BIOGEOCHEMICAL SURVEYS IN THE INTERIOR PLATEAU OF BRITISH COLUMBIA

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Geological Survey of Canada Contribution 1996167

KEYWORDS: Biogeochemistry, exploration, gold, copper, Clisbako, Fish Lake, lodgepole pine, alder, willow, Douglas fir, baseline data.

INTRODUCTION

Exploration for mineral deposits in the Interior Plateau is hampered by extensive forest cover, by glacial drift which blankets much of the bedrock, and by extensive plateau basalt. In this biogeoclimatic regime, tree roots penetrate to a depth of several metres and extract metals from the soil, glacial drift, locally the bedrock, and the waters contained within these media. The roots extract elements required by the trees, together with others not required for plant growth, but which the trees can tolerate. Many of the latter group of elements are stored in the outer bark, twig ends and tree tops. Thus, the extensive root system of a tree is able to integrate the geochemical signature of many cubic metres of the substrate, and amplify this signature by accumulating elements (notably many heavy metals) in the tree extremities. Surveys to collect and analyze tree and shrub tissues can, therefore, provide valuable information on the chemistry of the substrate and assist in defining areas of good mineral exploration potential.

With these principles in mind, biogeochemical surveys were conducted in two areas of the Interior (Chilcotin) Plateau: around epithermal mineralization near the Clisbako River, and near the Fish Lake porphyry copper-gold deposit (Figure 1). In both survey areas the dominant tree species is lodgepole pine (*Pinus contorta*), therefore this species was selected as the prime sample medium. Locally, other species were collected in order to characterize their biogeochemical signatures, and assess their relative abilities to detect concealed mineral deposits in this environment. There were no known biogeochemical data from the survey areas, or even from the Interior Plateau in general. Given this situation it was necessary to first conduct orientation surveys.

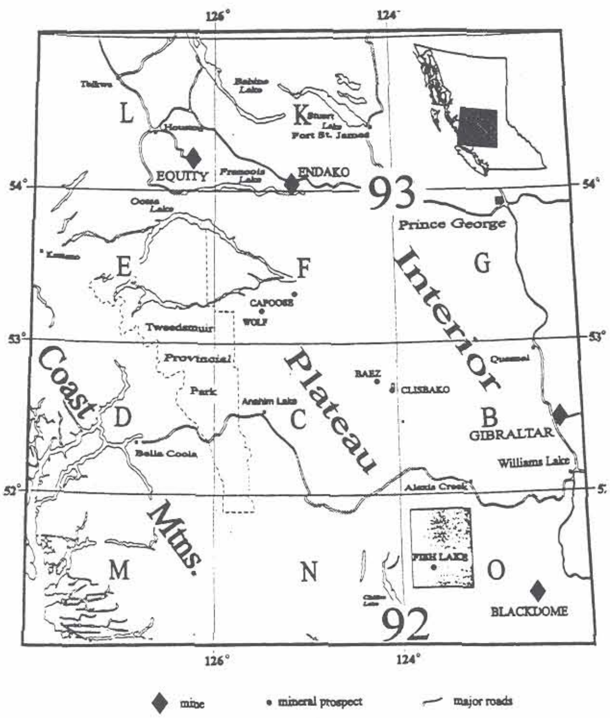


Figure 1. Location map.

GEOLOGY AND MINERALIZATION

CLISBAKO

Exposure in the Clisbako area is poor, with less than 4% rock outcrop which is restricted to gullies, incised drainages and road cuts (Schroeter and Lane, 1992). Figure 2 shows the general geology and the locations of mineralized showings within the Clisbako group of mineral claims. Schroeter and Lane (1992) note that three well developed hydrothermal alteration centres (North, Central and South zones), and subordinate alteration zones have been identified within a suite of Eocene Ootsa Lake Group volcanic rocks (Tipper, 1978) that range in composition from basalt to rhyolite. Hostrocks are rhyolitic breccias and tuffs that have been pervasively silicified, argillized and bleached by hydrothermal fluids. Sulphide concentrations are low (1 - 5%), and dominated by pyrite with local enrichment of marcasite, arsenopyrite and pyrargyrite as the main silver-bearing mineral (Dawson, 1991). No visible gold has been reported.

FISH LAKE

A geological map of the Fish Lake area (NTS 92O) published by Tipper (1978) has recently been revised. The southern part of the present survey area was mapped by Riddell *et al.* (1993), and the adjacent area to the north by Hickson and Higman (1993). The geological contacts shown on Figure 3 are based upon the published results, and comments by C.J. Hickson (personal communication). The region is largely drift covered and thick glaciofluvial deposits occupy the valleys (Plouffe, 1997, this volume). Laterally extensive flows of Miocene to Pleistocene basalt (Chilcotin Group), mostly less than 30 metres thick, cover large tracts of the survey area. These overlie Eocene volcanic rocks that range in composition from picritic basalt to rhyolite. Small Cretaceous to Tertiary granodioritic plutons occur at Cone Hill, Vedan Mountain and Newton Hill.

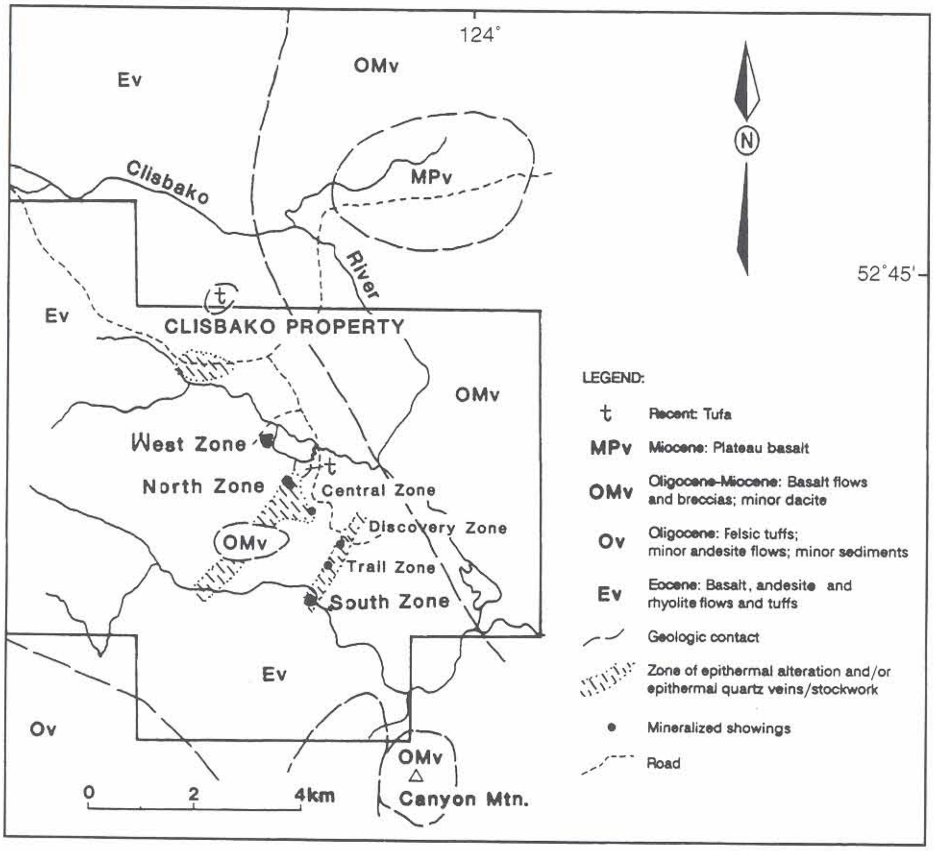
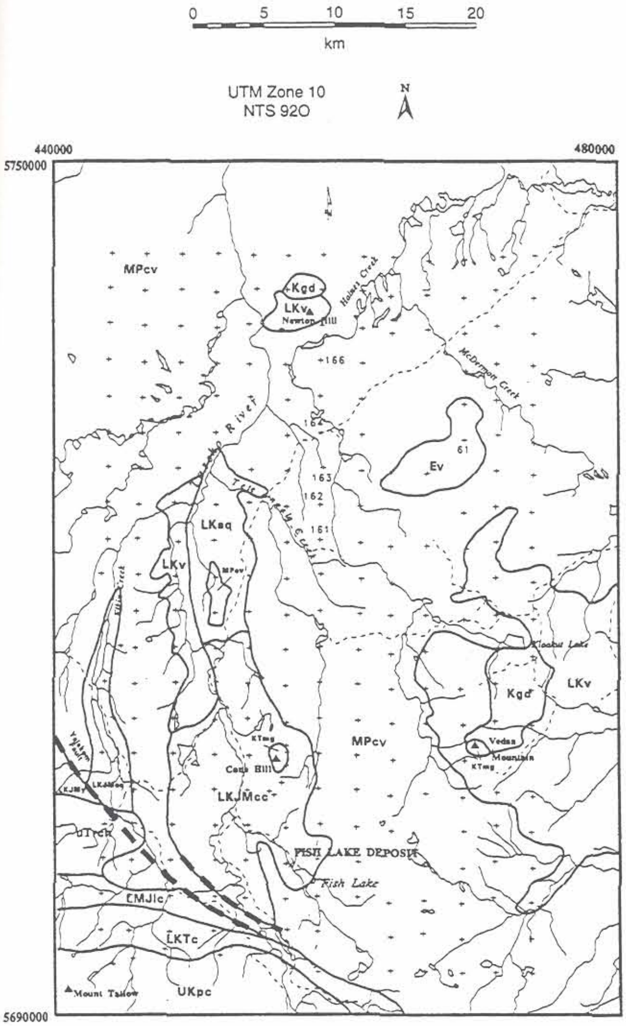


Figure 2. Geology of the Clisbako area with mineral showings (modified after Dawson, 1991 and Schroeter and Lane, 1992).

Photo 1. Lodgepole pine top - portion above where it is being held is the typical amount collected for analysis of the stem and branches, less the needles and cones.



LEGEND

MIOCENE AND PLIOCENE

Mpcv Basalt (olivine ± plagioclase)

EOCENE

Ev Picritic basalt; andesite; rhyolite

CRETACEOUS TO TERTIARY

KTmg Granodiorite and tonalite

CRETACEOUS

Kgd Granodiorite and diorite (porphyritic)

UKpc *(Powell Ck. Fm)* Volcanic flows and tuffs (andesitic)

LKtc *(Taylor Ck. Gp)* Clastic sediments

LKsq *(Silverquick Fm)* Sandstone and conglomerate

LKv Volcanic lavas and tuffs (rhyolite to andesite)

Jackass Mtn. Gp.

LKJMy *(Yalakom Mtn. Facies)* Clastic sediments

LKJMcc *(Churn Ck. Facies)* Marine sediments and conglom.

LMJlc *(Last Ck. Fm)* Clastic sediments

TRIASSIC

UTrch *(Hurley Fm)* Clastic and carbonate sediments

Figure 3. Simplified geology of the Fish Lake area, compiled from Tipper (1978), Hickson and Higman (1993) and Riddell *et al.* (1993). Lodgepole pine sample sites are marked as '+'; numbers by sample sites are those referred to in text.

Cretaceous strata are mostly clastic sediments with some felsic volcanic rocks. Clastic sedimentary rocks of Jurassic age crop out in the southwestern corner of the survey area, overlying Upper Triassic calcareous clastic beds of the Hurley Formation.

A major, steeply dipping fault system, named the Yalakom fault (Figure 3) by Leech (1953), has brought Triassic to Cretaceous strata in the southwest into juxtaposition with rocks ranging in age from Cretaceous to Pleistocene. Northeast of this fault the flood basalts and glacial deposits obscure the structure, but north and northeasterly striking faults have been recognized (*e.g.* Elkin Creek and Taseko Valley).

Mineralization has been found at Fish Lake, Newton Hill and Cone Hill. The Fish Lake deposit is by the far the largest known in the survey area. Preliminary engineering studies indicate a possible mineable reserve of 747 million tonnes grading 0.23% Cu and 0.446 g/t Au per ton at a strip ratio of 1.57:1 (Caira *et al.*, 1995). The deposit is oval in plan, 1.5 kilometres long, up to 800 metres wide, and extends to a maximum depth of 880 metres. Mineralization is disseminated chalcopyrite with bornite associated with potassic metasomatism, and has a halo of pyrite to the north and east that coincides with a zone of phyllic alteration.

ORIENTATION SURVEYS

SAMPLE COLLECTION, PREPARATION AND ANALYSIS

In the summer of 1992 a short visit was made to the Clisbako and Fish Lake areas to examine the distribution of tree and shrub species, and to collect a suite of representative tissues from common species in both areas. Twig and foliage samples were collected from dwarf birch (*Betula glandulosa*), Sitka alder (*Alnus sitchensis*), two species of willow (*Salix bebbiana* and *Salix barratiana*), Canada buffaloberry (*Shepherdia canadensis*) and lodgepole pine (*Pinus contorta*). Outer bark was scraped from the pines, and the latest three years growth from the top of the pines (Photo 1) was collected by climbing trees. The tops were required to determine if their inter-site chemical signatures were sufficiently varied to warrant conducting a helicopter-borne survey to obtain pine tops over a large area the following year. At Clisbako, 48 samples were collected from 27 sites; in the Fish Lake area 73 samples were collected from 37 sites.

All samples were sent to the Geological Survey of Canada laboratory in Ottawa for air drying. Samples were either macerated in preparation for analysis of dry tissue, or reduced to ash by controlled ignition in a kiln at 470°C. Unless otherwise stated, the data presented here are concentrations in ash; the main exception is mercury for which concentrations were determined on dry tissue, because it volatilizes during the ashing process. Determinations on ash were made for 35 elements by instrumental neutron activation analysis (INAA) at Activation Laboratories Ltd., Ancaster, Ontario, and for 32 elements by inductively coupled plasma emission spectrometry (ICP-ES) at Acme Laboratories Ltd., Vancouver, B.C. Mercury determinations were by cold vapour atomic absorption on tissue that was macerated but not ashed.

RESULTS OF ORIENTATION STUDIES

In general, trace element concentrations in the vegetation of the Interior Plateau are quite low, being mostly close to usual background levels for each species tested. However, metal enrichment occurs in tissues of several species growing close to zones of mineralization. Table 1 shows common background levels of selected elements in the species tested, and some examples of enrichment over mineralization in the survey areas.

CLISBAKO

From Table 1 it is evident that there are unusually high concentrations of gold in twigs of Sitka alder (300 ppb Au) and Bebb willow (123 ppb Au) in the Clisbako area. These samples were collected in a valley adjacent to the North zone (Figure 2). Glandular birch from the same location yielded 35 ppb gold in twig ash. Thallium, not reported in Table 1 because of some uncertainty with the accuracy of the analytical data, appears to be enriched in twigs of birch and the two species of willow. A lodgepole pine on argillized sinter flanking the valley, 100 metres to the east, yielded 54 ppb gold and 57 ppm arsenic in its outer bark. The top stems of the pines near the North zone are not enriched in gold but contain levels of other elements commonly enriched in epithermal systems, that are an order of magnitude above background for pine tops: up to 4 ppm silver, 11 ppm arsenic, 16 ppm cesium and 1000 ppm rubidium.

At the South zone, alder is enriched in molybdenum (162 ppm) and tungsten (18 ppm), whereas there are only subtle enrichments of metals in the pines. Near the West zone there are few metal enrichments in the vegetation, with 45 ppb gold in pine bark being the most notable exception.

Four kilometres northwest of the North zone there is a boggy area with whitish mud which has been interpreted as a hot-spring tufa deposit (Figure 2). Birch twigs from this site are strongly enriched in lithium (138 ppm) and strontium (6000 ppm) with moderately high concentrations of boron (966 ppm) and magnesium (5.9%). Background concentrations of these elements in birch are 2 ppm (Li),

TABLE 1
EXAMPLES OF METAL ENRICHMENT IN ASH OF TREES AND SHRUBS FROM THE CLISBAKO AND FISH LAKE AREAS

	Background*	Examples of Enrichments
Au ppb	5 - 10	300 ppb in alder twigs: Clisbako, N. zone 123 ppb in willow twigs: " N. zone 67 ppb in pine bark: Fish Lake (nr. trench) 57 ppb in pine bark: Fish Lake 54 ppb in pine bark: Clisbako, N. zone 45 ppb in pine bark: Clisbako, W.zone
Ag ppm	0.2	6 ppm in pine twigs: Fish Lake 4 ppm in pine tops: Clisbako, N. Zone
As ppm	2	57 ppm in pine bark: Clisbako, N. zone 37 ppm in birch twigs: " N. zone 32 ppm in pine bark: Fish Lake
Cd ppm	1	13 ppm in pine twigs: Fish Lake 10 ppm in pine tops: Clisbako, S. zone
Cs ppm	1	27 ppm in pine tops: Clisbako, S. zone
Cu ppm	80	431 ppm in alder twigs: Fish Lake 400 ppm in pine twigs: Fish Lake 367 ppm in pine bark: Fish Lake 330 ppm in pine tops: Clisbako, S. zone
Mo ppm	2	162 ppm in alder twigs: Clisbako, S. zone 127 ppm in alder twigs: Fish Lake 68 ppm in alder twigs: Clisbako, road cutting
Ni ppm	30	355 ppm in pine tops: Clisbako, road cutting 226 ppm in pine tops: Clisbako, S. zone
Sb ppm	0.2	6 ppm in pine bark: Clisbako, N. zone
W ppm	<1	18 ppm in alder twigs: Clisbako, S. zone

*Typical concentrations of metals in plants within the survey area from locations remote from known mineralization.

1500 ppm (Sr), 500 ppm (B), and 3% (Mg). A top stem of lodgepole pine from this site is similarly enriched in lithium and strontium. These analyses reflect the alkaline nature of the area and an association of element enrichments characteristic of ancient hot springs.

FISH LAKE

In the Taseko River valley (Figure 3), close to the main zone of mineralization at Fish Lake, the pine top stems show weak enrichment of gold, molybdenum, copper, cesium, nickel and sodium. Strongest biogeochemical contrast occurs a few hundred metres to the east of the Fish Lake valley. On the west-facing slope of the hill, pine bark is enriched in gold (up to 67 ppb in ash), copper (367 ppm), arsenic (32 ppm) and selenium (6 ppm), and an alder yielded 127 ppm molybdenum and 431 ppm copper. Trees growing over the surrounding plateau basalt were relatively enriched in chromium, iron, sodium, scandium and rare-earth elements.

SUMMARY OF RESULTS FROM THE ORIENTATION STUDY

The chemistry of the common trees and shrubs in the Clisbako area provides a clear indication of element enrichments typical of modern epithermal systems. Highest concentrations of gold, molybdenum, lithium and thallium occur in the twigs of the shrub alder, birch and willow. However, these species are not evenly distributed throughout the survey area, and they are therefore only of use in differentiating metalliferous valleys from those that are metal deficient. As such, they provide a powerful means for locating near-surface zones of mineralization, and can be used to focus exploration efforts. As a reconnaissance biogeochemical medium, the lodgepole pine is the optimum species because of its widespread occurrence. There is weak enrichment of gold, molybdenum, arsenic, cesium and nickel in the pine tops from sites close to the North and South zones of epithermal precious metal mineralization. The pine bark samples from the same sites yielded slightly higher concentrations of gold, silver, arsenic and cadmium, and confirmed the elevated background levels of molybdenum.

At Fish Lake the porphyry copper-gold deposit has generated mostly weak biogeochemical signatures, with the exception of molybdenum, copper and, locally, gold to the east of the deposit. From these data it was concluded that in the Fish Lake area, a reconnaissance-level biogeochemical survey making use of lodgepole pine top stems was likely to generate a subtle response to underlying porphyry-style mineralization, and therefore a second phase of study involving biogeochemical mapping was planned for the following year.

HELICOPTER-MOUNTED RECONNAISSANCE-LEVEL SURVEY

Pacific Phytometric Consultants (Surrey, B.C.) was contracted to collect tree-top samples from a helicopter at sites identified on 1:50 000-scale topographic maps. The contract specified that, wherever possible, a tree top should be sampled within a 200-metre radius of the preferred site. The only departures from the preassigned grid were due to recent burns, pine beetle kill, bogs and complex multi-storied, multi-species stands where pines were lower in the forest canopy and therefore could not be sampled with safety.

During a three-day period in early May, 1993, a 1625 square kilometre area was surveyed along 715 kilometres of grid lines at a spacing of 2.5 kilometres between sample sites (Figure 3). The top 0.5 metre, mostly comprising three years of growth, was snipped from a lodgepole pine at each of 276 sites. A single top (stem, branches, needles and cones - see Photo 1) from a healthy tree was collected at each sample station. Rounded-top lodgepole pines have thick branches and abundant cones making them difficult to cut with hand shears. In some cases it was possible to break the top of the tree by bending it and then cutting. The fresh weight of each sample varied from 500 grams to 1 kilogram. The total flying time was 15.9 hours to provide an overall productivity of 17.5 samples/hour (3.4 minutes/sample). Production was 22 sites/hour (2.75 minutes/sample) when flying along a predetermined line.

The survey crew consisted of the pilot, a navigator (who also bagged the samples), and a sampler, secured by a safety belt with two lanyards, who leaned out of the hovering helicopter to snip off the tree tops. Once the helicopter was positioned, the actual sample retrieval time was usually 5 to 10 seconds. Constant intercom communication between the flight crew is essential for safety and efficiency of sampling. More details of the sampling methods are given in Dunn and Scagel (1989), with modifications described in a second paper (Scagel and Dunn, in preparation). Site locations were located with an accuracy of 15 metres using a GARMON GPS-100 global positioning system receiving signals from at least five satellites.

RESULTS OF RECONNAISSANCE SURVEY

A detailed account of the sample preparation, the analytical program and the results are given in Dunn *et al.*, 1994. At the low sample density (1 site per 6 km^2) it was considered unlikely that any undiscovered zones of mineralization might be located: the objective of the survey was to define regional trends in geochemical patterns and spatial relationships of the elements which might provide focus for future exploration efforts. The data are summarized in Tables 2 and 3. Table 2 lists elements determined by INAA and represents total content of elements in ash. Table 3 lists elements determined by ICP-ES following an aqua regia digestion of the ash. This digestion provides total content of most elements, but only a partial digestion of a few elements (*e.g.*, Ba and probably Sr and B). The 50th percentile can be considered representative of the 'background' concentration of each element.

In addition to providing baseline data on the elemental content of the pine tops, the principal geochemical information to emerge from the reconnaissance survey is:

- Sample density was too low to outline the low-grade copper-gold mineralization at Fish Lake. However, there are several areas of relative enrich-

TABLE 2
CONCENTRATIONS OF ELEMENTS DETERMINED BY INAA IN ASH OF LODGEPOLE PINE TOPS FROM THE FISH LAKE RECONNAISSANCE SURVEY AREA (N = 276)

	Percentile Values		
	50th	90th	100th
Au ppb	8	18	40
As ppm	0.9	2.0	4.1
Br ppm	4	7	18
Ca %	8.8	13.1	25.8
Ce ppm	<3	5	16
Co ppm	7	12	23
Cr ppm	8	66	190
Cs ppm	0.3	3.7	29
Eu ppm	<0.01	<0.01	0.52
Fe %	0.35	0.59	1.86
Hf ppm	0.7	1.5	2.8
K %	29	34.5	43.5
La ppm	1.1	2.3	6.1
Lu ppm	<0.05	0.06	0.19
Mo ppm	<2	10	34
Na %	0.12	0.28	0.86
Nd ppm	<5	6	33
Rb ppm	110	390	1300
Sb ppm	0.1	0.3	9
Sc ppm	1.1	2.0	5.5
Se ppm	<2	<2	9
Sm ppm	0.2	0.4	1.7
Ta ppm	<0.5	<0.5	2.3
Th ppm	<0.1	0.4	0.9
U ppm	<0.1	<0.1	1.3
W ppm	<1	<1	8
Yb ppm	<0.05	0.27	0.93
Zn ppm	2100	2800	3500

TABLE 3
CONCENTRATIONS OF ELEMENTS DETERMINED BY ICP-EX (AQUA REGIA DIGESTION) IN ASH OF LODGEPOLE PINE TOPS FROM THE FISH LAKE RECONNAISSANCE SURVEY AREA (N = 276)

	Percentile Values		
	50th	90th	100th
Ag ppm	0.6	1.2	1.9
Al %	0.77	1.70	2.89
B ppm	558	739	1228
Ba ppm	22	56	152
Be ppm	<0.3	0.4	0.9
Cd ppm	3.3	6.4	10.8
Cu ppm	244	333	446
Li ppm	2	4	21
Mg %	7.4	10.3	13.2
Mn %	0.53	0.95	1.86
Ni ppm	73	169	435
P %	3.63	5.52	9.25
Pb ppm	7	15	89
Sr ppm	214	415	715
Ti %	<0.02	0.02	0.07
V ppm	<2	<2	16

ment of gold, and there is a weak northerly trend to some zones of enrichment (Figure 4).

- Chromium is the element most strongly concentrated over the zones of gold mineralization at Fish Lake and Cone Hill (Figure 5). However, this may reflect the underlying lithology (marine sediments of the Cretaceous Jackass Mountain Group) rather than the zones of mineralization.
- In the eastern part of the survey area, near Vedan Mountain, there is relative enrichment of gold, cesium (Figure 6), rubidium, tungsten and, to a lesser degree cadmium. Mercury in dry pine needles is also weakly enriched in this area (Figure 7). It is noteworthy that these elements are among those enriched in vegetation from zones of recent epithermal gold mineralization in New Zealand (Dunn, 1995). A similar pattern is exhibited by aluminum, possibly reflecting an increased level of alteration in the rocks in this area.
- Copper (Figure 8), molybdenum, lithium, nickel, phosphorus and silver are more enriched in the western part of the study area than in the east.

ANALYSES OF PINE CONES

Most of the tree top samples included cones. These were removed from the stems and set aside for further study. According to their state of maturity, they have different morphologies. New cones (1 year old) are small and dense and have a high ash yield. Two year old cones are closed, have a lower ash yield, and range in colour from green to brown. Cones that are three years or older are brown, suberized and mostly open, having shed their seeds. Comparison of open, closed and immature (small 1st year) cones from three trees indicates that the immature cones are enriched in potassium and rubidium with respect to the older cones, but are depleted in most other elements, or have similar concentrations. Nine trees yielded sufficient numbers of both open and closed cones to provide a preliminary indication of differences in their chemical compositions. Table 4 summarizes these differences for elements sufficiently concentrated to provide a comparison.

The data in Table 4 show that a biogeochemical survey using lodgepole pine cones must take their ages into the account. For some elements (*e.g.* Cr, Cs, Mo, Ni, Rb, Zn and possibly Au) the differences in cone age are not significant. For other elements, notably arsenic and antimony, the differences are substantial.

Given these observations, the analytical data obtained from the cones could be used to augment the data from the pine top stems and substantiate some of the sites indicating element enrichment. South of Newton Hill (site 166, Figure 3) cones yielded 110 ppb gold and 1100 ppm nickel. Twelve kilometres to the southeast (site 61) the concentrations were 48 ppb gold and 540 ppm nickel. This site yielded a relatively high gold concentration (31 ppb Au, 98th percentile value) in the pine top study (Dunn *et al.*, 1994). Many sites in the southeastern part of the survey area yielded anomalous enrichments of cesium (up to 57 ppm), substantiating the data from the pine top study.

TABLE 4
COMPARISON OF RELATIVE ENRICHMENTS OF ELEMENTS IN OLD (OPEN) AND YOUNG (CLOSED) CONES FROM NINE LODGEPOLE PINES IN THE INTERIOR PLATEAU

	No. of trees with element enriched in **open cones**	No. of trees with element enriched in **closed cones**	No. of trees with **similar enrichment** in both open and closed cones	Significant differences in composition
Au	5	1	3	no
As	9	-	-	yes
Br	5	3	1	no
Ca	8	-	1	yes
Co	6	-	3	no
Cr	4	-	5	no
Cs	1	1	7	no
Fe	7	2	-	yes
K	-	5	4	yes
La	6	-	3	yes
Mo	1	1	7	no
Na	7	-	2	yes
Ni	3	4	2	no
Rb	-	1	8	no
Sb	9	-	-	yes
Zn	1	-	8	no

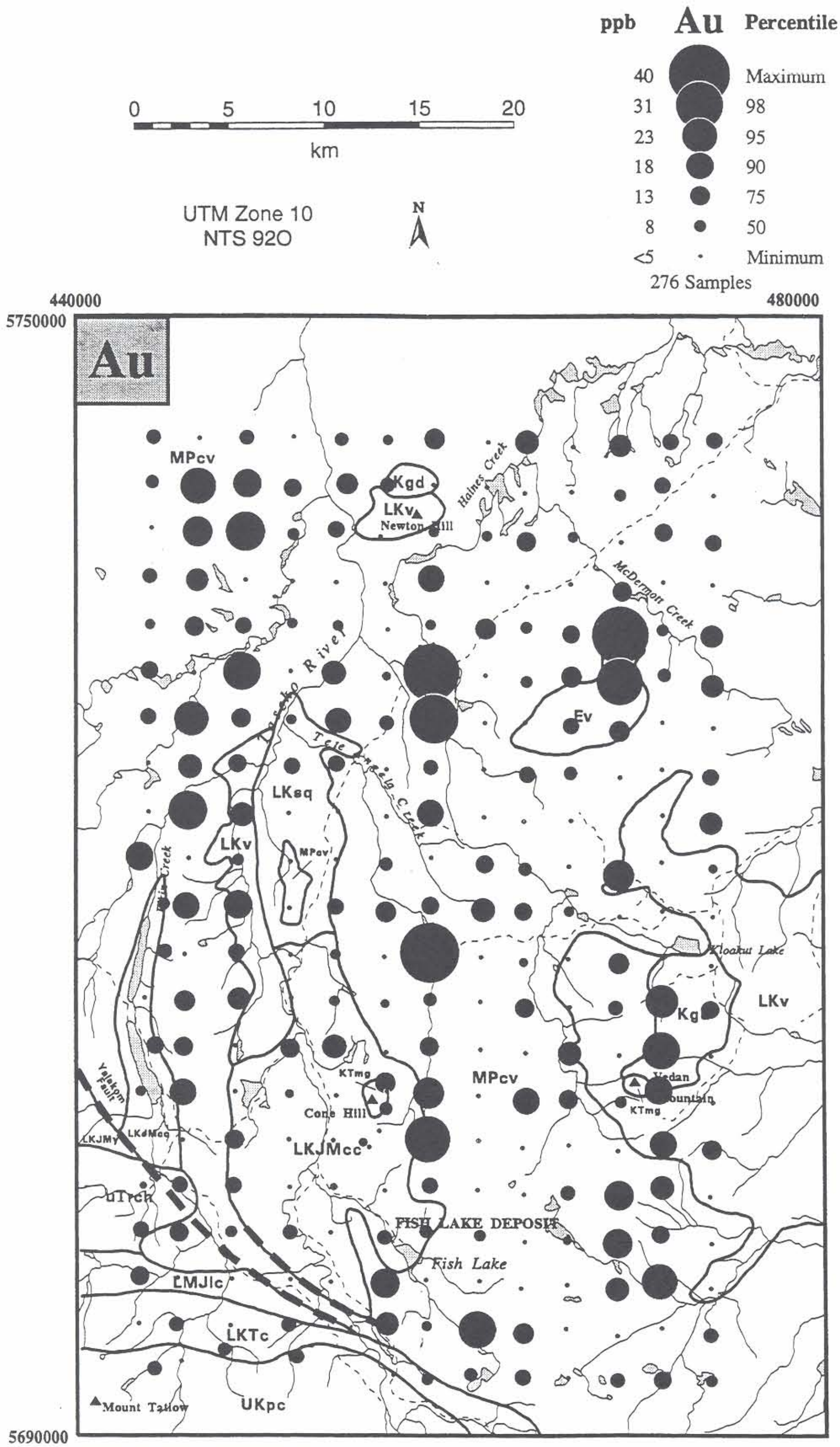


Figure 4. Gold in the ash of lodgepole pine top stems - Fish Lake area.

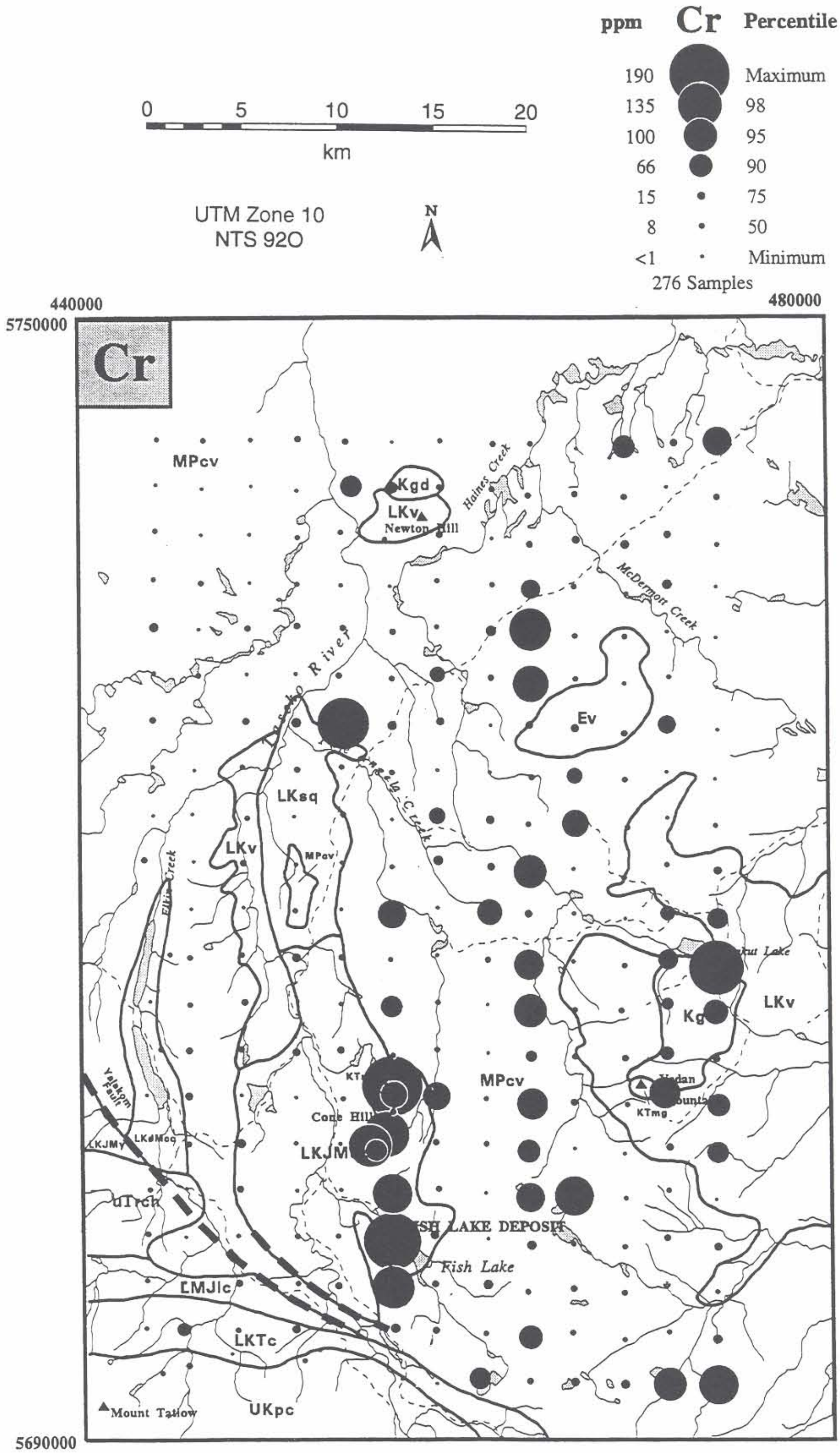


Figure 5. Chromium in the ash of lodgepole pne top stems - Fish Lake area.

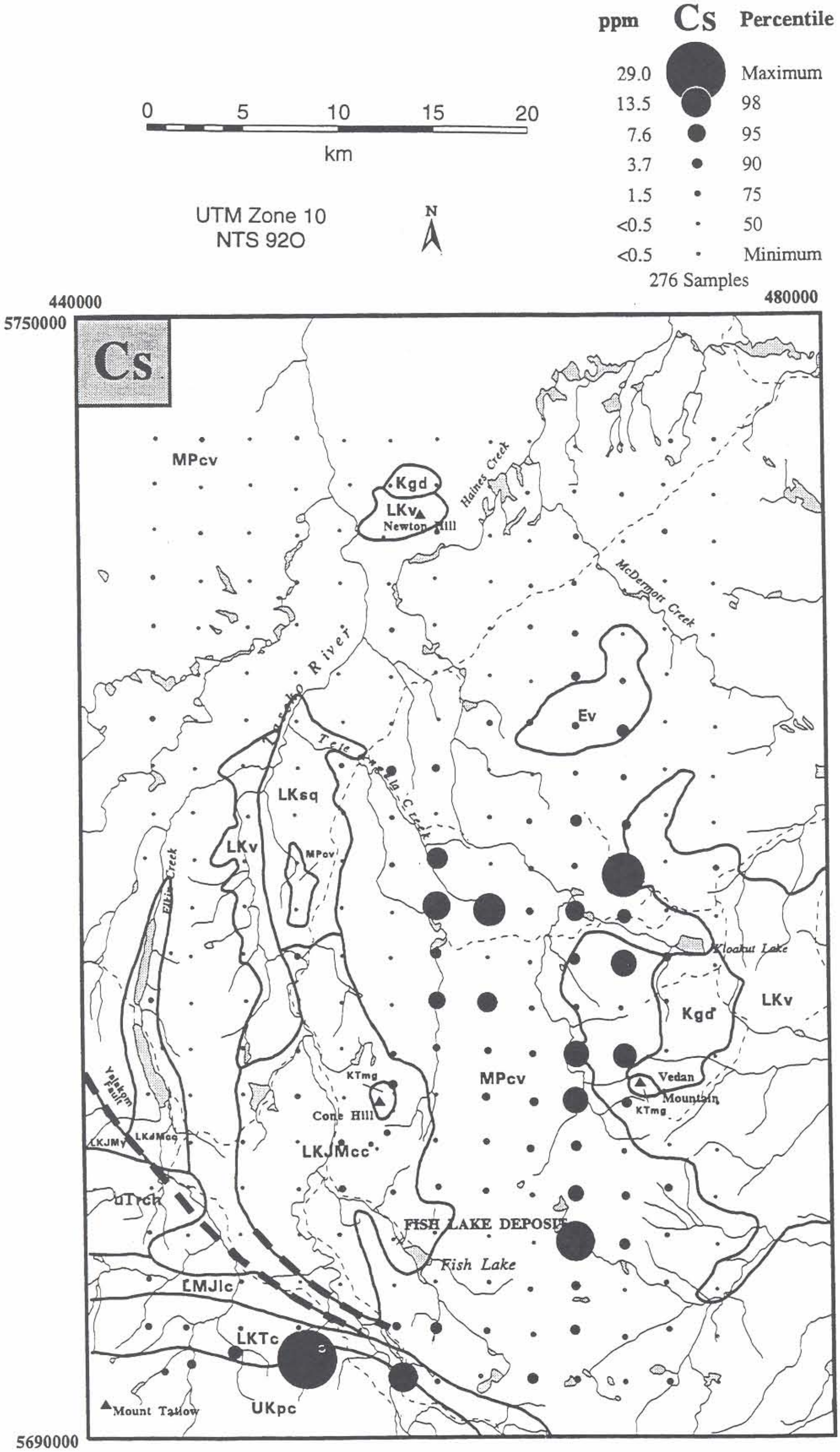


Figure 6. Cesium in the ash of lodgepole pine top stems - Fish Lake area.

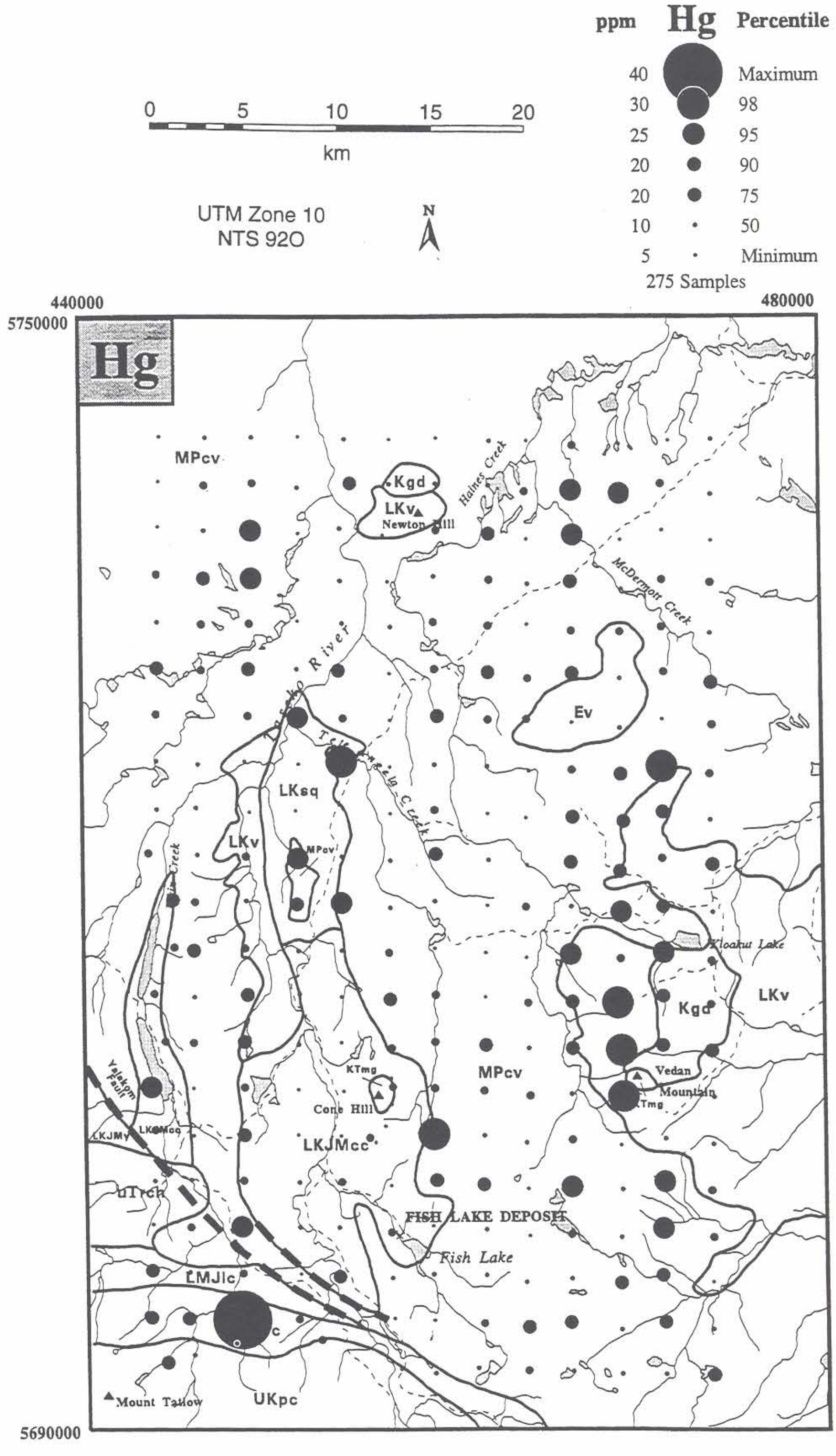


Figure 7. Mercury in dry lodgepole pine top stems - Fish Lake area.

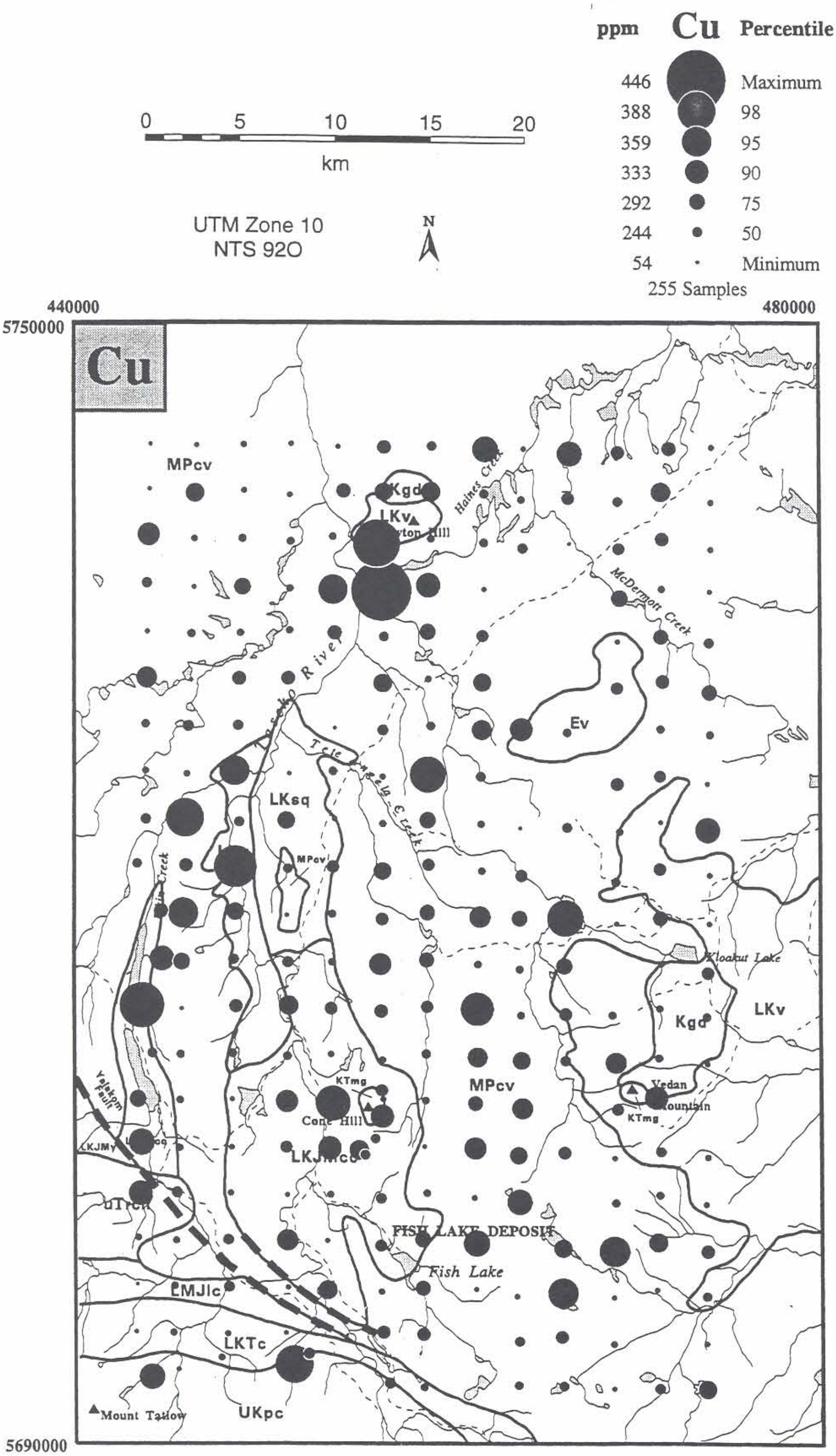


Figure 8. Copper in the ash of lodgepole pine top stems - Fish Lake area.

DETAILED STUDIES

A final phase of study involved detailed sampling at several locations within the area covered by the helicopter survey:

Cone Hill (Figure 3). Lodgepole pine bark samples were collected along three west-east traverses, 200 metres apart, across the southern flank of Cone Hill where gold enrichment in soils had been noted by Valerie Gold Resources Ltd. (A. G. Troup, *personal communication*, 1993). Along one line (L2300) sampled previously for B-horizon soils at 100-metre intervals, samples of pine bark were collected at a spacing of 200 metres (Figure 9). A plot of gold data indicates similar north-northeasterly trends of gold distribution in the two sample media at the eastern end of the traverses. There is a second zone of weak gold enrichment at the western end of line 2300 in an area not covered by the soil survey. This survey shows that, although the absolute concentrations of gold are different in the two sample media, the patterns of gold distribution are similar.

Newton Hill (Figure 3). In 1992, Verdstone Gold Corporation's annual report included results from trenching at Newton Hill. The most enriched section reported was 0.86 g/t Au (857 ppb Au) over 48 metres. Samples from the pine top reconnaissance survey did not detect the zone of known gold mineralization, because Douglas fir is the dominant species on Newton Hill. Lodgepole pine tops are lower in the forest canopy than those of the fir, and it would have been unsafe to sample them from a helicopter. The ground-based survey involved the collection of bark from lodgepole pine and/or Douglas fir at 31 sites, along two 800-metre lines 300 metres apart, according to availability. Both species from sites near the top of the hill were weakly enriched in gold (up to 40 ppb; background 5 ppb). On the northern flank of the hill the lodgepole pine indicated unusual enrichment of zinc (up to 6000 ppm; background 2000 ppm); and at several sites over the hill selenium was enriched in Douglas fir bark (up to 21 ppm; background 1 ppm). *Phacelia heterophylla*, a herbaceous perennial, yielded a high concentration of 15 ppb gold in fine, dry stems from one site. Also of note, was the enrichment of mercury in dry tissue of the epiphytic yellow lichen *Letharia vulpina* (235 ppb) and to a lesser degree in the red-stemmed feathermoss *Pleurozium schreberi* (100 ppb). In this area background concentrations in dry plant tissue are less than 30 ppb mercury. From the survey it was concluded that although the gold signature of the vegetation was more subtle than that in the soils (locally >50 ppb Au with up to 2120 ppb Au, Verdstone Gold Corporation, personal communication, 1993), judicious sampling and INA analysis of the vegetation revealed a mineral system enriched in gold, zinc, selenium and mercury, with weak enrichment of arsenic, barium and molybdenum. Copper, known to be associated with the gold, was not included in the analytical programme.

Other Areas. Several other areas that yielded weakly anomalous concentrations of elements were visited to determine if there was any obvious source for the metal enrichment. These included the area between Kloakut Lake and Vedan Mountain (Figure 3), and a zone of weak gold enrichment (up to 38 ppb Au) between Newton Hill and Tête Angela Creek [site Nos. 161-164 (Figure 3)]. Neither area yielded anomalous concentrations of gold in lodgepole pine bark, but both showed some enrichment of silver. Subsequent biogeochemical work by Better Resources (C.C. Rennie, Better Resources Limited, personal communication, 1994) in the Tête Angela Creek area found enrichment of gold in willow (140 ppb in ash: similar to that at Clisbako North zone), and mercury (up to 150 ppb in dry pine bark). To date no mineralization has been found.

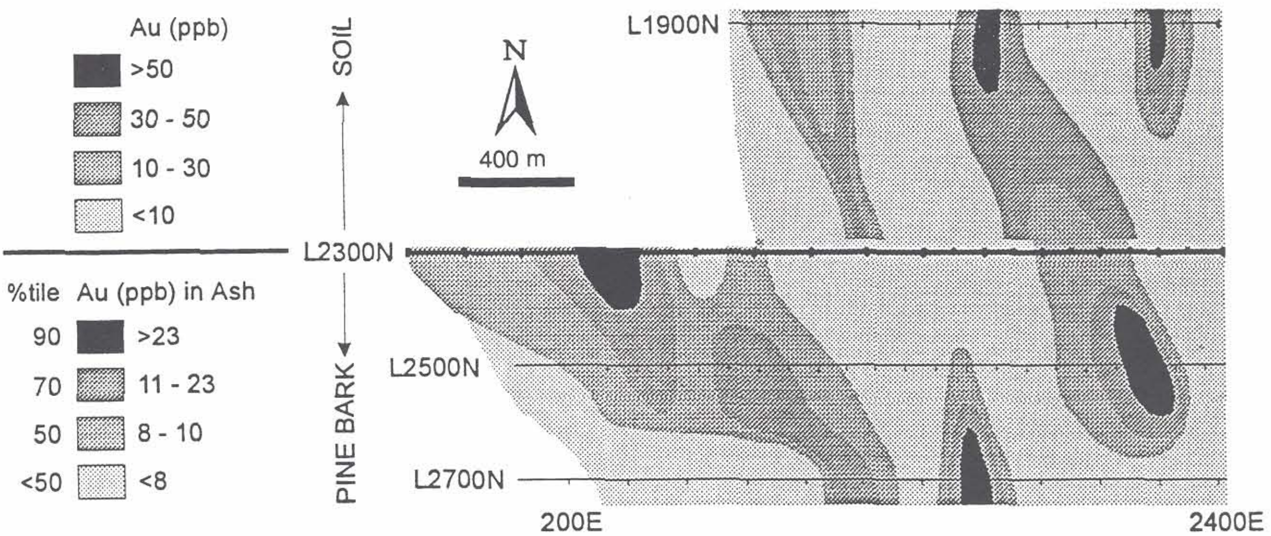


Figure 9. Distribution of gold in lodgepole pine bark and B-horizon soils. Samples from cut lines on the southern flank of Cone Hill (Figure 3). Soil data courtesy of A.G. Troup, Valerie Gold Resources Ltd. Contoured soil values (upper half) and bark values (lower half) indicate continuity of zones with relative gold enrichment.

CONCLUSIONS

Helicopter-borne tree-top sampling programs at a reconnaissance level provide an extremely rapid means of conducting geochemical surveys in forested terrain, regardless of topography and access. At a between-site spacing of 2.5 kilometres, an area of 100 square kilometres can be sampled in an hour of flying. This sample density allows recognition of major geochemical trends in the substrate, and the spatial relationships of zones of relative metal enrichment which may reflect lithogeochemical zonation of metals. Data should be viewed together with those of other data sets (*e.g.* gamma-ray spectrometry and Quaternary studies: Plouffe, 1997 this volume) to help in determining their significance. Some comparisons are discussed by Plouffe. The biogeochemical technique is a method of quickly screening an area to provide focus for more detailed ground studies.

Detailed studies have shown there to be a significant biogeochemical response to the mineralization at Clisbako with enrichment in gold, arsenic, molybdenum, tungsten, cesium and rubidium. Gold enrichment is particularly pronounced in twigs of shrub alder and willow. At Fish Lake there is weak enrichment of gold, molybdenum, copper, cesium, nickel and sodium, in pine tops and strong enrichment in chromium throughout the Fish Lake and Cone Hill area. Bark samples are locally enriched in gold, arsenic, copper and selenium, and alder is enriched in molybdenum and copper. Enrichment of gold, silver, selenium and mercury is noted elsewhere in the survey area.

It is concluded that the collection and analysis of plant tissues can provide information that can assist in focusing exploration efforts. By including biogeochemical methods in an exploration program, valuable primary information (*i.e.,* indications of mineralization not immediately apparent from other sample media) and secondary information (*i.e.,* substantiation of gamma ray signatures and/or enrichments found in till, soil or other sample media) can be obtained.

ACKNOWLEDGMENTS

I gratefully acknowledge the many people who have provided assistance and information to help in conducting these surveys. In particular: Rob Scagel (Pacific Phytometric Consultants) for sample collection, field assistance and for providing in-depth knowledge of the forests; Wendy Spirito, Robin Balma and Steve Adcock (GSC) for data compilation and map production; Tina Hearty, Alice MacLaurin and Alex Fitzpatrick for their assistance in preparing the samples for analysis; Nadia Caira and Ross Banner (Taseko Mines Ltd.) for information, their generous hospitality at the Fish Lake camp and for trucking the samples to Williams Lake; Rob Owens (Alpen Helicopters) for his skills at flying the helicopter to collect the samples.

I thank the following for many useful discussions and information: Cliff Rennie (Better Resources Limited, Vancouver); Art Troup and Frank Lang (Valerie Gold Resources Ltd., Vancouver); David Dunn and Steve Sorensen (Pioneer Metals Corporation, Vancouver); Herb Pickner (Panther Mines Ltd., Vancouver); Rudy Durfeld (Durfeld Geological Management, Williams Lake); Larry Reaugh (Verdstone Gold Corporation, Vancouver); and colleagues at the GSC in Ottawa and Vancouver.

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