A photograph of two geologists in a forest. One geologist, wearing a white shirt and a wide-brimmed hat, is using a tool to collect a sample from a tree trunk. The other geologist, wearing a yellow shirt and a white hat, is standing nearby. The background is filled with green foliage and trees.

# Geochemical Techniques for Detection of Blind Porphyry Copper-Gold Mineralization under Basalt Cover, Woodjam Property, South-Central British Columbia (NTS 093A/03, /06)

**Technical Report**  
August 2013

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*David R. Heberlein*  
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THE UNIVERSITY OF BRITISH COLUMBIA

**MDRU**  
Mineral Deposit Research Unit

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# Geochemical Techniques for Detection of Blind Porphyry Copper-Gold Mineralization under Basalt Cover, Woodjam Property, South-Central British Columbia (NTS 093A/03, /06)

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## ABSTRACT

Miocene to Pleistocene basaltic rocks of the Chilcotin Group cover bedrock prospective for porphyry Cu-Au mineralization over a large area of south-central British Columbia and has provided significant challenges to exploration in these areas. This report presents the findings of a study aimed at identifying deep penetrating geochemical techniques potentially capable of detecting mineralization under basalt cover.

Samples have been collected over known porphyry style Cu-Au mineralization at the Deerhorn and Three Firs prospects in the Woodjam area (Minfile No. 093A 078). In both areas, Chilcotin Group basalt cover occurs adjacent to concealed mineralization and at Three Firs an angled drill hole intersected basalt before hitting mineralization. A variety of sample media have been collected, including Ae-horizon and B-horizon soils, spruce bark and spruce twigs as well as a limited number of clay and carbonate amygdules in basalt. Electrical conductivity, pH, H<sup>+</sup> and H<sup>+</sup>a measurements were performed on Ae- or upper B-horizon soils whereas B-horizon soils have been analyzed using seven different leach techniques.

The results of this study indicate that detection of mineralization under basalt cover is feasible. Partial leach techniques on B-horizon soils, such as Bioleach, Enzyme Leach, or Ionic Leach digestions gave good contrast anomalies in soils attributable to mineralization concealed by glaciofluvial sediments and/or basalt. Elements that yielded compelling anomalies over mineralized areas in B-horizon soils at Deerhorn, Three Firs or both include: As, Cu, Zn, Ni, Se, W, Ag, REE, Tl. Results from more aggressive leaches (4 acid, aqua regia) are influenced by the type of cover (e.g., basalt vs. glaciofluvial sediment) and thus, the 4 acid technique can help in delineating geological units. Soil pH, H<sup>+</sup>, H<sup>+</sup>a and electrical conductivity data are generally consistent with the soil geochemistry. Inverse Difference Hydrogen (IDH) values are relatively low directly above mineralization and high at either margin, defining rabbit ear anomalies, irrespective of the type of cover. Spruce bark and twig geochemistry yield compelling signals for alkali metals Rb, Cs and K which are elevated above mineralization and are interpreted to reflect potassic alteration which is genetically and spatially closely related to porphyry style Cu-Au mineralization. At Three Firs spruce geochemistry returned elevated Rb and Cs over basalt cover and suggest the presence of potassic-altered rocks underneath. Limited data suggest that clay amygdules in basalt covering mineralization contain elevated Ag, Au, V, Cu and In, whereas calcite amygdules have elevated Mn and As.

Given that Chilcotin group basalts are vesicular and commonly affected by columnar jointing they are likely conducive to vertical ion transport from oxidizing sulfide bodies at depth. Deep penetrating exploration geochemistry should yield results comparable to areas where mineralization is covered by unconsolidated glaciofluvial sediments.

## INTRODUCTION

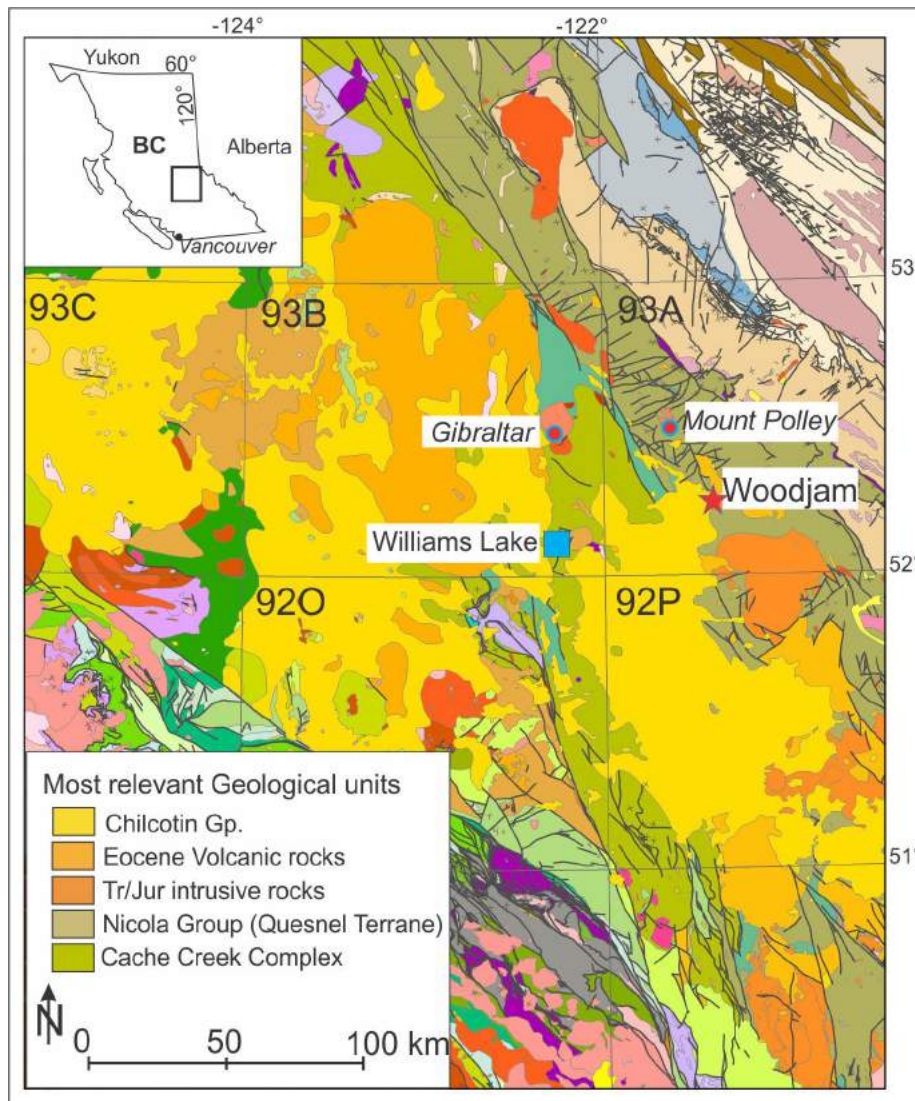
This report summarizes the results of the Geoscience BC project entitled: “Seeing through Chilcotin basalts: the geochemical signal of what is hidden underneath (092P, 093A, C)”. Field components of the study were undertaken in conjunction with another Geoscience BC project in the same area entitled: “Evaluation of plant exudates to assist in mineral exploration and the development of simple and cost effective field procedures and analytical methods” (see Heberlein et al., 2013).

Large areas prospective for porphyry and epithermal-style mineralization in central British Columbia are covered by either glaciofluvial sediments or young basalt units, most importantly of the Miocene to Pleistocene Chilcotin Group (Figure 1). Other recently completed Geoscience BC-funded projects have demonstrated that geochemical methods can assist in seeing through exotic cover (e.g., Cook and Dunn, 2007; Dunn et al., 2007; Barnett and Williams, 2009; Heberlein, 2010; Heberlein

and Samson, 2010; Heberlein and Dunn, 2011). In areas where basaltic lavas cover the bedrock, application of exploration geochemistry techniques has received relatively little attention in investigating the underlying bedrock, in part due to a lack of basalt covered sites in BC with well-known mineralization, where deep-penetrating geochemical methods could be tested. The present study is aimed at establishing a geochemical strategy to ‘see through’ the basalt cover, using a variety of analytical techniques on different sample media. Porphyry mineralization at the Woodjam property (Figure 1), the study site chosen for this project, occurs in close proximity to basalt cover and may also be present underneath.

## CHILCOTIN BASALT

The Chilcotin Group comprises mostly olivine-phyric basalts occurring as coherent lavas, with lesser tuffs and sedimentary units including sandstone, siltstone, shale and conglomerate (Bevier, 1983; Dohaney, 2009). Basalt flow units,

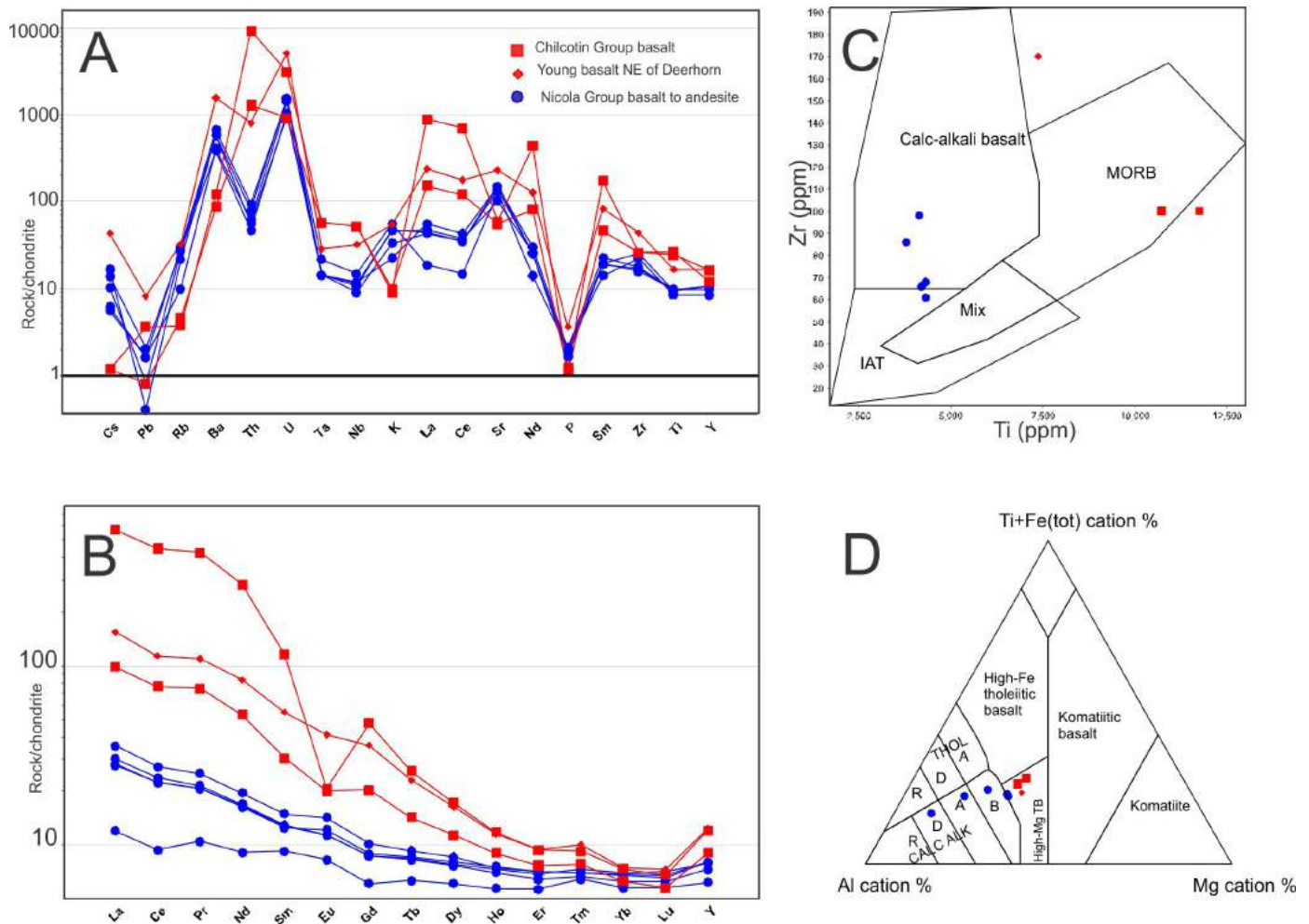


**Figure 1.** Regional geology of central British Columbia and location of the Woodjam study area as well as the nearby major porphyry deposits of Gibraltar and Mount Polley (after Massey et al., 2005); see inset for location within British Columbia

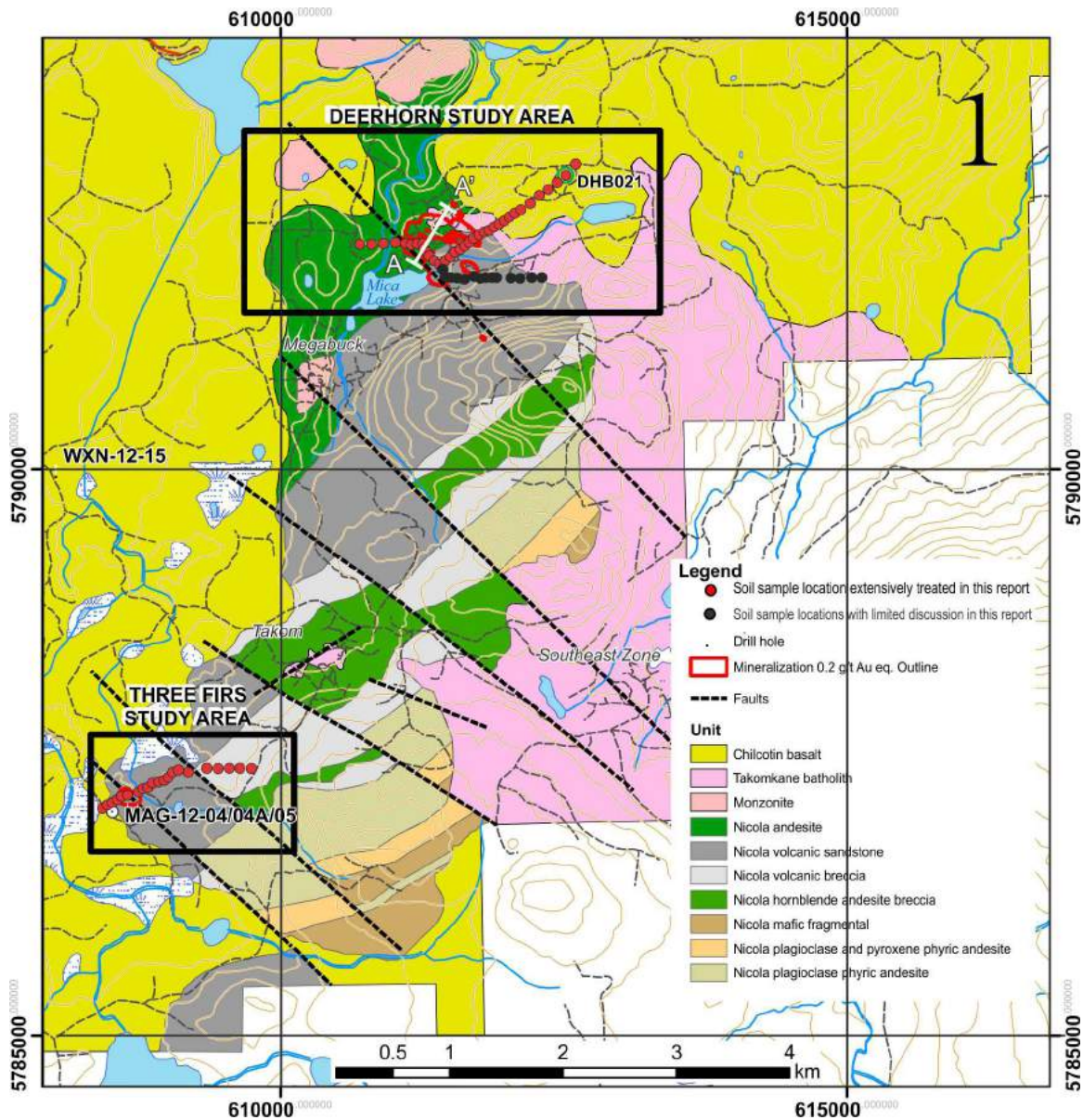
considered to be part of the Chilcotin Group, include lavas of Late Oligocene, Miocene and locally Pleistocene, age (Bevier, 1983). These units are not hydrothermally altered and weather brown and dark grey. They typically consist of highly vesiculated coherent lavas, featuring variable degrees of columnar jointing. Chemically, they cover a broad range of compositions, from alkali olivine-basalt and basaltic andesite to less common hawaiite, mugearite and trachyandesite (Dohaney, 2009). Traditionally, Chilcotin basalt units have been mapped as extensive plateaus (e.g., Massey et al., 2005; Figure 1) and are best exposed in the incised valleys of present-day rivers. Recent work (Andrews and Russell, 2008; Dohaney, 2009) has established that most of the basalt lavas actually followed low-lying topography and, in many places where the Chilcotin Group is mapped, the basalt cover may be thin or absent making surface geochemical exploration in those areas potentially viable. Their near surface presence is commonly indicated by angular boulders and colluvial debris.

Chilcotin Group rocks are commonly covered by extensive Quaternary glacial sediments.

Geochemically, the Chilcotin Group basalt units are distinctive from the underlying Triassic-age Nicola Group basalt flows and basalt-derived volcanoclastic sediments. In contrast to the Nicola Group (Vaca, 2012), these units have higher Ti, Ta, Nb, Th, U (Figure 2A) and light rare earth element contents (Figure 2B), do not have a clear-cut calc-alkalic arc signature, and plot in the tholeiitic (i.e., MORB) fields (Figures 2C, D; Dohaney, 2009). Chilcotin Group basalts also have higher Ni (110 to 180 ppm) than the Nicola Group (1395 ppm) in the study area. The Nicola Group and its along-strike equivalent Takla Group, host porphyry Cu-Au mineralization, including the Woodjam prospects (Figures 1, 3). Field sampling for this study was carried out over mineralization hosted by the Nicola Group, partially covered by the Chilcotin Group basalt units, the latter not known to be mineralized.



**Figure 2.** Whole-rock geochemistry of basalt to basaltic andesite in the Woodjam area, south-central British Columbia. Blue symbols indicate Triassic Nicola Group and red squares, Late Oligocene to Pliocene Chilcotin Group basalt sampled in the western part of the Woodjam property. Red diamonds indicate one sample taken northeast of the Deerhorn study area. The Nicola Group samples have an arc signature, whereas the Chilcotin and Deerhorn basalt units have a within-plate to tholeiitic signature: **A)** and **B)** chondrite-normalized spider diagrams (chondrite values from Sun and McDonough, 1989); **C)** basalt classification diagram; **D)** Jensen cation plot (Pearce et al., 1973; Jensen 1976) for basalt classification (diagrams modified from Rollinson, 1993; data for Nicola Group basalt units from Vaca, 2012). Abbreviations: IAT, island-arc tholeiite; MORB, mid-ocean ridge basalt.



**Figure 3.** Bedrock geology of the Woodjam South prospect, south-central British Columbia. (Modified from Blackwell et al. 2012; Rainbow et al. 2013). Map is in UTM NAD 83 projection, Zone 10. Red outlines denote surface projection of the +0.2 g/t Au equivalent mineralization. Specific drillhole and sample locations mentioned in the text are indicated. See Figure 4 for cross section A-A'.

## BENEFITS TO THE MINING INDUSTRY

This study is designed to test whether a geochemical signal of mineralization located beneath Chilcotin basalt is detectable using soil and vegetation geochemistry. It also aims to provide the mineral exploration community with a better understanding of different sampling media that can be used for geochemical exploration in regions with basalt cover. The study provides comparisons of element concentrations in soils and plants (spruce) subjected to various digestion methods and assesses the relative capabilities of each medium for recording the secondary geochemical-dispersion patterns of the geology, including blind mineral deposits, under cover. It also examines the trace-element composition of coatings and materials within vesicles in the basalt units to determine if mineralization signals

are preserved; a selection of results is reported herein and the full data tables are provided electronically.

## PROJECT AREA

Test sites selected for this study lie within Gold Fields Canada Exploration and Consolidated Woodjam Copper Corp.'s Woodjam property, which is located in the Cariboo Mining District of central BC (NTS map areas O93A/03/ 06; Figure 3). The property, which consists of 178 mineral claims totalling 58 470 ha, lies about 50 km to the northeast of Williams Lake. Horsefly, the nearest settlement and logistical base for the fieldwork, is within the property boundary and is accessible by a paved road from Williams Lake.

The two test sites, known as Deerhorn and Three Firs



(formerly known as Megalloy; Figure 3), lie 8 km to the southeast and 12 km south, respectively, of Horsefly; both are readily accessible via a network of well-maintained logging roads. Within those areas, an east-oriented and an east-northeast-oriented sample traverse pass from glacio-fluvial sediment-covered areas into glaciofluvial sediment and/or basalt-covered areas (Figure 3). On both transects, mineralization is known to underlie the unconsolidated sediments near the transition to basalt-covered areas. At the time of writing, no mineralized zone directly underlying basalt cover had been defined by drilling, although at Three Firs one of three angled drill holes (MAG12-04; Figure 3; Consolidated Woodjam Copper Corp., 2012a) passes through about 60 m of glaciofluvial material and about 30 m of basalt into mineralized bedrock. The top of the bedrock, which is fragmental and clay rich, contains Fe and Mn oxides just below the basalt; this can be interpreted either as a paleo-regolith or a fault gouge.

## **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 (Figure 3) lies at a fairly sharp transition between relatively flat, rolling topography typical of the Fraser Plateau on the western side of the mineralized zone, and low hills of the Quesnel Highland to the east. Elevations across the Deerhorn sample traverses, which cross the transition, vary from 900 m at the west to 1030 m at the highest point, close to the eastern end. A number of small lakes and ponds are dotted throughout the area; the largest of these is Mica Lake, which lies on the southwestern side of the mineralized zone. Lakes are linked by small streams and boggy depressions, which form part of a dendritic drainage pattern connecting with the Horsefly River about 5 km to the northeast of Deerhorn.

Three Firs lies in a similar physiographic setting to Deerhorn (Figure 3). 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. 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 the mineralization at both study areas. 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 at that location. 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., 2013a, b). Surficial deposits on the eastern shore of Mica Lake and southern limit of the projected mineralized zone (Figure 3) consist of well-sorted sand and gravel of probable glaciofluvial origin; the distribution of these deposits is unknown. A hill consisting of basaltic rocks assigned to the Chilcotin Group lies to the east-northeast of the mineralized zone (Figure 3). Samples collected along the east- and northeast-oriented traverse largely come from this basalt-covered area. The depth to bedrock below the basalt flows and potential presence of mineralization below this basalt is unknown.

At Three Firs, the cover environment comprises a Tertiary basalt unit beneath the glacial deposits in the western part of the sample traverse. Drilling has indicated that the basalt may cover a part of the mineralized zone. The basalt consists of a fresh, black, highly vesicular flow unit up to 20 m thick. Nicola Group rocks at its lower contact are fragmented and intensely clay-altered over several metres in what is either a gouge-filled fault zone or a paleoregolith. The extent of basalt 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 glacial till, which forms a blanket 40–100 m thick. There is no outcrop in the vicinity of the mineralization. Till cover appears to thin gradually eastward and outcrops of a distinctive ‘turkey-track’ feldspar porphyritic andesite 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 of no more than a metre or two thick.

## **REGIONAL GEOLOGICAL SETTING**

The Woodjam prospect 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 (Schiarezza et al., 2009, 2013). Oceanic rocks of the Late Paleozoic to Early Mesozoic Cache Creek terrane bound the Quesnel terrane to the west. 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 area, the Quesnel terrane is represented by Middle to Upper Triassic volcano-sedimentary rocks of the Nicola Group (Figures 1, 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 (Gold Fields Canada Exploration, unpublished data, 2012). Sandstone and conglomerate 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 which are associated with Cu-Au mineralization.

The Woodjam South property contains several centres of Early Jurassic porphyry-style Cu-Mo-Au mineralization (Schiarrizza, 2009; Sherlock et al., 2012; Mineral Deposit Research Unit, unpublished data, 2011). Style of mineralization, host rocks and metal association vary from one mineralized centre to another; these include the Southeast, Takom, Megabuck, Deerhorn and Three Firs zones (Figure 3; Del Real et al., 2013a). The Southeast zone is at the most advanced stage of exploration and is currently undergoing advanced exploration drilling. 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 at the advanced exploration drilling stage. 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 exploratory 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 basalt flows belonging to the Chilcotin Group. 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, defined by the red +0.2 g/t Au equivalent outline in Figure 3, is the surface projection of a pipe-like body containing a higher-grade shoot, which plunges steeply to the southeast (Figure 4; Del Real et al. 2013b, Gold Fields Canada Exploration, unpublished data, 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 quartz and magnetite stockwork and veinlets, and disseminated chalcopyrite mineralization. Low-grade mineralization is coincident with an arcuate chargeability anomaly, which extends

northwest of the Deerhorn drill site and continues south and west to the Megabuck East and Megabuck prospects.

Geological mapping and reconstruction of the bedrock geology from drilling by Gold Fields Canada Exploration (Figure 3; Blackwell et al. 2012) indicate that the mineralization is hosted in a southwest-striking, northwest-dipping package of Nicola Group andesite and volcanic-derived sandstone. Higher grade mineralization is associated with a number of northwest-striking dike-like monzonite bodies (Figure 4), which cross the contact between volcanic-derived sandstone in the southeast and andesite in the northwest of the mineralized zone. The intrusion and volcano-sedimentary units are offset by sets of west-northwest and northeast striking faults (Gold Fields Canada Exploration, unpublished data, 2012). Mineralization subcrops beneath a variable cover of Quaternary glacial and glaciofluvial deposits, which consist of a till blanket up to 40 m thick over the mineralization and a sequence of overlying glaciofluvial sand and gravel exposed in road-cuts near the southeastern shore of Mica Lake; the extent of these deposits is unknown. To the northeast of the mineralized area, coherent basalt flows, presumably of the Chilcotin Group, are present. The thickness of these basalts is unknown but they appear to be directly underlying the soil profile in at least part of the area.

### **Three Firs (Megalloy)**

Bedrock geology of the Three Firs study area is not well understood. Mineralization was only discovered at this prospect during the spring of 2012 and, at the time of sampling for this study, only three holes had encountered significant Cu-Au mineralization (Consolidated Woodjam Copper Corporation, 2012a). 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 difficult to resolve from the interpretation of ground and airborne magnetic data (Gold Fields Canada Exploration, unpublished data, 2012). Drilling shows that it consists of one or several coherent flows and forms a cap at least 20 m thick overlying the altered and mineralized Nicola Group rocks. The known distribution of basalt and the surface projections of the mineralized drill intersections are illustrated in Figure 3 (Gold Fields Canada Exploration, unpublished data, 2012) and indicated for reference in the geochemical plots below. Overlying the basalt are Quaternary glacial sediments. Where observed in drill road exposures, these appear to consist of a boulder till containing abundant large rounded clasts (up to 1 m in diameter) of 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 eastern part of the survey area.

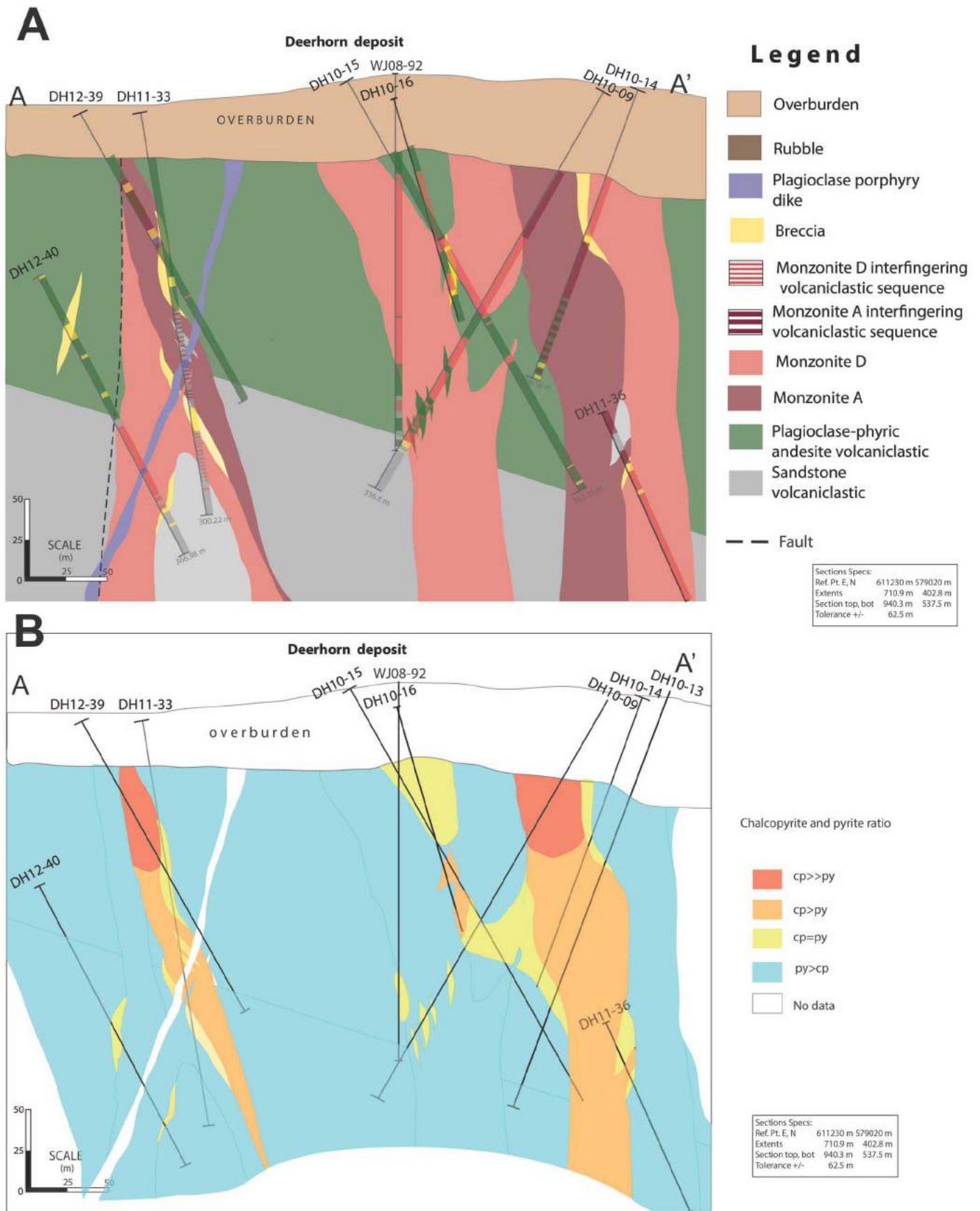


Figure 4. Interpreted sections through mineralization at Deerhorn. **A)** geology, **B)** sulfide assemblages and mineralization. Taken from Del Real et al. (2013b).

## FIELD PROCEDURES

### Soils

At each sample station, at least one hole was dug to a depth of about 50 cm to collect a few grams of the upper Ae-horizon (eluviated greyish zone immediately below the organic-rich Ah-horizon) for pH and conductivity measurements and the upper B-horizon (Bf- or Bm-horizon) for a variety of geochemical analyses (Table 1). Sample locations are shown on Figure 3 and the sample types illustrated in Figure 5. An angled sample traverse over two mineralized zones into a basalt covered area has been chosen to illustrate the geochemical patterns at Deerhorn. The sample locations on which most of the figures below are based on are indicated in red dots on Figure 3 whereas other locations only covered in some figures are shown in black.

### Basalt

In addition to whole-rock analyses for three Chilcotin Group basalt samples, eight samples of vesicle infill (amygdules hereafter) have been separated (Figure 6). These are both from Chilcotin basalt - proximal and apparently overlying sulphide mineralization at the Three Firs zone, and from drill core (WNX12-15) from an inferred background area located some 2 km to the north of known mineralization (Figure 3).

The amygdules consists of clay (poorly crystalline vermiculite) and carbonate (magnesian calcite). Infill was extracted from the rock using hardened-steel tools or, in the case of carbonate infill, hand-picked from the crushed rock. More than 0.5 g of material was collected and analyzed at ALS

Minerals Limited (Vancouver) using their low detection limit aqua regia multielement method (ME-MS41L package). The intention of this analytical work is to test the potential for clay and carbonate amygdules to record a geochemical signal from underlying mineralization; the results are shown in Figure 7.

## ANALYTICAL METHODS

Samples from B-horizon soils crossing the two zones of mineralization at Woodjam (Deerhorn and Three Firs) were submitted for comparative analysis by several commercially available total, partial and selective extraction techniques. The list below provides a summary of the various analytical methods employed. Note that Mobile Metal Ion (MMI) results are only discussed in an appendix to this report as no samples over basalt cover have been analyzed by this method:

- **Four-acid near-total digestion/ICP-MS:** the sample is digested with perchloric, nitric, hydrofluoric and hydrochloric acids, which dissolve the silicate portion, including most of the resistate minerals.
- **Aqua regia digestion/ICP-MS:** a partial leach consisting of 1:3 HNO<sub>3</sub>:HCl (acid-leachable component, especially sulphides, amorphous oxides, carbonates and organic matter).
- **Ionic Leach:** a proprietary sodium cyanide leach buffered to pH 8.5 using the chelating agents ammonium chloride, citric acid and ethylenediaminetetraacetic acid (EDTA). These bind onto labile ions extracted into solution by the

**Table 1.** Sample media and analytical methods employed. In addition to those listed, Ah-horizon and spruce bark and twigs were collected (see Heberlein et al., 2013) at the Woodjam prospect south-central BC.

Sample medium	Analytical package	Laboratory	# samples	Description
B-Horizon (upper)	ME-MS41	ALS <sup>1</sup>	70	Standard Aqua Regia leach (AR)
B-Horizon (upper)	ME-MS41L	ALS	70	Ultra Trace AR high sensitivity
B-Horizon (upper)	ME-MS61	ALS	70	4 acid strong leach (near total digestion)
B-Horizon (upper)	Au-ST43L Aqua Regia	ALS	70	Super-trace level gold (0.01 ppb)
B-Horizon (upper)	Ionic Leach	ALS	70	Sodium cyanide leach buffered to pH 8.5
B-Horizon (upper)	Enzyme Leach	Actlabs <sup>2</sup>	70	Proprietary weak leach (amorphous oxide coatings)
B-Horizon (upper)	SGH-GC-MS	Actlabs	50	Proprietary weak leach-organic compounds
B-Horizon (upper)	OSG-HR-GC	Actlabs	50	Proprietary weak leach-sulfur compounds
B-Horizon (upper)	Bioleach	Actlabs	70	Proprietary weak leach-remnant from bacteria
B-Horizon 10-25 cm depth	MMI	SGS <sup>3</sup>	27	Proprietary weak leach-loosely bound surface coatings
Vesicle infill	ME-MS41L	ALS	8	UltraTrace AR (high sensitivity)
Basalt whole rock	CCP-PKG01	ALS	3	Lithium borate fusion and complete characterization

<sup>1</sup> ALS Chemex (Vancouver)

<sup>2</sup> Activation Laboratories, Ltd. (Ancaster, Ontario)

<sup>3</sup> SGS Minerals Services (Lakefield, Ontario)



**Figure 5.** Suite of samples collected at each sample station for this study (not shown are spruce twigs and bark), Woodjam prospect, south-central British Columbia. The samples were collected together with those reported in Heberlein et al. (2013) and Ah results are discussed therein. MMI samples were not collected over basalt but results are briefly discussed in the appendix to this report.



**Figure 6.** Example of vesicular Chilcotin basalt, with beige-brown clay (vermiculite) infill and white calcite infill, from drillhole MAG-12-04 (at 70.9 m) in the Three Firs zone, Woodjam prospect, south-central British Columbia. These two types of infill have been separated and analyzed by inductively coupled plasma-mass spectrometry (ICP-MS) following an aqua regia digestion to test for a geochemical signature from underlying mineralization.

sodium cyanide solution and keep them in solution.

- **Enzyme Leach:** a proprietary method to selectively remove amorphous manganese-oxide coatings on soil particles, and thereby release trace elements into solution that are associated with these coatings.
- **Bioleach:** Bioleach is a proprietary technology developed by Actlabs Ltd. to dissolve remnant proteins that bacteria have left behind when they die. These proteins contain elements related to concealed mineral deposits, and they are considered to migrate upward by a variety of processes and become adsorbed on soil particles. Bioleach is designed to digest this soil component which can then be analyzed by ICP-MS.
- **Mobile Metal Ion™ (MMI):** a proprietary method requiring no sample preparation or drying. Elements in a 50 g sample are extracted in weak solutions of organic and inorganic compounds (details not specified). MMI solutions contain strong ligands, which detach and hold

in solution metal ions loosely bound to soil particles.

- **Soil Gas Hydrocarbons (SGH)<sup>SM</sup>:** a proprietary organic-based geochemical method, which detects 162 organic compounds in the C<sup>5</sup> to C<sup>17</sup> carbon-number range. These compounds provide a signature directly related to bacteriological interaction with sulphide mineralization at depth. Interpretation using proprietary methods is undertaken by Activation Laboratories Ltd. (Ancaster, Ontario).
- **Organo-Sulphur Geochemistry (OSG):** a proprietary method similar to SGH in its rationale, in that it involves the selective extraction of 105 organo-sulphur-based compounds in the C<sup>7</sup>–C<sup>17</sup> carbon series. It involves a very weak leach, almost aqueous, which isolates the compounds by high-resolution capillary-column gas chromatography.

## FIELD MEASUREMENTS

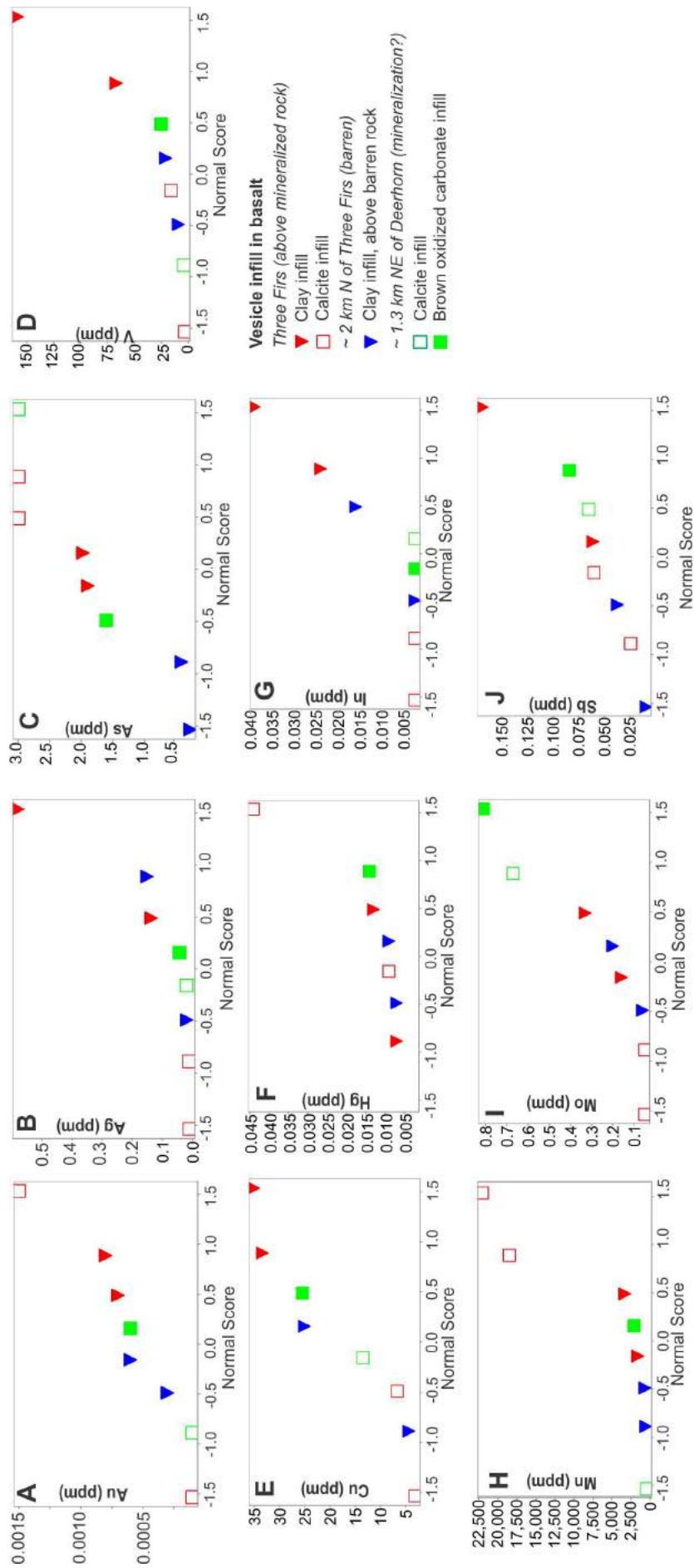
### Soil pH and Electrical Conductivity Measurements

Samples for soil pH and electrical conductivity (EC) measurements were collected from both study areas. 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<sup>®</sup> plastic bags.

Conductivity measurements were made on a 1:1 slurry of soil in demineralized water using a VWR<sup>®</sup> conductivity meter. Soil pH readings were taken on the same slurry using a double-junction pHTestr<sup>®</sup> 30 handheld pH meter manufactured by Oakton<sup>®</sup> Instruments. The instrument was calibrated daily using standard pH-buffer solutions at pH 4.01, 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 the second, 20 seconds after adding one drop of 5% acetic acid and stirring. The acidified pH (pHa) is an indication of the buffer capacity of the soils and the closer the pHa values are to the original pH, the greater the buffering capacity. Readings were recorded into an Excel<sup>®</sup> spreadsheet and converted to H<sup>+</sup> concentrations and inverse-difference hydrogen (IDH = 1/(H<sup>+</sup>a – H<sup>+</sup>: Smee, 2009) measurements for interpretation. IDH is the inverse of the difference between acidified and non-acidified H<sup>+</sup> concentrations in the soil and is a measure of the soil buffering capacity and is thought to be sensitive to remobilized carbonate around the edges of reduced columns (Hamilton, 1998; Smee, 2009).

## QUALITY CONTROL

Quality control measures employed for this study included the collection of field duplicate samples for each sample type. A total of 9 field duplicates were collected for each sample type



**Figure 7.** Chemistry (aqua regia) of vesicle infill in Chilcotin basalt, Woodjam prospect, south-central British Columbia. The x-axis on the probability plots shows the normal score in units of standard deviation for: **A)** Au; **B)** Ag; **C)** As; **D)** V; **E)** Cu; **F)** Hg; **G)** In; **H)** Mn; **I)** Mo; **J)** Sb. Analytical values are given in parts per million (ppm).

at randomly selected sample sites. At each duplicate sample site, material was collected using exactly the same procedures as those used for the original sample and from within 5 m of the original sample's location. Although some local-scale variability in soil pH and conductivity as well as some elements in B-horizon soil is apparent, the difference between original and duplicate sites is usually less than the overall variability in the apparent background (i.e. on either side of the influence of concealed mineralization) of the sampled profile. The exception is one sample location (DHB021) in the Deerhorn northeast-oriented sample line, where metal concentrations in the original B-horizon sample are double to triple those of the duplicate sample, irrespective of the digestion method used. Conductivity and pH values are similar between the original and duplicate sites. Because the elevated concentrations for some elements, including As, Cu and LREE, were obtained on two different aliquots sent to two different laboratories (ALS Ltd., Vancouver, and Activation Laboratories Ltd., Ancaster, Ontario), the discrepancy between the original and duplicate samples is interpreted to be predominantly the result of local-scale variability in the soil rather than sampling or analytical error. The tabulated relative standard deviation of field duplicates is summarized for each element and analytical method in Table 2.

## RESULTS

The principal analytical results are described below. A complete analytical database can be obtained through Geoscience BC's website with this report. For the following data presentation background is defined as the median value for each element in a particular dataset. The response ratio (a.k.a. median leveling) is the value of a sample divided by the median value, i.e., a response ratio of 4 indicates a concentration of a particular element 4 times the background. The statistics of geochemical responses above mineralization at Three Firs are discussed further at the end of this report.

### Basalt Amygdules

Some trace elements, including As, Sb, In and V are present in concentrations 5–8 times higher in clay-filled amygdules (vermiculite) near mineralization compared to similar amygdules in basalt over unmineralized Nicola Group (Figure 7). Gold, Ag, Mn and Cu values are also elevated in clay amygdules over mineralization. Based on two samples from Three Firs, the calcite amygdules appear to have higher As, Mn and Hg values than the clay amygdules over the mineralization. Carbonate-filled amygdules were not present at the background basalt location. Carbonate amygdules sampled from basalt found near the eastern end of the northeastern transect at Deerhorn (DHB021, Figure 3) contain elevated Cu and Mo and As values (Figure 7). Soil samples at this locality are also anomalous for As, Cu, Ni and rare earth elements (see below).

### Deerhorn survey area

For Deerhorn, a sample traverse from west of the deposit across two zones of buried mineralization into basalt covered areas (Figure 3) has been chosen to illustrate the possible masking effects of cover material (i.e. till vs. basalt), as well as the response to buried mineralization. Basalt cover is exposed at surface or buried beneath a thin cover of colluvium less than 100 m east of the surface projection of mineralization; however, there is no evidence from drilling that basalt actually overlies mineralization at Deerhorn. Note that the mineralized zones (western and eastern mineralized zones hereafter) are defined by the surface projection of the 0.2 g/t Au equivalent grade contour (Figure 3) but lower grade mineralization and sulfides are likely also present between and outside the two zones.

### Soil pH and Conductivity

Soil H<sup>+</sup> and conductivity results for Deerhorn are shown in Figures 8 and 9. Although there is considerable scatter in the data, some general patterns are apparent. Hydrogen-ion concentrations are highest (lowest pH) over Deerhorn mineralization. The acidified H<sup>+</sup> (H<sup>+</sup>a) values are higher near the margins than directly above the mineralized zones, although elevated H<sup>+</sup>a values do also occur some distance away from known mineralization (Figures 8, 9). H<sup>+</sup> and H<sup>+</sup>a concentrations are generally lower (higher pH) over basalt than in areas where only glacial sediments cover the bedrock (Figures 8, 9A) and possibly reflect the more buffering character of the basalt.

Elevated EC values occur at the margins of mineralized zones as well as distally (Figures 8, 9A). In general, the IDH results mimic the conductivity and H<sup>+</sup>a results quite well and the highest values occur at the eastern margin of the eastern mineralized zone. It is noteworthy that at site DHB021 (Figure 3), there are coincident high EC and IDH values over basalt. This sample site also coincides with apparently elevated Cu, Mo and As in carbonate vesicle infill (Figure 7).

Although the type of surface material (i.e., till vs. basalt) does seem to influence the soil pH, other parameters including the acidified H<sup>+</sup>, EC and IDH seem to be primarily controlled by the oxidizing sulfides in the ore body at depth.

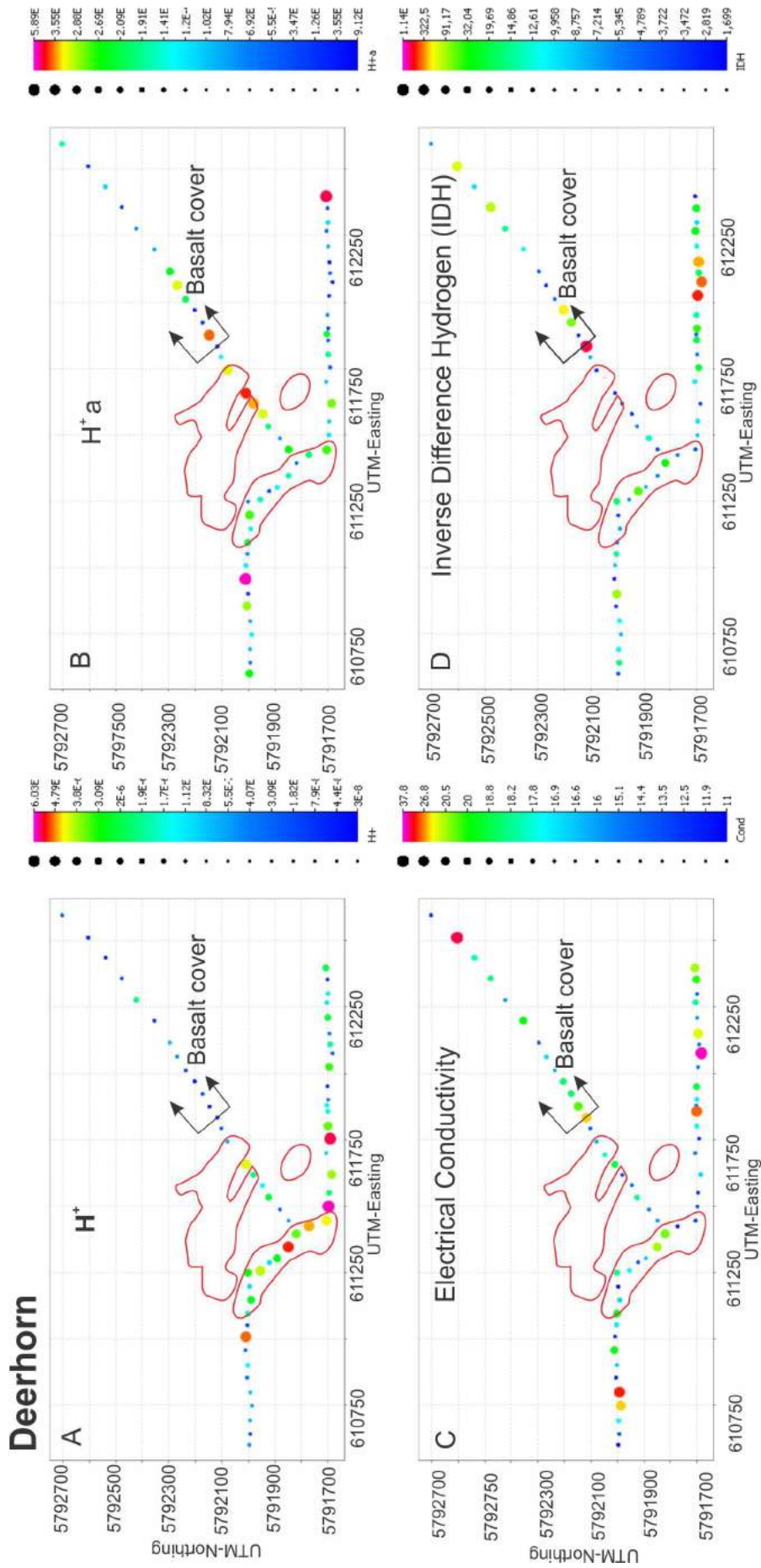
### B-horizon soil geochemistry

Five partial leach techniques have been applied to B-horizon soil samples. The response of the different elements varies and depends on the sample dissolution technique. Weak leaches such as Enzyme Leach or Bioleach target the weakly bound or labile elements adsorbed onto iron and manganese hydroxides or clay surfaces. Below, the response of a series of elements is discussed and illustrated. The responses of additional elements can be explored through the digital data files provided through the Geoscience BC website.

Table 2. Summary of standard deviations for field duplicates by element and analytical methods.

Element	Sp-Bk	Sp-Tw	B_MS23	B_MS41	B_MS41L	B_MS61	Bioleach	Enz. Leach	MMI
Ag	32.59%	30.80%	21.65%	34.53%	32.52%	70.53%	37.04%	9.43%	10.80%
As	51.85%	31.91%	23.71%	13.01%	9.71%	6.22%	1.87%	21.93%	
Au		85.78%	28.13%	72.30%	29.58%			4.71%	25.14%
Ba	17.40%	36.24%	32.57%	15.23%	16.39%	6.32%	16.22%	13.91%	13.99%
Bi		23.24%		11.31%	7.22%	6.76%	23.57%	25.72%	
Br			20.60%				7.60%	7.86%	
Ca	20.73%	13.60%	14.80%	13.98%	15.66%	10.81%		43.70%	9.51%
Cd	75.79%	66.05%	26.87%	19.29%	18.00%	6.82%	22.32%	25.60%	25.24%
Cl								40.94%	
Co	30.30%	45.27%	25.05%	12.44%	15.54%	8.84%	44.77%	28.42%	16.88%
Cr	11.91%	25.66%	38.30%	8.11%	8.59%	6.08%	8.52%	30.97%	14.98%
Cs	37.91%	58.02%	40.38%	11.04%	12.94%	5.98%	33.40%	50.63%	14.01%
Cu	8.47%	13.53%	25.24%	11.32%	12.73%	7.66%	49.20%	77.24%	17.83%
Dy	9.43%	39.73%	37.73%				16.60%	53.91%	52.45%
Er		22.83%	39.46%				18.39%	38.24%	50.93%
Eu		47.30%	35.77%				15.94%	23.08%	47.59%
Fe	45.05%	20.56%	24.19%	7.77%	7.35%	9.36%			24.68%
Gd		26.46%	40.26%				18.80%	49.94%	52.45%
Hg	21.59%	3.37%	35.10%	30.08%	20.33%		13.71%		
I			20.65%				8.45%	19.20%	
K	29.77%			14.77%	17.33%	3.85%			52.93%
La	47.14%	28.15%	33.59%	10.39%	12.45%	6.45%	16.29%	77.48%	54.77%
Mg	15.47%	19.52%	28.01%	10.62%	11.01%	8.39%			10.07%
Mn	36.02%	36.84%	43.49%	24.91%	25.34%	5.45%	56.87%	46.74%	16.51%
Mo	29.46%	26.04%	26.56%	15.63%	13.95%	15.24%	19.39%	32.01%	0.00%
Na		18.43%		23.57%	15.71%	7.03%			
Nd		15.71%	36.92%				17.76%	53.65%	55.42%
Ni	42.43%	47.92%	12.25%	9.90%	11.17%	6.80%	28.45%	18.91%	40.71%





**Figure 8.** Soil pH and conductivity data for the Deerhorn survey area, Woodjam prospect, south-central British Columbia. Areas under basalt cover and surface projection of the mineralization defined by the 0.2 g/t Au equivalent contours (red outlines), are represented by graphs showing **A**)  $H^+$ , concentration of hydrogen ions ( $\sim$ inverse of pH); **B**)  $H^+a$ , concentration of hydrogen ions after addition of 1 drop of 10% HCl acid; **c**) electrical conductivity in  $\mu S/m$ ; **d**) inverse difference hydrogen (IDH),  $1/(H^+a-H^+)$ .

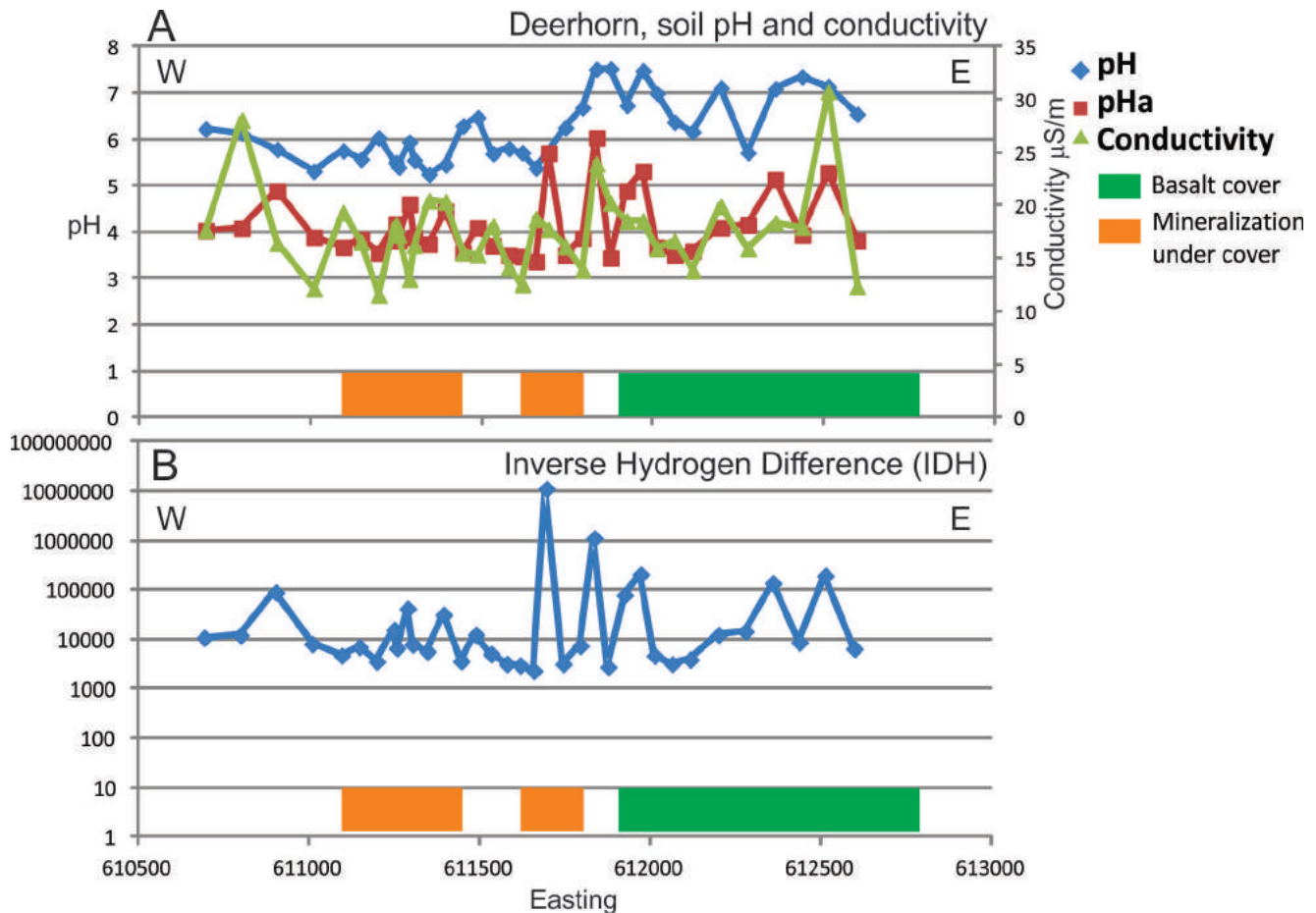


Figure 9. Soil pH data for the Deerhorn W to NE survey line presented as profiles. **A)** pH, pH<sub>a</sub> and electrical conductivity, **B)** IDH data.

### Basalt Signature

Figure 10 illustrates the responses for La, Th and Nb, elements that are not traditionally used for porphyry exploration. The reason for this choice is that these elements are present in considerably higher concentrations in Chilcotin Group basalts than in the underlying Nicola Group volcanic rocks (Figure 2) and therefore they may be useful indicators of the presence of basalt beneath the glacial sediment cover. The relatively aggressive near total 4 acid digestion shows an overall narrow range of concentrations for these elements. Most of the highest concentrations are from samples over basalt. Lanthanum and Th are also highest over basalt in the aqua regia results. This is consistent with the chemistry of the substrate, although the chemical signal of the basalt is very subtle. Lanthanum, Th and Nb are not anomalous in the vicinity of mineralization in the 4 acid digestion results, with the possible exception of a spike in Th and La values above the eastern margin of the mineralized zone. Weaker dissolution techniques, notably Bioleach but also aqua regia and Enzyme Leach, show prominent responses for La and Th in one sample from over the eastern edge of the mineralization and at one sample location (DHB021) over basalt in the eastern part of the line. Maximum response ratio values of 7 to 10 are observed. Niobium has considerably lower concentrations than Th in all digestions except for the 4 acid

technique, indicating that Nb is likely contained in resistate minerals that are not attacked by weaker digestions, whereas some La and Th is probably weakly bound and more readily dissolved. The Ionic Leach method differs from all other partial leaches in that it exhibits a noisy signal with highly variable La and Th concentrations but no pronounced anomalies.

### Mineralization Signature

Figures 11 and 12 illustrate the response of Cu, Zn, Ni, As, Ag and Sb. Copper has a strong response between the two mineralized zones in the 4 acid, aqua regia and Bioleach results and a moderate response in Enzyme and Ionic Leaches. Elevated Cu values at the second sample location from the east (DHB021), above basalt, as well as over the eastern margin of the mineralization coincide with high La and Th concentrations (Figure 11). Zinc exhibits high values between the two mineralized zones in the 4 acid and aqua regia results; however, they only partially coincide with the sample locations where high Cu concentrations are present (Figures 10, 11). These strong leaches also yield a high value of Zn in the second sample from the west. In the weaker partial leach techniques, the Zn signal is less distinct. High values occur between two mineralized centers, over the western edge of basalt cover (which is within 100 m of the eastern limit of known mineralization) and in the

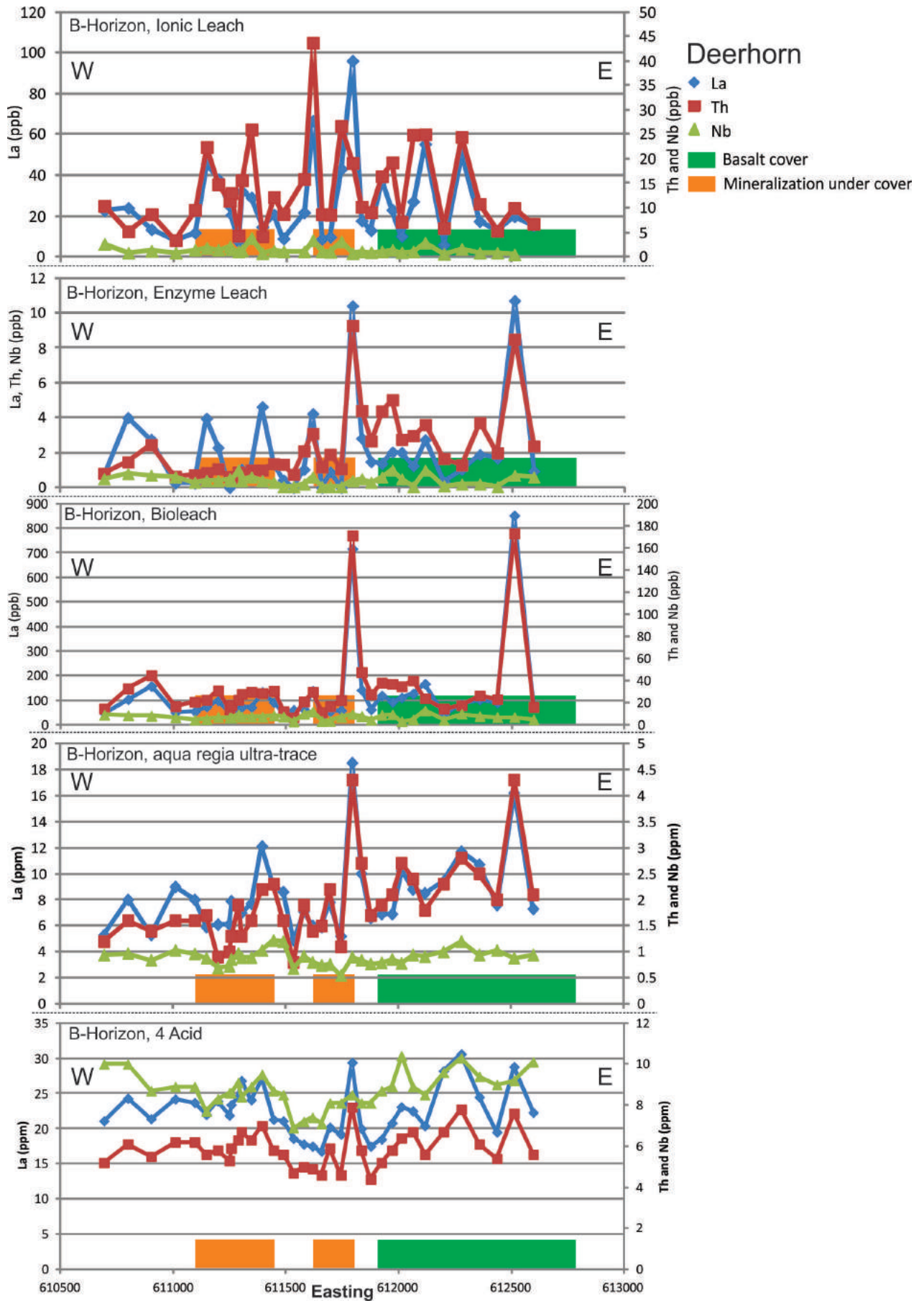


Figure 10. B-horizon soil geochemical results for La, Th and Nb at Deerhorn as function of analytical technique. See text for discussion.

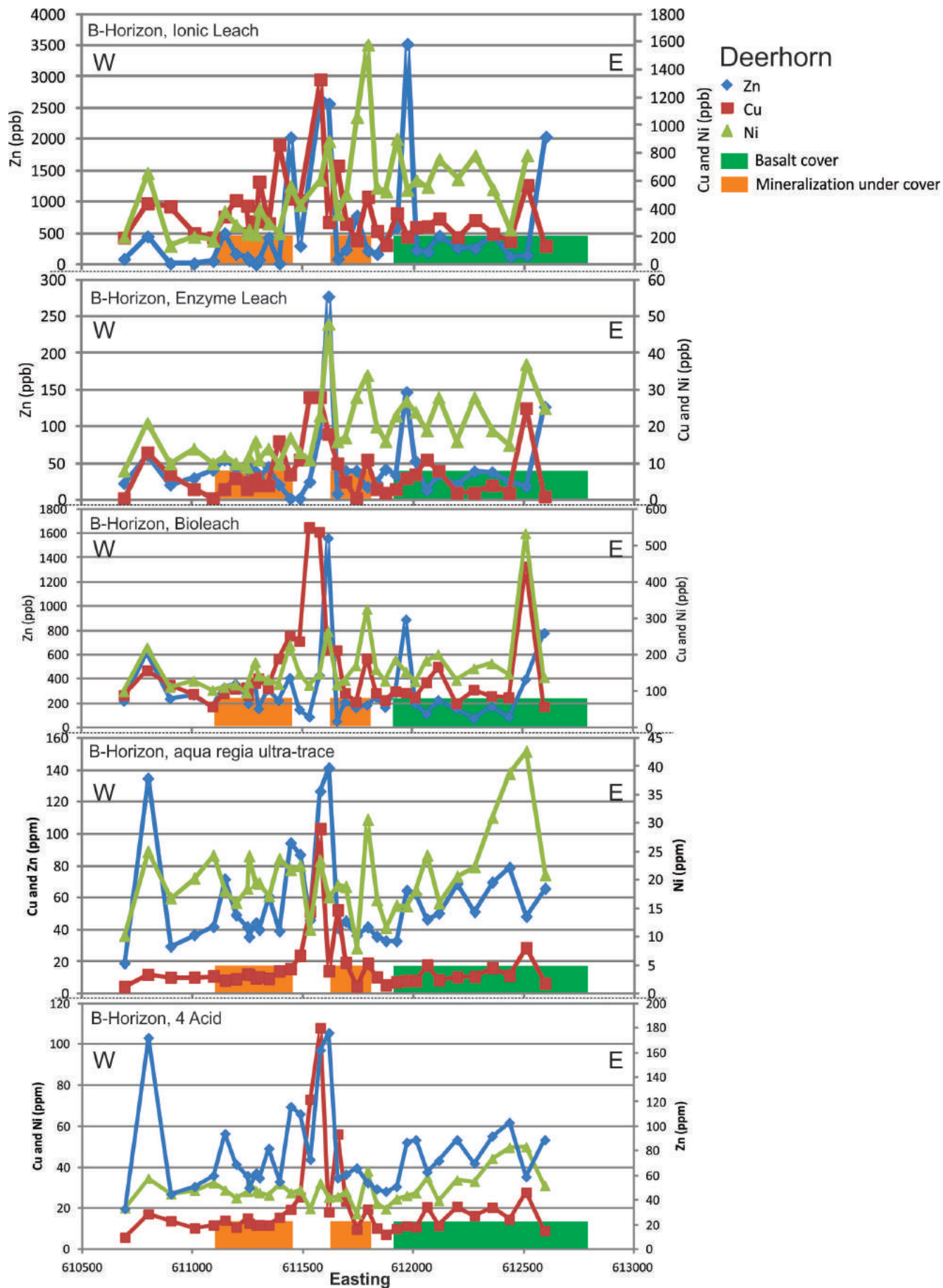


Figure 11. B-horizon soil geochemical results for Cu, Zn and Ni at Deerhorn as function of analytical technique. See text for discussion.

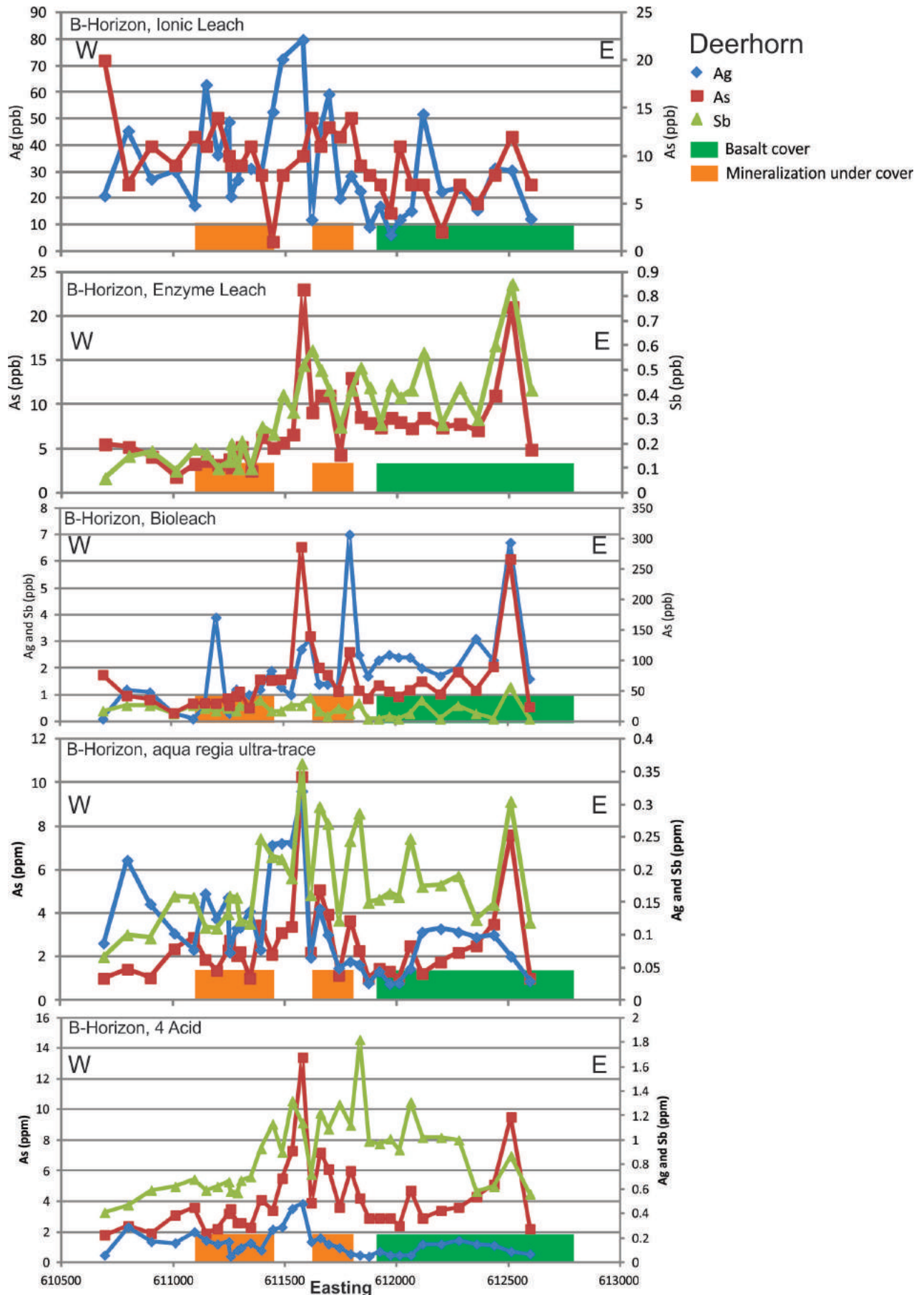


Figure 12. B-horizon soil geochemical results for As, Sb and Ag at Deerhorn as function of analytical technique. See text for discussion.

easternmost sample of the traverse (Figure 11). These high Zn values typically occur near mineralization within 50 to 100 m of the high Cu values but do not coincide with the latter (Figure 11). The Ionic Leach technique has the highest contrast response for Zn compared to all the other techniques (Figure 11).

Nickel shows a less clear response compared to Cu and Zn, but the weak Ionic Leach and Enzyme Leach techniques seem to produce the best results. Using these techniques, the highest Ni values are observed between the mineralized areas and above the eastern limit of mineralization (Figure 11). Locally, high Ni values coincide with higher Zn values, except over the second sample location from the east (DHB021) where high Ni coincides with elevated Cu (Figure 11). Bioleach, aqua regia and 4 acid data do not exhibit a Ni signal over mineralized areas but all show elevated values over basalt, the highest being the second sample location from the east (DHB021) where Cu, La and Th are also elevated. This is consistent with the whole rock compositions of the Nicola Group and the Chilcotin basalts. The latter have 110 to 180 ppm Ni, whereas the former have only 13 to 95 ppm Ni.

Arsenic has a similar response to Cu with highest values occurring between the mineralized zones and at site DHB021 (Figure 12). This signal is strongest in Bioleach and aqua regia but also present in Enzyme Leach and the 4 acid results. Overall the As response has the same pattern in all of these dissolution techniques except for Ionic Leach (Figure 12). Antimony was below the detection level by Ionic Leach. Silver values are highest between the mineralized areas in aqua regia and in Ionic Leach (Figure 12). Bioleach, in contrast shows a different response with high Ag values over the western and eastern edge of mineralization and also at site DHB021. The samples with the most elevated Ag values in aqua regia digestion have values below detection in Bioleach.

Antimony does not exhibit as clear a pattern as Cu, As, Zn, Ag or Ni. In the 4 acid results, it exhibits a broad bell shaped pattern with the highest values occurring above the eastern mineralized zone and between the two zones, but clearly lower values towards the ends of the sample traverse (Figure 12). Aqua regia results show a noisy pattern for Sb with only slightly higher values occurring between the mineralized zones and in the second sample from the east (Figure 12). Bioleach and Enzyme Leach show no clear response for this element and analytical values are close to detection limit.

A number of additional elements are significantly above background over mineralization in Bioleach and other partial leach results (Figure 13). Selenium, Mo, and In in the Bioleach data have about triple the background concentration over mineralization. Selenium and Tl, the latter only weakly elevated over mineralization, are also high (7 and 3 times background, respectively) at sample site DHB021 (Figure 13). The highest values of W occur over mineralization but W concentrations are only up to about twice the background (Figure 13).

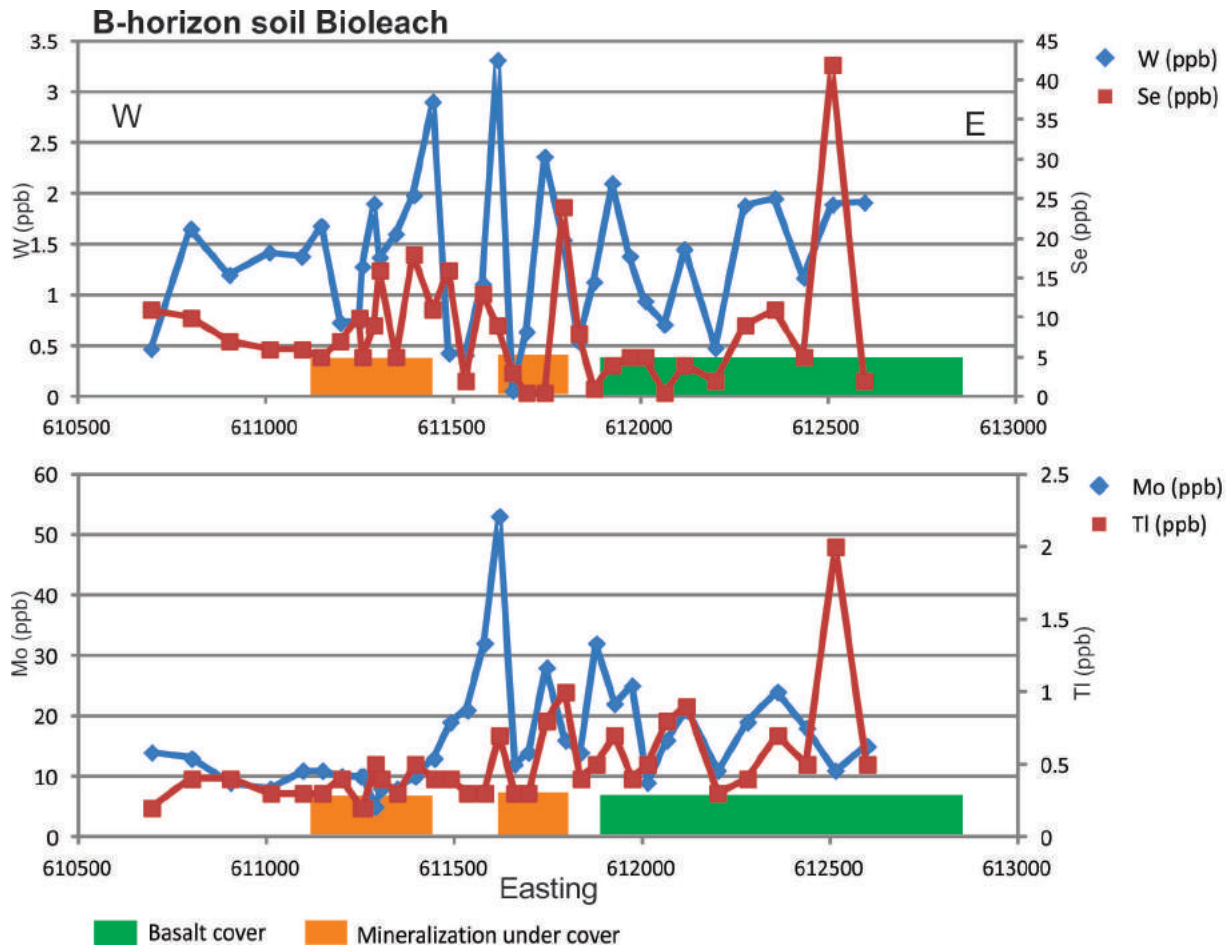
### ***B-horizon: effect of Fe content on element concentrations***

Partial leach techniques in soil geochemistry are aimed at dissolving weakly bound ions. Such ions may be adsorbed to Fe oxides, Mn oxides, clays or organic matter. By normalizing to the Fe content in soil samples, areas with anomalously high contents of certain metals can be distinguished from those where high metal concentrations are due to increased Fe content. A signal of mineralization recorded in the soil thus, can potentially be distinguished from those where Fe rich soils are responsible for elevated metal contents, such as in areas where Fe is hydromorphically concentrated. Figure 14 illustrates comparative plots of Zn, Cu and Ni for aqua regia and Ionic Leach results normalized by Fe for the Deerhorn sample transect. The analytical values for Fe in percent are taken from the 4 acid results which is for all intents and purposes a near total Fe concentration.

In the aqua regia results both Cu/Fe and Zn/Fe exhibit a similar, albeit slightly enhanced, signal between the two mineralized zones and over the eastern mineralized zone when compared to the analytical concentrations (Figure 14). Nickel, on the other hand has a slightly attenuated signal over the eastern part of the sample traverse, suggesting that its concentration is controlled by Fe. The Ionic Leach results also show subtle, but potentially important differences between absolute concentrations and metal/Fe ratios. Copper has an overall attenuated signal when ratioed to Fe and at the second sample site from the east (DHB021) is only marginally above background, whereas the westernmost samples have significantly lower Cu/Fe values than those samples collected above mineralization. When absolute concentrations are looked at this difference is not as apparent. Nickel, like Cu, has a slightly attenuated pattern when ratioed to Fe, but elevated values are maintained above the eastern mineralized zone as well as near the eastern end of the traverse. Nickel also is generally higher over Chilcotin basalt than over Nicola Group bedrock. Zinc does not seem to be strongly influenced by the Fe content of the soils and the Zn/Fe ratios have a similar albeit slightly enhanced pattern compared to Zn concentrations by themselves.

### ***Soil Gas Hydrocarbons (SGH) and Organo Sulfur Geochemistry (OSG)***

Neither SGH nor OSG present anomalies for particular elements but identify groups of hydrocarbons or organo-sulfur compounds that are believed to be linked to sulfur oxidizing bacterial activity in sulfide mineralization. Figure 15 and brief descriptions of the results are based on standard interpretations provided by Actlabs (Sutherland 2012a, b), which are also appended to this report. Results for low molecular weight SGH and OGS compound groups are presented in Figure 15A and 15B, respectively. Note that the sample transects discussed in this report contain fewer than the minimum number of samples



**Figure 13.** Bioleach results for W, Se, Mo and Tl at Deerhorn. Selenium is clearly elevated over mineralization as well as over sample site DHB021, whereas W, while also elevated over mineralization, provides less contrast.

recommended by Actlabs for these geochemical techniques and the results presented here are only for comparison with the B-horizon soil geochemical results.

Soil gas hydrocarbon results delineate an area of higher values between the mineralized zones at Deerhorn. This zone contains elevated low molecular weight SGH, commonly used as pathfinder for Cu and coincides well with high Cu, Zn, Ag and As in partial leach geochemical methods (Figure 15). Neither high SGH nor pathfinder element values occur directly above the surface projection of the mineralization, but above its edges in what may be interpreted as a rabbit-ear anomaly. The OSG response is similar to that of SGH and is consistent with an interpretation as a rabbit-ear anomaly (Figure 15). Note that both SGH and OSG results show a relatively elevated value near the western limit of the basalt cover. This location coincides with elevated Zn values mentioned above (Figures 11, 14). The OGS response also exhibits an elevated value at the second sample site (DHB021) from the east above basalt (Figure 15). This location also has elevated values of Cu, Ni, As, Sb, La, Se, Tl and Th in some of the partial leach techniques (Figures 10-14).

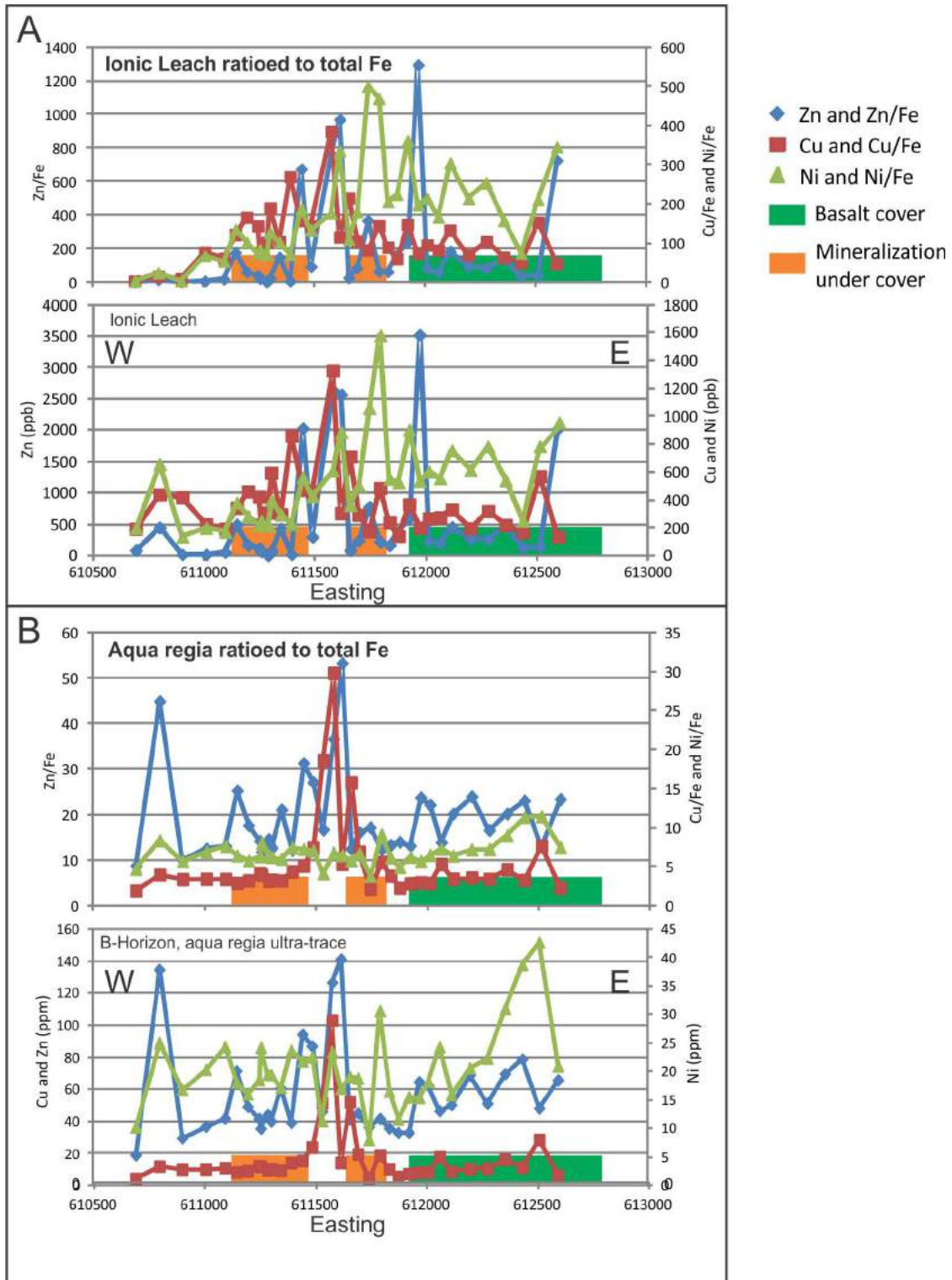
### **Vegetation results**

The dataset indicates no unusually high concentrations of any elements. Many elements returned concentrations below or close to the detection limits (DL) in the analysis of the dry spruce bark. In order to concentrate elements, spruce twigs were reduced to ash prior to analysis, resulting in many more elements reported with concentrations above DL. Each plant species and type of tissue (i.e. bark, twigs, needles etc.) has a different capability to absorb and store elements.

### **Spruce bark**

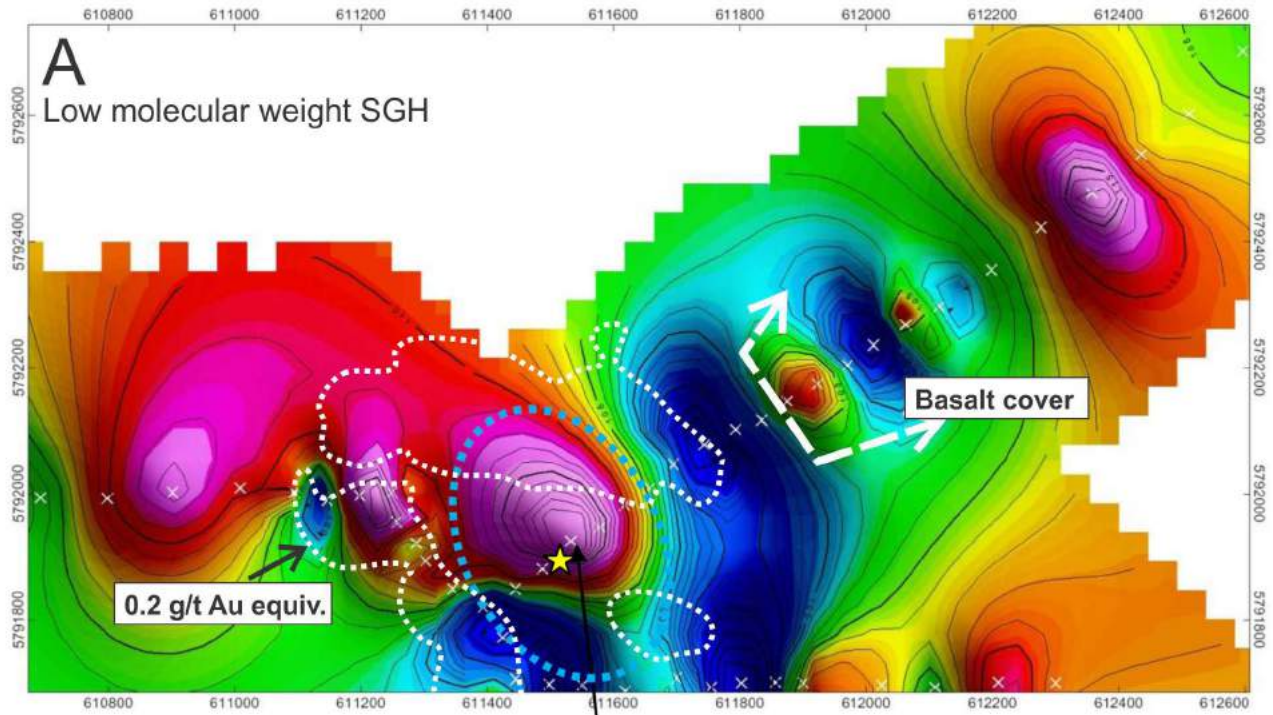
The nitric acid then aqua regia digestion of the dry vegetation tissues, spruce bark in this case, is a near total digestion for all elements. The precision of the analytical method is good to excellent for most elements except for Au and some of the high field strength elements (e.g. Hf, Nb, Ti, Zr) which generally have inferior precision.

Copper is an element that is required for a plant's metabolism and therefore concentrations of a few ppm Cu are typical and only excesses to those levels are likely to be

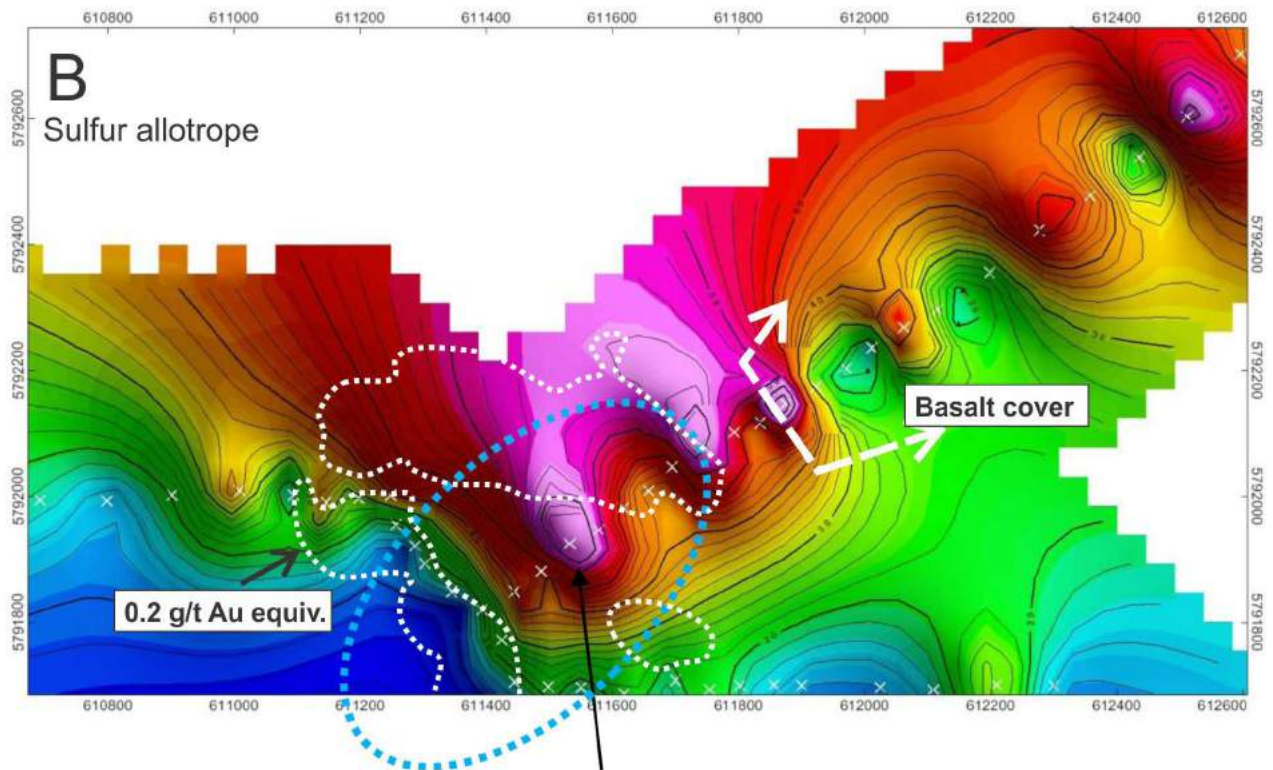


**Figure 14.** B-horizon soil geochemical results of Cu/Fe, Ni/Fe and Zn/Fe compared to absolute concentrations of Cu, Ni and Zn at Deerhorn. **A)** Ionic Leach digestion, **B)** Aqua regia digestion.





Apical Anomaly with SGH Copper Signature



Possible Nested Rabbit Ear Anomaly with OSG Copper Signature

**Figure 15.** Summary of soil gas hydrocarbon (SGH) and organo sulfur compound (OSG) data for Deerhorn. **A)** Low molecular weight SGH used as copper pathfinder; **B)** Sulfur allotrope in OGS used as copper pathfinder. White stippled line indicates surface projection of the 0.2 g/t Au grade contour. Blue stippled line indicates target anomaly interpreted from the SGH and OGS data alone (Sutherland, 2012a, b) Extent of basalt cover is indicated.

attributable to any concealed mineralization. In situations where a geochemical signature is subtle, it is commonly difficult to distinguish a 'mineralization' from a 'micro-nutrient' signature. This is the case at Deerhorn where the highest Cu concentration is located over mineralization, but at only one sample station which by itself is not definitive (Figure 16).

Gold concentrations are all below the detection limit (0.2 ppb Au) except at one site over the western end of the concealed mineralization where 0.2 ppb Au was recorded. This is probably just a random result caused by degraded precision at lowest concentrations, and is not considered to be a response to the mineralization. Similarly a single Bi result from the same area with a concentration at the detection limit is considered fortuitous. In the general vicinity of the buried mineralization, Cs, Rb and K concentrations are above the detection limit and clearly elevated in a number of samples (Figure 17). This suite of geochemically related alkali metals may be reflecting the presence of potassic alteration associated with the mineralization. Lead, S and Se also have slightly elevated levels over the zone of mineralization (Figure 18), although concentrations are very low and in the case of Se only reach twice the detection limit.

A few elements (e.g. Ba, Mo, Ni, Sr, Zn) show a general trend of increasing enrichment toward the east. In the case of Ni this may be attributable to the basaltic substrate, which is exposed at the surface in this area, whereas none of the other elements have inherently higher concentrations in the Chilcotin basalt than in the Nicola Group. Some examples are shown in

Figure 19. Note that the highest Ni concentration of all spruce bark samples at Deerhorn was detected in a single sample above the western mineralized zone where no basalt is known in the substrate, suggesting that Ni may be a useful pathfinder element in spruce bark.

**Spruce twig ash, Deerhorn**

By reducing the spruce twigs to ash prior to analysis, elements are concentrated about 30-fold, since the ash yield is approximately 3%. Consequently, the numbers reported from the analysis are substantially higher than for the dry spruce bark and concentrations of more elements are well above detection levels. However, there is the drawback that some elements volatilize during the ashing process – notably all the Hg, and some of the Cr and possibly As, S, Sb and Se. Fortunately, provided ashing conditions are similar, the proportion of any element that is lost is fairly consistent and so element distribution patterns can be meaningful. There is little variation among samples in the ash yield (about 2.6 to 3.4%) making negligible difference to the overall patterns, so the data have not been levelled to a dry-weight basis prior to plotting.

Copper and As concentrations are erratic and are slightly elevated over the western edge of the Chilcotin Basalt. Neither of these elements has a good response directly above or adjacent to mineralization. Although the highest Au value was recorded by a sample collected above the western part of mineralization it is only about twice the background and 20%

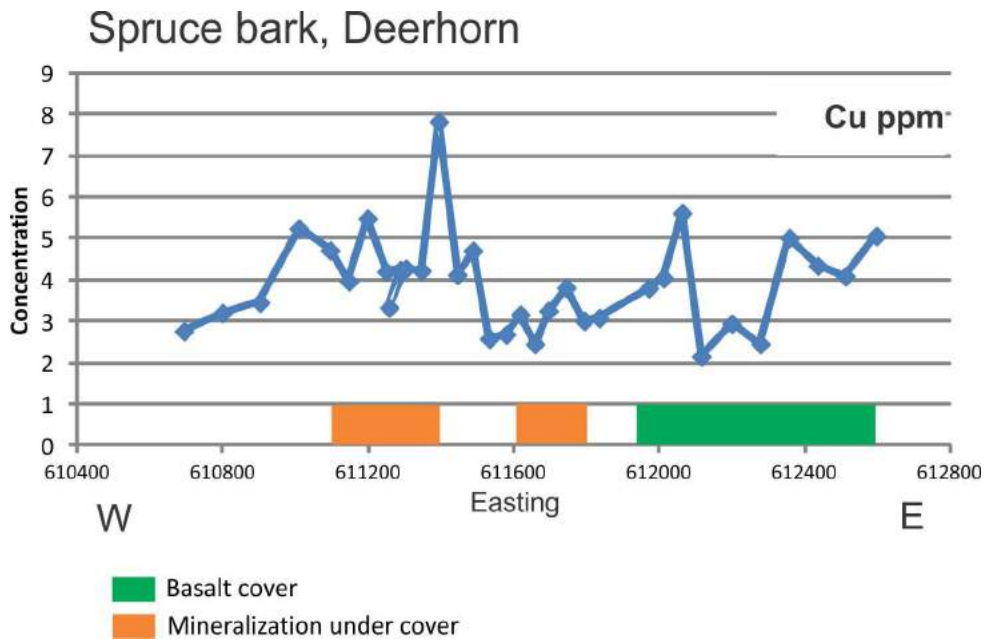


Figure 16. Analytical results for Cu in spruce bark at Deerhorn. Vegetation samples have usually been taken within less than 10-15 m of the corresponding soil samples.

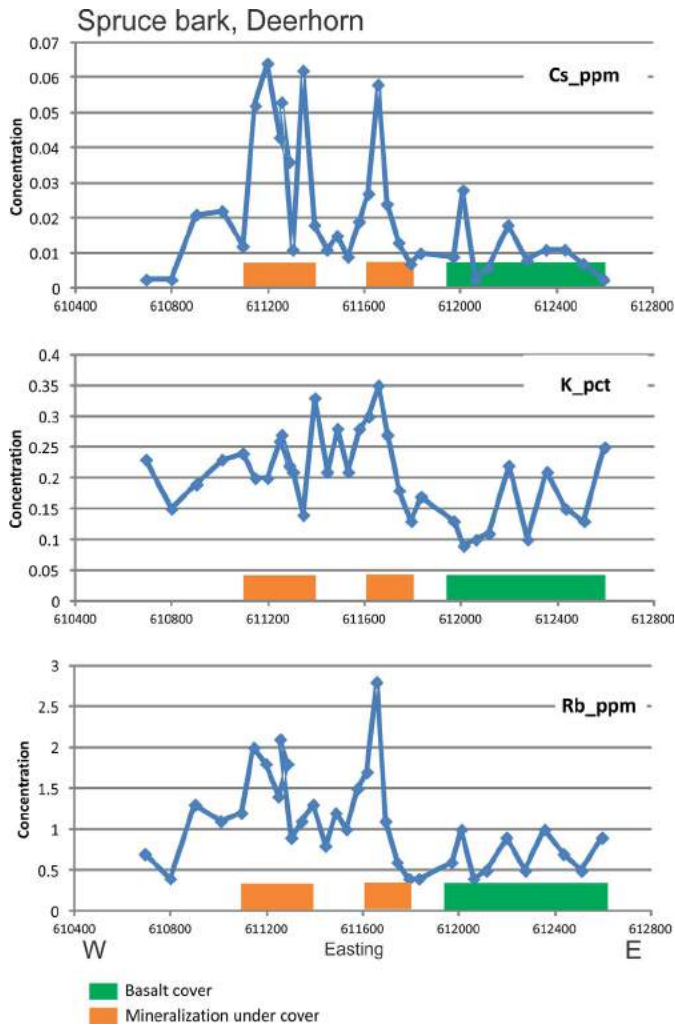


Figure 17. Analytical results for Cs, Rb and K in spruce bark at Deerhorn.

- 30% higher than other samples along the line away from the buried mineralization (Figure 20).

As documented for the spruce bark, ashed spruce twigs exhibit elevated Cs, Rb (Figure 20) and to a lesser extent K over mineralization. Thallium is elevated up to an order of magnitude above detection limit over the eastern part of mineralization (Figure 20). Platinum exhibits a single high value between the mineralized zones (Figure 20).

### Three Firs survey area

At the Three Firs prospect B-horizon soil and vegetation samples were collected on an ENE to E oriented traverse. In contrast to the Deerhorn line, Chilcotin Group basalts are not exposed at surface but they are present in the cover over the westernmost five soil sample sites. One angled diamond hole drilled by Goldfields (MAG-12-04; Figure 3) intersected about 30 m of basalt below about 60 m of glaciofluvial overburden before encountering sulfide-bearing bedrock of the Nicola Group. This drill hole was repeated because the first hole (MAG-12-04) was lost at the lower basalt contact. MAG-12-04/04A and the parallel

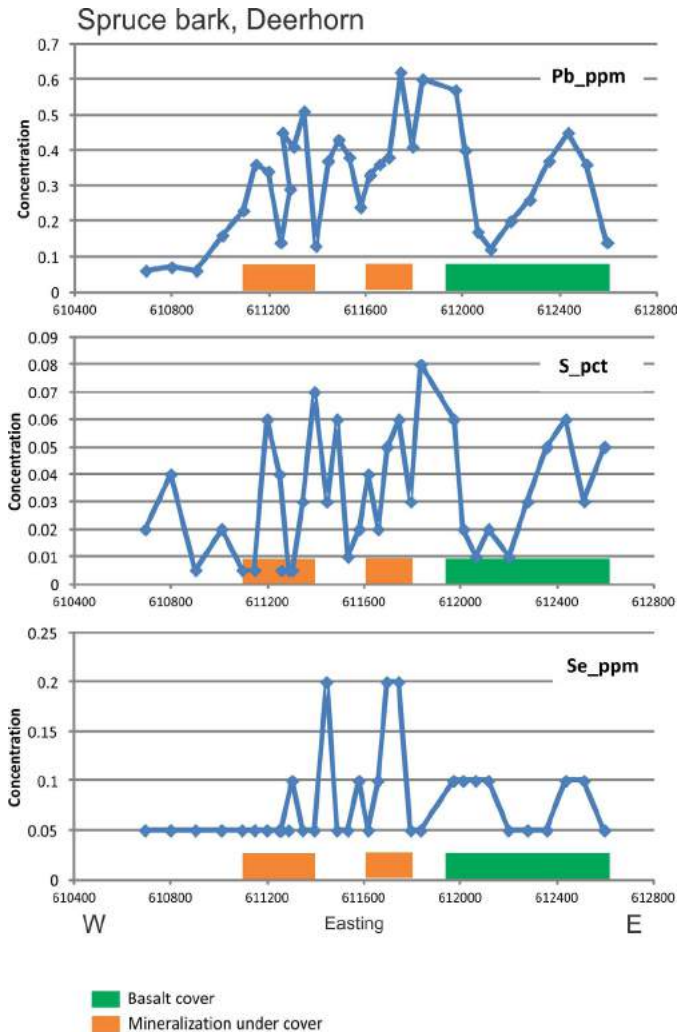


Figure 18. Analytical results for Pb, S and Se in spruce bark at Deerhorn.

MAG-12-05 were all collared near the fifth sample site from the west and were all drilled roughly parallel to the section line to the east at an angle of approximately 60° (Figure 3). On the basis of limited drilling, mineralization occurs to the east of this location and is covered by glaciofluvial sediments but potentially also by basalt.

### Soil pH and Electrical Conductivity

Soil H<sup>+</sup> and EC results for Three Firs are shown in Figures 21 and 22. Although there is considerable scatter in the data, some general patterns are apparent. Hydrogen-ion concentrations are highest (lowest pH) over the western margin of projected mineralization. The acidified H<sup>+</sup> (H<sup>+</sup>a) values are higher near the margins than directly above the mineralized zones at both localities, although high H<sup>+</sup>a values also occur distal to mineralization (Figures 21, 22). Electrical conductivity is most elevated over the mineralized zone but relatively low directly adjacent to it (Figure 22). In general, the IDH results mimic the conductivity and H<sup>+</sup>a results quite well and the highest IDH values occur directly above mineralization and to the west of

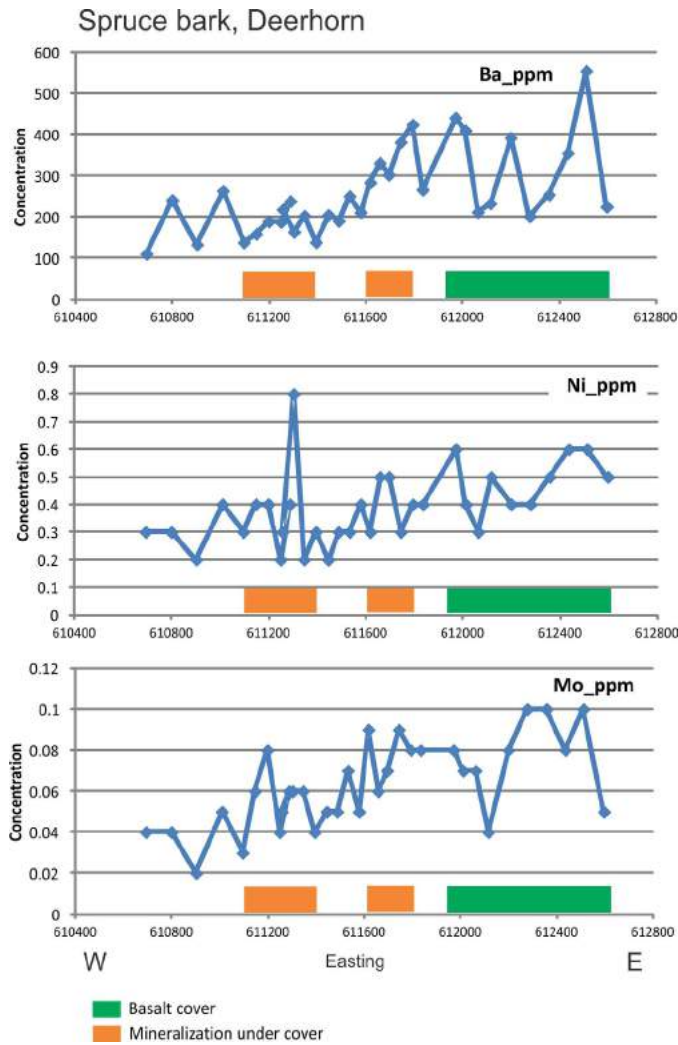


Figure 19. Analytical results for Mo, Ba and Ni in spruce bark at Deerhorn.

it. At the western end of the line the presence of carbonate reacting with HCl acid was recorded in the field in the B-horizon soil sample. This is consistent with the low  $H^+$ ,  $H^+a$  and high IDH recorded for the same location.

### ***B-horizon soil geochemistry Basalt Signature***

As observed at Deerhorn, La, Th and Nb do not show a clear signal above mineralization when strong digestion techniques (aqua regia and 4 acid) are used (Figure 23). Given the extensive glacial cover over the basalt, these elements are not present at higher concentrations above basalt either. The Bioleach and Enzyme Leach techniques do exhibit Th and La concentrations up to 4 to almost 9 times background above mineralization and over basalt at the western margin of the mineralization. Enzyme Leach also exhibits one elevated La value at the eastern limit of the mineralization whereas Th shows a single elevated value ~ 250 m E of the eastern margin of the zone (Figure 23). Ionic Leach, as observed at Deerhorn, does not yield an interpretable signal for these elements.

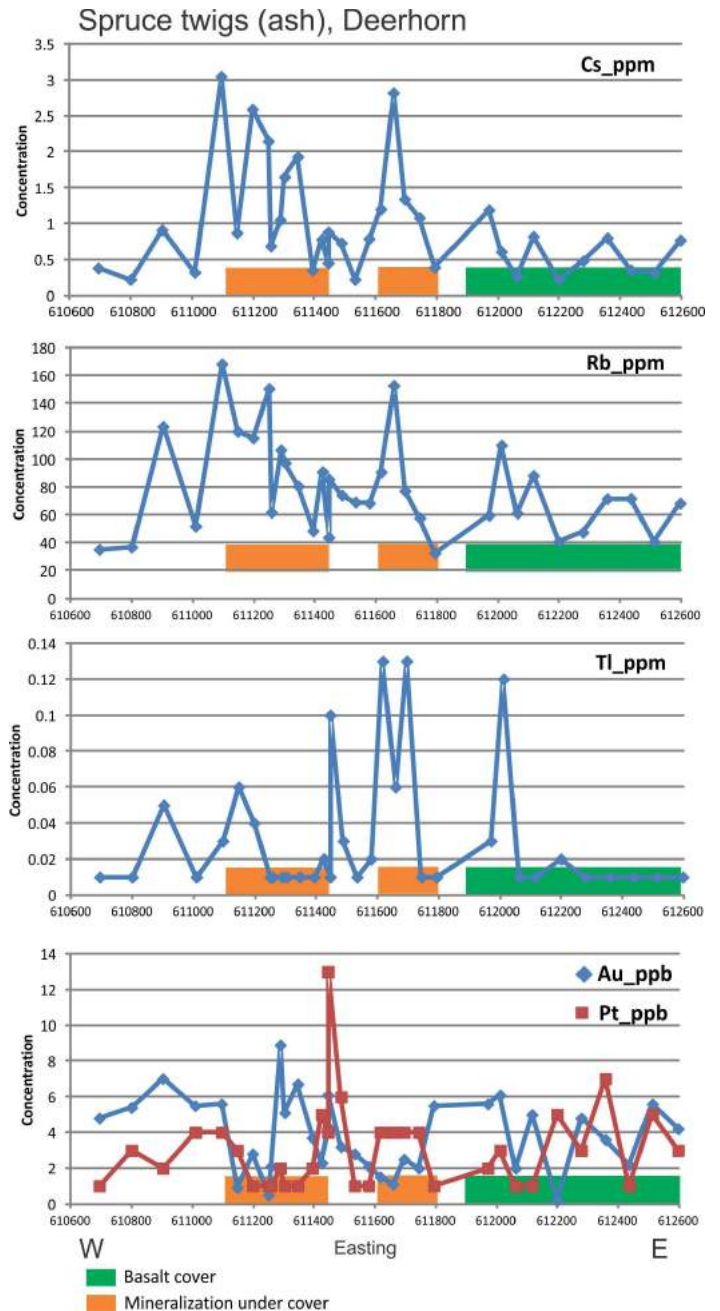
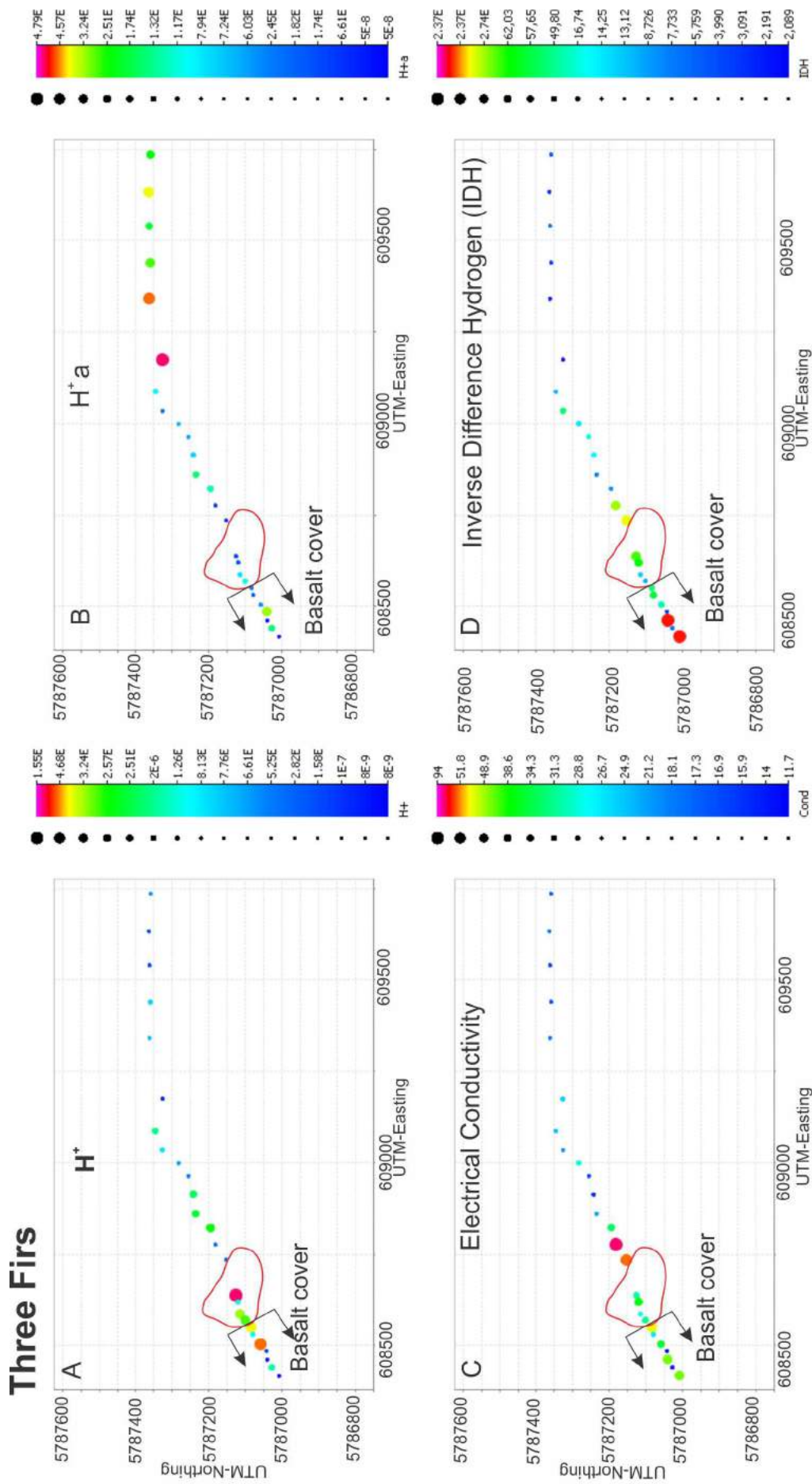


Figure 20. Analytical results for Au, Cs, Rb, Pt and Tl in ashed spruce twigs at Deerhorn.

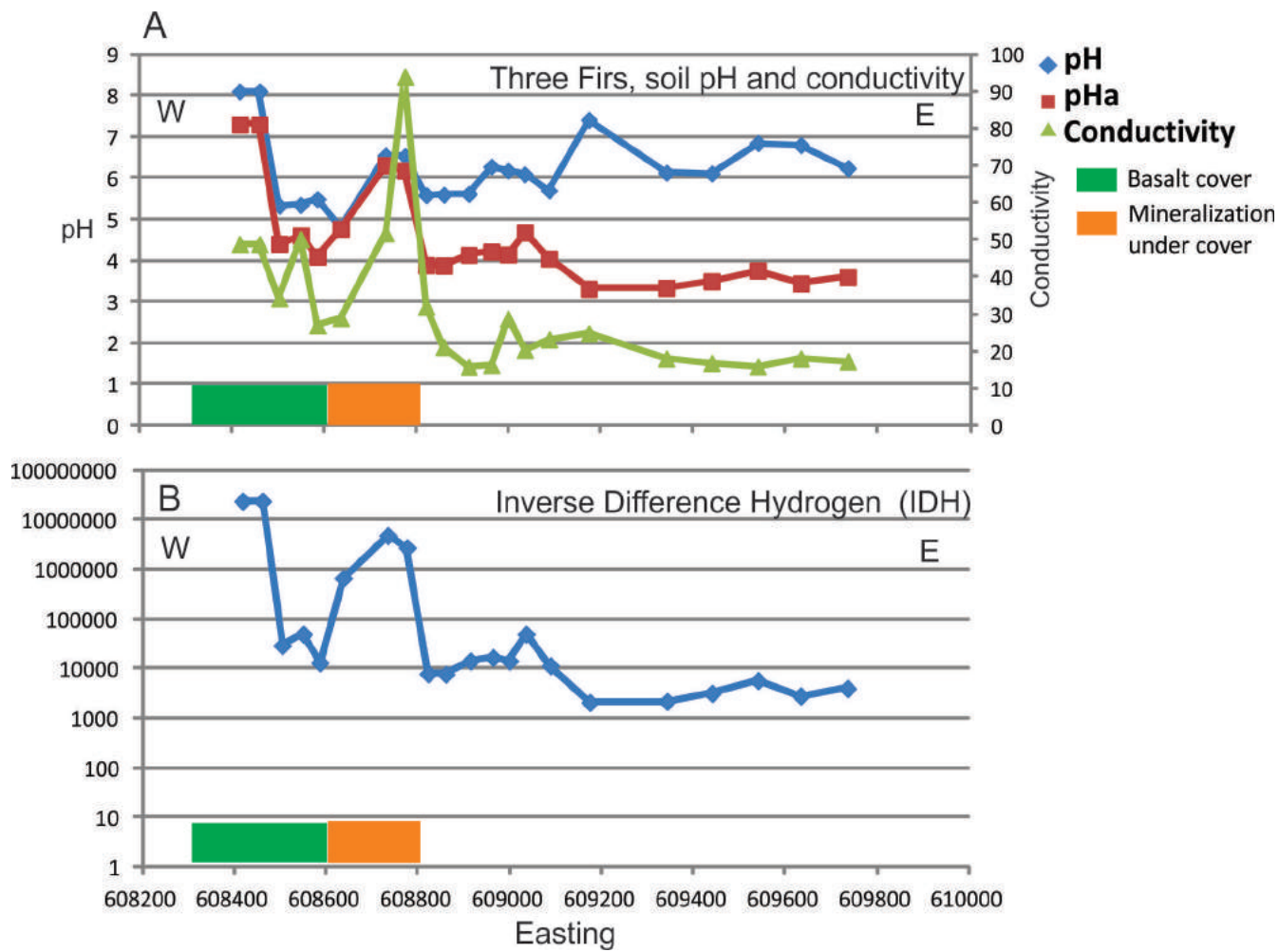
### ***Mineralization Signature***

The 4 acid and aqua regia techniques did not produce a distinctive signal for Cu, Zn, As, Ni, Ag or Sb above mineralization (Figures 24, 25).

**Bioleach:** Copper, Ni, As and Ag exhibit the best response using the Bioleach technique. The highest Cu, Ni, and Ag values for this method were recorded in samples taken directly over mineralization and in the case of Cu also at its western margin above the basalt (Figures 24, 25). Arsenic shows elevated values just west and east of the mineralized zone in what may be interpreted as a rabbit-ear anomaly (Figure 25). Zinc shows high



**Figure 21.** Soil pH and conductivity data for the Three Firs survey area, Woodjam prospect, south-central British Columbia. Areas under basalt cover and surface projection of the mineralization, defined by the 0.2  $\mu$ /Au equivalent contours, are represented by graphs showing **A**)  $H^+$ , concentration of hydrogen ions (~inverse of pH); **B**)  $H^+a$ , concentration of hydrogen ions after addition of 1 drop of 10% HCl acid; **C**) electrical conductivity in  $\mu$ S/m; **D**) IDH,  $1/(H^+a-H^+)$ . Note that the dataset includes regular soil samples for which only pH data were collected.



**Figure 22.** Soil pH data for the Deerhorn W to NE survey line presented as profiles. **A)** pH, pHa and electrical conductivity, **B)** Inverse-difference hydrogen (IDH) data. Note, for consistency, only pH data for sites where B-horizon soil samples were also collected are shown.

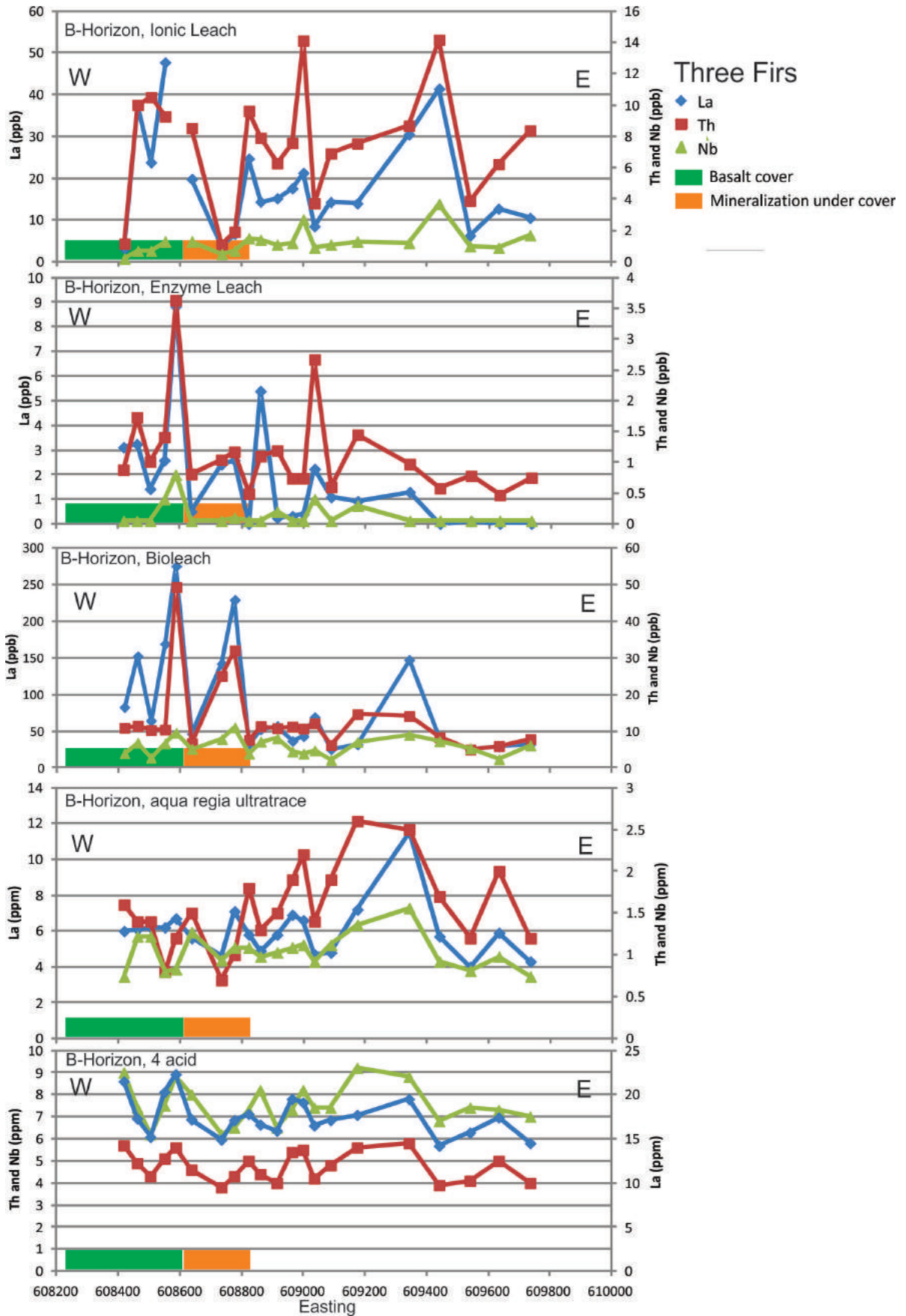


Figure 23. B-horizon soil geochemical results for La, Th and Nb at Three Firs as function of analytical technique. See text for discussion

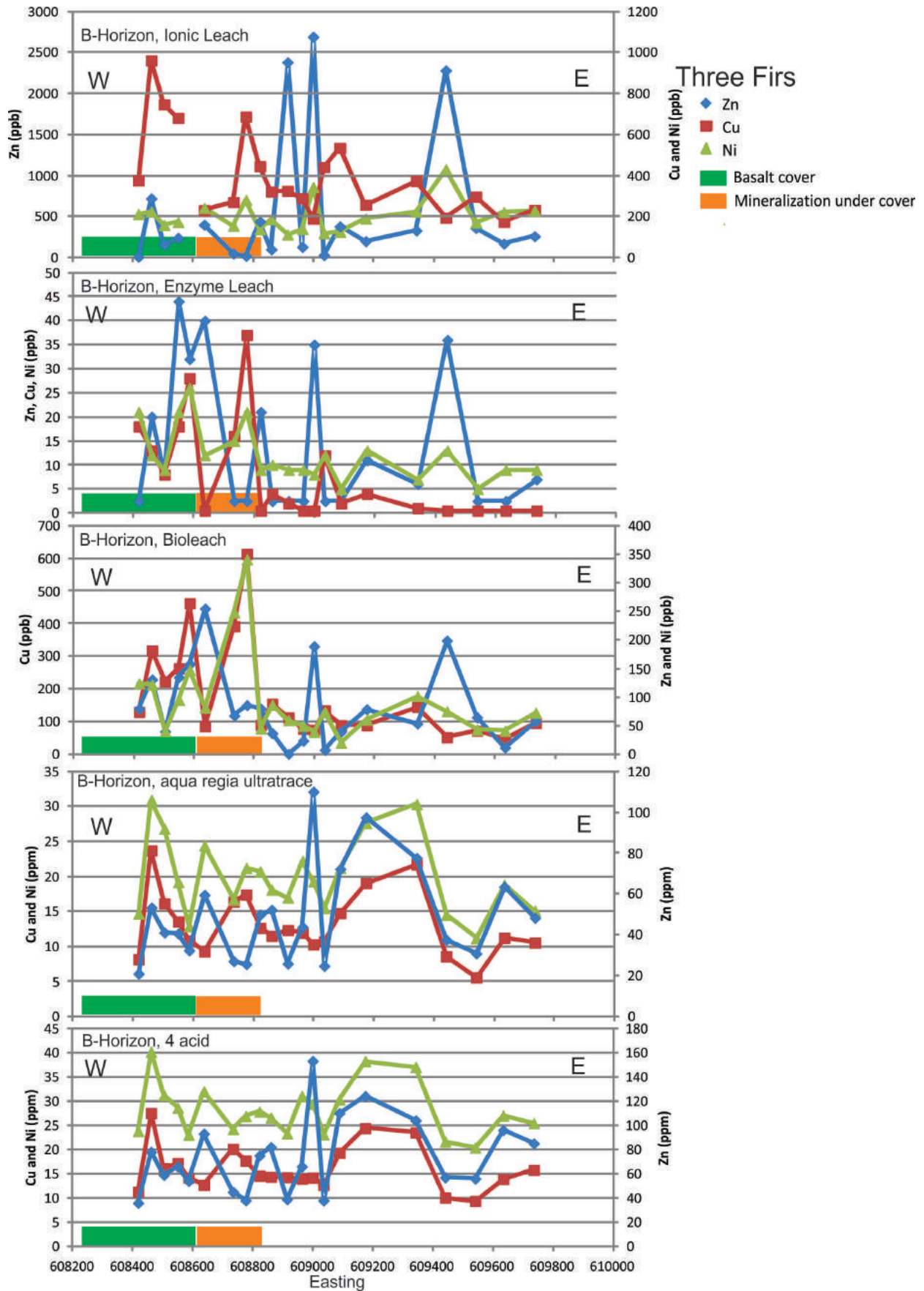


Figure 24. B-horizon soil geochemical results for Cu, Zn and Ni at Three Firs as function of analytical technique. See text for discussion.



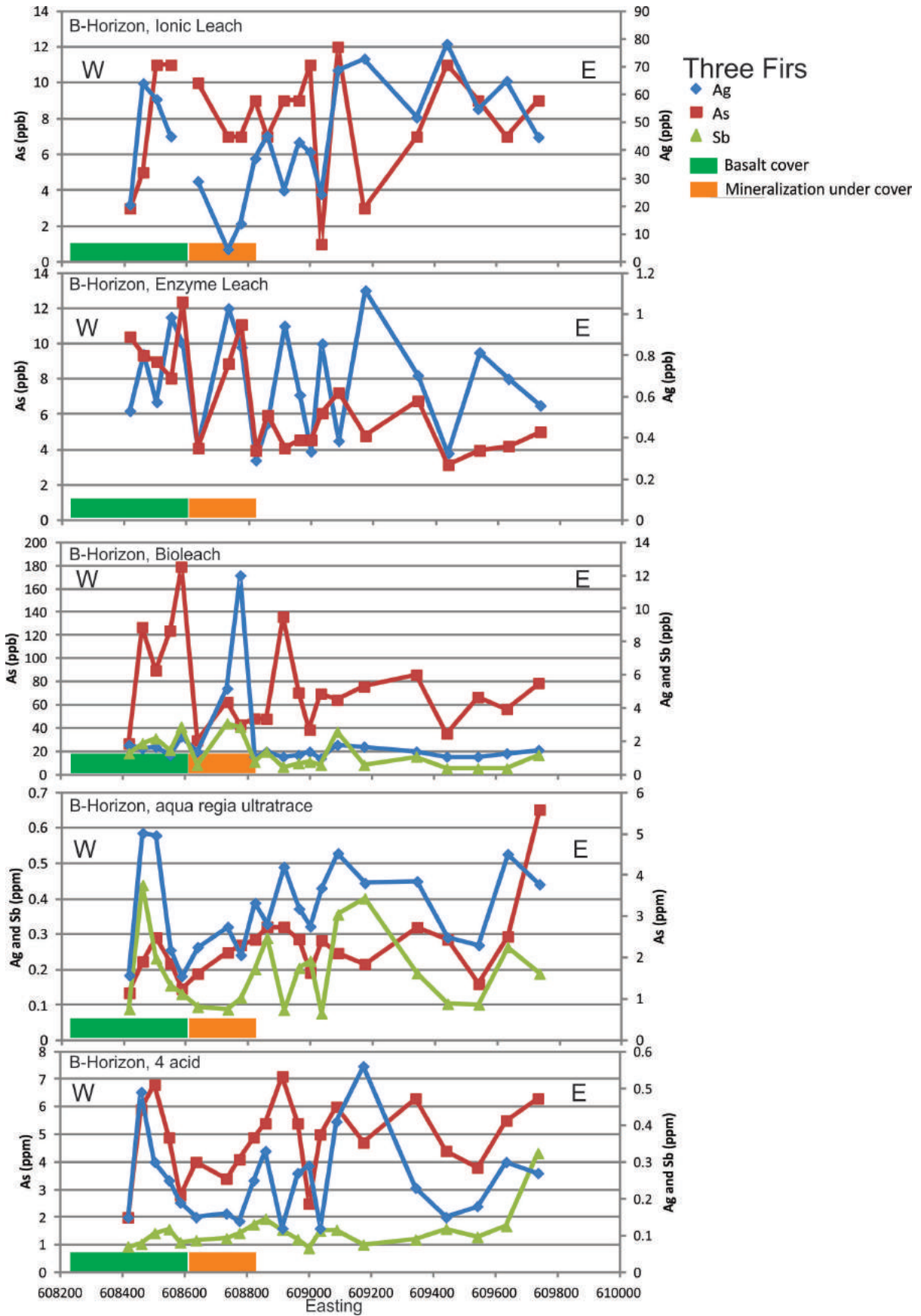


Figure 25. B-horizon soil geochemical results for As, Sb and Ag at Three Firs as function of analytical technique. See text for discussion.

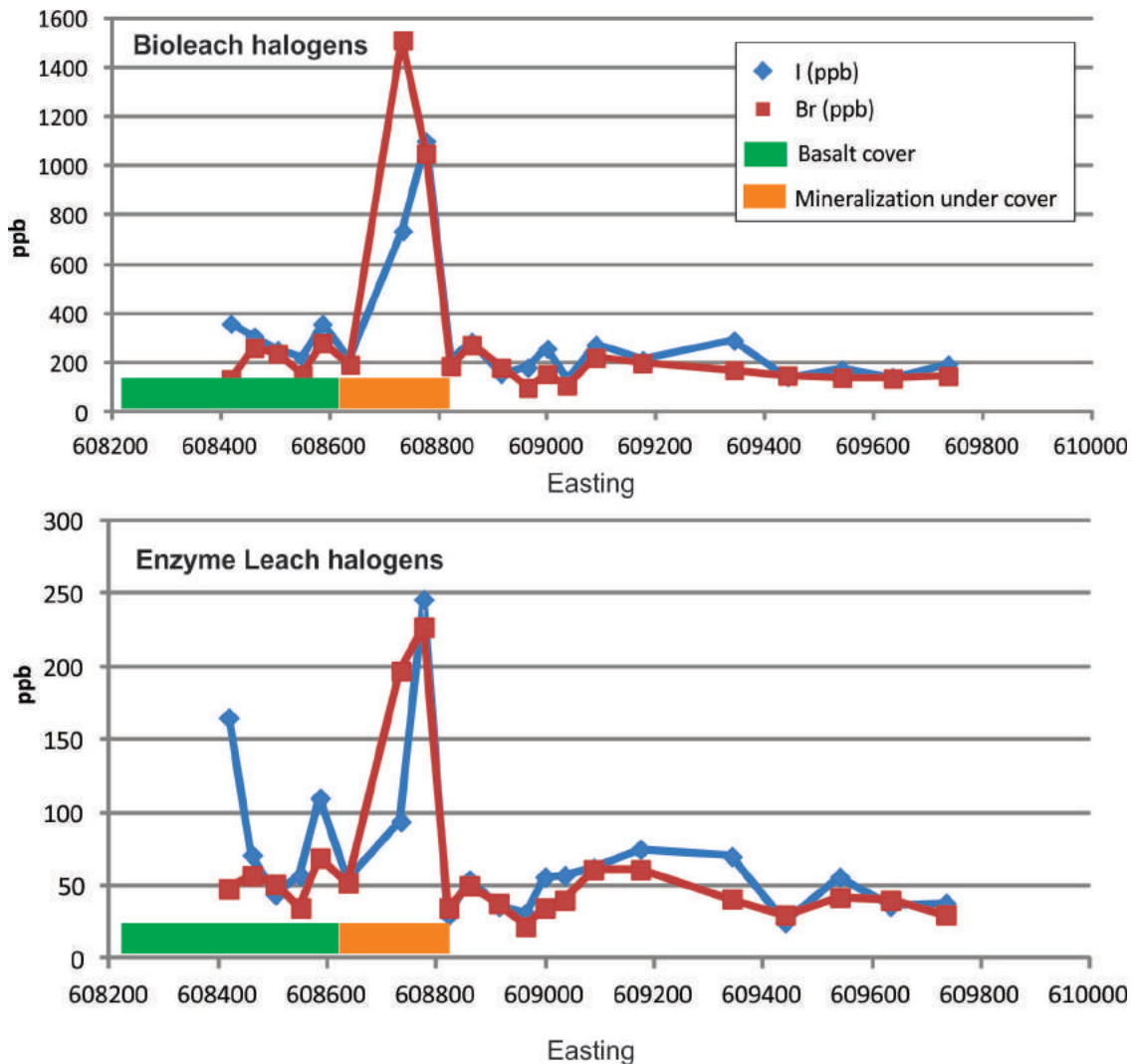
values at the western margin of the mineralized zone but also some unexplained elevated values in the eastern parts of the transect (Figure 24).

**Enzyme Leach:** Copper shows a similar pattern to Zn but has a slightly enhanced response compared to Bioleach. Nickel, in contrast has a less pronounced response compared to the Bioleach technique, but with the highest values still located above mineralization and at its western margin (Figure 24). A weak signal may also be interpreted for As, which has its highest values above and at the western margin of the mineralized zone (Figure 25). Zinc has a highly variable signal in the Enzyme Leach results with elevated values over the western margin of the zone but also for individual samples to the east.

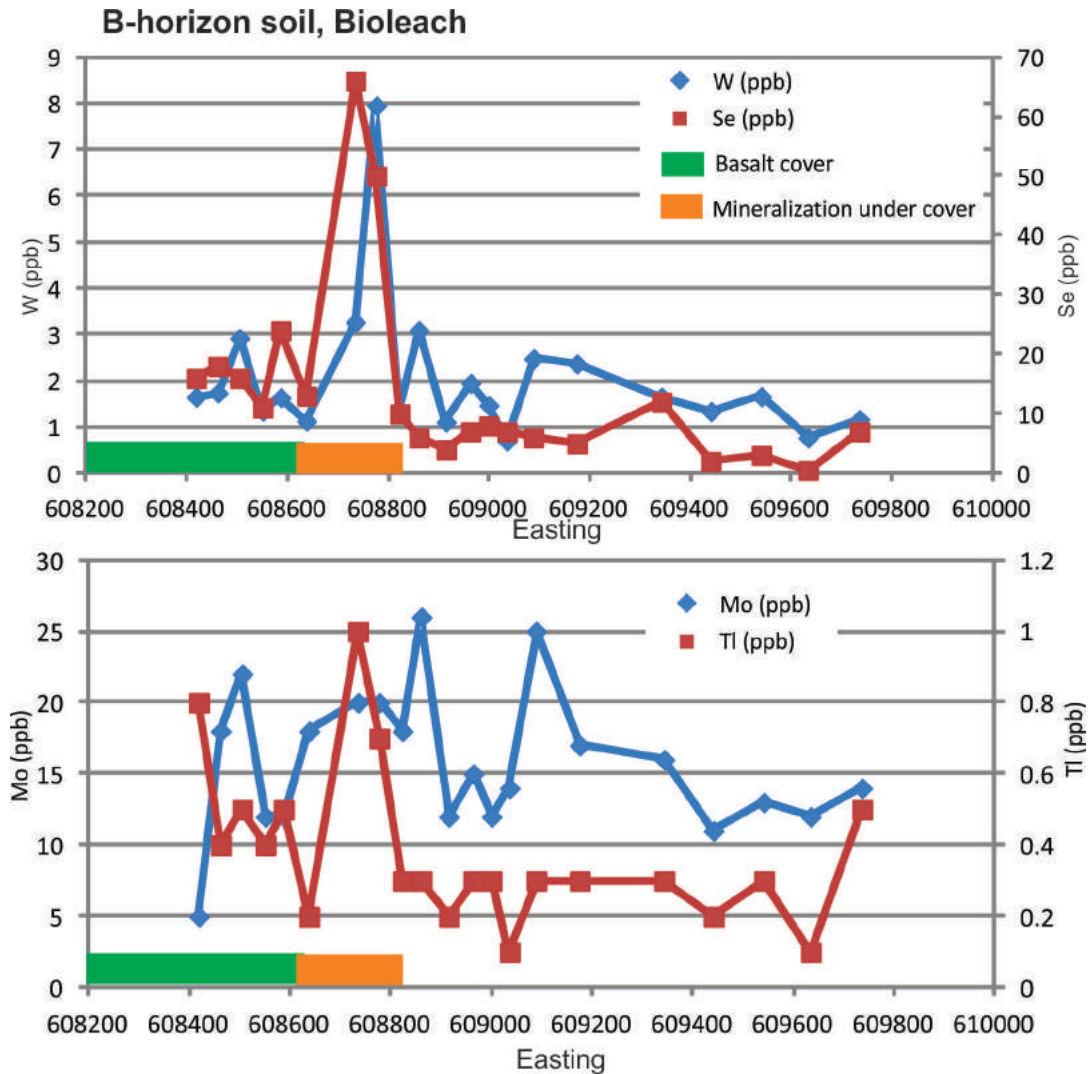
**Ionic Leach:** As for Enzyme Leach, the highest Zn values occur 100-200 m E of the mineralized zone. It is unknown whether this variation in Zn values reflects bedrock characteristics. Copper in Ionic Leach exhibits its highest values

above basalt cover west of the mineralization, as well as over the eastern margin of the mineralized zone, whereas Ni has relatively uniform concentrations along the transect. Note that for the sample collected above the western margin of the mineralization insufficient material was available for Ionic Leach. Silver and As in Ionic and Enzyme Leach do not produce recognizable responses over mineralization (Figure 25).

In addition to the elements described above, the halogens Br and I by both Bioleach and Enzyme Leach have clearly elevated values of ~ 4 to 10 times background directly over the mineralization (Figure 26). Bioleach results for W, Se and TI also show clearly elevated values over mineralization and a more compelling result than at Deerhorn. Selenium has values of up to 10 times background but W and TI also have good contrast with 3 to 5 times background values over mineralization (Figure 27). Molybdenum, in contrast to Deerhorn, does not show a compelling anomaly over mineralization (Figure 27).



**Figure 26.** B-horizon soil Bioleach and Enzyme Leach results for Br and I at Three Firs. Sample sites over mineralization have 3 to 9 times the background concentrations in these elements.



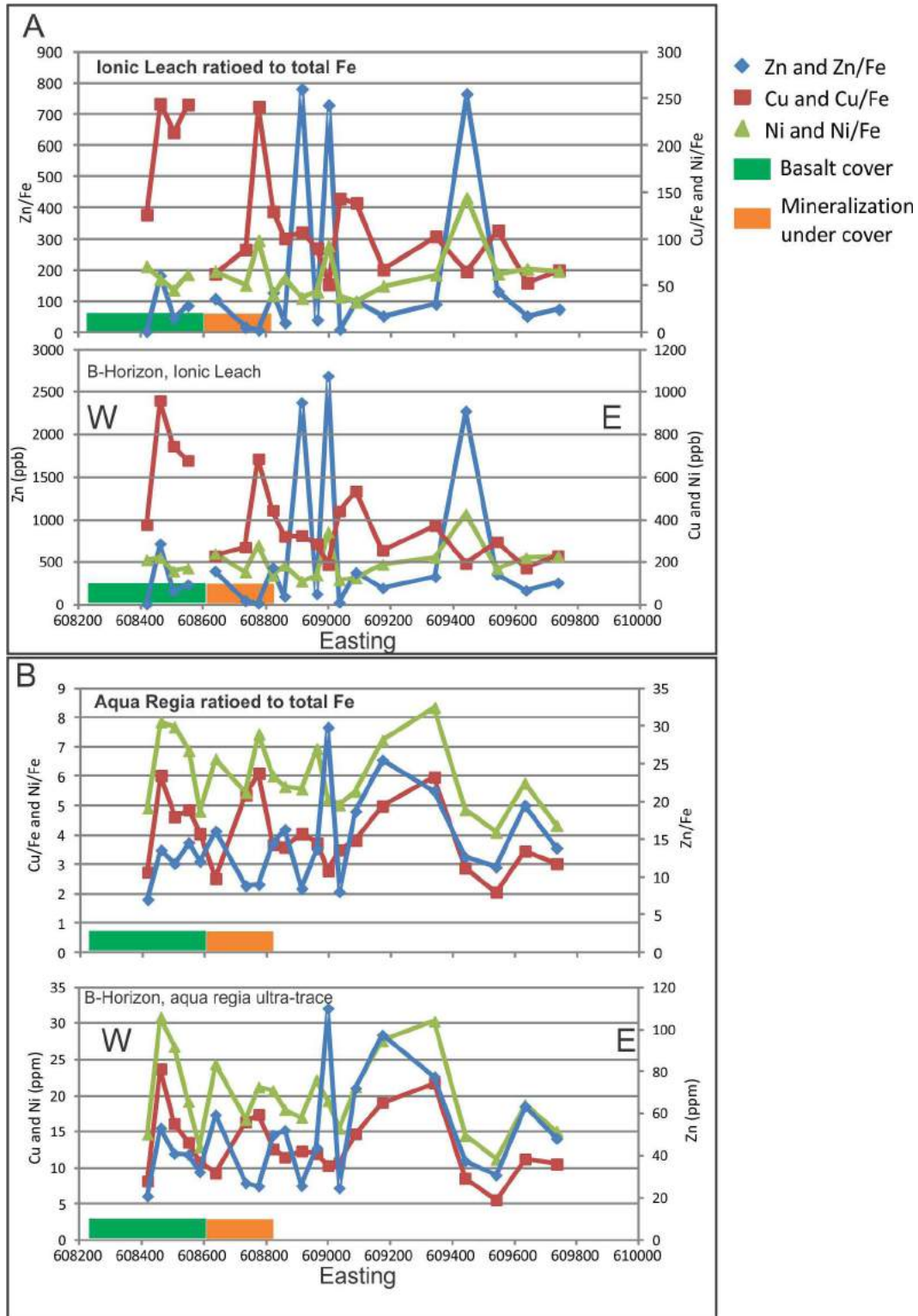
**Figure 27.** B-horizon soil Bioleach results for W, Se, Mo and Tl at Three Firs. Sample sites over mineralization have to ~4 and 10 times the background concentrations of W and Se, respectively. Thallium has a response ratio of 3.3 and Mo is not considered anomalous over mineralization.

***B-horizon: effect of Fe content on element concentrations***

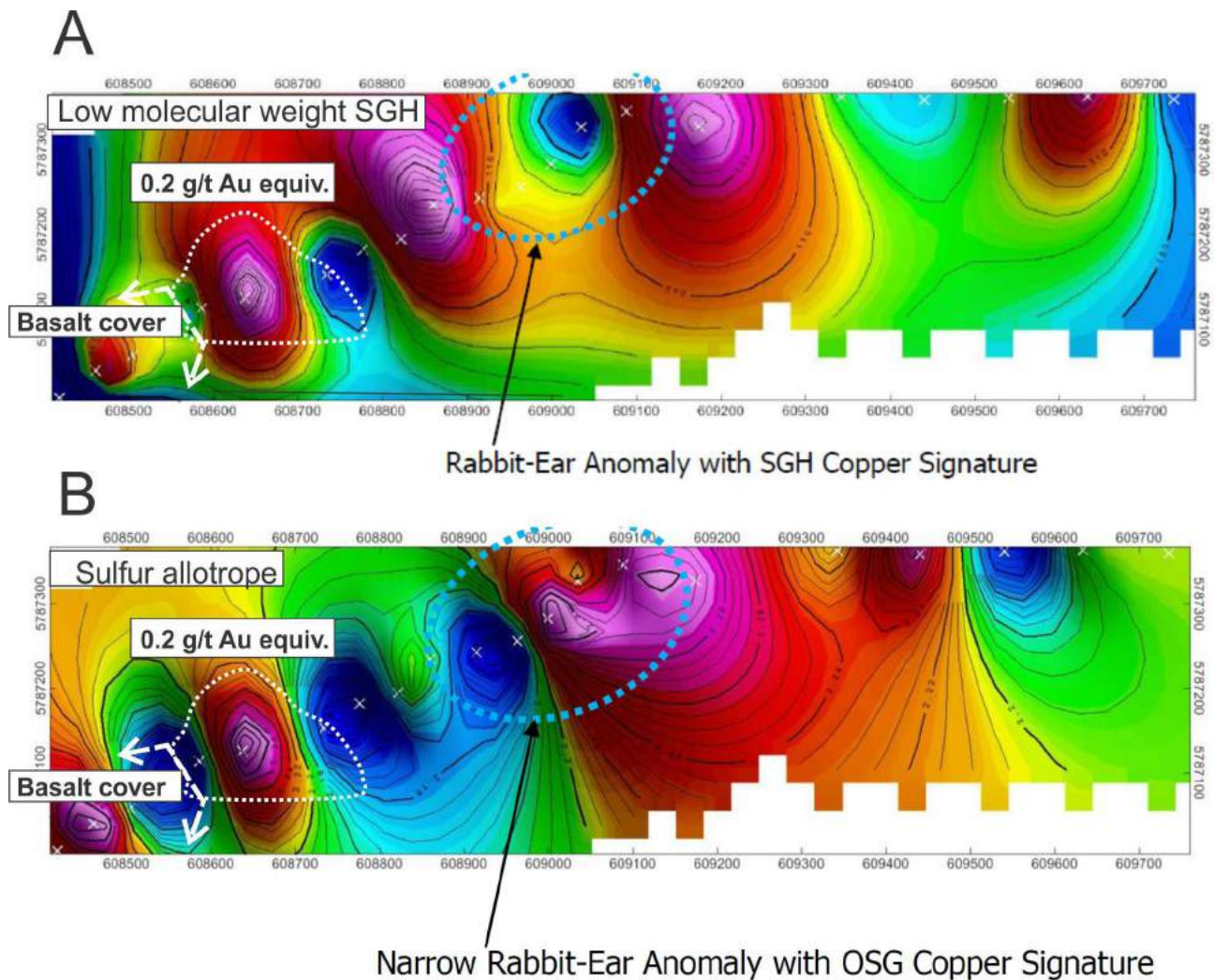
At Three Firs the difference between Cu concentrations and Cu/Fe ratios is more evident than at Deerhorn (Figure 28). Copper concentrations in the aqua regia results are highest at the second sample site from the west, whereas the Cu/Fe ratio is highest above mineralization. In the Ionic Leach results, Cu/Fe is enhanced in several samples over basalt and mineralization compared to absolute Cu concentrations. In contrast to the Cu results, Zn/Fe and Ni/Fe show very similar patterns compared to Zn and Ni concentrations in both the aqua regia and Ionic Leach results (Figure 28).

***Soil Gas hydrocarbons (SGH) and Organo sulfur geochemistry (OSG)***

The OGS and SGH responses are less clear than at Deerhorn with alternating high and low values observed (Figure 29). Elevated low-molecular weight SGH and OSG compounds occur directly above mineralization and are bordered by samples with lower values. Copper, Ni and Ag show a good response in the same location. The second sample site from the west exhibits an elevated OSG compound value that coincides with elevated Cu in some of the partial leach results, whereas the high OSG values to the NE along the line roughly coincide with high Zn values. Based on the SGH and OSG response alone, Sutherland (2012a,



**Figure 28.** B-horizon soil geochemical results of Cu/Fe, Ni/Fe and Zn/Fe compared to absolute concentrations of Cu, Ni and Zn at Three Firs. **A)** Ionic Leach digestion, **B)** Aqua Regia digestion.



**Figure 29.** Summary of soil gas hydrocarbon (SGH) and organo sulfur compound (OSG) data for Three Firs. White stippled line indicates surface projection of the 0.2 g/t Au grade contour. Blue stippled line indicates target anomaly interpreted from the SGH data alone (Sutherland, 2012 b) Extent of basalt cover is indicated. Note that number of samples is too low to meet standard requirements for SGH and OGS surveys.

b) interprets the most prospective target to be about 400 m northeast of the known mineralization. This discrepancy can potentially be attributed to the insufficient sample density for these methods at Three Firs but could also indicate the presence of unknown mineralization east of the drilled area.

#### **Vegetation results**

As with the vegetation geochemistry at Deerhorn, the dataset indicates no unusually high concentrations for any elements in the Three Firs survey area, but some relative enrichments are notable. Many elements in dry spruce bark returned concentrations below or close to the detection limits.

#### **Spruce bark**

There are a few elements of note that exhibit enrichments in spruce bark over, or adjacent to, the zone of known mineralization which may extend beneath the basalt cover to the west. Highest Cs and Rb concentrations occur right at this contact and over the basalt (Figure 30). No other element exhibits a distinct pattern of enrichment in the bark along this line. These high values over basalt are interpreted to reflect buried mineralization, rather than the basalt chemistry because the Chilcotin and Nicola Group basalts have similar Rb and Cs concentrations in the whole rock (Figure 2). Results are discussed in more detail in Heberlein et al. (2013 and in press).

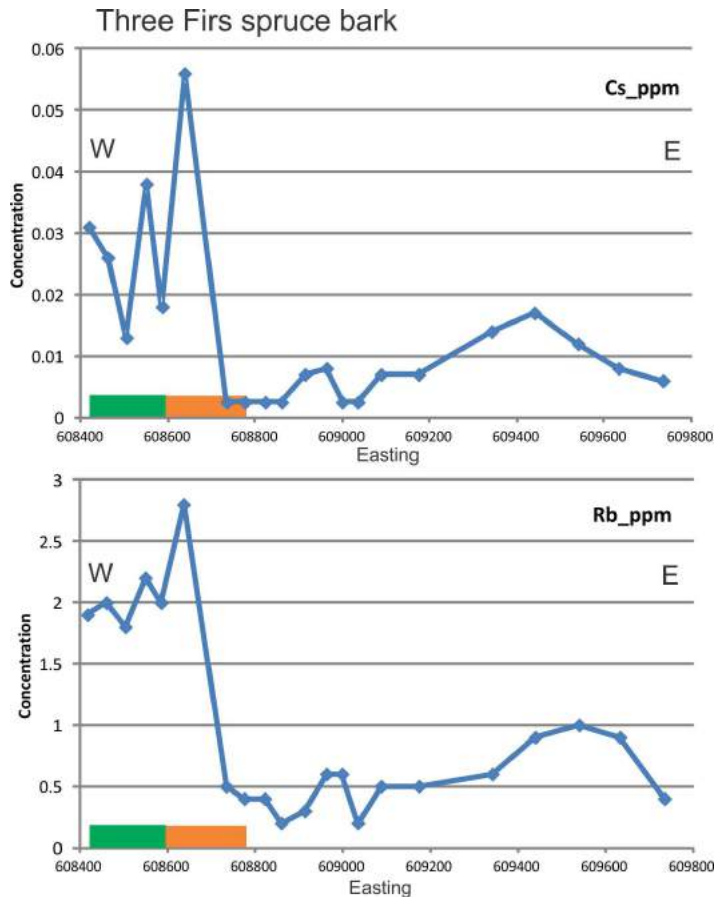


Figure 30. Analytical results for Cs and Rb in spruce bark at Three Firs.

### ***Spruce twig ash***

Ash yields from the spruce twigs collected at Three Firs were similar to those at Deerhorn. Comparisons of concentrations in ash and concentrations in ash levelled to a dry weight basis showed there to be no significant differences in the profiles of elements, and consequently the ash data have been used.

The highest Au value is located directly over the zone of mineralization. In this area there are also elevated levels of Mo, Pb, Cr, REE, Se, Fe, Sr, Sb Cs and Rb. Figure 31 illustrates profiles for Rb, Cs, Au, Pb and Mo as examples. Lead shows a broad area above and to either side of mineralization with elevated values 50 to 100% above background. Gold has a clearer contrast than Pb with the highest value over mineralization having more than double the concentration of the background. Over the edges of mineralization some samples may also be considered anomalous in Au with values up to 50% above background (Figure 31). Molybdenum also shows a reasonable response with the highest values reaching up to twice the background over the western and eastern limits of mineralization in what may be interpreted as rabbit-ear anomaly. Adjacent to the mineralized areas Cs, and

to a lesser extent Rb, have high values; in the case of Cs up to double the background over mineralization and adjacent areas to the west (Figure 31). More details are given in Heberlein et al. (2013 and in press).

## **DISCUSSION**

Deep penetrating geochemical techniques have been applied successfully in British Columbia over a number of porphyry Cu-Au deposits covered by glaciofluvial sediments (e.g., Heberlein, 2010; Heberlein and Samson, 2010; Heberlein and Dunn, 2011). These studies, however, did not test exploration geochemical methods in areas covered by younger volcanic units. In much of south central British Columbia bedrock prospective for porphyry and/or epithermal mineralization is covered by Miocene basalts which have deterred explorers from working in those areas. However, the results presented in this report suggest that, potentially, deep penetrating geochemical techniques can be successful in assisting in the search for concealed mineralization in basalt covered areas.

### **Potential effect of substrate variations**

Chilcotin Group basalts, although widespread, are rarely well exposed at surface due to cover of vegetation and glaciofluvial sediment. They are, however, chemically distinguishable from the underlying Triassic Nicola Group basaltic volcanic rocks that commonly host Cu-Au porphyry mineralization. Elements such as the light REE, Th, (Figure 2) and Ni are more concentrated in Chilcotin Group basalts than in underlying Triassic Nicola Group rocks. These elements are commonly slightly more concentrated in soil and vegetation samples taken directly above basalt substrate than those taken above till where no Chilcotin Group basalt cover is present. Likewise, background soil pH is higher above Chilcotin Group basalts than above till which reflects their more alkaline (buffering) and mafic composition. Where till covers Miocene basalt, and depending on the thickness of the till, the geochemical signal of basalt is probably too subtle to be detected in the soils and plants above. However, in the absence of good exposure, regional plant geochemistry (e.g. tree top geochemistry) has the potential to help delineate the extent of basalt cover as long as till cover is of limited thickness. Nickel would be an element of potential use in this context.

Soil geochemistry can also indicate the extent of young basalt in areas where till cover on basalt is thin or absent but only 4 acid digestion appears to be capable of geochemically detecting the difference between Nicola and Chilcotin Group signatures. Partial leach techniques such as aqua regia, Bioleach, Ionic Leach and Enzyme Leach, can detect weakly bound elements of exploration interest better and the geochemical variations observed in these datasets are interpreted to be the outcome of secondary dispersion processes rather than due to the substrate characteristics. Hence, by inference, partial leach techniques are sensitive to buried mineralization irrespective of the type of cover.

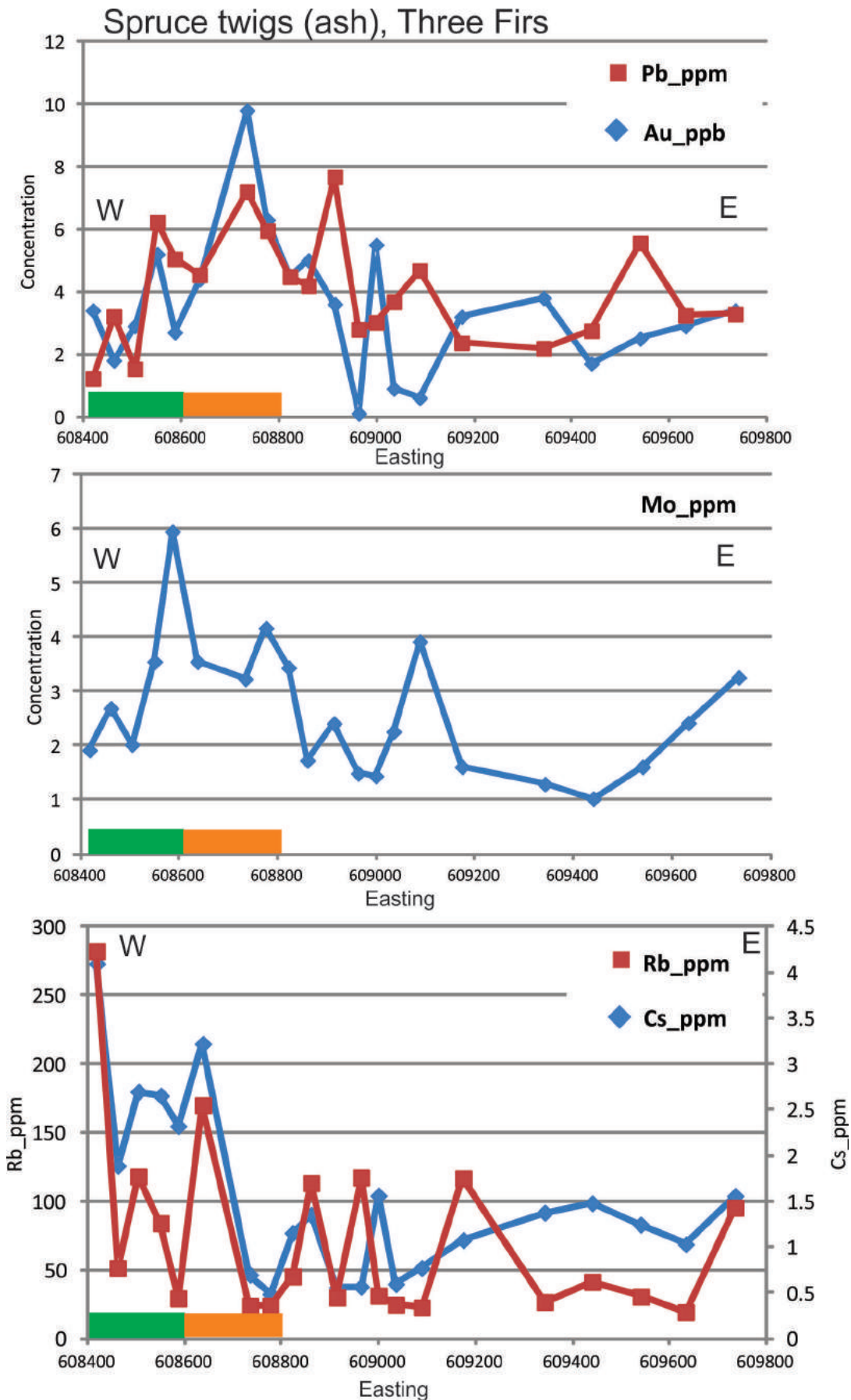


Figure 31. Analytical results for Au, Cs, Rb, Pb and Mo in ashed spruce twigs at Three Fir.

## **Techniques and elements that can detect mineralization**

The geochemical results at Deerhorn and Three Firs show some differences, but in general are comparable and consistent. At Three Firs IDH and EC define rabbit ear patterns with low values above the western margin of the mineralization and high values to either side of it. At Deerhorn, high IDH and EC are observed above the eastern mineralized zone as well as at the second sample site from the east (site DHB021). These patterns are reflected to variable degrees also in the B-horizon soil geochemistry. Among the different partial leach techniques, Bioleach in general yielded the most promising results with the highest contrast between samples near or above mineralization and background exhibited by, e.g., As, Ag, Br, Cu, I, Mo, REE, Se and Zn. These elements are commonly enriched three fold or more compared to background. However, the other partial leaches also show positive signals of specific elements related to concealed mineralization. For instance, Ionic Leach and Enzyme Leach detect the Zn signal quite well (to 5 times background over mineralization) but, e.g., Cu, Tl, Se and As have also compelling patterns in the Enzyme Leach data with at least 2 to 3 times background values over mineralization. At Deerhorn, high EC and IDH results coincide with elevated values for La and other REE, Ag, As, Cu, Ni, Se, and Tl but with the exception of the REE and Tl, these elements are also elevated to the west between the two mineralized zones.

At Three Firs the western edge of the mineralization generally coincides with a relative low in Ag, As, Cu, Ni, and REE as well as low IDH and EC. This low is flanked on either side by higher values in all of these elements and measurements, although on the western side of the mineralization elevated concentrations of elements are not always coincident. Overall, however, the pattern can be interpreted as a rabbit ear anomaly. Elements that have clearly elevated values directly above mineralization at Three Firs include the halogens I and Br as well as Se, Tl and W.

Unlike Cu or As, sample sites with high Zn values tend to be located away from the mineralization. High Zn values are observed above the mapped western extent of basalt as well as at the easternmost sample site at Deerhorn, about 100 m away from samples with elevated Cu or As. Between the two mineralized zones at Deerhorn, high Zn and Cu values roughly coincide. At Three Firs the highest Zn values occur to the east of the mineralization whereas above and west of it, the Zn signal is subdued and does not coincide well with elevated Cu or As values.

The SGH and OGS signatures yielded mixed results. The SGH method produced a pronounced apical anomaly of low molecular weight hydrocarbons between the mineralized zones at Deerhorn which coincides well with elevated Cu, As and Ag values. The OSG sulphur compounds also show a possible rabbit ear anomaly around the eastern mineralized zone. At Three Firs

both the OSG and SGH methods failed to produce a clear result perhaps because of insufficient sample populations; the zone of known mineralization does not underlie the most promising anomaly. A larger survey would be necessary to assess these techniques.

The vegetation geochemistry yielded subdued anomalies except for Cs, Rb and to a lesser extent K which are all present at elevated concentrations above the mineralized zones at both Deerhorn and Three Firs. These elements probably reflect the extent of potassic alteration which is intimately associated with mineralization. Many of the elements of interest are only present at concentrations close to detection limit in the dry spruce bark, but mostly well above detection in the ashed twigs. Some elements, e.g. Se, Mo and Au, have elevated values more than 50% above background near mineralization.

Limited data also suggest that clay and carbonate amygdules in basalt are potentially capable of detecting concealed mineralization. Although further work on a larger sample set will be needed, Mn and As in carbonate may be good indicators of proximity to mineralization. Other elements including Cu, Ag, Au, V, In and Sb are potentially adsorbed to clays. The drillcore from which background clay amygdules were sampled did not contain carbonate amygdules. This observation by itself is worth investigating further. Carbonate may preferentially precipitate above the periphery of oxidizing sulfide bodies, according to the model advanced by Hamilton (1998, 2000; see below). Thus, the presence of carbonate amygdules in basalt may guide exploration to concealed mineralization.

## **Summary of B-horizon soil responses using different techniques**

To summarize the abundance of data obtained from the many datasets, some fundamental parameters of use in describing the significance of the element signatures are provided in Table 3. This table is a summary of data by all the tested analytical methods from the Three Firs area. We have refrained from providing a similar summary table for the Deerhorn Survey area due to the greater complexity imposed by multiple concealed ore zones which makes it difficult to identify the type of geochemical response. The reader is referred to the digital files provided to explore these data further.

Once a dataset was deemed to be of adequate quality from QA/QC evaluations, the approach was to first calculate the response ratio values of each element determined by each method.

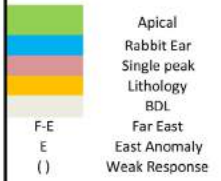
These calculations result in that every analytical number is changed to a relative concentration number (i.e. response ratio - RR).

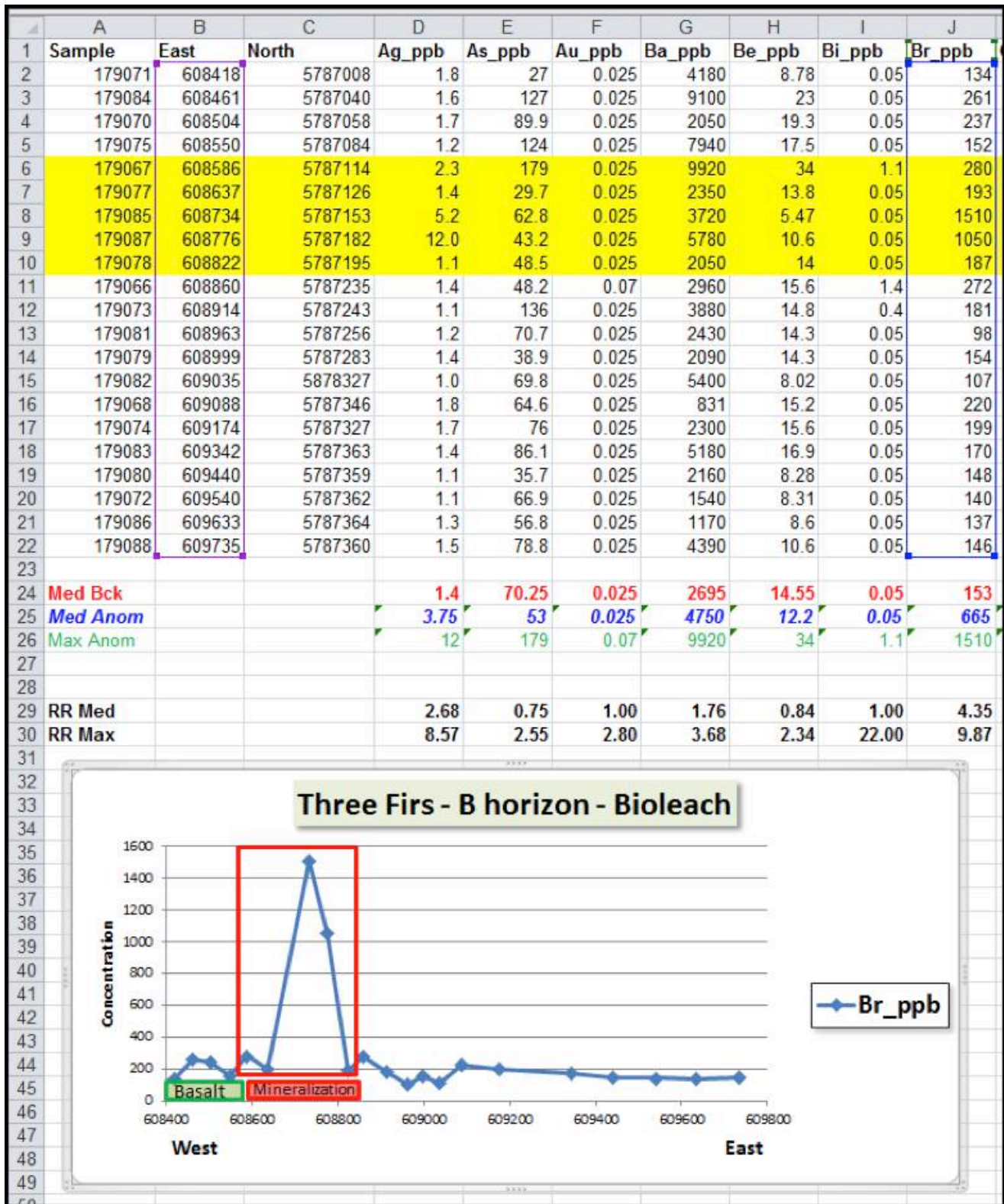
An example for the calculation of Response Ratios for Br in Bioleach data from Three Firs is shown and explained in the spreadsheet screen capture (Figure 32, column J). This procedure was followed for all elements by all methods and the



**Table 3.** Summary of responses of different elements in B-horizon soil geochemical data from Three Firs. Note that use of electronic data files provided on the Geoscience BC website is recommended to explore these data further.

	Bioleach		ME-MS41		ME-MS51		Enzyme Leach		Ionic Leach		Spruce Twigs		Spruce Bark		
	RR Max		RR Max		RR Max		RR Max		RR Max		RR Max		RR Max		
Ag	8.57		0.93		0.70		2.00		0.77		2.13	E	2.17	F-E	
Al			1.19		1.03						1.69		1.00		
As	2.55		0.80		0.76		1.59		1.11		1.44	E	0.50		
Au	1.00		1.79		1.79	F-E	24.00		2.07		2.88		1.00		
B			1.00								1.04		1.33		
Ba	3.68		1.16		1.00		1.42		1.43		0.93		2.89		
Be	2.34		1.27		1.17		1.64		1.79		4.00		1.00		
Bi	22.00		1.05		0.92		18.06		1.00		1.33		1.00		
Br	9.87						5.60		1.40						
Ca			4.41		1.45				2.40		1.18		1.60		
Cd	238.40	E	4.47		3.67		1.33	(E)	1.18	E	1.20	E	1.00	F-E	
Ce	4.02	(E)	1.32		1.23		6.21		1.58		2.15		1.25		
Cl	2.29						2.29								
Co	2.86	E	1.69		1.50		3.22		3.20	E	1.58		1.29		
Cr	4.07		1.15		1.12		1.82		1.61	E	2.27		1.10		
Cs	6.79	E, F-E	0.84		0.89	F-E	6.30		1.09	F-E	4.11		7.00		
Cu	5.86		1.45		1.40		18.50		2.12		1.10	E	1.03		
Dy	6.08	E					6.10		1.40		1.64		1.00		
Fe			1.26		1.13				1.33		1.83		1.00		
Er	6.26						5.39		1.32		2.25		1.00		
Eu	5.40						3.17		1.47		4.00		1.00		
Ga	2.80	E	1.28		1.07		4.11		1.18		1.27		1.00		
Gd	5.88						6.13		1.56		1.93		1.00		
Ge	4.10	E	1.33		1.28		1.78		1.00		1.50		1.00		
Hf	2.54		1.47		1.07		4.33		1.25		1		1.00	E	
Hg	3.95		1.33				2.00		1.23				1.55		
Ho	6.40						5.00		1.33		5.00		1.00		
I	5.12						4.39		1.40						
In	2.67	F-E	1.20		1.00		1.00		1.33		1		1.00		
K			1.23		1.02								2.00		
La	5.78		1.23	(E)	1.29		8.78		1.67	E	2.33		1.00		
Li	7.62		1.19		1.06		3.77		1.27	F-E	2.84		2.00		
Lu	6.32						3.67		1.33	(E)	1.00		1.00		
Mg			1.25		1.04				2.97		1.29		1.13		
Mn	2.93	E	1.18		1.10		4.69		1.57		1.16		1.04		
Mo	1.43		1.14		1.07		6.37		1.31		2.47		1.40		
Na			1.50		1.07						1.62		2.00		
Nb	1.93		1.12		1.19		16.00		1.30	E	1.56		1.00		
Nd	5.91						6.94		1.68	E	2.22		1.50		
Ni	5.09		1.16		1.15		2.89		1.49	E	2.24		1.00	F-E	
P			1.16		1.16						1.27		1.06		
Os	1.00						1								
Pb	1.82	E	1.02		1.10		12.00		1.65	E	1.96		1.36	F-E	
Pd	1.00						1		1.29		1		1.00		
Pr	5.74						7.37		1.69	E	2.33		1.00		
Pt	1.00						1		1.00		3.33		1.00		
Rb	1.85		1.15		1.02		1.98		1.58		2.38		4.67		
Re	14.00		2.00		3.00		1.64		1.00		6.00	F-E	1.00		
Ru	8.4						1								
Sb	3.26		1.10		0.94	F-E	2.26		1.00		1.74		1.00		
S			3.00		3.00						1.19		1.67		
Sc	3.06		1.10		1.04		4		1.38		1.50		2.00		
Se	9.43		3.50		1.00		5.00		1.78	F-E	4.00		4.00		
Sn			1.50		1.08		4.00		1.00		1.22	E	1.00		
Sm	5.78						6.28		1.62	E	1.77		1.00		
Sr	4.76		2.99		1.15		1.72		3.10		2.02		1.71		
Ta	1.00		1.00		1.20		1		1.00		1.00		2.00		
Tb	5.99						5.63		1.41	E	3.00		1.00		
Te	2.00		4.00		1.00		1.00		7.00		1.40		1.00		
Th	4.59		1.13		1.14		3.92		1.24		4.00		1.00		
Ti			1.05		1.11		2.73		1.50	(E)	1.19		1.00		
Tl	3.33		1.25		1.12		4.55		1.00		1.50		1.00		
Tm	6.08				1.31		4.20		1.25	(E)	1.00		1.00		
U	4.98		2.12	E	1.03		3.19		1.03	E	1.00		1.00		
V	4.14		1.10		1.00		4.46				2.33		2.00		
W	4.82		5.52		1.12	F-E	6.00		1.00		2.00		1.00		
Y	6.25		1.41		1.24		8.29		1.33	E	2.17		1.13		
Yb	6.24						4.96		1.35	E	2.20		1.00		
Zn	4.55		1.27		1.08		9.41		1.76	E	1.39		1.20		
Zr	2.91		1.25				4.27		1.49				1.00		
F									1.14						





**Figure 32.** Example of the calculation of relative concentrations or response ratios using built in statistical functions in Microsoft Excel software. Five samples were collected above mineralization (highlighted yellow and by red box in chart). 1. The median element concentrations of these 5 sites ("Med Anom" values shown in blue font, L25) are compared to the median of all sites along the transect ("Med Bck" - numbers in red font, L24). The latter value was taken as the background concentration. 2. The maximum value of the 5 selected samples is shown in green font (L26). 3. The value in L25 was then divided by that in L24 (i.e. anomaly divided by background) and the result shown as RR median (L29). 4. Finally, the RR maximum was calculated by dividing the Max anomaly (L26) by the median (L24). This now quantifies the magnitude of the anomaly that is depicted in the chart at the bottom of the figure. In the case of Br, the RR maximum is 9.87, or the maximum value is 10 times the background.

results summarized in Table 3. Maximum response ratios that exceed x 2 the background are highlighted in Table 3 according to the following colour scheme:

1. Green: Apical signatures – several sites with anomalous concentrations directly over the zone of mineralization
2. Pink: Single point anomalies – these should be considered with some caution since they are not always reproducible.
3. Blue: “Rabbit Ears” signatures – adjacent to the margins of the concealed mineralization.
4. Yellow: Signatures that may be influenced by underlying lithologies.
5. Red: Slightly higher response over mineralization, but values quite similar along the transect
6. Grey almost all values below DL.

The areas identified in the color key alongside the Table are shown in the example of Cs by Bioleach (Figure 33). In this chart Cs values are elevated over the basalt (potential ‘Lithological response’) and exhibit enrichments toward the east (‘East anomaly’) and at the far eastern end of the line. In some cases a RR >2 is not highlighted because it is not exclusive to the area of known mineralization. Note that the lithological response cannot in every case be confidently separated from a response related to mineralization. This is exemplified by light REE (e.g. La) which are elevated in Bioleach and Enzyme leach results above mineralization and adjacent areas, including above basalt (Figure 23). Chilcotin Group basalts contain overall higher LREE than Triassic Nicola Group basalts (Figure 2) but at Three Firs the former are covered also by ~ 60 m of glaciofluvial sediments.

Whereas Table 3 provides a comprehensive summary of the various anomalous signatures, it is still a kaleidoscope of colours that require further distillation in order to extract the essence of the abundance of information. Table 4 is an attempt to do this, by simply adding up the number of elements that have a relationship to the known zone of mineralization. From this it is apparent that the greatest number of elements that exhibit anomalies over the known zone of mineralization are from Bioleach, closely followed by ashed spruce twigs and then Enzyme Leach. One point to note is that the low number of anomalies shown by the spruce bark is probably because many elements concentrations were below detection; by ashing the bark it is probable that more elements would have been anomalous. Clearly the conventional aqua regia digestion of the soils and the total (4-acid) digestion were inferior methods for defining the location of the mineralization. By these methods Ca, Cd and S were the most useful elements, supplemented by U and W in the aqua regia digestion.

### **Observed geochemical patterns in the context of the reduced column model**

The geochemical patterns observed in both survey areas

are consistent with the reduced column (a.k.a. reduced chimney) model originally proposed by Hamilton (1998, 2000). In this model (Figure 34) reduced cations are transported upward from a sulfide-rich ore body along electrical potential gradients. Reduced cations, including Fe<sup>2+</sup>, oxidize near the surface and at the edge of the columns and generate acid which results in a low pH zone directly above mineralization. Carbonate in the soil is dissolved within this acid zone and reprecipitates over the edges of the column where pH conditions allow, thereby increasing the buffering capacity of the soil. The IDH of soil samples is a proxy for high buffering capacity and the presence of carbonates in the soil. While Hamilton’s model provides a good idea of the processes involved, it has to be borne in mind that it is an idealized model. In the present study, the mineralization is of porphyry style which commonly has no sharply defined edges. Outside the actual mineralization, pyrite and low levels of chalcopyrite or sphalerite may still be present and pyrite oxidation will influence the cation flux. Likewise, heterogeneous overburden, groundwater and topography will have an influence on the surface geochemistry above concealed mineralization. A summary interpretation of the observed geochemical pattern of Zn and Cu as well as pH and IDH loosely contextualized within Hamilton’s reduced column model is presented in Figure 35 for Deerhorn and Figure 36 for Three Firs. Note that there are a large number of additional elements not depicted in Figures 35 and 36 that show a characteristic pattern over mineralization.

At Deerhorn, the highest IDH values are observed above the eastern margin of the eastern mineralized zone, whereas it is lowest between the mineralized areas (Figure 35). It is also high near the eastern limit of the sample traverse (at site DHB021). A relative IDH low occurs between the mineralized zones. The highest Cu values in soil coincide with an IDH low between the mineralized zones but high Cu values also occur where IDH is high over basalt at the eastern end of the sample traverse and over the eastern margin of mineralization. Zinc in soils is highest marginal to, and more distal from, the mineralization compared to Cu, possibly reflecting primary metal zonation in the bedrock or the mobility of Zn at higher pH (>6) than for Cu (<5). The area between the mineralized zones is difficult to interpret because of the presence of potentially overlapping reduced columns or low grade sulfide mineralization at depth. However, elevated Zn values occur east of high Cu values at both the eastern limit of mineralization above basalt substrate and also at the end of the sample profile, east of the sample site with high Cu and IDH values (Figure 35).

At Three Firs, the soil H<sup>+</sup>, IDH, Cu and Zn geochemical patterns can be reconciled well with the reduced column model. Directly above mineralization, IDH values are low but are elevated to either side of the mineralized zone (Figure 36). Copper coincides with an IDH low and high Cu concentrations are observed above mineralization and just to the west of it. High Zn values occur marginal to the high Cu in soil and coincide with high IDH (Figure 36).

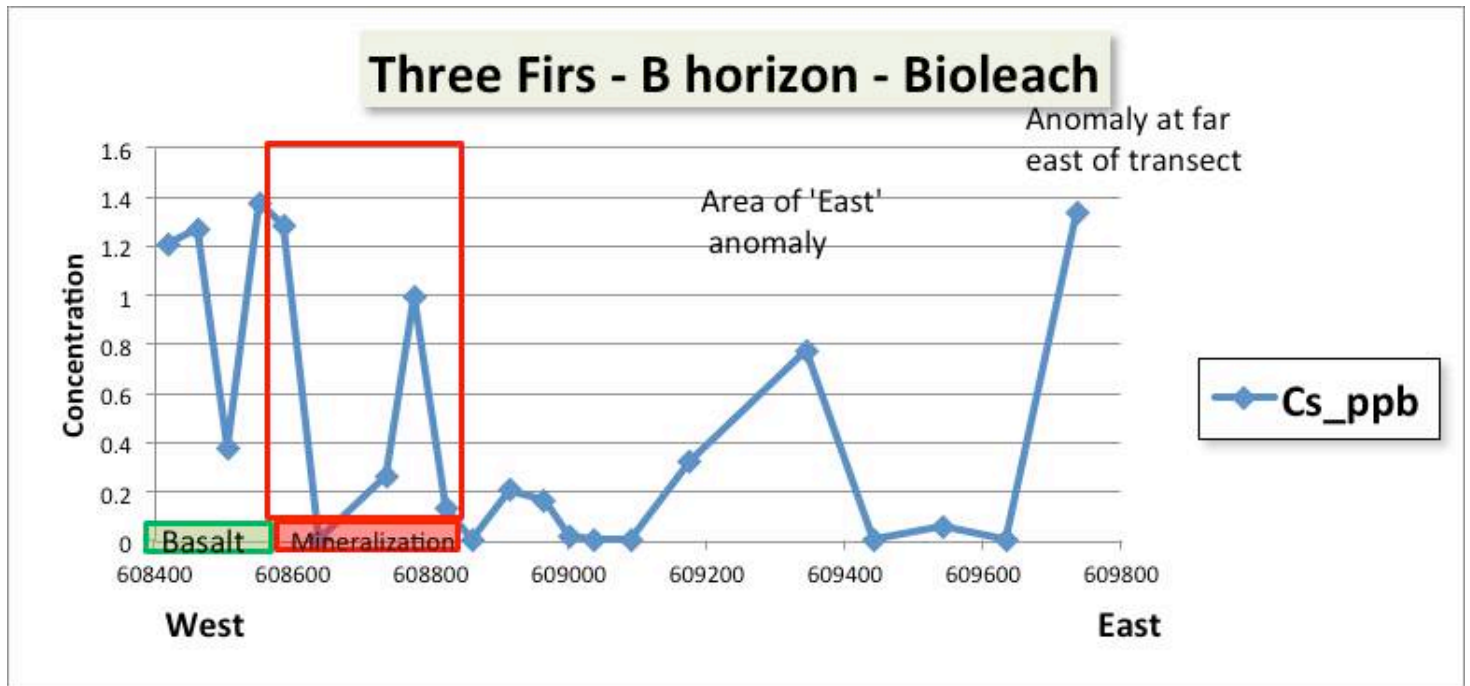
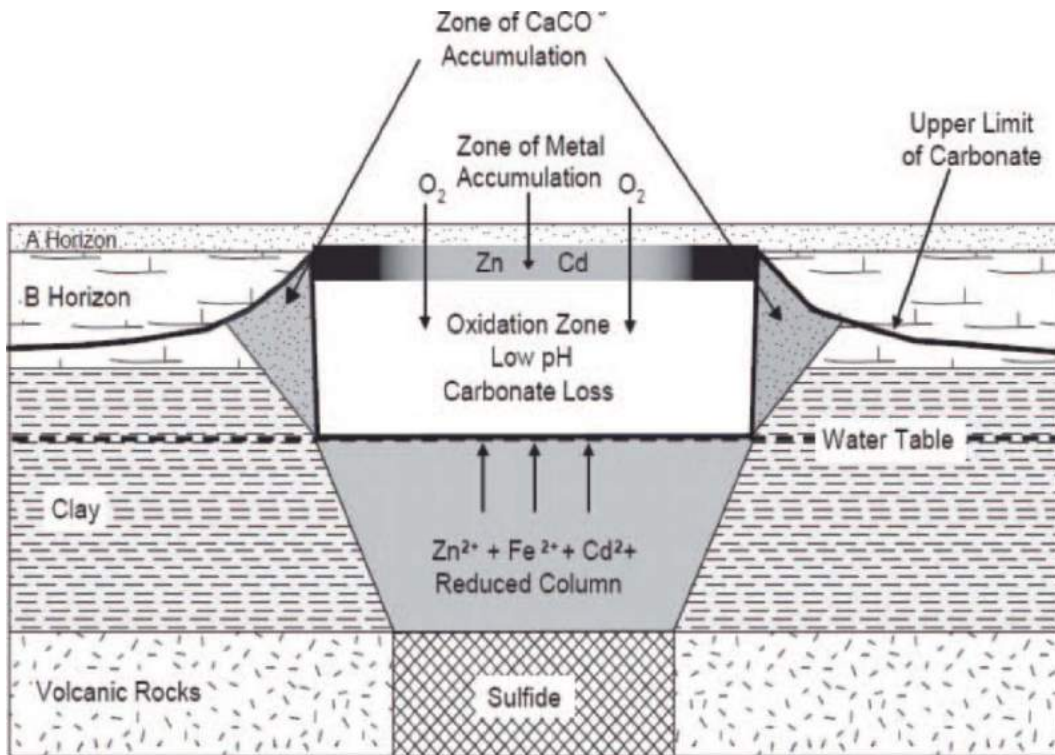


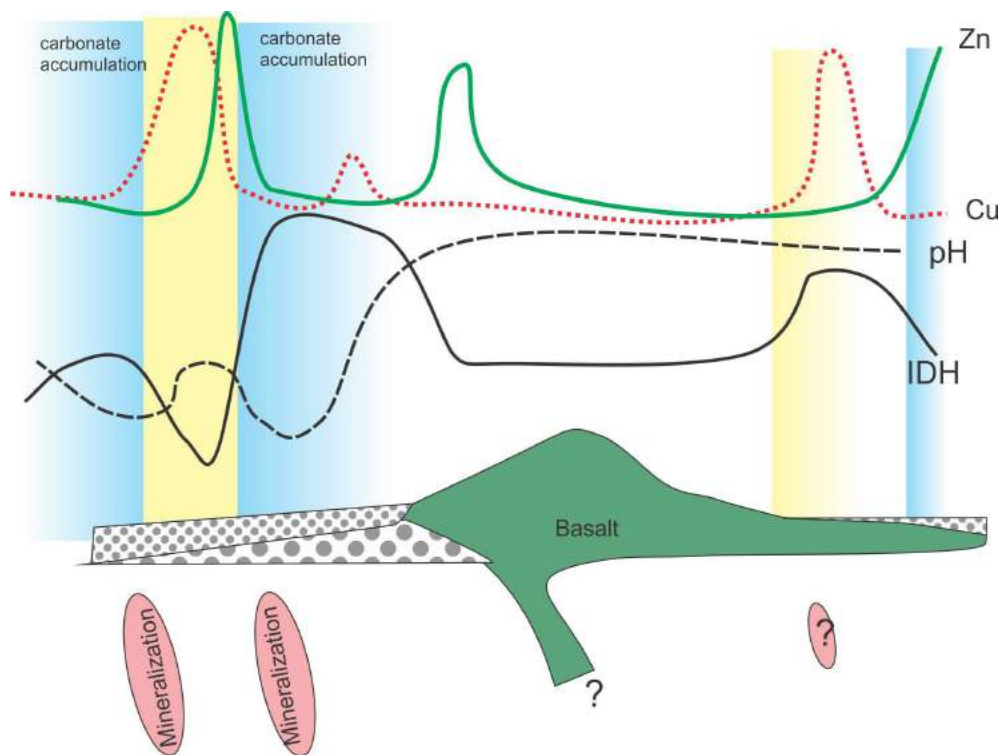
Figure 33. Example of the Bioleach response of Cs at Three Firs. The areas referred to in Table 3 are indicated.

Table 4. General summary of geochemical responses as a function of sample media and analytical method.

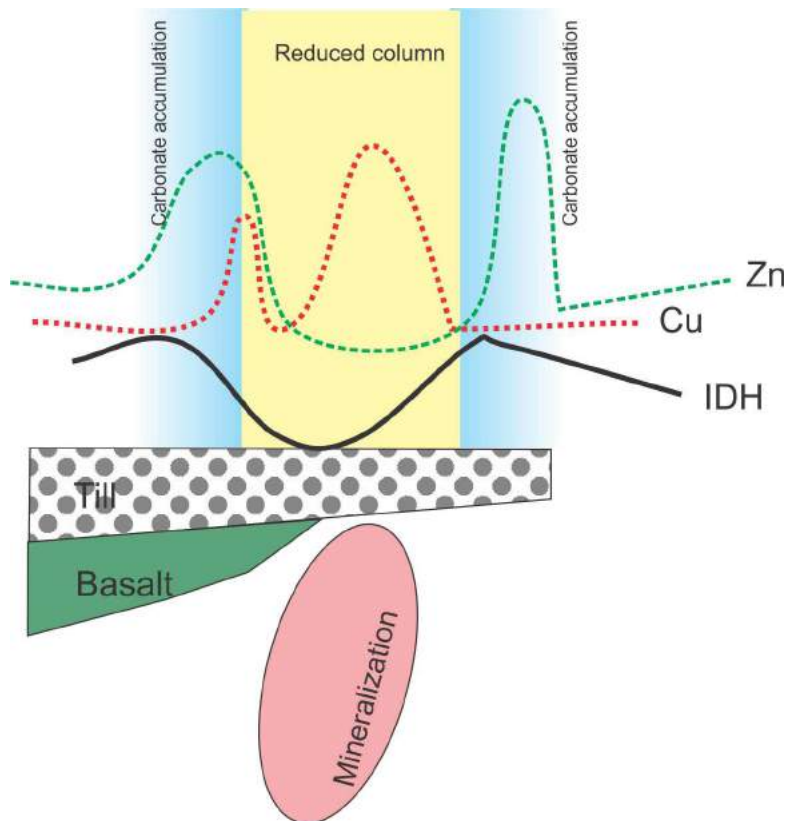
Type of anomaly over mineralization	Bioleach	Aqua regia	Total (4-acid)	Enzyme leach	Ionic leach	Spruce twigs (ash)	Spruce bark (dry)
	Total number of elements	Total number of elements	Total number of elements	Total number of elements	Total number of elements	Total number of elements	Total number of elements
Apical	17	6	3	9	1	14	1
Rabbit Ear	4	0	0	10	0	3	1
Single peak	3	0	1	0	0	0	0
Subtle, non-definitive	4	1	1	5	4	9	8
<b>Grand totals</b>	<b>28</b>	<b>7</b>	<b>5</b>	<b>24</b>	<b>5</b>	<b>26</b>	<b>10</b>



**Figure 34.** The reduced column model. Figure was taken from Cohen et al. (2010) but concept is based on Hamilton (1998, 2000). The figure shows the development of a reduced column over sulphides in transported regolith. Metals mobile under reducing conditions migrate vertically along redox gradients. Above the water table metals are oxidized, creating a zone of low pH and carbonate loss. Carbonate precipitates at the edge of the reduced column. Metals such as Zn and Cd accumulate near surface.



**Figure 35.** Interpreted section showing the geochemical pattern at Three Firs in the context of the reduced column model of Hamilton (1998, 2000). The presence of multiple ore bodies which are tilted approximately 10° - 20° to the NW (Fig. 4), makes the observed geochemical pattern more complex to reconcile with the model.



**Figure 36.** Interpreted section showing the geochemical pattern at Three Firs in the context of the reduced column model of Hamilton (1998, 2000). Note the extent under the basalt and exact orientation of mineralized body is not known.

At Three Firs the interpreted reduced column above mineralization straddles the limit between till covered and basalt + till-covered bedrock, indicating that the geochemical signal originating from an oxidizing sulfide body at depth penetrates basalt cover as well as glaciofluvial sediments. This is also observed at Deerhorn, especially with respect to Zn east of the mineralized zone. The high Cu, Zn and IDH measurements at the eastern end of the sample traverse at Deerhorn also occur over basalt but the significance of this single sample location is presently unknown.

## CONCLUSIONS

- The geochemical techniques applied in this study indicate that detection of mineralization under basalt cover is possible.
- Partial leach techniques on B-horizon soils, above all Bioleach, but also Enzyme Leach, Ionic Leach and to a lesser extent aqua regia digestions gave good contrast anomalies in soils attributable to concealed mineralization. In this context, elements that yielded compelling anomalies over mineralized areas in B-horizon soils at Deerhorn, Three Firs or both include: As, Cu, Zn, Ni, Se, W, Ag, REE, Tl, In and others.
- Results from more aggressive leaches (4 acid, aqua regia) are influenced by the type of cover (e.g., basalt vs. glaciofluvial sediment). The 4 acid technique can help

in delineating geological units but is not the method of choice for detecting mineralization.

- Soil  $H^+$ ,  $H^+a$  and EC data are generally consistent with the soil geochemistry. IDH values are relatively low directly above mineralization and high at either margin, defining rabbit ear anomalies.
- In general, spruce bark and twig geochemistry yield more subtle, but still interpretable results compared to the soil geochemical data. The alkali metals Rb, Cs and K produce the most compelling signals. They are elevated above mineralization and are interpreted to reflect potassic alteration which is genetically and spatially closely related to porphyry style Cu-Au mineralization. At Three Firs elevated Rb and Cs occur over basalt cover and suggest the presence of potassic-altered rocks underneath.
- Given that Chilcotin group basalts are vesicular and commonly affected by columnar jointing, it is reasonable to assume that they are conduits for vertical ion transport from an oxidizing sulfide body at depth. Limited data suggest that amygdules in basalt can record underlying mineralization.

## RECOMMENDATIONS AND LIMITATIONS

The geochemical response of B-horizon soils and plants are strongly dependent on the climatic conditions, surface materials, soil maturity and physiography. The results suggest

that geochemical exploration for mineralization under basalt cover is potentially viable. Some aspects of the current study require follow-up work. Further sampling and analytical work on amygdale geochemistry would be necessary for proper evaluation of that sample medium. Further B-horizon soil sampling over basalt covered areas NE of Deerhorn in conjunction with evaluation of other geological data is recommended. Currently there is only subtle indication that mineralization may be present under the basalt cover in that area. A higher sample density is also needed to properly evaluate the SGH and OSG methods.

Each analytical method and sample medium has its own strengths and weaknesses. Soil pH and EC measurements can be made in the exploration camp and provide a dataset capable of identifying potential sulfide mineralization under the cover. Sampling for this method is quick and only a small amount of material from the Ae or top of the B-horizon (if Ae-horizon is not present) is needed.

B-horizon soils if analysed using partial leach techniques work well for the identification of trace element anomalies related to mineralization. Partial leach techniques, above all, Bioleach and Enzyme Leach, but also aqua regia gave the best results in this study. Aggressive 4 acid near total digestion, while of limited use for detecting anomalies related to mineralization, may work well for defining the extent of geological units. Plant geochemistry promises rapid identification of potassic alteration zones and some commodity elements under cover as well definition of the distribution of some geological units.

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## APPENDIX: COMPARISON OF MMI AND OTHER PARTIAL LEACH METHODS

As part of the project “Seeing through Chilcotin basalts: the geochemical signal of what is hidden under-neath (092P, 093A, C)”, and in addition to the sample traverses discussed in the report, 27 samples have been collected for Mobile Metal Ion (MMI) analysis. None of these sample locations are in basalt covered areas (Figure A1), and for that reason the MMI results are only presented in this appendix to the report. Figures A2 and A3 present a comparison of MMI with Bioleach, Enzyme Leach and Ionic Leach results for Cu, Zn, Ni, Cs and Rb. Figure A4 presents the MMI results for Au and Ag. The reader is encouraged to explore also the digital data files provided with this report.

## RESULTS

The sample traverse is characterized by a swampy area where the soils were clay rich and water saturated, which had a significant effect on soil geochemistry through the hydromorphic addition of a number of elements. In all partial leach methods the values of Ni and Cu are by far the highest in the swampy area (Figure A2), whereas Zn is only elevated in the Bioleach and Enzyme leach results (Figure A2). Overall, the Cu, Zn and Ni signals above mineralization are subtle. Zinc shows elevated values above mineralization in the Ionic Leach and Bioleach data but also at the western limit of the sample traverse, whereas the Enzyme leach results for Zn are ambiguous with respect to mineralization. The MMI results show elevated Zn values largely at the western extent of the sample traverse where no concealed mineralization is known (Figure A2). Copper is somewhat elevated in two samples above mineralization in the Ionic Leach results, whereas a single value in the Enzyme Leach results may be considered anomalous above mineralization (Figure A2). The MMI method yields a broad zone of elevated Cu values centered on and around the swampy area but no compelling anomaly above mineralization (Figure A2). Nickel in the MMI data is lowest above mineralization. In the other partial leach methods, with the possible exception of Ionic Leach (cf. also Figure 11 in the report), Ni is not distinctly above background (Figure A2) and, thus, is of limited use as pathfinder element in this case.

Rubidium and Cs are elements that are commonly enriched in potassic alteration zones. The analytical results for these elements are shown in Figure A3. As with Cu, Zn and Ni, the concentration of these elements seems to be strongly influenced by hydromorphic concentration in swampy areas. In the Ionic Leach, Enzyme Leach and Bioleach results the Cs and Rb concentrations are highest in the swampy area whereas no compelling anomaly has been detected above mineralization using these methods. The MMI results for Rb and Cs are distinct from the other partial leach techniques. The highest Rb concentrations do not only come from the swampy area but also from the western limit of the sample traverse. However, overall the Rb is variable and does not show an interpretable pattern.

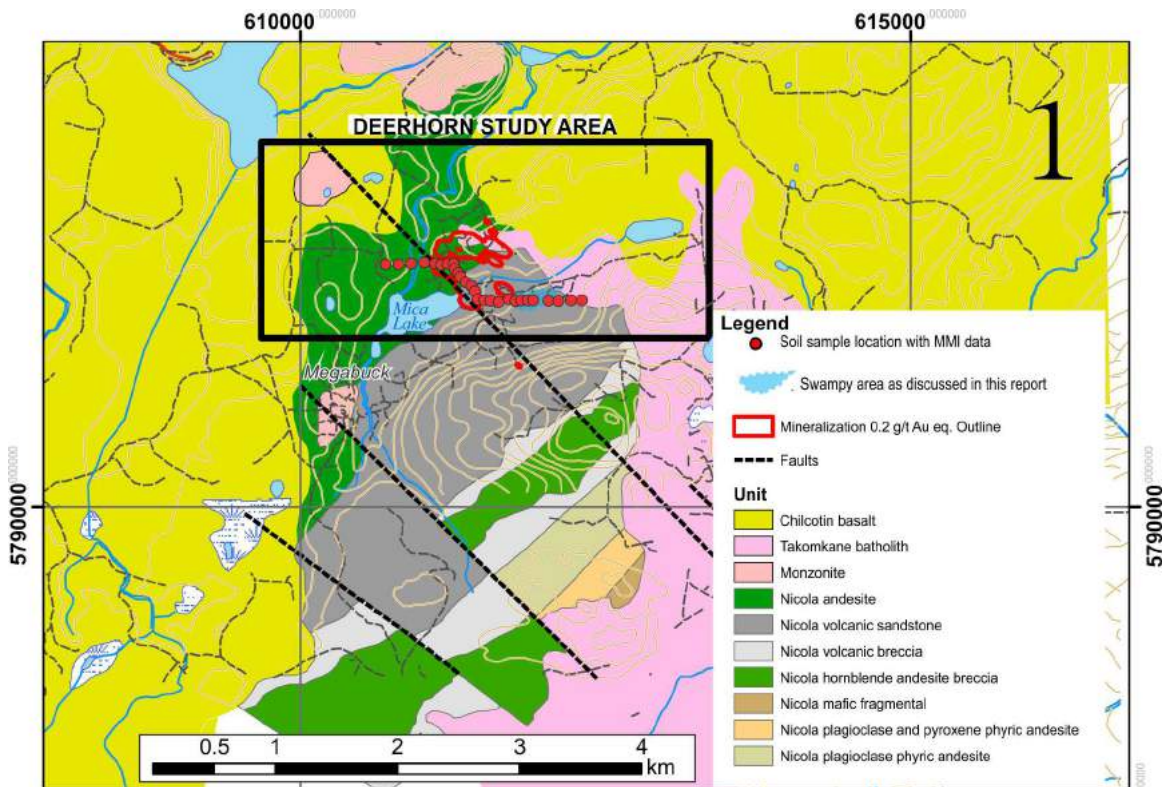
Cesium has one high value in the swampy area and one directly above mineralization with lower values in between. Somewhat elevated Cs values are also observed at the western limit of the sample traverse away from mineralization.

Gold and Ag are generally above detection limit in the MMI results but close or at LOD for the other partial leach methods. These are therefore only shown for MMI (Figure A4). The highest Au concentrations are observed in a single sample site just to the east of the mineralized zone but elevated Au values are also observed in the swampy areas. Silver is also highest just to the east of the mineralized zone and additional relatively elevated Ag values are observed above and just west of the mineralized zone. In contrast to most other elements discussed above, Ag is not particularly elevated in the swampy area. However, overall the Ag signal above mineralization cannot be considered a compelling anomaly.

## DISCUSSION AND CONCLUSION

Based on the results presented above it is evident that partial leach geochemical techniques are prone to delineating false positives in water saturated clay rich soils, which probably can be attributed to hydromorphic mobilization in those environments. This effect seems to be particularly pronounced for Cu and Ni in the MMI method. For Zn and Cu, the Ionic, Enzyme and Bioleach methods produce reasonably compelling anomalies above mineralization whereas no such case can be made for MMI. However, the latter method may be superior to other partial leaches for other elements. A subtle possible rabbit ear anomaly is shown for Ag whereas Cs is elevated above mineralization in the MMI data. Thus, it is in the realm of possibilities that the MMI method is capable of detecting Cs anomalies related to potassic alteration.

In general, the Ionic Leach, Bioleach and Enzyme Leach results are similar to each other but somewhat distinct from those from MMI. This discrepancy may be due to differences between these proprietary laboratory methods but could also be the effect of the sample medium. Samples for MMI are taken at a standard depth of 10 to 25 cm, irrespective of the soil type, whereas for the other methods the upper B or Bf horizon is targeted.



**Figure A1.** Locations of sample sites in the Deerhorn area for which MMI results were obtained (in addition to other soil geochemical datasets). Geology from Blackwell et al. (2012).

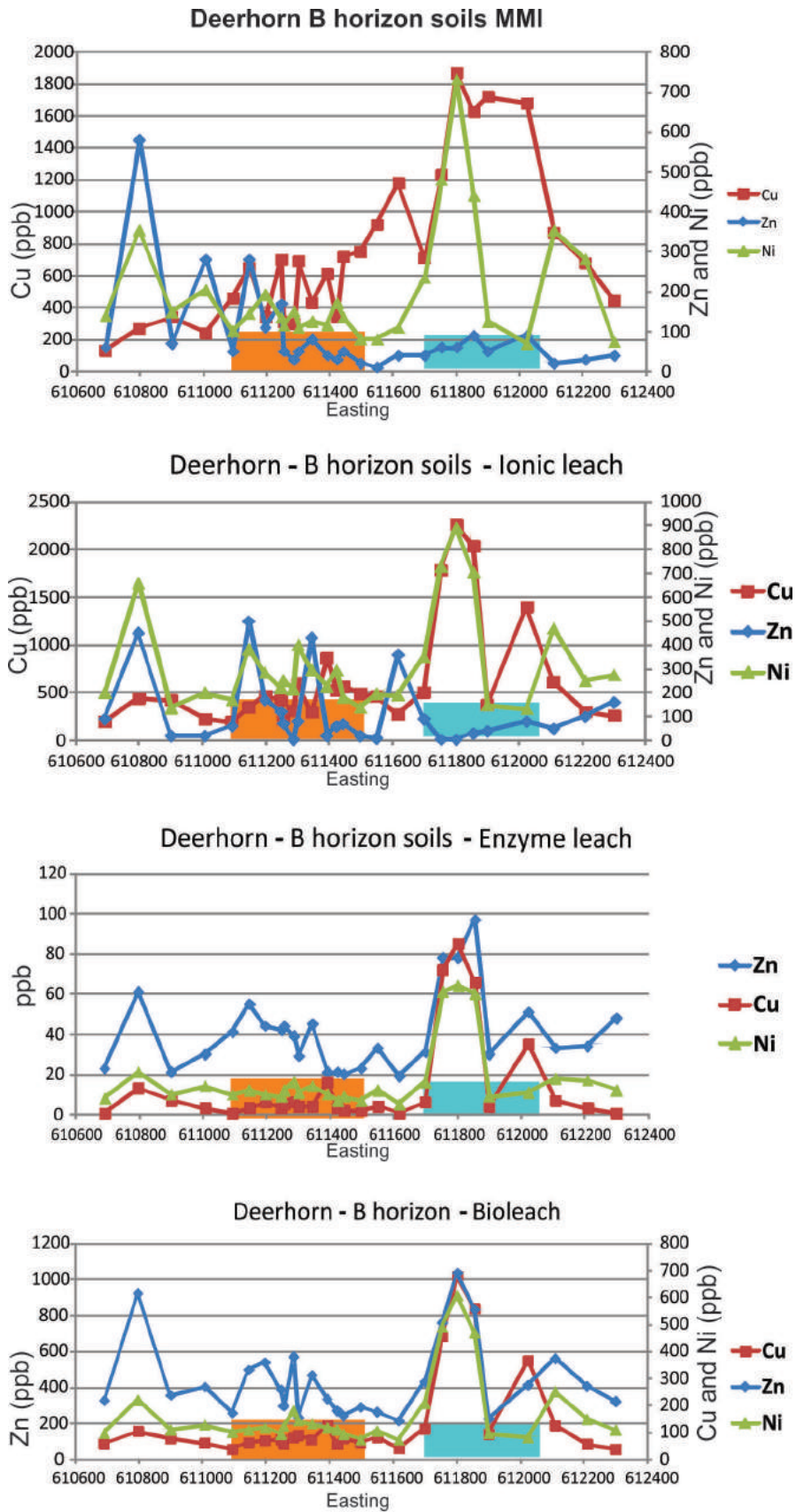


Figure A2. Comparison of analytical results for Zn, Cu and Ni using different partial leach methods.

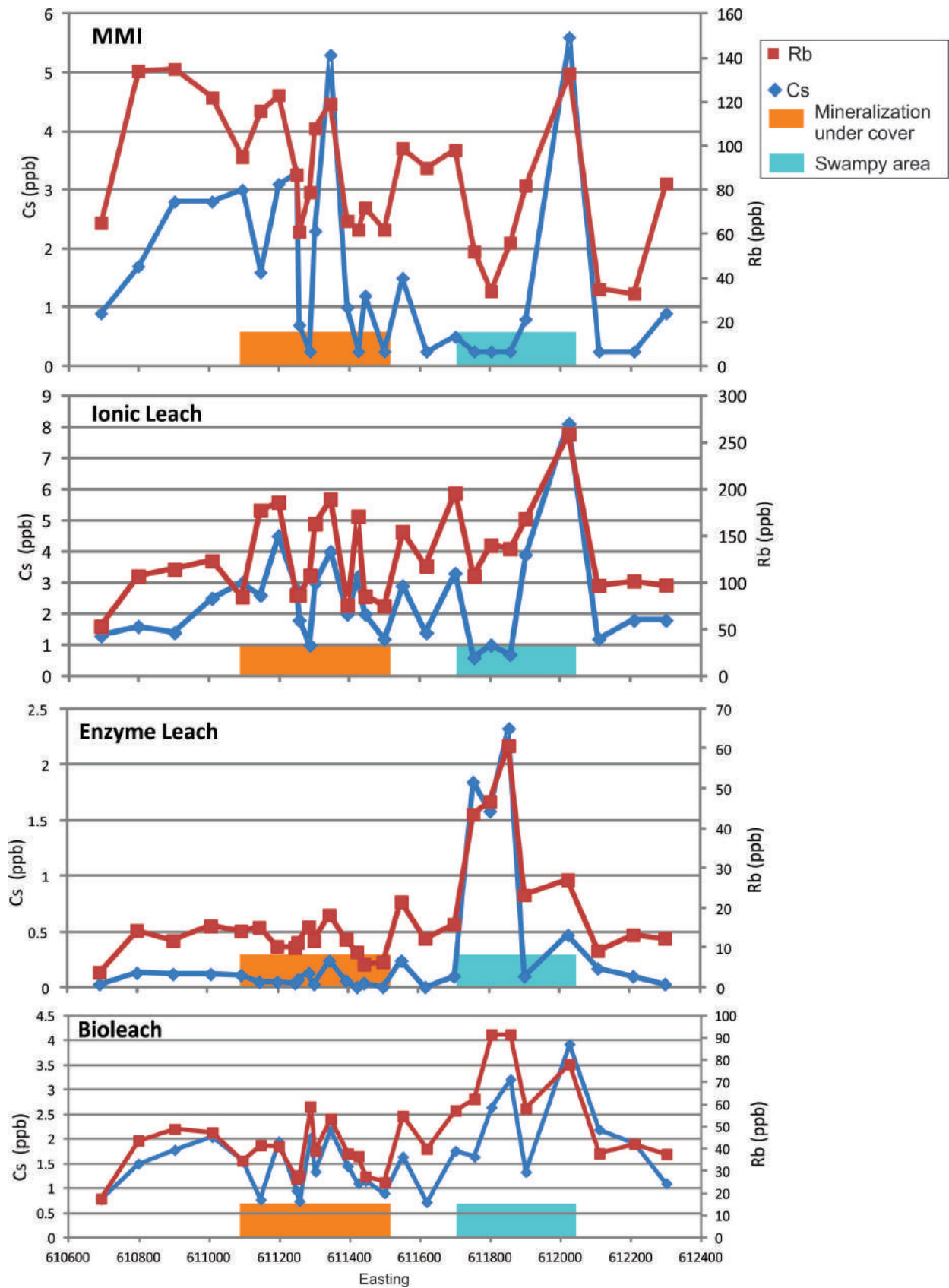


Figure A3. Comparison of analytical results for Cs and Rb using different partial leach methods.

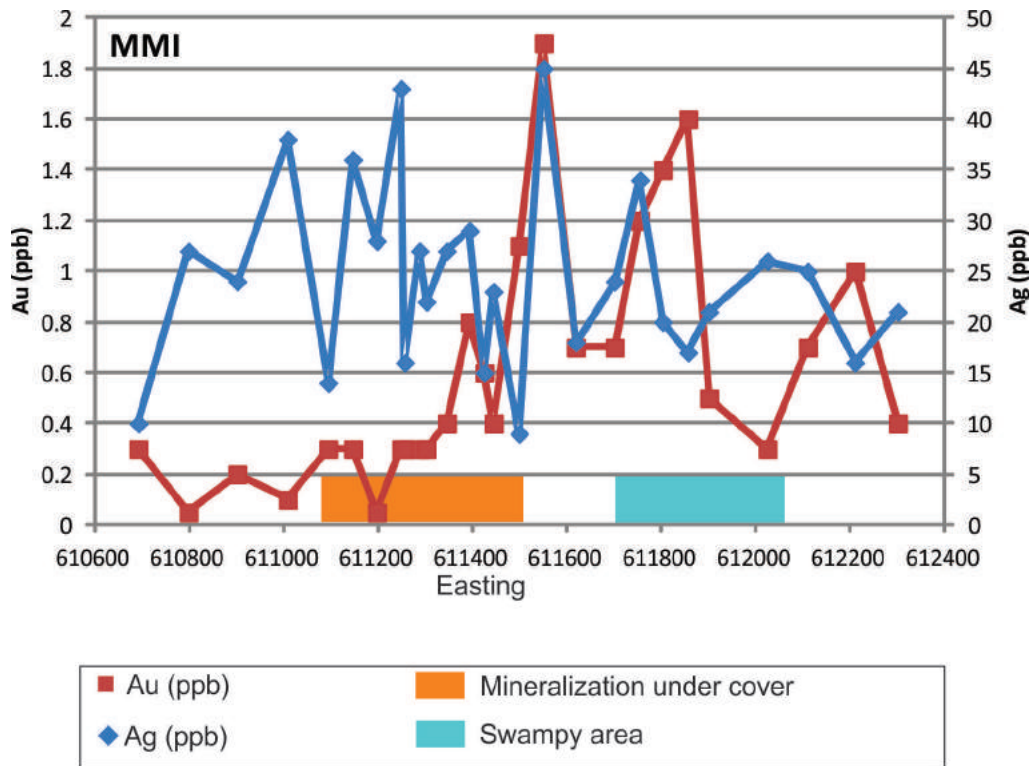


Figure A4. Gold and Ag analytical results by the MMI method.

