Use of Organic Media in the Geochemical Detection of Blind Porphyry Copper-Gold Mineralization in the Woodjam Property Area, South-Central British Columbia (NTS 093A/03, /06)

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Introduction

This paper covers activities conducted under a Geoscience BC project entitled "Evaluation of plant exudates to assist in mineral exploration and the development of simple and cost effective field procedures and analytical methods". Large areas prospective for porphyry and epithermal-style mineralization in central British Columbia are covered by either glaciofluvial sediments or young basalt units. In areas where the cover is unconsolidated material of glacial origin, recently completed Geoscience BC-funded projects significantly advanced the understanding of the underlying bedrock geology and have demonstrated means of seeing through this type of cover using geochemistry (e.g., Cook and Dunn, 2007; Dunn et al., 2007; Barnett and Williams, 2009; Heberlein, 2010; Heberlein and Samson, 2010; Heberlein and Dunn, 2011). However, geochemistry is not commonly used to investigate the underlying geology in those areas covered by young basalt flows. The present study is aimed at establishing a geochemical strategy to see through basalt cover, using a variety of analytical techniques on a variety of organic or organically-derived sample media to test what works best.

Plant Exudates

It has long been established that plant exudates can contain metals translocated from underlying mineralization, through the plant and into the sap. The most dramatic of these discoveries is that of the Sève Bleue tree (*Sebertia acuminata*) from New Caledonia. Its name comes from the bright blue sap that derives the colour from the extraordinarily high concentrations of Ni that it contains (Jaffré et al., 1976); the sap was found to contain a phenomenal 25.74% Ni on a dry-weight basis. Plant exudates (saps, fluids transpired through leaf pores, salts and particulates on leaf surfaces, which have crystallized from the plant fluids) may provide a simple and cost-effective sample medium. The authors are not aware of any published records of these media being used for geochemical exploration purposes in BC.

Keywords: *deep-penetrating geochemistry, Woodjam, copper-gold porphyry, biogeochemistry, exudates, bark, spruce, Ah soils, charcoal, soil pH, soil conductivity*

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Application to Exploration

Kyuregyan and Burnutyan (1972) demonstrated that plant saps could be used in exploration for Au, because the sap Au content was significantly higher than that of other aqueous extracts of the plant material or of the underlying soil. Saps from birch are the most studied, both because of the ubiquity of birch in the boreal forests (especially Siberia and Finland) and of their strong sap flow in the spring. Krendelev and Pogrebnyak (1979) conducted a sampling program in an area of permafrost over an intensively fractured and hydrothermally-altered Au-mineralized stockwork in Transbaikal, where most of the Au is associated with pyrite and there is a 0.5–4 m cover of unconsolidated sediments. The mean Au content from analysis of 73 samples was reported as 0.011–0.33 ppb; Zn concentrations in fresh sap from trees growing over Zn-rich ore reached 17.2 ppm. The authors observed that, in the vascular system of the birch species studied (*Betula platyphylla*), there is no biological barrier against the absorption of Zn and concluded that the best anomaly to background contrast was obtained by calculating the Zn/(K+Ca+Mg) ratio. Harju and Huldén (1990) conducted an exhaustive survey in southern Finland, where they collected sap samples from many species of birch (mostly *Betula verrucosa*) over a 10-year period. Sap samples collected along transects over a zone of base-metal mineralization revealed clear anomalies of Ag, Cd, Zn and Pb above the orebody (Figure 1). More details of the use of saps in exploration are summarized in Dunn (2007).

In addition, consideration was given to the collection of cuticle and salt particulates on leaf tissues. This collection technique was tested by Barringer (1975), who compared the geochemical expression in soil, conifer vegetation and vegetation particulates sampled over Zn mineralization in Ontario. Later, some interesting positive results were recorded over Cu/Pb/Zn sulphides in the United Kingdom by Horler et al. (1980).

Benefits to the Mining Industry

This study is designed to provide the mineral-exploration community with a better understanding of different organic sampling media that can be used for biogeochemical exploration in regions with thick glacial sediment or Tertiary basalt cover. It provides comparisons of metal concentrations in vegetation, the Ah-soil horizon and charcoal debris, and assesses the relative capabilities of each medium for preserving the secondary geochemical dispersion patterns related to a blind mineral deposit. The study also examines metal concentrations in saps, leaf coatings and transpired fluids to determine whether direct sampling of these 'exudates' is an effective way of detecting blind mineralization. If successful, exudate geochemistry could provide the exploration community with an alternative sampling medium for local- and regional-scale geochemical sampling programs in areas where conventional soil-sampling methods are found to be ineffective.

Project Area

Test sites selected for this study lie within Gold Fields Canada Exploration (Vancouver) and Consolidated Woodjam Copper Corp.'s (Vancouver) Woodjam property, which is located in the Cariboo Mining District of central BC (NTS map areas 093A/03, /06; Figure 2). The property, which consists of 178 mineral claims totalling 58 470 ha, is located about 65 km to the northeast of Williams Lake. Horsefly, the nearest settlement and logistical base for the fieldwork, lies within the property boundary and is accessible by a paved road from Williams Lake. The two test sites, known as Deerhorn and Three Firs (also formally known as Megalloy; Figure 2), lie 8 and 12 km respectively to the southeast and south of Horsefly; both are readily accessible via a network of well-maintained logging roads.

Surficial Environment

The project area lies at the boundary between the Fraser Plateau and Quesnel Highland physiographic regions of central BC (Holland, 1964). The terrain in the study areas has characteristics of both regions. The Deerhorn test site lies at a fairly sharp transition between relatively flat rolling topography typical of the Fraser Plateau on the western side of the mineralized zone, to low hills of the Quesnel Highland to the east (Figure 2). Elevations across the Deerhorn sample traverse, which crosses the transition, vary from 900 m at the western end to 1030 m at the highest point, close to the eastern end. A number of small lakes and ponds

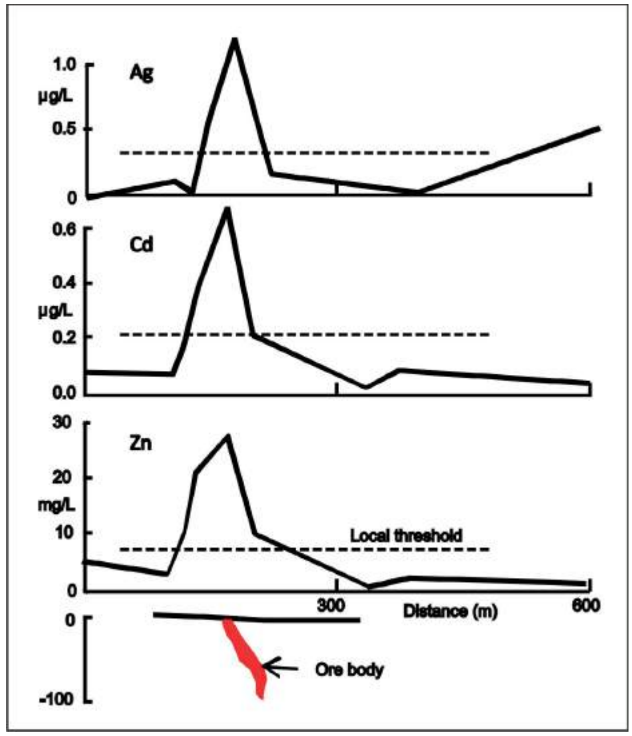


Figure 1. Transect across a skarn-type polymetallic sulphide deposit in Finland. Concentrations of Ag, Cd and Zn in birch sap (*Betula verrucosa*) are given in ì g/L (ppb), whereas that of Zn is given in mg/L (after Harju and Huldén, 1990).

are scattered throughout the area and are linked by small streams and boggy depressions, which form part of a dendritic drainage pattern connecting with the Horsefly River, some 5 km to the northeast of Deerhorn. The Three Firs test site lies in a similar physiographic setting to Deerhorn (Figure 2). More than half of the Three Firs sample traverse crosses relatively flat terrain typical of the Fraser Plateau, where elevations range from 975 to 1000 m asl. At these lower elevations, a number of swamps and small creeks define a northwest-flowing dendritic drainage pattern, which merges with Woodjam Creek, some 8 km to the northwest. The terrain gradually rises eastward into the rounded hills of the Quesnel Highland, where the maximum elevation at the eastern end of the line is 1140 m.

Quaternary glacial deposits cover extents of mineralization at both study areas (Levson, 2010). To the east of Deerhorn, surficial deposits consist of an intermittent till veneer, which mantles the hillsides and becomes thicker in topographic depressions. The maximum thickness of the till is unknown but the presence of outcrops on the northern flank of the hillside east of Deerhorn suggests that it is likely to be no more than a few metres thick. Glacial landforms, such as drumlinoid features, are present in this area and east of the sample traverse. Their long axes indicate a west-northwesterly ice-flow direction. Cover thickens rapidly westward onto the lowlands and drilling at Deerhorn has shown that the bedrock surface is buried beneath up to 60 m of till and glaciofluvial sediments (Skinner, 2010; del Real et al., 2013). Surficial deposits on the eastern shore of Mica lake and southern limit of the projected mineralized zone consist of well-sorted sand and gravel of probable glaciofluvial origin; the distribution of these deposits is unknown.

At Three Firs, the cover environment is complicated by the presence of a Tertiary basalt unit (Chilcotin Group?) beneath the glacial deposits. Drilling has shown that the basalt probably obscures a part of the mineralized zone. It consists of fresh, black, highly vesicular lava ranging from 2 to 20 m thick (A. Rainbow, pers. comm., 2012). Nicola Group rocks at its lower contact are intensely weathered over several metres in what is likely to be a paleoregolith. This clay- and oxide-rich zone is alternatively interpreted as a fault-gouge zone by Gold Fields Canada Exploration geologists (A. Rainbow, pers. comm., 2012). The extent of volcanic cover is unknown, although its distribution is most likely restricted to paleovalleys rather than forming a continuous cap over the mineralized area. This would be typical of other occurrences of Chilcotin Group flows in the region (Dohaney, 2009). Surficial deposits at Three Firs consist predominantly of till, which forms a blanket 40 to 100 m thick over the Nicola Group and basalt unit (A. Rainbow, pers. comm., 2012). There is no outcrop in the vicinity of the mineralization. Till cover appears to thin gradually east-

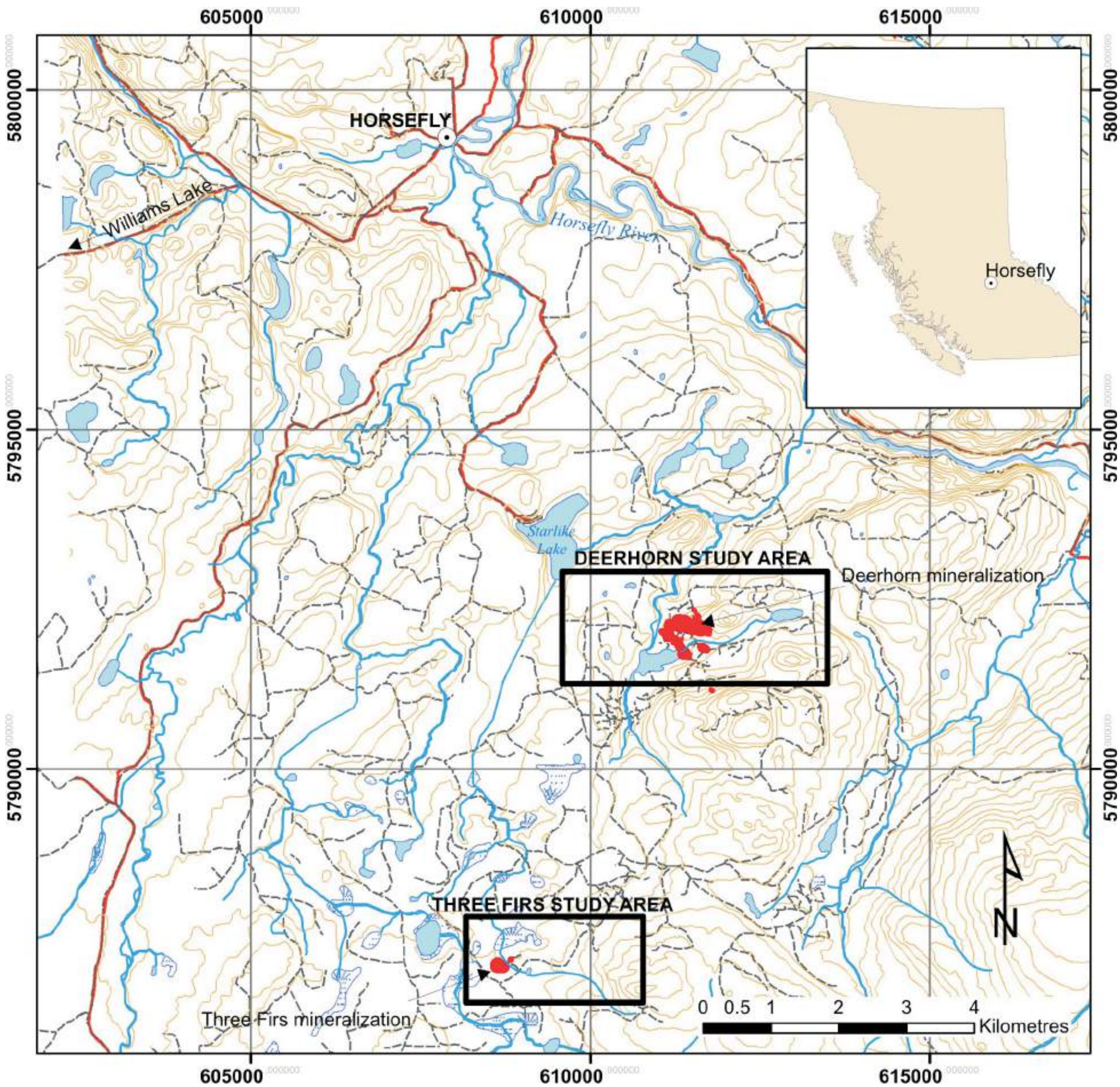


Figure 2. Location of study areas at the Woodjam property, south-central British Columbia. Red shapes represent the surface projection of mineralization defined by the +0.20 g/t Au equivalent cutoff (J. Blackwell, pers. comm., 2012).

ward and outcrops of a distinctive 'turkey-track' feldspar porphyry become widespread in the east-central part of the sample traverse. On the hillside, at the eastern end of the traverse, till cover is present as a thin veneer no more than a metre or two thick.

Regional Geological Setting

The Woodjam property area lies in the southern part of the highly prospective Quesnel terrane: a Late Triassic to Early Jurassic magmatic arc complex, which extends for most of the length of the Canadian Cordillera. It is flanked to the east by assemblages of Proterozoic and Paleozoic carbonate and siliciclastic rocks of ancestral North American affinity, but is separated from them by a sliver of oceanic basalt and chert of the Slide Mountain terrane (Schiarizza et al., 2009). Oceanic rocks of the Late Paleozoic to Early Mesozoic Cache Creek terrane bound the Quesnel terrane to the west (Figure 3). The southern part of the Quesnel terrane hosts a number of important Cu-Au porphyry deposits; nearby examples include Gibraltar and Mount Polley.

In the Woodjam property area, the Quesnel terrane is represented by Middle to Upper Triassic volcano-sedimentary rocks of the Nicola Group (Figure 3). Locally this consists of a shallow northwest-dipping sequence of volcanic and volcanic-derived sedimentary rocks, which include augite-phyric basalt flows and polymictic breccias containing latite, trachyte and equivalent volcanic clasts (Skinner, 2010). Sandstones and conglomerates are intercalated with the volcanic units. A suite of more or less coeval intrusions of alkaline to calcalkaline affinity intrudes the volcanic and sedimentary sequence. These intrusions include the Early Jurassic Takomkane batholith, located to the south and east of the project area, and a number of smaller syenite, monzonite, quartz monzonite and monzodiorite stocks and dikes within the Woodjam property itself; many of these are associated with Cu-Au mineralization (J. Blackwell, pers. comm., 2012).

The Woodjam South property contains several centres of Early Jurassic porphyry-style Cu-Mo-Au mineralization (Schiarizza et al., 2009). Style of mineralization, hostrocks and metal association vary from one mineralized centre to

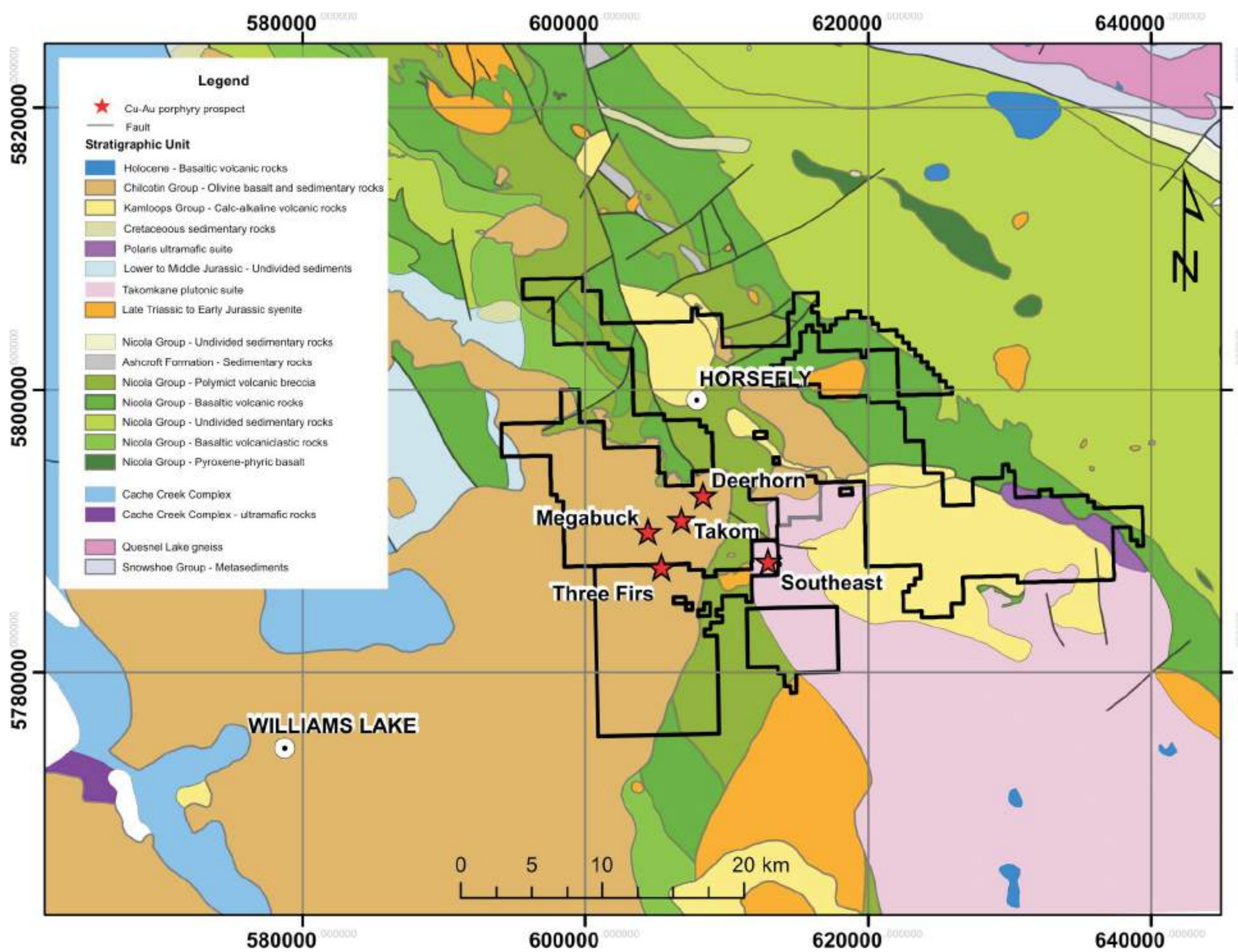


Figure 3. Regional geology of the Woodjam property area, south-central British Columbia.

another; these include the Southeast, Takom, Megabuck, Deerhorn and Three Firs (Megalloy) prospects (Figures 3 and 4). The Southeast zone is currently at the most advanced stage of exploration and has an inferred, pit-constrained resource of 146.5 Mt grading 0.33% Cu (Sherlock et al., 2012). Copper-molybdenum mineralization is hosted in intrusive rocks, which form part of the Takomkane batholith. Deerhorn is the next most advanced prospect and is currently undergoing exploration drilling. It is characterized by Cu-Au mineralization hosted in Nicola Group volcanic rocks and a series of small porphyry stocks and dikes (see below). The remaining prospects are all at the explor-

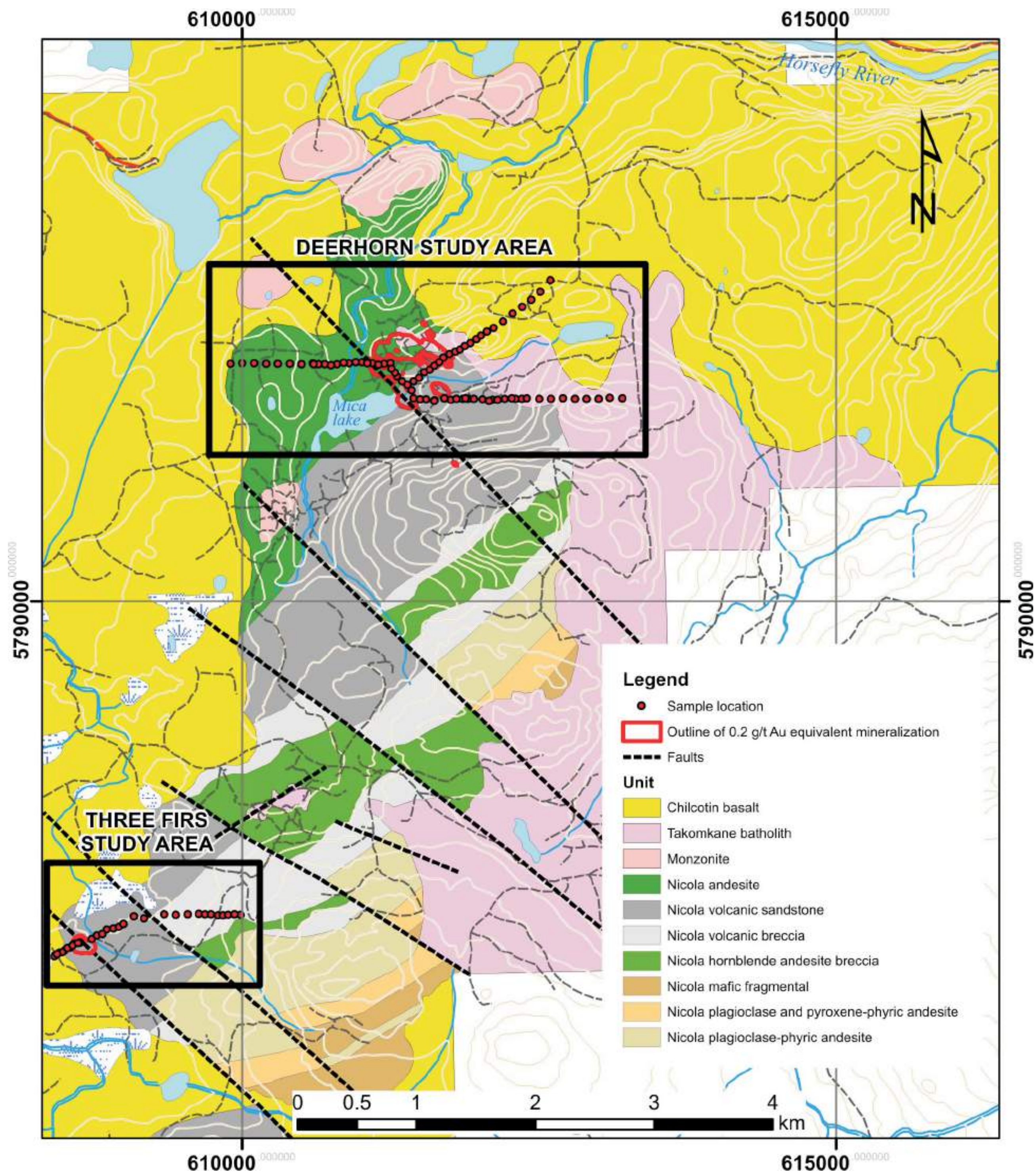


Figure 4. Bedrock geology of the Woodjam South property area, south-central British Columbia (after Del Real et al., 2013; J. Blackwell, pers. comm., 2012). Place name with the generic in lower case is unofficial.

atory drilling stage. Three Firs represents a new discovery that was made early in 2012 (Consolidated Woodjam Copper Corp., 2012a); it is currently in the initial drill-testing stage. Nicola Group rocks in much of the western part of the Woodjam South property area and an area to the east of Deerhorn are covered by younger Cenozoic rocks belonging to the Chilcotin Group (Bevier, 1983; Dohaney, 2009). These consist of olivine basalt lavas, tuffs and sedimentary units, including sandstone, siltstone, shale and conglomerate. This younger volcanic and sedimentary rock cover masks prospective areas of the underlying Nicola Group.

Geology of Test Areas

Deerhorn

Deerhorn is a blind zone of porphyry Cu-Au–style mineralization, which was discovered by drilling a large chargeability anomaly in 2007 (Skinner, 2010). The mineralization, shown by the red +0.20 g/t Au equivalent outline in Figures 2 and 4, is the surface projection of a pipe-like body containing a higher-grade shoot, which plunges at a moderate angle to the southeast (J. Blackwell, pers. comm., 2012). Its dimensions are approximately 350 m in strike, 100 m in width and 200 m in depth (Consolidated Woodjam Copper Corp., 2012b). Higher grade mineralization is enclosed within a much more extensive lower-grade envelope defined by a quartz and magnetite stockwork, veinlets and disseminated chalcopyrite mineralization. Low-grade mineralization is locally associated with a chargeability anomaly that extends northwest of the Deerhorn drilling and continues south and west to the Megabuck East and Megabuck prospects, which suggests that the three prospects are likely part of a single larger mineralized system.

Geological mapping and reconstruction of the bedrock geology from drilling by Gold Fields Canada Exploration (Figure 4; J. Blackwell, pers. comm., 2012) indicates that the mineralization is hosted in a northeast-striking, northwest-dipping package of Nicola Group andesite and volcanic sandstone. Higher-grade mineralization is associated with a number of northwest-striking dike-like monzonite bodies 30–75 m wide, which cross the contact between volcanic-derived sandstone units in the southeast and andesitic rocks in the northwest of the mineralized zone. The intrusion and volcano-sedimentary units are offset by sets of west-northwest- and northeast-striking faults (J. Blackwell, pers. comm., 2012).Copper-Au mineralization subcrops beneath a variable cover of Quaternary glacial and glaciofluvial deposits. The deposits consist of a till blanket up to 40 m thick over the mineralization and a sequence of overlying glaciofluvial sand and gravel exposed in roadcuts near the southeastern shore of Mica lake. The distribution of these deposits is unknown but they are not likely to be extensive.

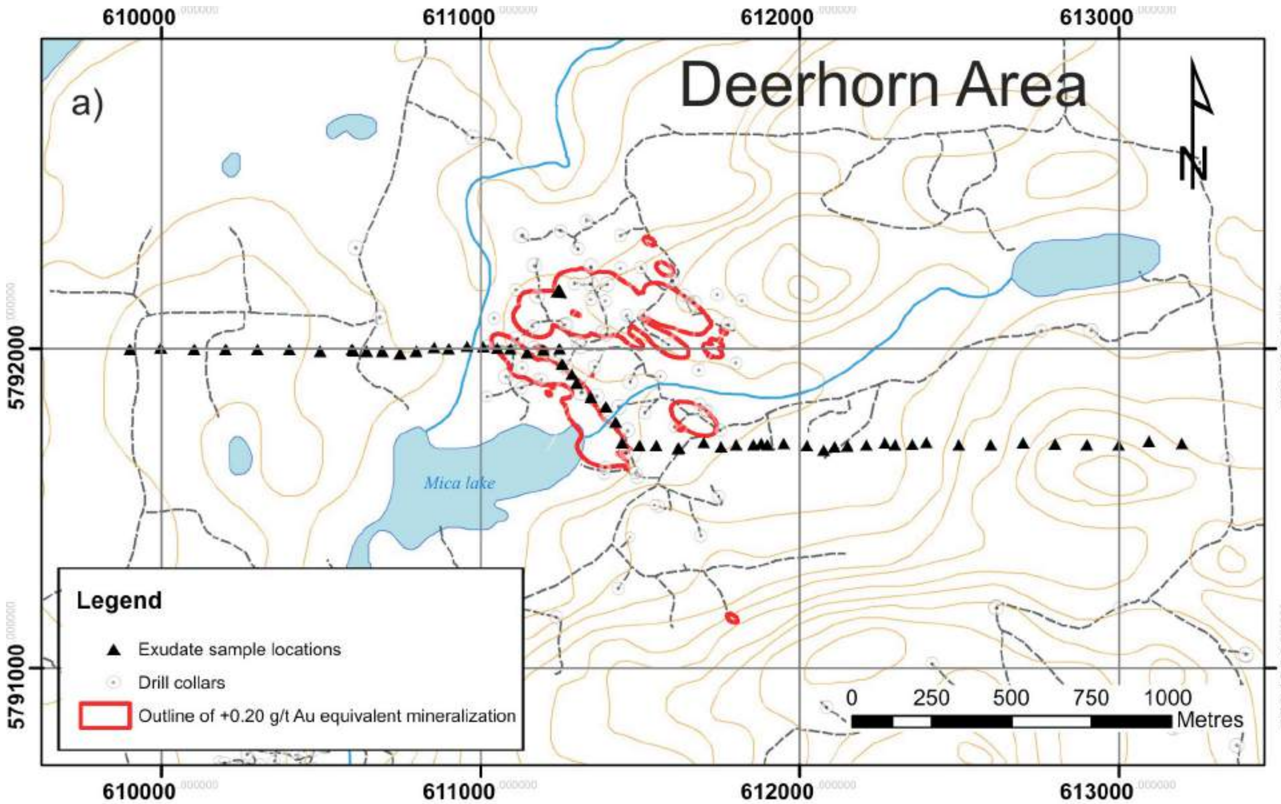
Three Firs (Megalloy)

Bedrock geology of the Three Firs study area is not exposed. Mineralization was discovered at this prospect during the early spring of 2012. At the time of sampling for this study, only three holes had encountered significant Cu and Au mineralization. What makes this study area appealing from a deep-penetrating–geochemistry standpoint is the presence of a basalt unit, inferred to be part of the Chilcotin Group, which overlies at least part of the mineralized zone. The extent of the basalt is unknown and it is difficult to determine from the interpretation of ground and airborne magnetic data. A basalt cap at least 30 m thick covering the underlying altered and mineralized Nicola Group rocks has been intersected by drilling. Figure 4 illustrates the known distribution of basalt and the surface projections of the mineralized drill intersections.

Quaternary glacial sediments overlie the basalt; where observed in drill road exposures, the sediments appear to consist of a boulder till containing abundant large rounded clasts (up to 1 m in diameter) of a distinctive ‘turkey-track’ andesite porphyry that is known to outcrop near the eastern end of the sample traverse and immediately to the southeast. The size and composition of the boulders indicate that the till is locally derived and possibly forms only a thin veneer across the survey area.

Field Procedures

The Woodjam area is in the sub-boreal spruce biogeoclimatic zone, dominated by white spruce and/or Engelmann spruce hybrids, to the west and the interior cedar-western hemlock biogeoclimatic zone to the east. Douglas fir occurs in the drier areas, with some large trees, and some lodgepole pine and western red cedar. Birch and poplar, scattered throughout, are the most common deciduous species. The understorey has shrub alder. Samples were collected along traverses across the surface projections of the known Cu-Au mineralization (Figure 5). The Deerhorn traverse (Figure 5a) is 3500 m long with sample sites spaced at 100 m intervals in background areas and at 50 m intervals over the projected Cu-Au mineralization. The eastern and western thirds of the traverse have east-west orientations, while the central part over the mineralized zone is oriented northwest-southeast in order to avoid Mica lake. At Three Firs (Figure 5b), the traverse line is 1650 m long. The western half over the Cu-Au mineralization has a northeasterly orientation and the eastern half is aligned east-west. Again sample sites were spaced at 50 m intervals over the known mineralization and at 100 m intervals in inferred background areas; background could only be achieved at the eastern end of the line. Sampling was not possible to the west of the mineralization due to the proximity of the property boundary.



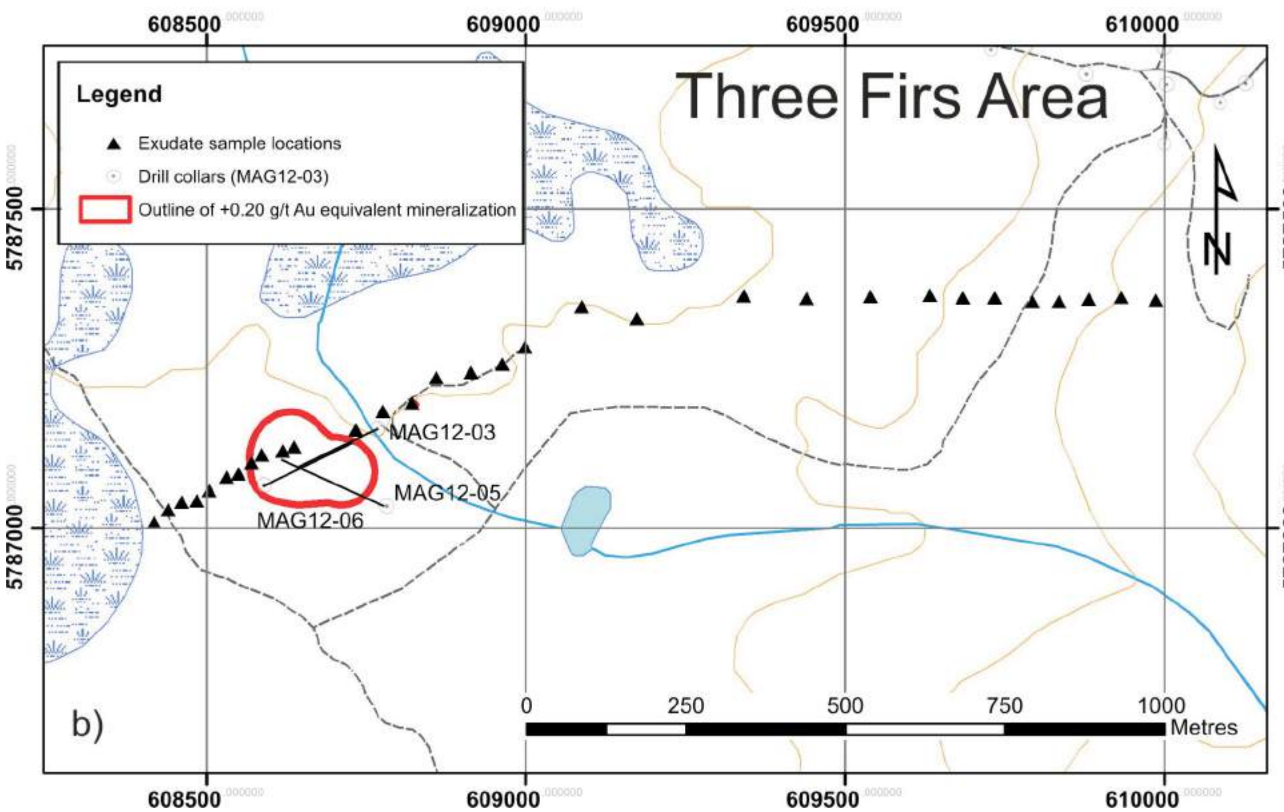


Figure 5. Location of sample sites at the Woodjam property, south-central British Columbia: **a)** Deerhorn traverse; **b)** Three Firs traverse. The red outline denotes the surface projection of the +0.20 g/t Au equivalent mineralization. Place name with the generic in lower case is unofficial.

Samples were collected on two occasions. The bulk of the sampling was completed in early July. Initial results indicated that the lines sampled should be extended in order to reach well into 'background' areas. Furthermore, the quality of some of the foliar samples from the exudate component might have been compromised; therefore, some additional sampling was warranted, as well as some repeat sampling to determine if significant seasonal differences in chemistry had taken place. This follow-up phase was undertaken during a two-day period at the beginning of September.

Vegetation and Exudates

For the vegetation sampling, the dominant tree species proved to be white spruce, which were therefore the focus for the biogeochemical sampling. Both twigs and outer bark were sampled, and the spruce trunks proved to be good sources for the collection of congealed sap. Alder were sufficiently abundant that leaves could be readily collected for some of the surface-wax tests.

Vegetation

The outer bark from white spruce (*Picea glauca*) was obtained by scraping the scales from around the circumference of a single large tree using a hardened-steel paint scraper, and pouring the scales into a standard kraft paper soil bag (a fairly full bag contained approximately 50 g; Figure 6a).

Samples of twigs and needles of white spruce comprising the most recent 5–7 years of growth were snipped from around the circumference of a single tree. In central BC, this amount of growth is typically about a hand-span in length, at which point, the twig diameter is 4–5 mm (Figure 6b). This diameter is quite critical because many trace elements concentrate in the bark part of the twig, whereas the woody tissue (the cortex) has lower concentrations of most elements. Consequently, unless there is a consistency in the diameters of the twigs that are collected, any analysis of twig tissue can result in variability among samples simply because of the differing ratios of woody tissue to twig bark. The twig with needles samples were placed into porous polypropylene bags ('Hubco' Inc.'s Sentry II). The use of plastic bags is to be avoided because samples soon release their moisture and become very soggy; if there is any delay in processing they develop moulds and lose their integrity.

In the laboratory, all vegetation samples were thoroughly dried at 80°C in an oven with a forced-air fan for 24 hours to

Figure 6. Sampling procedure for white-spruce bark and twigs at the Woodjam property, south-central British Columbia.

remove moisture. The needles could then be separated from the twigs. In preparation for chemical analysis, each bark sample was then milled to a powder using a Wiley mill. The spruce twigs, less the needles, were weighed in aluminum trays, which were placed in a kiln dedicated to plant tissues, and reduced to ash by controlled ignition at 475°C for 24 hours.

Plant Exudates

Several different types of plant exudates were collected (Figures 7–9):

- White-spruce sap, the congealed material that had accumulated on the surface of the tree trunks, tended to exude from the sites of dead branches or damaged surfaces (e.g., grazed by falling trees). A pocket knife, or the paint scraper used also for removing outer-bark scales (Figure 7a), was used to delicately pick/scrape off a sufficient amount of the congealed sap (about 1 g; Figure 7b) to fill a small polyethylene vial. Two or three minutes were usually sufficient to collect the required amount.
- Leaves of alder were collected in order to strip off the surface waxes using chloroform. During the first phase of the survey (July, 2012), they were stuffed into 250 mL polyethylene bottles and the lids screwed on tightly. This proved not to be the optimal procedure, since the leaves soon turned brown and started to decompose unless they were refrigerated the day of collection. During the second phase (early September), they were put into kraft paper sample bags.
- The current year's growth of spruce twigs and needles was snipped from several branches following the same procedures as those used for the alder leaves. Though these did not deteriorate like the alder, they were nevertheless put into kraft paper sample bags during the second phase of sampling.
- During a hot summer's day, plants transpire fluids through the stomata on their foliage. Gold has been reported in these fluids from studies in Siberia (Kyuregyan and Burnutyan, 1972). In order to collect this material (referred to here as 'transpired fluids'), plastic bags were tied over the twigs of several spruce trees and left in the hot sunshine for a day (Figure 8a). At the end of the day, the sites were revisited and the accumulated liquid was poured from the plastic bags into plastic vials and sealed (Figure 8b). On a cool day no 'sweats' accumulated, whereas on a hot day more than 50 mL was obtained from each tree. During the first phase of sample collection, more than 50 mL of fluid was collected in a single sunny day. During the second phase, when it was cool and cloudy, no fluids accumulated. The bags were left for a week (including some sunny days), after which Gold Fields Canada Exploration personnel were able to return to the sample sites and retrieve the fluids that had transpired during that period.

Horler et al. (1980) experimented with the collection of plant-surface particles from gorse bushes in southwestern England and concluded that the analysis of these particulates provided a useful geochemical indicator. Attempts were made to collect these particulates using the same type of cyclone (with a similar vacuum attachment) as that described in the paper by Horler et al. (1980; Figures. 8c and d). Unfortunately, because there had been substantial rain just prior to both field visits, no particulates could be collected; all plant surfaces (mostly alder and spruce in the field area) failed to produce any particulate material.

Ah and Charcoal Samples

Ah-soil–horizon sampling involved rolling back the surface moss-mat and leaf-litter layer (LF and LFH horizon) and scraping the black humic material accumulated at the

Figure 7. Collection of white-spruce sap at the Woodjam property, south-central British Columbia: **a)** congealed sap on trunks; **b)** sample size of approximately 1g.

Figure 8. Collection of exudate samples at the Woodjam property, south-central British Columbia: **a)** and **b)** transpired fluids; **c** and **d)** surface particulates, using a vacuum and cyclone system.

top surface of the mineral soil profile. In order to obtain enough material (50–75 g) and to create a composite sample to reduce within-site variability, several areas were sampled at each sample station. Samples were placed in kraft paper sample bags. An Ah-horizon sample and a charcoal sample (where present) were collected at each site. Charcoal fragments were hand-picked from the Ah horizon and placed in Ziploc® plastic bags. The amount and size of fragments present was found to be quite variable from station to station. At some locations, only minute chips (<1 mm) were obtained and it was necessary to collect charcoal from several spots within a 10 m radius of the sample location in order to collect sufficient material for a sample (approximately 50 g). At other sample sites, carbonized twigs, bark or wood could be sampled relatively easily.

Quality Control

Quality control measures employed for this study included the collection of field duplicate samples for each sample type as well as the insertion of 'blind' control samples (milled or ashed vegetation of similar matrix and known composition) for the vegetation analysis. A total of seven field duplicates were collected for each sample type at randomly selected sample sites. At each site, material was col-

Figure 9. Photograph shows all media collected for the exudate study (except charcoal) at the Woodjam property in south-central British Columbia.

lected using exactly the same procedures as the original sample and from within 5 m of the original sample. Control samples for the vegetation were inserted at a frequency of 1 per 10 field samples.

Analytical Methods

Table 1 provides a summary of the types of materials collected for the exudate study and the analytical protocols used. Analysis of the milled dry bark samples was carried out at Acme Analytical Laboratories Ltd. (Vancouver) using their 1VE2-MS method. This involves dissolution of a 1 g aliquot of milled material in nitric acid followed by aqua-regia digestion, heating on a hot plate, then diluting to a constant weight with de-ionized water; the analytical finish is by inductively coupled plasma–mass spectrometry (ICP-MS).

Ashed spruce-twig samples were sent to Acme Analytical Laboratories Ltd., where 0.25 g aliquots were dissolved in modified aqua regia (method code Group 1F) and analyzed by ICP-MS and inductively coupled plasma–emission spectrometry (ICP-ES) for 53 elements and selected REE. Saps were analyzed at Queen’s University Facility for Isotope Research (QFIR) by digesting 0.5 g of sample in 6 ml of concentrated nitric acid using a microwave digestion system manufactured by Anton Paar. Microwave power was set at 1400W and the total cycle time was 40 minutes, including power ramp up and cool down. Clear solutions with no solid residues were obtained and analyzed for 55 elements on an Element sector field ICP-MS manufactured by Thermo Fisher Scientific Inc. Transpired fluids were analyzed directly on the sector field ICP-MS at QFIR for the same suite of elements as the saps. Minimum dilutions were achieved by spiking 4 mL of sample with 80 µL of ultrapure concentrated nitric acid to provide a matrix with maximum instrumental sensitivity: the combination of minimum dilution and maximum sensitivity was necessary to effectively assess this very low-concentration medium. Alder leaves were placed in ultrapure chloroform and processed for 5 minutes in an ultrasonic bath to remove surface waxes and crystallized exudates. The leachate was then transferred into clean Teflon® beakers and allowed to evaporate to dryness in a Class 1000 cleanroom. The residue was then taken up in 2% nitric acid and analyzed on the sector field ICP-MS at QFIR.

Field Measurements

Soil pH and Electrical Conductivity Measurements

Samples for soil pH and electrical conductivity (EC) measurements were collected from both study areas (Figure 5). Where possible, material was collected from the top centimetre of the leached Ae horizon (in podzol profiles) and from the top of the B horizon, where the Ae horizon was either absent or poorly developed (e.g., in brunisol profiles). At sample sites with poor drainage, where organic material comprises the upper part of the profile, no sample was collected. Samples were placed in heavy-duty double-seal Ziploc® plastic bags.

Conductivity measurements were made on a 1:1 slurry of soil in demineralized water using a VWR® conductivity meter. Soil pH readings were taken on the same slurry using a double-junction pHTestr® 30 handheld pH meter manufactured by Oakton® Instruments The instrument was calibrated daily using standard pH buffer solutions at pH 4.00, 7.00 and 10.00. Two pH measurements were taken on each sample: the first one 20 seconds after immersion of the electrode into the slurry and a second, 20 seconds after adding one drop of 10% hydrochloric acid and stirring. Readings were recorded into an Excel® spreadsheet and converted to H^+ concentrations for interpretation.

Table 1. Sample media and analytical methods employed on plant tissues and exudates, south-central British Columbia.

Medium	No. of samples	Process	Analysis	Survey area
White spruce twigs	69	Needles separated and twigs reduced to ash	Acme method 1F04[1]	Deerhorn and Three Firs
White spruce outer bark	68	Milled to powder - analysis of dry tissue	Acme method 1VE2	Deerhorn and Three Firs
Alder leaves	41	Leached in chloroform to remove surface waxes	QFIR - HR-ICP-MS[2]	Deerhorn
First year white spruce twigs with needles	41	Leached in chloroform to remove surface waxes	QFIR - HR-ICP-MS	Deerhorn
Spruce sap (congealed)	43	Microwave digestion in concentrated nitric acid	QFIR - HR-ICP-MS	Deerhorn
Transpired fluids	10	Analysis by direct aspiration after spiking with 4 mL of sample with 80 L of ultrapure nitric acid	QFIR - HR-ICP-MS	Deerhorn
Leaf surface particulates	0	Unsuccessful - no samples	None	Deerhorn
Ah	72	Dried, sieved and digested in modified aqua regia	Acme method 1F04	Deerhorn and Three Firs
Charcoal	72	Dried, milled and digested in modified aqua regia	Acme method 1F04	Deerhorn

1 Acme Analytical Laboratories Ltd., Vancouver, BC; all analyses by inductively coupled plasma-mass spectrometry (ICP-MS), supplemented by inductively coupled plasma-emission spectrometry, except those at QFIR done using high resolution (HR) ICP-MS

2 Queen's University Facility for Isotope Research (QFIR), Kingston, Ontario, in collaboration with W. Macfarlane

Preliminary Results

Many of the analytical results, particularly those related to the plant exudate samples, were pending at the time this report was prepared. Nevertheless preliminary analytical results for some of the other sample media, namely charcoal, spruce bark and twigs are available for discussion. Patterns for selected elements for each of these media are described below.

Charcoal

Results for four elements from the Deerhorn area are illustrated in Figure 10. The profile plots show the approximate position of the surface projection of the mineralization (defined by the +0.20 g/t Au equivalent cutoff) as a red bar. This part of the traverse also corresponds to the segment with a northwestern orientation, as shown in Figure 5a. The plots show the raw values for Rb, Ca, As and Cu.

Rubidium results (Figure 10a) show two distinct features. Over the mineralization it defines a moderate contrast, multiple peak response. The strongest peak (6.1 ppm) coincides with the southeastern half of the projected mineralized zone. A second, slightly lower, contrast peak (2.5 ppm) occurs about 100 m to the west of the projected mineralization. Together these features appear to define an asymmetrical rabbit-ear–like pattern. The source of Rb is likely to be the potassic alteration associated with the Cu-Au mineralization at depth. A second high-contrast response occurs further east, in an area that is interpreted as being underlain by unmineralized rock. This feature has almost as much contrast as the response over the mineralization (to 5.3 ppm). The cause of this feature is not known but there are two possible explanations. One is the presence of subcropping syenite near the eastern edge of the feature; these K-rich rocks are a probable source of Rb. The second possible explanation is hydromorphic enrichment in a swampy drainage, the position of which is indicated by the blue bar in Figure 10a.

Calcium results (Figure 10b) highlight the position of the mineralization with a rabbit-ear–like pattern. A sharp single-sample response (2.6%) coincides with the southeastern edge of the zone. Over the central and northwestern part of the zone, Ca values are moderately elevated above background and increase to a maximum over the northwestern limit of the projected mineralization (1.8%). Rabbit-ear patterns in Ca and other pH-sensitive elements are well documented over the edges of blind sulphide bodies (e.g., Smee, 1997; Heberlein and Samson, 2010) and are thought to be caused by redistribution of these elements in response to variations in near-surface pH caused by oxidation of sulphides at depth (Smee, 1998). Calcium does not show a corresponding enrichment to the second Rb response on the eastern part of the line; this suggests that the rubidium feature is not likely to be related to sulphide mineralization.

Two elements related to the mineralization are illustrated in Figures 10c and d. Arsenic (Figure 10c) defines a sharp single-sample feature (13.3 ppm) located near the southeastern margin of the mineralized zone. There is no corresponding peak over the opposite margin. Values are at background levels for the rest of the line, with no significant enrichment in the swampy drainage to the east. Antimony shows a similar pattern (see Figure 11). Copper, on the other hand, has a relatively noisy profile (Figure 10d). Background concentrations average about 5 ppm but there is considerable variation above and below this level. Nevertheless, there does appear to be a low-contrast response to the mineralized zone, which has the form of a rabbit-ear anomaly. The two peaks (13.3 and 16.2 ppm) coincide closely with the projected edges of the underlying mineralization. Like Rb, Cu shows significant enrichment over the swampy area east of the mineralized zone, where two adjacent samples define a moderate-contrast feature with a maximum value of 17.1 ppm coinciding with the western edge of the swamp (charcoal could not be collected from the middle of the swampy area). This response is interpreted as a hydromorphic anomaly.

Vegetation

It should be noted that, in the case of the spruce bark, the dry matter was used for analysis, whereas the spruce twigs were reduced to ash prior to analysis. The ashing process results in approximately a 50-fold increase in element concentrations because the ash yield is only about 2% of the dry tissue. This process serves to bring concentration levels of some elements to well above the detection levels, resulting in more precise data. Elements illustrated for the spruce bark (Figure 11) are Cs (a surrogate for Rb and K), Cu and Sb (with a geochemical affinity for As).

Cesium is an element that can occur in association with Au deposits. It occurs with Au deposits at Hemlo and Getchell, occurring primarily in the mineral galkhaite [$(Cs,Tl)(Hg,Cu,Zn)_6(As,Sb)_4Si_2$]. It has also been noted in vegetation peripheral to the Au-As-Sb mineralization at the top of Mount Washington, Vancouver Island, and in plants surrounding the hydrothermal pools on the North Island of New Zealand (Dunn, 2007). Whereas Cs, Rb and K are all alkali elements, which tend to show similar patterns in rocks and soils, they sometimes adopt different paths in vegetation. This is primarily because K is an essential structural element in plant tissues and Rb is required in trace amounts, whereas Cs has no known function. Consequently, Cs in plants is a better indicator of potassic alteration than K itself (Figure 11a).Copper is another essential element for plant metabolism, which is why increased concentrations in plants growing over Cu-rich mineralization are generally quite subtle; this situation is illustrated in the Cu pattern of dry spruce bark (Figure 11b).Antimony tends to follow As and, in the spruce bark (Figure 11c), the high-

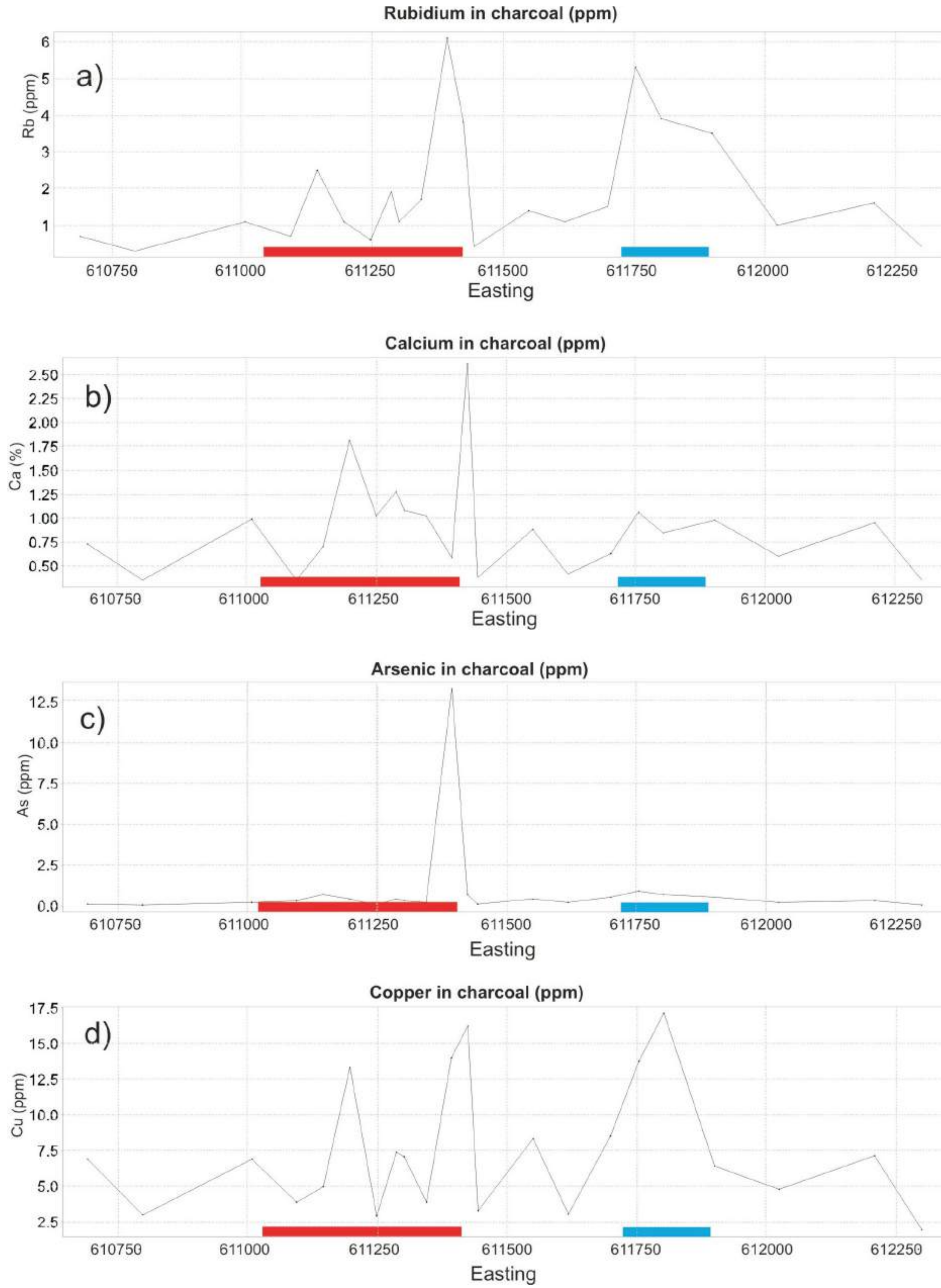


Figure 10. Results for selected elements in charcoal at the Woodjam property, south-central British Columbia: **a)** rubidium; **b)** calcium; **c)** arsenic and **d)** copper. The surface projection of the mineralization, defined by the +0.20 g/t Au equivalent cutoff, is shown by the red bar. The blue bar indicates the approximate location of a swampy drainage.

est concentration (although at low levels) coincides with the highest As in the charcoal (see Figure 10a).

In the spruce-twig ash, Cs (Figure 12a) presents a similar picture to that of Cs in the dry spruce bark. Similarly, Sb has by far the highest concentration directly over the surface projection of the mineralization (Figure 12b; see also As in Figure 10c). The highest Au concentration occurs over the southeastern part of the mineralized zone, and the lowest Au values are adjacent to the northwestern (Figure 12b) area of the zone.

Discussion and Conclusions

Preliminary results demonstrate that several of the organic media (charcoal, spruce bark and spruce twigs) all exhibit elevated levels of several elements, which indicate both alteration (Cs, Rb) and mineralization (Cu, As, Sb and Au). A second phase of sampling has extended the Deerhorn transect both to the east and west to help better define the significance of the anomalous signatures that were observed. It appears that the elevated concentrations of alkali metals may be reflecting a zone of potassic alteration,

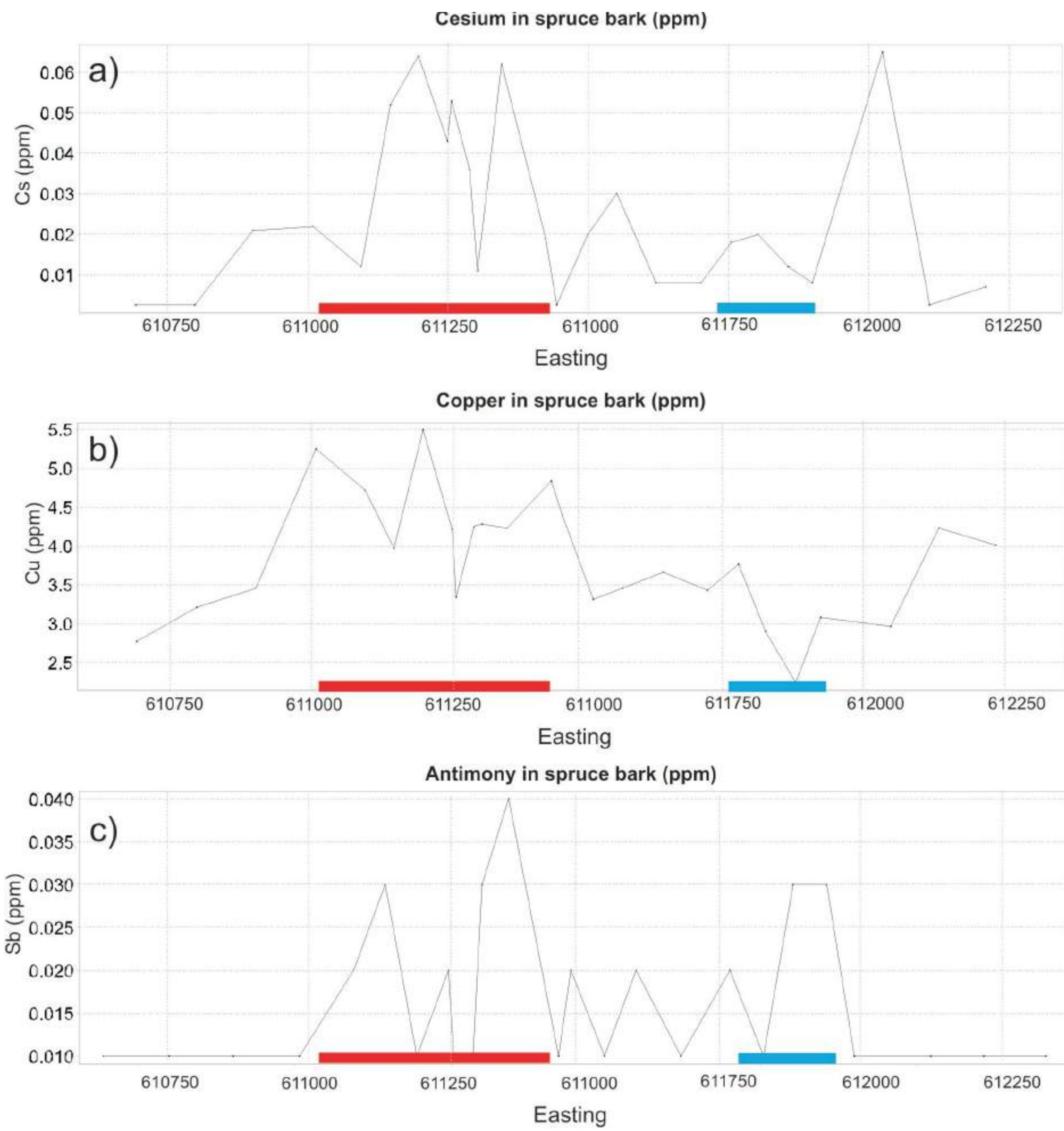


Figure 11. Results for selected elements in spruce bark at the Woodjam property, south-central British Columbia: **a)** cesium; **b)** copper and **c)** antimony. The surface projection of the mineralization, defined by the +0.20 g/t Au equivalent cutoff, is shown by the red bar. The blue bar indicates the approximate location of a swampy drainage.

within which commodity (Cu and Au) and pathfinder (As and Sb) elements are relatively concentrated. At the time of writing, no analytical data had been received for the saps and other exudate liquids. Attempts to obtain plant particulates from leaf surfaces have proven to be unsuccessful, which suggests that this is not a practical approach to exploration in the central BC environment.

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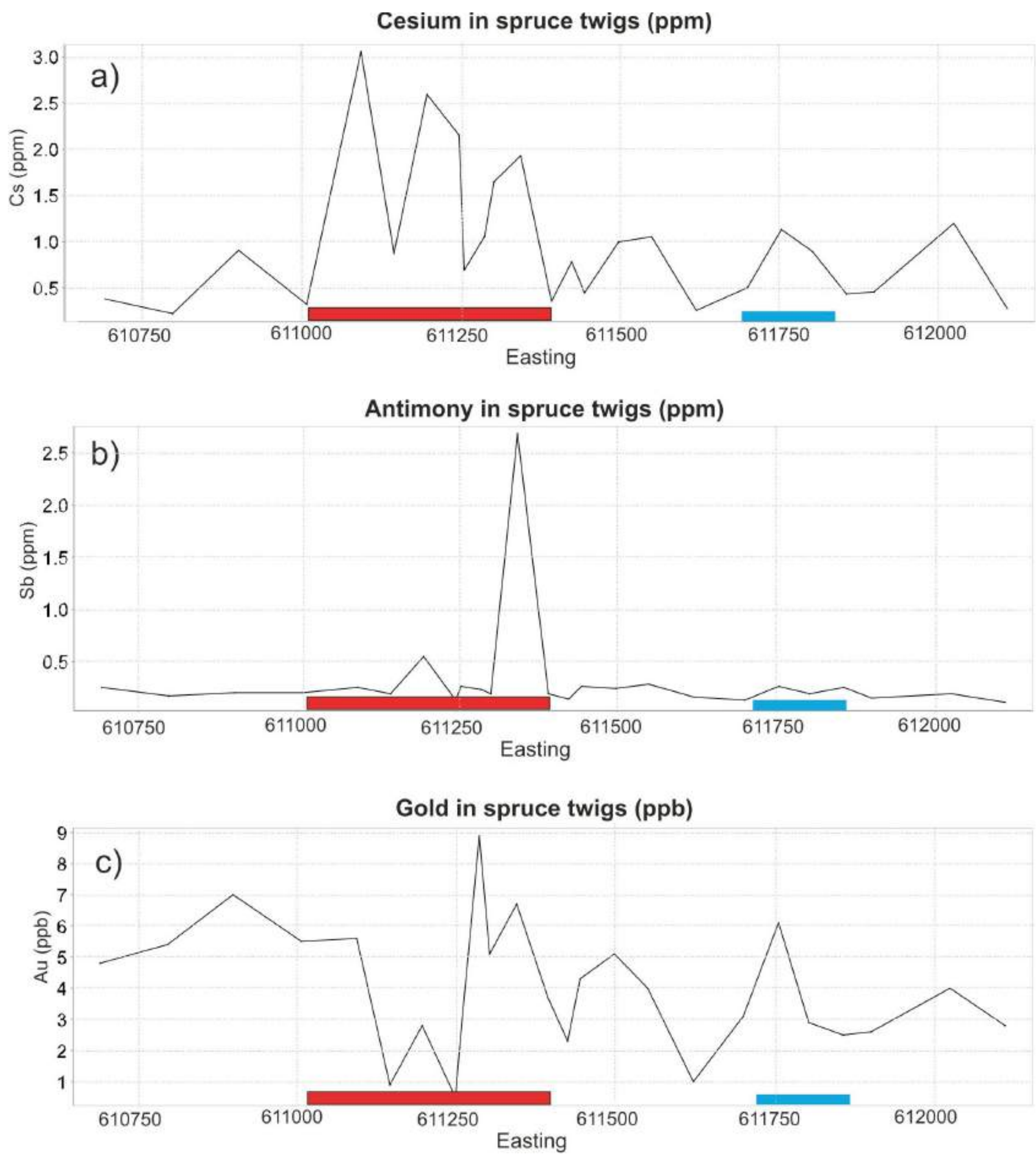

Figure 12. Results for selected elements in spruce-twig ash at the Woodjam property, south-central British Columbia: **a)** cesium, **b)** gold and **c)** antimony. The surface projection of the mineralization, defined by the +0.20 g/t Au equivalent cut-off, is shown by the red bar. The blue bar indicates the approximate location of a swampy drainage.

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