GEOLOGICAL SURVEY OF CANADA - OPEN FILE 2002

(Parts of NTS Sheets 11D, E and F)

CANADA - NOVA SCOTIA MINERAL DEVELOPMENT AGREEMENT (1984 - 1989)

RECONNAISSANCE BIOGEOCHEMICAL SURVEY, EASTERN NOVA SCOTIA

Colin E. Dunn, Roxane M.P Banville, Stephen W. Adcock

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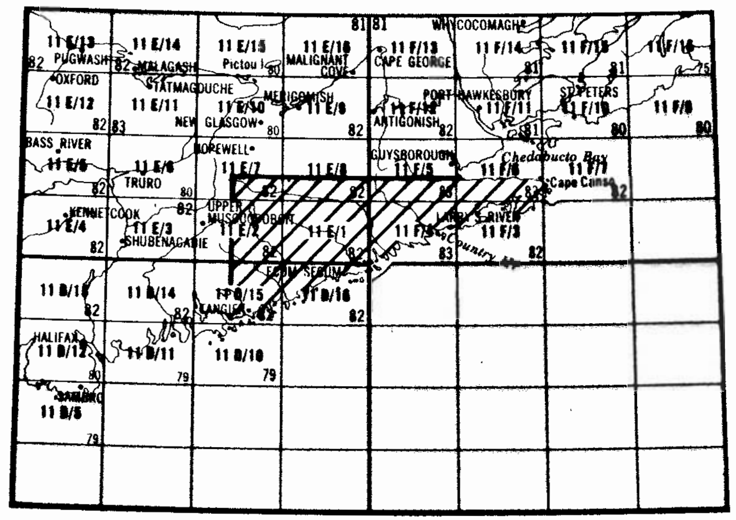

Survey Area with Respect to National Topographic System (NTS) Map Sheets

Region d'Etude avec Respect au Système National de réference Cartographique

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Geological Survey of Canada Open File 2002

INTRODUCTION

This is the first Open File of data from a reconnaissance biogeochemical survey in Canada. Included are data for 35 elements and maps for 27 elements in ashed twigs of balsam fir (Abies balsamea), plus one ash percentage map.

The survey was conducted in the early summer of 1987 by the Geological Survey of Canada in conjunction with the Nova Scotia Department of Mines and Energy, under the Canada - Nova Scotia Mineral Development Agreement (1984 - 1989).

The value to exploration of conventional reconnaissance geochemical surveys that involve the collection of materials such as lake or stream sediments and waters, has been extensively tried, tested and documented. No previous attempt has been made to assess the value to exploration of an extensive biogeochemical survey in eastern Canada. However, the results of several surveys conducted in Saskatchewan have demonstrated the potential value to mineral exploration of information obtained from examination of regional patterns of plant chemistry (e.g. Dunn, 1983).

Unlike other geochemical sample media, plants require certain elements for their very existence. Zinc, for example, is needed for the plants' metabolism. Therefore, subtle differences in Zn concentrations between sample sites are more likely to reflect the state of health of the plant than significant differences in the chemistry of the substrate. However, major differences in Zn concentrations may reflect the presence of Zn mineralization.

ÉTUDE BIOGÉOCHIMIQUE DE RECONNAISSANCE, PARTIE EST DE LA NOUVELLE-ÉCOSSE

Commission géologique du Canada, dossier public n° 2002

INTRODUCTION

Le présent document constitue le premier dossier public auquel sont versées des données provenant d'une étude biogéochimique de reconnaissance menée au Canada. Il renferme des données sur 35 éléments, des cartes montrant la concentration de 27 éléments dans la cendre de brindilles de sapin baumier (Abies balsamea), et une carte de rendement de cendre, exprimé en pourcentage.

L'étude, qui s'est déroulée au début de l'été 1987, a été effectuée par la Commission géologique du Canada de concert avec le ministère des Mines et de l'Énergie de la Nouvelle-Écosse, dans le cadre de l'Entente Canada-Nouvelle-Écosse sur l'exploitation minérale (1984-1989).

On connaît très bien la valeur, pour l'exploration, des études géochimiques de reconnaissance classiques puisque elle a été très bien vérifiée et documentée. Ces études consistent, par exemple, à prélever dans les lacs ou les ruisseaux des échantillons d'eau ou de sédiments. Cepandant, on n'avait jamais tenté auparavant de déterminer la valeur, pour l'exploration, d'une vaste étude biogéochmique menée dans l'est du Canada. Les résultats de plusieurs études réalisées en Saskatchewan (p. ex., Dunn, 1983) ont toutefois montré que l'examen des variations régionales de la composition chimique des plantes pourrait s'avérer utile en exploration minière.

Contrairement aux autres sources échantillonnées au cours d'études géochimiques, les plantes ont besoin de certains éléments pour survivre. Par exemple, le métabolisme des plantes exige un certain apport de zinc: ainsi, il est bien plus probable que des variations minimes de la concentration de Zn d'une localité d'échantillonnage à une autre témoignent de l'état de santé des plantes plutôt que de changements importants dans la

CAUTION: In light of the example of Zn, the reader is urged to treat the interpretation of the biogeochemical data with caution, and to take into consideration the text notes provided for each element. Biogeochemistry is a complex science involving the interaction of organic and inorganic processes that are controlled by a host of physicochemical parameters. Notwithstanding these complexities, careful and systematic collection and preparation of vegetation samples can provide cost-effective new insight, not readily obtainable by other means, to the chemistry of the substrate and its groundwaters.

composition chimique du substratum. Toutefois, des écarts considérables dans les concentrations de Zn peuvent refléter la présence d'une minéralisation de Zn.

ATTENTION À la lumière de l'exemple que l'on vient de donner, il convient d'inciter le lecteur à tenir compte des renseignements fournis au sujet de chaque éléments. Il reste que la biogéochimie est une science complexe où interagissent des processus organiques et inorganiques régis par une série de paramètres physico-chimiques. Néanmoins, la cueillette et la préparation soignée et systématique d'échantillons de plantes s'avère une manière nouvelle et rentable d'obtenir des renseignements sur la composition chimique du substratum et des eaux souterraines, renseignements que l'on peut difficilement se procurer autrement.

CREDITS

C.E.Dunn developed the methodology and directed the survey.

N.Richmond, R.M.P.Banville, and P.James acted as sub-party leaders.

Sample Collection: C.E.Dunn, N.Richmond, R.M.P.Banville, P.James, K. Kaiser, D. Wilkinson, K. Hattie and G. Dixon.

Sample Preparation: C.E.Dunn, N.Richmond, R.M.P.Banville, M.Coyne, and A. MacLaurin.

Data Management: R.M.P.Banville.

Computer Programming: S.W.Adcock developed a program to operate on a VAX computer for plotting the maps.

Map Production: S.W.Adcock and R.M.P.Banville.

Instrumental Neutron Activation Analysis: by contract to Activation Laboratories Ltd.,Brantford, Ontario.

SURVEY DESCRIPTION

Over a three week period, commencing late in May, 1987, samples were collected from 854 sites within a 5000 sq. km area of the Meguma terrain of eastern Nova Scotia. Over 250 of these sites comprised detailed surveys over zones of particular interest in the Beaver Dam area (Rogers et al., in prep.), leaving 593 sites as the regional component of the study. Data presented here are from the regional study only, giving a sample density of approximately 1 per 8 sq. km. Samples were collected at 2 km intervals along all driveable roads and tracks. Three 4-wheel-drive trucks were used, each with a crew of two. At each sample location a tree was selected that was at least 50 m from a highway, or 10 m from a little-used track.

A brief orientation survey of the area showed that the most common species is balsam fir (Abies balsamea). From previous work (Dunn, 1986a) it was known that this species can absorb gold and accumulate it in twigs, hence balsam fir twigs were selected as the prime sample medium. Red spruce (Picea rubens) twigs and shrub alder (Alnus crispa) twigs were collected at most sites for future study, since the additional time for collection was only a couple of minutes. Spruce bark was scraped from every fifth tree, and results from this medium are published in Dunn, 1988. The remainder of this Open File deals with balsam fir twig chemistry.

The chemistry of a twig varies along its length. This variation is attributable more to changes in the ratio of twig bark to twig wood than to annual differences in metal accumulations, because many metals concentrate in and immediately beneath the bark. Therefore, to smooth out these variations, twigs collected were of similar diameter and appearance, and as a secondary consideration, wherever possible a similar amount of growth was collected. At most sample sites a practical amount to collect in this environment proved to be the most recent five to seven years of growth. Data on the number of years of growth collected at each location is recorded on the accompanying field data sheets. These differences do not have a significant bearing on the patterns of metal distribution that are portrayed on the maps.

There are seasonal variations in the chemistry of twigs. For that reason the survey was completed as quickly as possible. The chemistry of samples collected at one time of the year should not be compared with those obtained at another time without applying an appropriate normalizing factor. No accurate factor is yet available.

SAMPLE COLLECTION, PREPARATION, AND ANALYSIS

At each sample location 200 - 250g of fresh twigs and needles were snipped from the branch 'leaders' using standard anvil-type garden pruning snips (Teflon coated). Usually, 4 or 5 twigs (5 - 7 years growth) gave sufficient material. Samples were placed in heavy duty brown paper hardware bags (approximately 25 x 35 cm) and fastened with masking tape. They were partially air-dried, then remaining moisture removed in a microwave oven.

When dry the needles separate easily from the twigs. Balsam fir, like other conifers, has higher concentrations of most elements in twigs than in needles. The needles were archived, and the yield of 30 - 40g of dry twig was placed in aluminum trays. The trays were placed in a pottery kiln, and the temperature slowly raised (over 2 - 3 hours) to 470°C. After a further 12 hours no charcoal remained, and the twigs were reduced to 0.5 - 1g of ash. All of the ash was accurately weighed and compacted into small polyethylene vials, suitable for instrumental neutron activation analysis (INAA), and submitted for a 35 element analysis. Appropriate standards and duplicates were inserted to ensure quality control. All the data presented in this report were obtained by INAA. The precision obtained varied from one element to the next and according to the concentration of element present. Most samples contained concentrations of elements substantially higher than detection limits, thereby providing analytical precision of better than +/- 10 percent.

GEOLOGY

Bedrock and Mineralization

Most of the study area is underlain by turbidites (Goldenville Formation) and slates (Halifax Formation) of the Cambro-Ordovician Meguma Group. These were intruded by granitic rocks during the Acadian Orogeny (370 Ma), which gave rise to extensive folding and faulting, accompanied by regional greenschist to amphibolite grade metamorphism. A series of northeast trending anticlines form dome-like structures. Many of the numerous gold deposits in the region are associated with these domes, especially near large scale shear zones that exhibit silicic, carbonate and phyllic alteration (Kontak and Smith, 1988). Arsenopyrite is a common accessory mineral.

The transparent 1:500 000 geological overlay map provided in the pocket, and the 1:250 000 sample location map are digitized computer-plotted summaries derived from four sources: 1) Liscomb Complex, based on mapping by K. Ford (unpublished); 2) east of 62° 30', based on an unpublished map compiled recently by D. Keppie (NSDME); 3) the southwestern portion is taken from McMullin et al. (1986); and 4) the Craignish/Strathlorne boundary in the northwest is from Keppie (1979).

Many gold mineralization occurrences have been reported from the survey area. These are detailed on 1:100 000 scale maps produced by NSDME (McMullin et al., 1986). For the sake of clarity, only 'Gold Districts', as categorized by McMullin et al. (1986), are plotted on the 1:500 000 overlay, and on the 1:250 000 sample location and geology maps.

Quaternary Deposits

The chemistry of trees is influenced partly by the bedrock, but primarily by the chemical composition of groundwaters and surficial deposits. Therefore, consideration of the physical and chemical nature of the glacial deposits is relevant to interpretation of the biogeochemical patterns. Ground moraines cover much of the area.

The Pleistocene geology of the survey area has been studied and mapped by Stea and Fowler (1979), and the broad patterns of glacial dispersion are summarized in Stea et al. (1988). The following summary is derived from these two studies, to which the reader is referred for further details.

Most of the area experienced two phases of ice movement, resulting in a glacial cover of, on average, 3 - 4 m. The first ice direction was toward the southeast, and deposited mainly silty tills. The second was southerly and deposited reddish clay-rich material known as the Lawrencetown Till (Grant, 1975). However, the latter till is present as only scattered occurrences over most of the study area, and is a 'hybrid' mixture of reddish clays and quartzitic silts.

South and east of Guysborough granitic rocks predominate (see 1:250 000 map), and the resultant granitic tills are thin. The western granites (e.g. Liscomb Game Sanctuary area), too, have a veneer of granite till. Between the granites there are deposits of quartzite till and slate till. Over much of the remainder of the survey area there is a cover of quartzite till and swarms of southeast-trending drumlins that are mostly 1 - 2 km in length and up to 25 m high. A few patches of 'hybrid' red quartzite are present, notably over an area in excess of 100 sq. km, centred approximately 15 km northwest of Liscomb Mills. Locally, glaciofluvial deposits occupy the valleys of the major rivers. Lawrencetown (clay-rich) and Upland (sandy) tills comprise the dominant cover of the Horton Group.

ELEMENT DISTRIBUTION MAPS

Map Production and Data Handling

The maps are all drawn using the Universal Transverse Mercator projection, with a central meridian of 63° (Zone 20). This projection is the same as that used for the 'Geological Map of the Province of Nova Scotia' (Keppie, 1979). Map plots in this Open File were produced by the APPMAP geochemical mapping software of the GSC. Computations were performed on a VAX minicomputer, with output to a Versatec 400 dpi electrostatic plotter. The approximate outline of the coast used in the 1:500 000 maps was digitized by staff of the NSDME.

The contouring algorithm divided the map area into 1.6 x 1.6 km squares in order to create a regular grid. If one square contained more that one value, the average was calculated. If a square contained no samples, a value was interpolated using a commercial software package ('UNIRAS'). The same software was used for contouring the data calculated for each grid cell. Areas more than three km from the nearest sample were left unshaded.

Element concentrations below analytical detection limits were reduced to 5/8 of the detection limit for data plotting and statistical calculations. Variable detection limits (due to analytical interferences or INAA counting procedures) for some elements caused some problems, since in a few cases reduction to 5/8 resulted in values which were still above the usual detection limit. In these cases, the values were reduced to below the usual detection limits. Tungsten values for sites 64 and 105 were adjusted to <1.0 ppm, and the uranium value for site 828 was adjusted to <0.2 ppm. For samples with duplicate analyses only the first (suffix 'x' in the data listings) was plotted.

Transparent Overlay

A 1:500 000 scale transparent overlay is provided to help in locating individual samples (identified by sample number on the folded 1:250 000 scale map), and relating their positions to bedrock geology, main communities, and all gold districts (McMullin et al., 1986).

Ash

The map of ash yield from the twigs is presented because Russian workers (Chukhrov et al., 1979) have noted that high ash yield of plants can be related to areas of intensely weathered bedrock. If this association occurs in Nova Scotia there may be exploration significance to the patterns observed, since zones of alteration (often related to mineralization) are subject to relatively intense weathering.

Gold

Gold is not known to be an essential element for plant growth. Consequently, patterns of Au distribution reflect zones of relative gold enrichment in soils, groundwaters and near surface rocks. Background levels of Au in ashed conifer twigs are commonly 5 - 10 ppb.

Arsenic

This element is renowned for its toxicity, yet plants (especially Douglas-fir) can accumulate extraordinary amounts without exhibiting any visible harmful affects (Warren et al., 1964). Arsenic is an essential element for the metabolism of carbohydrates in fungi and algae. A few ppm As in fir twigs is to be expected. The abundance of samples with over 5 ppm As is a reflection of the high background levels of As in the Meguma Group. A noteworthy feature of the map is the common coincidence of high As with zones of Au enrichment.

Barium

All samples yielded more than the INAA detection limit of 50 ppm Ba. A notable feature of the Ba map is the enrichment in Ba of samples from close to the margin of the Horton Group, in the northern part of the study area.

Bromine

This is a volatile element, probably non-essential to terrestrial plants, which can be complexed within plants in many forms. Some complexes volatilize during the ashing process, causing losses of 30 - 90 percent of the Br contained within the plant tissues. However, it has been noted (Dunn, 1986b) that where there is gold mineralization there is sometimes enrichment of Br in plant ash. It seems that a stable Br compound is retained.

It was expected that Br enrichment would occur in those samples from close to the shore, due to the influence of the salt-spray from the sea. However, most high concentrations of Br occur several kilometres inland. It is probable that Br from the salt-spray volatilized during the ashing process, and that the zones of Br enrichment are related to local chemistry and physicochemical conditions.

Calcium

Calcium is a major 'building block' element, essential for the rigidity of cell walls in most plants. The variations in Ca content of the twigs may influence the distribution of some trace elements.

Cobalt

Traces of Co are required by some plants to assist in the fixation of major nutrients (e.g. N, S). One ppm Co in ash is all that is required by most plants, and conifer twigs commonly have up to 5 ppm Co. It has been noted (Dunn, 1986b) that some plants exhibit Co enrichment in the vicinities of gold mineralization in northern Saskatchewan.

Chromium

Chromium is a non-essential element for which precise INAA data are obtained at low ppm levels. Concentrations are locally higher than the 10 - 20 ppm commonly found in conifer twig ash, especially in the east and in the vicinities of some of the major gold occurrences. Since Cr enrichment (e.g. fuchsite) is characteristic of some gold deposits, the Cr distribution among the firs may reflect zones influenced by mineralizing fluids.

Iron and Associated Elements (Hafnium, Scandium, the Rare Earth Elements [represented as maps by Lanthanum, Europium, and Ytterbium], and Tantalum

Iron is essential for photosynthesis and is a major constituent of chlorophyll. It appears, too, that Fe strongly controls the distribution of Hf, Sc, REE and Ta, since this group of elements is commonly inter-related in plants. It is, however, noteworthy that Hf (and to a lesser extent Sc) has concentrations considerably higher than the common maximum of 1 ppm Hf in plant ash. Furthermore, it is unusual for any Ta concentrations to be above detection levels.

Potassium, Rubidium and Caesium

These three elements have close geochemical affinities, but their paths diverge in vegetation. Potassium (not determined in all samples) is an essential and major element for plant growth. Concentrations in the ash of conifer twigs are commonly between 20 and 30 percent. There is an antagonism between K and Rb in plants (Kabata-Pendias and Pendias, 1984), causing different distribution patterns for the two elements in balsam fir. Note that K analyses were not obtained for all samples, hence the relatively large blank areas on the map. Caesium in plants has moderately close affinity to Rb, but the effects of the granites (especially in the east) give greater contrast for Cs.

Molybdenum

Molybdenum in trace amounts is required for nitrogen fixation and nitrate reduction. INAA data for Mo in the low ppm range have poor precision, and balsam fir has a low tendency to concentrate Mo in its twigs. For these reasons there is little significance in the many small anomalies shown on the Mo map.

Sodium

The effects of salt-spray from the sea are evident on the Na map, since most of the high Na concentrations occur in trees from sites near the shore.

Nickel

This element is essential for assisting in the translocation of nitrogen in some plants, but its general essentiality is unproven. It occurs in some porphyrins. INAA has low sensitivity to Ni (detection limit of 50 ppm Ni), hence it is detectable in only a few samples, most of which come from the Horton Group.

Antimony

Excellent precision is obtained for traces of Sb by INAA, so that variations in the sub-ppm concentrations are real, and not an artifact of the analytical technique. Antimony, however, is not significantly enriched in any of the balsam fir samples, and it is a non-essential element for plant health.

Selenium

Traces of Se are essential for some plants and for human health. The detection level for Se by INAA varies, according to the time lapse between sample irradiation and signal counting, because of the short half-life of the isotope measured. As a result the data listings show variable detection limits which, for computational and map plotting purposes, have been assigned values of less than 2 ppm Se.

Strontium

INAA has poor sensitivity to traces of Sr, and analytical precision is worse than for most other elements considered in this study. However, Sr concentrations are significantly above detection limits in over 80 percent of the samples, such that the areas of Sr enrichment depict significant regional variations.

Tungsten

The detection limit for W by INAA varies according to the matrix composition of the sample, and the time that elapses between sample irradiation and isotope counting. Usually a concentration of 1 ppm W can be detected, so that the clusters of samples showing 2 ppm W and greater in the western part of the map are considered to reflect a regional trend of W enrichment. No plant requirement for W is known.

Thorium and Uranium

Neither element is essential for plant growth. INAA provides data of excellent reproducibility at sub-ppm levels. The similar patterns of the two maps show that, as in other geological media, they maintain a close association in the Plant Kingdom.

Zinc

Since Zn is essential for carbohydrate and protein metabolism, differences of a few 100 ppm Zn in balsam fir ash are probably attributable to the health of the tree rather than subtle changes in substrate chemistry. However, the Zn map shows a range in concentration of over 4000 ppm Zn; therefore, the regional pattern of Zn distribution is reflecting broad differences across the area.

Other Elements

Data listings include values for a few additional elements. Most of these are the rare-earths (cerium, neodymium, samarium, terbium and lutetium), which closely follow the three rare-earths (lanthanum, europium and ytterbium) for which maps are presented.

Each sample was scanned for silver, iridium and mercury. No sample yielded more than the detection level for Ag of 2 ppm. All Ir analyses showed concentrations of less than 2 ppb, indicating no obvious platinum-group elements in the area. All Hg analyses showed less than 1 ppm, suggesting that there are no strong associations of Hg with mineralization: although most Hg volatilizes during ashing of the twigs, it has been shown that there is sometimes residual Hg in plant ash (in the form of a carbide) in the vicinities of some mineral deposits (Kovalevskii, 1986).

NOTES ON THE BIOGEOCHEMICAL DATA LISTINGS (APPENDICES A and B)

Appendix A lists salient field data and all analytical data obtained for the balsam fir twig ash. Appendix B provides some simple statistical analysis of the data by treating the data set as a whole, and by dividing the data according to the underlying bedrock geology (according to stratigraphic formation for the sediments, or lithology for intrusions). Abbreviations used in the appendices are explained in Table 1.

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This open file is modelled after the style of National Geochemical Reconnaissance Open File series produced by the GSC under the guidance of E.H.W. Hornbrook and P.W.B. Friske. We thank them for their advice on the production of this publication, and many GSC staff members for providing us with information to assist in this study.

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TABLE 1: EXPLANATION OF ABBREVIATIONS USED IN APPENDICES

MAP	National topographic system (NTS): First three characters refer to 1:250,000 scale quadrangle; remaining two characters identify the 1:50,000 scale map sheet within the quadrangle.
SAMPLE ID	First two digits refer to the year the survey was conducted; the next four comprise the sample number. An alphabetic suffix (x or y) indicates a duplicate sample.
ZONE and UTM	The Universal Transverse Mercator (UTM) zone followed by easting and northing co-ordinates (in metres).
ROCK TYPE	Observed or predicted underlying bedrock lithology: ECS – Carboniferous: Strathmore Formation ECCN – Carboniferous: Craignish Formation DC – Devono-Carboniferous, undifferentiated DCg – Devono-Carboniferous granitoids ?DCgb – Gabbro: possibly Devono-Carboniferous COH – Cambro-Ordovician: Halifax Formation COG – Cambro-Ordovician: Goldenville Formation ?COmm – Metamorphic rocks: possibly Cambro-Ordovician
SAMPLE TYPE	All are balsam fir twigs.
YEARS OF GROWTH	Number of years of twig growth collected (*i.e.*, '5' equals the most recent five years of growth).
SLOPE	0 = flat ground 1 = slight incline followed by downward compass direction (*e.g.*, 1E = slight downward incline to the east) 2 = moderate incline 3 = steep incline
FOREST TYPE	Type of forest cover and degree of groundwater saturation
IN APPENDIX B:	N = number of samples Cum = cumulative frequency d.l. = detection limit