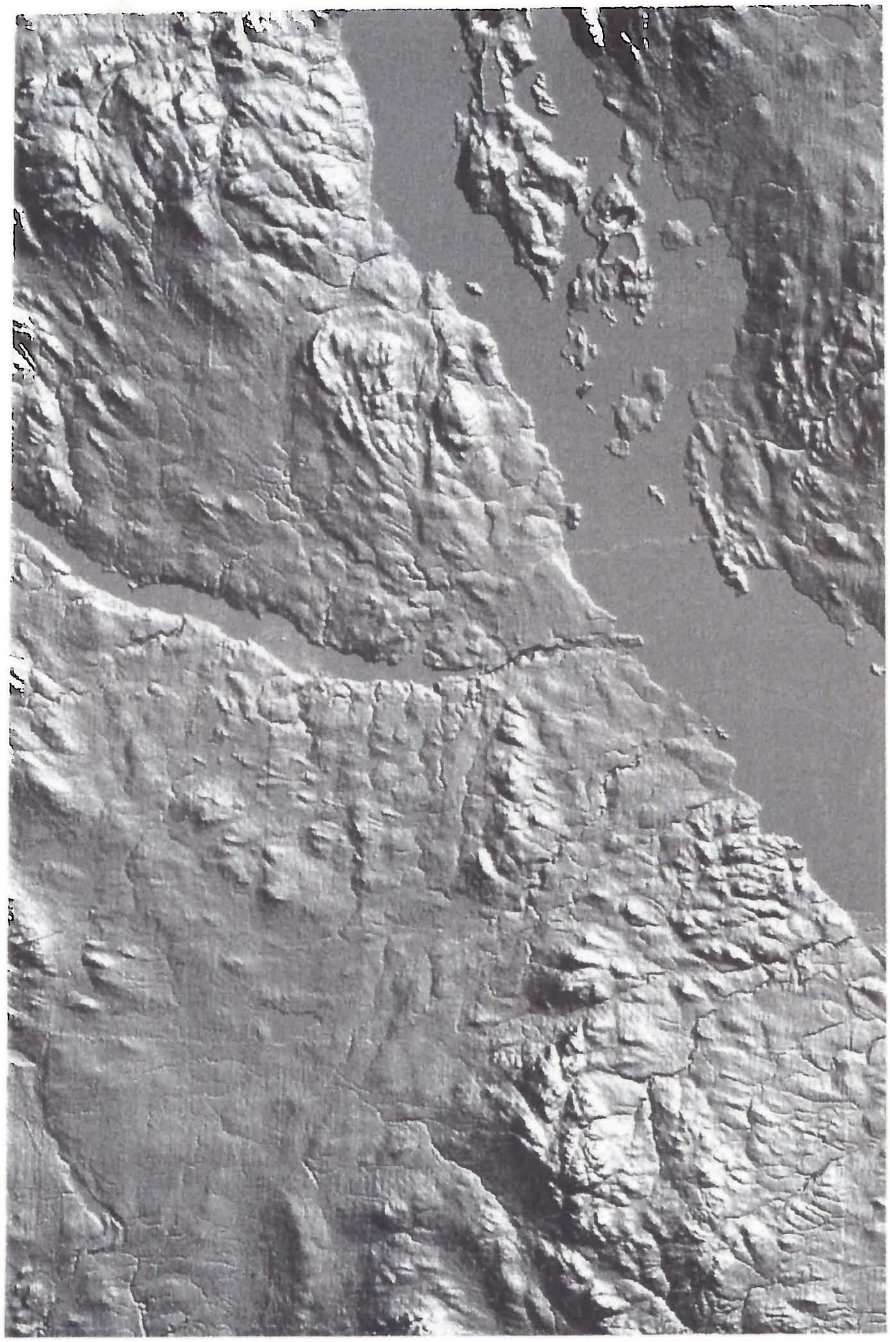
CORDILLERAN SECTION

GEOLOGICAL ASSOCIATION OF CANADA

NEW GEOLOGICAL CONSTRAINTS ON MESOZOIC TO TERTIARY METALLOGENESIS AND ON MINERAL EXPLORATION IN CENTRAL BRITISH COLUMBIA: NECHAKO NATMAP PROJECT



SHORT COURSE EXTENDED ABSTRACTS

A SHORT COURSE ORGANIZED BY THE
GEOLOGICAL ASSOCIATION OF CANADA,
CORDILLERAN SECTION
SIMON FRASER UNIVERSITY,
HARBOUR CENTRE CAMPUS
VANCOUVER, BRITISH COLUMBIA
MARCH 27, 1998

COORDINATORS AND EDITORS:
L.C. STRUIK, GEOLOGICAL SURVEY OF CANADA, PACIFIC DIVISION, VANCOUVER
D.G. MACINTYRE, BRITISH COLUMBIA GEOLOGICAL SURVEY, VICTORIA

Nechako

CORDILLERAN SECTION
GAC
GEOLOGICAL ASSOCIATION OF CANADA

NEW GEOLOGICAL CONSTRAINTS ON MESOZOIC TO TERTIARY METALLOGENESIS AND ON MINERAL EXPLORATION IN CENTRAL BRITISH COLUMBIA: NECHAKO NATMAP PROJECT

27 March, 1998
Simon Fraser University
Harbour Centre Campus

A Short Course Sponsored by the Cordilleran Section of the Geological Association of Canada

Course Program

08:25 Struik, L.C. and MacIntyre, D.G.
Introduction

08:30 Anderson, R.G.
Influence of Eocene tectonics and magmatism on the Mesozoic arc and orogenic collapse: New developments in Nechako River map area.

09:15 Dunn, C. and Cook, S.
Application of geochemical surveys to mapping and mineral exploration in the Nechako/Babine region.

10:00 Coffee

10:15 Levson, V.
Glaciation and its effects on the dispersal and burial of mineral deposits in west-central British Columbia.

10:50 Stumpf, A.
Ice-flow and its implications for drift prospecting in central British Columbia.

11:25 Plouffe, A.
History of glacial lakes and an overview of the till geochemistry as an aid for mineral exploration on the Nechako Plateau.

12:00 Lunch

13:00 Lowe, C. and Enkin, R.
New constraints on bedrock geology and mineral exploration in central British Columbia: analyses of aeromagnetic, paleomagnetic and gravity data

13:45 MacIntyre, D.G.
Late Cretaceous to Early Tertiary tectonics, magmatism and mineral deposits, central British Columbia.

14:30 Schiarizza, P.
Sitlika rocks of the Kutcho Assemblage and their tectonic relationship to the Cache Creek and Takla groups near Takla Lake.

15:15 Coffee

15:30 Struik, L.C. and Orchard, M.J.
Cache Creek Group: Its paleoenvironment, structural stacking, stratigraphy, and implications for the Pinchi Fault.

16:15 Anderson, R.G., Whalen, J.B. and Villeneuve, M.E.
Triassic to Eocene composite intrusions and molybdenum metallogeny: the Endako Batholith redefined.

17:00 End

Regional and Detailed Biogeochemical Surveys in the Nechako NATMAP Area and in the Babine Porphyry Belt

Colin E. Dunn
Geological Survey of Canada
601 Booth St.
Ottawa, ON, K1A 0E8

Introduction and Rationale for Biogeochemical Surveys

The roots of a single large tree extract elements from many cubic metres of soil, overburden, groundwater and sometimes bedrock. These elements are then transferred to aerial parts of the tree where they may become locally concentrated. In a multi-disciplinary survey program, data derived from the analysis of an appropriate vegetation sample medium permits geochemical mapping, with enhanced background to anomaly contrast of certain elements, which may assist both in mapping bedrock and in the search for concealed zones of mineralization.

Whereas till geochemistry provides valuable information on the elemental composition of surficial sediments and their provenance, consideration of analytical data from vegetation penetrating the till provides additional insight into the chemical nature of the substrate. Locally, comparison of till and biogeochemical data can assist in determining vectors and distance from a mineralised source. There are commonly some similarities in element distribution patterns derived from the two sample media, but also some significant differences that require some explanation.

Firstly, analysis of a till sample involves sieving and selection of one size fraction from a bulk sample commonly weighing approximately 5 kg, dug from a single small pit. The tree roots, however, may extend through several cubic metres of soil (all horizons) and till, on occasion reaching and penetrating joints and fractures in bedrock. The tree, therefore, extracts elements from a large volume of material of diverse composition, including groundwater. Some elements that are dissolved in groundwater can be readily extracted by the tree roots, but may not precipitate on till and soil particles.

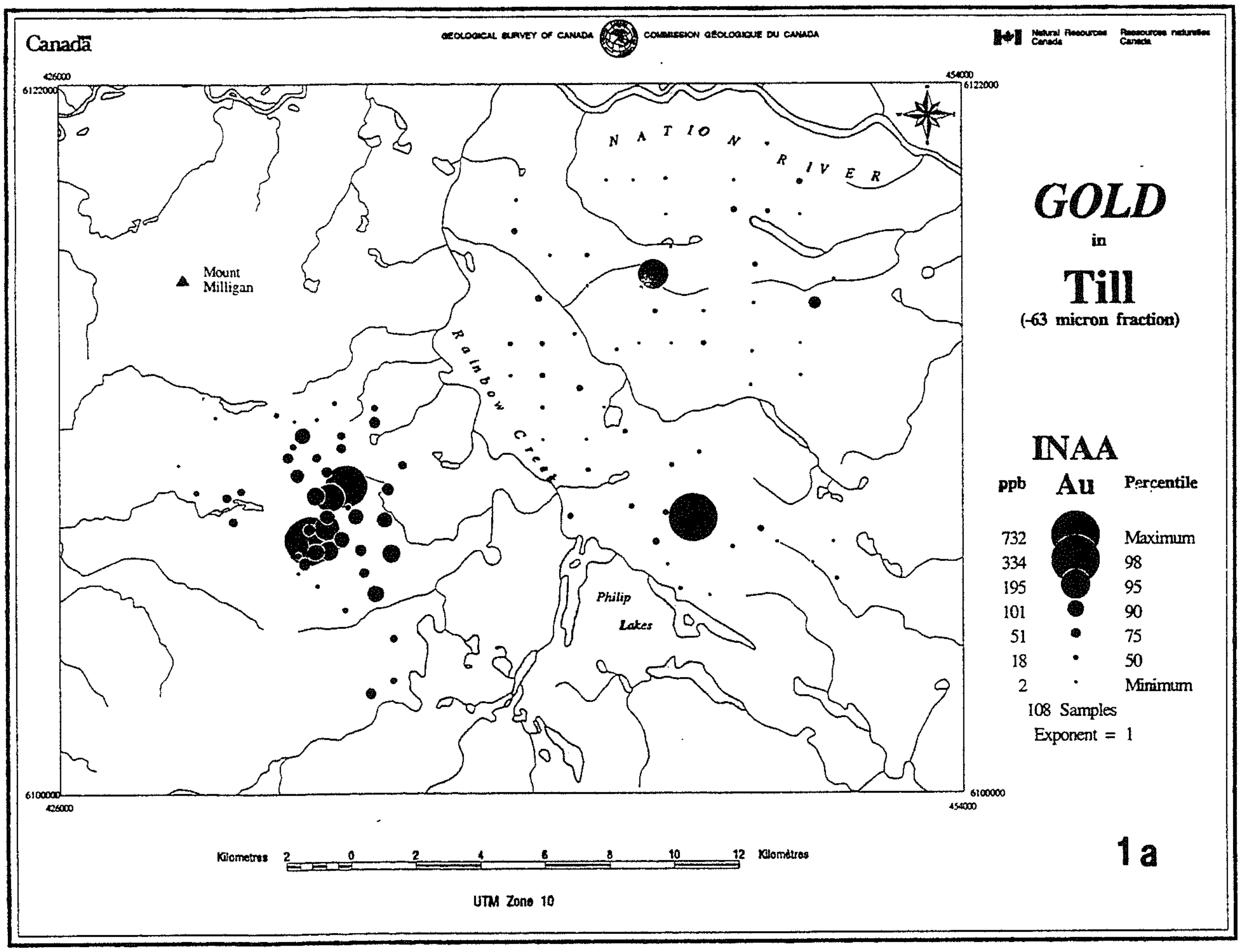
A second factor of importance is the barrier mechanism established at the root/sediment interface by some plants for some elements (Kovalevskii, 1979). Because each species of plant has a different requirement for, and tolerance to, a range of chemical elements, some partitioning of elements takes place and there is selective absorption and transference into the plants. For biogeochemical exploration, conifers are good sample media because they are primitive plants that have a wide tolerance to many trace elements. The outer bark may, by analogy, be equated with biotite in rocks, in that it is something of a repository for many elements that do not fit elsewhere or are not required for the metabolic function of the tree.

A third factor is that slight enrichments of metals in till samples are unlikely to be reflected in the vegetation as weak biogeochemical anomalies. This is especially true in the ppb (Au) and ppm ranges of concentration common in till samples. Some of these metals may not be present in a chemical form that is *available* for uptake (e.g. Cr structurally bound in chromite). Some may be excluded from uptake at the roots or only partially absorbed, and some may be taken up but dispersed among tree tissues to the extent that inter-site variations are so small that they cannot be detected.

The net result of these factors is that the geochemical information supplied by the vegetation is different from that of the till. Just as two methods of geophysical survey will provide totally different information, so will two methods of geochemical survey. A high correlation between distribution patterns of two geochemical sample media is the exception rather than the rule. In geological environments where there is sufficient concentration of metals to form a mineral deposit, such a 'critical mass' of elements may be sufficient to generate biogeochemical anomalies above (by upward diffusion) or close to (by movement in electrochemical cells) the mineral source. Tills, however, usually have geochemical anomalies displaced down-ice from the mineralised source. Such factors need to be taken into consideration when interpreting geochemical results.

Valuable exploration information can be obtained from the analysis of till samples. When this information is coupled with analysis of vegetation samples, a powerful combination is provided for assisting in the exploration for mineral deposits. Figure 1 shows an example from the Mount Milligan Cu/Au porphyry deposit, located 150 km northwest of Prince George. The map of gold in till (from Sibbick et al., 1996) shows strong enrichment at several sites in the western part of the survey area, and an anomalous sample east of Philip Lakes. The plot of gold in ash of lodgepole pine bark (from Dunn et al., 1996) shows that the highest concentrations occur, in both areas, to the west (i.e. up-ice) of the till anomalies, directly over zones of mineralization.

Figure 1: Mount Milligan area, central BC - Comparison of distribution patterns of gold in a) till and b) ash of lodgepole pine bark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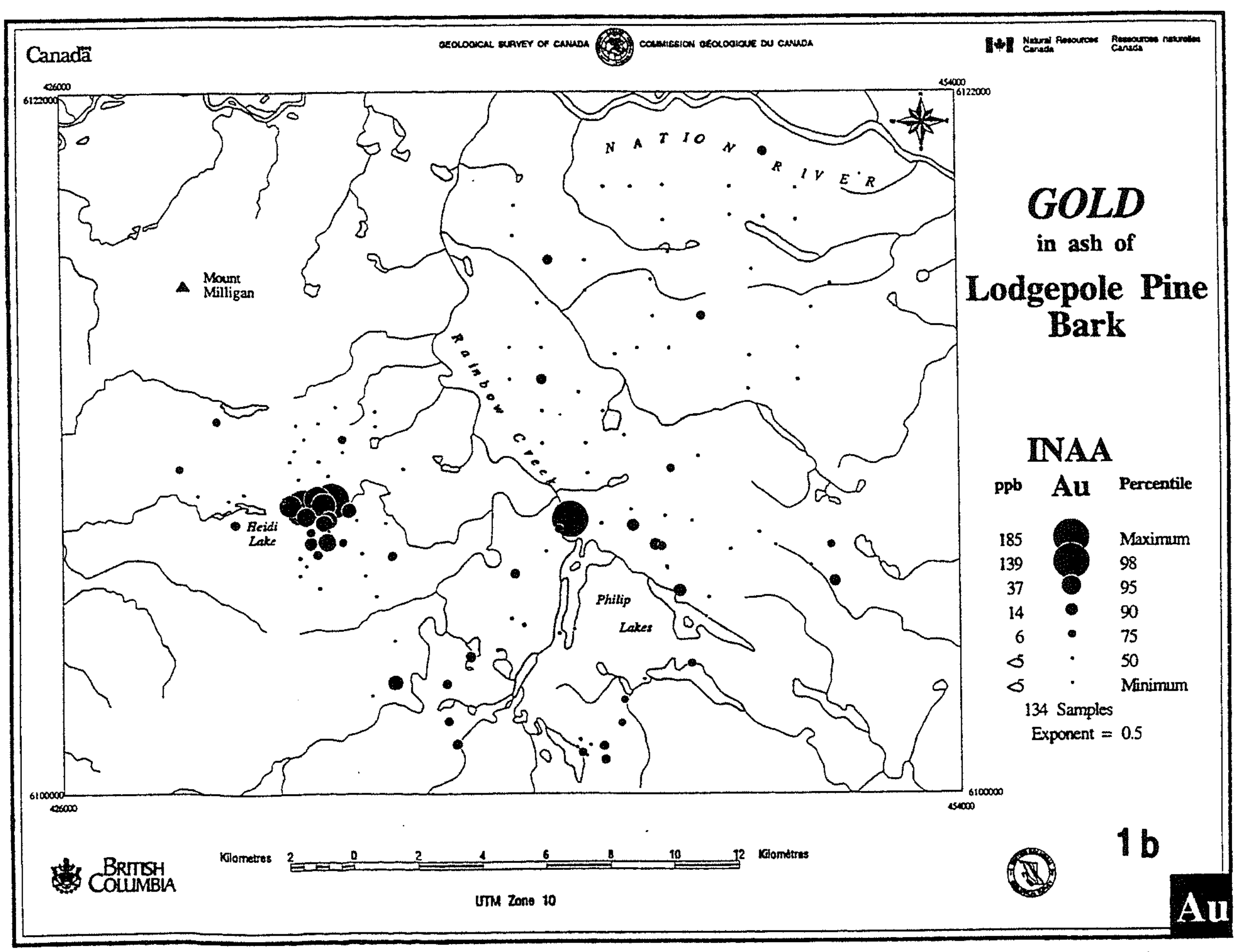
NATION RIVER
Mount Milligan
Rainbow Creek
Philip Lakes
GOLD
in
Till
(-63 micron fraction)
INAA
ppb
Au
Percentile
732 Maximum
334 98
195 95
101 90
51 75
18 50
2 Minimum
108 Samples
Exponent = 1
Kilometres 2 0 2 4 6 8 10 12 Kilomètres
UTM Zone 10
1a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GOLD
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Lodgepole Pine
Bark
INAA
ppb
Au
Percentile
185 Maximum
139 98
37 95
14 90
6 75
<5 50
<5 Minimum
134 Samples
Exponent = 0.5
British Columbia
Kilometres 2 0 2 4 6 8 10 12 Kilomètres
UTM Zone 10
1b
Au

Reconnaissance Survey

Lodgepole pine is the most common tree species in the Nechako area, and many metals concentrate in its outer bark. Hence, pine bark was selected as the sample medium for a reconnaissance-level biogeochemical survey in the Nechako project area. The procedure adopted was to use a paint scraper to remove approximately 100g of outer bark from around the circumference of mature trees. The scrapings were placed into 'kraft' soil bags. The preferred sample interval was 2 km along roads, trails, and tracks. In 1996, bark samples were obtained from 236 sites in the northeastern quadrant of the Nechako River map sheet (93F/15 and 16). The following summer, trees at 265 sites were sampled in the two 1:50,000 NTS map sheets to the west (93F/13 and 14). Because of the lack of roads and trails in some areas, the sampling grid is not even throughout the survey area. However, on average the sample coverage is approximately 1 site per 7 km^2

Bark samples were returned to the GSC laboratories in Ottawa where they were reduced to ash by controlled ignition at 470°C for 24 hours. They were then submitted for multi-element analysis by instrumental neutron activation (INAA) and inductively coupled plasma emission spectrometry (ICP-ES) at Activation Laboratories Ltd. (Ancaster, ON). The INAA analysis reports the total concentration of elements in the sample. The ICP-ES is performed on an aqua regia digest of the ashes, and provides data on the total or near total concentrations of most elements.

Commonly, lodgepole pine outer bark contains <2 ppm Mo in ash. In map sheets 93F/15 and 16 the median Mo concentration is 8 ppm, and to the west in 93F/13 and 14 the median is 11.5 ppm Mo. This attests to the significant regional enrichment of molybdenum, culminating just north of the survey area in the Endako molybdenum mine. Figure 2 shows the area covered in the 1996 survey (93F/15,16), with dots sizes proportional to the relative concentrations of Mo (from Dunn, in prep.).

Figure 2: Molybdenum in ash of lodgepole pine bark – Nechako River area – Map Sheets NTS 93F/15 and 16

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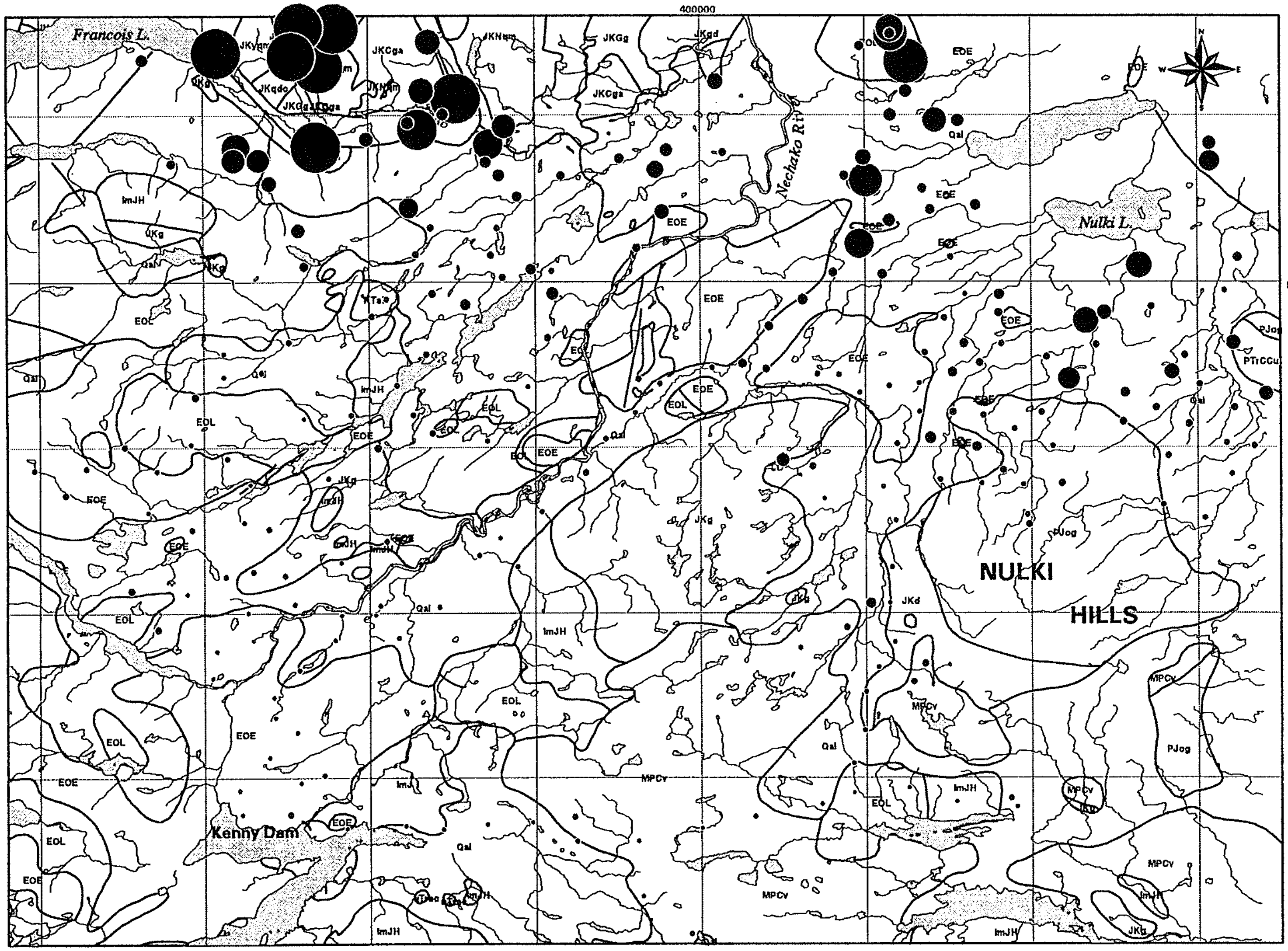

MOLYBDENUM
in ash of Lodgepole Pine Bark

ICP-ES

ppm	Mo	Percentile
296		Maximum
141		98
84		95
58		90
20		75
8		50
<2		Minimum

229 Samples

Exponent = 1

Scale 1:400 000 - Échelle 1/400 000

Kilometres 10 0 10 20 30 40 Kilomètres

UTM Zone 10

NATMAP
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Canada's National Geoscience Mapping Program
Le Programme national de cartographie géoscientifique du Canada

Figure 3 is a sketch map showing the main locations in and around the 1996 survey area (NTS 93 F/15 and 16), with broadly categorised geological units (from a digital compilation by the BC Geological Survey), and the main zones of metal enrichment defined by the lodgepole pine bark. Enrichment of Mo around the Endako Mine has been omitted and is discussed later (see section on 'Endako'). Similarly, a zone of Cr and Co enrichment along the western margin of the Nulki Hills is discussed later.

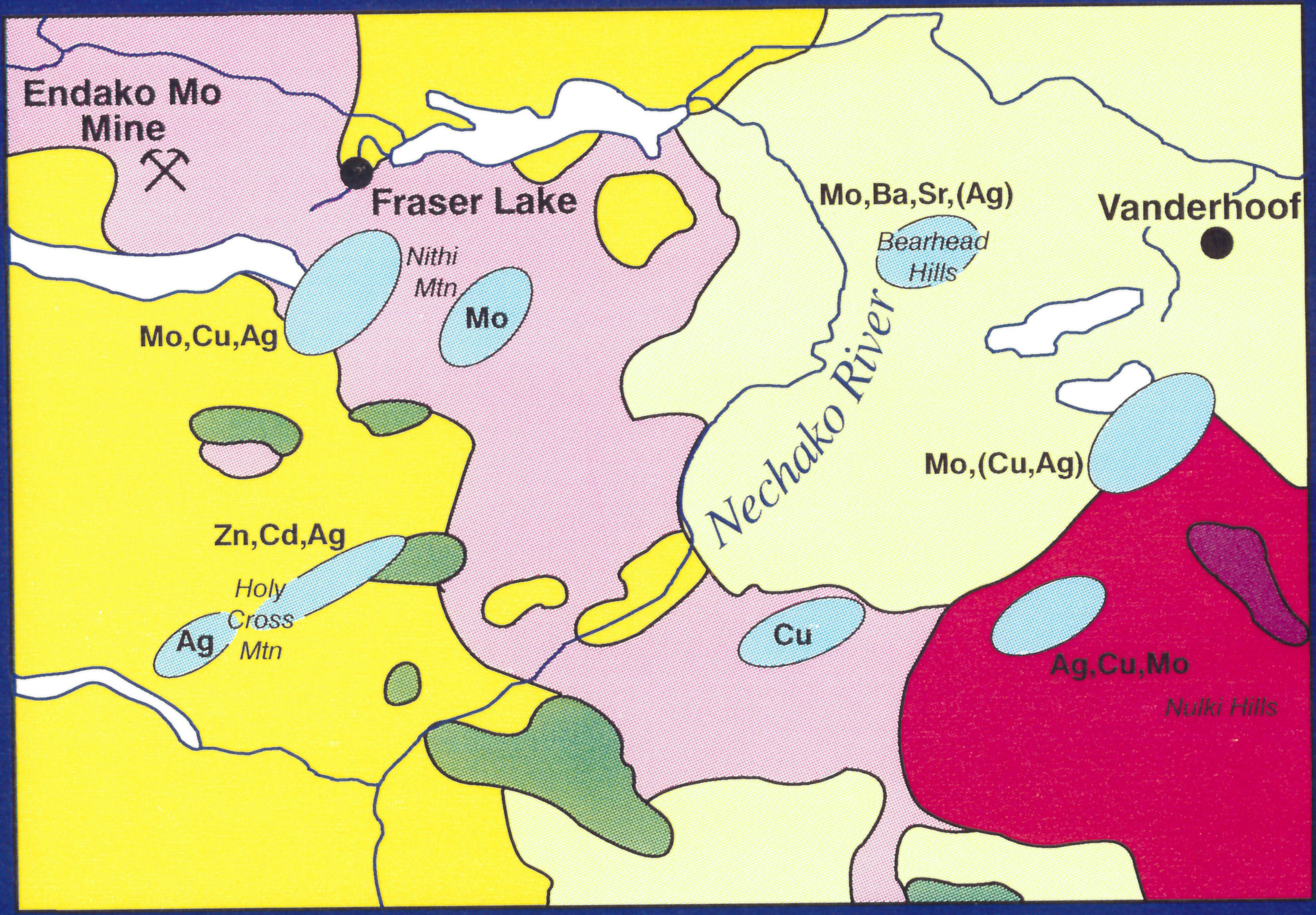
In general, concentrations of elements other than Mo are not unusually high, although local enrichments do occur at several localities. Relative enrichments of metals (shown as blue ovals) outline several zones of known mineralization: e.g. Holy Cross [Zn, Cd, Mn, Ag], and Nithi Mountain [Mo, Cu, Ag]. Each zone encompasses several square kilometres and is identified from the analysis of several samples. In addition, there are other areas where mineralization has not previously been reported, that are of similar anomaly magnitude and extent to those of Holy Cross and Nithi Mountain (Fig. 3). Of note are enrichments of:

- Mo, Cu, and Ag in two areas, in association with the orthogneiss comprising the Nulki Hills (north east part of NTS 93F/16).
- Mo, Ba, and Sr enrichment with minor Ag north of Goldie Creek around Bearhead Hills (north central part of NTS 93F/16). At this locality is a quarry into layered felsic tuff (Endako Group) which has tridymite, the high temperature form of quartz, on bedding planes. This high heat source could have provided the engine for mobilising and localising mineralization. The source of the high Mo values in samples from this area has not been identified.
- Mo north of Uncha Lake (northern part of NTS 93F/13), just west of Fig. 3.

Figure 3: Zones of relative element enrichment in ash of lodgepole pine bark – Nechako River maps sheet (NTS 93 F/15 and 16)

Geological units (broadly categorised) are:
Pale Yellow – Endako Group, mafic volcanics
Dark Yellow – Ootsa Lake Group: Felsic to mafic volcanics
Pink – Felsic intrusions
Red – Orthogneiss (Nulki Hills)
Green – Takla Group: Mafic volcanics
Purple – Cache Creek Group: Ultramafics

LODGEPOLE PINE BARK: ZONES OF METAL ENRICHMENT



The Kluskus Road skirts the western margin of the Nulki Hills (93F/16). Stations selected for sample collection off this road (minimum of 50 m into the forest) show relative enrichment of several metals, notably Cr and Co (Fig. 4). The immediate suspicion is that these anomalous trends are related to dust, derived from the unpaved road, that has settled on the tree surfaces. In order to test this possibility, sites of two borrow pits along the Kluskus Road (km 35 and km 36) were visited and samples of rock, soil, road-dust and vegetation collected. Analytical data from these samples are summarised in Table 1.

Km 35:	Cr (ppm)	Co (ppm)
Olivine Basalt (oxidized)	410	48
Residual soil (-80)	140	38
Road dust (-80)	84	19
Km 36:		
Olivine Basalt (unoxidized)	260	41
Residual soil (-80)	210	41
Road dust (-80)	130	24
Lodgepole pine bark (ash)	130	32
Lodgepole pine bark (dry)	7	1.8
Alder twig (ash)	22	13
Alder twig (dry)	0.7	0.4

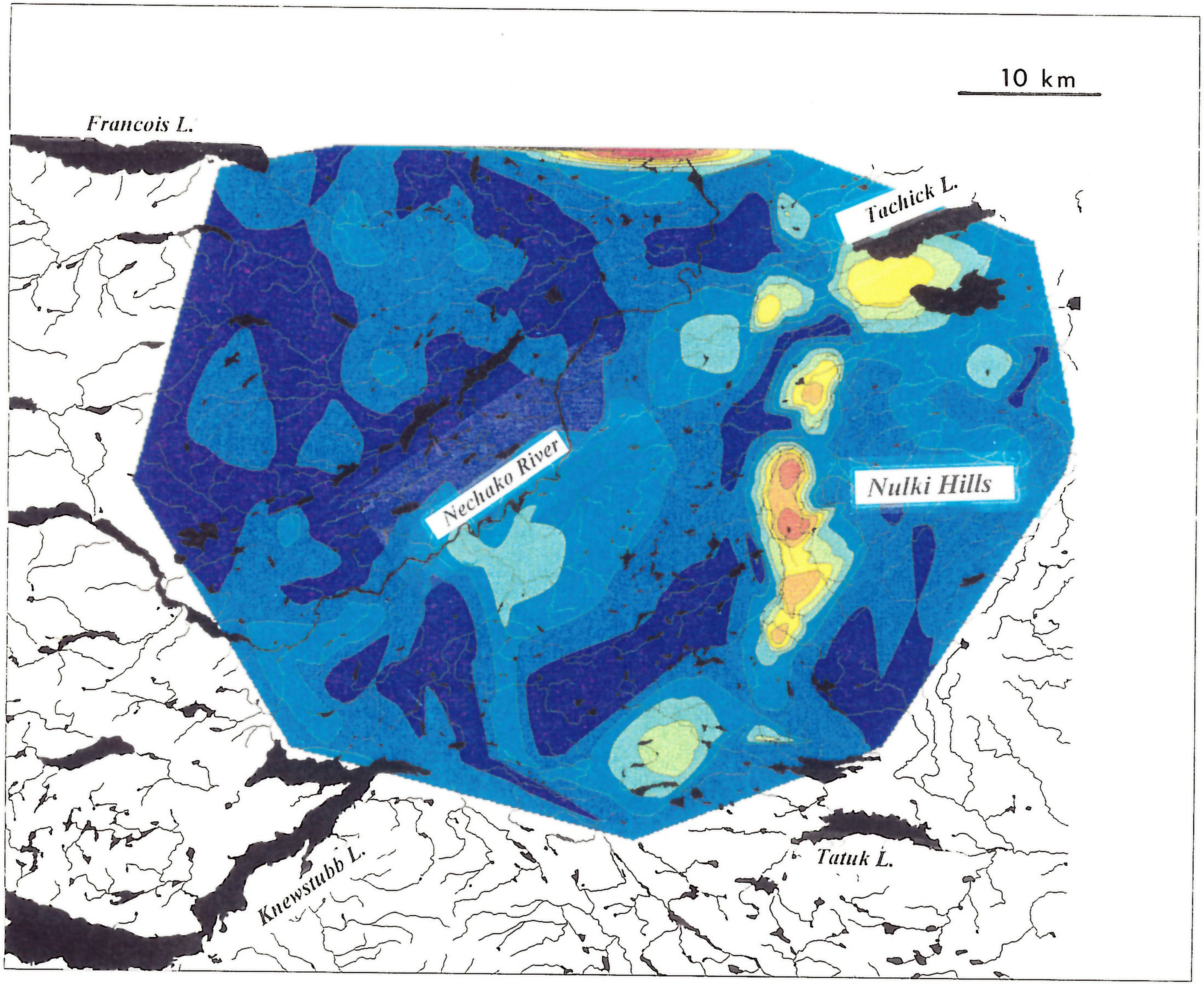
Table 1: Concentrations of Cr and Co in rocks, soils, road dust and vegetation at two sites along the Kluskus Road

Levels of Cr and Co are moderately high in the olivine basalts and sediments. Concentrations of these elements in the ash of lodgepole pine bark are similar to those of the road dust, but this may be fortuitous because the alder yielded substantially lower concentrations. If the bark anomalies were due to dust contamination it might be expected that similar Co and Cr values would occur in all plant species. Since this is not the case, it appears that there is preferential uptake of these elements by the pine, which then concentrates them in its outer bark.

From these results it is concluded that there may be some contamination of samples from the road-dust, but the bark chemistry is reflecting a highly mafic zone of rocks that parallels the road and is obscured by the overburden. The biogeochemical data suggest that this zone may extend into the Tachick Lake area (Fig. 4) where the overburden comprises glacial lake sediments. A second zone of enrichment occurs in association with elevated levels of Mo at the northern limit of the map.

Figure 4: Cobalt concentrations in ash of lodgepole pine bark, Nechako River area, map sheets 93 F/15 and 16.

COBALT in Ash of Lodgepole Pine Bark
Nechako River



Co

Co ppm	Percentile
>35	100
31.5	90
28	80
24.5	70
21	60
17.5	50
14	40
10.5	30
7	20
3.5	10
<3.5	Min.

Endako Mine

The Endako Mo mine (Fig. 3) occurs within a large composite batholith, and is associated with pervasive kaolinization. Samples of common plant species were collected from a roadside site 1 km east of the Endako mine entrance in order to evaluate their relative abilities to take up Mo. Table 2 shows high to extremely high concentrations, ranging from 342 ppm Mo in fireweed stems to 12,100 ppm Mo in lodgepole pine bark. The latter is partially attributable to particulate material lodged in the bark, since it could not all be removed by washing.

		Mo (ppm) in ash	Mo (ppm) in dry tissue
Alder	Twigs	2390	50
	Leaves	3530	152
Willow	Twigs	1260	45
	Leaves	2380	176
Cottonwood	Twigs	594	25
	Leaves	1230	93
Aspen	Twigs	1070	34
	Leaves	3470	184
Soopolallie	Stems	5250	85
	Leaves	2440	212
Fireweed	Stems	342	26
	Leaves	2950	376
White spruce	Twigs	4280	134
	Needles	790	69
Subalpine fir	Twigs	6480	309
	Needles	2120	114
Lodgepole pine	Bark (outer)	12100	518

Table 2: Molybdenum in vegetation from a site 1 km east of the Endako mine

In the same area, a study was made to determine the extent of the Mo `footprint' associated with the mineralization and the mine workings. Samples of the large shrub Sitka alder were collected at regular intervals along the road from the mine site north-eastward to Endako village. Each sample comprised approximately 7 lengths of the most recent three years growth of twig. Samples were washed prior to separation of twigs from leaves, and then reduced to ash by controlled ignition. Table 3 shows the significant concentrations close to the mine, which decrease with distance from the mine, but are still more than 20 times normal background levels at a distance of 6 km. It is likely that some of this signature is a reflection of the extensive regional enrichment of Mo in the bedrock, but some is attributable to particulates from the mine workings which have settled on the ground and subsequently been absorbed by the plants. The full regional 'footprint' of the Mo has yet to be determined.

	Sitka Alder	
Distance from mine, along road to Endako village	**Twigs**	**Leaves**
Entrance	4280 (155)	6510 (351)
1 km east	2390 (50)	3530 (152)
2 km east	1190 (29)	1500 (74)
4 km east	494 (12)	374 (18)
6 km east	436 (8.5)	212 (8.3)
Background	<20 (<0.4)	<20 (<0.8)

Table 3: Molybdenum (ppm) in Sitka alder (*Alnus sinuata)*: Endako Mine area (Concentrations in ash, with equivalent values in dry tissue in parentheses)

Rare Earth Elements

Work by Bob Anderson and Joe Whalen has identified distinct REE patterns (chondrite normalised) for various intrusive phases. However, outcrops of the intrusives are locally inadequate for detailed mapping, therefore the use of REE in plants was investigated to determine if they could be of use in differentiating underlying bedrock. One of the chemical peculiarities of ferns is that they are able to accumulate high concentrations of the rare earth elements (REE). Old alder twigs exhibit the same phenomenon, but to a lesser degree. During the 1996 field season it was observed that there is patchy development of ferns, but the shrub alder is a common plant in the survey area.

The approach taken was to visit several localities with Bob Anderson to collect vegetaion samples where rock samples had been collected and their REE contents determined. In addition, vegetation samples were collected at other till-covered localities. The most common species encountered were the shrub alder (*Alnus sinuata*), soopolallie (buffaloberry – *Shepherdia canadensis*), and lodgepole pine (*Pinus contorta*). Ferns were only found at two sites. Pine bark, alder twigs and leaves, and soopolallie twigs and leaves were sampled at several sites on Nithi granite, Casey granite, the Stag Lake intermediate phase, and volcanic rocks of the Chilcotin.

Figure 5 shows plots of two samples of Nithi Phase rock (upper profiles) and two of lodgepole pine bark. The patterns are remarkably similar. Figure 6 shows a single rock sample and a single pine bark sample from the Casey Phase. Although similar, the heavy rare earths (HREE) are slightly depleted in the pine bark. This HREE depletion appears to be characteristic of plant uptake: Figure 7 shows this for alder twigs and leaves, pine bark, and a strong depletion in fern. Another characteristic of some species is a slight depletion in Ce. Of the species and tissues tested to date that which gives the REE pattern closest to that of the underlying rock is the outer bark of lodgepole pine. Of interest is the observation that the REE patterns of vegetation growing on till deposited on, for example, Nithi Phase rocks exhibit the signatures of that phase. Although there are limitations to this simple and inexpensive approach of using vegetation to define REE signatures of underlying bedrock, further development of the technique could prove to be of use for assisting in bedrock mapping.

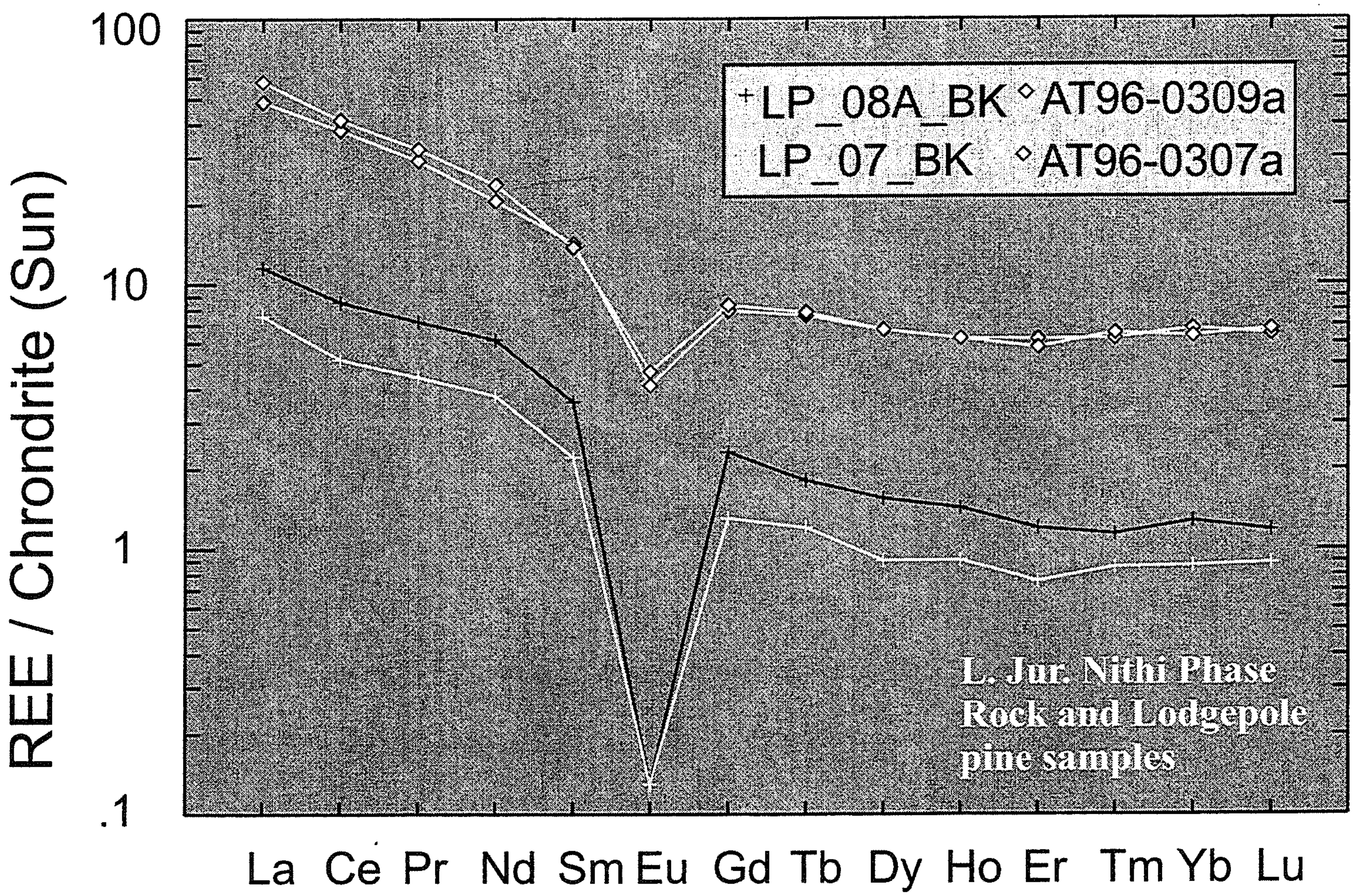


Figure 5: Nithi Phase – rock samples (upper two profiles), and lodgepole pine bark samples from the same sites.

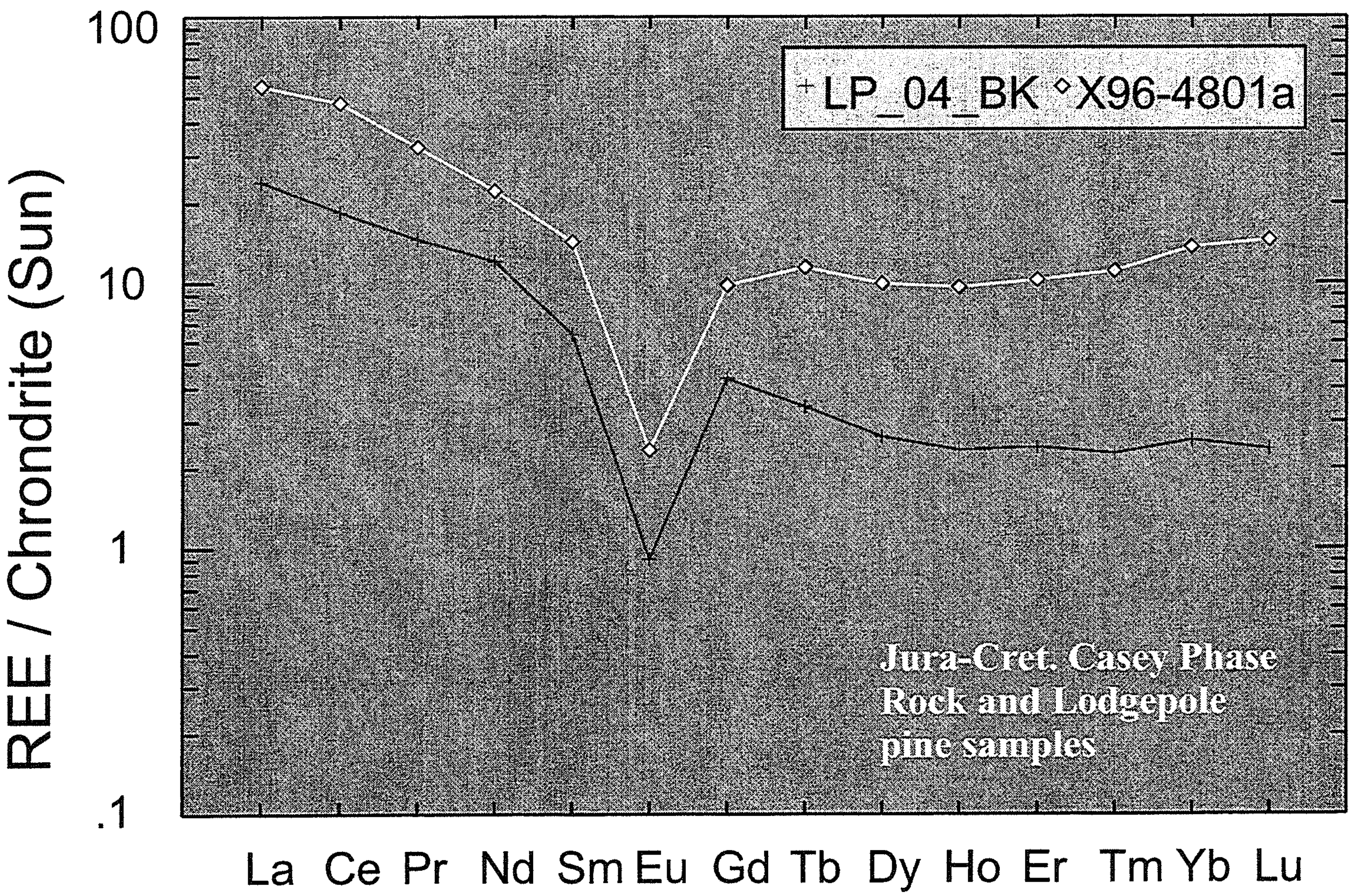


Figure 6: Casey Phase – rock sample (upper profile) and lodgepole pine bark from the same site

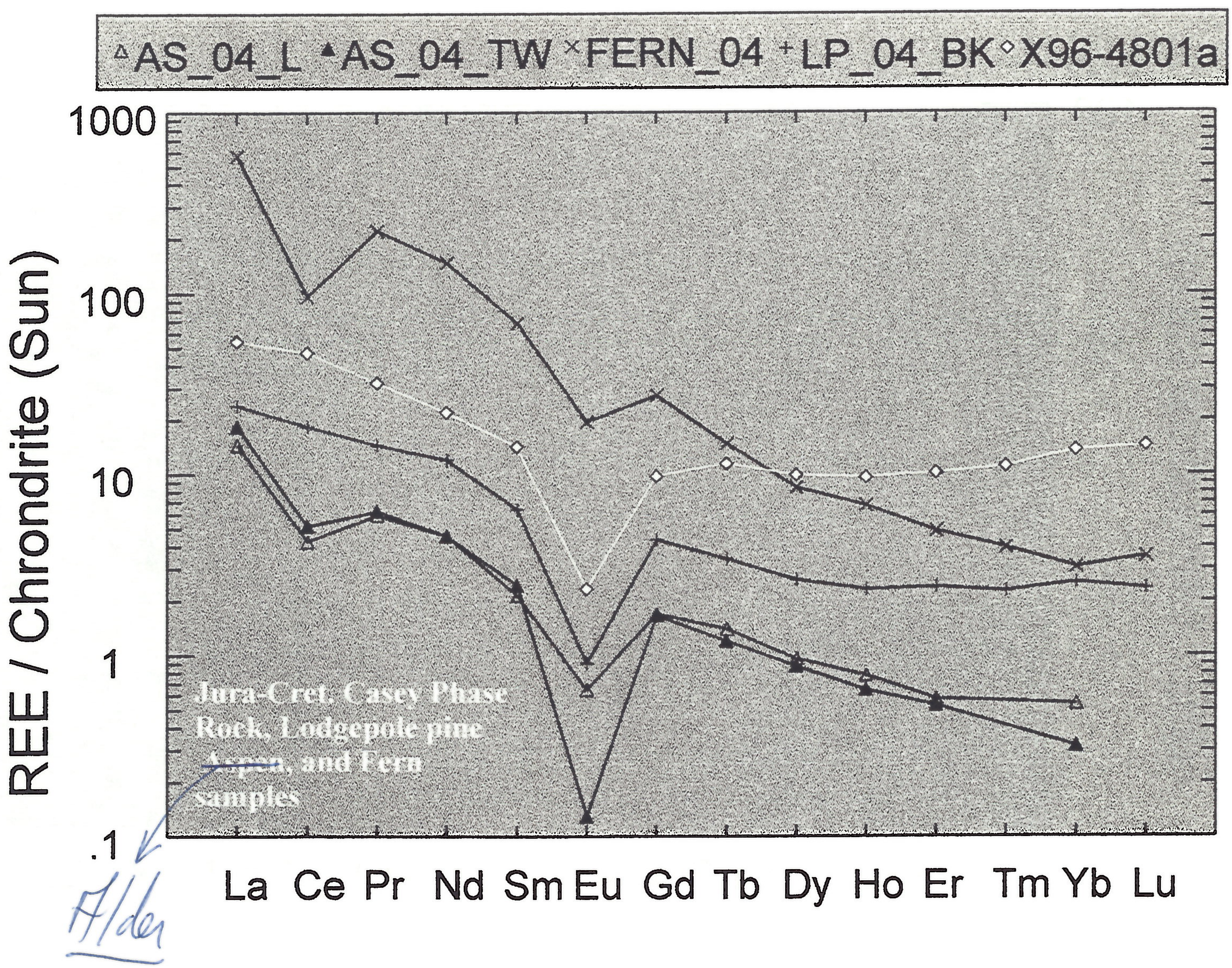


Figure 7: Casey Phase – Rock sample (diamond symbol, X96-4801a); Fern (x – Fern_04), Sitka alder leaf (open triangle, AS_04_L); Sitka alder twig (filled triangle, AS_04_4TW); lodgepole pine bark (+ sign, LP_04_BK)

Babine Area

In the Babine Porphyry Belt, detailed sampling, run in conjunction with the till sampling program of Steve Cook, involved the collection of lodgepole pine bark and alder twigs across zones of Cu/Mo mineralization north of Lennac Lake. At the Lennac property, located 20 km SSW of Granisle (Babine Lake), lower Jurassic volcanic and volcaniclastic rocks of the Telkwa Formation are intruded by porphyritic granodiorite. Sulphides (pyrite, chalcopyrite, molybdenite and minor sphalerite) border the intrusions, and there is local enrichment of gold.

Samples were collected from 130 sites within an area of 100 km^2 at a spacing of 200 m along traverses normal to the bedrock strike. Results show locally high concentrations of Cu, Mo, Ag and Cd, and traces of Au. In this environment the alder is of particular use because it has the ability to highly concentrate Mo and, to a lesser degree, Cu. Close to the Suratt Cu showing the ash of alder twigs yielded 301 ppm Mo and 364 ppm Cu. At a trench approximately 100 m to the southeast, into a showing of molybdenite stockwork with chalcopyrite, alder twigs yielded a similar concentration of Cu, 83 ppb Au (an order of magnitude above background), and remarkable enrichment of 2449 ppm Mo. This magnitude of concentration is similar to the 2390 ppm Mo recorded in alder twig ash from near the Endako Mo mine (Table 2). Elsewhere in the survey area, at overburden-covered sites with no known mineralization, alder yielded up to 1250 ppm Mo, and pine bark yielded maxima of 809 ppm Cu, 7.5 ppm Ag and 63 ppb Au. Cadmium is highly enriched in the pine bark (up to 123 ppm Cd) and the pine bark data indicate east-west trends of enrichment in Cu and Cd.

Concluding Remarks

Judicious selection of vegetation species and tissues, followed by standard careful quality control procedures, can provide data which can assist in bedrock mapping and provide focus for exploration efforts. Procedures are simple and cost-effective. However, as in any exploration geochemical survey program, in order to optimise the value of the data, care must be exercised in the selection of suitable sample materials, and sample sites that are free from local contamination. In interpreting the data, due consideration should be given to any potential source of airborne particulate material that might be augmenting the geochemical signal of the sample medium.

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