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The elemental and isotopic behaviour of lead and thallium during hydrothermal alteration in porphyry systems

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Porphyry deposits present complex mineralogical, textural, and geochemical variations associated with hydrothermal alteration and the economic concentration of critical metals. The Red Chris porphyry deposit in Northwestern British Columbia, Canada is an important producer of copper (Cu) and gold (Au). Mineralization is centred on the c.a. 206 Ma Red Stock, emplaced over multiple pulses of intrusive magmatism. High and intermediate-temperature alteration assemblages are present, ranging from deep syn-mineralization potassic alteration, dominated by magnetite, biotite, and alkali feldspar, to shallow phyllic assemblages, dominated by sericite, quartz, and pyrite. Chalcopyrite, bornite, and pyrite are the main sulphide minerals present.

At Red Chris, phyllic alteration transitions to Cu-sulphide dominant potassic alteration at depth, presenting an opportunity to test a novel Tl-Pb approach to quantifying hydrothermal alteration and its potential links to mineralization. The circulating hydrothermal fluids responsible for Cu-porphyry deposit genesis also mobilize and disperse Tl. Thallium stable isotope fractionation should reflect some combination of hydrothermal fluid redox conditions, temperature, and mineralogy. Although Tl and Pb can display similar elemental behaviour, Pb isotopic composition reflects radioactive decay processes and is unaffected by hydrothermal fluid conditions. Thus, the combination of stable Tl isotopes and radiogenic Pb isotopes may isolate the effects of hydrothermal circulation, alteration, and conditions favourable for Cu-deposit genesis.

Twelve Red Chris samples were selected to represent phyllic and potassic alteration types and span the inferred vertical transition between Cu-poor fluids responsible for phyllic alteration and Cu-rich fluids that generate potassic assemblages. Shortwave infrared spectroscopy (SWIR) and micro-X-ray fluorescence spectroscopy (μXRF) were used to characterize sample mineralogy and major-element chemistry. For example, sulphide mineralization is intimately linked to potassic alteration, with chalcopyrite, bornite, and pyrite predominantly found in quartz veins in potassic samples.

Our new SWIR and μXRF data guides the selection of locations for trace element and combined Pb-Tl isotopic analysis. We aim to make direct links between mineralogy, alteration styles, textures, trace element and isotope chemistry to quantify hydrothermal conditions and processes during porphyry genesis.