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Porphyry copper alteration imaging with aeromagnetic data at Highland Valley Copper, British Columbia, Canada

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Summary

The Highland Valley Copper (HVC) district has been studied in great detail via multiple methods, and through different disciplines as part of the Canadian Mining Innovation Council (CMIC) Footprints project. Following geological and petro-physical investigations, this district was also the focus of detailed aeromagnetic inversions over the common host rock phases and altered rocks. The inversions were conducted using geological constraints obtained from surface and borehole geology and physical properties constraints from hand sample measurements. These inversions outline areas of alteration spatially related to the porphyry Cu systems and mapped alteration in the HVC district.

Introduction

The Highland Valley Copper district is hosted in the Triassic Guichon Creek batholith of the Quesnel terrane in south-central B.C, and is the largest known porphyry system in Canada (McMillian, 1985; Figure 1). This metallogenic system has been the subject of extensive studies conducted by the NSERC-CMIC Mineral Exploration Footprints Project, which have included geological, geochemical, and mineralogical data collection, petro-physical studies, and geophysical inversion. Aeromagnetic data were of particular interest because of the availability of a recent high-resolution 250 m line spacing survey flown over the batholith for Teck Resources Limited (Teck) in 1997. This paper presents results and conclusions from detailed geophysical inversions that are constrained by geological mapping and modeling, and sample petrophysical properties.

Geology and physical properties

The HVC district comprises at least 4 distinct porphyry Cu-Mo systems hosted in the Upper Triassic Guichon Creek batholith (McMillan, 1985): the fault off-set Valley-Lornex deposit, Bethlehem, Highmont, and JA (Byrne et al., 2013). Production began in 1962 at Bethlehem and has continued intermittently until the present time. All HVC operations have now been amalgamated under the ownership of Teck. The Guichon batholith is compositionally zoned with older equigranular mafic phases (Border, Guichon, Chataway) at the margins and porphyritic felsic phases (Bethlehem, Skeena, and Bethsaida) located in the center (Figure 1; McMillian, 1985). The Cu-Mo systems are hosted within inner phases of the batholith at the intersection of NW and NE–trending structures, and dome shaped features in the intrusive contacts (Byrne et al., 2013). Copper sulphide mineralization is predominantly associated with quartz veins with associated K-feldspar, or coarse-muscovite, or fine-grained white mica alteration halos (Lesage et al., 2016). Outboard of well Cu-mineralized domains alteration consists of sericite, montmorillonite, epidote, carbonate, and prehnite in plagioclase, and chlorite in mafic sites (Lesage et al., 2016). Veins of epidote with K-feldspar-destructive albite halos are also common in the district (Byrne et al., 2017). Lithological and alteration mapping was completed throughout the district and around the Cu centers. Physical properties of outcrop and borehole samples from different igneous phases and alteration facies were measured by the Geological Survey of Canada petrophysics lab in Victoria, BC and by École Polytechnique de Montréal. Geochemical analysis and physical property measurements were conducted on the same samples. The magnetic susceptibilities for the batholith phases are displayed in Figure 2. Organized by intrusive phases, altered rocks have a wider range and generally lower average magnetic susceptibility compared to fresh rocks.

Alteration index

Porphyry Cu alteration of porphyry systems is often associated with a decrease in magnetism. So, in principle, magnetism can be used to detect alteration. However, as observed by Ayuso et al. (2010), this is not always the case. Figure 2 shows the distribution of susceptibilities observed for the Guichon Creek batholith phases. Magnetic susceptibility is not related directly to the alteration and the Cu centers (Figure 2). It is possible, however, to propose a rock classification that provides information on alteration, based on magnetic susceptibility. For each host rock phase, minimum and maximum susceptibilities of unaltered rock are included in the range of all the samples (unaltered plus altered), these bounds are used to define a class of unaltered and altered rocks. The remaining samples with magnetic susceptibilities below the minimum and maximum susceptibility define a class of rocks that are potentially related to porphyry alteration. This is defined as an alteration index with two classes: 1) unaltered and altered, and 2) altered only.

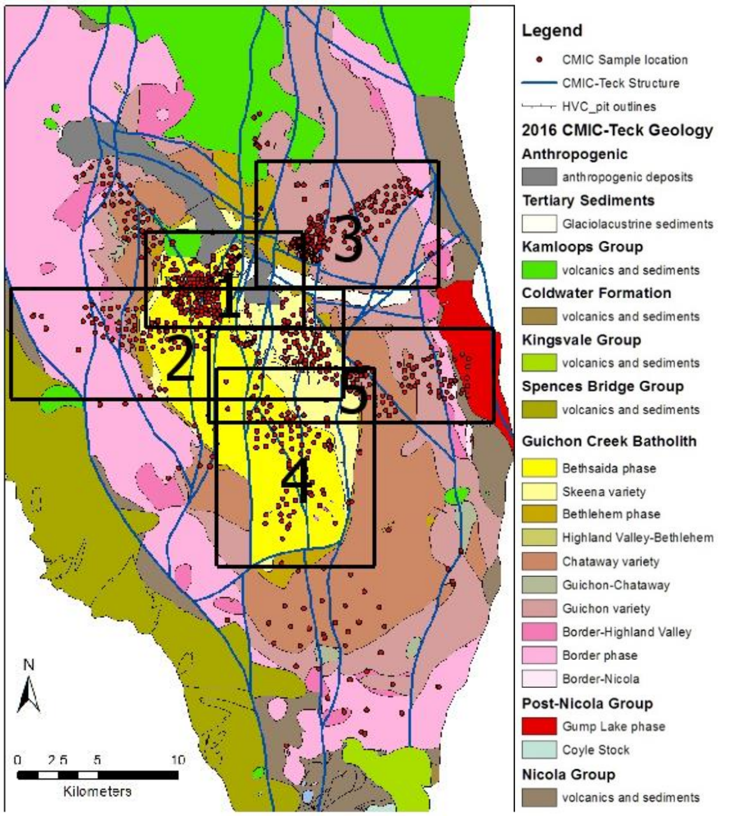

Figure 1: Geology of the mid-Triassic Guichon Creek batholith, host to the Highland Valley Copper district. The four known porphyry centers are within different intrusive phases of the batholith (pink through yellow), which intrude the Nicola Group volcanic strata (green) (modified form McMillan, 1985). The red dots are the location of the CMIC samples and the boxes are the locations of the detailed inversions.

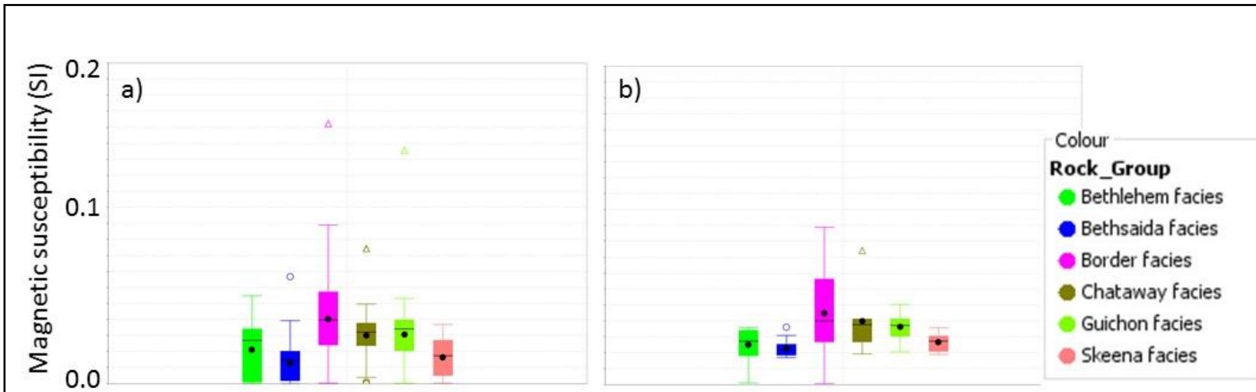

Figure 2: Magnetic susceptibility range for the major rock units for a) all samples and b) unaltered samples.

Inversion

For geophysical inversion, we used VPmg (Fullagar and Pears, 2007). This program allows including geological boundaries in the model. It is linked with Gocad software within which the geological model was built. Furthermore, different geological domains can be subdivided in vertical sub-cells of defined lateral area. First, the complete Teck survey was inverted without constraints to be used as regional for the block inversions (Figure 3). As confirmed by the physical property analysis, the felsic inner phases (Bethsaida, Skeena and Bethlehem phases) have lower susceptibilities than the outer mafic phases (Guichon, Chataway and Border). The Border unit in particular is characterized by a wide range of susceptibilities. The batholith scale inversion was used as regional survey of the inversion of the five detailed inversions (located on Figure 1). Only the results for block 5 are presented in this abstract.

Block 5

In block, the geology map displays mafic equigranular rocks at the eastern margin of the batholith zone to felsic and porphyritic rocks in the center of the batholith (Figure 4a). Copper mineralization is spatially associated with a porphyry dike complex that is parallel to the Skeena-Bethsaida contact (Figure 4a). Alteration is centered on the porphyry dike complex and focused in NW and N-S trending domains in the center of the batholith (Figure 4b). The 3D geological model and physical property constraints were used to invert the aeromagnetic data. Magnetic susceptibility results of the inversion (Figure 4c) at near surface elevation (1300 m MSL) show the transition between the more susceptible Guichon and Chataway on the east of the block, and the less magnetically susceptible Bethsaida and Skeena to the west. As stated above, two populations of petro-physical data can be distinguished: one of mixed altered or unaltered rocks and a second of definitively altered rocks. Based on this relationship, we define an alteration index for the two populations, which is estimated from the inverted susceptibility (Figure 4d). Altered rock domains predicted by the inversion alteration index mostly overlap with mapped porphyry Cu veins and alteration. Additionally, the alteration index predicts the presence of altered rocks undercover where no mapping was possible.

Conclusions

Detailed aeromagnetic inversions over the HVC district allow delineation of regions of distinct magnetic susceptibility, located in the different phases of the batholith, that cannot be explained by the expected least altered rock magnetic susceptibility response. Based on the geology and the physical property information, these volumes overlap with zones of porphyry Cu-related

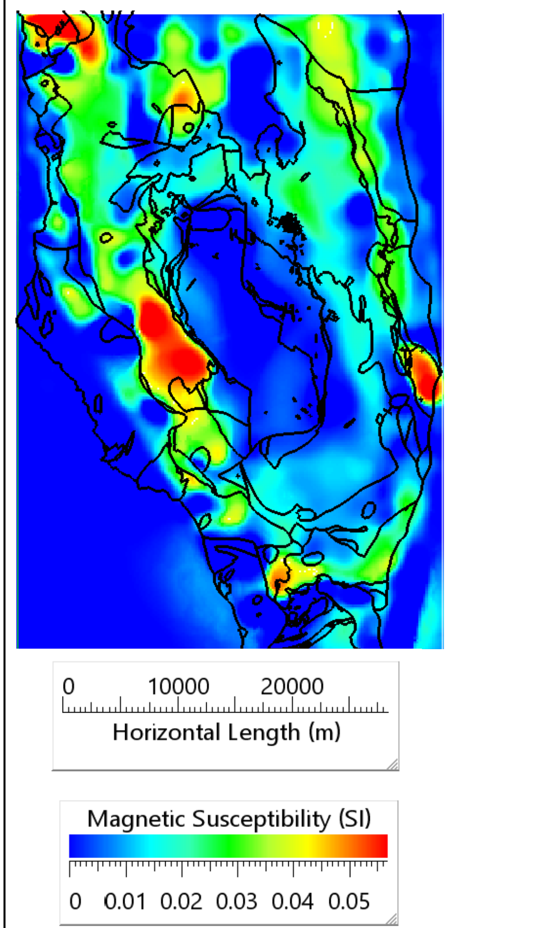

Figure 3: Batholith scale unconstrained magnetic susceptibility inversion at 34 m ASL (~1000 m below the surface). The surface lithologic domain boundaries are overlaid in black.

alteration. This study shows that when the relevant information is available, namely geological information and physical properties, it is possible to use geophysics to map the alteration of a porphyry Cu system. Unfortunately, such information is not commonly available to exploration geoscientists, nevertheless, this study provides a methodology and shows the potential of the approach.

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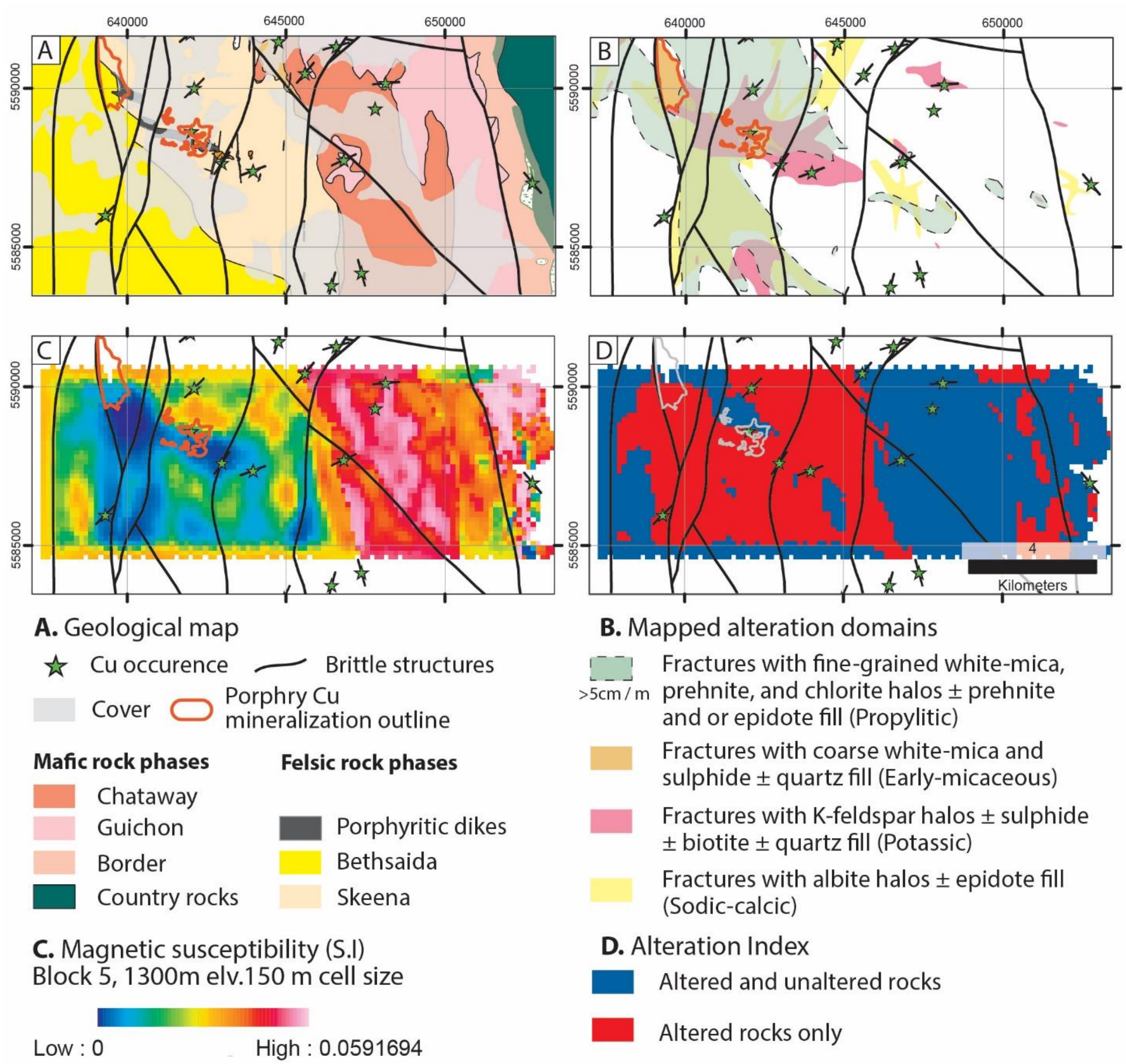

Figure 4: Block 5 area in the Guichon batholith. A. Lithology, structure, and cover in the block 5 area. Note in general rocks young from the eastern margin towards the center of the batholith. B. Mapped vein and alteration facies around the Lornex and Highmont porphyry Cu centers (assemblages are in parenthesis). C. Magnetic susceptibility response. D Calculated alteration index.

EDITED REFERENCES

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