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SPRUCE TREE CHEMISTRY TO ASSIST IN GEOLOGICAL MAPPING OF AN OVERBURDEN-COVERED EXTENSIONAL FAULT, CENTRAL BRITISH COLUMBIA

D. Chan and L.C. Struik

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Cover photo

View of the forests of the McLeod Lake map area as seen looking northeast from Mount Prince in the southwestern part of the map area. Weedon Lake study area described in this report lies in the background of the photograph (photo by L.C. Struik, 1988) GSC 1995-008.

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SPRUCE TREE CHEMISTRY TO ASSIST IN GEOLOGICAL MAPPING OF AN OVERBURDEN-COVERED EXTENSIONAL FAULT, CENTRAL BRITISH COLUMBIA

Abstract

*Biogeochemical surveys were conducted over a 150 km^2 area near Weedon Lake during late spring of 1988 and 1989. Twigs of black spruce (*Picea mariana*) were collected in an area covered by glacial material and overlying a fault zone – the Weedon Fault – which juxtaposes Triassic basalt with Mesozoic and Tertiary gneiss and granite. Twig ash was analyzed for 35 elements by instrumental neutron activation.*

Results indicate that certain elements – namely Fe, Co, U, and rare-earth elements – found in spruce trees could reflect the chemical contrast between the two bedrock types on either side of Weedon Fault, despite the presence of glacial overburden. For some transects, concentration contrasts are quite sharp and appear to clearly delineate the fault, while others are much less noticeable and are subtle contrasts. For elements such as Ca and Zn, concentrations were controlled by the growth characteristics of spruce trees rather than the bedrock composition.

High Au concentrations in twigs were found scattered throughout the study area and have no obvious relationship with the fault. In several areas, anomalous Au concentrations were accompanied by enrichment of Ba and As. Whereas data analysis revealed no significant statistical correlation between Au and any other element, spatial relationships were noted.

Résumé

*Des levés biogéochimiques ont été entrepris dans une région de 150 km^2, près du lac Weedon, en fin de printemps 1988 et 1989. Des rameaux d'épinettes noires (*Picea mariana*) ont été prélevés dans une région tapissée de matériaux glaciaires qui recouvrent la faille de Weedon, laquelle juxtapose des basaltes du Trias à des gneiss et des granites du Mésozoïque et du Tertiaire. Les rameaux réduits en cendre ont été analysés pour 35 éléments, par activation neutronique instrumentale.*

Les résultats indiquent que certains éléments (Fe, Co, U et éléments des terres rares) identifiés dans les épinettes pouvaient refléter les différences chimiques qui existent entre les types de substratum rocheux de part et d'autre de la faille de Weedon, en dépit de l'existence de dépôts glaciaires. Dans le cas de certains cheminements, les différences dans les concentrations sont assez prononcées et semblent clairement délimiter la faille; dans d'autres, cependant, les différences sont beaucoup moins notables et plus subtiles. Dans le cas des éléments comme le Ca et le Zn, les concentrations correspondaient aux caractéristiques de croissance des épinettes noires plutôt qu'à la composition du substratum rocheux.

De fortes concentrations aurifères dans les rameaux ont été identifiées dans toute la région étudiée; elles n'ont pas de rapports évidents avec la faille. Dans plusieurs zones, des concentrations aurifères anomales étaient accompagnées de fortes teneurs en Ba et en As. L'analyse des données n'a révélé aucune corrélation statistique significative entre l'or et tout autre élément; des rapports spatiaux ont cependant été notés.

SUMMARY

Spruce trees were regionally sampled and chemically analyzed to assist in the mapping of subsurface bedrock geology in central British Columbia. Much of central British Columbia is covered by a veneer of glacial deposits. In the McLeod Lake map area, glacial till and fluvial deposits cover an area where Takla Group basalt and diorite, and Wolverine Metamorphic Complex granitoids and gneisses are juxtaposed across a regional normal fault (Weedon Fault). Spruce tree twigs (primarily black spruce) were systematically sampled across the suspected location of the fault. The chemistry of the trees was determined to test the hypothesis that bedrock chemistry would be reflected in the tree chemistry.

The biogeochemical survey was done over 150 km^2 near Weedon Lake, British Columbia during the late May of 1988 and 1989. Twig samples were taken at 250 m and 500 m intervals along variably spaced traverses perpendicular to the suspected fault zone. The twigs of black spruce (locally white spruce) were of similar age and size, and were collected from the bottoms of the trees. The twigs were shipped to the GSC laboratories in Ottawa where they were stripped of needles, dried, and ashed. The ash was analyzed for 35 elements by instrumental neutron activation. Of these elements 8 were consistently below detection limit and were not considered further in the investigation.

Statistical investigation of the element concentrations revealed tree growth characteristics and substrate relationships. A large difference in overall concentrations between the two sample years appears to reflect changes in the spring growth pattern perhaps controlled by climate differences. Warmer, moist conditions in the late winter months of 1988 probably led to the onset of an earlier spring and gave extra time for element accumulation within the trees. Another possible factor that could have contributed to this variation may have been that samples taken in the first year were much closer to logging roads than in 1989. Contamination, of mostly silicates and possibly other elements, due to dust from these roads, may have occurred. Some element concentrations (Ca, Zn) were influenced by the tree metabolism.

Correlations were discovered between certain tree element concentrations and substrate element concentrations (Fe, Co, U, rare-earth elements). These correlations confirmed the interpreted position of the contact between the Takla Group basalt and Wolverine Complex granitoids and gneiss. They also confirmed the hypothesis that regional variations in bedrock lithology could be mapped in the tree chemistry. No particular element was found to be concentrated along the trace of the Weedon Fault.

SOMMAIRE

Des épinettes ont fait l'objet d'un échantillonnage régional et d'analyses chimiques, comme aide à la cartographie géologique du substratum rocheux dans le centre de la Colombie-Britannique. La majeure partie de ce territoire est recouverte d'un placage de dépôts glaciaires. Dans la région du lac McLeod, du till glaciaire et des dépôts fluviatiles couvrent une zone où du basalte et de la diorite du Groupe de Takla sont en juxtaposition avec des granitoïdes et des gneiss du Complexe métamorphique de Wolverine, par l'intermédiaire d'une faille normale régionale (la faille de Weedon). On a prélevé systématiquement des rameaux d'épinettes (surtout d'épinettes noires) à l'emplacement présupposé de la faille. La chimie des arbres a été déterminée pour vérifier l'hypothèse selon laquelle la chimie du substratum rocheux correspond à celle des arbres.

Le levé biogéochimique a été effectué sur un territoire de 150 km^2, près du lac Weedon, en Colombie-Britannique, à la fin du mois de mai de 1988 et de 1989. Les rameaux ont été prélevés à des intervalles de 250 et de 500 mètres, le long de cheminements espacés de façon variable et perpendiculaires à la zone de failles présupposée. Les rameaux d'épinettes noires (par endroit d'épinettes blanches) étaient d'âge et de dimension semblables et ont été pris au bas des arbres. Ils ont été expédiés au laboratoire de la CGC, à Ottawa, où on les a débarrassés de leurs aiguilles, séchés et réduits en cendre. Les cendres ont été analysées pour 35 éléments par activation neutronique instrumentale. La teneur de huit de ces éléments était systématiquement inférieure à la limite de détection; on ne s'est donc plus préoccupé de leur analyse pour le reste de l'étude.

L'analyse statistique des concentrations d'éléments a révélé l'existence de rapports entre les caractéristiques de croissance des arbres et le substrat. Un grand écart dans les concentrations globales entre les deux années d'échantillonnage semble refléter des variations dans la croissance printanière, lesquelles sont peut-être le résultat de différences climatiques. Des conditions plus chaudes et humides durant les derniers mois de l'hiver de 1988 sont probablement à l'origine d'un printemps plus hâtif, donc d'une plus grande période de temps pour l'accumulation des éléments dans les arbres. Un autre facteur qui peut avoir contribué à cette variation est le fait que les échantillons prélevés durant la première année étaient situés beaucoup plus près des routes d'exploitation forestière que ceux de 1989. Il peut y avoir eu une contamination par la poussière provenant de ces routes, surtout en silicates et peut-être en d'autres éléments. Certaines concentrations d'éléments (Ca, Zn) ont été influencées par le métabolisme des arbres.

Des corrélations ont été établies entre certaines concentrations d'éléments dans les arbres et dans le substrat (Fe, Co, U, terres rares). Ces corrélations ont confirmé la position, résultant de l'interprétation, du contact entre, d'une part, le basalte du Groupe Takla et, d'autre part, les granitoïdes et les gneiss du Complexe de Wolverine. Elles ont aussi corroboré l'hypothèse selon laquelle les variations régionales de la lithologie du substratum peuvent être cartographiées par la chimie des arbres. Aucun élément particulier n'a été trouvé en concentrations le long de la trace de la faille de Weedon.

Gold concentrations were found to be higher than average for trees from other surveys. The gold concentrations are not systematic with relation to the Weedon Fault. Locally anomalous gold concentrations were accompanied with enriched barium and arsenic.

This survey has shown biogeochemistry to be an effective and efficient geochemical tool. It samples multiple substrates rather than the single horizons of soil samples. It is especially useful in areas of heavy glacial overburden. Twig sampling proved to be a much faster and less strenuous activity than traditional till or soil sampling and the cost was comparable to other geochemical methods. The importance of sampling consistency cannot be over-stressed, as there are a multitude of factors that affect the uptake of elements. Minimizing these factors through uniform conditions of sampling is required to achieve the most accurate analyses and results.

On a observé que les concentrations aurifères étaient plus élevées que la moyenne dans le cas d'arbres ayant fait l'objet d'autres études. Les concentrations aurifères ne sont pas en relation systématique avec la faille de Weedon. Par endroits, des concentrations anomales d'or étaient accompagnées de hautes teneurs en baryum et en arsenic.

Ce levé a démontré que la biogéochimie peut être un outil géochimique efficace et efficient. Elle permet d'échantillonner des substrats multiples plutôt que de simples horizons par échantillonnage des sols. Elle est surtout utile dans les régions où les dépôts glaciaires sont épais. Le prélèvement des rameaux s'est révélé une activité plus rapide et moins épuisante que l'échantillonnage régulier des tills et des sols et le coût se comparait aux autres méthodes géochimiques. On ne peut trop mettre l'accent sur l'importance d'une bonne méthode d'échantillonnage, compte tenu du fait qu'il y a une multitude de facteurs qui influent sur l'assimilation des éléments. Il est nécessaire de minimiser ces facteurs par des conditions uniformes d'échantillonnage, afin d'en arriver à des analyses et à des résultats d'une précision maximale.

INTRODUCTION

Bedrock geology of the McLeod Lake map area is mostly covered by unconsolidated Pleistocene deposits. Complexities within the bedrock geology and its significance for economic mineral potential and local chemistry have stimulated the need to map the bedrock under the unconsolidated cover; however, defining the geology cannot be done simply by extrapolating from bedrock exposures because the overburden cover is so vast. An approach examined in this report is the application of black spruce twig chemistry to assist in mapping the concealed bedrock.

Through multi-element analysis of black spruce trees (*Picea mariana*) an attempt was made to: 1) map the Weedon Fault, since there is a different bedrock chemistry found on either side of the fault; 2) detect any significant concentrations of economic minerals near or along the suspected fault trace (an extension fault along which minerals can be deposited by hydrothermal activity); and 3) record the local biogeochemical signature as a baseline for further research in exploration and environmental management.

Cost effectiveness and improved analytical techniques, coupled with a multitude of background data and literature (see Brooks, 1983; Erdman and Olsen, 1985; Dunn, 1989a) have made biogeochemistry a viable prospecting tool for a variety of economic minerals. Unlike soils or tills, plants derive their chemical composition from multiple sources which may include all soil horizons, bedrock, groundwater, and surface water. In areas of glacial terrain and transported overburden, this method may be effective in revealing buried mineralization and bedrock composition.

Although plants require certain elements for their growth, their root systems can accumulate both essential and nonessential elements in measurable quantities, including Au, Ag (Warren and Delavault, 1950), U (Barakso, 1979), and platinum group elements (Dunn, 1986a). Pape (1981) successfully conducted multi-element analysis of plant ash to recognize underlying rock types. He was able to observe tectonic fault zones based on the concentration levels of highly mobile Na. Dunn (1986c) and Ashton and Riese (1989) were also able to differentiate lithology and recognize fault and contact zones using biogeochemistry.

Factors and conditions affecting element uptake in organic matter are complex, however a complete understanding is not required to utilize plants as sampling media. When certain rules and guidelines such as those outlined by Dunn (1991a) are carefully followed in the design and implementation of a biogeochemical survey, meaningful and unique information can be obtained. There is no attempt here to completely characterize the potential chemical sources such as the distribution of glacial materials or the flux of groundwater; rather the tree chemistry is used to support a possible model of bedrock distribution.

LOCATION AND SETTING

Environment

The project area is located in central British Columbia on the NTS 93J, 1:250 000 scale McLeod Lake map sheet and the NTS 93J/11, 1:50 000 scale Weedon Lake map sheet (Fig. 1). The area is accessible by a network of logging roads. The terrain in the study area of approximately 150 km^2, is typical

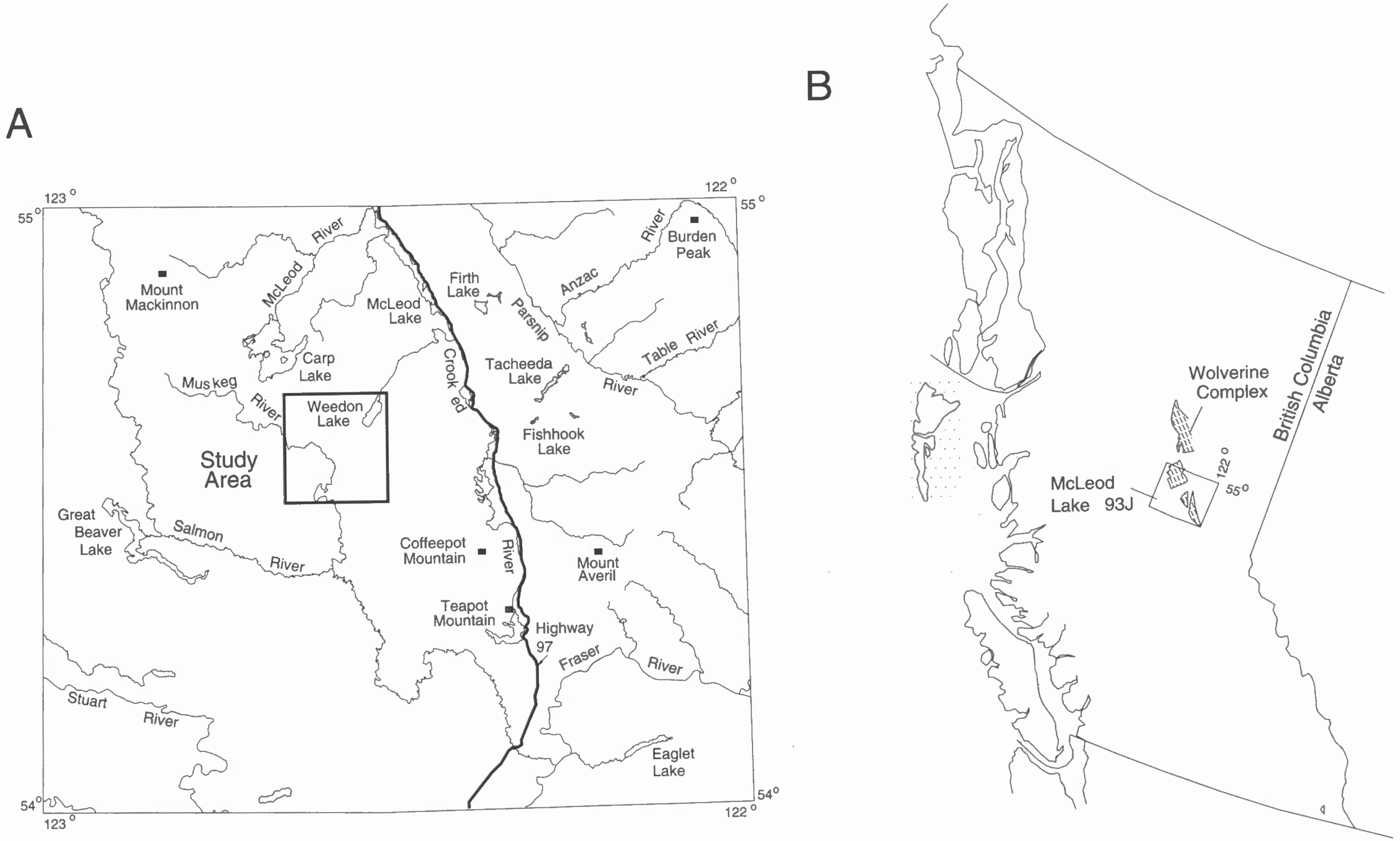


Figure 1. Location of study area; Weedon Lake, British Columbia. *A*) Study area with McLeod Lake map area, *B*) Location of McLeod Lake map area in British Columbia.

of the Interior Plateau. Topography is low and rolling with elevations ranging from 2500 ft. (760 m) to 3200 ft. (975 m). The landscape of moderately dense forest cover is interrupted throughout by numerous lakes, marshes, streams, and other wetlands. This area has been interpreted as belonging to the Sub-boreal Spruce biogeoclimatic zone (Krajina, 1969). Climate is characterized by short, warm summers followed by severe winters. Temperature conditions range from -50°C to +35°C. Annual precipitation averages 45-60 cm with much of it falling during the late autumn and winter months. Average sunshine during the spring and summer months is 250 hours, dropping to below 85 hours during fall and winter.

The area is mostly old growth forest with recent logging activities. The cut-blocks encountered along traverses are approximately 2-5 years in age. Black and white spruce (*Picea mariana; Picea glauca*), lodgepole pine (*Pinus contorta*), and subalpine fir (*Abies lasiocarpa*) are the dominant conifers. The main deciduous trees, including aspen (*Populus spp.*), willow (*Salix spp.*), and alder (*Alnus spp.*), are common in lowland and riparian areas. In poorly drained, damp regions, only black spruce are found. Extremely wet and swampy conditions prohibit the growth of trees and encourage mainly grasses, mosses, and small shrubs.

Regional bedrock geology

Weedon Lake area (Fig. 1) is underlain primarily by rocks of the Wolverine Metamorphic Complex and the Takla Group. These rocks form part of the morphogeological Omineca Belt that traverses the length of the Canadian Cordillera (Gabrielse and Yorath, p. 16, 1991; Fig. 2). The rock types and geological history of these local rock suites are common throughout the Omineca Belt.

Wolverine Metamorphic Complex records the compression of the Precambrian through Early Jurassic continental margin of western North America during the Mesozoic and early Tertiary (Parrish, 1976; Deville and Struik, 1990; Struik, 1993). The complex consists of mainly sillimanite-grade paragneiss, amphibolite, calc-silicate, marble, large volumes of deformed granite and granodiorite, and undeformed granite, granodiorite, and syenite. Northwest of McLeod Lake map area, rocks of the Precambrian Ingenika Group and Cambrian Atan Group form part of the protolith for the Complex (Ferri and Melville, 1990).

Ingenika Group consists of continent-derived arkosic sandstone, shale, and carbonate. Atan Group consists of continental shelf quartz sandstone, shale, and reefal and shallow water limestone.

Takla Group basalt, diorite, volcaniclastics, greywacke, and minor limestone formed offshore of the western margin of Triassic and Early Jurassic North America as an island arc (Monger et al., 1972). During Mesozoic compression, the Takla arc was thrust eastward over the margin (Monger et al., 1972). Takla Group forms part of Quesnel Terrane which includes the Nicola Group of southern British Columbia (Wheeler and McFeely, 1991). The island arc suite is known for its late stage (Early Jurassic) intrusives which host Cu-Au deposits.

Wolverine Metamorphic Complex was uplifted and exposed during the Tertiary (primarily during the Eocene and Oligocene) by northwest directed crustal extension (Deville and Struik, 1990; Struik, 1993). Compressional fabric within the complex is overprinted with extensional fabric near the contact with overlying low-grade sequences. Shallow extensional faults and dextral strike-slip faults bound the complex in the McLeod Lake map area (Struik, 1993; Fig. 3). The complex has all the characteristics of a core complex formed as a pull-apart during dextral strike-slip motion (Parrish et al., 1988; Struik, 1989; Deville and Struik, 1990; Struik, 1993). Rock sequences that originally lay between the Takla Group and the Wolverine Metamorphic Complex are thought to underlie the Takla Group in the hanging wall of the low-angle extension faults above the complex. These rocks include equivalents of upper Paleozoic Slide Mountain, Earn, Road River, and Kechika groups (Struik, 1992).

Economic mineral occurrences are known in the region. They are primarily Cu and Cu-Au intrusive systems in Takla Group rocks (Nelson et al., 1991), with Hg along strike-slip faults (Armstrong, 1949; Paterson, 1977). Precious metals found locally in placer deposits may also occur as lodes deposited by hydrothermal systems along the extension faults bounding the Wolverine complex (Struik, 1989). Such precious-metal deposits are known from similar tectonic environments in the western United States (Wilkins et al., 1986) and interpreted for southern Canada (Tempelman-Kluit and Parkinson, 1986).

Local geology

Weedon Fault in central McLeod Lake map area (Fig. 1) is interpreted as a low-angle extension fault separating the hanging wall Takla Group basalt from the footwall Wolverine complex felsic and amphibolitic rock. Struik and Fuller (1988) interpreted the fault to follow the contact between and Takla Group and Wolverine complex as mapped by Muller and Tipper (1969) using aeromagnetic intensity patterns.

Wolverine complex northwest of the Weedon Fault consists mainly of garnet-muscovite granite pegmatite and sillimanite-muscovite-biotite psammite. Amphibolite and calc-silicate exposures, a marble unit (interpreted from some boulders of marble), and tufa springs lie in a thin belt northeast of Joanne Lake. Takla Group southeast of the fault consists mainly of agglomeratic augite basalt and a hornblende diorite pluton (Fig. 4). Takla Group basalt is exposed east of Weedon Lake and appears to be progressively more deeply buried by glacial deposits to the south and southwest of the lake.

The formation of the Weedon Fault by crustal thinning and tectonic denudation of the Wolverine complex makes it a target for economic mineral deposits.

Quaternary geology

The surficial geology of the Weedon Lake area is dominated by Pleistocene glacial deposits, which obscure most of the bedrock geology. The Fraser glaciation of approximately

15 000 years ago (Clague et al., 1987) has been recognized as the final stage of glacial history for this area (Tipper, 1971). During that time, ice originating from the Coast Mountains flowed down onto the Interior Plateau travelling northeast before being diverted by glaciers from the Cariboo Mountains to the east.

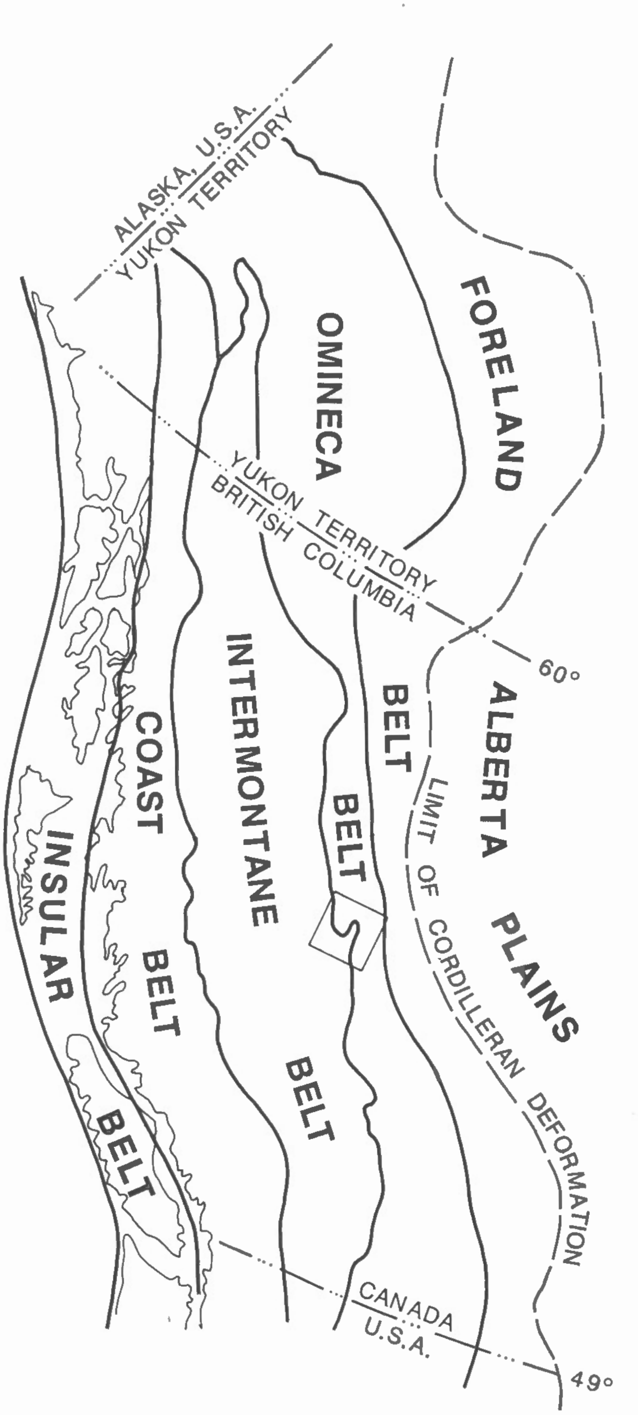


Figure 2. Morphogeological belts of the Canadian Cordillera with the location of the McLeod Lake area (see Fig. 1 for detail).

Glacial grooves and drumlins dominate the landscape and clearly define the northeasterly direction of ice advance (Fig. 4). Till, the main deposit type, covers approximately 60% of the study area, including most of the Weedon Fault. Also within the area, and partially overlying the fault, are the remnants of a northeast-trending meltwater channel, subparallel to both fault trace and ice movement, and marked by lower elevations. Sand and gravel, sorted and deposited by glaciofluvial processes, are present along many of the roads south and southwest of Weedon Lake. Outwash plains, esker complexes, and lateral overflow channels are other glacial features found in the area. The absence of terminal moraines, kettle deposits, and other ice stagnation features suggests constantly active ice during both advance and retreat of the Fraser ice sheet.

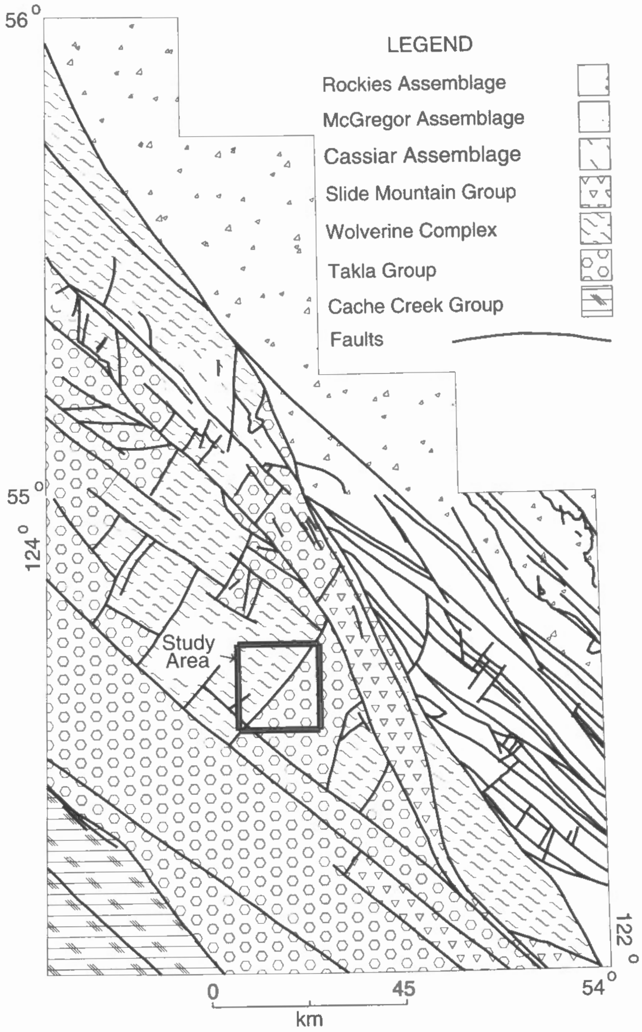


Figure 3. Generalized bedrock geology of the McLeod Lake and Pine Pass (SW) map areas encompassing the study area (Struik, 1993).

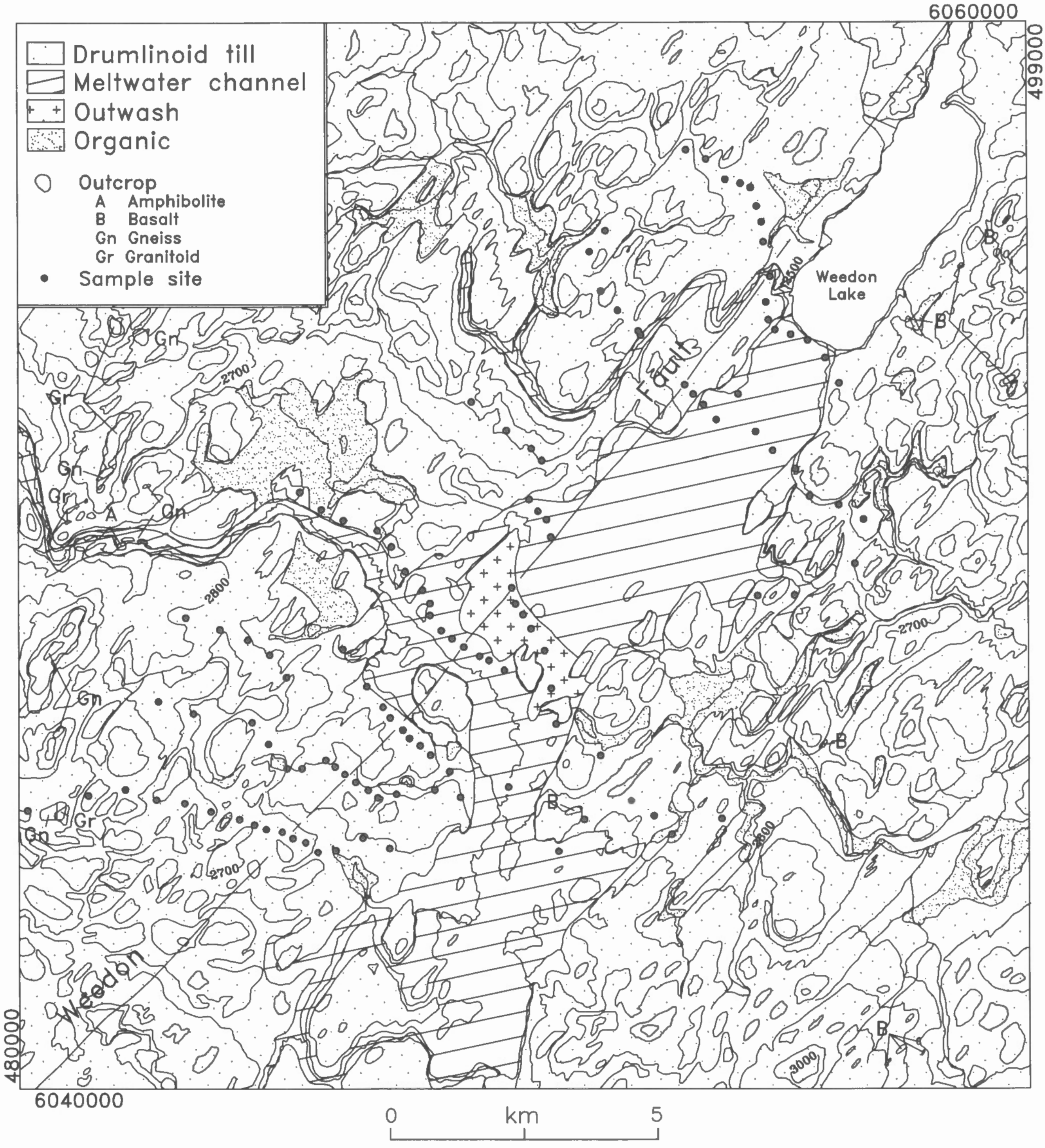


Figure 4. Surficial geology and outcrop distribution. Outcrop type: Gn (gneiss), Gr (granite), B (basalt), A (amphibolite).

METHOD

Sampling

Sampling consistency over time is an important consideration for any biogeochemical study. Species, age, tree organ type, and health of the material sampled all play significant roles in varying element concentrations, and inconsistencies will often make comparisons difficult (Dunn, 1983). For this project black spruce (*Picea mariana*) twigs were chosen as the sampling medium. In addition to the overall abundance of black spruce in the area, previous work is most abundant (Dunn, 1981, 1988, 1989b; Warren et al., 1968; Cohen et al., 1987) thus allowing for more data comparisons. Spruce has been reliably shown to accumulate a variety of nonessential metals and their pathfinders, including Au, Ag, U, As, platinum group metals, and Hg (see references above).

Seasonal variations also contribute to fluctuations in plant chemistry and may enhance or diminish anomaly-to-background contrasts. Evidence from Schiller et al., (1973) and Cohen et al. (1987) indicates that spring, a time of accelerated sap rise, appears to be the optimum sampling season since this is when the highest concentrations occur; therefore this project was conducted in spring to take advantage of these findings.

Fieldwork was carried out in late May of 1988 and 1989. Black spruce twigs were collected along seven traverse lines across the suspected position of the Weedon Fault. Within 1 km of either side of the fault, samples were collected at 250 m intervals along the traverse route. Beyond this 1 km zone, additional samples were taken at 500 m intervals up to 3 km away from the fault (Fig. 5). The philosophy for this sampling approach was to maintain a regional spread of sites with as simple a control grid as possible. In all, 151 samples were collected and analyzed.

Sampling in 1988 lasted two days beginning May 27. Four traverses, using two sampling teams, were conducted along existing logging roads that crosscut the fault. To minimize contamination of samples from roads (through leaching and airborne particles), collection sites were at least 30 m from the roadside. The 1989 sampling period began on May 24. A single sampling team completed three traverses in a total of four days. These cross-country traverses were located between the previous year's lines in order to increase the sampling density. Summary cross-sections of topography, tree distribution, glacial deposit type, and sample sites for the seven transects are presented in Figure 6. Of the 50 samples taken in 1989, 11 were later discovered to be white spruce (Fig. 5).

At each sample site, twigs of similar size and diameter (approximately five to ten years of growth), taken from trees of similar size and age, were collected from within reaching distance using teflon-coated anvil clippers. Approximately 100-150 g of combined twig and needle from each sample tree was placed in 20 x 30 cm cloth bags.

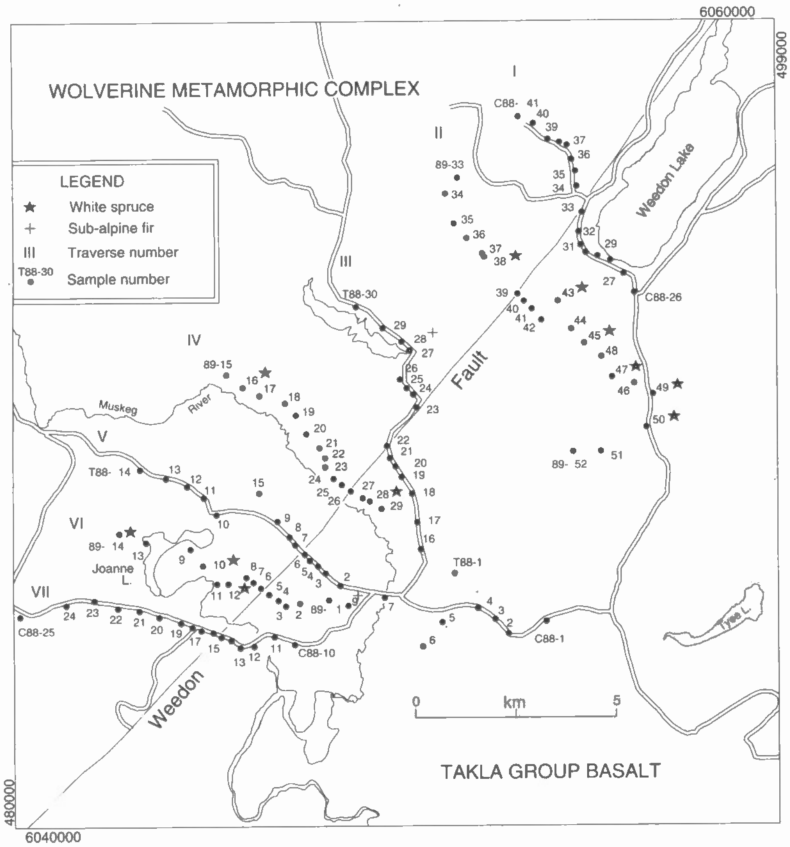


Figure 5.

Location of sample sites and road access.

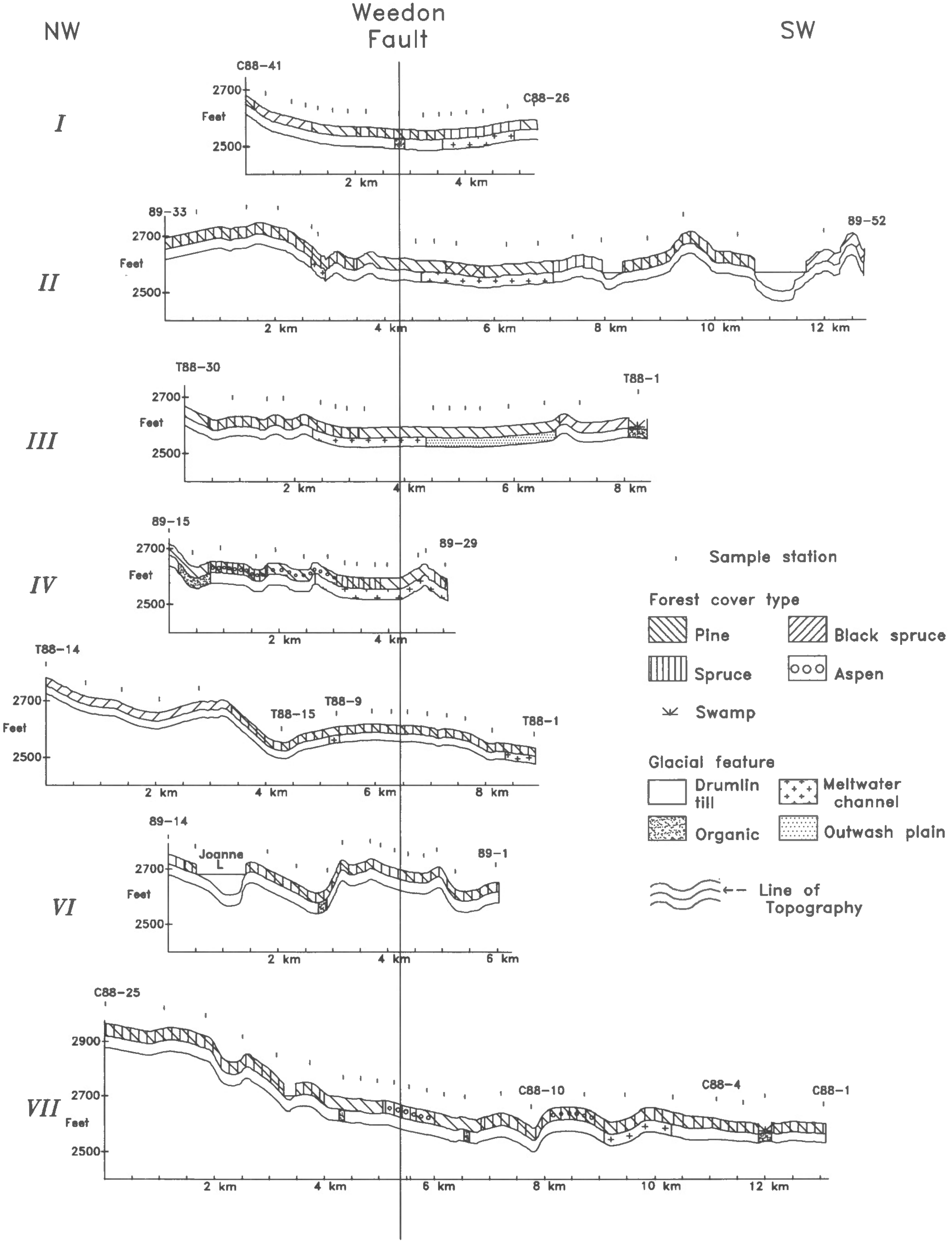


***Figure 6.** Distribution of tree types and glacial deposits along the topographic profiles of the traverse lines.*

Sampling time was usually quick and the light load of twigs proved to be a definite advantage for the cross-country traverses. Some minor problems arose during the sampling process. Logging activities often created difficulties in obtaining twig samples since extensive clear-cut blocks left no trees to sample. Logged areas were unavoidable in this region, and resulted in missed samples or lengthy detours to obtain one. Species identification and distribution also created difficulties in the field. Although the decision was made to sample only black spruce, sampling errors resulted in two non-spruce samples in 1988 and almost a dozen samples of white spruce in 1989. Another occasional problem was the absence of reachable twigs which led to shoulder-standing in order to obtain a sample.

Analysis

The bagged twig and needle samples were shipped to the Geological Survey of Canada in Ottawa for preparation and chemical analysis, using the technique described by Dunn (1986c). The samples were first air dried and microwaved to remove all moisture. The needles were then separated from the woody material and archived for possible future use. The twigs were weighed, then ashed in a kiln at 470°C; the resultant products were placed in vials and subjected to multi-element analysis performed by Activation Laboratories (ACTLABS) using instrumental neutron activation analysis (INAA). Costs for sample preparation and analyses were approximately $15/sample (1990 prices).

Concentration values received from the lab were then transferred to a database and subsequent analyses were performed on these data using simple statistical programs and a geological statistics package. Maps and graphs were generated using CAD and spreadsheet programs.

RESULTS

Data received from ACTLABS are provided in Appendix A. Units of concentration and minimum detection levels for ash samples are given for each element. Overall precision and accuracy based on seven duplicate pairs and eight standards were generally better than ± 10% with greater differences near detection limit.

Of the 35 elements tested, eight were found to be consistently below the limits of detection and were subsequently discarded from any further data analyses. Of these elements Ag, Ir, W, Tb, Ta, and Ni likely reflect the actual concentrations within the sample, whereas any Hg would have been volatized during the ashing process (C.E. Dunn, pers. comm., 1989) as would some Se (Dunn, 1986b). Of the remaining 27 elements, concentrations below detection level were reduced to one-half the detection limit for statistical purposes. Summary statistics and probability plots for these elements were performed separately for 1988 and 1989 samples and are included in Appendix B.

Annual variation

Basic statistics for the elements (mean and median), for 1988 and 1989 samples, revealed mean element concentration values appreciably higher in the first year (Table 1). Concentrations for 18 of the 27 elements were found to be greater in 1988, with the remaining nine elements either higher in 1989 or generally consistent between years. As a result of this, values for the two years were not combined and statistical analyses were done separately for each year.

Variation of element concentrations from one year to another was not unexpected, since it has been observed by others (Dunn, 1983; Stednick and Riese, 1987) in past

Table 1. Mean and median concentration values (ppm) for 1988 and 1989 samples

	MEAN 1988	MEDIAN 1988	MEAN 1989	MEDIAN 1989
Au	12.19^{*}	11.0^{*}	6.51^{*}	7.15^{*}
As	6.61	6.2	11.59	12.49
Ba	2818.38	2697.7	3757.8	4049.5
Br	10.3	10	19.06	17
Ca	12.5^{+}	13.46^{+}	18.67^{+}	18.1^{+}
Co	9.37	10	4.84	5
Cr	43.55	60	11.4	11
Cs	1.31	1.3	0.771	0.85
Fe	1.21^{+}	1.30^{+}	$.388^{+}$	0.38^{+}
Hf	1.54	1.7	0.62	0.8
K	10.02^{+}	10.3^{+}	13.38^{+}	12.95^{+}
Mo	3.56	4	4.07	5
Na	6918.3	7500	2492.6	2440.1
Rb	89.13	68.55	98.14	93.5
Sb	0.97	0.8	0.6	0.6
Sc	4.46	5.4	1.22	1.2
Sr	877	2.83	1264.1	1200.1
Th	1.02	1.2	0.34	0.4
U	0.33	0.6	0.067	0.05
Zn	1312.2	1256	2204.8	2099.9
La	7.35	7.95	2.6	2.65
Ce	13.3	15	4.14	4.5
Nd	5.82	7.15	3.16	2.5
Sm	1.34	1.35	0.38	0.4
Eu	0.2	0.42	0.019	0.01
Yb	0.714	0.84	0.2	0.25
Lu	0.091	0.11	0.036	0.025

*ppb
$^{+}$per cent

surveys; however, the variation between years differs widely between elements, and the magnitude of that variation for some elements was surprisingly large. To illustrate, Mo concentration median for the two years (4.0 and 5.0 ppm) show little variation compared to Na values of 7500 and 2440.1 ppm. For most of the elements, a substantial difference between 1988 and 1989 values exists that cannot be explained by natural variations or sampling error.

Species variation

The opportunity arose to compare the chemistry of twigs from white spruce with those from black spruce. Note, however that only 11 white spruce samples were taken so that statistical analysis is somewhat restricted and any conclusions can only be regarded as tentative.

Dunn (1991b) noted that black and red spruce have similar chemical compositions, but found them distinctly different from those of white and Engelmann spruce. For this survey, the data for most elements obtained from the 1989 collection of white spruce more closely resemble the black spruce concentrations of the same year than those of 1988. An assemblage of elements, observed to be higher in either black or white species were compared using median values obtained in this survey. Iron, sodium, chromium, thorium, and uranium levels were found to be higher in black spruce, confirming observations by Dunn (1991b). Rubidium, calcium, strontium, and zinc values showed greater concentrations in white spruce.

Lithological variation

Chemistry of the trees overlying the area was used to differentiate between the felsic and mafic rocks and thereby more clearly define the position of the Weedon Fault. Spruce tree chemistry was also used to search for potential economic mineral deposits along the Weedon Fault. To assess possible chemical differences in spruce twigs on either side of Weedon Fault, a significance test was performed on a selection of element concentrations. The elements chosen represent common constituents of either felsic or mafic rock compositions. By performing this test it was hoped that element concentrations of twig ash from trees overlying mafic Takla Group basalt could be distinguished from those overlying felsic granite of the Wolverine complex. The mean concentrations of twenty-two element populations were compared for each year using the Student's t-test and are shown in Tables 2, 3, and 4.

Based on 37 degrees of freedom and at 95% confidence, nine elements were found to have significant t-values (>2.04) in 1989. In 1988, based on 67 degrees of freedom, eighteen elements (including all elements significant in 1989) were considered to be significant (>2.0). The 1989 white spruce element means were also tested and resulted in significant t-values for only two elements – Ba and Na.

At the upper confidence level (99.5%) there is again a greater number of elements with significant t-values in 1988 than 1989; a total of fifteen elements with meaningful t-values in 1988 compared to only five the following year. For both years Cr, Na, Sc, Th, and Yb showed highly significant concentration differences between the two sides of the fault. All of these elements displayed greater concentrations southwest of the fault, an area underlain by Takla Group basalt. A test using 1989 white spruce elements did not produce any t-values above the 99.5% level.

In most cases variations across the fault appear to reflect bedrock compositions. There were, however, some unexpected results. Concentrations of Na and Th, elements more abundant in felsic rocks, were found to be greater in trees overlying mafic rocks. In conifers these elements characteristically follow Fe, which is enriched in mafic rocks. Conversely, Ca and Zn concentrations were greater in areas underlain by felsic material despite their abundance in mafic compositions. These two elements are essential for plant growth and may therefore not reflect concentrations in the underlying rocks.

A selection of element profiles (As, Au, Co, Fe, K, La, Sc, U, Zn) were plotted for two traverses – one from each year (Fig. 7). In addition, concentration profiles of Cr were plotted for all seven traverses (Fig. 8). These profiles effectively illustrate both the variation of concentration between years, and in some cases the variation of element concentrations between either side of the fault. Chromium transects II, IV, and VI – sampled in 1989 – show much smaller values than 1988 transects (I, III, V, VII). Both years obtained highly significant t-values, however the subdued contrast of concentration values across the fault make it less obvious than those of 1988. Iron, lanthanum, and uranium values along transect I appear to delineate the contrasting bedrock chemistry perfectly.

Probability plots were used to construct maps for 16 elements (Fig. 9), outlining the distribution of concentration levels above the 80, 90, and 95th percentiles. By plotting percentiles separately for both years, as opposed to simply indicating the largest numbers, normalization and combination of two distinct data sets was accomplished. While there are elements which indicate a relationship to one or the other side of the fault, there do not appear to be any elements – metals in particular – related to the inferred Weedon Fault itself.

Element correlations

Correlation analysis was conducted to determine possible interrelationships between element pairs. R-values were calculated using a selection of elements, and are displayed in a correlation coefficient matrix (Table 5).

A high degree of linear correlation based on 99% probability exists for most of the elements in the table. Consistent negative correlation values occur for Ca, K, and Zn, indicating an inverse relationship with the other elements. Values for Cs, Rb, Br, and Mo had few relationships with other elements. Linear regression plots are also given (Fig. 10) illustrating the range of r-values found in the matrix.

Table 2. T-test evaluation for black spruce population – 1988 Takla Group basalt vs. Wolverine Metamorphic Complex

	TAKLA N = 34	WOLVERINE N = 35	T VALUE		TAKLA N = 34	WOLVERINE N = 35	T VALUE
Au ppb	X = 14.59 m = 9.0 s = 20.46 < 5 to 119	X = 28.2 m = 11.0 s = 35.54 < 5 to 168	4.40	La ppm	X = 10.5 m = 9.7 s = 4.43 2.9 to 19.0	X = 6.64 m = 5.85 s = 3.50 2.0 to 15	3.94
As ppm	X = 7.81 m = 6.40 s = 5.17 2.0 to 21.0	X = 7.64 m = 6.05 s = 4.48 2.0 to 24	0.235	Mo ppm	X = 4.46 m = 4.0 s = 2.53 < 2. to 10.0	X = 4.37 m = 4.0 s = 2.89 < 2. to 12.0	0.36
Ba ppm	X = 2597.06 m = 2200.0 s = 1110.42 1400 to 5500	X = 3440.0 m = 3150.0 s = 1161.69 2000 to 6100	-3.50	Na ppm	X = 9994.12 m = 9950 s = 4105.26 2790-17800	X = 6396 m = 5165 s = 3890.8 1760-16600	3.88
Br ppm	X = 10.74 m = 9.0 s = 9.48 4.0 to 60.0	X = 13.31 m = 12.0 s = 8.92 4.0 to 55.0	-2.03	Rb ppm	X = 84.18 m = 78.0 s = 32.83 39 to 150	X = 109.77 m = 98.5 s = 50.44 55 to 280	-2.79
Ca %	X = 11.43 m = 10.8 s = 4.50 5.6 to 24.8	X = 15.09 m = 14.25 s = 3.58 7.3 to 21.2	-3.98	Sb ppm	X = 1.79 m = 0.9 s = 1.84 0.5 to 6.2	X = 0.846 m = .750 s = 0.366 0.2 to 1.9	2.95
Co ppm	X = 12.03 m = 12.0 s = 3.88 4.0 to 19	X = 8.53 m = 8.50 s = 3.23 1.5 to 15.0	3.58	Sc ppm	X = 6.89 m = 6.5 s = 2.99 1.7 to 13	X = 4.05 m = 3.9 s = 2.47 0.6 to 9.9	4.18
Cr ppm	X = 61.74 m = 62.0 s = 24.77 15.0 to 130	X = 40.37 m = 40.0 s = 22.69 10 to 90	3.82	Sr ppm	X = 857.21 m = 780.0 s = 618.99 155 to 4000	X = 1213.57 m = 1050.0 s = 727.21 155 to 3400	-2.42
Cs ppm	X = 1.47 m = 1.4 s = .571 <.5 to 2.8	X = 1.60 m = 1.25 s = 1.24 <.5 to 5.9	-0.16	Th ppm	X = 1.49 m = 1.6 s = 0.642 0.3 to 3.0	X = 0.976 m = 0.950 s = 0.523 <.1 to 2.1	3.20
Fe %	X = 1.752 m = 1.66 s = 0.739 0.50 to 3.37	X = 1.11 m = 1.07 s = 0.609 0.26 to 2.62	3.88	U ppm	X = 0.797 m = .800 s = 0.496 <.1 to 2.3	X = 0.401 m = 0.075 s = 0.448 <.1 to 1.5	4.42
Hf ppm	X = 1.87 m = 1.90 s = 0.703 <.5 to 3.1	X = 1.58 m = 1.40 s = 0.608 <.5 to 2.9	.908	Yb ppm	X = 1.07 m = 1.0 s = .455 0.31 to 1.92	X = 0.679 m = 0.61 s = 0.365 <.05 to 1.43	3.45
K %	X = 9.31 m = 9.22 s = 3.27 2.67 to 17.5	X = 12.15 m = 11.25 s = 4.06 5.09 to 21.2	-3.04	Zn ppm	X = 1193.53 m = 1100 s = 447.36 520 to 2500	X = 1636.57 m = 1600.0 s = 659.62 870 to 3800	-3.46

Significance values for t-test
n = 69; Degrees of Freedom (n-2) = 67
95.0% confidence level = **2.00**
99.5% confidence level = **2.91**

Table 3. T-test evaluation for black spruce population – 1989 Takla Group basalt vs. Wolverine Metamorphic Complex

	TAKLA N = 17	WOLVERINE N = 22	T VALUE		TAKLA N = 17	WOLVERINE N = 22	T VALUE
Au ppb	X = 8.06 m = 7.0 s = 5.03 < 5 to 21.0	X = 7.89 m = 7.0 s = 7.80 < 5 to 43.0	0.592	La ppm	X = 3.271 m = 3.0 s = 1.35 1.5 to 6.9	X = 2.28 m = 2.4 s = 0.78 1.0 to 3.7	2.82
As ppm	X = 12.29 m = 10.4 s = 6.37 4.7 to 25.0	X = 13.23 m = 13.0 s = 5.88 2.5 to 24.0	-0.283	Mo ppm	X = 4.82 m = 5.0 s = 2.35 < 2. to 10.	X = 3.96 m = 4.0 s = 2.24 < 2. to 9.0	1.05
Ba ppm	X = 3876.47 m = 4050 s = 1258.24 2100 to 6300	X = 4209.09 m = 4300 s = 1525.30 1700 to 8500	-.472	Na ppm	X =3097.65 m = 2715.0 s = 1245.91 1690 - 6000	X = 2161.82 m = 2040.0 s = 616.37 1250 - 3360	3.14
Br ppm	X = 19.882 m = 17.0 s = 6.36 15. to 34.	X = 20.96 m = 20.0 s = 8.45 11.0 to 35.	-0.33	Rb ppm	X = 112.12 m = 99.50 s = 37.48 59.2 to 210	X = 117.27 m = 94.0 s = 81.33 53 to 450	.380
Ca %	X = 17.99 m = 17.55 s = 2.24 15.1 to 23.2	X = 19.577 m = 19.6 s = 2.57 15.2 to 24.3	-2.12	Sb ppm	X = 0.959 m = 0.65 s = 0.893 0.3 to 4.1	X = 0.518 m = 0.5 s = 0.261 0.3 to 1.4	2.88
Co ppm	X = 6.0 m = 5.0 s = 3.59 2.0 to 16.0	X = 4.68 m = 4.0 s = 2.24 2.0 to 12.0	1.15	Sc ppm	X = 1.688 m = 1.55 s = 0.81 0.7 to 3.7	X = 1.009 m = 1.0 s = 0.383 0.4 to 1.8	3.45
Cr ppm	X = 16.24 m = 14.5 s = 7.30 7.0 to 35	X = 9.46 m = 10 s = 4.19 4.0 to 19	3.87	Sr ppm	X = 1324.71 m = 1200 s = 407.51 780 to 2100	X = 1281.82 m = 1200 s = 423.35 810 to 2300	0.39
Cs ppm	X = 1.112 m = 0.95 s = .789 <.5 to 3.7	X = .848 m = 0.80 s = .734 <.5 to 2.3	1.30	Th ppm	X = .541 m = 0.50 s = .240 0.2 to 1.0	X = .293 m = 0.3 s = .167 .05 to .50	3.37
Fe %	X = .513 m = .435 s = .247 .22 to 1.14	X = 0.333 m = .320 s = 0.124 .190 to .60	2.95	U ppm	X = 0.109 m = 0.05 s = 0.153 <.1 to 0.6	X = 0.098 m = 0.05 s = 0.122 <.1 to 0.5	.251
Hf ppm	X = .812 m = .80 s = .472 <.5 to 1.4	X = .732 m = 0.80 s = .432 <.5 to 1.5	.385	Yb ppm	X = .324 m = .280 s = .127 .19 to .63	X = 0.18 m = .210 s = .118 <.05 to .380	3.32
K %	X = 13.458 m = 13.1 s = 3.61 7.91 to 20.5	X = 14.61 m = 13.9 s = 3.60 9.07 to 21.4	-1.12	Zn ppm	X = 2117.65 m = 2100 s = 542.3 1400 - 4000	X = 2322.73 m = 2400 s = 578.02 1100 to 3600	-1.04

Significance values for t-test
n = 39; Degrees of Freedom (n-2) = 37
95.0% confidence level = **2.04**
99.5% confidence level = **3.03**

Concentration values from spruce twigs were compared to values collected from a regional stream sediment survey of the same area. This comparison emphasizes the differences between silt and plant geochemical surveys. Plant metabolism controls much of the element uptake unlike the straightforward concentrations in the silts. These sediments, taken in 1985 (British Columbia Geological Survey, 1988) originate from a large source area and represent concentration levels from both sides of the fault. These samples were analyzed using atomic absorption spectroscopy (except for U), resulting in different detection levels for some elements. Concentration values, however, appear adequately above detection level to make comparisons. Eight elements common to both surveys were compared (Table 6).

Barium, molybdenum, zinc, antimony, and uranium differ substantially between surveys. With the exception of U, sediment mean values appear to be lower than those found in the ash of the twig samples. Concentrations of Co, As, and Fe show lesser variation.

Table 4. T-test evaluation for white spruce population – 1989 Takla Group basalt vs. Wolverine Metamorphic Complex

	TAKLA N = 6	WOLVERINE N = 5	T VALUE		TAKLA N = 6	WOLVERINE N = 5	T VALUE
Au ppb	X = 6.67 m = 7.5 s = 3.40	X = 5.2 m = 6.0 s = 2.75	0.85	La ppm	X = 5.95 m = 3.45 s = 5.52	X = 1.60 m = 1.50 s = 0.37	1.93
As ppm	X = 12.93 m = 12.0 s = 4.74	X = 9.88 m = 12.0 s = 5.43	1.10	Mo ppm	X = 3.0 m = 2.5 s = 2.28	X = 2.20 m = 1.0 s = 1.64	0.723
Ba ppm	X = 2700.00 m = 2350.0 s = 885.0	X = 3800 m = 3700 s = 1039	-2.09	Na ppm	X = 6313.3 m = 6291.8 s = 2715	X = 1634 m = 1560 s = 294	4.20
Br ppm	X = 17.83 m = 16.0 s = 8.77	X = 23.8 m = 19.0 s = 13.63	-0.97	Rb ppm	X = 127.3 m = 95.0 s = 80.8	X = 212.4 m = 170.0 s = 146.21	-1.36
Ca %	X = 14.57 m = 16.4 s = 4.37	X = 20.94 m = 21.4 s = 3.08	-3.02	Sb ppm	X = 2.17 m = .65 s = 2.51	X = 0.380 m = 0.40 s = 0.080	1.75
Co ppm	X = 8.33 m = 6.0 s = 5.92	X = 5.60 m = 6.0 s = 2.61	1.05	Sc ppm	X = 3.82 m = 1.3 s = 4.32	X = 0.72 m = 0.7 s = 0.19	1.76
Cr ppm	X = 28.83 m = 13.5 s = 27.7	X = 5.80 m = 5.0 s = 1.64	2.03	Sr ppm	X = 1190 m = 1200 s = 298	X = 1272.0 m = 1100.0 s = 406.0	-.428
Cs ppm	X = 1.28 m = 1.2 s = 1.05	X = 1.64 m = 2.30 s = 1.31	-0.56	Th ppm	X =0.87 m = 0.3 s = 0.93	X = 0.20 m = 0.30 s = 0.14	1.75
Fe %	X = 1.07 m = 0.43 s = 1.13	X = 0.21 m = 0.21 s = 0.04	1.86	U ppm	X = 0.350 m = .050 s = 0.470	X = 0.05 m = 0.05 s = 0	1.56
Hf ppm	X = 0.93 m = 0.25 s = 1.07	X = 0.25 m = 0.25 s = 0	1.56	Yb ppm	X = 0.63 m = .36 s = .64	X = 0.08 m = 0.025 s = 0.07	2.10
K %	X = 15.03 m = 16.95 s = 4.81	X = 16.08 m = 15.80 s = 3.26	-0.45	Zn ppm	X = 1763.33 m = 1700 s = 773.0	X = 2340.0 m = 2500.0 s = 792.46	1.35

Significance values for t-test
n = 69; Degrees of Freedom (n-2) = 67
95.0% confidence level = **2.36**
99.5% confidence level = **4.03**

Table 5. Correlation matrix of elements 1988 (upper) and 1989 (lower)

	Au	As	Ba	Br	Ca	Co	Cr	Cs	Fe	Hf	K	La	Na	Rb	Sb	Au	As	U	Yb
Zn	-.1484 .0210	.0745 .0528	**.6168** .3497	.2084 .3458	**.6480** .4024	-.5411 -.4260	-.6299 -.3982	.0345 -.1040	-.5972 -.4110	.0154 .1268	**.5562** .0519	-.5719 -.3991	-.5472 -.3924	.2501 -.0737	-.1358 -.4522	-.6155 -.3956	-.6127 -.4305	-.4390 -.3394	-.5871 -.4221
Yb	-.0065 -.0033	**.3261** .2309	-.6256 -.2837	-.2023 -.3385	-.7839 -.7184	**.7805** **.6909**	**.8191** **.9463**	.0820 .1754	**.8948** **.9561**	**.6941** **.6318**	-.6354 -.3778	**.9775** **.9613**	**.8616** **.9302**	-.4172 -.2072	**.4976** **.8538**	**.8876** **.9420**	**.8640** **.9100**	**.6403** **.7902**	
U	.0647 .0426	**.3230** .1066	-.4688 -.2484	-.2939 -.2159	-.6702 -.5769	**.7113** **.4756**	**.6915** **.8534**	-.0757 .1057	**.8702** **.7621**	**.6403** **.6330**	-.5544 -.4219	**.7174** **.8303**	**.7783** **.9083**	-.4653 -.2089	**.3939** **.7223**	**.7431** **.8948**	**.7066** **.7998**		
Th	-.1325 .1226	.2930 .1312	-.6265 -.2578	-.2125 -.3967	-.8244 -.7325	**.8493** **.6937**	**.8995** **.9627**	.1211 .1708	**.9284** **.9441**	**.7852** **.6445**	-.7683 -.4805	**.8766** **.9408**	**.8914** **.9349**	-.3914 -.2153	**.4147** **.8424**	**.9285** **.9473**			
Sc	.0612 .0528	**.3925** .1604	-.6778 -.2539	-.2087 -.2897	-.8308 -.7172	**.8530** **.6548**	**.8937** **.9627**	.0441 .1523	**.9825** **.9808**	**.8024** **.6842**	-.7136 -.4484	**.9041** **.9699**	**.9376** **.9935**	-.4523 -.2264	**.5181** **.8849**				
Sb	.1375 .1622	**.6772** .1959	-.3440 -.1843	.1592 -.2958	-.2772 -.6667	**.5406** **.6689**	**.3398** **.8383**	.1080 .1920	**.8768** **.5438**	**.3468** **.5176**	-.2247 -.3672	**.4760** **.8664**	**.4747** **.8775**	-.1582 -.1582					
Rb	.0003 .2340	-.1726 -.1494	**.3608** .0516	.0810 .2519	**.4336** .0045	-.4287 -.0376	-.4311 -.2803	**.4057** **.6114**	-.4630 -.2265	-.4711 -.3313	**.5318** **.4161**	-.4465 -.2471	-.4695 -.2302						
Na	.0725 .0543	-.3717 .1631	**.6518** .2530	-.2358 -.2661	-.8204 -.7224	**.7922** **.6556**	**.8684** **.9651**	.0427 .1430	**.9531** **.9787**	**.8201** **.7016**	-.6847 -.4839	**.9570** -.4665							
La	-.0295 .0628	**.3371** .1387	**.6140** -.2161	-.1962 -.2712	-.7908 -.7262	**.7865** **.6758**	**.8265** **.9743**	.0620 .1278	**.9083** **.9838**	**.7309** **.6739**	-.6654 -.4499								
K	.0097 .2159	-.1177 -.1201	**.4099** -.2238	.2080 .1035	-.6118 .0582	-.6734 -.3375	-.7367 -.4371	-.1459 -.1035	**.7423** .4154	-.7628 -.4295									
Hf	.0154 .1286	.2740 .1379	-.4779 -.0516	-.2460 -.0954	-.7580 -.5106	**.6564** .3868	**.7917** **.6834**	.0449 -.0206	**.8268** **.6535**										
Fe	.0860 .0332	**.4097** .1448	**.6787** -.2753	-.2003 -.2777	-.8363 .-7362	**.8672** **.6602**	**.9150** **.9821**	.0559 .1283											
Cs	-.2020 -.0471	.0611 .0069	-.0181 .1226	.1979 .0744	.0234 -.2107	.0383 .2180	.0435 .0924												
Cr	.0882 .0614	.2660 .1112	**.6108** -.2730	-.2881 .2705	-.8071 -.7582	**.7937** **.6515**													
Co	-.0455 .1490	-.4469 .0923	**.5622** -.2000	-.1368 -.2861	-.7091 -.4886														
Ca	.0810 .0916	-.2619 .0084	**.7045** **.4421**	.2141 -.1368															
Br	-.2024 .0052	**.4002** -.0964	.0978 .1785																
Ba	.1346 .2513	-.2266 .1673																	
As	-.0138 -.1274																		

Significance Values for r
1988
For 67 degrees of freedom (n-2)
99% confidence level = **0.325**
1989
For 37 degrees of freedom (n-2)
99% confidence level = **0.418**

Gold

Gold levels in spruce ash were unusually high in 1988 samples; background levels in black spruce twigs elsewhere are commonly less than 10 ppb Au (Dunn, 1986b). Gold concentration values range from below detection level (5 ppb) to above 100 ppb in 1988 samples and are below 45 ppb in 1989 samples. Mean and median values using log transformed data of the 1988 survey are 12.19 and 11.0 ppb respectively and of the 1989 survey, 6.5 and 7.2 ppb respectively.

A single value of 187 ppb Au, sampled on transect III at T88-28 (1988 sample), was later discovered to be from subalpine fir. Despite this, adjacent black spruce with Au values in the upper ranges (above the 80th percentile) confirm a probable zone of Au enrichment. Another zone of high

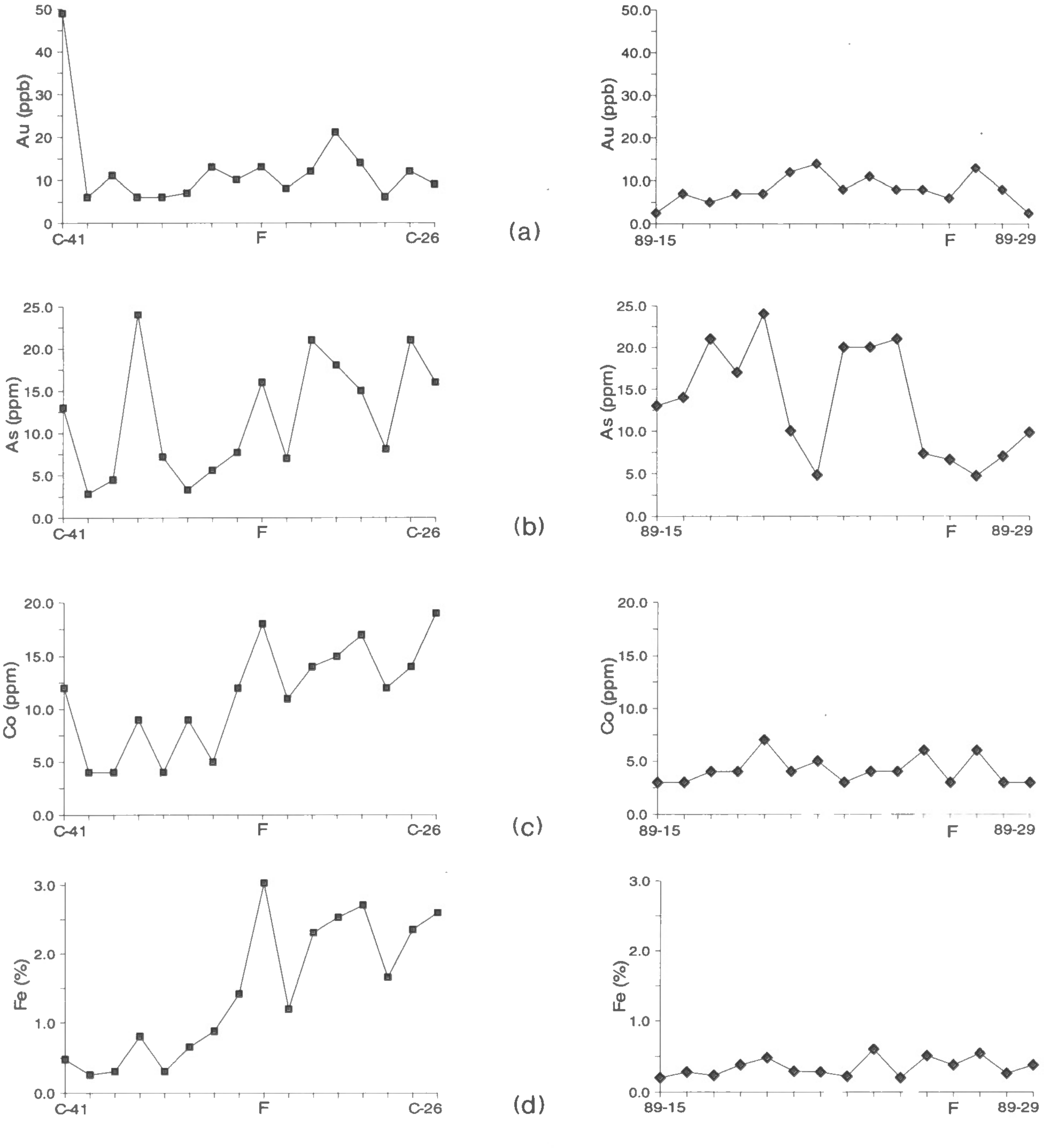


Figure 7. *Element concentration profiles along 1988 sample traverse I (C88-41 to C88-26; squares) and 1989 traverse II (89-15 to 89-29; diamonds) for selected elements:* ***A)*** *Au,* ***B)*** *As,* ***C)*** *Co,* ***D)*** *Fe,* ***E)*** *K,* ***F)*** *La,* ***G)*** *U,* ***H)*** *Zn. F denotes inferred position of Weedon Fault.*

Au occurs at transect V (1988 sample) with values of 73 and 162 ppb. High concentrations of Au in 1989 samples occur mostly as single station anomalies. Transects IV and VI exhibit possible small zones of enrichment with two adjacent anomalous stations.

Unlike many of the elements listed in Table 5, Au is noteworthy for its low statistical correlation with other elements determined in this survey. In one exception, the r-value for Au and Sr obtained in 1989 samples had a relatively high correlation coefficient (0.4436), yet the corresponding 1988 r-value does not support this.

A visual comparison of Au anomalies with other metals and common pathfinders reveals some possible relationships with As and Ba. Enriched levels of these elements are found to be either adjacent to or occupying the same stations containing high Au (cf. Dunn, 1986a, b). It should be noted that this is not the case for the Au zone in transect V. With

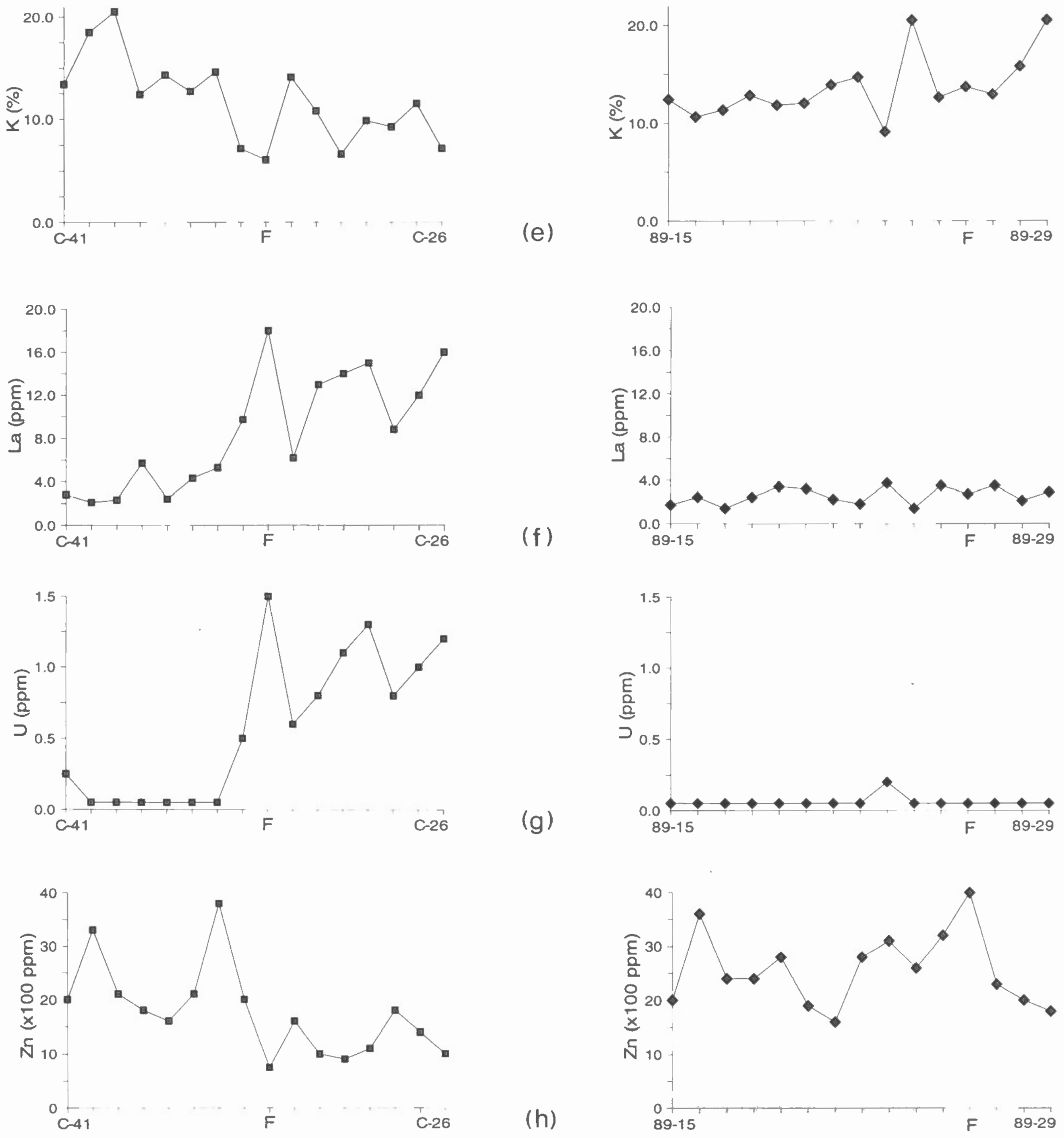


Figure 7 (cont.)

the possible exception of Rb, there appear to be no visual correlations of any element within this zone. Anomalous levels of Au do not appear to be directly related to the fault. A two-site anomaly of high Au levels on transect VI fall directly on the proposed Weedon Fault, however the remaining high level zones are found to be scattered randomly throughout the area up to 3 km away on either side of the interpreted fault line.

It is difficult to conclude whether or not a Au concentration difference exists between the two sides of the fault. While 1988 values are highly significant, values for neither black nor white spruce are significant in 1989 samples.

Other elements

Arsenic, barium, and molybdenum appear to have higher than usual levels of concentration (C.E. Dunn, pers. comm., 1991). Spruce twigs overlying known metasomatic mineralization

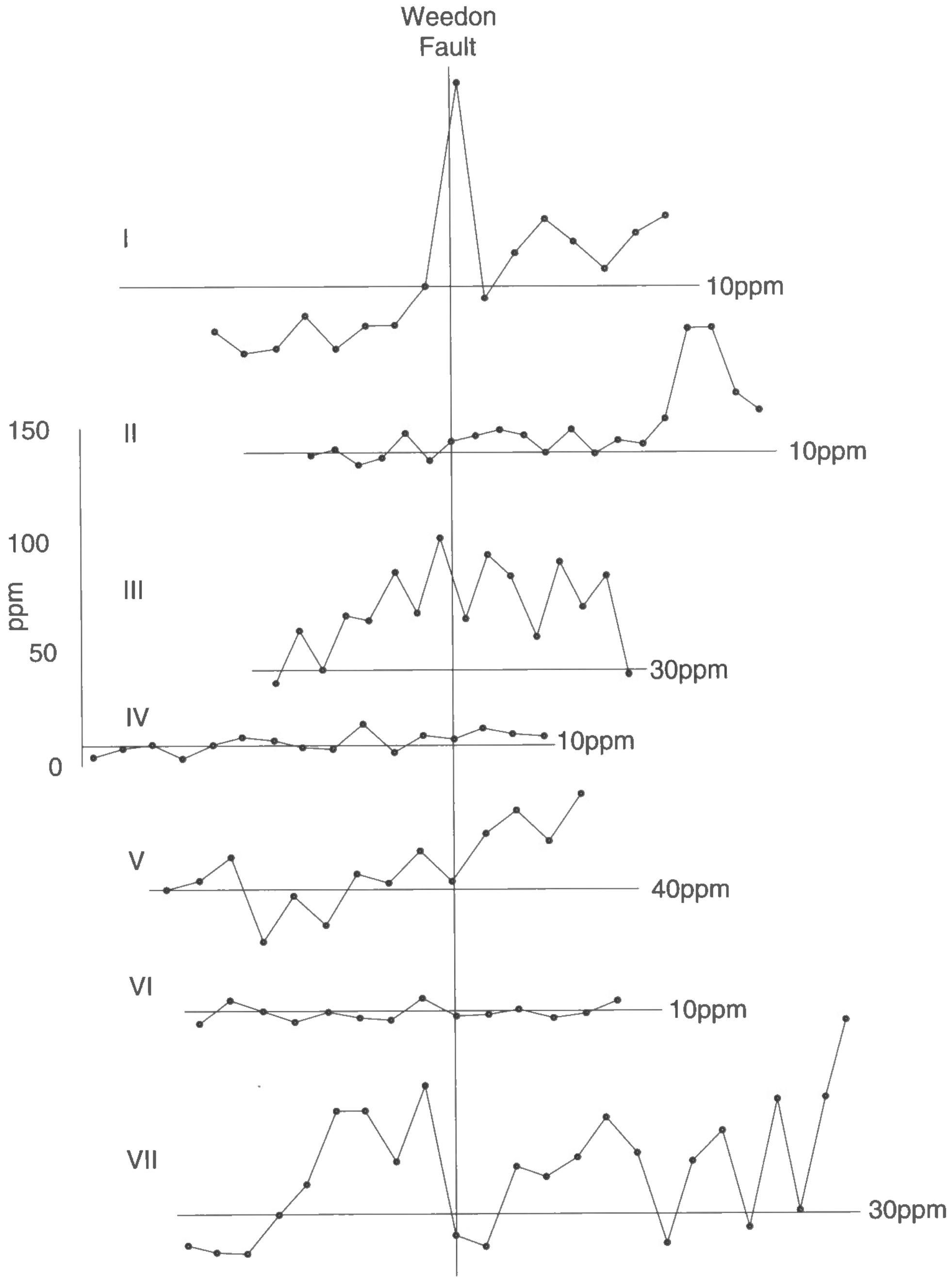


Figure 8. Profiles of chromium concentration (in ppm) along sampling traverses. Vertical scale of transect IV applies to all transects.

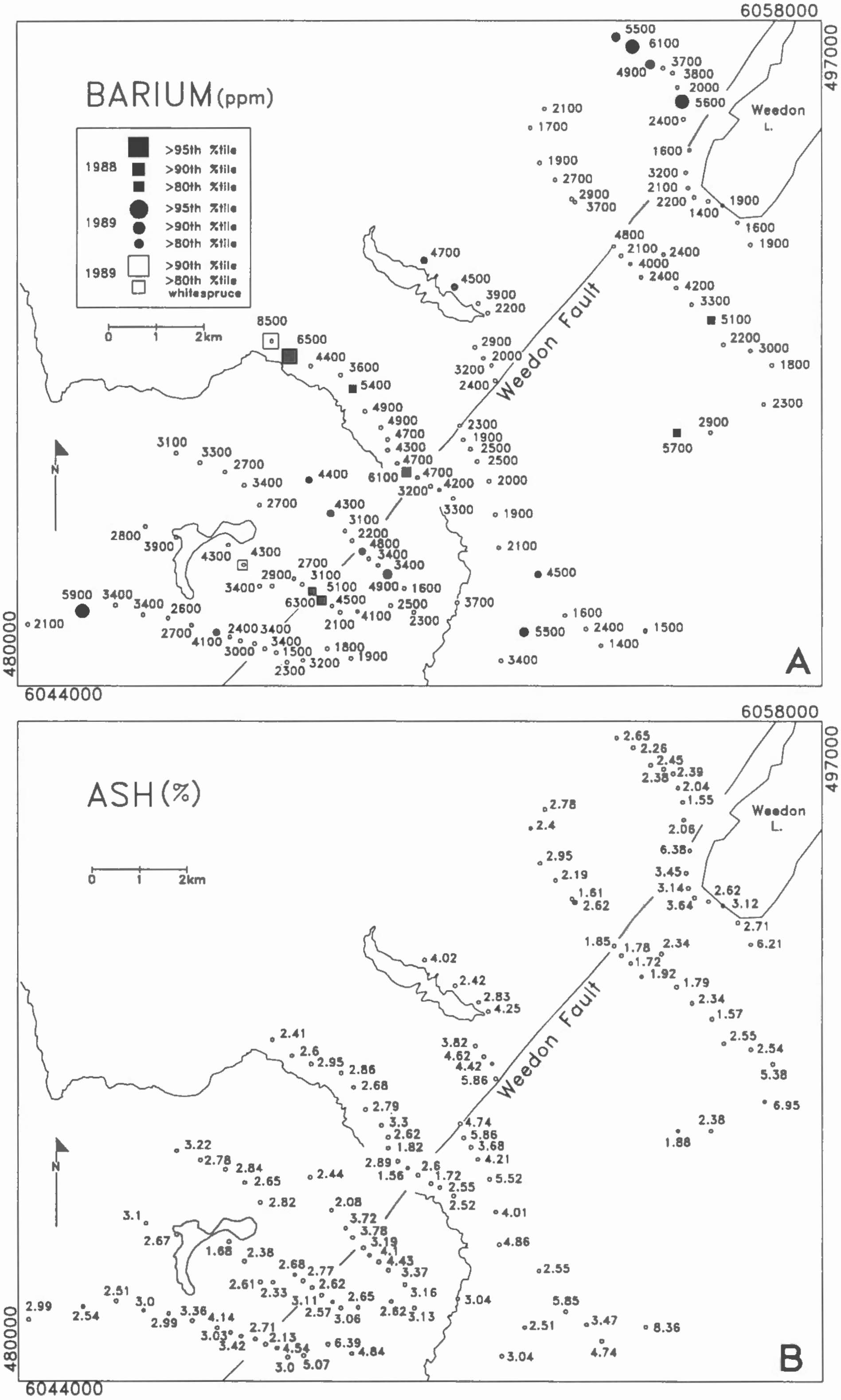


Figure 9. Concentration data in spruce twig ash: A) barium, B) ash, C) antimony, D) arsenic, E) calcium, F) chromium, G) cobalt, H) gold, I) iron, J) molybdenum, K) potassium, L) rubidium, M) sodium, N) strontium, O) uranium, P) zinc. Values greater than 80th percentile are indicated.

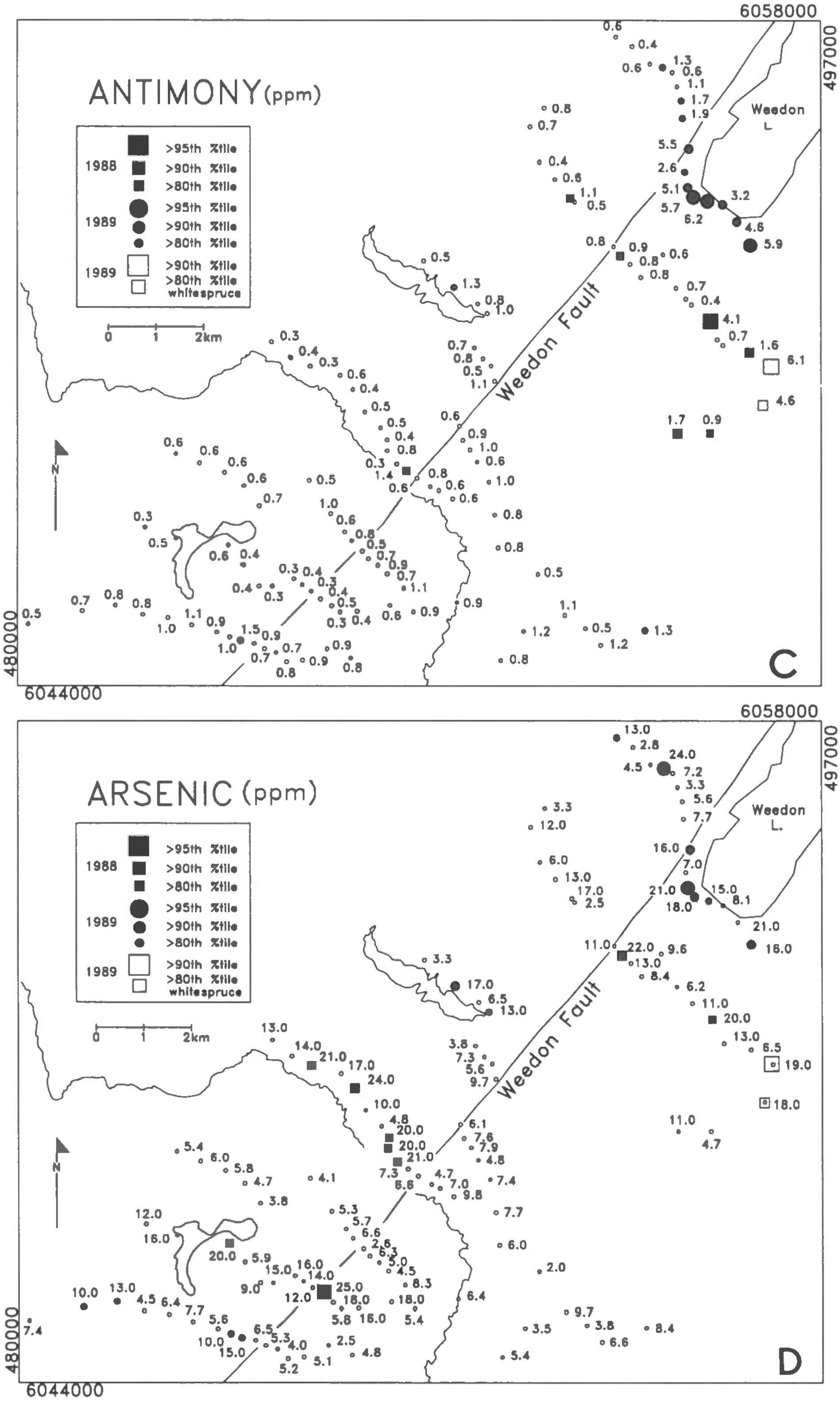
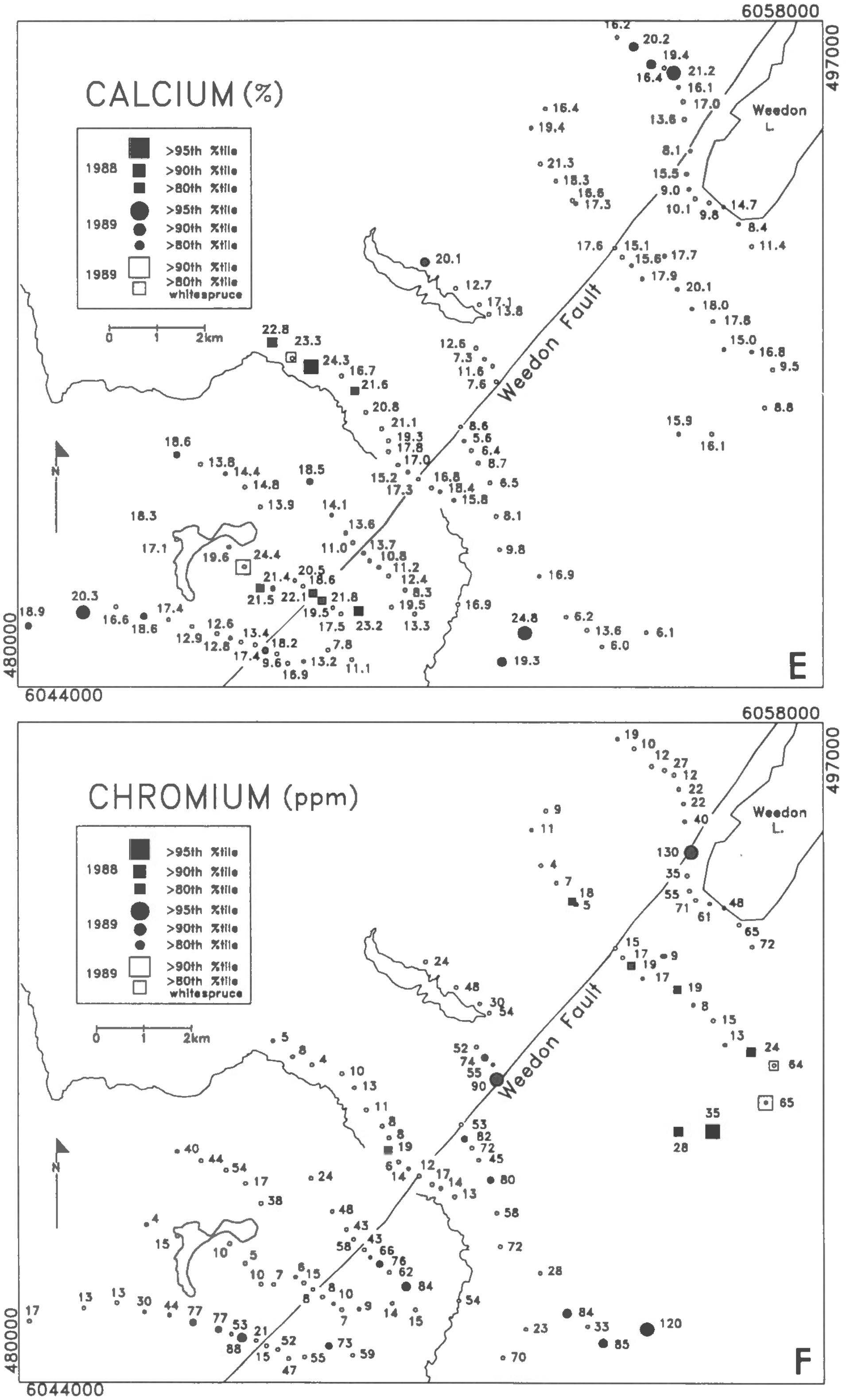


Figure 9. (cont.)



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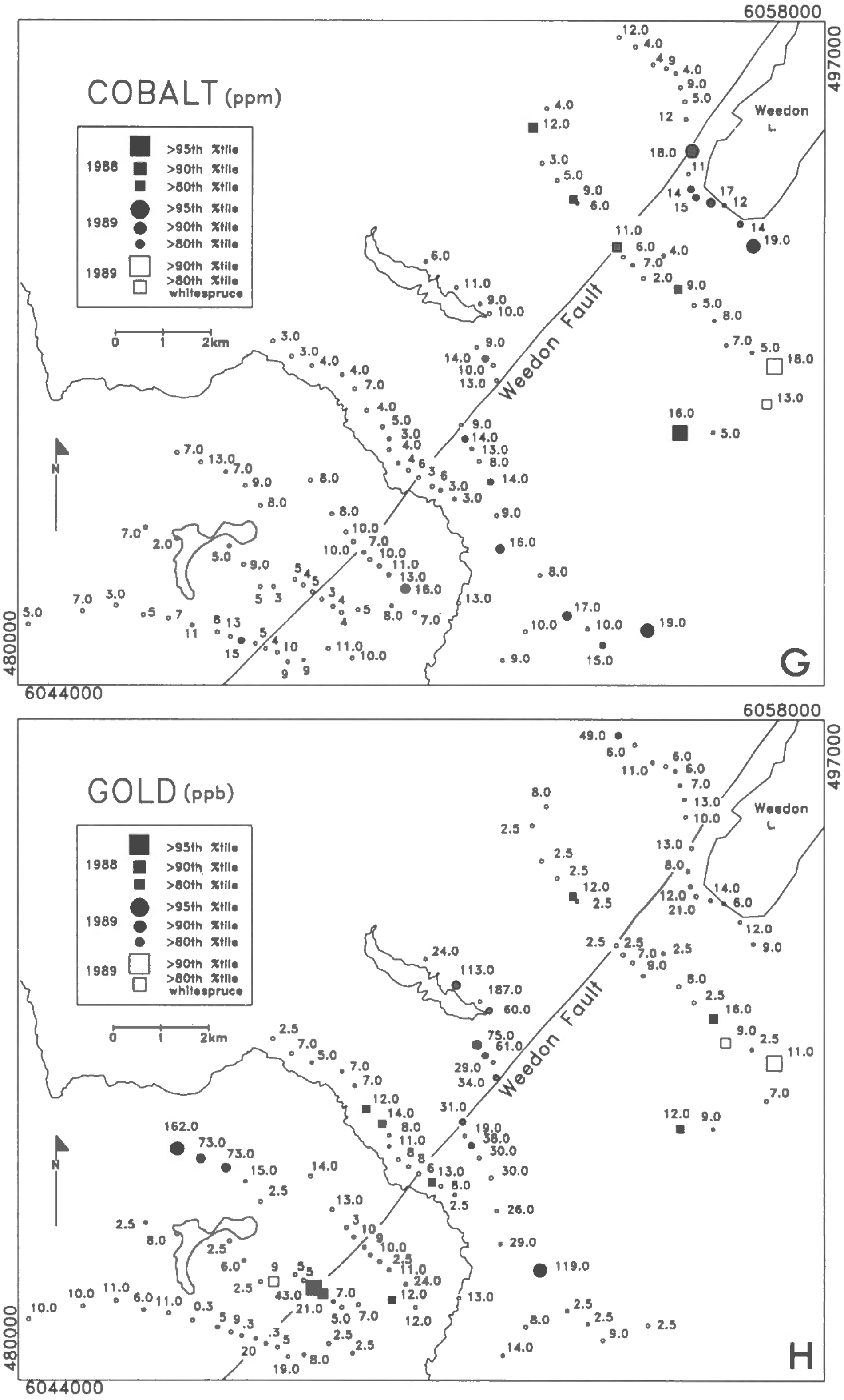

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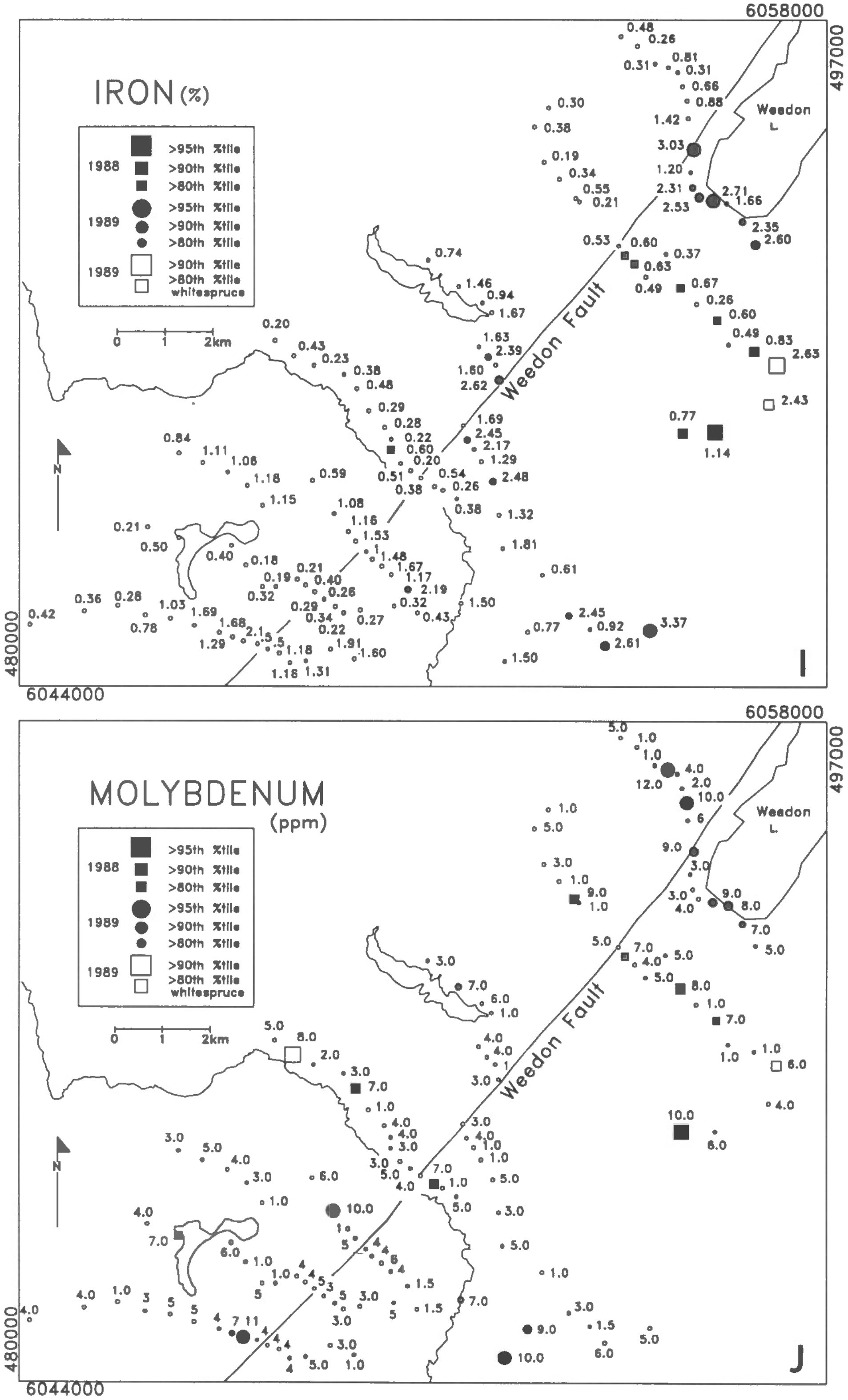
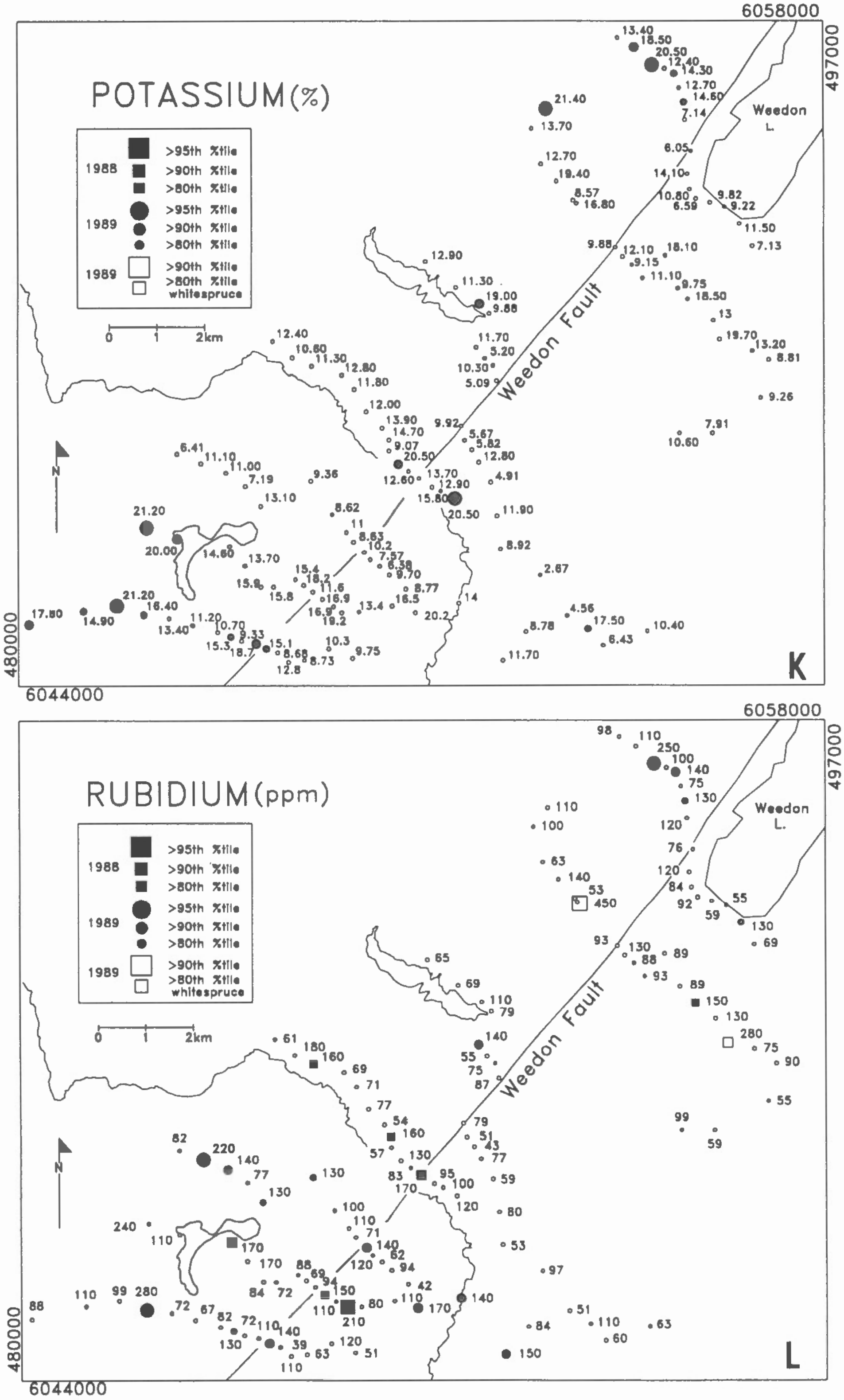


Figure 9. (cont.)



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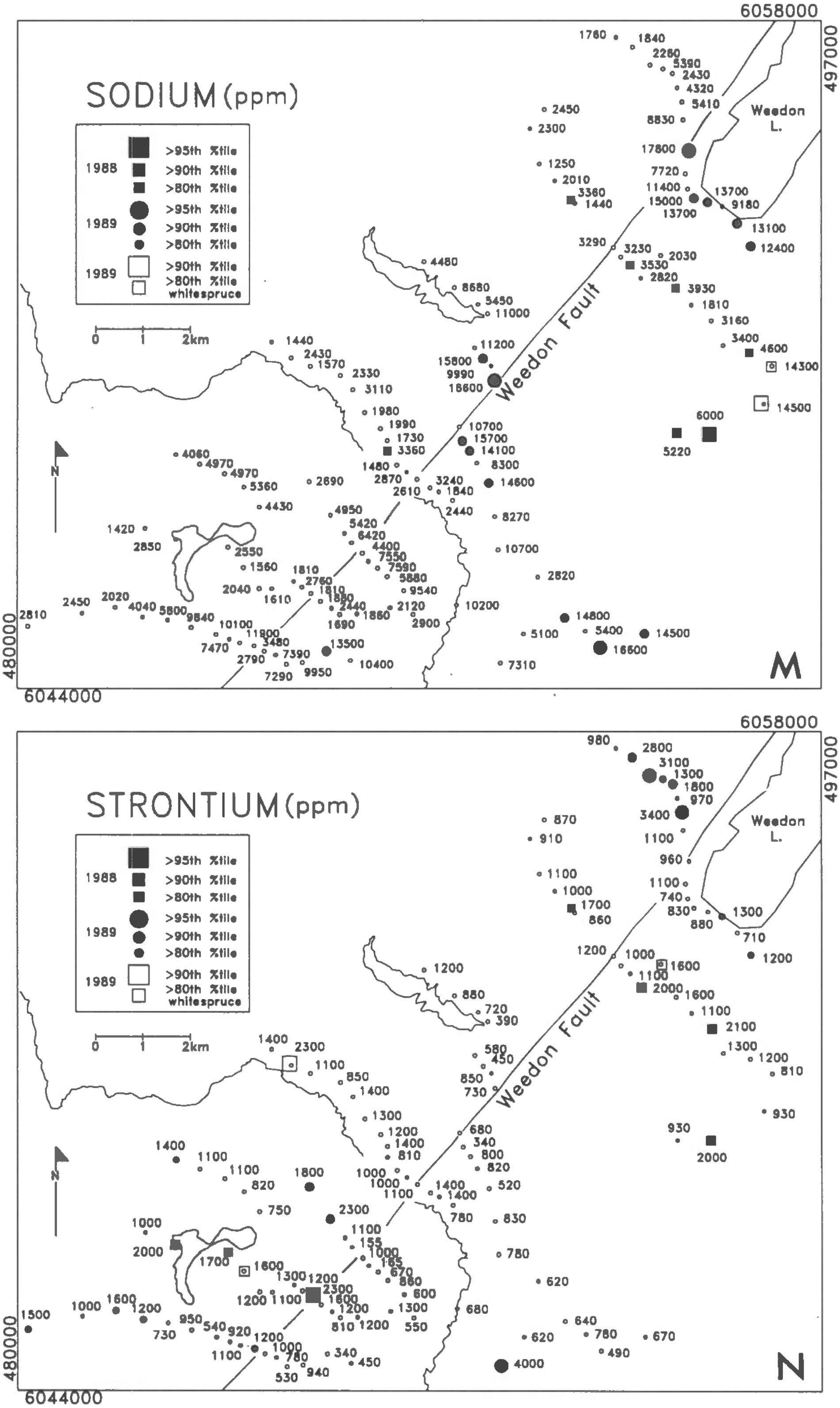

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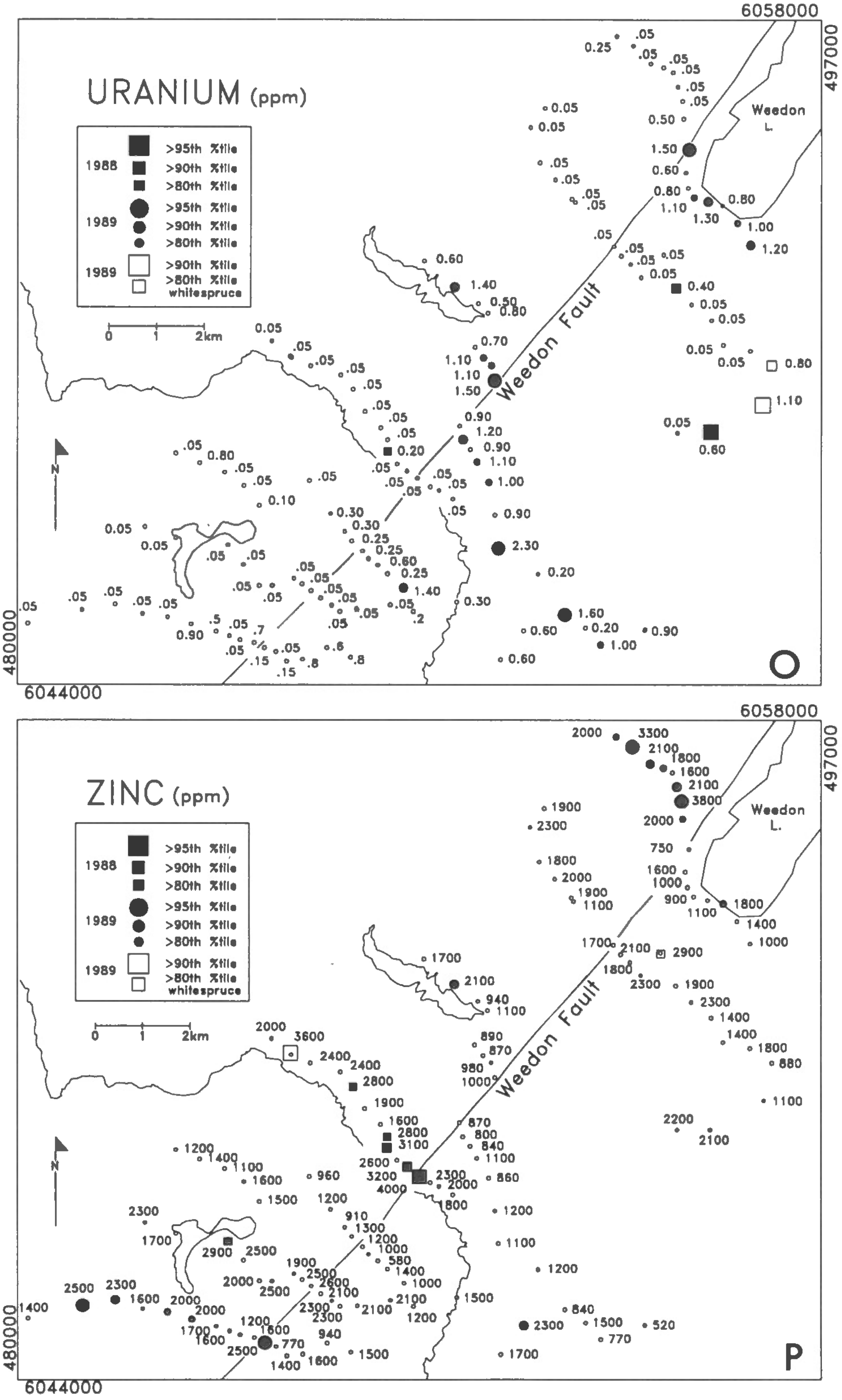

Figure 9. (cont.)

and sampled by Warren et al. (1968), contained mean As values of 7 and 13 ppm. Mean values of 6.6 and 11.6 ppm for the two years were obtained in this survey. Values for Mo, usually below the detection level of 2 ppm (C.E. Dunn, pers. comm., 1991), are 3.5 and 4.1 ppm.

The sensitivity of black spruce to U has been well documented by Dunn (1983). Uranium in this area appears to be well below background levels of 0.5 ppm (Hawkes and Webb, 1962) with mean values of 0.33 and 0.07 ppm. For most stations in 1989 sampling, U is below the minimum detection level of 0.10 ppm. Significant correlation with Fe, Zn, and Sm determined in this survey support observations of the same by Dunn (1981).

Iridium values are found to be below detection in all samples indicating the probable absence of platinum group metals in the area (Dunn et al., 1989).

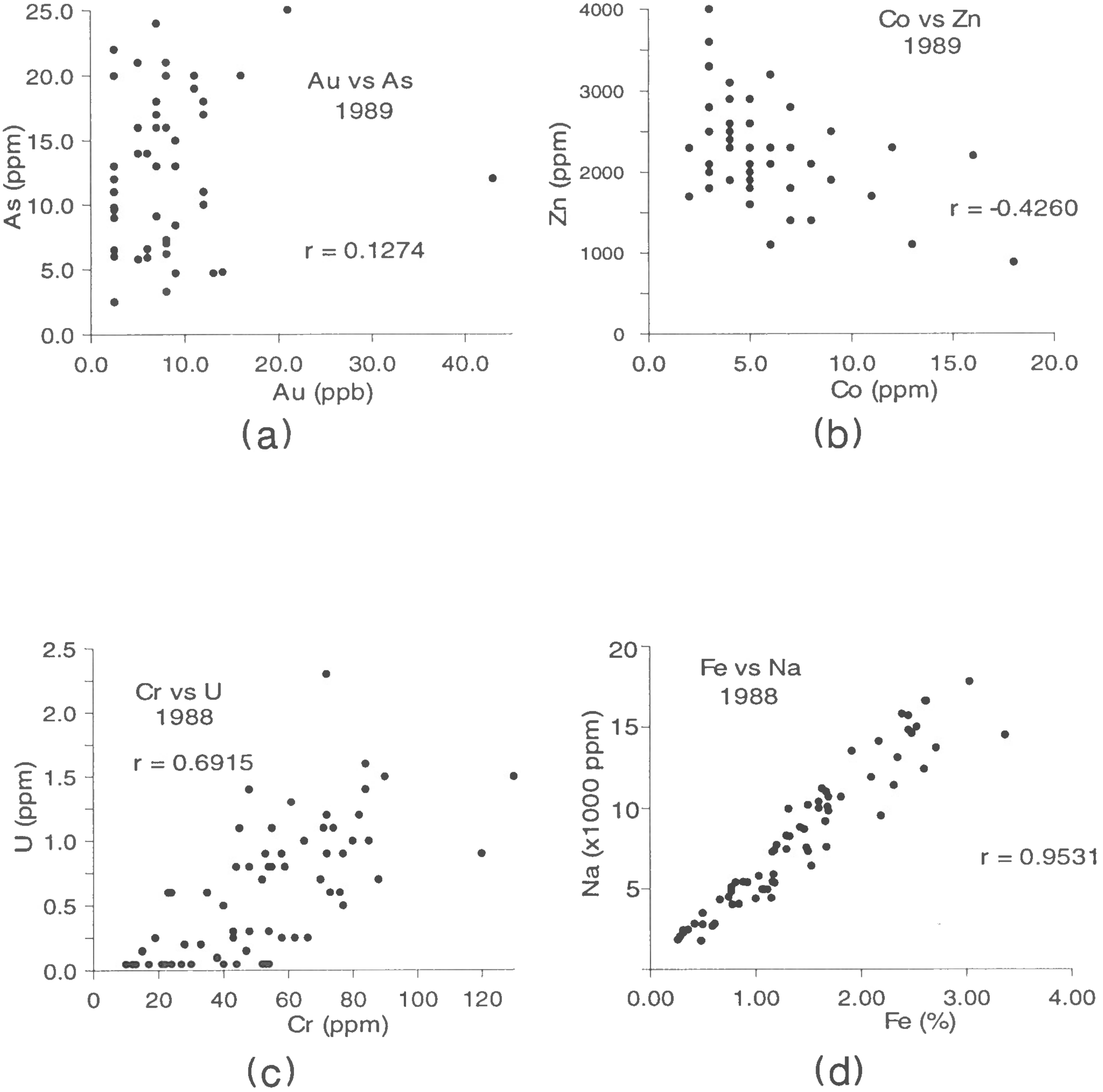

*Figure 10. Scatterplots illustrating range of r-values; **a)** Au vs. As, **b)** Co vs. Zn, **c)** Cr vs. U, **d)** Fe vs. Na.*

Table 6. Element concentrations from black spruce twig ash and stream sediment survey, Weedon Lake area

	REGIONAL SEDIMENTS 1987	SPRUCE SURVEY 1988	SPRUCE SURVEY 1989
As	5.53 ppm	7.74 ppm	12.36 ppm
Ba	761.33 ppm	2588.57 ppm	3525.09 ppm
Co	12.2 ppm	11.89 ppm	6.74 ppm
Fe	2.49%	1.72%	0.67%
Mo	3.47 ppm	4.37 ppm	4.61 ppm
U	3.43 ppm	0.78 ppm	0.17 ppm
Zn	84.46 ppm	1193.72 ppm	2938.26 ppm
Sb	0.40 ppm	0.80 ppm	0.50 ppm

Ash yield

Mean percentage ash yield of twigs was higher in 1988 samples (3.16%) than in those collected the following year (2.6%). The 1988 values range from 1.6 to 8.36% and 1989 values range from 1.6 to 6.95%. Spruce twig ash yields are generally close to 2.0%, so 1988 sample levels are considered high (C.E. Dunn, pers. comm., 1991). Ash levels along transect III are especially high with an average 4.34% yield. These higher levels in 1988 samples are likely due in large part to dust originating from the nearby logging roads. Traverses conducted in 1989, for the most part, were away from roads so were not subject to this source. At some sample sites logging roads were encountered along the 1989 traverse II (89-47 to 89-52). These stations exhibit the highest ash yields for that year and seem to confirm the substantial contribution made by the road dust.

Higher ash yields dilute the absolute concentration of most trace elements, since dust contaminants are mostly silicates. Samples with high ash yields and associated values of high Au or any other element would be considered anomalous since the excess levels of ash are actually subduing these values. The higher ash content of 1988 samples would mean that the variation between the two years is even greater than the uncorrected concentrations imply.

DISCUSSION

Annual variation

Climate may account for the distinct differences between the two years of sampling. Monthly temperature and precipitation data obtained from the weather station at Prince George Airport (Fig. 11) suggest a colder, drier climate in the start of 1989 which may have resulted in a late spring and delayed movement of sap through the trees. Several elements such as As, Zn, Rb, and Sr are more enriched in samples collected in 1989, suggesting that uptake by some elements may not be affected by climate or that other factors, as yet unrealized, influence the uptake of elements.

Contrasting these observations, Stednick and Riese (1987) found between-year variation of elements nonessential to tree growth (notably Au), but relative stability of essential elements such as Zn. In the 1988-1989 study essential elements Zn, K, and Fe showed considerable between-year variation as did nonessential elements.

Lithological variation

Concentration profiles for U, Zn, Fe (with associated elements La and Sc), and Cr (Fig. 7 and 8) would seem to indicate that bedrock chemistry does have a strong influence on the chemical make-up of the trees. It is important to note however that although this survey has been successful in identifying the different bedrock composition, the trees are a reflection of multiple substrates such as soil, groundwater, glacial and recent fluvial deposits, and bedrock. In addition to this, growth processes within the tree itself influence the uptake of elements.

The contradiction of plant and bedrock element abundance for Ca, Zn, Th, and Na in this survey illustrates the inevitable complexities of utilizing biological systems. While it is possible that these results may be reflecting

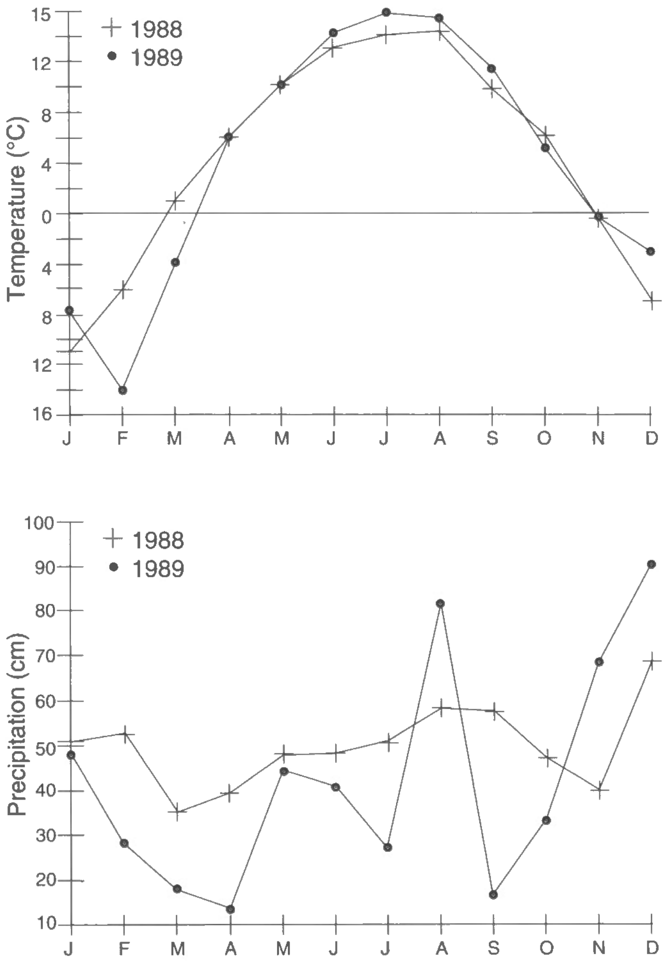

Figure 11. Monthly temperature and precipitation values for 1988 and 1989 obtained from the Prince George airport weather station.

element abundance in other media (i.e., groundwater or glacial deposits), it may be that the tree's metabolism itself is promoting or inhibiting the accumulation of an element.

Element relationships, again established by the plant, could also affect the uptake of elements. The strong antagonism that exists between Fe and both Ca and Zn in spruce trees (C.E. Dunn, pers. comm., 1991) may be responsible for the unexpected distribution of the latter elements in this study. The presence of high Fe concentrations east of Weedon Fault may have caused a reduction in Zn and Ca values while the lower Fe values in areas west of the fault may have allowed for increased uptake of Zn and Ca. Analysis of a fairly large selection of elements and an understanding of some tree metabolic characteristics is required to avoid the possibility of misinterpretation.

Previous studies have been successful in detecting fault zones based on coincident element anomalies. Pape (1981) recognized the superimposition of Ba-Mo and Na anomalies along fault zones in Germany. Ashton and Riese (1989) found that Au and As anomalies in Oregon, U.S.A. were often related to bedrock contact zones. Element anomalies in this study do not appear to delineate the suspected position of Weedon Fault. The lack of anomalous metal concentrations is perhaps due to the absence of mineralization along the fault, since elements indicating faults in the previous studies appear to be related to extensive mineralization within or near the fault.

Gold

The lack of anomalous Au concentration along the interpreted Weedon Fault suggests that the suspected position of the fault may be misinterpreted, or the fault is too constricted to allow hydrothermal movement, or it is simply not a source of Au mineralization. There are, however, suggestions of potential mineralization in this area that may be worth further investigation. Levels of Au along the entire length of transect III are quite high (41 ppb) and well above usual background levels of < 10 ppb Au. For comparison, a mean Au content in black spruce twigs overlying Au mineralization in Saskatchewan was 44 ppb (Dunn, 1986b).

The possibility of contamination of samples from transect III has been considered. Samplers were not known to be wearing jewellery but samples collected along this transect were taken close (20 to 40 m) to the road – a possible source of contamination. C.E. Dunn (pers. comm., 1991) has found that in order to totally eliminate any possible road contamination, samples should be taken at least 500 m away; however, this is unlikely to explain Au enrichment since three other transects surveyed close to logging roads did not record similar levels of Au. Enrichment of Au (above 80th percentile) along this transect was accompanied by elevated levels of As and Ba.

Samples along transect III also yield above average ash values. Chukhrov et al. (1979) observed higher ash yields in areas where bedrock is more weathered. On the basis of high Au and ash values this may indicate the presence of another fault, although there is no other substantial geological evidence.

CONCLUSION

Concentrations of certain elements analyzed in this survey indicate a significant difference across the fault both statistically and visually. This is believed to be due in large part, to the different chemistry of the underlying granite and basalt. Elements that displayed concentrations contrary to expectations based on this assumption may indicate influences by other substrates, or more likely to processes within the tree which promote or discourage certain element accumulation.

For some elements such as Fe, concentration profiles along some transects displayed distinct breaks, probably representing a fairly accurate position of the fault; however, these distinctive profiles were not consistently observed along all the transects, thus preventing a visual recognition of the fault for the entire study area. Biogeochemical data in this survey gave no evidence of any element being deposited preferentially along the Weedon Fault, although this phenomenon has been observed elsewhere by others.

Twig samples were collected consecutively for two years during the spring. Despite this attempt at a temporal and seasonal consistency between the sampling periods, significant concentration variation, occurred between 1988 and 1989 for most elements. Climatic conditions were likely the major factor in creating this disparity. Warmer, moist conditions in the late winter months of 1988 probably led to the onset of an earlier spring and gave extra time for element accumulation within the trees.

Another possible factor that could have contributed to this variation may have been that samples taken in the first year were much closer to logging roads than those in 1989. Contamination of mostly silicates and possibly other elements, due to dust from these roads may have occurred. Higher than normal ash values in 1988 samples and in samples collected near roads in the following year appear to indicate some affect of dust from roads on the trees.

Several sites of potential Au mineralization have been outlined based on concentrations found in ashed twigs. In most cases, similar distributions of common Au pathfinders – Ba and As – are associated with these sites. Transect III contains the highest concentrations of Au. In addition, ash yields for this transect are also high and together may indicate an area of faulting. Further investigation is required to determine if these values are valid or whether contamination might have occurred.

This survey has shown biogeochemistry to be an effective and efficient geochemical tool. Its ability to sample multiple substrates makes it a superior sample medium to soils. It is especially useful in areas of heavy glacial overburden. Twig sampling proved to be a much faster and less strenuous activity than traditional till or soil sampling and the cost is comparable to other geochemical methods. The importance of sampling consistency cannot be over-stressed. There are a multitude of known and yet to be discovered factors that affect the uptake of elements. Minimizing these factors in the collection of samples is required in order to achieve the most accurate analyses and results.

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Colin Dunn supervised the preparation and analysis of the samples and shared his knowledge of spruce geochemistry throughout the project. We are grateful for his guidance throughout the project and his review of the manuscript. Aletha Buschman assisted in the final stages of manuscript preparation.

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APPENDIX A

Spruce twig sample analyses (INAA)

Appendix A consists of a data table showing sample number, UTM location, and spruce twig analyses for 27 elements using INAA. Elements consistently below detection level were not included. Concentration units vary for each element and are indicated.

Appendix A (cont.)

SAMPLE #	89-01	89-02	89-03	89-04	89-05	89-06	89-07	89-08	89-09	89-10	89-11	89-12
EASTING	487860	487150	486800	486625	486390	486190	486000	485825	484450	484750	485100	485375
NORTHING	6045690	6045610	6045550	6045675	6045825	6045985	6046125	6046250	6046960	6046550	6046100	6046100
Au (ppb)	12	7	5	7	21	43	5	5	<5	6	<5	9
As (ppm)	18	16	5.8	18	25	12	14	16	20	5.9	9	15
Ba (ppm)	2500	4100	2100	4500	6300	5100	3100	2700	4300	4300	3400	2900
Br (ppm)	34	17	32	17	17	14	17	11	19	19	19	15
Ca (%)	19.5	23.2	17.5	19.5	21.8	22.1	18.6	20.5	19.6	24.4	21.5	21.4
Co (ppm)	8	5	4	4	3	5	4	5	5	9	5	3
Cr (ppm)	14	9	7	10	8	8	15	6	10	5	10	7
Cs (ppm)	0.8	0.7	3.7	1	1.4	0.5	1.3	<0.5	1.7	3.1	<0.5	<0.5
Fe (%)	0.32	0.27	0.22	0.34	0.29	0.26	0.4	0.21	0.4	0.18	0.32	0.19
Hf (ppm)	0.7	<0.5	0.7	1.2	<0.5	0.8	1	<0.5	<0.5	<0.5	<0.5	<0.5
K (%)	16.5	13.4	19.2	16.9	16.9	11.6	18.2	15.4	14.6	13.7	15.9	15.8
Mo (ppm)	5	3	3	5	3	5	4	4	6	<2.0	5	<2.0
Na (ppm)	2120	1860	1690	2440	1880	1810	2760	1810	2550	1560	2040	1610
Rb (ppm)	110	80	210	110	150	94	69	88	170	170	84	72
Sb (ppm)	0.6	0.4	0.3	0.5	0.4	0.3	0.4	0.3	0.6	0.4	0.4	0.3
Sc (ppm)	0.9	0.9	0.7	1.2	0.9	0.8	1.3	0.7	1.3	0.7	1	0.6
Sr (ppm)	1300	1200	810	1200	1600	2300	1200	1300	1700	1600	1200	1100
Th (ppm)	0.2	0.3	0.2	0.5	0.4	0.4	0.3	0.3	0.5	0.3	0.3	<0.1
U (ppm)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Zn (ppm)	2100	2100	2300	2300	2100	2600	2500	1900	2900	2500	2000	2500
La (ppm)	1.9	1.8	1.5	2.6	2.1	1.8	2.7	1.5	2.7	1.7	2.2	1.3
Ce (ppm)	4	5	1.5	4	<3	4	6	<3	5	3	5	<3
Nd (ppm)	2.5	9	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Sm (ppm)	0.3	0.3	0.2	0.4	0.3	0.3	0.4	0.2	0.4	0.2	0.3	0.2
Eu (ppm)	0.01	0.01	0.01	0.01	0.015	0.01	0.19	0.01	0.015	0.01	0.01	0.01
Yb (ppm)	0.19	0.25	0.19	0.25	0.19	<.05	0.32	0.1	0.28	<.05	0.21	0.15
Lu (ppm)	<.05	<.05	0.05	<.05	<.05	0.025	<.05	<.05	<.05	<.05	<.05	<.05

SAMPLE #	89-13	89-14	89-15	89-16	89-16A	89-17	89-18	89-19	89-20	89-21	89-22	89-23
EASTING	483350	482700	485360	485750	485750	486175	486810	487075	487325	487660	487800	487800
NORTHING	6047120	6047345	6051260	6050940	6050940	6050740	6050545	6050250	6049775	6049440	6049190	6048960
Au (ppb)	8	<5	<5	6	7	5	7	7	12	14	8	11
As (ppm)	16	12	13	14	9.1	21	17	24	10	4.8	20	20
Ba (ppm)	3900	2800	8500	5300	6500	4400	3600	5400	4900	4900	4700	4300
Br (ppm)	14	12	15	46	17	26	35	30	31	30	25	21
Ca (%)	17.1	18.3	22.8	23.3	22	24.3	16.7	21.6	20.8	21.1	19.3	17.8
Co (ppm)	2	7	3	3	3	4	4	7	4	5	3	4
Cr (ppm)	15	4	5	8	10	4	10	13	11	8	8	19
Cs (ppm)	0.7	2.3	0.5	<0.5	1.9	0.9	0.8	0.8	<0.5	<0.5	0.9	0.9
Fe (%)	0.5	0.21	0.2	0.28	0.43	0.23	0.38	0.48	0.29	0.28	0.22	0.6
Hf (ppm)	0.9	<0.5	<0.5	<0.5	1.5	<0.5	0.8	1.3	1.2	1.1	0.9	1.2
K (%)	20	21.2	12.4	12.9	10.6	11.3	12.8	11.8	12	13.9	14.7	9.07
Mo (ppm)	7	4	5	4	8	2	3	7	<2.0	4	4	3
Na (ppm)	2850	1420	1440	2140	2430	1570	2330	3110	1980	1990	1730	3360
Rb (ppm)	110	240	61	130	180	160	69	71	77	54	160	57
Sb (ppm)	0.5	0.3	0.3	0.4	0.4	0.3	0.6	0.4	0.5	0.5	0.4	0.8
Sc (ppm)	1.4	0.8	0.7	1	1.2	0.6	1.1	1.4	1	1	0.8	1.8
Sr (ppm)	2000	1000	1400	1800	2300	1100	850	1400	1300	1200	1400	810
Th (ppm)	0.5	0.3	<0.1	<0.1	0.3	0.1	0.3	0.4	0.3	0.3	<0.1	0.5
U (ppm)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.2
Zn (ppm)	1700	2300	2000	3300	3600	2400	2400	2800	1900	1600	2800	3100
La (ppm)	3	1.5	1.7	2.2	2.4	1.4	2.4	3.4	3.2	2.2	1.8	3.7
Ce (ppm)	4	<3	<3	4	4	<3	4	5	4	4	<3	7
Nd (ppm)	2.5	2.5	2.5	2.5	12	2.5	2.5	2.5	2.5	2.5	2.5	7
Sm (ppm)	0.5	0.2	0.2	0.3	0.4	0.2	0.4	0.5	0.3	0.3	0.2	0.5
Eu (ppm)	0.01	0.01	0.01	0.01	0.015	0.01	0.01	0.01	0.16	0.015	0.01	0.18
Yb (ppm)	0.24	0.17	<.05	<.05	0.25	0.19	0.18	0.33	<.05	0.17	0.25	0.38
Lu (ppm)	0.06	<.05	<.05	<.05	<.05	0.025	0.025	<.05	<.05	<.05	<.05	0.07

SAMPLE #	89-24	89-25	89-26	89-27	89-28	89-29	89-33	89-34	89-35	89-36	89-37	89-38
EASTING	488000	488210	488430	488710	488890	489185	491125	490825	491025	491350	491700	491775
NORTHING	6048680	6048525	6048380	6048200	6048120	6047940	6056152	6055750	6055005	6054650	6054250	6054175
Au (ppb)	8	8	6	13	8	<5	8	<5	<5	2.5	12	<5
As (ppm)	21	7.3	6.6	4.7	7	9.8	3.3	12	6	13	17	2.5
Ba (ppm)	4700	6100	4700	3200	4200	3300	2100	1700	1900	2700	2900	3700
Br (ppm)	28	20	32	16	20	15	23	11	15	13	14	27
Ca (%)	17	15.2	17.3	16.8	18.4	15.8	16.4	19.4	21.3	18.3	16.6	17.3
Co (ppm)	4	6	3	6	3	3	4	12	3	5	9	6
Cr (ppm)	6	14	12	17	14	13	9	11	4	7	18	5
Cs (ppm)	0.9	1	1.1	1.4	0.9	<0.5	<0.5	0.6	0.7	1	0.9	2.3
Fe (%)	0.2	0.51	0.38	0.54	0.26	0.38	0.3	0.38	0.19	0.34	0.55	0.21
Hf (ppm)	1.1	1.2	<0.5	<0.5	<0.5	0.9	0.6	0.5	<0.5	<0.5	<0.5	<0.5
K (%)	20.5	12.6	13.7	12.9	15.8	20.5	21.4	13.7	12.7	19.4	8.57	16.8
Mo (ppm)	3	5	4	7	<2.0	5	<2.0	5	3	<2.0	9	<2.0
Na (ppm)	1480	2870	2610	3240	1840	2440	2450	2300	1250	2010	3360	1440
Rb (ppm)	130	83	170	95	100	120	110	100	63	140	53	450
Sb (ppm)	0.3	1.4	0.6	0.8	0.6	0.6	0.8	0.7	0.4	0.6	1.1	0.5
Sc (ppm)	0.5	1.6	1.4	1.8	0.9	1.3	0.9	1.2	0.4	1	1.8	0.5
Sr (ppm)	1000	1000	1100	1400	1400	780	870	910	1100	1000	1700	860
Th (ppm)	0.1	0.4	0.4	0.8	0.3	0.5	0.3	0.5	<0.1	0.2	0.7	0.3
U (ppm)	0.05	0.05	0.05	0.05	0.05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.05
Zn (ppm)	2600	3200	4000	2300	2000	1800	1900	2300	1800	2000	1900	1100
La (ppm)	1.4	3.5	2.7	3.5	2.1	2.9	2	2.5	1	2.4	3.6	1.3
Ce (ppm)	<3	5	6	6	5	5	4	4	4	<3	8	<3
Nd (ppm)	7	7	7	2.5	2.5	2.5	2.5	2.5	2.5	2.5	8	2.5
Sm (ppm)	0.2	0.5	0.3	0.6	0.3	0.4	0.3	0.4	0.1	0.3	0.5	0.2
Eu (ppm)	0.01	0.015	0.01	0.01	0.015	0.01	0.01	0.01	0.01	0.01	0.16	0.01
Yb (ppm)	<.05	0.24	0.2	0.26	0.19	0.31	0.17	0.29	<.05	0.21	0.38	<.05
Lu (ppm)	<.05	<.05	<.05	0.06	<.05	<.05	<.05	<.05	<.05	0.05	<.05	<.05

SAMPLE #	89-39	89-40	89-41	89-42	89-43	89-44	89-45	89-46	89-47	89-48	89-49	89-50
EASTING	492600	492750	492950	493175	493600	493925	494250	495475	494925	494675	495950	495775
NORTHING	6053250	6053050	6052875	6052600	6053075	6052375	6052025	6051025	6051175	6051700	6050750	6049925
Au (ppb)	<5	<5	7	9	<5	8	<5	<5	9	16	11	7
As (ppm)	11	22	13	8.4	9.6	6.2	11	6.5	13	20	19	18
Ba (ppm)	4800	2100	4000	2400	2400	4200	3300	3000	2200	5100	1800	2300
Br (ppm)	16	15	15	17	16	20	16	16	34	16	9	12
Ca (%)	17.6	15.1	15.6	17.9	17.7	20.1	18	16.8	15	17.8	9.5	8.8
Co (ppm)	11	6	7	2	4	9	5	5	7	8	18	13
Cr (ppm)	15	17	19	17	9	19	8	24	13	15	64	65
Cs (ppm)	0.6	1.4	1.3	0.7	<0.5	<0.5	<0.5	0.7	3	1.9	1.8	1.5
Fe (%)	0.53	0.6	0.63	0.49	0.37	0.67	0.26	0.83	0.49	0.6	2.63	2.43
Hf (ppm)	1.3	<0.5	1.4	1.1	<0.5	1.1	<0.5	1.2	<0.5	<0.5	2.1	2.5
K (%)	9.88	12.1	9.15	11.1	18.1	9.75	18.5	13.2	19.7	13	8.81	9.26
Mo (ppm)	5	7	4	5	5	8	<2.0	<2.0	<2.0	7	6	4
Na (ppm)	3290	3230	3530	2820	2030	3930	1810	4600	3400	3160	14300	14500
Rb (ppm)	93	130	88	93	89	89	150	75	280	130	90	55
Sb (ppm)	0.8	0.9	0.8	0.8	0.6	0.7	0.4	1.6	0.7	4.1	6.1	4.6
Sc (ppm)	1.8	2	2.1	1.7	0.9	2	0.8	2.7	1.6	1.8	10	8.7
Sr (ppm)	1200	1000	1100	2000	1600	1600	1100	1200	1300	2100	810	930
Th (ppm)	0.5	0.7	0.9	0.5	0.2	0.6	0.3	0.7	0.3	0.6	2.3	1.8
U (ppm)	<0.1	<0.1	<0.1	<0.1	<0.1	0.4	<0.1	<0.1	<0.1	<0.1	0.8	1.1
Zn (ppm)	1700	2100	1800	2300	2900	1900	2300	1800	1400	1400	880	1100
La (ppm)	3.6	3.4	4.2	3.1	1.7	1.6	3.9	4.2	3	3.8	14	11
Ce (ppm)	5	7	7	6	<3	3	6	8	4	6	26	21
Nd (ppm)	2.5	2.5	2.5	2.5	2.5	2.5	7	2.5	2.5	2.5	11	11
Sm (ppm)	0.5	0.5	0.6	0.5	0.3	0.3	0.6	0.8	0.5	0.6	2.8	2.2
Eu (ppm)	0.01	0.015	0.015	0.01	0.01	0.01	0.01	0.21	0.2	0.015	0.68	0.6
Yb (ppm)	0.4	0.35	0.37	0.25	<.05	<.05	0.43	0.42	0.28	0.4	1.6	1.24
Lu (ppm)	0.06	0.06	<.05	0.06	<.05	<.05	0.07	0.12	<.05	0.07	0.28	0.25

Appendix A (cont.)

SAMPLE #	89-51	89-52	C88-01	C88-02	C88-03	C88-04	C88-05	C88-06	C88-06	C88-07	C88-09	C88-10
EASTING NORTHING	494650 6049325	493950 6049325	490990 6046340	492320 6044850	492000 6045200	491560 6045475	490685 6045140	490200 6044525	490200 6044525	489270 6045745	488350 6045550	487025 6044575
Au (ppb)	9	12	<5	9	<5	<5	8	<5	14	13	12	<5
As (ppm)	4.7	11	8.4	6.6	3.8	9.7	3.5	5.4	2.5	6.4	5.4	4.8
Ba (ppm)	2900	5700	1500	1400	2400	1600	5500	3400	3300	3700	2300	1900
Br (ppm)	21	18	6	7	15	7	8	12	19	20	12	7
Ca (%)	16.1	15.9	6.1	6	13.6	6.2	24.8	13.5	19.3	16.9	13.3	11.1
Co (ppm)	5	16	19	15	10	17	10	9	4	13	7	10
Cr (ppm)	35	28	120	85	33	84	23	70	24	54	15	59
Cs (ppm)	1.2	1	0.9	2	1.9	1.8	1.7	2.8	1.8	2.1	1.4	0.9
Fe (%)	1.14	0.77	3.37	2.61	0.92	2.45	0.77	1.5	0.77	1.5	0.43	1.6
Hf (ppm)	1.3	1.4	2.8	2.6	<0.5	2.6	<0.5	1.8	1.4	0.3	1	1.7
K (%)	7.91	10.6	2.67	6.43	17.5	4.56	8.78	7.18	11.7	14	20.2	9.75
Mo (ppm)	6	10	<2.0	6	1.5	5	9	3	10	7	1.5	<2.0
Na (ppm)	6000	5220	14500	16600	5400	14800	5100	7310	4820	10200	2900	10400
Rb (ppm)	59	99	63	60	110	51	84	150	78	140	170	51
Sb (ppm)	0.9	1.7	1.3	1.2	0.5	1.1	1.2	0.7	0.8	0.9	0.9	0.8
Sc (ppm)	3.7	2.7	13	11	3.4	9.7	2.9	5.5	2.7	6	1.4	6.6
Sr (ppm)	2000	930	670	490	780	640	620	1500	4000	680	550	450
Th (ppm)	1	0.9	3	2	0.8	1.9	0.6	1.5	0.6	1.7	0.5	1.2
U (ppm)	0.6	<0.1	0.9	1	0.2	1.6	0.6	0.7	0.6	0.3	0.2	0.8
Zn (ppm)	2100	2200	520	770	1500	840	2300	910	1700	1500	1200	1500
La (ppm)	6.9	4.9	15	19	13	5.1	5.6	7.7	4.9	9.1	2.7	9.7
Ce (ppm)	14	10	28	34	25	10	10	16	9	20	7	18
Nd (ppm)	2.5	2.5	7	18	9	3	10	6	2.5	22	3.5	8
Sm (ppm)	1.2	0.8	3	3.3	2.8	0.9	1	1.3	0.8	1.8	0.5	1.8
Eu (ppm)	0.38	0.27	0.72	0.77	0.5	0.7	0.39	0.015	0.015	0.38	0.5	0.43
Yb (ppm)	0.63	0.49	1.52	*1.92	1.43	0.47	0.43	0.69	0.45	1	0.36	0.86
Lu (ppm)	0.13	0.07	0.29	0.11	0.27	0.12	<.05	0.07	<.05	0.2	<.05	0.19

SAMPLE #	C88-11	C88-12	C88-13	C88-14	C88-15	C88-16	C88-17	C88-18	C88-19	C88-20	C88-21	C88-22
EASTING NORTHING	486525 6044775	486010 6044540	485675 6044500	485450 6044700	485210 6044775	484995 6044885	484700 6044950	484475 6045025	484200 6045125	483675 6045275	483175 6045425	482650 6045500
Au (ppb)	<5	8	19	5	<5	20	<5	9	5	0.3	11	6
As (ppm)	2.5	5.1	5.2	4	5.3	6.5	15	10	5.6	7.7	6.4	4.5
Ba (ppm)	1800	3200	2300	1500	3400	3400	3000	2400	4100	2700	2600	3400
Br (ppm)	4	9	11	10	8	14	10	13	8	10	10	9
Ca (%)	7.8	13.2	16.9	9.6	18.2	17.4	13.4	12.8	12.6	12.9	17.4	18.6
Co (ppm)	11	9	9	10	4	5	15	13	8	11	7	5
Cr (ppm)	73	55	47	52	15	21	88	53	77	77	44	30
Cs (ppm)	1.9	1.4	1.2	<0.5	1	<0.5	2	1.3	1	1.1	1	5.8
Fe (%)	1.91	1.31	1.16	1.18	0.5	0.5	2.1	1.29	1.68	1.69	1.03	0.78
Hf (ppm)	2.5	2	1.6	1.4	0.9	1.1	2.6	1.6	2.3	1.8	1.3	1
K (%)	10.3	8.73	12.8	8.68	15.1	18.7	9.33	15.3	10.7	11.2	13.4	16.4
Mo (ppm)	3	5	4	4	4	4	11	7	4	5	5	3
Na (ppm)	13500	9950	7290	7390	2790	3480	11900	7470	10100	9840	5800	4040
Rb (ppm)	120	63	110	39	140	110	72	130	82	67	72	280
Sb (ppm)	0.9	0.9	0.8	0.7	0.7	0.9	1.5	1	0.9	1.1	1	0.8
Sc (ppm)	8.1	0.7	4.5	4.7	0.7	2	8.3	4.9	6.6	5.9	4	2.8
Sr (ppm)	340	940	530	780	1000	1200	1100	920	540	950	730	1200
Th (ppm)	1.7	1.2	0.7	1	0.3	0.2	1.7	1.1	1.6	1.2	0.7	0.6
U (ppm)	0.6	0.8	0.15	<0.1	0.15	<0.1	0.7	<0.1	0.5	0.9	<0.1	<0.1
Zn (ppm)	940	1600	1400	770	2500	1600	1200	1600	1700	2000	2000	1600
La (ppm)	12	8.2	6.3	7	2.9	3.2	13	4.4	10	8.2	5.9	4.4
Ce (ppm)	22	15	11	13	7	5	23	8	19	16	11	8
Nd (ppm)	7	2.5	9	8	2.5	2.5	14	0.25	11	8	88	2.5
Sm (ppm)	2.3	1.6	1.2	1.3	0.5	0.6	2.6	0.8	1.9	1.5	1.1	0.8
Eu (ppm)	0.54	0.41	0.32	0.01	0.16	0.01	0.71	0.015	0.49	0.43	0.28	0.015
Yb (ppm)	1.11	0.82	0.68	0.78	0.31	0.31	1.23	0.6	1.01	0.86	0.62	0.6
Lu (ppm)	0.2	0.15	0.12	0.13	<.05	<.05	0.11	0.09	0.12	0.15	<.05	0.09

SAMPLE #	C88-23	C88-24	C88-25	C88-26	C88-27	C88-28	C88-29	C88-30	C88-31	C88-32	C88-33	C88-34
EASTING	482075	481375	480225	495500	495225	494925	494600	494300	494175	494125	494200	494075
NORTHING	6045700	6045575	6045300	6053275	6053750	6054125	6054200	6054275	6054475	6054800	6055275	6055925
Au (ppb)	11	10	10	9	12	6	14	21	12	8	13	10
As (ppm)	13	10	7.4	16	21	8.1	15	18	21	7	16	7.7
Ba (ppm)	3400	5900	2100	1900	1600	1900	1400	2200	2100	3200	1600	2400
Br (ppm)	16	12	13	6	7	14	11	10	60	9	7	15
Ca (%)	16.6	20.3	18.9	11.4	8.4	14.7	9.8	10.1	9	15.5	8.1	13.6
Co (ppm)	3	7	5	19	14	12	17	15	14	11	18	12
Cr (ppm)	13	13	17	72	65	48	61	71	55	35	130	40
Cs (ppm)	0.8	0.9	0.7	<0.5	2.3	1.4	1.3	2	2.3	1.2	2.2	5.9
Fe (%)	0.28	0.36	0.42	2.6	2.35	1.66	2.71	2.53	2.31	1.2	3.03	1.42
Hf (ppm)	0.25	1.2	0.9	2.5	2.1	1.8	2	2.3	2.1	1.5	3.1	2.2
K (%)	21.2	14.9	17.8	7.13	11.5	9.22	9.82	6.59	10.8	14.1	6.05	7.14
Mo (ppm)	<2.0	4	4	5	7	8	9	4	3	3	9	6
Na (ppm)	2020	2450	2810	12400	13100	9180	13700	15000	11400	7720	17800	8830
Rb (ppm)	99	110	88	69	130	55	59	92	84	120	76	120
Sb (ppm)	0.8	0.7	0.5	5.9	4.6	3.2	6.2	5.7	5.1	2.6	5.5	1.9
Sc (ppm)	1	1.3	1.7	10	8.7	6.2	11	9.7	8.8	4.5	12	5.4
Sr (ppm)	1600	1000	1500	1200	710	1300	880	830	740	1100	960	1100
Th (ppm)	0.05	0.2	0.3	2.3	1.7	1.2	1.9	1.9	1.6	1.1	2.4	1.5
U (ppm)	<0.1	<0.1	<0.1	1.2	1	0.8	1.3	1.1	0.8	0.6	1.5	0.5
Zn (ppm)	2300	2500	1400	1000	1400	1800	1100	900	1000	1600	750	2000
La (ppm)	2	2.4	2.8	16	12	8.8	15	14	13	6.2	18	9.7
Ce (ppm)	<3	4	6	27	21	16	27	24	23	11	31	16
Nd (ppm)	2.5	2.5	2.5	16	12	8	16	16	11	0.25	17	2.5
Sm (ppm)	0.3	0.2	0.4	3.1	2.5	1.7	3.1	2.7	2.5	1.3	3.5	1.8
Eu (ppm)	0.02	0.01	0.015	0.88	0.68	0.45	0.85	0.71	0.7	0.33	0.95	0.38
Yb (ppm)	0.13	0.22	0.21	1.6	1.36	0.91	1.71	1.43	1.24	0.78	1.83	0.93
Lu (ppm)	<.05	<.05	0.07	0.11	0.22	0.1	0.2	0.14	0.17	0.11	0.12	0.14

SAMPLE #	C88-35	C88-36	C88-37	C88-38	C88-39	C88-40	C88-41	T88-01	T88-02	T88-03	T88-04	T88-05
EASTING	494050	493950	493850	493650	493375	493000	492650	493260	488150	487800	487600	487400
NORTHING	6056300	6056600	6056900	6057000	6057075	6057450	6057650	6045150	6046050	6046350	6046525	6046670
Au (ppb)	13	7	6	6	11	6	49	119	24	11	<5	10
As (ppm)	5.6	3.3	7.2	24	4.5	2.8	13	2	8.3	4.5	5	6.3
Ba (ppm)	5600	2000	3800	3700	4900	6100	5500	4500	1600	4900	3400	3400
Br (ppm)	13	29	27	55	13	14	12	9	13	12	7	10
Ca (%)	17	16.1	21.2	16.4	19.4	20.2	16.2	16.9	8.3	12.4	11.2	10.8
Co (ppm)	5	9	4	9	4	4	12	8	16	13	11	10
Cr (ppm)	22	22	12	27	12	10	19	28	84	62	76	66
Cs (ppm)	2.5	1.1	1.5	2.8	0.6	0.9	0.8	1.2	1.2	1.3	1.7	1.6
Fe (%)	0.88	0.66	0.31	0.81	0.31	0.26	0.48	0.61	2.19	1.17	1.67	1.48
Hf (ppm)	1.4	1.3	1	1.3	0.9	1.2	1.1	1.5	2.2	1.8	1.9	2
K (%)	14.6	12.7	14.3	12.4	20.5	18.5	13.4	10.4	8.77	9.7	6.38	7.57
Mo (ppm)	10	2	4	12	<2.0	<2.0	5	3	1.5	4	6	4
Na (ppm)	5410	4320	2430	5390	2260	1840	1760	2820	9540	5880	7590	7550
Rb (ppm)	130	75	140	100	250	110	98	97	42	94	62	120
Sb (ppm)	1.7	1.1	0.6	1.3	0.6	0.4	0.6	0.5	1.1	0.7	0.9	0.7
Sc (ppm)	2.9	2.4	1.2	2.9	1.1	0.9	1.4	2.2	7.9	4.5	6.5	5.9
Sr (ppm)	3400	970	1800	1300	3100	2800	980	620	600	860	670	165
Th (ppm)	0.8	0.7	0.3	0.9	0.3	0.4	0.6	0.4	1.9	1	1.5	1.7
U (ppm)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.25	0.2	1.4	0.25	0.6	0.25
Zn (ppm)	3800	2100	1600	1800	2100	3300	2000	1200	1000	1400	580	1000
La (ppm)	5.3	4.3	2.4	5.7	2.3	2.1	2.8	4	13	6.9	11	8.3
Ce (ppm)	11	6	4	11	5	4	7	6	24	14	20	18
Nd (ppm)	0.25	2.5	2.5	0.25	2.5	2.5	2.5	2.5	16	12	2.5	2.5
Sm (ppm)	1	0.8	0.4	0.9	0.4	0.3	0.3	0.6	2.2	1.2	1.9	1.4
Eu (ppm)	0.02	0.01	0.01	0.27	0.015	0.02	0.05	0.03	0.53	0.045	0.55	0.41
Yb (ppm)	0.6	0.46	0.26	0.48	0.29	0.025	0.065	0.37	1.46	0.88	1.23	0.84
Lu (ppm)	<.05	0.08	<.05	<.05	<.05	<.05	<.05	0.09	0.08	0.13	0.15	0.09

Appendix A (cont.)

SAMPLE #	T88-06	T88-07	T88-08	T88-09	T88-10	T88-11	T88-12	T88-13	T88-14	T88-15	T88-16	T88-17
EASTING	487275	487050	486900	486600	485100	484780	484375	483850	483350	486150	490150	490075
NORTHING	6046825	6047050	6047250	6047625	6047800	6048220	6048500	6048700	6048900	6048330	6046900	6047600
Au (ppb)	9	10	3	13	<5	15	73	73	162	14	29	26
As (ppm)	2.6	6.6	5.7	5.3	3.8	4.7	5.8	6	5.4	4.1	6	7.7
Ba (ppm)	4800	2200	3100	4300	2700	3400	2700	3300	3100	4400	2100	1900
Br (ppm)	11	13	12	13	21	12	12	9	7	12	4	7
Ca (%)	13.7	11	13.6	14.1	13.9	14.8	14.4	13.8	18.6	18.5	9.8	8.1
Co (ppm)	7	10	10	8	8	9	7	13	7	8	16	9
Cr (ppm)	43	58	43	48	38	17	54	44	40	24	72	58
Cs (ppm)	1.8	2.9	1.3	2.6	1.2	1.3	1.5	2.4	1.4	1.7	1.3	1
Fe (%)	1	1.53	1.16	1.08	1.15	1.18	1.06	1.11	0.84	0.59	1.81	1.32
Hf (ppm)	1.5	1.8	1.1	2	1	2.1	1.3	1.1	1.6	1.4	1.7	1.6
K (%)	10.2	8.63	11	8.62	13.1	7.19	11	11.1	6.41	9.36	8.92	11.9
Mo (ppm)	4	5	<2.0	10	<2.0	3	4	5	3	6	5	3
Na (ppm)	4400	6420	5420	4950	4430	5360	4970	4970	4060	2690	10700	8270
Rb (ppm)	140	71	110	100	130	77	140	220	82	130	53	80
Sb (ppm)	0.5	0.8	0.6	1	0.7	0.6	0.6	0.6	0.6	0.5	0.8	0.8
Sc (ppm)	3.4	5.9	4.8	3.9	4.1	4.4	3.9	4.3	3.3	1.9	7.5	5.6
Sr (ppm)	1000	155	1100	2300	750	820	1100	1100	1400	1800	780	830
Th (ppm)	1	1.4	1.4	1.1	1	1	1.1	1.4	0.7	0.6	1.8	1.3
U (ppm)	0.25	0.25	0.3	0.3	0.1	<0.1	<0.1	0.8	<0.1	<0.1	2.3	0.9
Zn (ppm)	1200	1300	910	1200	1500	1600	1100	1400	1200	960	1100	1200
La (ppm)	5.4	9	7.3	7	5.8	6.7	6.4	7.2	5.3	4	13	9.4
Ce (ppm)	9	18	15	14	9	14	12	13	11	5	23	15
Nd (ppm)	2.5	12	12	3	2.5	2.5	2.5	2.5	2.5	2.5	14	12
Sm (ppm)	0.9	1.6	1.3	1.1	1	1.2	1.1	1.1	0.9	0.25	2.6	1.8
Eu (ppm)	0.5	0.49	0.48	0.6	0.05	0.29	0.38	0.22	0.38	0.19	0.56	0.51
Yb (ppm)	0.54	0.93	0.98	0.88	0.58	0.75	0.8	0.74	0.49	0.39	1.27	0.99
Lu (ppm)	0.09	0.1	0.15	0.12	0.08	0.12	0.08	0.12	0.05	0.07	0.25	0.1

SAMPLE #	T88-18	T88-19	T88-20	T88-21	T88-22	T88-23	T88-24	T88-25	T88-26	T88-27	T88-28	T88-29	T88-30
EASTING	489950	489700	489550	489400	489325	490075	490000	489830	489650	489920	489720	489220	488575
NORTHING	6048300	6048720	6048975	6049175	6049475	6050425	6050750	6050900	6051125	6051850	6052050	6052400	6052950
Au (ppb)	30	30	38	19	31	34	29	61	75	60	187	113	24
As (ppm)	7.4	4.8	7.9	7.6	6.1	9.7	5.6	7.3	3.8	13	6.5	17	3.3
Ba (ppm)	2000	2500	2500	1900	2300	2400	3200	2000	2900	2200	3900	4500	4700
Br (ppm)	7	5	8	5	6	11	6	5	4	7	4	12	11
Ca (%)	6.5	8.7	6.4	5.6	8.6	7.6	11.6	7.3	12.6	13.8	17.1	12.7	20.1
Co (ppm)	14	8	13	14	9	13	10	14	9	10	9	11	6
Cr (ppm)	80	45	72	82	53	90	55	74	52	54	30	48	24
Cs (ppm)	1	0.7	1.4	1.3	1.1	1	1.1	1.3	1.7	1.3	0.25	0.3	1.1
Fe (%)	2.48	1.29	2.17	2.45	1.69	2.62	1.6	2.39	1.63	1.67	0.94	1.46	0.74
Hf (ppm)	2.7	1.8	2.7	2.6	1.8	2.9	2.3	2.9	2.3	1.8	1.2	2	1.5
K (%)	4.91	12.8	5.82	5.67	9.92	5.09	10.3	5.2	11.7	9.88	19	11.3	12.9
Mo (ppm)	5	<2.0	<2.0	4	3	3	<2.0	4	4	<2.0	6	7	3
Na (ppm)	14600	8300	14100	15700	10700	16600	9990	15800	11200	11000	5450	8680	4480
Rb (ppm)	59	77	43	51	79	87	75	55	140	79	110	69	65
Sb (ppm)	1	0.6	1	0.9	0.6	1.1	0.5	0.8	0.7	1	0.8	1.3	0.5
Sc (ppm)	10	5.4	9.1	10	6.8	9.9	6	9.4	6.6	6.8	3.7	5.6	2.9
Sr (ppm)	520	820	800	340	680	730	850	450	580	390	720	880	1200
Th (ppm)	2.2	1.1	1.7	2.7	1.3	1.9	1.5	2.1	1.5	1.4	0.5	0.8	0.8
U (ppm)	1	1.1	0.9	1.2	0.9	1.5	1.1	1.1	0.7	0.8	0.5	1.4	0.6
Zn (ppm)	860	1100	840	800	870	1000	980	870	890	1100	940	2100	1700
La (ppm)	18	8.5	15	16	11	14	8.9	15	9.3	10	6.8	9.7	4.9
Ce (ppm)	33	15	28	28	20	26	16	28	17	17	11	17	8
Nd (ppm)	16	9	21	20	13	14	11	15	11	16	8	3	2.5
Sm (ppm)	3.6	1.5	3.1	3.2	2.2	2.7	1.6	2.7	1.8	2	1.3	1.9	0.9
Eu (ppm)	0.97	0.45	0.83	0.84	0.57	0.81	0.51	0.68	0.43	0.44	0.36	0.46	0.045
Yb (ppm)	1.72	0.85	1.42	1.58	1.06	1.43	0.97	1.33	0.83	1.07	0.58	1.06	0.56
Lu (ppm)	0.2	0.11	0.15	0.1	0.22	<.05	0.15	0.24	0.15	0.23	0.12	0.15	0.09

APPENDIX B

Summary statistics of element concentrations in ash of black spruce twigs

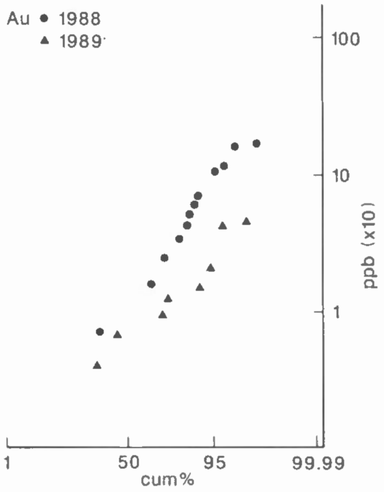
Appendix B provides summary statistics for 27 elements including minimum detection level (d.l.), total number of samples, mean, median, standard deviation (std. dev.), minimum and maximum value, and an accompanying probability plot for each element.

Appendix B (cont.)

Au (ppb)

d.l. = 5.0

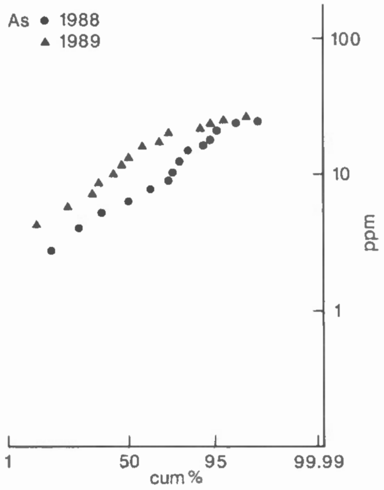
	1988	1989
n	69	39
mean	12.19	6.51
median	11.00	7.15
std. dev.	29.61	7.14
minimum	< 5	< 5
maximum	162	43



As (ppm)

d.l. = 0.5

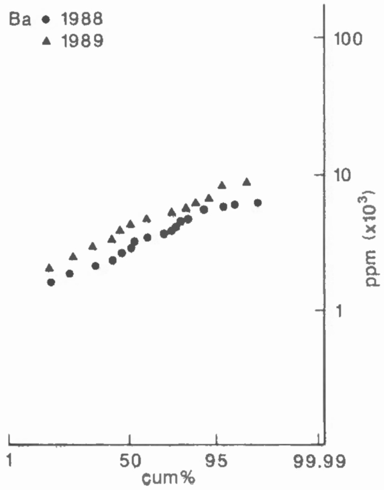
	1988	1989
n	69	39
mean	6.61	11.59
median	6.20	12.49
std. dev.	4.80	6.1
minimum	2.0	3.30
maximum	24.0	25.0



Ba (ppm)

d.l. = 10

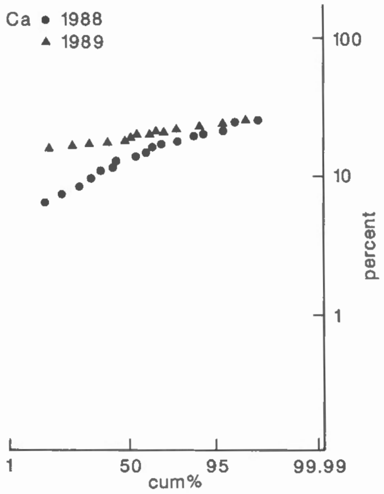
	1988	1989
n	69	39
mean	2818.38	3757.83
median	2697.70	4049.5
std. dev.	1205.6	1472.9
minimum	1400	1700
maximum	6100	8500



Ca (%)

d.l. = 0.2

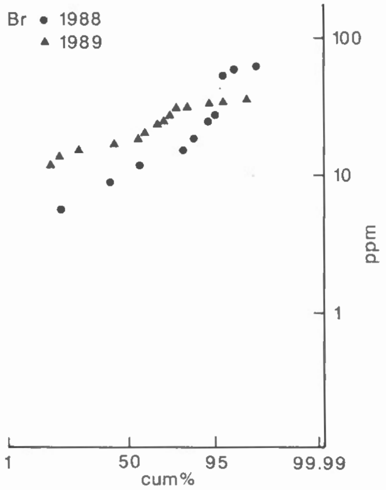
	1988	1989
n	69	39
mean	12.5	18.67
median	13.46	18.10
std. dev.	4.4	2.5
minimum	5.6	15.1
maximum	24.8	24.3



Br (ppm)

d.l. = 1.0

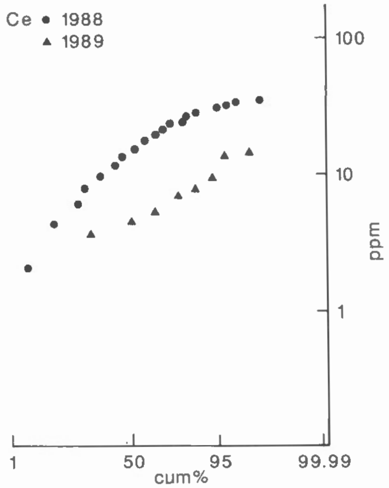
	1988	1989
n	69	39
mean	10.3	19.06
median	10.0	17.0
std. dev.	9.2	6.8
minimum	4.0	11.0
maximum	60.0	35.0



Ce (ppm)

d.l. = 3.0

	1988	1989
n	69	39
mean	13.3	4.14
median	7.15	4.47
std. dev.	8.0	2.6
minimum	< 3	< 3
maximum	34.0	14.0

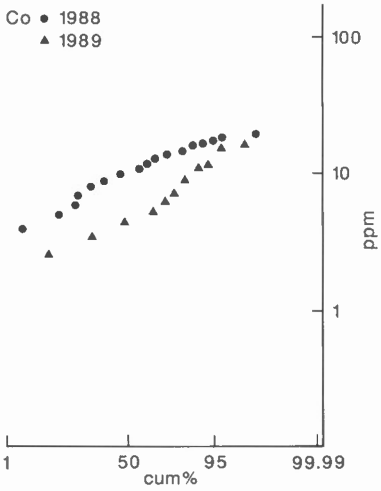


Appendix B (cont.)

Co (ppm)

d.l. = 1.0

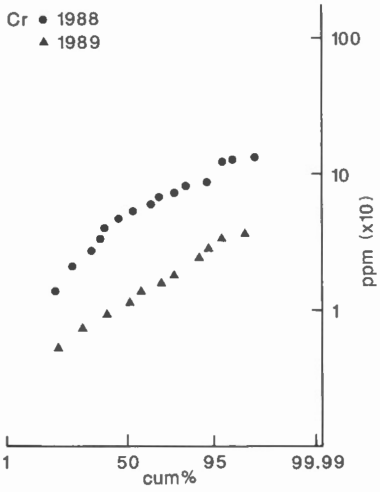
	1988	1989
n	69	39
mean	9.37	4.84
median	10.0	5.0
std. dev.	4.0	2.9
minimum	1.5	2.0
maximum	19.0	16.0



Cr (ppm)

d.l. = 1.0

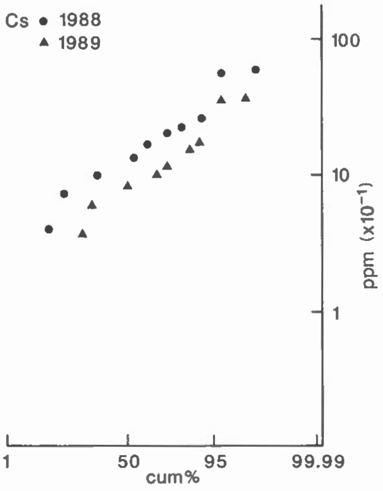
	1988	1989
n	69	39
mean	43.6	11.4
median	60.0	11.0
std. dev.	25.9	6.5
minimum	10.0	4.0
maximum	130.0	35.0



Cs (ppm)

d.l. = 0.5

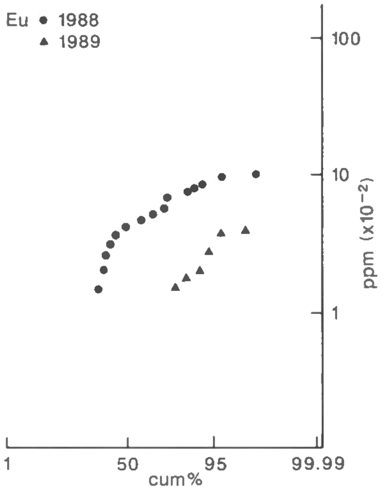
	1988	1989
n	69	39
mean	1.31	0.77
median	1.30	0.85
std. dev.	0.97	0.64
minimum	<.5	<.5
maximum	5.9	3.7



Eu (ppm)

d.l. = 0.01

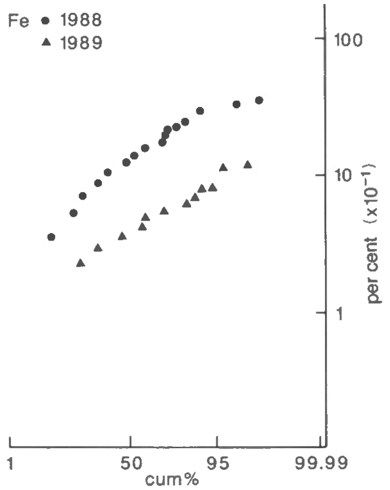
	1988	1989
n	69	39
mean	0.20	0.019
median	0.42	0.01
std. dev.	0.29	.09
minimum	0.01	0.01
maximum	0.97	0.38



Fe (%)

d.l. = 0.05

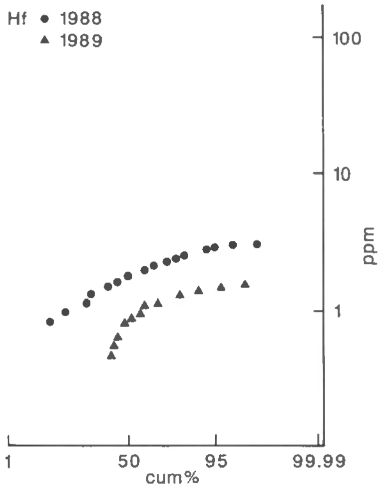
	1988	1989
n	69	39
mean	1.21	0.388
median	1.30	0.380
std. dev.	0.75	0.20
minimum	0.26	0.19
maximum	3.37	1.14



Hf (ppm)

d.l. = 0.5

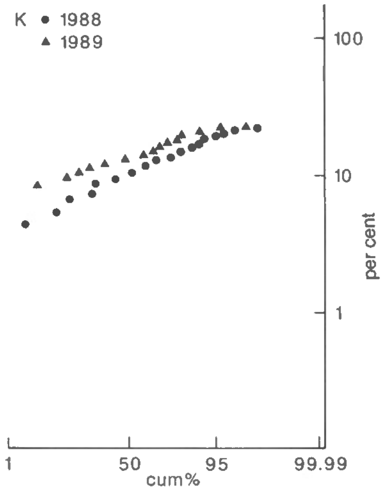
	1988	1989
n	69	39
mean	1.54	0.62
median	1.70	0.80
std. dev.	0.67	0.45
minimum	<.5	<.5
maximum	3.1	1.5



K (%)

d.l. = 0.05

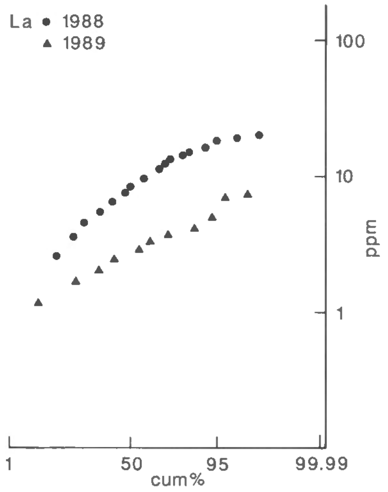
	1988	1989
n	69	39
mean	10.02	13.38
median	10.3	12.95
std. dev.	3.9	3.6
minimum	2.67	7.91
maximum	21.20	21.4



La (ppm)

d.l. = 0.1

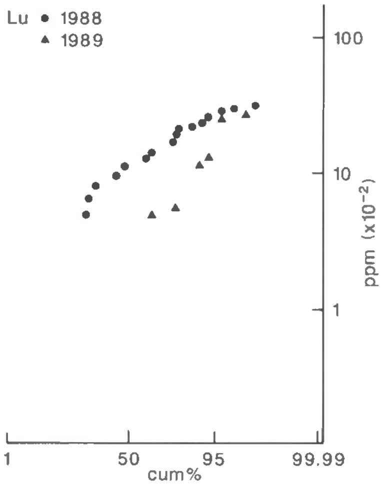
	1988	1989
n	69	39
mean	7.35	2.6
median	7.95	2.65
std. dev.	4.4	1.1
minimum	2.0	1.0
maximum	19.0	6.9



Lu (ppm)

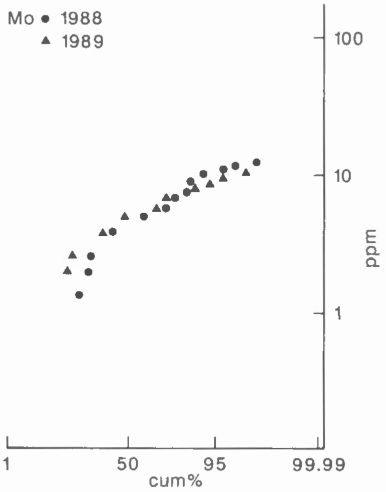
d.l. = 0.05

	1988	1989
n	69	39
mean	0.091	0.036
median	0.11	0.025
std. dev.	0.07	0.04
minimum	<.05	<.05
maximum	0.29	0.25



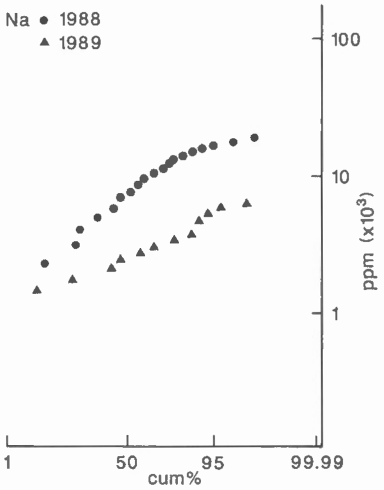
Mo (ppm)
d.l. = 2.0

	1988	1989
n	69	39
mean	3.56	4.07
median	4.0	5.0
std. dev.	2.7	2.2
minimum	< 2	< 2
maximum	12.0	10.0



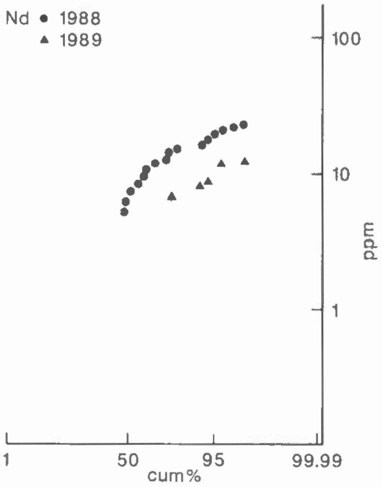
Na (ppm)
d.l. = 10

	1988	1989
n	69	39
mean	6918.3	2492.6
median	7500	2440.1
std. dev.	4362.5	1019.0
minimum	1760	1250
maximum	17800	6000



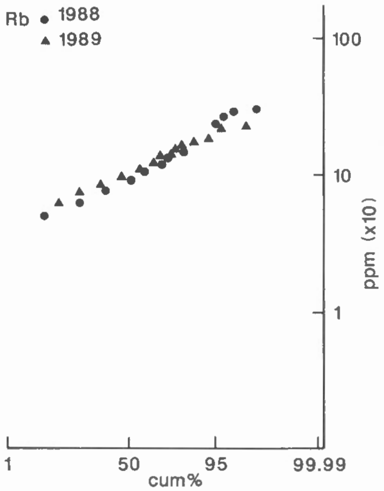
Nd (ppm)
d.l. = 5.0

	1988	1989
n	69	39
mean	5.10	3.16
median	7.15	2.50
std. dev.	5.9	2.4
minimum	< 5	< 5
maximum	22.0	12.0

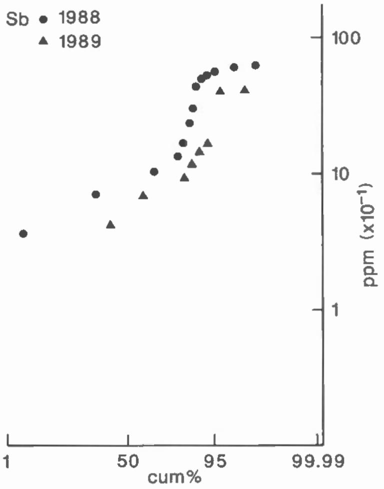


Appendix B (cont.)

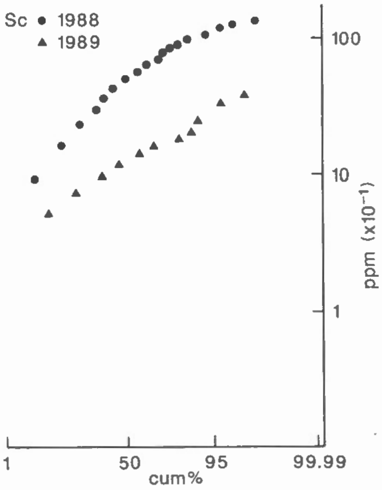
Rb (ppm) d.l. = 5		
	1988	1989
n .	69	39
mean	89.13	98.14
median	68.55	93,50
std. dev.	44.29	39.21
minimum	39	53
maximum	280	210



Sb (ppm) d.l. = 0.1		
	1988	1989
n	69	39
mean	0.97	0.602
median	0.80	0.60
std. dev.	1.4	0.65
minimum	0.20	0.30
maximum	6.2	4.1



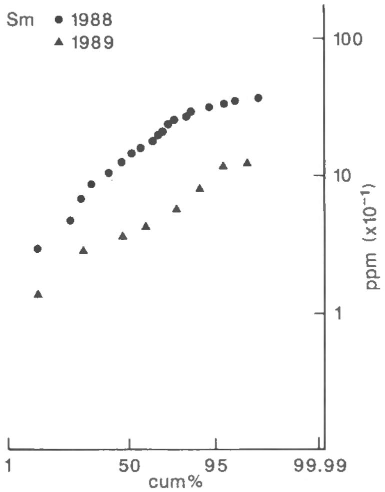
Sc (ppm) d.l. = 0.1		
	1988	1989
n	69	39
mean	4.46	1.22
median	5.40	1.2
std. dev.	3.1	0.7
minimum	0.6	0.4
maximum	13.0	3.7



Sm (ppm)

d.l. = 0.1

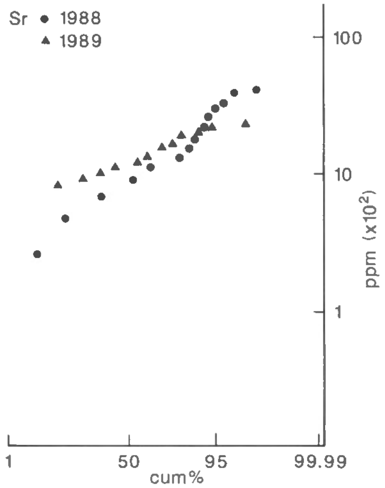
	1988	1989
n	69	39
mean	1.3	0.375
median	1.35	0.40
std. dev.	0.91	0.21
minimum	0.2	0.1
maximum	3.6	1.2



Sr (ppm)

d.l. = 100

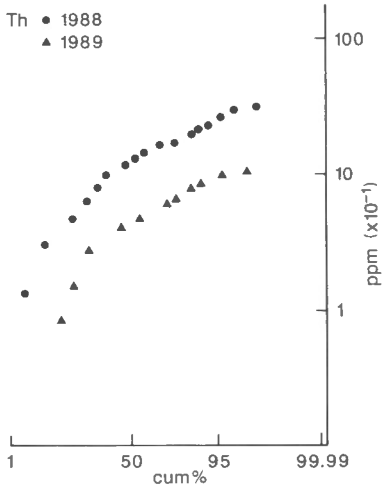
	1988	1989
n	69	39
mean	877	1264.1
median	855	1200.1
std. dev.	694.6	418.3
minimum	155	780
maximum	4000	2300



Th (ppm)

d.l. = 0.1

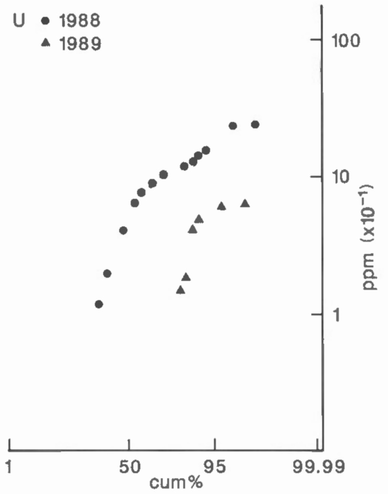
	1988	1989
n	69	39
mean	1.02	0.34
median	1.20	0.40
std. dev.	0.64	0.24
minimum	<.1	<.1
maximum	3.0	1.0



Appendix B (cont.)

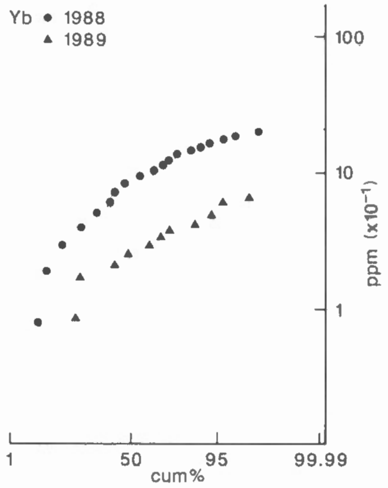
U (ppm)
d.l. = 0.1

	1988	1989
n	69	39
mean	0.33	0.067
median	0.6	0.05
std. dev.	0.51	0.141
minimum	<.1	<.1
maximum	2.3	0.6



Yb (ppm)
d.l. = 0.05

	1988	1989
n	69	39
mean	0.74	0.20
median	0.84	0.25
std. dev.	0.45	0.14
minimum	<.05	<.05
maximum	1.92	0.63



Zn (ppm)
d.l. = 20

	1988	1989
n	69	39
mean	1312.2	2204.8
median	1256.0	2099.9
std. dev.	603.7	547.1
minimum	520	1400
maximum	3800	4000