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Using Trace Elements in Zircon to Recognize Variability in Porphyry Magma Fertility Signatures Within and Between Arcs and Arc Settings in British Columbia, Arizona, and Chile

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Porphyry copper deposit formation depends on magmatic characteristics related to its oxidation state, temperature, metal, water, chlorine, and sulphur content. Trace elements in zircon (TEZ) signatures and zircon grain morphology are robust indicators of many of these attributes. Zircon composition can provide porphyry-fertile signatures and identify magmatic processes that favor economic porphyry mineralization, allowing for focused exploration targeting. However, the scale of variability of fertility indicators within an evolving arc, along an arc segment, or across a migrating arc has not been well established. Similarly, fundamental questions such as, “What is the variability of TEZ fertility characteristics between arcs or arc segments with different basement types or crustal thicknesses?” are uncertain. What are their links to the petrogenetic, magmatic, and tectonic processes that control the magma formation?

Identifying fertile magmatic signatures and interpreting favourable magmatic processes requires that they can be resolved and differentiated from background arc signatures. Furthermore, the effective application of TEZ signatures as an exploration tool requires the evaluation of large areas with few samples. We utilize fluvial sand and glacial till samples to evaluate entire drainage basins or up-ice regions, compared to bedrock samples from economic terrain. Such materials have sampled numerous rock units and can provide an array of zircon populations that can provide a range of TEZ signatures needed to evaluate a target region.

Zircons have been extracted from rock, stream, and glacial till samples from three prolific porphyry copper belts, then analyzed by LA-ICP-MS. Our results identify the variability of TEZ within arc environments as indicators of porphyry fertility for numerous magmatic bodies within each of the three regions: south-central British Columbia, east-central Arizona, and central Chile.

The Late Triassic-Early Jurassic Quesnellia island-arc terrane in southern BC has three subparallel magmatic axes that young to the east. Older (229-206 Ma), large, composite and zoned, calc-alkaline granodiorite-tonalite suite batholiths emplaced 3-7 km deep with Cu-Mo deposits transitioned (204-200 Ma) to smaller, composite, shallowly emplaced (~1 km) alkaline syenite-diorite suite plutons and intrusive complexes with Au-rich Cu-Au deposits. Subsequent more inboard Early Jurassic (202-193 Ma) large, composite and zoned, calc-alkaline to high-K granodiorite-quartz diorite suite batholiths emplaced at 3- to 5-km depths host Cu-Mo and Cu-Au deposits are the youngest arc component.

East-central Arizona hosts Laramide-aged continental-margin magmatism (~75-61 Ma) with associated porphyry copper deposits within granodioritic to granitic plutons. The magmas likely have variable sources and evolution but with a large crustal component indicated by abundant inherited zircons within the magmas.

Central Chile’s late Miocene-early Pliocene Cu belt hosts giant porphyry copper deposit clusters. Cenozoic magmatism progressively evolved from an Oligo-Miocene tholeiitic arc to a more calc-alkaline affinity during the Mio-Pliocene. Porphyry copper deposits preferentially formed during intrusive and volcanic stages during the late constructive period in the waning stages of the arc.

The ability to recognize fertile arc magmas and their variability within and between different arc settings with TEZ signatures will enable explorers to distinguish magmas that have the potential to form economic porphyry Cu deposits from those that are barren.