

Surficial Geochemical Footprint of Buried Porphyry Cu-Mo Mineralization at the Highland Valley Copper Operations, South-Central British Columbia: Project Update

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Introduction

South-central British Columbia (BC) is well known for its endowment in porphyry copper deposits (McMillan and Panteleyev, 1995). These deposits include calcalkaline porphyry Cu-Mo (\pm Au) and alkaline porphyry Cu-Au systems (Logan and Schroeter, 2013). The economy of BC has benefited greatly from the development of many of these deposits, mostly discovered from mineralized outcrop or geochemical anomalies from suboutcropping mineralization under till of reasonably local origin. As the number of outcropping and suboutcropping discoveries declines, exploration geologists must develop ways to explore through to those covered with glacial material of remote origin, such as glaciofluvial cover that conceals mineralized bedrock.

This research is part of the Porphyry Cu Subproject of the National Sciences and Engineering Research Council (NSERC) and Canada Mining Innovation Council (CMIC)'s mineral exploration Footprints Project. This subproject aims to quantify and identify the footprint of porphyry Cu-(Mo) mineralization at the Highland Valley Copper (HVC) operations in south-central BC, through a multidisciplinary, integrated approach. The research is also part of the Mineral Deposit Research Unit (MDRU) Exploration Geochemistry Initiative, a collaborative research program established at the University of British Columbia (UBC) to understand mobility and transport of elements from buried mineralized bedrock to surface environment.

The identified deposits at HVC comprise five main clusters of porphyry-style mineralization, whose current state of production varies from developed to undeveloped. The J.A. and Highmont South targets comprise two mineralized areas that are both undeveloped and buried under variable thicknesses of glacial and preglacial sedimentary cover. Surficial geochemical studies at these two buried targets aim to fully characterize mineralogical and chemical changes that manifest themselves in the surficial environment after glacial dispersal and soil development over mineralized bedrock. The research will help develop surficial geochemical exploration models that can be applied to the search for other buried Cu-(Mo) porphyry mineralization. This paper provides an update on the progress of the project, which is expected to be completed by August 2017.

Background

Teck Resources Limited ('Teck') has a 100% interest in Highland Valley Copper (HVC), which is located in south-central BC, 15 km west of the Municipality of Logan Lake, and consists of five known porphyry-style Cu-Mo mineralized bodies (Figure 1). These clusters include: 1) the active producing Valley, Lornex and Highmont pits; 2) the past producing Bethlehem deposit; and 3) the buried J.A. deposit, all of which are centrally located within the Guichon Creek batholith (GCB; Byrne et al., 2013). The sulphide-bearing mineralized bedrock buried under glacially transported cover at HVC makes it an interesting site to test surficial geochemical exploration techniques.

Bedrock Geology

The GCB is part of the Quesnel terrane, which represents an island-arc setting (Northcote, 1969; Logan and Schroeter, 2016). The batholith was emplaced in the Late Triassic into the sedimentary and volcanic strata of the Permian Cache Creek and Late Triassic Nicola groups. The GCB has a sur-

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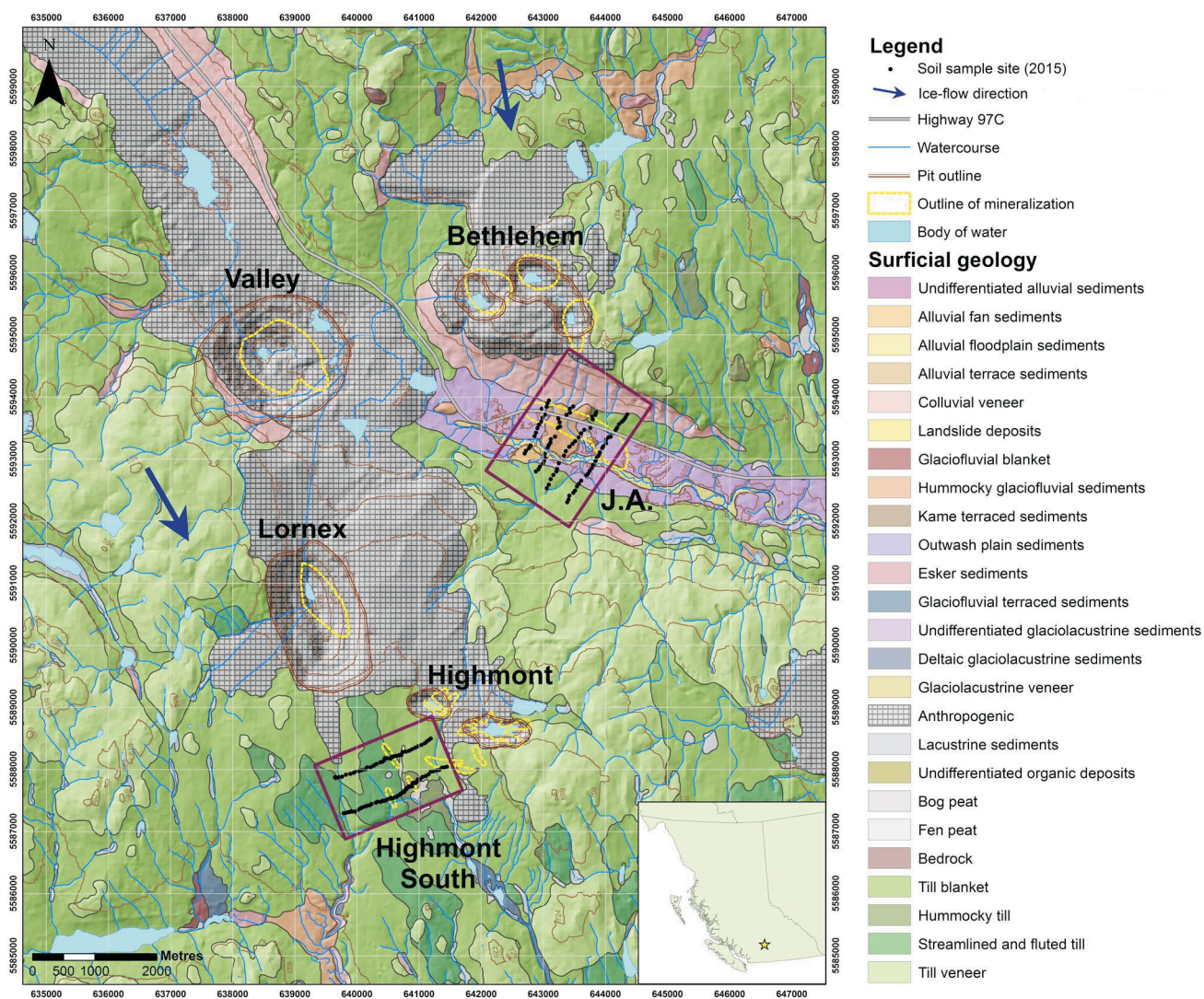


Figure 1. Surficial geology of the Highland Valley Copper mine operations area, south-central British Columbia (surficial geology and ice-flow direction from Plouffe and Ferbey, 2015).

face area of approximately 1100 km² and is calcalkalic in composition. The batholith was unroofed by the Jurassic period, with Early Jurassic to Eocene sedimentary and volcanic strata unconformably overlying the batholith (Northcote, 1969).

Zones of buried, undeveloped mineralized bedrock at HVC include: J.A. and Highmont South, which is interpreted as a small area of auxiliary mineralization to the main Highmont deposits. The buried Highmont South targets occur near the lithological boundary between the Skeena variety of quartz diorite and the Bethsaida quartz monzonite (Reed and Jambor, 1976). A large composite quartz-feldspar porphyry dike, the Gnawed Mountain porphyry dike, is emplaced to the north of Highmont South and is interpreted to have had a significant influence on the development of the Highmont deposits as a whole, specifically by controlling sulphide zoning (Byrne et al., 2013). The J.A. target is lo-

cated in a down-dropped fault block, straddling the contact between the Bethlehem granodiorite and the quartz diorite to granodiorite of the Guichon variety. The Guichon–Bethlehem contact is cut by a zone of quartz-plagioclase porphyry (possible Bethsaida-phase offshoot) in the southern portion of the deposit (McMillan, 1976).

Surficial Geology

Present-day physiography of the study area is strongly influenced by the style of deglaciation experienced. Rolling uplands and steep-walled, flat-floored valleys characteristic to the field sites are a function of ice retreating northward and the development of ice-contact and proglacial land systems, including various glaciolacustrine and glaciofluvial deposits (Figure 1; Bobrowsky et al, 2002). The resultant geography supports open grasslands with sagebrush, and slopes dominated by species of pine and spruce.

The study area (Figure 1) is covered by varying thicknesses of glacial sediments, with ice flow trending predominantly south-southeast (Plouffe and Ferbey, 2015). The Highmont South target (Figure 2) subcrops beneath 2–10 m of till (averaging 5–6 m). The J.A. target (Figure 3) sits beneath significantly thicker overburden, averaging 170 m and up to 300 m in thickness. Between the glacial overburden and the bedrock at the J.A. deposit sit sequences of preglacial sediments, which shielded the mineralized bedrock from glacial erosion (Plouffe and Ferbey, 2015). This may pose a problem for till-based exploration, such as the search for porphyry indicator minerals, as the till will not include fragments of the mineralized bedrock from the targeted mineralization.

Objectives of the Research Project

Geochemical investigations were undertaken in the field and laboratory to support the following research objectives:

- define the surficial response, in different materials, to the presence of buried mineralization;
- identify processes contributing to the generation of false anomalies and noise in data; and
- evaluate various exploration methods to develop a future framework for surficial geochemical exploration of buried porphyry-Cu deposits in glacially-covered terrain.

The following fieldwork was conducted to address these research questions through characterization of the surficial materials and processes at both field areas.

Surficial Mapping

Detailed surficial mapping is required for an exploration geochemical survey in order to select the most suitable sample sites, and to integrate and fully understand geochemical data in terms of different regolith units and surface processes. Fieldwork in 2015 started with surficial mapping to identify soil-sampling sites in the least disturbed areas, which showed the least variability in material type and amount of water saturation. The field area was traversed and mapping was completed at 1:2500 scale, recording all anthropogenic features that would influence sample-site selection such as exploration trenches, drill pads, old agricultural infrastructure, roads, zones of mechanical reforestation and forestry burn piles. Natural disturbances such as intense animal activity and past forest fires were noted. Additional information recorded included observations on geomorphology, water saturation and vegetation type.

Additional reconnaissance carried out during the 2016 field season aided in the development of regolith maps for both the J.A. and Highmont South field areas (Figures 2, 3). Both regolith maps make use of surficial geology presented in BC Geological Survey Geoscience Map 2015-3 (Plouffe and Ferbey, 2015), incorporating surficial interpretations

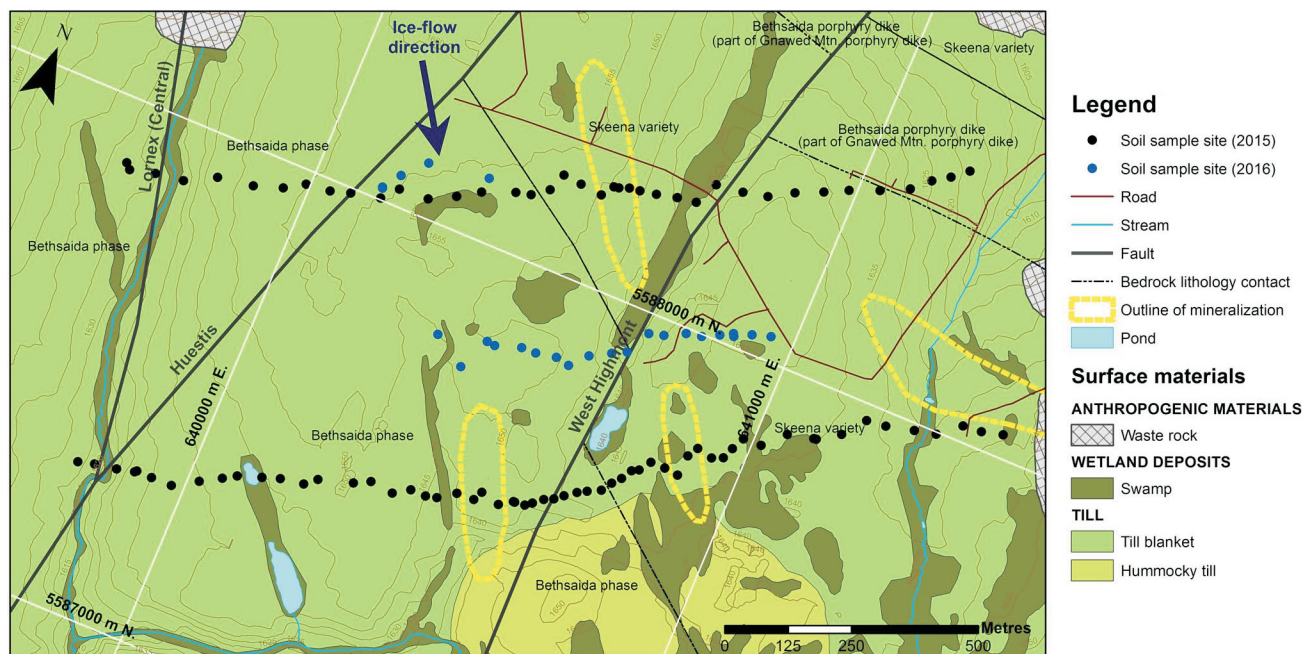


Figure 2. Surficial geology of the Highmont South study area at the Highland Valley Copper mine operations; surficial geology is modified from Plouffe and Ferbey (2015), using the Geological Survey of Canada's data model for surficial geology, version 1.2 (Deblonde et al., 2012); bedrock geology and structure adapted from McMillan et al. (2009) based on work done in August 2016 by Teck Resources Limited and the Canadian Mining Innovation Council. Abbreviation: Mtn., mountain.

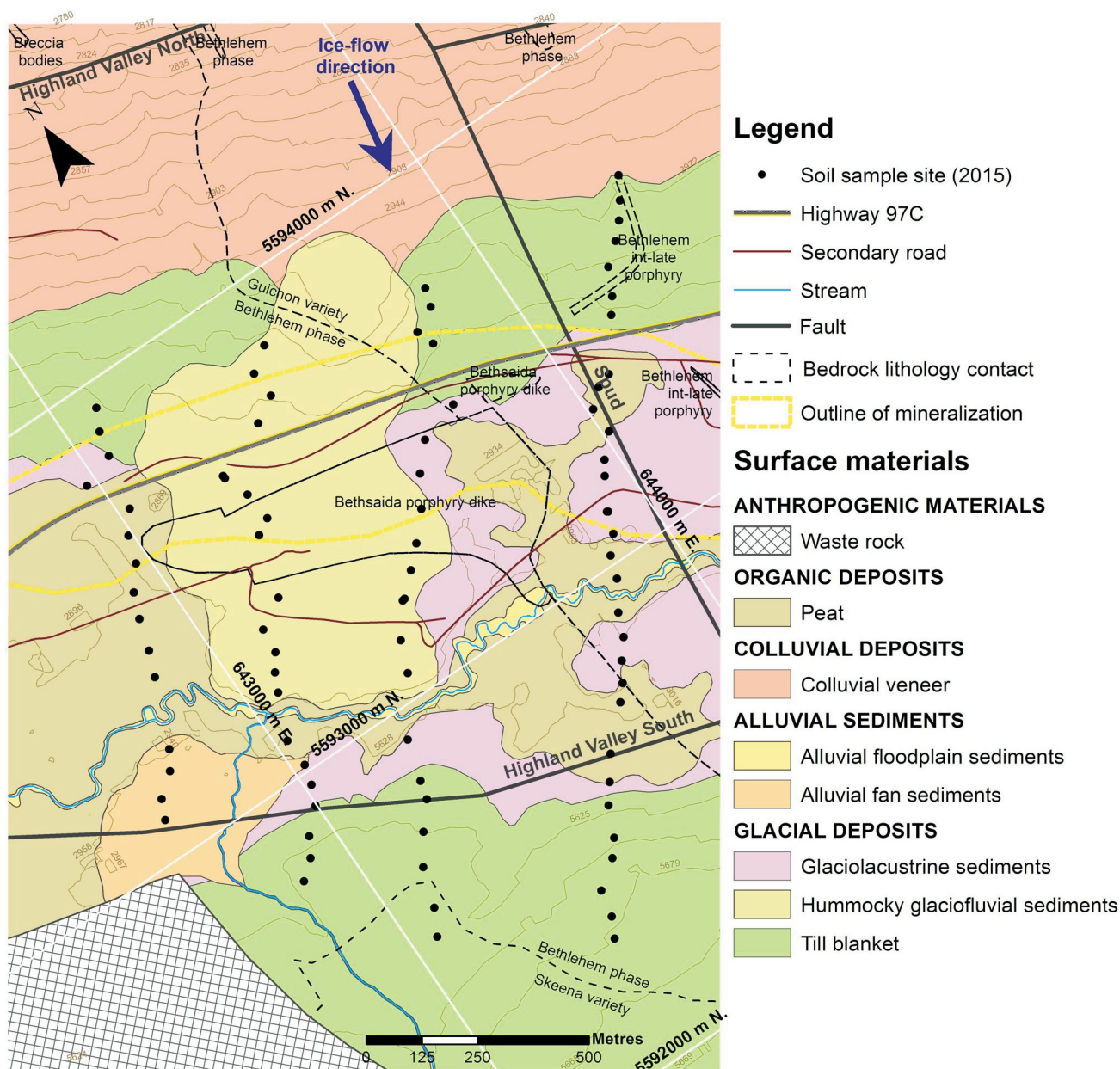


Figure 3. Surficial geology of the J.A. study area at the Highland Valley Copper mine operations; surficial geology is modified from Plouffe and Ferbey (2015), using the Geological Survey of Canada's data model for surficial geology, version 1.20 (Deblonde et al., 2012); bedrock geology and structure adapted from McMillan et al. (2009) based on work done in August 2016 by Teck Resources Limited and the Canadian Mining Innovation Council.

and field observations to bring the details from a 1:50 000 scale to an approximately 1:10 000 scale representation.

Soil Sampling and Field Measurements

Two soil transects were sampled crossing buried targets perpendicular to mineralization at Highmont South, with 25 m site spacing close to and over the top of the targets, and 50 m site spacing out into background areas. A total of 93 soil samples were collected at the Highmont South targets in 2015. Four soil transects cross the buried J.A. target, again perpendicular to mineralization, all with 50 m spac-

ing between sample sites and with approximately 200–300 m spacing between transects. A total of 85 soil samples were collected at the J.A. target. A full quality assurance–quality control program was implemented with the samples, including insertion of certified reference materials and duplicate samples.

At each sample site, a detailed description was recorded and in situ physicochemical measurements were conducted for each soil horizon identified. Typical soil profiles encountered during sampling at both Highmont South and J.A. can be seen in Figure 4a–f. The upper 10 cm of the

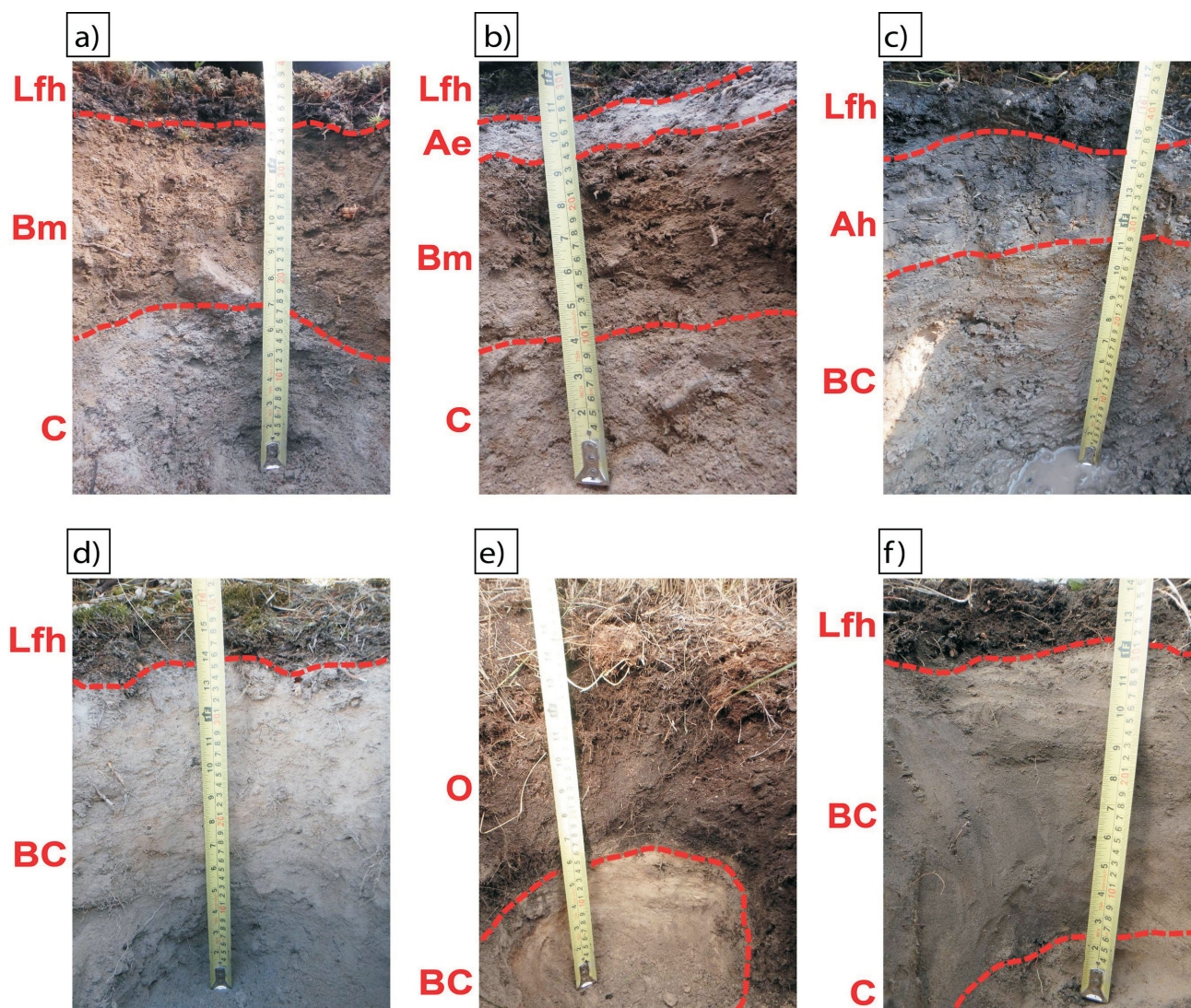


Figure 4. Typical soil profiles encountered during sampling at Highmont South (a–c) and J.A. (d–f), showing **a)** a Brunisol developed over till blanket material; **b)** a more well-developed Brunisol with an Ae horizon, developed over till blanket material; **c)** a clay-rich, water-saturated soil (Gleysol); **d)** a Brunisol developed over sandy glaciofluvial sediments; **e)** a sand-rich soil profile with no real B horizon (Regosol); **f)** an organic soil (peat) developed over glaciolacustrine sediments. Soil horizons are named based on the Canadian system of soil classification (Soil Classification Working Group, 1998).

B horizon was targeted for the soil sample itself and subsequent soil-slurry tests. The in situ measurements included electrical conductivity (EC), soil moisture and pH. Soil was sifted in the field through a <6.3 mm sieve and samples were collected for multi-element analysis. Slurry tests using the sampled medium and de-ionized water in a 1:1 volumetric ratio were conducted to measure oxidation-reduction potential, EC, pH, acidified pH (to test the soil's buffering capacity) and free-chlorine content.

GORE-SORBER® hydrocarbon collectors were inserted at the bottom of each sampled hole, including duplicate holes, for approximately 40 days. The collectors are composed of activated carbon within a GORE-TEX® sheath, which allows the carbon to passively sequester volatile organic and inorganic compounds within the soil through a

water-impermeable yet gas-permeable membrane (Anderson, 2006). A total of 187 sample modules have been analyzed by Amplified Geochemical Imaging (Newark, Delaware) for volatile organic and inorganic compounds; sensitive gas chromatography and mass spectrometry were used to detect these compounds in a parts per trillion range (Anderson, 2006). Results are to be interpreted alongside the rest of the geochemical data and in the context of the regolith maps to determine their efficacy in geochemical surveys over deeply buried sulphide mineralization.

Fieldwork completed in the 2016 season included soil-profile microsampling at 5 cm intervals down a soil profile to assess the influence of anthropogenic inputs, if any, to the soil surface as well as demonstrate the most ideal soil horizon to sample from for the purpose of exploratory soil sur-

veys. Tree coring was conducted to temporally understand the influence of anthropogenic inputs and decouple them from mineralization-derived and background signals.

Laboratory Analysis Techniques

Soil samples were submitted to Bureau Veritas Commodities Canada Limited (Vancouver) for drying at <60 °C and screening to <180 µm, with separate de-ionized water extraction and aqua-regia digestion, both followed by multi-element inductively coupled plasma–mass spectrometry. Total organic carbon was also measured by combustion furnace and infrared spectrometry. The multi-element analytical data from these tests will be subjected to various statistical techniques to identify the surficial response to the presence of buried mineralization.

In addition, pulps from the 2015 soil samples were analyzed for total element concentrations using an Innov-X field-portable X-ray fluorescence (XRF) analyzer manufactured by Olympus. This exercise assessed the use of a hand-held XRF unit as a quicker and cost-effective method to carry out total chemical analysis of soil samples on site instead of sending them out to commercial facilities.

Discussion and Ongoing Work

The pulps from selected 2015 soil samples will additionally be analyzed using X-ray diffraction to identify clay minerals. This will give insight into the relative cation-exchange capacities of the different materials and their ability to adsorb trace elements, both naturally sourced and from anthropogenic inputs.

Split portions of selected 2015 soil samples will be screened to two fractions: <2 mm and 2–6.3 mm. These fractions will be visually investigated under a binocular microscope to determine the presence and abundance of any relict sulphide grains that occur in each sample. This step will help identify glacially transported clastic sulphide material in the samples.

Eighteen soil samples, nine from each target, were selected and submitted for Cu-isotope studies in-house at UBC's Pacific Centre for Isotopic and Geochemical Research to help determine the source of Cu-ion migration (e.g., clastic contribution from till versus migration from buried sulphide mineralization). Sequential leaching on these samples will be completed to further constrain the source and residency of Cu as well as to determine the most effective leaching method to use in routine exploration geochemical soil surveys.

All chemical and physicochemical data from the research and fieldwork will be integrated and evaluated in the context of the regolith maps to identify the controls on the presence and abundance of elemental signatures. This work will generate more applicable exploration models, which

will expand beyond traditional frameworks and make use of new technologies.

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