

Halogens in Surface Exploration Geochemistry: Evaluation and Development of Methods for Detecting Buried Mineral Deposits (NTS 093F/03), Central British Columbia¹

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INTRODUCTION

A striking feature of the current MINFILE (2005) mineral occurrence map of BC is that a significant part of central BC has very few mineral discoveries (Fig. 1). Much of this area has a cover of Quaternary deposits and/or volcanic rocks and, given the fact that it is underlain by the generally 'fertile' Quesnel Terrane, there is good reason to be optimistic that significant buried mineralization may be present. The challenge is, therefore, to develop a method for detecting mineralization hidden beneath this cover. Various geochemical selective extraction methods are steadily being refined to assist the search for buried mineralization in BC (Cook and Dunn, 2006), and the present study aims at augmenting this 'tool box' of techniques by developing some new methodology.

The halogens comprise five nonmetallic elements whose compounds form salts. The term 'halogen' means 'salt-former' and, at room temperature, they exist in all three states of matter: solid (iodine, astatine), liquid (bromine) and gas (fluorine, chlorine). However, they all form diatomic molecules that are gases at normal temperatures and pressures, and therefore are mobile and play significant roles in the atmosphere, hydrosphere and biosphere. They are the most organophilic elemental family, such that they react with organic compounds on contact and are therefore readily absorbed by plants. Of these elements, astatine is radioactive and not considered in this study. The remaining halogens are commonly associated with the emplacement of mineral deposits, as witnessed by their presence in many minerals and in the saline fluid inclusions that are typical of many mineral deposits. Their volatility renders them good candidates to examine as 'pathfinder elements' in surface geochemical media, where they may be captured on soil particles and taken up by vegetation.

Fluorine-rich minerals are characteristic of late-stage hydrothermal systems. Fluid inclusions associated with

mineral deposits are commonly rich in NaCl (e.g., ~50% NaCl in inclusions within Cu porphyries), attesting to the highly saline environment of many ore-forming processes. In recent years, fluid inclusion studies have included determinations of Br and I. Furthermore, some styles of mineralization, such as the Broken Hill Sedex deposits in Australia, have high levels of F and Cl in fluorite, apatite and amphiboles. During the degradation of these mineral deposits, whether due to the reaction with subsurface waters, subtle changes in pressure or fracturing by slight seismic activity, some of the halogen component may be released.

The high contents of Br, Cl and I in seaweed have long been known. Relatively little information is available on the distribution of these elements within and among land plants, and their relationships to mineralization have received little attention except in Russia, from where detailed information is difficult to obtain. Some published and personal observations are:

- Pine needles are good indicators of F; the standard pine needle control NIST 1575a is reported to contain an average of 389 ppm F.
- Spruce needles can contain >1000 ppm Cl (C.E. Dunn, unpublished data).
- Br levels are commonly elevated in vegetation growing over Au deposits (Dunn, 1985).
- Unpublished scanning electron microscope investigations by the senior author have revealed chlorides of potassium and bismuth formed in the trunk wood of trees growing on the epithermal Au system at Mt. Washington (Vancouver Island), demonstrating the metal complexing of halogens within plant tissues.
- Iodine enrichment occurs in plants growing over porphyry deposits (Al Ajely *et al.*, 1985).

Outside of the former Soviet Union, the halogens have been little used in mineral exploration; this is partly because of inadequate easily accessible analytical methodology for determinations at low concentrations. An account of the significance of I and Br for indicating deep ore deposits has recently been made available as an English translation of a classic Russian work (Trofimov and Rychkov, 2004). They demonstrated the exceptional migrational abilities of I and Br in different geological settings, and "show these elements to be highly effective in exploring for deeply buried endogenous ore bodies and using this technique has resulted in finding new highly prospective ore bodies...up to 1,000 m depth." They stated that "within all deposits studied, iodine and bromine occupy the position most distant from ore bodies. This extreme zonal position makes it possible to use these elements as very effective indicators of hidden ore deposits." They concluded that "sec-

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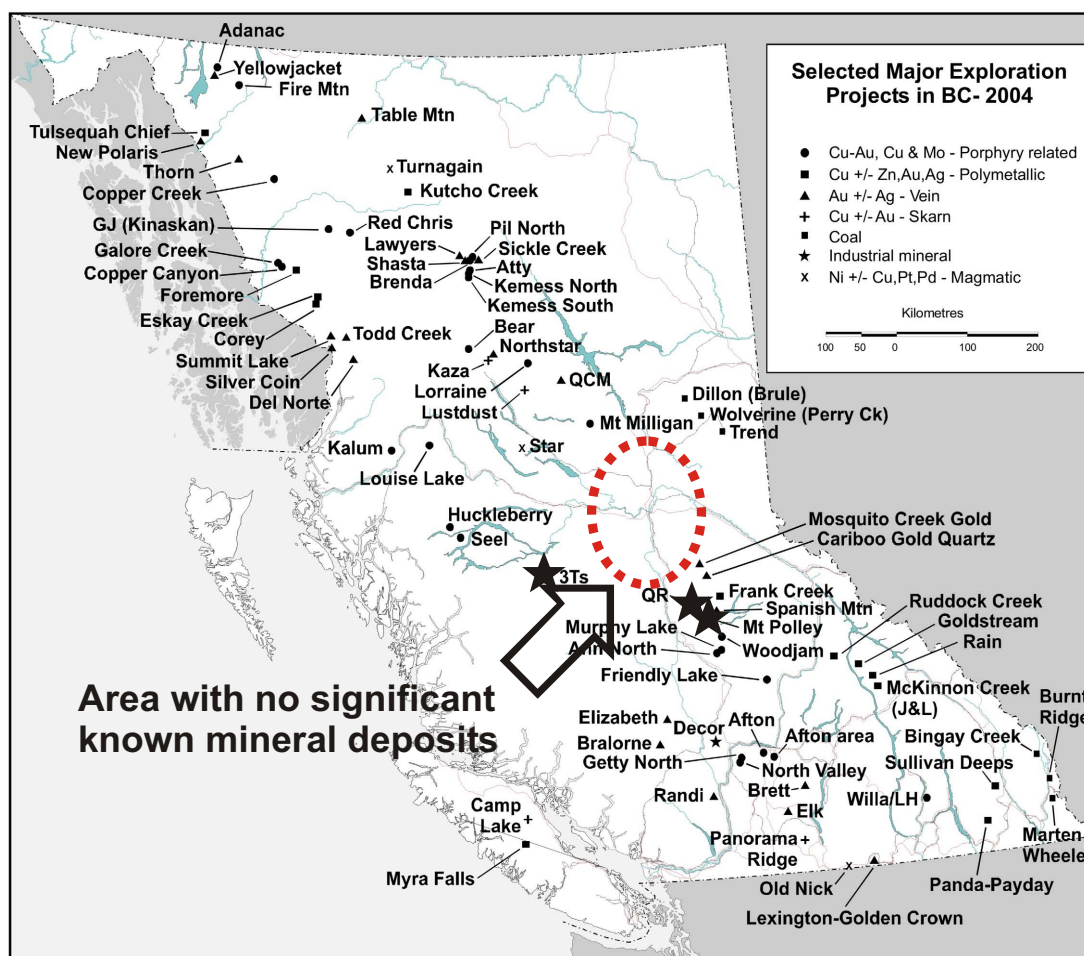


Figure 1. Area outlined for focusing on halogen geochemistry method development. Grey stars indicate areas of focused studies: Mt. Polley, QR and 3Ts. Map base from the BC Ministry of Energy, Mines and Petroleum Resources (2005).

ondary geochemical haloesare still insufficiently studied, and biogeochemical halos of these elements have yet to be found [because there are no reported studies]. These problems must be the primary focus of further studies. We must improve the analytical determinations of iodine and bromine and then transfer this understanding to the analytical instrumentation”.

FOCUS OF FIELD STUDIES

As part of a two-year program, the focus in this first year is to obtain suitable vegetation and soil samples for analysis and investigate their geochemical signatures over a range of mineral deposit styles typically found in central BC: a Cu-Au porphyry (Mt. Polley), a Au skarn (QR) and nearby Au/Mo mineralization associated with gabbro, and a Au-Ag epithermal system (3Ts). The aims are to,

- determine the geochemical response of volatile elements (halogens) to known mineralization;
- compare these responses to trace element signatures of the same samples;
- assess the potential value of halogen geochemistry to the exploration for minerals concealed by volcanic rocks and glacial deposits;

- by evaluating and comparing commercially available analytical methods, identify gaps in analytical methodology and develop new analytical techniques (in year 2) most suited to the geological and physiographic environments of central BC; and
- develop new technology and methods for passing on to Canadian analytical laboratories and to the exploration community at large.

A summary of the samples collected in each of the three survey areas is given in Table 1. This table shows that there was a considerably larger collection of vegetation samples than of soil. This is partly because two or three different plant tissues could be collected in the time that was required for collecting the soil samples and recording relevant observations, and partly because, at the time of collection, it was unknown which plant species would be the most suitable for accumulating the halogens. Russian literature has indicated that they tend to concentrate in the foliage, so the prime sample medium at each area was foliage of common species, with pine bark as a secondary collection. In view of the ease of collection of the vegetation samples, an extra minute was spent at those sites where a third species was commonly present (*e.g.*, Mt. Polley). No single species was present at all locations. Lodgepole pine was the most common species, but foliage could not be collected because

TABLE 1. SUMMARY OF SOIL AND VEGETATION SAMPLES COLLECTED AT EACH LOCATION. PRINCIPAL VEGETATION SAMPLES SENT FOR ANALYSIS ARE SHOWN IN BOLD ITALICS

Location	Areas Sampled	Soil Sites		Vegetation Sites	
		n ¹	Horizon	Species	n ¹
Mt. Polley	Boundary Zone	45	B	Western redcedar foliage	46
	Boundary Zone			Engelmann spruce outer bark	41
	Pond Zone	60	B	Subalpine fir foliage	54
	Pond Zone			Western redcedar foliage	58
	Pond Zone			Engelmann spruce outer bark	21
QR	Main and West Zones ²	0		Douglas-fir needles (crowns)²	100
	Northern extension	0		Douglas-fir needles (low branches)	10
	Northern extension			Lodgepole pine outer bark	21
	Eastern IP' transect	32	B	Engelmann spruce foliage	32
	Eastern IP' transect			Lodgepole pine outer bark	31
	Cariboo Zone	24	B	Engelmann spruce foliage	23
	Cariboo			Lodgepole pine outer bark	13
3Ts	Tommy vein transect	20	B ³	White spruce foliage	43
	Tommy vein transect			Lodgepole pine outer bark	40
	Ted vein transect	15	B ³	White spruce foliage	24
	Ted vein transect			Lodgepole pine outer bark	24

¹ excluding field duplicates

² archived samples from collection made in 1988, prior to site development

³ multi-horizon samples collected (see Cook and Dunn, 2006)

most trees were dead from mountain pine beetle infestation. Bark remained the only choice. Whereas this might have proved to be an optimal sample medium, it was desirable to obtain information on additional species (including spruce bark) because of the likelihood that millions of acres of central BC will have sparse pine populations once the dead trees have been felled.

Mt. Polley (Imperial Metals Corporation)

Located 56 km northeast of Williams Lake in central BC, the Mt. Polley mine lies between Polley and Bootjack lakes. Mineralization includes Cu-Au-Ag porphyry. The open pit Cu-Ag mine was commissioned in 1997 and ore from the Cariboo and Bell pits was mined until September 2001 when, due to low metal prices, the mine was idled. Subsequent increases in metal prices resulted in reopening of the mine in March of 2005. While the mine was closed, exploration continued and significant new zones of mineralization were discovered. Areas surrounding two recently discovered zones, the Boundary and Pond, have undergone little surface disruption and proved suitable for focusing the sampling program of the present study (Fig. 2).

Including field duplicates, 55 samples were collected north of the Boundary zone, mostly at 50 m intervals along two north-south parallel lines (100 m apart). Figure 2 shows the location of the Boundary zone and the area sampled (marked as 'Boundary zone extension'). See Figures 6–9 for detailed locations of sample sites. Sample sites extended from till-covered brecciated monzonite northward to Jurassic volcanic cover of unknown thickness. The collection, detailed in Table 1, comprised B-horizon soil, foliage of western redcedar (*Thuja plicata*)⁴ and outer bark from Engelmann spruce (*Picea engelmannii*). For simplicity, the western redcedar will be referred to as 'cedar', since this is the name commonly used by those working in the forests of BC.

At the Pond zone (Fig. 2), sampling was undertaken at 75 sites at 50 m intervals, along two parallel east-west lines 100 m apart that traverse brecciated monzonite, and mineralized Triassic basalt that hosts the monzonite. The sample collection comprised B-horizon soil and foliage of subalpine fir and western redcedar. Spruce was rare, so relatively few samples of spruce outer bark were collected (details in Table 1).

QR (Cross Lake Minerals Ltd.)

Located 58 km southeast of Quesnel, the QR is a Au skarn situated near the eastern edge of the north-westerly-trending assemblage of Upper Triassic–Lower Jurassic volcanic rocks of the Quesnel Trough (Fox *et al.*, 1987). The deposits occur in association with propylitized and carbonatized fragmental mafic volcanic rocks. Ore is associated with pyrite in stockworks and in massive basaltic tuff. Associated minerals include epidote, chlorite, anhydrite and carbonate. Gold occurs with Ag as micrometre-size particles along pyrite and chalcopyrite boundaries. Details of the geology and mineralogy are given in Fox *et al.* (1987) and Melling and Watkinson (1988).

Biogeochemical studies were conducted over the QR deposit in the late 1980s, prior to mine development (Dunn, 1989; Dunn and Scagel, 1989). Archived vegetation samples from an area now stripped of vegetation were available from the Geological Survey of Canada (GSC) to comple-

⁴ Nomenclature: In February 1988 *Thuja plicata* was designated the official tree of BC, but it is not a true cedar (genus *Cedrus*) and belongs to the cypress family. In order to avoid confusion with a true cedar, botanists spell the popular name 'redcedar' rather than 'red cedar'. Following somewhat dissimilar logic, the Douglas-fir is hyphenated, because it is not a true fir.

ment new geochemical work. This unique material offered a valuable opportunity to determine the halogen signatures prior to any mine development. The 1988 and 1989 surveys indicated a strong positive response between mineralization and Au in the vegetation (e.g., Fig. 3), at a time when the only development was drilling and some minor trenching.

This summer, a few samples of Douglas-fir foliage were collected to the north of the area shown in Figure 3. Sampling was limited, because a tailings pond now occupies the site of the Au anomaly in tree tops (Fig. 4). Furthermore, foliage from lower limbs has different concentrations of some elements compared to foliage at tree tops and, on this occasion, there was no opportunity to collect samples from the tops of the 20–40 m tall Douglas-firs.

A second area sampled was an IP geophysical anomaly to the east of the tailings pond (henceforth referred to as the IP zone), where Douglas-fir was rare (Fig. 4). It represented a target that exploration personnel from Cross Lake Minerals considered worth examining from a geochemical standpoint. Including controls, 32 sites at 50 m intervals were sampled northward along two parallel lines, set 100 m apart. Sample media were B-horizon soil, foliage from Engelmann spruce and outer bark from lodgepole pine. Six kilometres to the east of the area depicted in Figure 4, the Cariboo zone (Au, Cu, Mo associated with gabbro) was a third target. The area is not disturbed by any mining activities, and a single north-south line was sampled at 50 m intervals over a distance of 1250 m. The same sample media were collected as at the IP zone.

3Ts (Southern Rio Resources Ltd.)

Three contiguous properties, totalling 34 km², cover a bonanza-style, epithermal Au-Ag camp located approximately 120 km southwest of Vanderhoof. There is only minor disturbance of the ground. Geological details of this area are given in Bottomer (2003a, b) and Cook and Dunn (2006).

Fieldwork at 3Ts was complicated by the fact that, recently, easy access to the field area had been made impossible by decommissioning of the only good-quality trail. Minor trails required the use of all-terrain vehicles.

The Tommy and Ted Au-bearing quartz veins were the prime targets over which the sampling transects were designed (Fig. 5). In total, 46 B-horizon soil samples were collected at the same time as a significant collection of multi-horizon samples that are discussed in the paper by Cook and Dunn (2006). Vegetation was considerably easier to collect than the soil; approximately 150 samples were collected, comprising equal proportions of white spruce (*Picea glauca*) foliage and outer bark from lodgepole pine (*Pinus contorta*). Vegetation sampling extended across the Tommy vein eastward to the Ringer boulder showing, and eastward across the Ted vein to the Adrian West boulder showing.

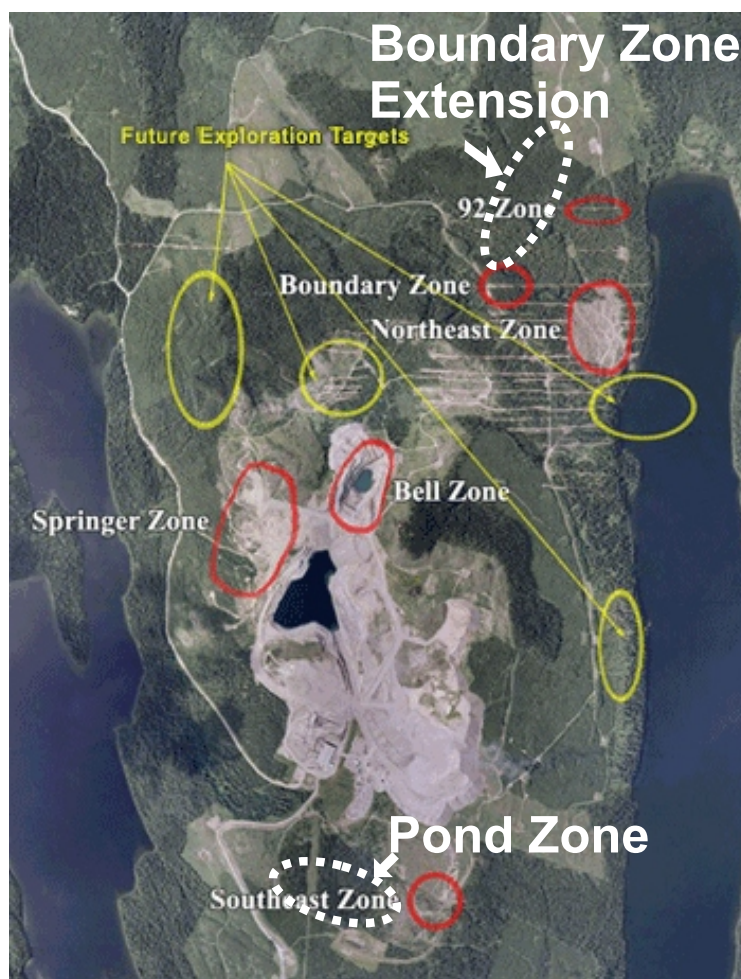


Figure 2. Locations of principal ore zones at Mt. Polley, and the two little-disturbed areas selected for this study: Boundary zone extension and Pond zone (annotated from airphoto downloaded from Imperial Metals Corporation website (<http://www.imperialmetals.com/s/ MountPolley.asp>) 28-Oct-05).

SAMPLE COLLECTION AND PREPARATION

At each sample location (mostly at 50 m intervals), a B-horizon soil was collected from the typical Brunisol profile. In addition, 4–5 samples of twigs and foliage comprising the most recent 3 years of growth were placed in a porous polypropylene bag (Hubco Sentry II) and, on most traverses where available, outer bark of lodgepole pine was scraped using a hardened steel paint scraper and a standard 'kraft' paper soil bag half-filled with the scrapings (about 50 g). Many of the pines were dead or dying because of the rampant pine beetle 'kill'. However, this was not a problem for the sample integrity and quality because outer bark scales are dead tissue even when a tree is alive.

In the laboratory, soil samples were dried at 40°C and sieved to –80 ASTM (180 µm). Vegetation samples were dried at 70°C in an oven for 24 hours to remove all moisture. The foliage could then be separated from the twigs. Each foliage and bark sample was then milled to a powder in preparation for chemical analysis.

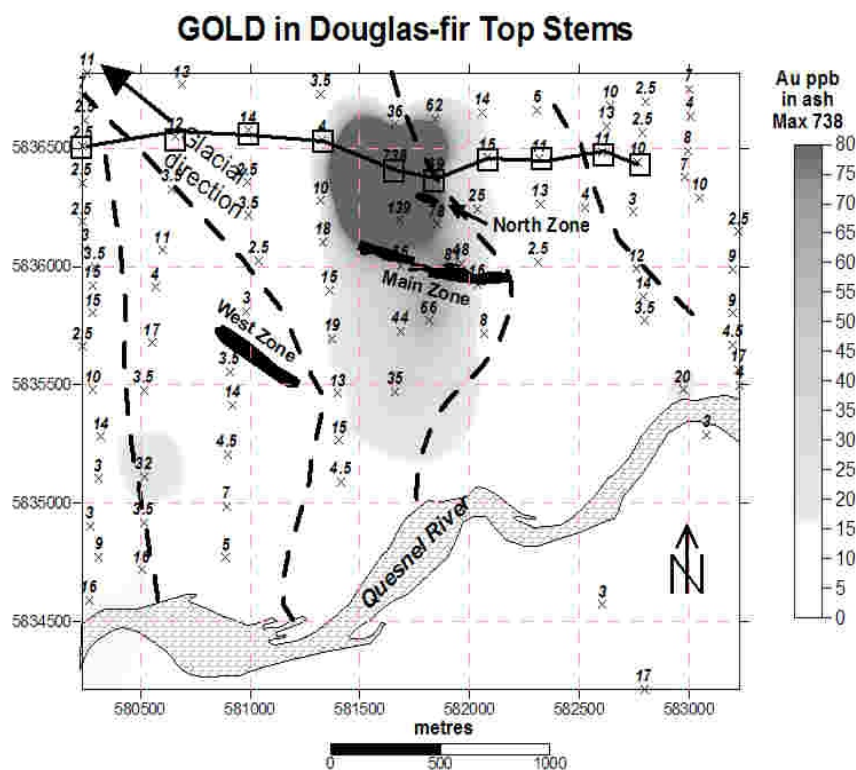


Figure 3. QR deposit: 1988 survey (Dunn and Scagel, 1989). Geological features after Fox *et al.* (1987). Deposits as known in 1988 are shown as solid black polygons. They mostly subcropped beneath the till or, as in the case of the West zone, were buried except for the northwestern and southeastern parts. Dashed lines represent faults. Sites outlined by linked squares indicate those selected as test samples for halogens in needles. Five pine bark samples (not shown) selected for testing were from a 500 m northwest-southeast traverse across the Main zone.

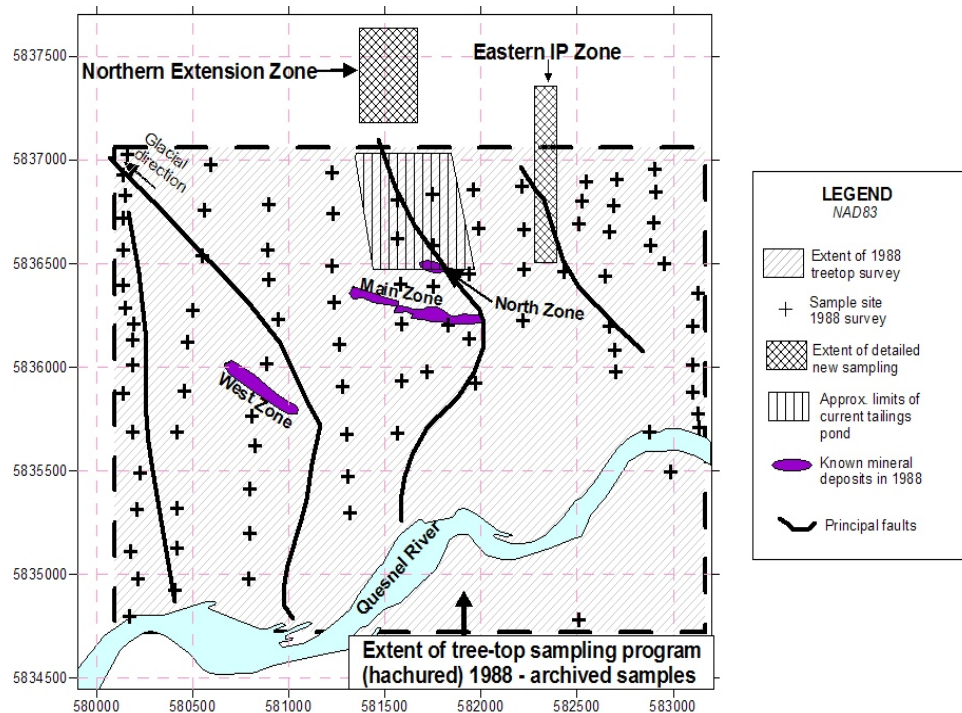


Figure 4. QR deposits: locations of the areas surveyed in 1988 and for this survey.

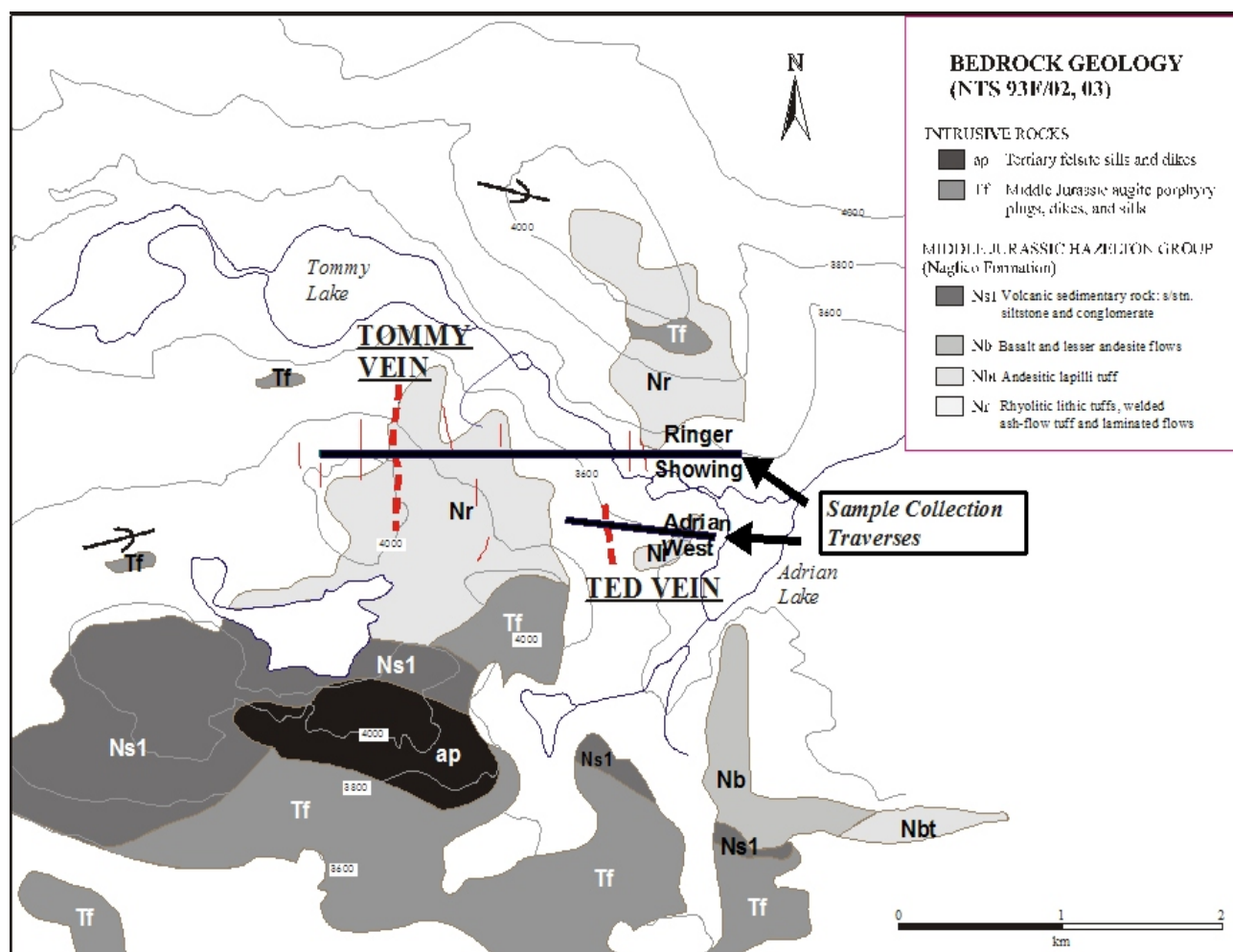


Figure 5. 3Ts: general geology, topography and location of traverses across the north-south mineralized veins and boulder occurrences (Ringer showing and Adrian West). Modified after Diakow and Webster (1994). Note that the soil sampling extended only over the western half of the traverse across the Tommy vein. Note also that unit Tf has recently been dated by Jim Mortensen to be a Late Cretaceous microdiorite intrusion (L. Bottomer, pers. comm., 2005).

ANALYSIS OF TEST SAMPLES

In order to ascertain the optimal analytical method for the halogens, a set of 35 test samples was selected for analysis by several laboratories using a variety of methods. In the final selection of the method by which all of the newly collected samples would be analyzed, consideration was to be given to both the appropriate level of sensitivity and the cost of analysis.

The vegetation test samples were Douglas-fir (*Pseudotsuga menziesii*) needles and lodgepole pine (*Pinus contorta*) outer bark collected in 1988 and 1989 from the vicinity of the QR deposit and archived at the Geological Survey of Canada in Ottawa. Ten samples of needles and five samples of bark were chosen from sites that spanned the Au biogeochemical anomaly (Fig. 3). In addition, five vegetation controls of known composition were included. They were two samples of V6, a composite of pine twigs and needles developed in 1990 by the senior author using CANMET facilities; two samples of CLV-2, CANMET spruce needles (certified values); and one sample of V13, mountain hemlock needles developed recently by the senior author and Acme Analytical Laboratories Ltd.

The suite of archived samples represented suitable test material in that prior analysis had shown there to be elevated levels of Au in these samples from sites over or adjacent to known Au deposits (Fig. 3). Furthermore, some halogens have been shown to accumulate in foliage, and some limited halogen data (Cl and Br) were available for V6. Nothing was known about the halogen content of bark; however, since bark is known to accumulate many metals that are surplus to plant metabolism, the tests should determine if this would be a suitable sample medium for the halogens.

No appropriate soils were available from over known mineralization, so tests were performed on five splits each of GSC controls that had certified values for many elements. They were STSD-1 and STSD-4 (both stream sediments), and TILL-4.

Table 2 lists the suite of methods for which analyses were requested at various Canadian laboratories. At that time, it was not known if optimal results would be from a total halogen analysis (e.g., INAA or XRF) or from an analysis involving a partial extraction (e.g., leaching by water or pH-controlled ammonium acetate). With regard to the vegetation, it was considered that a partial extraction might yield similar results to a 'total' analysis, because of the high

solubilities of the halogens. However, for soil, there may be greater differences, because some halogens may be structurally bound in crystal lattices and therefore not readily extracted by a weak leach (*e.g.*, Cl in biotite and amphiboles; F and/or Cl in apatite). However, since the objective of this program was to investigate the distribution of halogens that might be derived from concealed mineralization, it was the labile (readily leached) portion of any halogens that would be of principal interest, and not the structurally bound halogens.

Subsequently, portions of each sample were sent to Activation Laboratories Ltd. in order to test the potential suitability for halogen determinations by high resolution ICP-MS of several experimental methods currently being developed.

RESULTS

Halogens

At the time of writing, most of the data on the test samples have been received and results indicate some significant complications with regard to obtaining consistent and accurate data. Some data sets are clearly inadequate and/or inaccurate, emphasizing the need to develop appropriate analytical methodologies.

For example, for the vegetation, total F obtained by one method yielded concentrations of 60–80 ppm F, whereas values obtained by another method were <10 ppm F; furthermore, analysis by a partial (water) leach returned values for the same samples mostly in excess of 1000 ppm F. Alchemy at its best! A selection of these differences is shown in Table 3.

In the analysis of vegetation samples by ion chromatography (Dionex), F⁻ is the first halogen to be evolved. Whereas it may appear that F⁻ gives a clean positive signature, a variety of unknown organic compounds greatly en-

TABLE 2. SELECTION OF ANALYTICAL METHODS TO BE UNDERTAKEN AT VARIOUS LABORATORIES ON 20 SAMPLES OF MILLED VEGETATION AND 15 SOIL SAMPLES

INAA:	epithermal neutron activation for Cl, Br and I
ICP-MS	water leach: approximately 50 elements
ICP-MS	ammonium acetate pH 7 leach: approximately 50 elements
ICP-ES	water leach: 10 elements
ICP-ES	ammonium acetate pH 7 leach: 10 elements
Ion chromatography	water leach: all available anions
Ion chromatography	ammonium acetate pH 7 leach: all available anions
F_{water leach}	selective ion electrode
Cl_{water leach}	selective ion electrode
F_{fusion} (Teflon bomb)	selective ion electrode
Enzyme LeachSM:	full suite of elements including I, Br and semiquantitative Cl
XRF (high resolution):	halogens

TABLE 3. VEGETATION SAMPLES ANALYZED FOR F BY SEVERAL DIFFERENT METHODS AT DIFFERENT LABORATORIES. NO CERTIFIED VALUES AVAILABLE FOR THE CONTROLS

	Lab A1	Lab A2	Lab A3	Lab B	Lab C	Lab D
Sample	Dionex (IC)	Sel. Ion	NaOH	Dionex (IC)	Dionex (IC)	XRF
	Water Leach	Electrode	Fusion	Water Leach	Water Leach	Total
	F (ppm)	Water Leach	Total	F (ppm)	F (ppm)	F (ppm)
	F (ppm)	F (ppm)	F (ppm)	F (ppm)	F (ppm)	F (ppm)
DFN_04	1241	0.36	<10	27.2	1380	75
DFN_08	1529	0.34	20	35.1	1776	
DFN_14	1324	0.2	<10	26.6	1476	78
DFN_22	839	0.24	<10	24.5	1168	86
DFN_33	1383	0.15	<10	16.3	1613	63
DFN_45	1429	0.23	<10	45.5	1623	72
DFN_60	1121	0.21	<10	26.2	1255	72
DFN_65	1253	0.15	<10	32.8	1393	68
DFN_70	1616	0.19	<10	17.6	2028	65
DFN_74	1170	0.2	<10	20.2	1318	83
LP-BK-09	74	0.14	<10	15.1	124	
LP-BK-11	64	0.11	<10	18.0	109	
LP-BK-28	99	0.14			128	
LP-BK-68	63	0.09	<10	23.9	102	
LP-BK-73	88	0.22	<10	24.2	115	
Controls:						
V6	70	1.17	<10	0.75	83	96
V6	77	0.6	<10	0.92	83	81
CLV-2	774	0.34	<10	21.2	900	<25
CLV-2	1022	0.34	<10	10.9	906	80
V13	2284	0.17	<10	33.8	2666	<42

hance the presumed fluoride signature, generating a false analysis. It seems that this is a significant analytical problem that would need to be resolved.

As a consequence of results such as those shown in Table 3, samples from the field traverses have not yet been sent for analysis (October 2005). Recently received data by other methods, however, do indicate some positive associations of F and I with the locations of the Au anomaly in tree tops shown in Figure 3. Figure 6 shows selective ion electrode determinations (SIE) of fluoride in a water leach of 1 g samples of dry vegetation. From these and other data, it appears that there are typically higher concentrations of F in foliage than bark.

With regard to halogen anomalies associated with mineralization, although Figures 6 and 7 show some increased values where there are elevated levels of Au in tree tops, it should be noted that such a relationship may not always occur, depending on the nature of the mineralization, depth of burial, and fracturing of the overlying bedrock. Trofimov and Rychkov (2004) note that an I and/or Br halo may occur marginal to a halo of other pathfinder elements (e.g., As, Hg) that are themselves marginal to an ore body. As a result, the spatial relationship of the halogens may form a broad halo anomaly at the surface over a deeply buried ore deposit, with peak values surrounding the deposit. Along transects over mineralization, the appearance would be the classic 'rabbit ears' type of anomaly. These patterns will be examined when the halogen data are received.

Determinations of I in the same materials by a range of methods have generated results that are as diverse as those for fluorine. However, there is a reasonable correspondence between I determined by INAA and by enzyme leach (Fig. 7).

There was insufficient archived bark material available for running all samples by all methods; however, preliminary data from several analytical methods indicate that I is considerably more concentrated in the bark than in the foliage.

Data for Cl and Br show similar substantial variability among the various analytical methods that were tested, and neither element shows the positive response over the test traverse that was noted for F and I.

Multielement ICP-MS

Soil samples were submitted to Acme Analytical Laboratories Ltd., Vancouver, for a 53-element ICP-MS analysis by method 1F (aqua regia digestion) and pH determinations. Vegetation samples were analyzed at Acme by method 1VE-MS (nitric acid followed by aqua regia digestion). A portion of each sieved soil and milled vegetation sample was set aside for later analysis of the halogens, once a suitable method(s) had been identified.

The multielement ICP-MS results on the B-horizon soil and the principal sets of vegetation (foliage) were obtained within a few weeks of the field samples being sub-

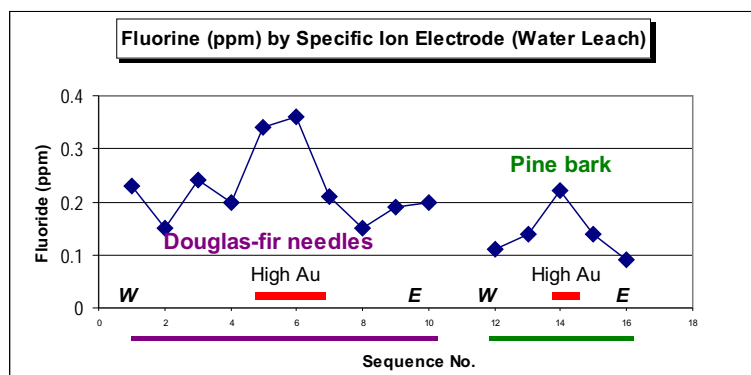


Figure 6. Concentrations of F with respect to Au biogeochemical anomalies at QR. Left profile shows dry Douglas-fir needles; right profile shows dry lodgepole pine outer bark. Samples collected in 1988 and 1989 prior to mine development. Determinations by selective ion electrode on a water leach.

mitted for analysis. The multielement data for these samples are required for comparison of the commodity elements (especially Au, Ag, Cu) with the data ultimately to be obtained for the halogens. Recently, data have also been acquired for some of the bark samples, in light of the relative enrichment of I (in bark compared to foliage) revealed from the test samples. More bark samples will be processed. To date, a total of approximately 60 000 analytical determinations have been made on the full set of field and test samples.

The quality-control and quality-assurance procedures for all samples were the same as those described in Cook and Dunn (2006). In brief, field duplicates were collected at every tenth sample site, and appropriate quality-control samples inserted at a minimum of one in every twenty samples.

An outline is presented, by mineral occurrence, of selected geochemical features of the large datasets acquired for the soil and vegetation tissues. Details will be provided in the final report that will be prepared by March 2006.

Mt. Polley

BOUNDARY ZONE

At the more northerly of the two zones studied, the Boundary zone (Fig. 2), western redcedar foliage was se-

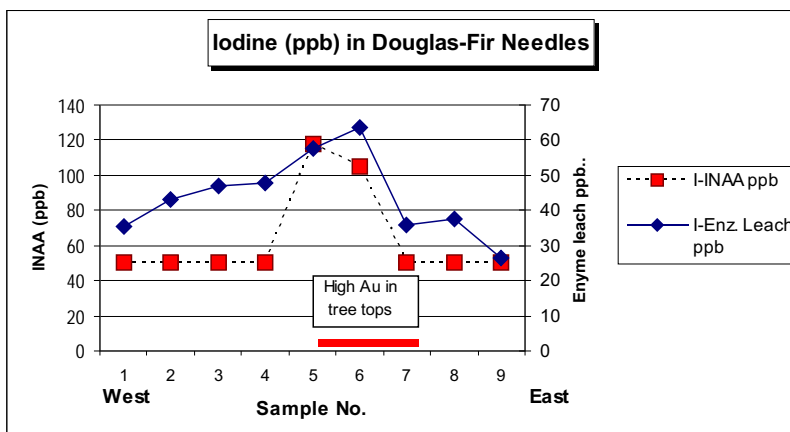


Figure 7. Concentrations of I in dry Douglas-fir needles from tree tops at QR. Comparison of results from an enzyme leach and by INAA. Detection level by INAA was 100 ppb; values below detection are shown as half detection (50 ppb).

lected as the principal vegetation sampling medium. Table 4 is a statistical summary of element concentrations in dry tissue. Table 5 shows the same statistical parameters for the soil samples.

These tables are provided for general information on element levels encountered in this environment, and serve as a yardstick against which to compare data from future surveys. In general, elements considered somewhat concentrated in the cedar foliage are Au, Cu and Mo; notable concentrations in the soil include Ag, As, Au, Cu, Hg and V.

A comparison of several commodity elements in the soil with those in the cedar foliage is instructive, in that anomalous concentrations appear at different localities (Fig. 8–11). Previous studies of concentrations in soil versus vegetation in glaciated terrain, at Beaver Dam, Nova Scotia (Dunn *et al.*, 1991) and Mt. Milligan, BC (Dunn *et al.*, 1996), have found that vegetation anomalies tend to be more directly over mineralization than the soil.

The implication from the above comparisons is that the zone of mineralization occurs in the centre of the survey area, as indicated by the vegetation, rather than farther to the south where most of the soil anomalies lie. It is considered that a significant local concentration of a metal is required in order to be reflected in the plant chemistry: there is insufficient concentration of metals in a soil anomaly (even though it constitutes a geochemical anomaly) to be reflected in the vegetation. The soil anomaly is commonly displaced by down-ice or downslope dispersion or dispersal, whereas a biogeochemical anomaly typically occurs directly over a mineralized source.

POND ZONE

Farther south, two east-west traverses were conducted over an area considered by Imperial Metals to have good potential for a continuation of the Pond zone that lies immediately to the south (Fig. 2). A short distance beyond the eastern extension of the traverses lies the Southeast zone of proven mineralization. Along these traverses, in addition to B-horizon soil samples, foliage was collected from both western redcedar and subalpine fir. The latter has been selected as the principal vegetation sampling medium for analysis, partly because this permits testing the relative sensitivity of this species, compared to the cedar from the Boundary zone, to halogen uptake.

Table 6 presents a statistical breakdown of the analysis of the subalpine fir foliage, and Table 7 gives the information from –80 mesh B-horizon soil from the same sites. Elements in the fir needles that are enriched for conifer foliage in general include Au, Cu, Zn and, most notably, Re. Notable concentrations in the soil include As, Au and Cu; Re, too, is slightly elevated in the soil.

Figure 12 presents plots of selected elements along the northernmost of the two traverses. Soil is shown on the left and vegetation on the right. Of note are the peaks at the eastern end of the line: Au, Mo and Re in both media, and Cu in soil but not in the vegetation. Copper in vegetation is anomalous in this area (background is usually around 8 ppm, and there is up to 14 ppm present), but far less so than in the west (around 300–350 ppm), where Cu is coincident with Au in the vegetation. The inference is that there are two different styles of mineralization present: a Cu, Au, Fe association with Cs, REEs and Cd at the western anomaly, which is displaced, like that indicated at the Boundary zone, about 50 m west of the principal multielement soil anomalies (Ag, Bi, Mo, Pb, Sb, Se, Te); and a second zone of Au enrichment in

the east, where the association from the soil (Co, Cr, Ni, Mg and REEs, with an associated Hg and U signature) indicates a mafic substrate. The vegetation signature is predominantly Au, Mo, Pb, Li, Rb and Re.

QR Deposit

ANALYSIS OF ARCHIVED NEEDLES FROM DOUGLAS-FIR TOPS

Analysis of the dry needle tissue confirmed and refined the original anomalies identified from analysis of the top stems (Dunn and Scagel, 1989). Previously, no data were obtained from the needles. The correspondence of the anomalies in the dry needles (Fig. 13; by ICP-MS) compared to the ashed top stems (Fig. 3; by INAA) confirms and validates the robustness of the geochemical signature, and in fact enhances the relationship of the biogeochemical signature to the subcropping mineralization at either end of the West zone. New data from the northern extension of the principal anomaly does not indicate an extension to the north. However, the multielement dataset shows that, in general, there are quite substantial differences between needles from the tree tops collected in 1988 and those from the lower branches that were collected this year. There is no systematic increase or decrease of elements that might be attributed to either contamination from mining activities or long-term natural variations in plant chemistry.

IP ZONE

Two traverses (Fig. 4) were conducted to collect soils and spruce foliage from north-south lines about 500 m east of the Main zone anomaly (Fig. 3, 13). These lines were selected because of the presence of an IP anomaly of unknown origin. A one to three-station multielement anomaly occurs in soil along one of the two transects. Element enrichments include Ag, As, Au, Co, Cu, Mo, Ni, Sb, Se, Te and traces of Pt. Data from the spruce needles do not show any significant enrichment. However, spruce needles usually only yield very subtle indications of metal enrichments in the substrate: they were selected for this project because spruce was the only common species from which foliage could be collected in this area, and because the literature has indicated that foliage is more likely than twigs to yield enrichments of the halogens. Data are pending for a set of pine bark samples.

CARIBOO ZONE

The third area of study in the vicinity of the QR deposit lies 6 km to the east. Past surveys have demonstrated that the 'Cariboo' zone has multielement soil anomalies: notably Au, As and Sb, with Mo as another zone to the north, mostly associated with gabbro. Since this area has undergone little disturbance, it was selected for a single 1400 m north-south traverse. In addition to the soil, spruce foliage and pine bark (where available) were collected. Examples of soil data are shown in Figure 14. The soil results indicate three zones of multielement enrichment involving Ag, Au, Bi, Cu and Hg, among others. The central zone is subtle with respect to Ag, Au and Bi, but has a strong Hg and Cu signature. Only the northern zone includes a Mo signature. Several ppb Pt are present at the southern end of the line.

The vegetation signatures are considerably more subtle (again, only spruce needles have been analyzed to date) and, once again, the anomalies that do occur are displaced

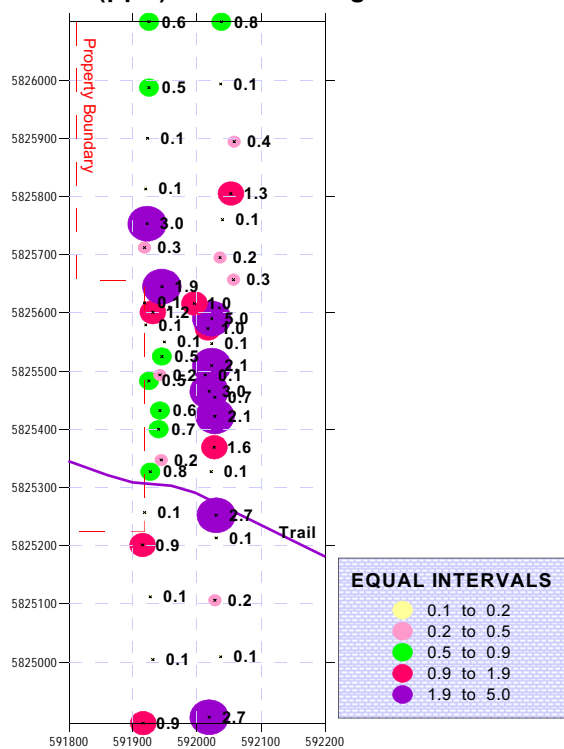
TABLE 4. MT. POLLEY BOUNDARY ZONE: STATISTICAL SUMMARY FOR ANALYSIS BY ICP-MS OF DRY WESTERN REDCEDAR FOLIAGE

Element	Units	N	Mean	Std. Dev.	Minimum	Percentiles				Maximum
						50 th	70 th	80 th	90 th	
Ag	ppb	46	3.1	1.0	1	3	4	4	4	6
Al	%	46	0.005	0.001	0.005	0.005	0.005	0.005	0.006	0.01
As	ppm	46	0.09	0.05	0.05	0.05	0.1	0.1	0.13	0.3
Au	ppb	46	0.86	1.05	0.1	0.5	0.9	1.48	2.7	5
B	ppm	46	17	4.2	11	16	18	20	23	29
Ba	ppm	46	29	15.3	6.7	25	38	44	51	63
Be	ppm	46	0.05	0.007	0.05	0.05	0.05	0.05	0.05	0.1
Bi	ppm	46	0.01	0.002	0.01	0.01	0.01	0.01	0.01	0.02
Ca	%	46	1.18	0.19	0.85	1.15	1.229	1.31	1.53	1.66
Cd	ppm	46	0.03	0.02	0.005	0.03	0.04	0.05	0.06	0.07
Ce	ppm	46	0.06	0.02	0.03	0.06	0.07	0.08	0.1	0.11
Co	ppm	46	0.06	0.02	0.02	0.055	0.069	0.076	0.083	0.1
Cr	ppm	46	2.1	0.17	1.7	2.1	2.2	2.26	2.33	2.5
Cs	ppm	46	0.02	0.01	0.007	0.016	0.02	0.022	0.035	0.065
Cu	ppm	46	5.5	1.5	2.2	5.3	5.9	6.8	7.6	11.0
Fe	%	46	0.013	0.004	0.006	0.012	0.014	0.015	0.02	0.023
Ga	ppm	46	0.05	0	0.05	0.05	0.05	0.05	0.05	0.05
Ge	ppm	46	0.006	0.002	0.005	0.005	0.005	0.01	0.01	0.01
Hf	ppm	46	0.002	0.001	0.001	0.002	0.003	0.003	0.004	0.006
Hg	ppb	46	24	6.9	14	23	27	28	33	42
In	ppm	46	0.01	0	0.01	0.01	0.01	0.01	0.01	0.01
K	%	46	0.53	0.11	0.3	0.53	0.589	0.62	0.679	0.77
La	ppm	46	0.04	0.02	0.02	0.04	0.049	0.05	0.07	0.08
Li	ppm	46	0.05	0.06	0.005	0.03	0.07	0.09	0.11	0.38
Mg	%	46	0.10	0.02	0.059	0.102	0.112	0.119	0.126	0.147
Mn	ppm	46	176	97	34	159	208	248	345	412
Mo	ppm	46	1.5	1.4	0.39	1.2	1.5	1.8	2.5	10.1
Na	%	46	0.002	0	0.001	0.002	0.002	0.002	0.002	0.003
Nb	ppm	46	0.013	0.01	0.005	0.01	0.019	0.02	0.03	0.07
Ni	ppm	46	1.4	0.7	0.2	1.2	1.6	1.8	2.2	3.6
P	%	46	0.125	0.03	0.066	0.123	0.137	0.144	0.163	0.187
Pb	ppm	46	0.11	0.08	0.05	0.09	0.119	0.12	0.14	0.58
Pd	ppb	46	1	0	1	1	1	1	1	1
Pt	ppb	46	0.5	0.14	0.5	0.5	0.5	0.5	0.65	1
Rb	ppm	46	2.4	1.6	0.6	2.05	2.88	3.3	3.9	9.5
Re	ppb	46	0.7	0.31	0.5	0.5	1	1	1	2
S	%	46	0.1	0.04	0.005	0.07	0.1	0.116	0.13	0.16
Sb	ppm	46	0.04	0.05	0.01	0.02	0.04	0.05	0.06	0.34
Sc	ppm	46	0.23	0.06	0.1	0.2	0.3	0.3	0.3	0.3
Se	ppm	46	0.17	0.05	0.1	0.2	0.2	0.2	0.2	0.3
Sn	ppm	46	0.04	0.05	0.01	0.03	0.049	0.06	0.08	0.32
Sr	ppm	46	62	24	24	60	78	86	92	117
Ta	ppm	46	0.001	0	0.001	0.001	0.001	0.001	0.001	0.002
Te	ppm	46	0.01	0	0.01	0.01	0.01	0.01	0.01	0.01
Th	ppm	46	0.005	0	0.005	0.005	0.005	0.005	0.005	0.005
Ti	ppm	46	8.2	1.5	5	8	8.9	9	10	12
Tl	ppm	46	0.01	0	0.01	0.01	0.01	0.01	0.01	0.01
U	ppm	46	0.005	0	0.005	0.005	0.005	0.005	0.005	0.005
V	ppm	46	1	0	1	1	1	1	1	1
W	ppm	46	0.06	0.04	0.05	0.05	0.05	0.05	0.05	0.3
Y	ppm	46	0.03	0.01	0.013	0.03	0.034	0.037	0.049	0.061
Zn	ppm	46	11.6	2.9	5.9	12.1	12.7	13.8	15.1	20.8
Zr	ppm	46	0.06	0.09	0.02	0.05	0.05	0.05	0.07	0.68

TABLE 5. MT. POLLEY BOUNDARY ZONE: STATISTICAL SUMMARY FOR ANALYSIS BY ICP-MS
OF -80 MESH B-HORIZON SOIL

Element	Units	N	Mean	Std. Dev.	Min- imum	Percentiles				Max- imum
						50 th	70 th	80 th	90 th	
Ag	ppb	45	262	303	35	189	248	295	565	1545
Al	%	45	2.4	0.84	1.21	2.16	2.606	2.858	3.426	6.16
As	ppm	45	6.6	3.0	2.7	5.9	7.9	8.3	10.8	15.9
Au	ppb	45	5.7	8.8	0.2	2.1	5.0	8.8	16.8	40.2
B	ppm	45	4.3	2.7	2	4	4	4	8	16
Ba	ppm	45	173	80	80	155	199	218	306	429
Be	ppm	45	0.5	0.41	0.2	0.4	0.5	0.58	0.64	3.1
Bi	ppm	45	0.15	0.12	0.07	0.12	0.14	0.15	0.21	0.83
Ca	%	45	0.54	0.252	0.24	0.47	0.58	0.67	0.90	1.37
Cd	ppm	45	0.29	0.23	0.06	0.27	0.31	0.38	0.43	1.55
Ce	ppm	45	16.3	6.4	6.5	15.4	17.8	20.5	24.7	39.3
Co	ppm	45	13.3	2.9	8.2	13.6	14.7	15.4	15.7	25
Cr	ppm	45	51	21	4.2	56	65	72	75	80
Cs	ppm	45	2.3	1.8	0.62	1.73	2.19	2.81	4.48	11.42
Cu	ppm	45	118	198	8.07	52	91	145	269	1106
Fe	%	45	3.8	0.53	2.72	3.87	4.082	4.186	4.356	5.92
Ga	ppm	45	7.4	1.7	5.1	6.7	8.1	8.5	10.0	13.8
Ge	ppm	45	-0.1		-0.1	-0.1	-0.1	-0.1	-0.1	0.1
Hf	ppm	45	0.075	0.047	0.02	0.06	0.08	0.106	0.13	0.29
Hg	ppb	45	81	91	16	45	66	106	202	469
In	ppm	45	0.03	0.009	0.02	0.03	0.03	0.03	0.04	0.06
K	%	45	0.106	0.045	0.06	0.1	0.11	0.118	0.14	0.3
La	ppm	45	9.6	4.6	3.5	8.8	10.1	11.1	14.5	28.1
Li	ppm	45	23	12.4	11.5	20	22	24	29	92
Mg	%	45	0.65	0.19	0.21	0.66	0.732	0.75	0.854	1.34
Mn	ppm	45	670	330	323	604	782	879	1040	1932
Mo	ppm	45	1.09	0.88	0.2	0.72	1.29	1.56	2.38	4.01
Na	%	45	0.011	0.004	0.006	0.01	0.013	0.014	0.016	0.028
Nb	ppm	45	0.8	0.25	0.2	0.79	0.88	1.01	1.17	1.45
Ni	ppm	45	28	14	3.1	31	35.2	38.3	42.8	73.3
P	%	45	0.122	0.073	0.026	0.105	0.156	0.178	0.217	0.422
Pb	ppm	45	10.5	13.2	4.91	7.14	9.5	11.7	14.9	94.3
Pd	ppb	45	-10		-10	-10	-10	-10	-10	-10
Pt	ppb	45	-2		-2	-2	2	2	2	2
Rb	ppm	45	10.6	3.1	6.3	10	11	12	13	25
Re	ppb	45	-1		-1	-1	1	1	1	2
S	%	45	0.002	0.014	-0.01	-0.01	0.01	0.01	0.02	0.04
Sb	ppm	45	0.26	0.1	0.14	0.24	0.26	0.3	0.44	0.58
Sc	ppm	45	4.6	2.4	2.6	4.1	4.74	5.08	6.18	18.4
Se	ppm	45	0.2	0.2	-0.1	0.1	0.2	0.3	0.64	0.7
Sn	ppm	45	0.5	0.10	0.3	0.5	0.5	0.5	0.6	0.8
Sr	ppm	45	56	21	26.2	51	59	64	86	127
Ta	ppm	45	-0.05	0	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05
Te	ppm	45	0.025	0.04	-0.02	0.02	0.04	0.058	0.09	0.11
Th	ppm	45	1.95	0.82	0.7	1.8	2.12	2.5	2.92	5.5
Ti	%	45	0.10	0.03	0.073	0.1	0.1	0.1	0.2	0.2
Tl	ppm	45	0.06	0.04	0.04	0.05	0.05	0.06	0.064	0.27
U	ppm	45	0.57	0.39	0.3	0.5	0.5	0.6	0.82	2.8
V	ppm	45	113	20	67	117	124.4	128	137.8	155
W	ppm	45	0.09	0.17	-0.1	0.1	0.1	0.2	0.2	0.9
Y	ppm	45	4.8	5.8	2.1	3.2	3.9	4.8	6.6	37.2
Zn	ppm	45	100	30	53	94	121	130	142	176
Zr	ppm	45	3.75	2.16	1.5	3.2	3.62	5.32	6.9	11.9
pH		45	5.47	0.5	4.4	5.4	5.7	5.8	6.24	6.7

**Mt. Polley, Boundary Zone
GOLD(ppb) - Cedar Foliage**



**Mt. Polley, Boundary Zone
GOLD (ppb) - B-Horizon Soils**

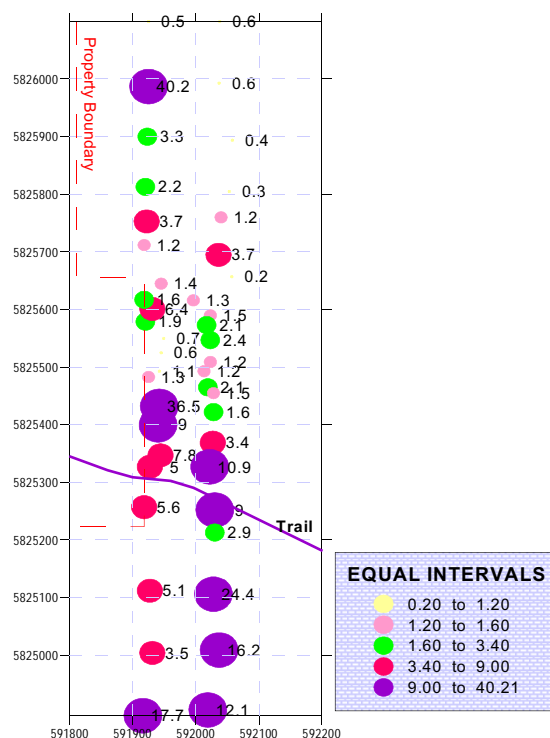
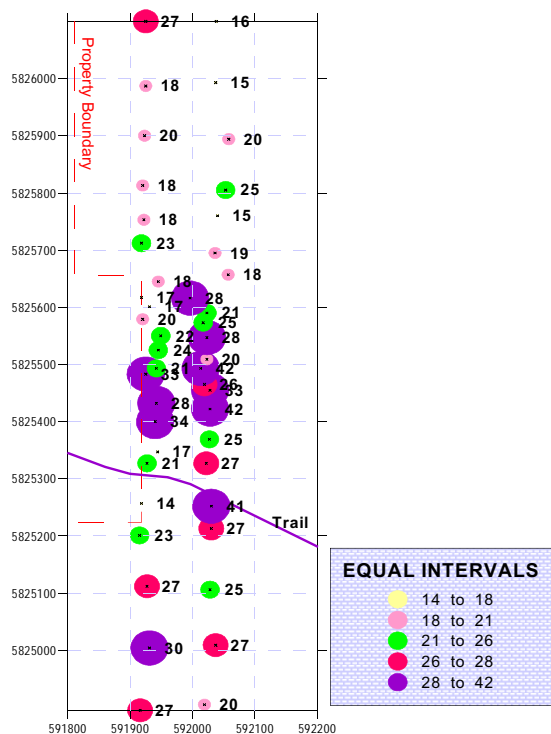


Figure 8. Mt. Polley Boundary zone: Au in dry cedar foliage compared to B-horizon soil.

**Mt. Polley, Boundary Zone
MERCURY (ppm) - Cedar Foliage**



**Mt. Polley, Boundary Zone
MERCURY(ppb) - B-Horizon Soils**

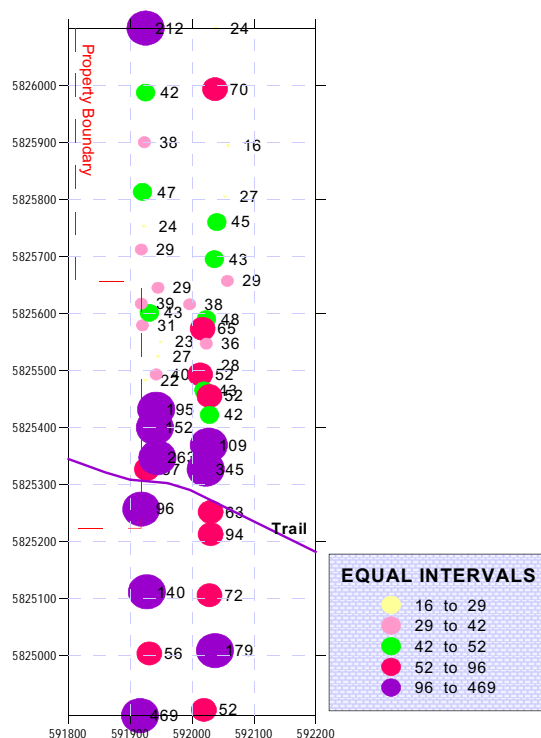
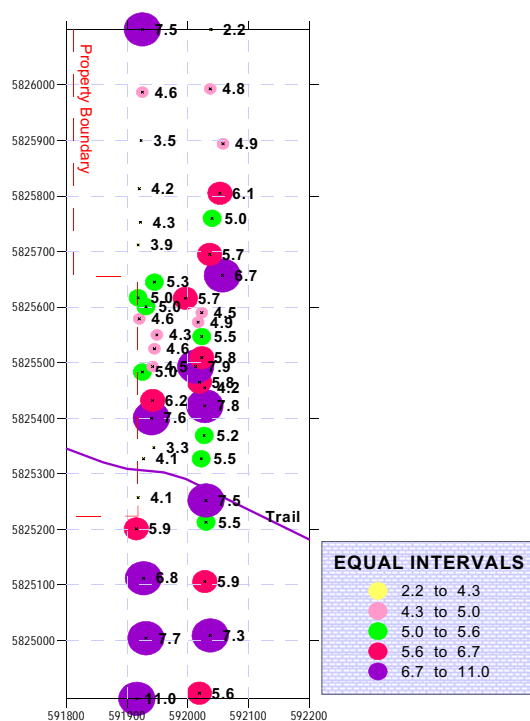


Figure 9. Mt. Polley Boundary zone: Hg in dry cedar foliage compared to B-horizon soil.

**Mt. Polley, Boundary Zone
COPPER (ppm) - Cedar Foliage**



**Mt. Polley, Boundary Zone
COPPER (ppm) - B-Horizon Soils**

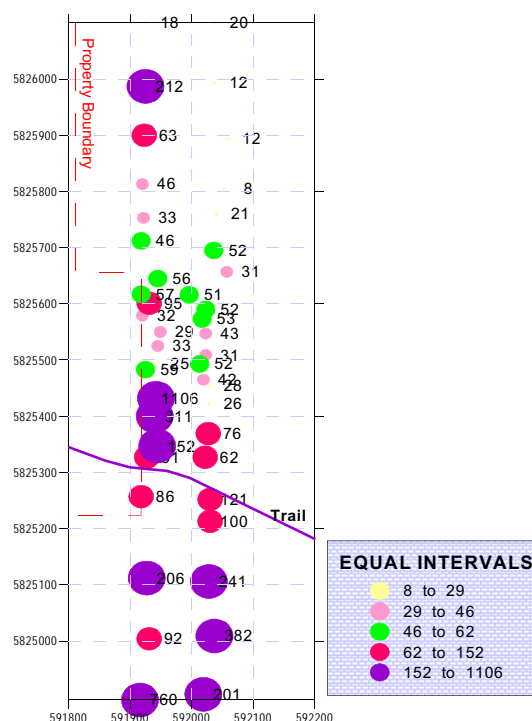
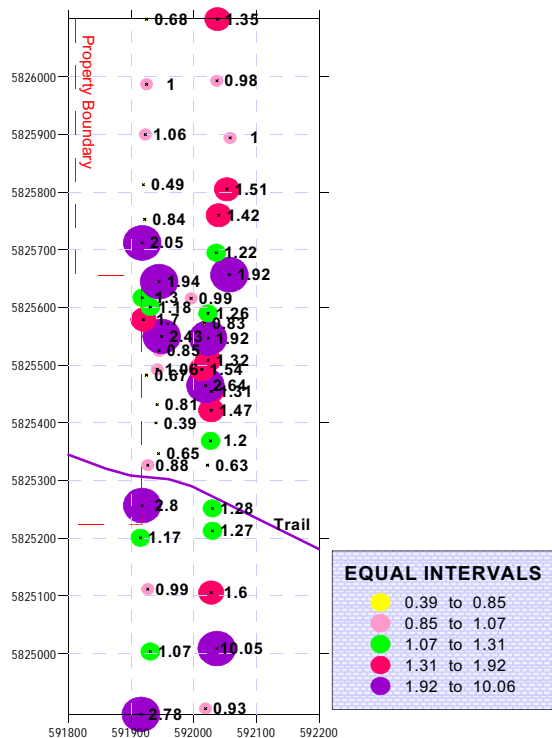


Figure 10. Mt. Polley Boundary zone: Cu in dry cedar foliage compared to B-horizon soil.

**Mt. Polley, Boundary Zone
MOLYBDENUM (ppm) - Cedar Foliage**



**Mt. Polley, Boundary Zone
MOLYBDENUM (ppm) - B-Horizon Soils**

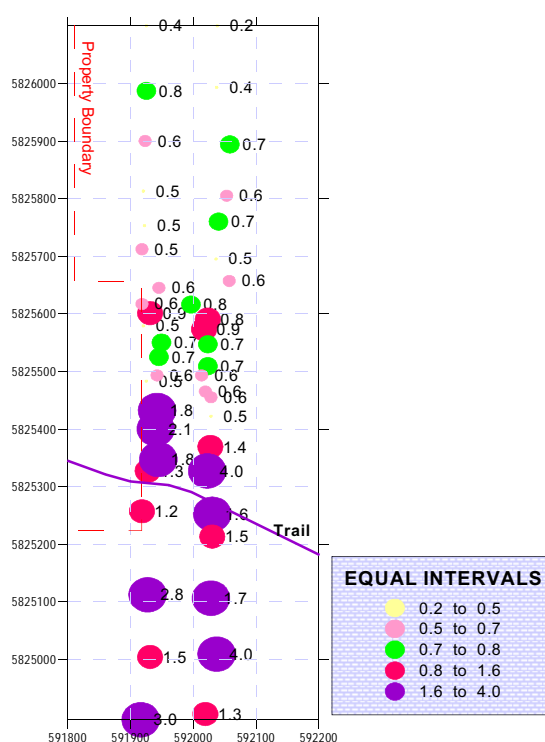


Figure 11. Mt. Polley Boundary zone: Mo in dry cedar foliage compared to B-horizon soil.

TABLE 6. POND ZONE: STATISTICAL SUMMARY FOR ANALYSIS BY ICP-MS OF DRY SUBALPINE FIR FOLIAGE

Element	Units	N	Mean	Std. Dev.	Minimum	Percentiles				Maximum
						50 th	70 th	80 th	90 th	
Ag	ppb	54	7.8	5.4	3	6	7	8	15	36
Al	%	54	0.02	0.009	0.005	0.02	0.02	0.02	0.03	0.05
As	ppm	54	0.3	0.6	0.05	0.1	0.2	0.2	0.4	3.7
Au	ppb	54	1.4	1.3	0.1	0.9	1.6	2.2	3.1	5.5
B	ppm	54	14	5	5	14	17	20	23	25
Ba	ppm	54	81	38	2.8	73	93	105	134	208
Ca	%	54	0.858	0.244	0.43	0.835	0.935	1.04	1.19	1.68
Cd	ppm	54	0.06	0.04	0.01	0.05	0.07	0.08	0.12	0.17
Ce	ppm	54	0.07	0.03	0.02	0.08	0.09	0.09	0.11	0.20
Co	ppm	54	0.12	0.05	0.04	0.11	0.14	0.15	0.17	0.28
Cr	ppm	54	1.96	0.13	1.70	2.00	2.00	2.10	2.15	2.20
Cs	ppm	54	0.065	0.113	0.006	0.032	0.056	0.078	0.154	0.779
Cu	ppm	54	11.6	4.6	4.1	10.5	12.8	14.4	16.8	33.6
Fe	%	54	0.018	0.008	0.006	0.017	0.021	0.024	0.027	0.056
Ga	ppm	54			0.05	0.1	0.1	0.1	0.1	0.1
Ge	ppm	54			0.005	0.01	0.01	0.01	0.015	0.02
Hf	ppm	54	0.002	0.001	0.001	0.002	0.002	0.003	0.003	0.005
Hg	ppb	54	26	8	11	26	31	32	37	51
In	ppm	54	0.01	0	0.01	0.01	0.01	0.01	0.01	0.01
K	%	54	0.509	0.082	0.35	0.52	0.555	0.57	0.605	0.74
La	ppm	54	0.04	0.02	0.01	0.04	0.05	0.06	0.06	0.11
Li	ppm	54	0.16	0.34	0.01	0.08	0.10	0.11	0.21	2.23
Mg	%	54	0.096	0.023	0.038	0.097	0.108	0.119	0.125	0.154
Mn	ppm	54	1253	751	346	1151	1573	1894	2150	4536
Mo	ppm	54	0.14	0.09	0.05	0.13	0.15	0.17	0.21	0.54
Na	%	54	0.002	0	0.001	0.002	0.002	0.002	0.003	0.003
Nb	ppm	54	0.011	0.01	0.005	0.01	0.01	0.01	0.03	0.06
Ni	ppm	54	0.7	0.3	0.3	0.7	0.8	0.9	1.1	2.0
P	%	54	0.152	0.025	0.099	0.15	0.163	0.168	0.18	0.233
Pb	ppm	54	0.16	0.07	0.06	0.15	0.19	0.21	0.27	0.46
Rb	ppm	54	5.3	2.4	1.1	4.8	6.2	6.9	9.5	10.9
Re	ppb	54	2.9	10.8	0.5	0.5	1	1	4.5	77
S	%	54	0.084	0.024	0.005	0.09	0.1	0.1	0.115	0.12
Sb	ppm	54	0.03	0.01	0.01	0.02	0.03	0.04	0.05	0.07
Sc	ppm	54	0.24	0.06	0.1	0.2	0.3	0.3	0.3	0.3
Se	ppm	54	0.19	0.09	0.1	0.2	0.2	0.2	0.2	0.6
Sn	ppm	54	0.03	0.02	0.01	0.02	0.03	0.04	0.05	0.1
Sr	ppm	54	26	9	6	25	28	33	40	52
Th	ppm	54	0.005	0	0.005	0.005	0.005	0.005	0.005	0.005
Ti	ppm	54	9.9	2.5	5	10	11	12	12.5	20
Tl	ppm	54	0.024	0.016	0.01	0.02	0.03	0.04	0.05	0.07
U	ppm	54	0.005	0.001	0.005	0.005	0.005	0.005	0.005	0.01
Y	ppm	54	0.05	0.02	0.01	0.04	0.05	0.06	0.07	0.12
Zn	ppm	54	47	16	12	47	55	58	66	90
Zr	ppm	54	0.04	0.01	0.02	0.03	0.04	0.05	0.05	0.09

TABLE 7. POND ZONE: STATISTICAL SUMMARY FOR ANALYSIS BY ICP-MS OF -80 MESH B-HORIZON SOIL

Element	Units	N	Mean	Std. Dev.	Minimum	Percentiles				Maximum
						50 th	70 th	80 th	90 th	
Ag	ppb	60	282	235	67	227	287	392	486	1732
Al	%	60	1.766	0.518	0.92	1.71	1.987	2.242	2.536	2.98
As	ppm	60	5.9	3.0	2.2	4.9	6.7	7.5	11.4	16.3
Au	ppb	60	15	22	-0.2	7.4	15.4	21	41	149
B	ppm	60	2.3	0.9	1	2	3	3	4	5
Ba	ppm	60	107	39	41	107	118	131	160	238
Be	ppm	60	0.42	0.15	0.2	0.4	0.5	0.6	0.6	0.9
Bi	ppm	60	0.17	0.12	0.07	0.13	0.17	0.21	0.26	0.7
Ca	%	60	0.388	0.196	0.17	0.34	0.407	0.478	0.629	1.36
Cd	ppm	60	0.22	0.11	0.09	0.2	0.25	0.28	0.39	0.59
Ce	ppm	60	17	4	10.2	16.7	18.2	19.5	21.3	33.1
Co	ppm	60	10.2	3.5	4.5	9.7	10.8	11.7	16.5	21.6
Cr	ppm	60	31	9	18	29	33	38	45	57
Cs	ppm	60	2.8	2.6	0.76	1.89	2.75	3.22	6.37	15.30
Cu	ppm	60	72	102	11	41	63	85	152	652
Fe	%	60	3.053	0.783	1.86	2.875	3.308	3.75	4.083	5.65
Ga	ppm	60	6.2	1.5	3.8	6.1	6.8	7.5	8.7	10.0
Ge	ppm	60			-0.1	-0.1	-0.1	-0.1	-0.1	0.1
Hf	ppm	60	0.048	0.022	-0.02	0.049	0.06	0.068	0.08	0.11
Hg	ppb	60	39	19	9	39	47	51	61	119
In	ppm	60	0.02	0.02	-0.02	0.02	0.02	0.03	0.03	0.04
K	%	60	0.084	0.031	0.04	0.08	0.1	0.1	0.119	0.19
La	ppm	60	9.6	1.6	6.2	9.5	10.4	11.1	11.7	13.8
Li	ppm	60	18.6	5.2	7.9	18.2	20.1	22.1	27.2	30.9
Mg	%	60	0.482	0.215	0.17	0.45	0.524	0.598	0.767	1.22
Mn	ppm	60	620	374	237	479	701	851	1165	1881
Mo	ppm	60	1.7	1.6	0.5	1.1	1.5	2.3	4.2	7.2
Na	%	60	0.008	0.004	0.005	0.007	0.008	0.009	0.01	0.031
Nb	ppm	60	0.83	0.17	0.50	0.80	0.92	0.98	1.10	1.25
Ni	ppm	60	18.4	8.4	6.6	17	21	23	31	51
P	%	60	0.104	0.057	0.032	0.089	0.111	0.134	0.204	0.292
Pb	ppm	60	7.0	2.1	4.5	6.5	7.1	8.0	10.6	13.9
Pd	ppb	60	-10	0	-10	-10	-10	-10	-10	-10
Pt	ppb	60	-2		-2	-2	-2	-2	2	2
Rb	ppm	60	13.4	4.1	7.1	13.3	14.5	16.2	20.3	23.8
Re	ppb	60		1.9	-1	-1	-1	-0.39	1.9	7
S	%	60	0.011	0.045	-0.01	0.01	0.01	0.018	0.03	0.31
Sb	ppm	60	0.29	0.08	0.15	0.28	0.33	0.36	0.41	0.52
Sc	ppm	60	3.2	1.4	1.6	2.9	3.3	3.68	4.27	10.7
Se	ppm	60	0.36	0.39	-0.1	0.2	0.387	0.48	0.7	2.2
Sn	ppm	60	0.45	0.14	0.3	0.4	0.5	0.5	0.6	1.2
Sr	ppm	60	58	39	19	44	57	77	109	232
Ta	ppm	60		0	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05
Te	ppm	60	0.013	0.029	-0.02	0.02	0.03	0.03	0.05	0.09
Th	ppm	60	2.06	0.50	0.7	2.08	2.4	2.5	2.69	3.1
Ti	%	60	0.103	0.039	0.049	0.094	0.112	0.123	0.148	0.276
Tl	ppm	60	0.07	0.03	0.03	0.07	0.08	0.10	0.11	0.18
U	ppm	60	0.42	0.12	0.2	0.4	0.4	0.5	0.5	1
V	ppm	60	84	22	49	80	88	99	111	158
W	ppm	60	0.14	0.16	-0.1	0.1	0.2	0.2	0.39	0.6
Y	ppm	60	3.4	1.7	1.6	3.0	3.4	3.9	4.7	12.9
Zn	ppm	60	98	38	49	86	120	131	152	197
Zr	ppm	60	2.1	0.7	0.8	1.9	2.3	2.5	3.0	5.2
pH		59	5.1	0.5	4.3	5.1	5.2	5.4	5.8	6.4

SOIL

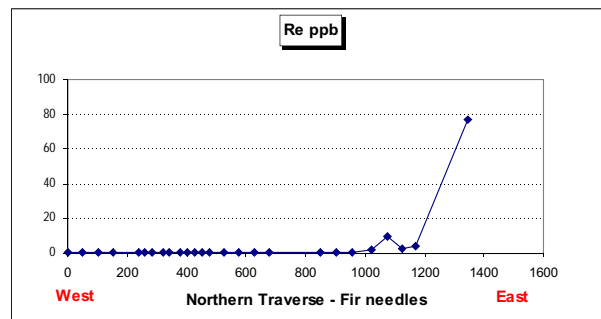
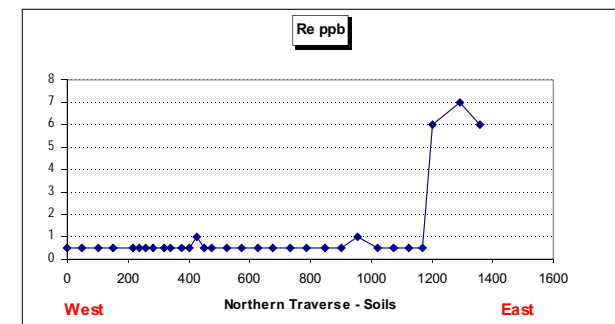
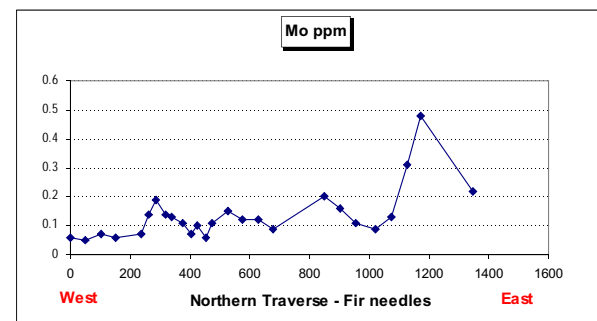
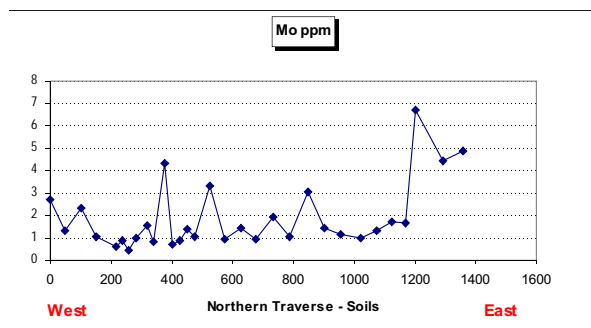
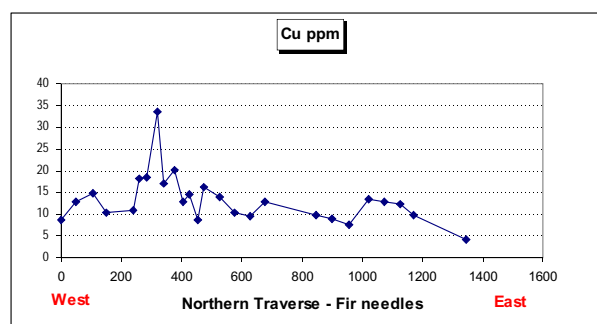
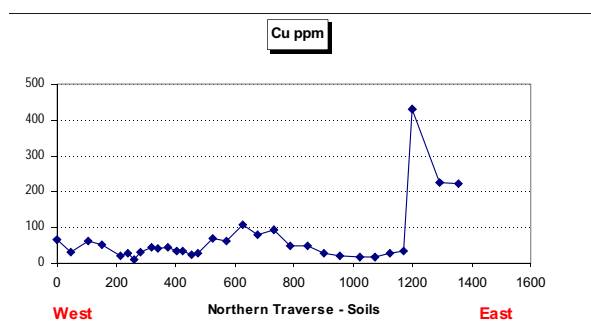
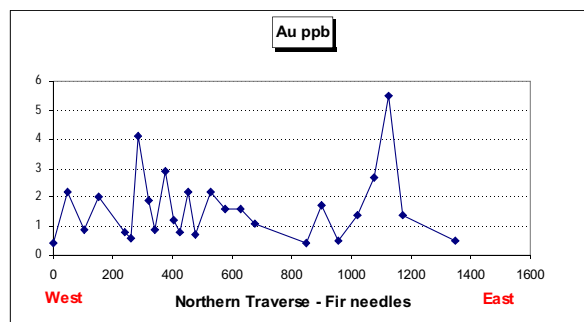
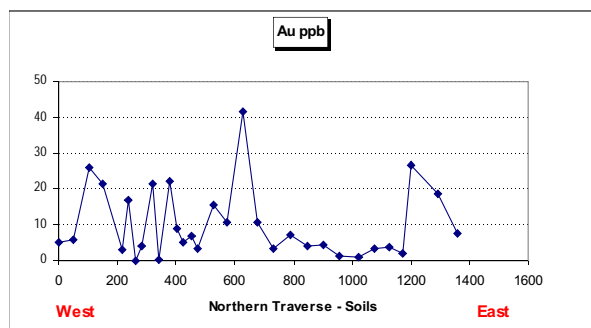


Figure 12. Pond zone: profiles of element concentrations in soil and foliage of subalpine fir along the northern east-west traverse (soil in left column, subalpine fir needles in right column).

from those in the soil by about 50 m. Figure 15 presents examples of a few elements.

3Ts Prospect

TOMMY VEIN TO THE RINGER SHOWING

The traverse covering these occurrences is shown in Figure 5. As noted, soil samples were only collected along the western half of the transect, and preliminary details of their multifaceted analyses are outlined in Cook and Dunn (2006).

Vegetation coverage is primarily white spruce, and lodgepole pine that has suffered from the mountain pine beetle kill. Sample media were spruce foliage and outer bark of the pine, and both have been analyzed. The foliage was originally selected as the priority medium for the halogens, but recent data on test samples of bark have yielded relatively high concentrations of iodine, so the bark samples will also be submitted for halogen analysis.

Near the west end of the traverse, a number of veins have been recognized and the spruce needles indicate subtle enrichment of several elements throughout this zone in general, with some enrichments closely related to the principal veins (Tommy and Larry) and, to a lesser extent, the

narrower Ian vein. Farther east, the Mint vein was traversed and it, too, generates a subtle biogeochemical signature. The source of the boulders that constitute the Ringer showing has yet to be identified, and could be located at sites between the Mint vein and the Ringer showing where subtle peaks occur, since the direction of ice movement would have transported the boulders in an easterly direction. Figure 16 presents profiles of several elements in dry spruce needles that show some of these relationships. Gold is not shown because values in the sub-ppb level were too imprecise to be meaningful.

Of interest is a sharp increase in Mo at the eastern extremity of the traverse. This is evident from both the spruce foliage and the pine bark (Fig. 17), but with the bark yielding almost an order of magnitude more Mo. Iron, too, shows strong enrichment in the bark in this area. The enrichment suggests either a change in bedrock or, given the high concentrations in the bark, Mo mineralization.

TED VEIN TO ADRIAN WEST BOULDERS

The same plant species and tissues as those along the Tommy vein traverse were collected along the traverse extending from the Ted vein to the southern edge of the boulder showing near Adrian Lake (Fig. 5). Figure 18 shows the profiles across the Ted vein of S and Zn in each tissue type.

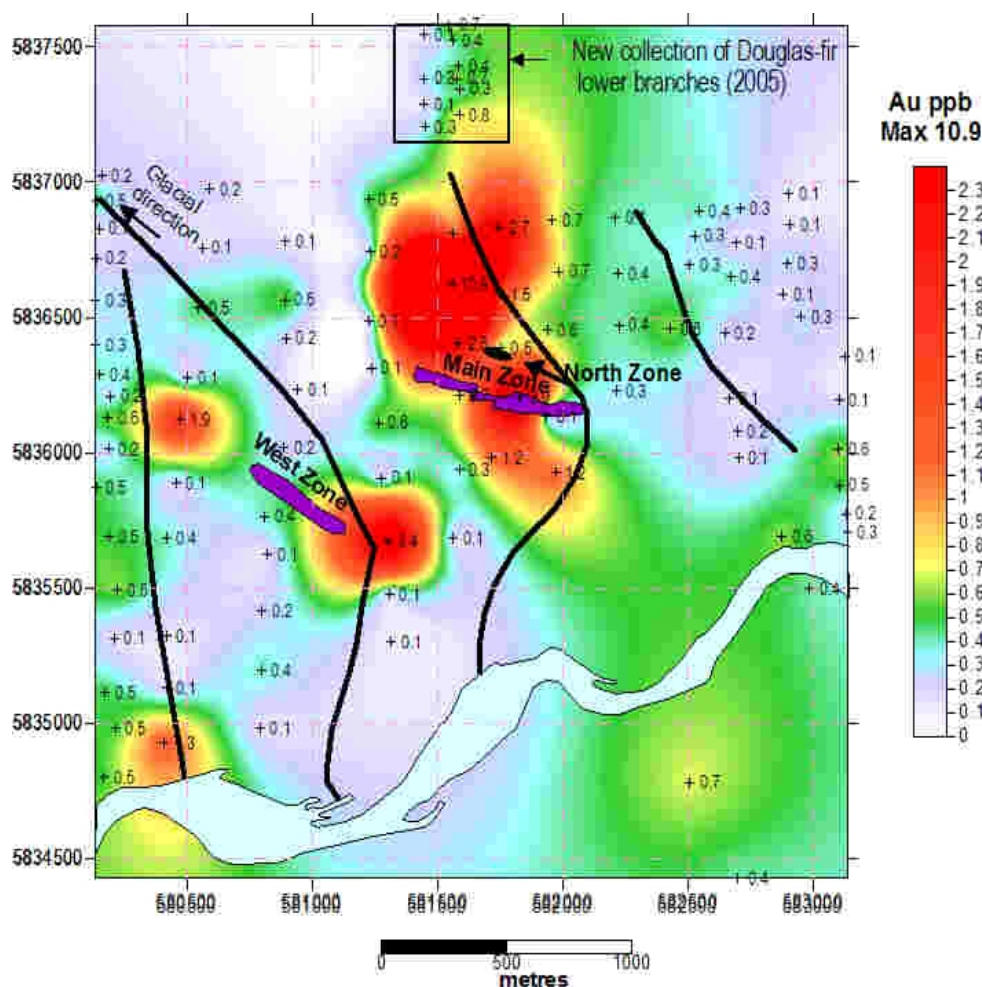


Figure 13. Plot of Au in dry Douglas-fir needles from tree tops, with cluster of samples in the north showing results of new data from lower branches.

Molybdenum enrichment at the eastern end of the line suggests some stratigraphic continuity with the end of the line to the north, in the vicinity of the Ringer showing (Fig. 5).

In general, the response of the vegetation to known mineralization is less pronounced than the signatures derived from the soil (Cook and Dunn, 2006). It remains to be seen if the halogen signatures will be more definitive.

SUMMARY AND PRELIMINARY CONCLUSIONS

Gold-rich Douglas-fir needles and lodgepole pine bark archived from GSC surveys over the QR deposit in the late 1980s have served as preliminary samples for testing and developing various methods to determine the halogen elements: F, Cl, Br and I. Several portions of each of three standard soil samples (STSD-1, STSD-4 and TILL-4) were

used for developing methods appropriate for B-horizon soil.

Fifteen different methods were tested at commercial laboratories in Canada and at the GSC, of which some methods were duplicated at several of the laboratories. The test data indicate widely divergent results for most of the halogens. This is due, in part, to differences between 'total' and 'partial' analyses, but problems mostly lie in selecting appropriate digestions and instrumentation. Whereas the ion chromatograph would appear to be ideal for determining the halogens and other anions, the problems in obtaining accurate and precise data are at present sufficiently significant, especially for the vegetation, that this is not the recommended technique.

At this time, it appears that ICP-MS is the preferred technique for I, Br and probably Cl, and experimental data from various leaches will be used for the final decision on the currently optimal analytical method. Fluoride determi-

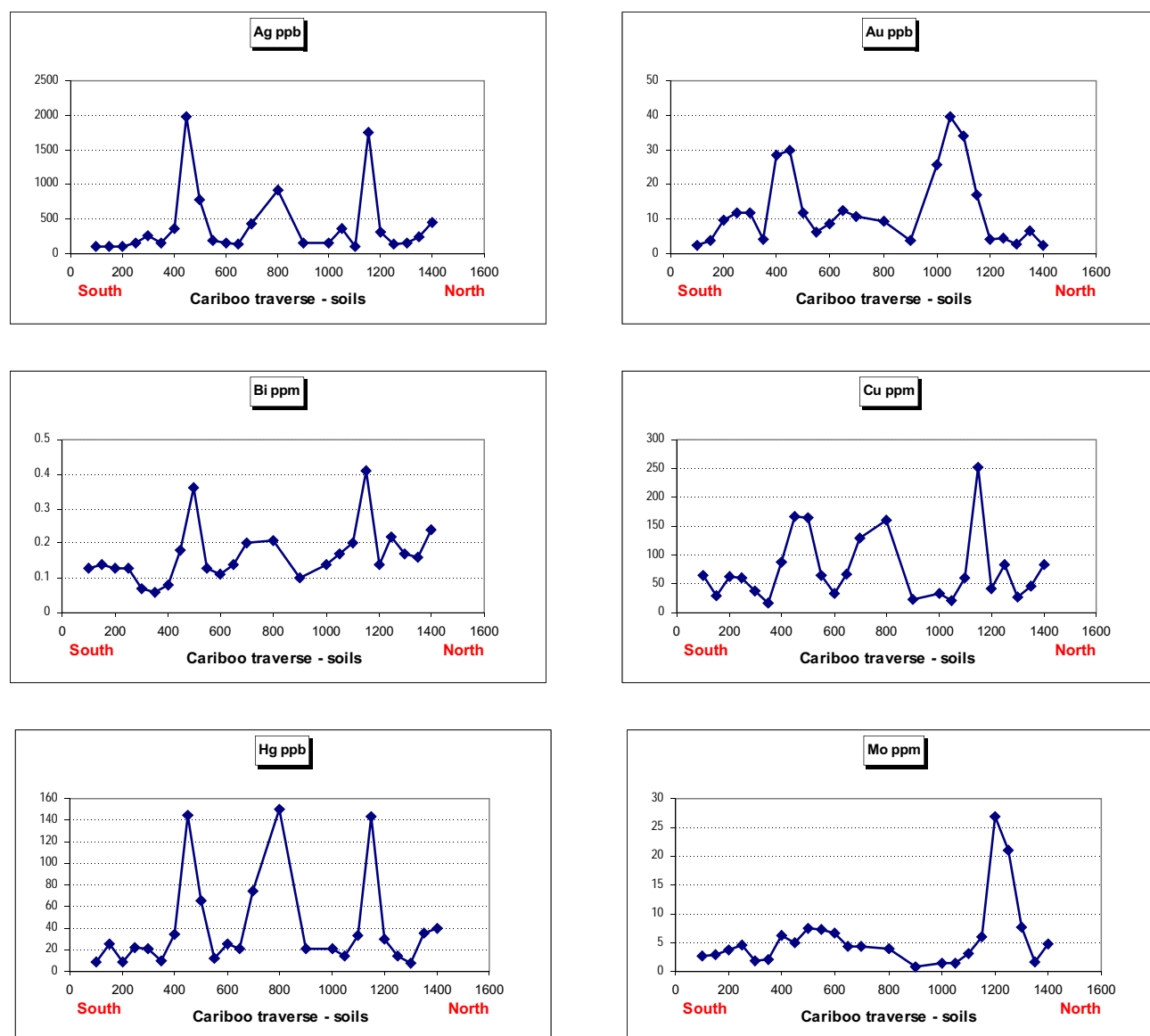


Figure 14. Cariboo zone (6 km east of QR deposit): examples of multi-element signatures in B-horizon soils

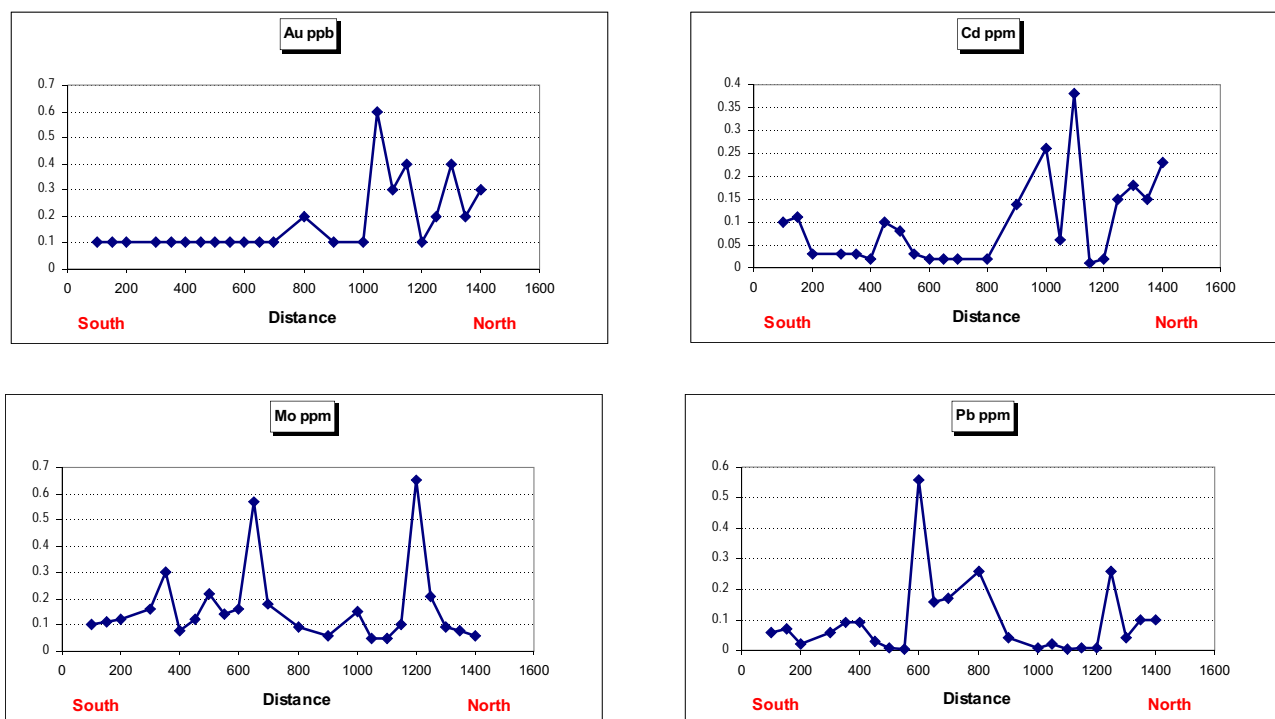


Figure 15. Cariboo zone: element concentrations in dry spruce needles.

nations are likely to be conducted using a selective ion electrode on a water leach of both soil and vegetation.

Multielement analyses (by ICP-MS for 53 elements) provide data on the distribution of elements in soil and vegetation with respect to known mineralization at the three survey areas. A few points of note are some unusually high Re results from the Mt. Polley area; some high Mo results near two mineralized boulder occurrences at 3Ts; enrichment of base and precious metals, including traces of Pt, at the Cariboo zone (east of the QR deposit). In general, the soil provides stronger signatures than the vegetation tissues that were tested, but the vegetation suggests evidence of mineralization from a number of trace elements that are not evident from the soil. Also, vegetation anomalies appear to be located more directly over concealed mineralization than anomalies present in the soil, because the latter are displaced either downslope or down-ice from mineralization.

Details of the multielement analytical data and the halogen data that have yet to be obtained will be presented in a final report submitted to Geoscience BC by March 2006.

ACKNOWLEDGMENTS

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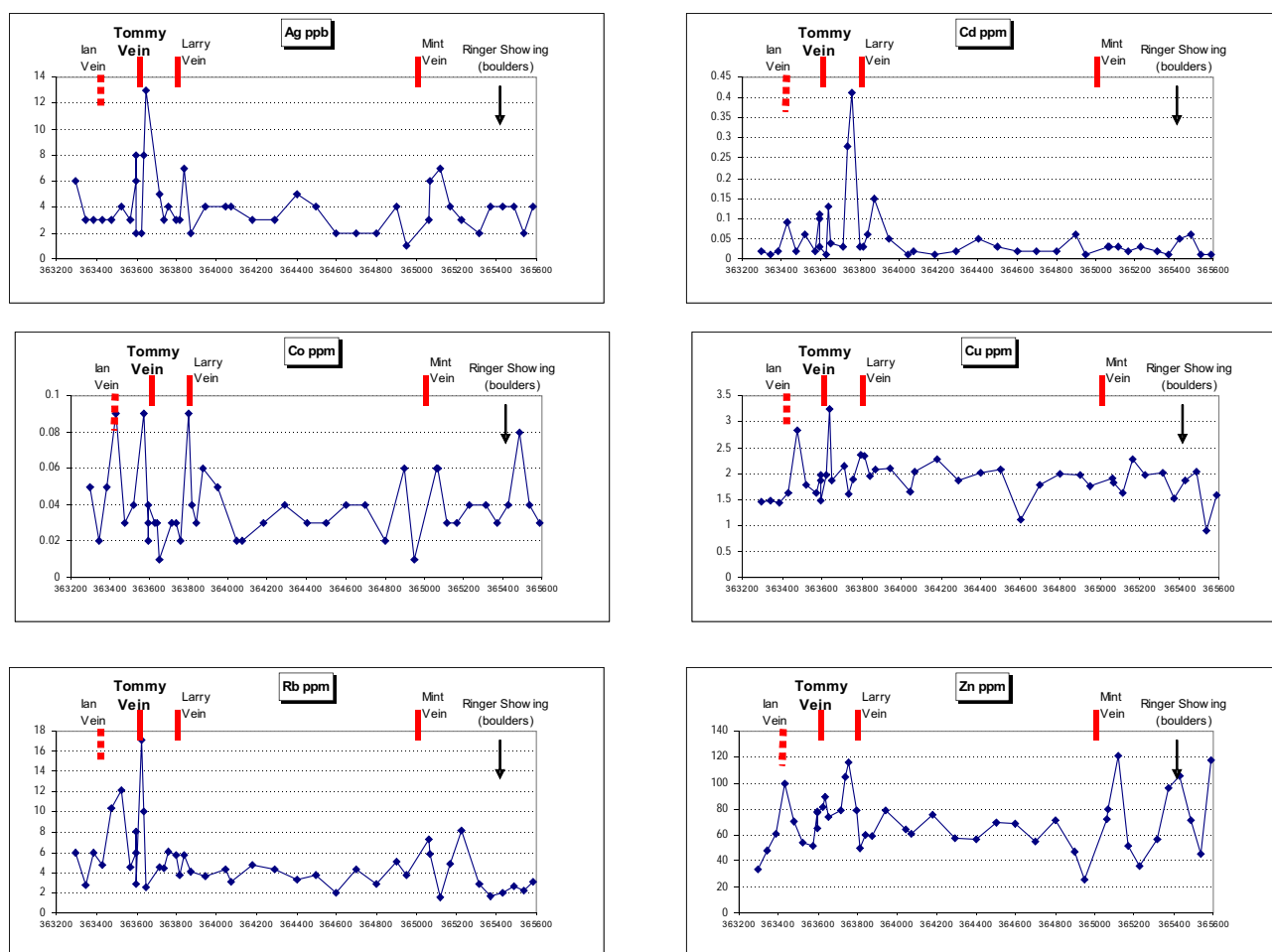


Figure 16. 3Ts prospect: concentrations of selected elements in dry spruce needles along a 2.4 km traverse across several known Au-bearing veins.

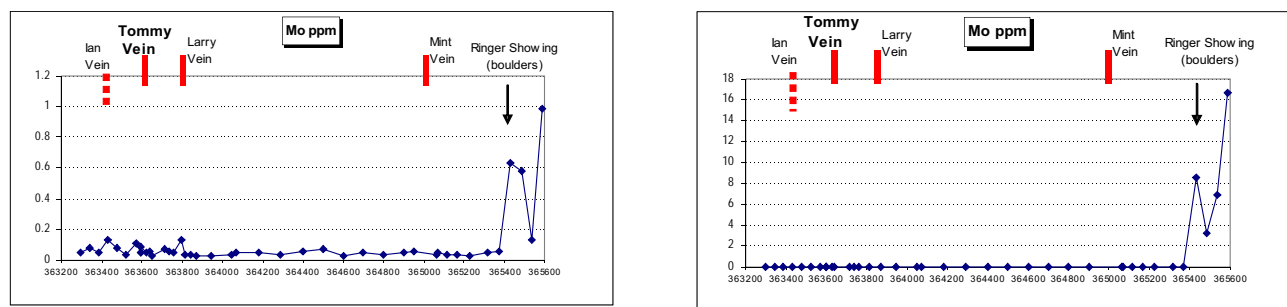


Figure 17. 3Ts prospect: profile across Au-bearing veins, showing Mo in spruce needles (left) and pine bark (right).

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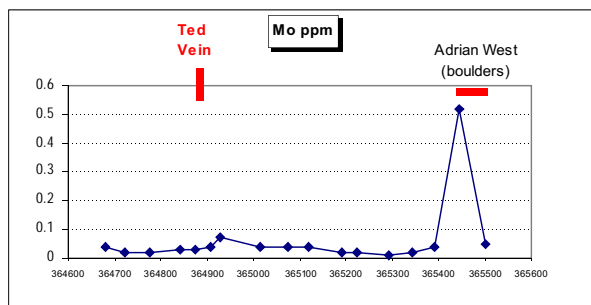
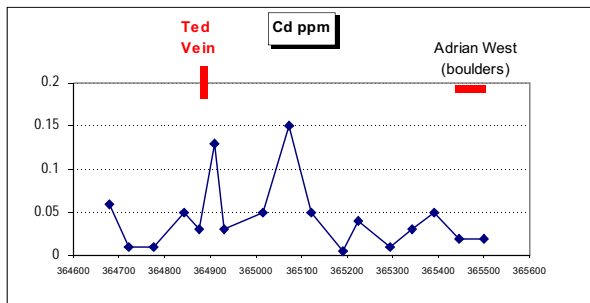
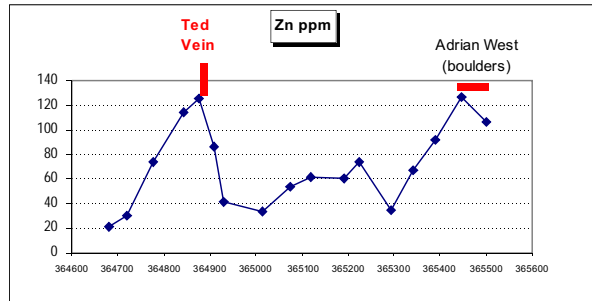
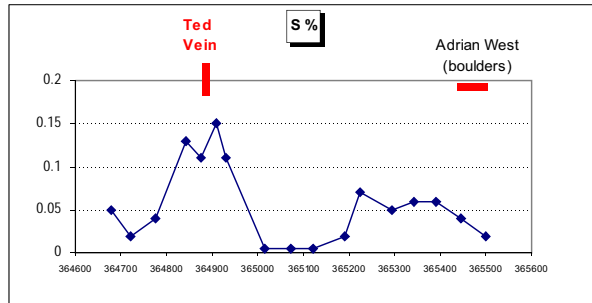
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Spruce Needles



Pine bark

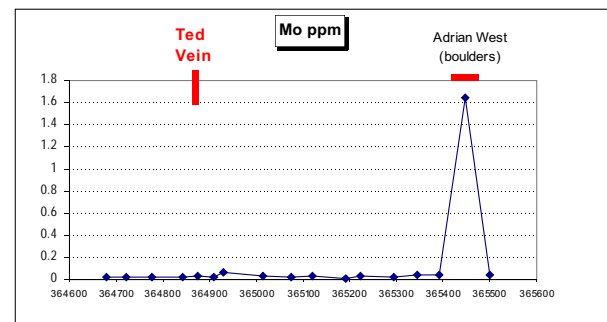
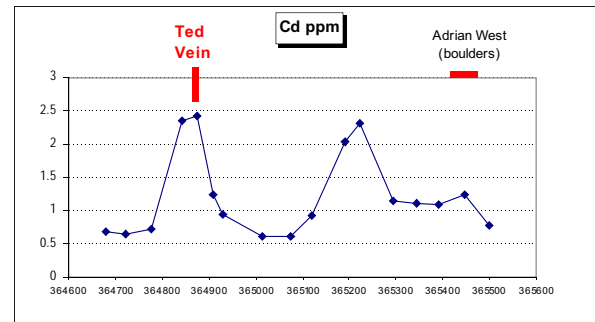
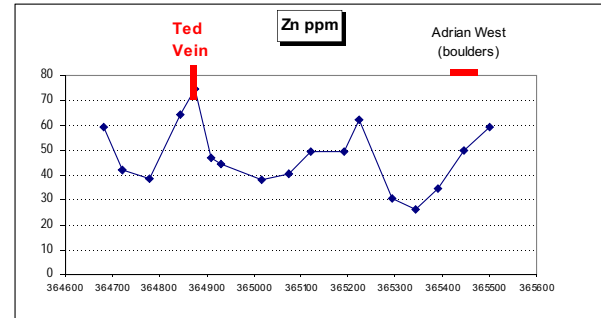
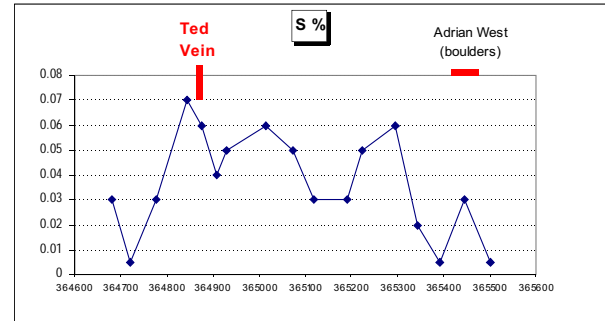


Figure 18. 3Ts prospect: southern traverse across the Ted vein, showing concentrations of S, Zn, Cd and Mo in spruce needles (left column) and pine bark (right column).

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