

Geochemical Mapping of the Deerhorn Copper-Gold Porphyry Deposit and Associated Alteration through Transported Cover, Central British Columbia (NTS 093A/03)

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Introduction

Central British Columbia comprises at least three volcanic arc terranes that are considered important hosts of porphyry copper deposits (McMillan and Panteleyev, 1995; Logan and Mihalynuk, 2014). These deposits are significant contributors to the economy of BC; however, discoveries of new economic deposits, which are mostly discovered from outcrop, have declined in the past 20 years. Deposits may be overlain by young (<9000 years) glacial overburden, making their discovery challenging. Anomalous geochemical responses have been reported in several independent initiatives targeting sulphide deposits buried by younger glacial cover (Hamilton et al., 2004; Bissig et al., 2013; Eppinger et al., 2013); however, the transfer of these results into practical exploration tools has been inhibited by a lack of understanding surrounding the genesis of the anomalies. Innovative research into geochemical technology, surface materials and surface processes will lead to the development of novel exploration tools, increasing the likelihood of new discoveries.

The Deerhorn Cu-Au porphyry deposit (MINFILE 093A 269; BC Geological Survey, 2015), located 70 km northeast of Williams Lake (Figure 1), is one of at least five undeveloped porphyry systems that form the Woodjam area, which is currently being explored by Consolidated Woodjam Copper (and previously by Gold Fields Canada Exploration). The deposit and its immediate surroundings are covered by 10 to 150 m of glacial sediment <9000 years old with little or no evidence of extensive surface disturbance other than logging activities and exploration drilling. Mining has not been initiated. The subglacial paleosurface of the Deerhorn Cu-Au porphyry has been mapped from

drill core (Figure 1; Sherlock et al., 2013; del Real Contreras, 2015). Bissig et al. (2013) indicated the presence of anomalous geochemistry over the porphyry. This study significantly expands on that previous work, extending the survey an additional three sampling lines to produce a surficial geochemistry map. This study also adds new exploration methods, including metal isotopes (Cu, Mo and Pb), a self-potential geophysical survey and an organic geochemical application assessment. Chemical and physical parameters of the surface environment (e.g., geomorphology, soil types, pH, moisture content, oxidation reduction potential [ORP] and organic carbon content) will be integrated with the data to differentiate the response of mineralization from background responses and potential false positives.

Background

The Deerhorn Cu-Au porphyry is a high-K, calcalkaline intrusive complex discovered in 2009 by Consolidated Woodjam Copper and Gold Fields Canada Exploration. Between 2009 and 2011, 37 drillholes defined the underlying geology and current mineral resource estimate of 38.2 Mt grading 0.22% Cu and 0.49 g/t Au (Sherlock et al., 2013). Volcanic and sedimentary rocks are intruded by three distinct monzonite intrusions. Mineralization, which consists of disseminated and vein-hosted Cu and Au, is preferentially hosted in the monzonitic intrusions in comparison with the local country rocks, which consist of thickly bedded, volcanic-derived sandstone that is overlain by andesite flow breccia (R. Sherlock, pers. comm., 2015). The mineralized resource is defined by a zone approximately 500 m in diameter occurring at the bedrock-till interface.

Late Wisconsinan glaciation (Dyke and Prest, 1987) may have unroofed the deposit as it is currently exposed in subcrop. Glaciofluvial, glacial and glaciolacustrine sediments overlie the mineralization and surrounding country rocks. These till deposits are now densely vegetated by mixed conifer forest, which is being selectively logged.

Keywords: geochemistry, geophysics, exploration, anomaly recognition, porphyry, soil sampling, hydrocarbon, inorganic chemistry, organic chemistry, SP survey, regolith mapping, Cu-Mo-Pb isotopes

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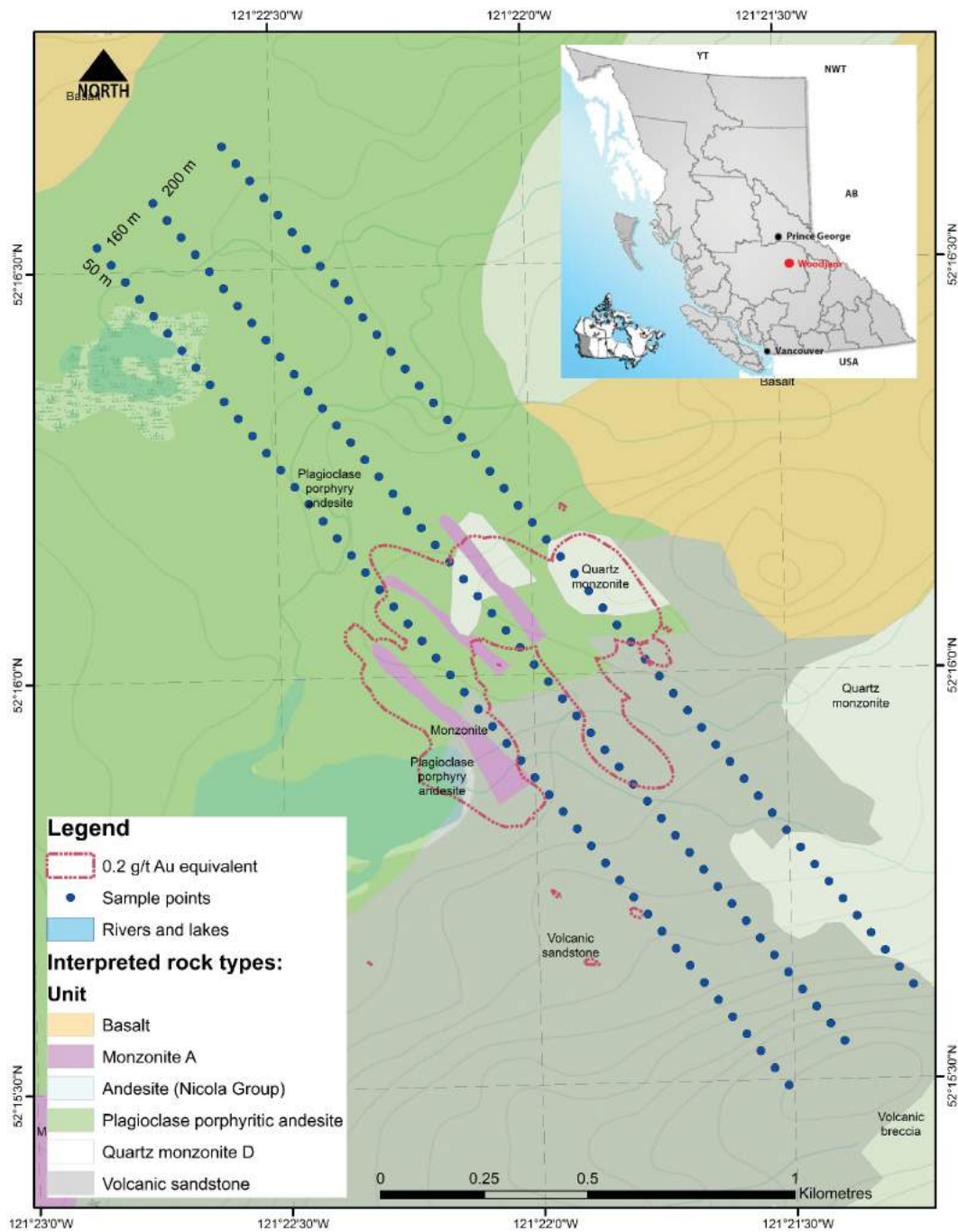


Figure 1. Bedrock geology of the Woodjam project area (Quaternary overburden removed), showing the location of the mineralized zone and the three sample lines completed as part of this study. The three transect lines show the area of detailed regolith mapping shown in Figure 2. The location of study area is identified in the inset. Geological map shapefile courtesy of Gold Fields Canada Exploration and Consolidated Woodjam Copper.

During the 2015 summer field season, 24 days were spent traversing the project area to construct a surface regolith map. A total of 157 soil samples was collected for chemical analysis. Hydrocarbon collectors were placed in the ground at each sample site for 63 days and a self-potential geophysical survey was conducted over the mineralized zone. Detailed field data were collected at each sample location.

Regolith Mapping

In May 2015, an area 2.5 by 0.6 km that encompassed the sampling and geophysical survey slocations underwent regolith mapping . Geomorphological units, anthropogenic activities and potential contamination, vegetation types and topographic variations were noted during the mapping

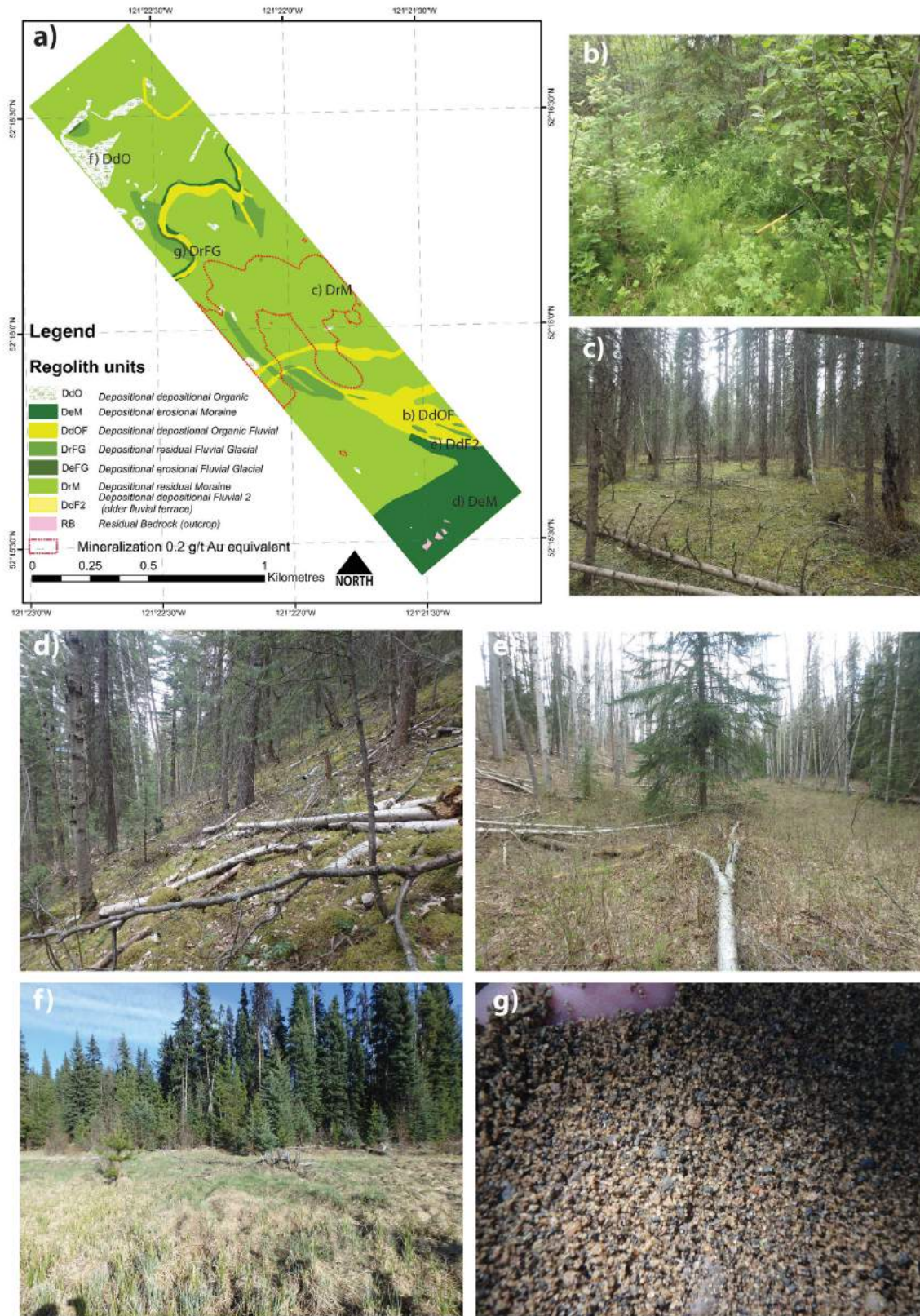


Figure 2. a) Regolith (surficial geology) of the study area (as shown in Figure 1); mapping is classified under the RED (residual, erosional and depositional) mapping scheme introduced by the Cooperative Research Centre for Landscape Environments and Mineral Exploration (Pain, 2008); geomorphological modifiers (to the right-hand side of an RED classification) are classified under the terrain classification system for British Columbia (Howes and Ken, 1997); **b–g)** photographs of example locations of the residual, erosional and depositional (RED) environments; location of each photo indicated in Figure 2a.

(Figure 2). Regolith mapping over the deposit, combined with inorganic and organic chemistry assays, confirmed geochemical relationships that are dependent on the geomorphological environment. Awareness of these relationships can assist in identifying and deprioritizing potential false anomalies, while characterizing the background noise for removal by data filtering. This approach can strengthen subtle anomalies that may be related to buried mineralization.

Soil Sampling

A total of 157 soil samples (including seven duplicates) were collected from the upper B soil horizon (immediately below the Ae horizon, where present) on a predetermined set of three lines at 200 m spacing with 50 m spaced samples crossing mineralization and extending into background on either side of the deposit. The lines were oriented to minimize variability in the subcrop geology, take into account two stages of ice movement and avoid the lake to the southwest. Extensive metadata were collected at each location, including

- descriptions of all soil horizons present in the profile, their depths, colour, in situ pH, conductivity and moisture content (Figure 3);
- the ratio of soil to de-ionized water slurry (1:1) measurements including pH, acidified pH (following the method of Smee [2009]) and ORP;
- vegetation types, canopy and under-canopy height;
- slope and aspect measurements; and
- photographic documentation of the sample environment and soil profile.

All samples were submitted to ALS Laboratories (Vancouver, BC) for aqua-regia digestion, de-ionized water extrac-

tions, inductively coupled plasma–mass spectrometry (ICP-MS) multi-element analysis and C_{org} measurement.

Reducing the Impact of Major Components in Soils on Trace-Element Variability

Organic matter (analyzed using ALS assay C-IRO6a), along with clay, quartz and mineral and rock fragments, can be a significant component in soil. Organic acids, created during the breakdown of plant material, have a significant capacity to sequester and retain cations from the ambient environment. Organic material tends to accumulate in depressions, such as in swamps or drainage channels, resulting in the generation of potential false anomalies (Figure 4). Accounting for the variation in organic carbon, for example by simple normalization, can reduce the significance of organic enhanced trace-metal responses.

Self-Potential Survey

Electrochemistry has shown potential for identifying buried sulphide ore deposits due to the reduced nature of regolith increasing the conductivity above oxidizing sulphide ore (Smee, 1983; Hamilton et al., 2004). A self-potential (SP; also known as spontaneous potential) survey was conducted along each sample line at the end of July 2015 to image the electrical response at the surface (Figure 5). At the Deerhorn Cu-Au porphyry deposit, measurements using Cu-CuSO₄ electrodes were recorded at 50 m intervals, using the same locations as the soil samples collected along the soil survey transects. Evaluation of the Deerhorn SP data is ongoing, in particular taking into account the surface variability recorded during the regolith mapping and soil sampling. Soil moisture at each SP station requires integration with the SP data. This is important given the observations of Burr (1981) and Corry et al.

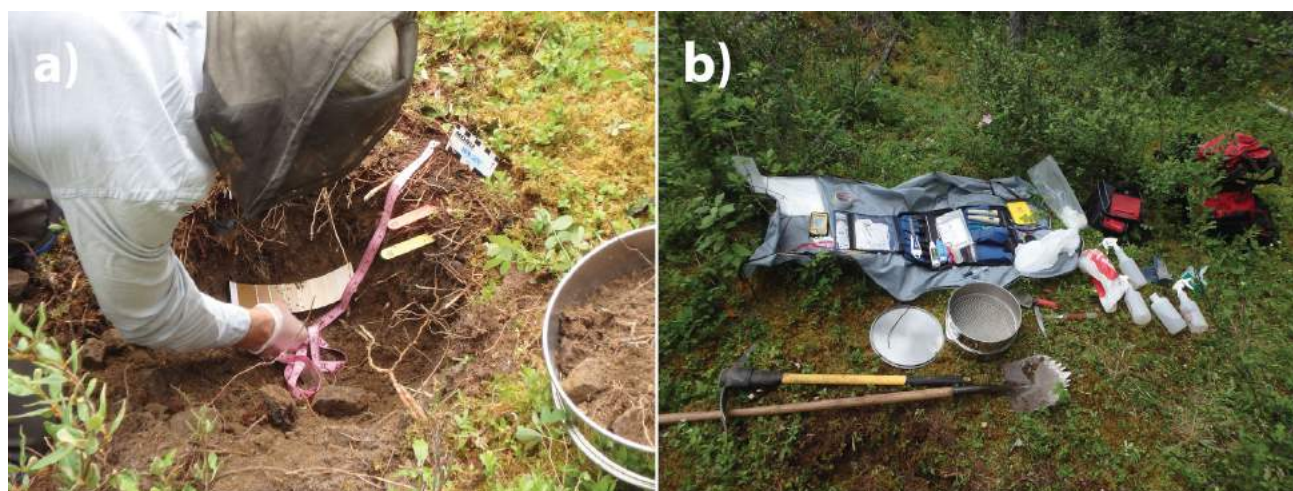


Figure 3. a) Soil profile measurement undertaken at each location; **b)** equipment used to conduct soil survey.

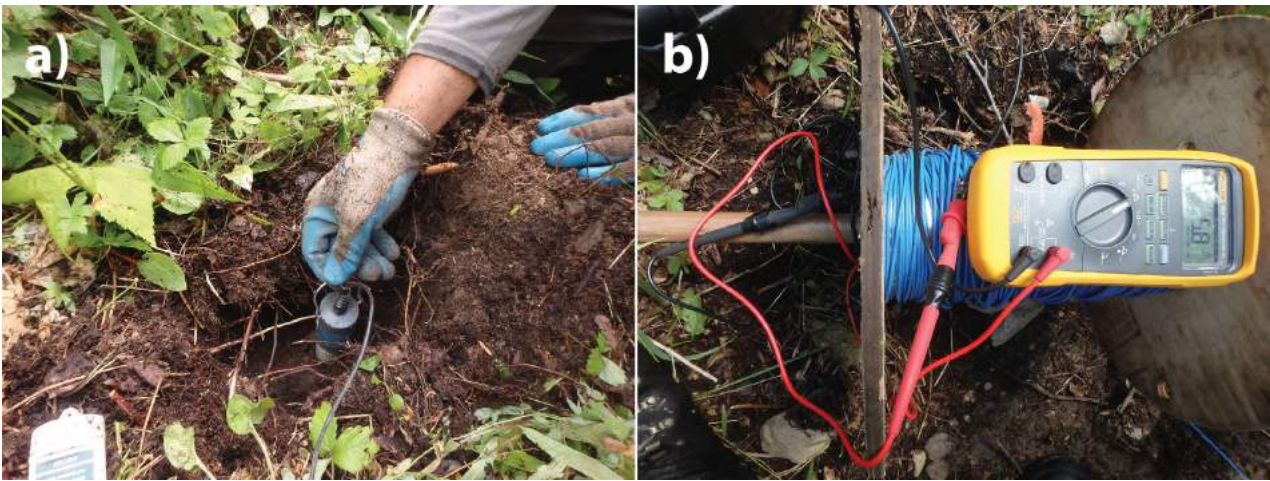


Figure 4. a) Insertion of copper–copper sulphate electrode used during the self-potential survey; b) copper wire and voltmeter used for the self-potential survey connected to copper-copper electrode.

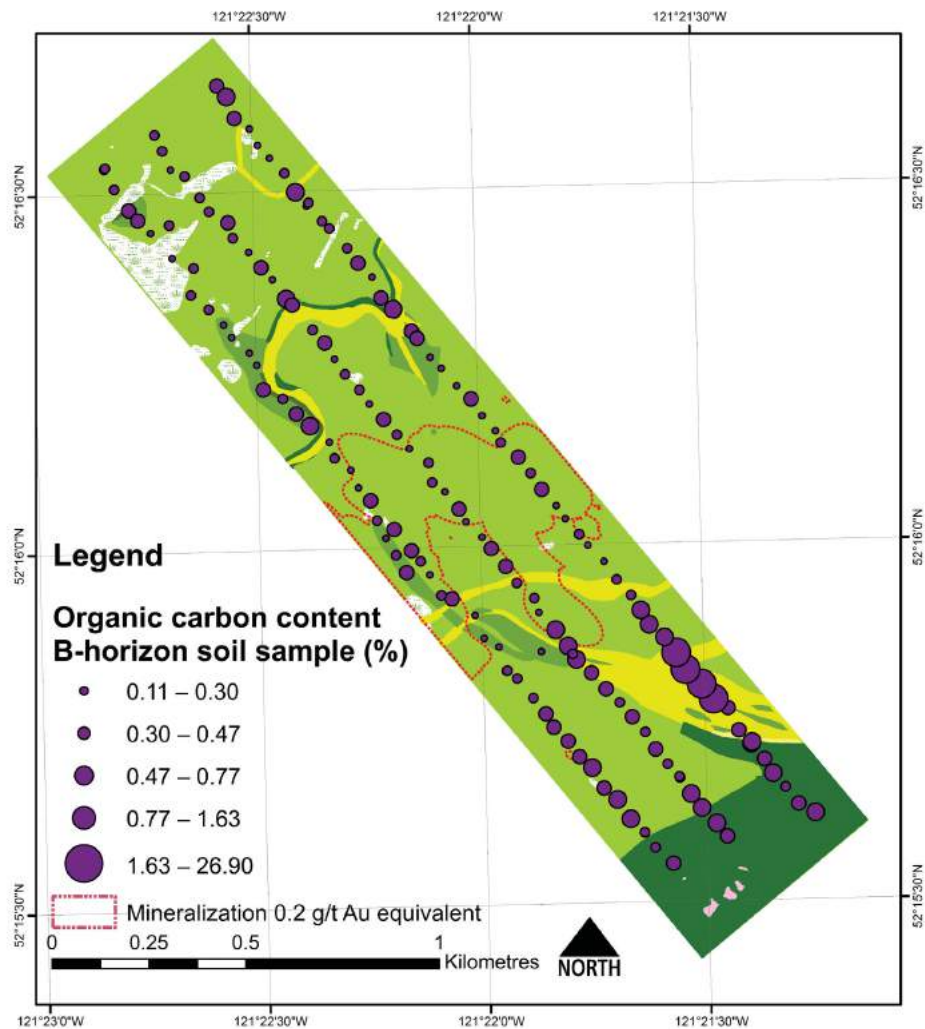


Figure 5. Spatial attribute map for organic chemistry results (C_{org}) over the Deerhorn Cu-Au porphyry deposit. Organic-rich swamps and organic fluvial areas mapped as Depositional depositional Organic Fluvial (DdOF) and Depositional depositional Organic (DdO) in Figure 2 correlate with higher concentrations of C_{org} . The locations of results displayed represent the 150 pre-determined locations (including seven field duplicates) for the soil profile analyses and soil sampling survey, as well as the subsequent hydrocarbon collection and self-potential survey locations. Legend as in Figure 2.

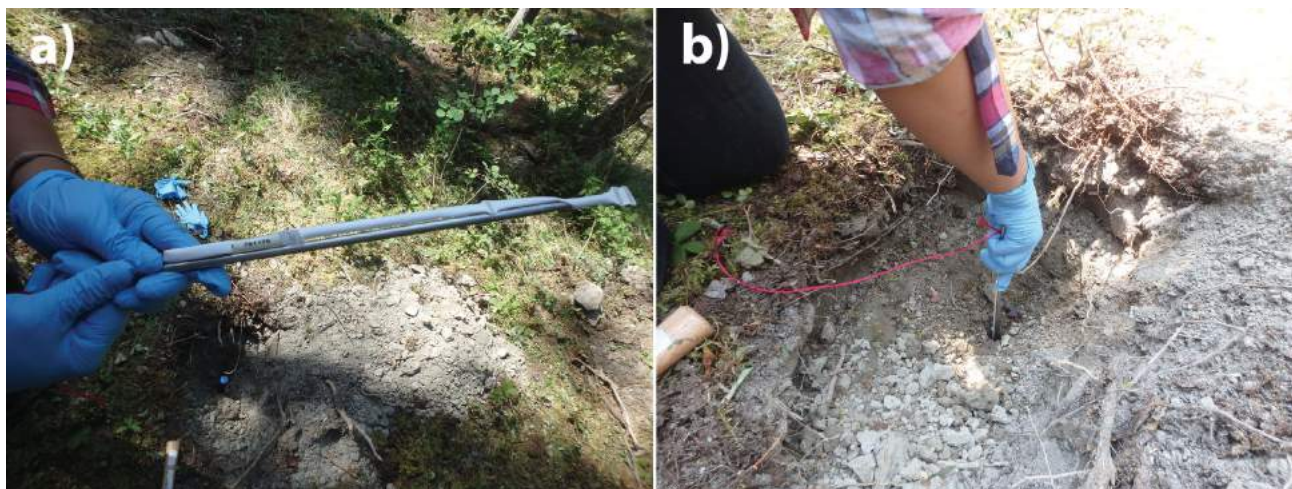


Figure 6. a) Gore-Tex® membrane hydrocarbon collector supplied by AGI Laboratories; b) insertion of hydrocarbon collector 45–60 cm below the surface.

(1983) that variable moisture content can induce a strong interference in voltage measurements.

Hydrocarbon Collection

In total, 157 hydrocarbon collectors (including seven duplicates) consisting of water-impermeable–gas-permeable Gore-Tex® membranes housing activated carbon were buried at a depth of 45–60 cm and left for 63 days at each sample location (Figure 6). The hydrocarbons in the collectors will be analyzed by thermal desorption followed by high-resolution gas chromatography–mass spectroscopy at Amplified Geochemical Imaging (Delaware, United States; Anderson, 2006). These data will be integrated with the inorganic and regolith data to determine if a viable response in the hydrocarbons can be detected and correlated with mineralization.

Summary

Extensive geomorphological and surface mapping was undertaken at the Deerhorn Cu-Au porphyry deposit and is being integrated with the organic, inorganic and physico-chemical results from 150 sample sites in the till that overlies the deposit and the surrounding area to differentiate true anomalous response from background noise and false anomalies. A critical component that is often overlooked in the interpretation of geochemical surveys is quantifying the history of the horizon being sampled. The integration of the surface, environment, relative age and composition information will allow for a filtering of the surface noise and will enable the identification of subtle geochemical anomalies related to mineralization.

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