undersaturated rocks, which also display heavy rare-earth elements depletion relative to deposits associated with silica-saturated rocks. In contrast, apatite from the unmineralized Zippa Mountain suite lacks enrichment in V, S, and As but still contains elevated Sr concentrations (up to 8 wt%).

These data indicate that the high concentrations of redox-sensitive elements in apatite reflect the oxidized nature of the mineralizing environment. Moreover, the anomalous chemistry of apatite from silica-undersaturated deposits appears more strongly influenced by magmatic-hydrothermal processes rather than primary melt composition. Apatite with such distinctive enrichments thus represents a useful indicator of silica-undersaturated Cu-Au porphyry mineralization.