Characteristics of sodic-calcic alteration footprints around porphyry Cu deposits; an example from the Highland Valley Copper district, South Central, British Columbia

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Four major porphyry Cu (± Mo) systems, hosted in various intrusive facies of the Late Triassic Guichon Creek batholith, occur in the Highland Valley Copper (HVC) district. Limited exposure and airborne magnetic data indicate that the batholith has an oval shape, elongate to the northwest, with a long-axis of approximately 60 kilometers and a short-axis of 25 kilometers. The batholith is compositionally zoned from older mafic-rich diorites on the margins to younger, mafic-poor, granodiorites and quartz granodiorites in the center, where the Cu deposits occur. We present here the first systematic mapping and characterization of district-scale sodic-calcic alteration, and its paragenesis, at HVC. Representative vein and alteration halo samples were collected from outcrop, at approximately 500 meter spaced centers, from the margins of the batholith towards and into the porphyry deposits along multiple (~2 kilometer wide) traverses. Samples were portioned for geochemical analysis and a representative slab cut. Rock slabs from these samples were stained for calcic plagioclase and K-feldspar, and scanned with a hyperspectral scanner (x, y, λ). Integrating feldspar-staining results with hyperspectral images is an effective way to fully describe anhydrous and hydrous alteration mineralogy and elucidate timing relationships. Structurally focused domains of epidote veins with K-feldspar, and locally plagioclase, destructive albite ± epidote alteration halos characterize sodic-calcic alteration. Pervasive albite alteration, locally accompanied by actinolite and relict garnet, occurs close to the porphyry centers. Sodic-calcic alteration appears to have occurred between stages of major Cu mineralization and represents a significant fluid flow event that is expressed up to 7 kilometers away from the Cu centers in north-northeast and northwest-trending structures. Rocks affected by sodic-calcic alteration were typically overprinted by feldspar destructive white-mica alteration, locally with accessory prehnite, but still show characteristic major and minor element enrichments and depletions; elevated Na_2O, CaO and Cl, a decrease in K_2O and FeO, and high Na/Ba and Sr/Ba. Major oxide anomalies and starting elemental ratios, however, are strongly influenced by protolith composition.

Introduction

Four major porphyry Cu (± Mo) systems, hosted in various intrusive facies of the Guichon Creek batholith, occur in the Highland Valley Copper (HVC) district (Byrne et al., 2013) (Massey et al., 2005) (Fig. 1). The calc-alkalic Guichon Creek batholith intruded ~235 Ma Nicola Group andesitic rocks of the Quesnel Island arc terrane in

between approximately ~212-204 Ma, prior to docking with ancestral North America(Logan and Mihalynuk, 2014; Mihalynuk et al., 2016).
We present here the first systematic mapping and characterization of district-scale sodic-calcic alteration (epidote-albite-actinolite), and its paragenesis, at HVC.

The number and quality of porphyry Cu deposit (PCD) discoveries is declining (Thompson, 2016), thus the exploration and mining industry requires new paradigms and tools to more effectively explore for covered and highly fertile systems. The CMIC initiative at HVC aims to develop new tools and an integrated common earth model utilizing various data sets, including geology and lithogeochemistry, to understand and image distal footprints of PCD's.

Research Question

As part of CMIC footprint network project, the primary aim of our work is to map the distribution and describe the geological features associated with and surrounding the Cu systems at HVC. What is the most prominent distal expression of hydrothermal alteration? How does this alteration express in the field, and what are the lithogeochemical responses? What do these features tell us about the processes involved in forming, and how to recognize, the footprints around large Cu systems?

Research methodology

Geological Mapping

Mapping focused on vein fracture frequency, alteration mineralogy and paragenesis. Representative vein and alteration halo samples were collected from outcrop, at approximately 500 meter spaced centers, from the margins of the batholith towards and into the porphyry deposits along multiple traverses (fig. 2). Samples were portioned for geochemical analysis and a representative slab cut.

Rock Slab Analysis

Rock slabs were stained for calcic plagioclase and K-feldspar(Norman, 1974), and scanned with a hyperspectral scanner (x, y, 1000nm to 2500nm λ; 0.4mm/pixel). Feldspar staining highlights subtle veinlets of prehnite, K-feldspar, and feldspar destructive alteration. Spectral analysis and interpretation identifies hydroxyl-bearing minerals and some compositional variation.

Lithogeochemistry

Major oxides were analyzed at ACME Analytical Laboratory, Vancouver, using method LF200 (lithium borate fusion, ICP-ES) The same whole rock fusion solution is analyzed by AQ252 method (Aqua Regia, ICP-MS) to determine concentrations of trace elements. Loss on Ignition (LOI) is report as % weight loss on a 1 g split ignited at 1000°C. LECO analysis determined total C and S on a 0.2 g sample split. Halogens (F, Cl and Br) were analyzed by INAA at Act Labs in Ontario.

Results

Domains of high vein frequency (> 1 / m) highlight fluid pathways within the district (fig.2) Vein fill of epidote with halos of albite, albite-white mica, or albite-epidote ± actinolite and chlorite characterize Na-Ca in the district. Actinolite appears to be more common proximal to the Cu centers with minor amounts of garnet and pyroxene, retrograded to pumpellyite and chlorite, found locally in the pits. Domains of high vein frequency (> 1 / m) highlight Na-Ca fluid pathways within the district (figs.2) extending up to 7 km away from Valley and Lornex Cu centers.

Rocks affected by sodic-calcic alteration were typically overprinted by feldspar destructive white-mica alteration, locally with accessory prehnite, but still show characteristic major and minor element signature; enriched in Na, Ca, Sr and Cl, depleted in K and Fe, and high Na/Ba, Na/K and Sr/Ba. This signature contrasts with Rb enrichment associated with K-metasomatism (white mica, K-feldspar and biotite).

Implications

Staining highlights difficult to recognize weak albite alteration

Non-concentric alteration zonation; explore along strike within Na-Ca domains and up geothermal gradient

High Na/K, Fe depletion and anomalous concentrations of Sr characterize Na-Ca metasomatism

There maybe two sources of hydrothermal fluids in the district, magmatic and non-magmatic (seawater or meteoric)

A working hypothesis is that external fluids were drawn inward along regional structures towards the cupola regions and dike swarms of the active porphyry Cu magmatic-hydrothermal systems; i.e., Yerington model (Dilles and Einaudi, 2001)

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