



## **GEOLOGICAL SURVEY OF CANADA**

**OPEN FILE 2556**

---

# **Reconnaissance Biogeochemical Survey**

## **Southwestern Nova Scotia**

### **Part 1 - Red Spruce Bark**

### **Parts of NTS 20O,P, 21A,B**

---

**Colin E. Dunn, Stephen W. Adcock, Wendy A. Spirito**

**1992**

---



## **GEOLOGICAL SURVEY OF CANADA**

**OPEN FILE 2556**

---

# **Reconnaissance Biogeochemical Survey**

## **Southwestern Nova Scotia**

### **Part 1 - Red Spruce Bark**

### **Parts of NTS 20O,P, 21A,B**

---

**Colin E. Dunn, Stephen W. Adcock, Wendy A. Spirito**

**1992**

---

# RECONNAISSANCE BIOGEOCHEMICAL SURVEY, SOUTHWESTERN NOVA SCOTIA: PART 1 - RED SPRUCE BARK

*C.E.Dunn, S.W. Adcock, and W.A. Spirito*

COOPERATION

COOPERATION  
AGREEMENT ON  
MINERAL DEVELOPMENT

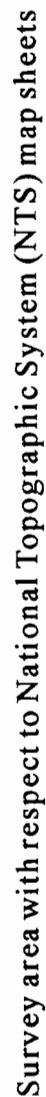
ENTENTE DE  
COOPERATION SUR  
L'EXPLOITATION MINÉRALE

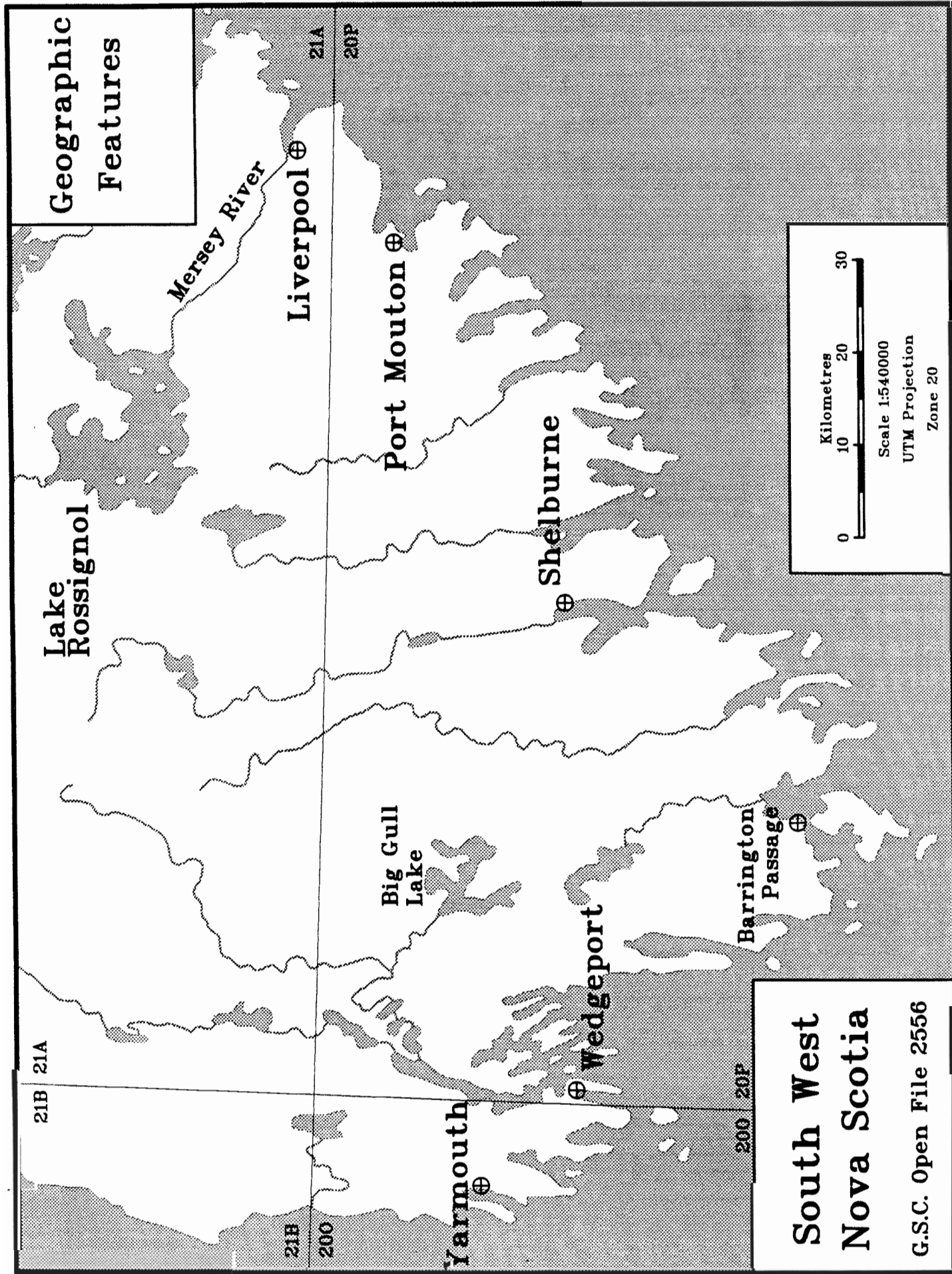
Contribution to Canada-Nova Scotia Cooperation Agreement on Mineral Development 1990-1992, a subsidiary agreement under the Economic and Regional Development Agreement. Project funded by the Geological Survey of Canada.

Contribution à l'Entente de coopération Canada-Nova Scotia sur l'exploitation minérale 1990-1992 dans le cadre de l'Entente de développement économique et régional. Ce projet a été financé par la Commission géologique du Canada.

Canada

Nova Scotia  
 Province of  
Nova Scotia





## TABLE OF CONTENTS

|  |    |
|--|----|
| Introduction . . . . .   | 5  |
| Credits . . . . .  | 6  |
| Survey Description and Methodology . . . . .   | 7  |
| Geology . . . . .  | 15 |
| Map Production and Data Handling . . . . .   | 17 |
| Element Distribution Maps . . . . .  | 19 |
| Notes on the Biogeochemical Data Listings (Appendices A and B) . . . . .                                     | 31 |
| Acknowledgements . . . . .   | 31 |
| References . . . . .   | 33 |
| Figure 1: Scatterplots of analytical duplicate pairs for Au, As, Zn (INAA), Cu, Pb, Ni<br>(ICP-ES) . . . . . | 12 |
| Table 1: Mean and Standard Deviation for Standard V2 (N=28) analyzed by INA . . . . .                        | 10 |
| Table 2: Mean and Standard Deviation for Standard V2 (N=28) analyzed by ICP-ES . . . . .                     | 11 |
| Table 3: Determination Limits and Substitution Values for Elements Analysed by<br>INAA . . . . .             | 13 |
| Table 4: Determination Limits and Substitution Values for Elements Analysed by ICP-<br>ES . . . . .          | 14 |

|  |                  |
|--|------------------|
| Table 5: Abbreviations Used in Appendix A . . . . .  | 32               |
| Table 6: Abbreviations Used in Appendix B . . . . .  | 32               |
| Appendix A - Field and Analytical Data . . . . .     | separate booklet |
| Appendix B - Statistical Summary . . . . .           | separate booklet |
| Element Concentration Maps . . . . .                 | envelope         |
| Geology Overlay . . . . .                            | envelope         |
| Geology and Sample Location Map (1:250000) . . . . . | envelope         |

## Introduction

This Open File contains data from a reconnaissance biogeochemical survey in southwestern Nova Scotia. The survey was conducted in May, 1991, by the Geological Survey of Canada under the Canada - Nova Scotia Cooperation Agreement on Mineral Development (1990 - 1992). It represents the first of a series of biogeochemical Open Files of different tree tissues from several species in the same area. Included are field observations, data listings, statistical summaries, a geology and sample location map, and element distribution maps. The maps show the ash yield of outer bark from red spruce (*Picea rubens*), and the concentrations of 32 elements determined by instrumental neutron activation (INA) analysis, and of 13 elements determined by inductively-coupled plasma emission spectrometry (ICP-ES). All data quoted are concentrations in ash remaining after controlled ignition at 470°C. The ashing process concentrates the elements with little or no loss of elements except those of high volatility (e.g. Br and Hg).

The value to exploration of reconnaissance geochemical surveys that involve the collection of lake or stream sediments and waters, has been extensively tried, tested and documented. However, reconnaissance-level biogeochemical surveys received little attention until a survey of similar magnitude to that reported here was conducted in southeastern Nova Scotia in 1987. Results were published as an Open File (Dunn et al., 1989), and interpretive accounts are given in Dunn (1988, 1990), Rogers and Dunn, 1989, Dunn et al. (1991), and Rogers and Dunn (in prep.).

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

In light of the Zn example, 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 many 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, into the chemistry of the substrate and its groundwaters.

The data listed in Appendix A are available in digital form from:

Publications Distribution  
Geological Survey of Canada  
601 Booth Street  
Ottawa  
Ontario  
K1A 0E8

Tel (613) 995-4342

The data will be supplied on MS-DOS (IBM-PC) 3.5" 1.44 Mb diskettes, as both an RBASE UNLOAD file (ASCII format; can be read by any text editing software; can be imported directly into an RBASE database), and as a .DBF file, which can be read by any DBASE-compatible software.

## Credits

**Survey design, direction, and sampling methodology:** C.E.Dunn.

**Field party leader:** S.W. Adcock.

**Sub-party leaders:** P. James and G. Benteau, assisted by C. Logan, S. Alvarado, R. Johnson, and S. Phaneuf.

**Sample Preparation:** undertaken and supervised by R. Cardinal, with the assistance of S. Lambert, C. Logan, S. Alvarado, and M. Peters.

**Data Management:** W.A. Spirito and S.W. Adcock.

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

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

**Inductively-Coupled Plasma Emission Spectrometry:** by contract to Min-En Laboratories Ltd., Vancouver, B.C.

## **Survey Description and Methodology**

### **Scope of Survey**

During a three week period, commencing early in May, 1991, samples were collected from approximately 500 sites within a 5000 sq.km area of southwestern Nova Scotia. The northern boundary of the survey area was latitude 44°15'. The eastern boundary was the Mersey River. Although the average sample density was 1 per 10 sq. km the sampling grid was irregular because of difficulty in accessing some areas. In general, samples were collected at 2 km intervals along driveable roads and tracks, with limited helicopter support for accessing remote areas. Three trucks were used, each with a crew of two. At each sample location vegetation samples were selected from a site at least 50 m from a highway, or 10 m from a little-used track.

### **Sample locations**

The 1:10000 LRIS (Land Registration Information Service) maps were used for almost all of the field work. The only exceptions were for those sites sampled by helicopter where their use was impractical because of time constraints, and a handful of sites for which the 1:10000 maps were not available (e.g. out with another field crew). For these sites, 1:50000 NTS maps were used. The 1:10000 maps use the Nova Scotia modified transverse Mercator (MTM) projection, in conjunction with the ATS77 datum (Kouba, 1978; LRIS, no date). The ATS77 datum is a precursor and very similar to the NAD83 datum. The 1:50000 maps use the NAD27 datum and the usual UTM projection. A program (CONV77) was purchased from LRIS to convert MTM coordinates to UTM coordinates, based on the ATS77 datum. Unfortunately, conversion from ATS77 to NAD27 is very complex, and not practical for the present project.

Therefore, the UTM coordinates listed in Appendix A for samples collected using the 1:10000 base maps are based on the ATS77 datum. A geographic location's UTM coordinates for the NAD27 and ATS77 data may differ by up to a few hundred metres. This difference is not important when plotted on a scale of 1:250000, but if a user wishes to determine the exact location for a particular sample, care should be taken to use maps based on the appropriate datum. [The next generation of NTS 1:50000 maps will be based on the NAD83 datum.]

### Sample Collection

An orientation survey of the area conducted in October, 1990, showed that the most common species are balsam fir (*Abies balsamea*), red spruce (*Picea rubens*), and tamarack (*Larix laricina*). Chemical analysis of twigs from these species and the outer bark of the spruce and tamarack indicated that each was sensitive to a particular range of elements, but that the red spruce bark had generally higher concentrations of trace metals than the other tissues that were collected. Consequently, spruce bark was selected as the principal sample medium, but in addition, samples of tamarack bark and the twigs of the three species were collected at most sites. Data from these species will be presented in future open file releases.

The outer bark of the spruce was collected by scraping about 50 g of loose scales into a plastic pan, and transferring samples to a standard 'kraft' paper soil bag. A paint scraper proved to be an effective tool for removing the bark scales. Care was taken to select only red spruce trees, since the other species of spruce present in the area (white spruce - *Picea glauca*) has a different chemical composition (Dunn, 1991). Also, care was taken *not* to include the inner bark for the same reason.

There are seasonal variations in the chemistry of twigs, but outer bark is dead tissue, and therefore its composition does not change during the course of the year. However, since twigs were also collected the survey was completed as quickly as possible.

### Sample Preparation and Analysis

Approximately 50 g of dry bark was weighed into aluminium 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 bark was reduced to approximately 1 g of ash.

Half was accurately weighed and compacted into small polyethylene vials, suitable for instrumental neutron activation analysis (INAA), and submitted for the determination of 35 elements (maps are provided for 32 of these elements - concentrations of Hg, Ir, and Tb were all below the detection levels of 1 ppm, 2 ppb, and 0.5 ppm, respectively).

The remaining half of the ash sample was submitted for multi-element ICP-ES analysis, following an aqua regia digestion. For most elements this extraction is 'total', although for some (e.g. Al, B) it is only partial. However, the analytical precision was extremely good for most elements, such that the relative element distribution patterns are meaningful even if the absolute concentrations are only partial.

Appropriate standards and duplicates were inserted to ensure quality control. The precision obtained varied between elements and with element concentration. Of the elements reported here, most samples contained levels substantially higher than detection limits, thereby providing analytical precision of better than  $\pm 10\%$ .

Data on mean values and standard deviations obtained for each element in a standard ash sample (V2) are given in Tables 1 and 2. Examples of the reproducibility of the data on two sample splits are presented graphically for Au, As, Zn, Ni, Cu, and Pb in Figure 1. Tables 3 and 4 show the determination (lowermost detection) limits quoted for each element by the analytical laboratories, and the substitution values used for statistical calculations where analyses yielded concentrations below detection.

Table 1: Mean and Standard Deviation for Standard V2 (N=28) analyzed by INA

| Element    |    | Mean | Standard Deviation |
|------------|----|------|--------------------|
| Gold       | Au | 14   | 3                  |
| Silver     | Ag | 13   | 3                  |
| Arsenic    | As | 2.0  | 0.5                |
| Barium     | Ba | 2643 | 204                |
| Bromine    | Br | 16   | 2                  |
| Calcium    | Ca | 26   | 2                  |
| Cobalt     | Co | 4    | 0.5                |
| Chromium   | Cr | 28   | 3                  |
| Cesium     | Cs | 2.7  | 0.3                |
| Iron       | Fe | 1.37 | 0.27               |
| Hafnium    | Hf | 1.3  | 0.2                |
| Potassium  | K  | 7.11 | 0.70               |
| Molybdenum | Mo | 4    | 1                  |
| Sodium     | Na | 5677 | 387                |
| Rubidium   | Rb | 189  | 19                 |
| Antimony   | Sb | 1.2  | 0.1                |
| Scandium   | Sc | 1    | 0.14               |
| Selenium   | Se | *    | *                  |
| Tin        | Sn | *    | *                  |
| Strontium  | Sr | 1300 | 156                |
| Tantalum   | Ta | *    | *                  |
| Thorium    | Th | 1.1  | 0.2                |
| Uranium    | U  | 0.6  | 0.2                |
| Tungsten   | W  | *    | *                  |
| Zinc       | Zn | 2346 | 164                |
| Lanthanum  | La | 4.0  | 0.5                |
| Cerium     | Ce | 7    | 1                  |
| Neodymium  | Nd | *    | *                  |
| Samarium   | Sm | *    | *                  |
| Europium   | Eu | *    | *                  |
| Ytterbium  | Yb | 0.20 | 0.02               |
| Lutetium   | Lu | *    | *                  |

\* all values below the determination limit

Table 2: Mean and Standard Deviation for Standard V2 (N=28) analyzed by ICP-ES

| Element    |    | Mean  | Standard<br>Deviation |
|------------|----|-------|-----------------------|
| Aluminium  | Al | 7945  | 888                   |
| Boron      | B  | 169   | 26                    |
| Beryllium  | Be | *     | *                     |
| Cadmium    | Cd | 2     | 1                     |
| Copper     | Cu | 150   | 39                    |
| Lithium    | Li | 2     | 0.9                   |
| Magnesium  | Mg | 33046 | 2137                  |
| Manganese  | Mn | 17416 | 2728                  |
| Nickel     | Ni | 44    | 4                     |
| Phosphorus | P  | 10659 | 435                   |
| Lead       | Pb | 428   | 160                   |
| Titanium   | Ti | 511   | 56                    |
| Vanadium   | V  | 21.4  | 25.7                  |

\* all values below the determination limit

Figure 1: Scatterplots of analytical duplicate pairs for Au, As, Zn (INAA), Cu, Pb, Ni (ICP-ES)

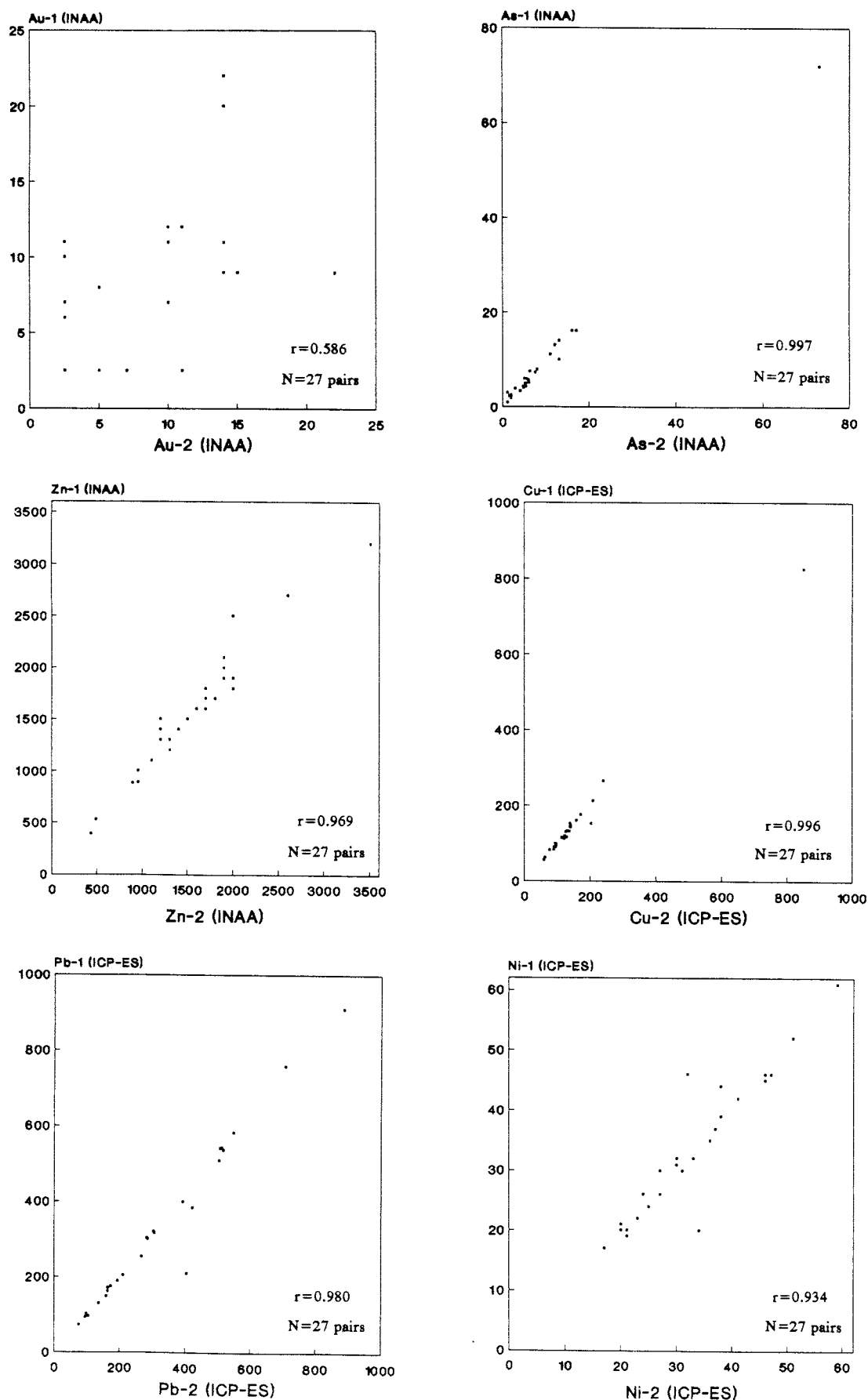


Table 3: Determination Limits and Substitution Values for Elements Analysed by INAA

| Element    |    | Units of Measure | Determination Limit | Substitution Value |
|------------|----|------------------|---------------------|--------------------|
| Gold       | Au | ppb              | 5                   | 2.5                |
| Silver     | Ag | ppm              | 2                   | 1                  |
| Arsenic    | As | ppm              | 0.5                 | *                  |
| Barium     | Ba | ppm              | 10                  | *                  |
| Bromine    | Br | ppm              | 1                   | *                  |
| Calcium    | Ca | %                | 0.2                 | *                  |
| Cobalt     | Co | ppm              | 1                   | *                  |
| Chromium   | Cr | ppm              | 1                   | 0.5                |
| Caesium    | Cs | ppm              | 0.5                 | 0.25               |
| Iron       | Fe | %                | 0.05                | 0.025              |
| Hafnium    | Hf | ppm              | 0.5                 | 0.25               |
| Potassium  | K  | %                | 0.05                | *                  |
| Molybdenum | Mo | ppm              | 2                   | 1                  |
| Sodium     | Na | ppm              | 10                  | *                  |
| Rubidium   | Rb | ppm              | 5                   | 2.5                |
| Antimony   | Sb | ppm              | 0.1                 | *                  |
| Scandium   | Sc | ppm              | 0.1                 | 0.05               |
| Selenium   | Se | ppm              | 2                   | 1                  |
| Tin        | Sn | %                | 0.005               | 0.0025             |
| Strontium  | Sr | ppm              | 300                 | 150                |
| Tantalum   | Ta | ppm              | 0.50                | 0.25               |
| Thorium    | Th | ppm              | 0.1                 | 0.05               |
| Uranium    | U  | ppm              | 0.1                 | 0.05               |
| Tungsten   | W  | ppm              | 1                   | 0.5                |
| Zinc       | Zn | ppm              | 20                  | 10                 |
| Lanthanum  | La | ppm              | 0.1                 | 0.05               |
| Cerium     | Ce | ppm              | 3                   | 1.5                |
| Neodymium  | Nd | ppm              | 5                   | 2.5                |
| Samarium   | Sm | ppm              | 0.1                 | *                  |
| Europium   | Eu | ppm              | 0.01                | 0.005              |
| Ytterbium  | Yb | ppm              | 0.05                | 0.025              |
| Lutetium   | Lu | ppm              | 0.05                | 0.025              |

\* all values above the determination limit

Table 4: Determination Limits and Substitution Values for Elements Analysed by ICP-ES

| Element    |    | Units of Measure | Determination Limit | Substitution Value |
|------------|----|------------------|---------------------|--------------------|
| Aluminium  | Al | ppm              | 1                   | *                  |
| Boron      | B  | ppm              | 1                   | *                  |
| Beryllium  | Be | ppm              | 0.2                 | 0.1                |
| Cadmium    | Cd | ppm              | 0.2                 | 0.1                |
| Copper     | Cu | ppm              | 1                   | *                  |
| Lithium    | Li | ppm              | 1                   | *                  |
| Magnesium  | Mg | ppm              | 10                  | *                  |
| Manganese  | Mn | ppm              | 1                   | *                  |
| Nickel     | Ni | ppm              | 1                   | *                  |
| Phosphorus | P  | ppm              | 10                  | *                  |
| Lead       | Pb | ppm              | 1                   | *                  |
| Titanium   | Ti | ppm              | 10                  | *                  |
| Vanadium   | V  | ppm              | 0.1                 | *                  |

\* all values above the determination limit

## 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. Major plutonism of granitic rocks during the Early Carboniferous, notably the South Mountain Batholith in the north, was accompanied by extensive folding and faulting, and regional greenschist to amphibolite grade metamorphism (Taylor, 1967). West of Shelburne, Late Carboniferous intrusion of the Barrington Passage Tonalite (Reynolds et al., 1981) produced a thermal metamorphic overprint (Rogers, 1985). The Shelburne diabase dyke intruded the area during the Early Jurassic.

Keppie (1979) considered that the major folds of the Meguma Group formed at ca. 370 m.y., in the early stages of the Acadian Orogeny, forming north to northeast-trending flexures. A major strike-slip fault (Tobeatic Fault) striking northeastward from the Yarmouth area along the southern margin of the granite, divides the Meguma Terrane into northwest and southeast structural zones (Giles, 1985).

The most notable mineralization in the area is the greisen-hosted tin deposit at East Kemptville, where it is associated with W, U, alkali and base metals. It was mined from 1985 until production ceased in 1992. Mineralization is dominated by cassiterite with topaz, muscovite and zinnwaldite, with associated arsenopyrite, chalcopyrite, fluorite, galena, molybdenite, pyrite, pyrrhotite, sphalerite, and wolframite. Other mineral deposits have been recorded at Duck Pond (Sn), west of East Kemptville; Brazil Lake (Li), northeast of Yarmouth; Dominique (Sn), southeast of Yarmouth. Enrichments of Au, Be and Mo are recorded from across the southern part of the survey area. Details of these and other deposits in the Meguma Terrane can be found in a recent compilation by Sangster (1990).

### **Geological base map compilation**

The transparent geological overlay map provided in the pocket, and the coloured 1:250000 sample location map are digitized computer-plotted compilations derived from the following sources:

Donohoe, H.V. Jr. and Grantham, R.G. (1989). Geological Highway Map of Nova Scotia, second edition, Atlantic Geoscience Society, Halifax, AGS Special Publication No. 1.

Ham, L.J. and MacDonald, M.A. (1991). Preliminary geological map of Wentworth Lake, NTS sheet 21A/4 (and part of 20P/13). N.S. Dept. Natural Resources, Open File Map 91-020.

Hope, T.L., Douma, S.L. and Raeside, R.P. (1988). Geology of the Port Mouton - Lockeport area, southwestern Nova Scotia. GSC Open File 1768.

Rogers, H.D. (1986). Igneous and metamorphic geology of Shelburne and eastern Yarmouth counties, Nova Scotia. GSC Open File 1374.

Rogers, H.D. (1988). Field relations, petrography, and geochemistry of granitoid plutons in the shelburne area, southern Nova Scotia. GSC Open File 1835.

Taylor, F.C. (1967). Reconnaissance geology of Shelburne map-area, Nova Scotia. GSC Memoir 349.

### **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.

Most of the survey area is covered with Beaver River till which ranges in thickness from

1 - 10 m, with an average of 3 m (Stea, 1982; Stea and Grant, 1982). Drumlin facies are 2 - 20 m thick, generally elongated toward the southeast in the direction of the dominant ice flow, but more southerly in the Yarmouth area. The dominant till is a light bluish-grey quartzite till with angular, loose clasts that are commonly more than 16 mm in diameter. Locally, there are several large (mostly 100 - 200 km<sup>2</sup>) areas of greyish-orange to yellowish-brown granite till. Less common are areas of slate till, derived from the Meguma slates. In addition, there are smaller patches of sandy ablation till, glacial outwash deposits, and ice contact stratified drift.

## 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 VAXMAP geochemical mapping software used by the Applied Geochemistry Subdivision of the GSC. Computations were performed on a VAX minicomputer, with output to a Hewlett-Packard Laserjet printer (for the small maps) and to a Synergy electrostatic printer (large coloured map).

The coastline and drainage were obtained in digital form from Surveys, Mapping and Resource Sector of the Dept. of Energy, Mines and Resources. For the small scale maps, the digital data were purchased from the National Atlas Information Service. These data were derived from 1:2000000 scale original maps. Features are accurate to about 200m. This led to some samples which were collected near lakes or the ocean being plotted in the water. The 1:250000 map was plotted from data purchased from the Canada Centre for Geomatics. These data were derived from the 1:250000 NTS map sheets, and therefore are much more accurate than the NAIS data. There is too much detail for them to be useful as base maps at a scale of 1:500000.

Element concentrations below analytical detection limits were reduced to half of the determination limit for data plotting and statistical calculations. For samples with duplicate analyses, data from the first of each duplicate pair were used in the statistical analysis.

The dot maps are based on a method first developed by Bjorklund and Gustavsson (1987). It was used as the primary data presentation method by the Nordkalott project (Bolviken et al., 1986), and since then has become a popular technique at the GSC (Thorleifson and Kristjansson, 1990; McClenaghan, DiLabio and Laurus, 1992; Coker et al., in preparation). The dot size is proportional to the analytical value, according to the following formula (in FORTRAN notation):

$$\text{RADIUS} = \text{RSYM} * ( \text{RA} ** \text{RFOPT} / \text{RV} ** \text{RFOPT} )$$

RSYM:        the maximum dot radius, defined by the user in millimetres.  
RA:           the analytical value to be plotted  
RV:           the analytical value at a specified percentile  
RFOPT:       an exponent

If RA is greater than RV, then RA is set equal to RV. RV is generally set equal to the analytical value corresponding to the 95th or 98th percentile. All samples with values greater than RV will therefore be plotted with a constant dot size equal to RSYM. If the calculated value of RADIUS drops below a certain minimum radius, as defined by the user, then a dot of that minimum radius is plotted. This ensures that dots do not become minuscule. RFOPT is defined by the user, and is usually set in the range 1 to 2. Increasing RFOPT emphasises those samples with high values.

## **Element Distribution Maps**

Before interpreting the element distribution maps, the reader is advised to note the comments provided under each of the element headings. These notes are organized alphabetically by element symbol, dealing first with those elements determined by INAA, followed by those determined by ICP-ES (except for the rare earth elements, which are grouped together after Zn). This sequence is the same as the element listings in Appendix A and the statistical summary in Appendix B.

### **Transparent Overlay**

A transparent overlay at the same scale as the element distribution maps is provided to help in locating individual samples (identified by sample number on the folded 1:250 000 scale colour map), and in relating their positions to main communities, bedrock geology, mineral deposits and showings, and the East Kemptville multi-element tin deposit.

### **Ash Yield**

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.

### ***Distribution Maps of Elements Determined by INAA***

#### **Gold (Au)**

Gold is not known to be essential for plant growth and health. Consequently, patterns of Au distribution reflect zones of relative gold enrichment in soils, groundwaters and near surface rocks. Background levels of Au in the ash of spruce bark are commonly less than 10 ppb Au, which is the median value obtained for the current data set. Because of the low (ppb) traces of Au that are present, the precision of the INAA on duplicate pairs, although acceptable, is not as good as that of most other elements determined by this method (see Figure 1). In general,

Au concentrations in the study area are low, but local clusters of samples with Au enrichment, especially when associated with enrichment of the 'pathfinder' elements As and Sb, are worthy of closer examination (e.g. #1007 - #1013, #1024 - #1027, #3093 - #3095). Samples collected over the Barrington Passage Tonalite have a higher median concentration of Au than those collected over other rock types.

### **Silver (Ag)**

The analytical detection limit for Ag in plant ash is 2 ppm Ag. Ninety-five percent of the samples yielded less than this concentration. The highest concentrations occur in samples from areas underlain by Goldenville Formation.

### **Arsenic (As)**

Arsenic is known for its toxicity, yet plants (especially Douglas-fir) can accumulate extraordinary amounts without exhibiting any visible harmful affects (Warren et al., 1964; Dunn and Scagel, 1989). Arsenic is an essential element for the metabolism of carbohydrates in fungi and algae, and a few ppm As in most conifer tissues is to be expected. The abundance of samples with over 5 ppm As (median is 7.7 ppm As) is a reflection of the high background levels of As in the Meguma Group. A noteworthy feature on the map is the multi-site enrichments around East Kemptville.

### **Barium (Ba)**

All samples yielded substantially more barium than the INAA detection limit of 10 ppm Ba. Spruce bark commonly contains 1000 - 2000 ppm Ba, but some unusually high concentrations occur within the map area, locally up to 10,000 ppm in samples from areas underlain by Goldenville and Halifax formations of the Meguma Group.

### **Bromine (Br)**

Bromine is a volatile element, present in most, if not all terrestrial plants, but is not known to be an essential element. It can form many different complexes within plants. 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, 1986) that where gold mineralization exists, there is sometimes enrichment of Br in plant ash, indicating that a stable Br compound is retained.

It was expected that Br enrichment would occur in shoreline samples, due to the influence of Br-bearing salt spray from the ocean. However, most high concentrations of Br occur inland. It is likely 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 (Ca)**

Calcium is a major 'building block' element, essential for the rigidity of cell walls in most plants. The variations in Ca content of the bark may influence the distribution of some trace elements. For example, a statistical analysis of multi-element data sets commonly reveals a strong association of Ca with Ba and Zn. The statistical summary of the Ca data (p. B7) shows that samples collected over the Barrington Passage Tonalite and the White Rock Formation contain substantially lower concentrations than those collected over the other geological substrates.

### **Cobalt (Co)**

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, but conifer twigs usually have 5 - 10 ppm Co. Plant tissues commonly contain elevated levels of Co over ultramafic rocks, and it has been observed that some plants exhibit Co enrichment in the vicinities of gold mineralization in northern Saskatchewan (Dunn, 1986). The map of southwestern Nova Scotia shows relatively high Co concentrations associated with the White Rock and Halifax formations in the western part of the survey area.

### **Chromium (Cr)**

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 Cr commonly found in conifer bark ash, especially in the west where there is a striking similarity to the distribution pattern exhibited by Co. Statistics show (p.B9) that bark from spruce collected over the White Rock Formation contain, on average, almost twice the concentration of Cr found in trees from elsewhere in the survey area.

### **Caesium (Cs)**

This alkali metal performs no known essential function in plant tissues, and is usually present at less than 3 ppm Cs in spruce bark ash. Although more geochemical partitioning of Cs from Rb occurs in plant tissues than in rocks, both metals are enriched in trees from areas where there are alkali metal-rich phases in granitic bodies. This enrichment is apparent at East Kemptville and at sites approximately 25 km to the northeast.

### **Iron (Fe)**

Iron is essential for photosynthesis and is a major constituent of chlorophyll. In addition, there is a residual content of Fe which reflects the composition of the substrate. The map of Fe distribution closely parallels that of Cr and, to a lesser extent Co, suggesting a mafic rock association. Statistical analysis of the data (p. B11) shows the strong control of the White Rock Formation on plant chemistry, where Fe concentrations are almost double those of samples from areas underlain by other formations.

### **Hafnium (Hf)**

The content of Hf in the ash of spruce bark is commonly 1 - 2 ppm Hf, except where Fe concentrations are high. The uptake of Hf by plants may also be controlled by Zr, due to their close geochemical affinities.

### **Potassium (K)**

Potassium has no structural role in plants, but it serves a number of catalytic roles and is required in large amounts (Bidwell, 1979). It is very important in the overall metabolism of plants. Lower concentrations are present in bark than in most other plant tissues, with only 3% as the median value. In environments where there is an abundance of K, trees may excrete unwanted amounts into the outer bark. If this is the case, sites with relatively high levels of K in bark may reflect potassic-rich substrate (e.g. K-rich clays or felsic rocks).

### **Molybdenum (Mo)**

Molybdenum is required in trace amounts by most plants for nitrogen fixation and nitrate reduction. Concentrations are usually <2 ppm Mo in spruce bark, although over highly alkaline soils the trees more readily absorb Mo and therefore slightly higher levels may be expected. In general, however, concentrations of more than a few ppm Mo may be expected to reflect some Mo enrichment in the substrate (e.g. East Kemptville area).

### **Sodium (Na)**

The effect of salt-spray from the sea is evident on the Na map, since most of the elevated Na concentrations occur in trees from sites near the shore.

### **Rubidium (Rb)**

There is an antagonism between K and Rb in plants (Kabata-Pendias and Pendias, 1984) because of their competition for the same binding sites, thereby causing different distribution patterns for the two elements. Caesium is also involved, but the strong correlation commonly shown between Rb and Cs in trees (cf. maps of Cs and Rb distributions) indicates that antagonism does not occur at the levels of concentration normally found. The enrichment of alkali metals in the East Kemptville area is apparent from the map of Rb distribution, and statistical analysis (p. B16) shows that most of the high Rb values are associated with trees from granitic areas.

### **Antimony (Sb)**

Excellent analytical 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. Although Sb can be readily taken up by plants in soluble forms, it is considered a non-essential element (Kabata-Pendias and Pendias, 1984) and is usually present at low ppm levels. An analysis of 120 ppm Sb is recorded in a sample from site #3046 (west of the Barrington Passage Tonalite) in association with As and weakly anomalous Au. In general, Sb anomalies are scattered, and only cluster at sites near East Kemptville.

### **Scandium (Sc)**

Data on the essentiality of Sc in biologic systems are inconclusive (Horovitz, 1988). If required, Sc is needed only in 'ultra-trace' amounts, and therefore its presence in bark is controlled essentially by the chemistry of the substrate and by the distribution of other elements. In particular, there is a near perfect correlation between Sc and Fe.

### **Selenium (Se)**

Traces of Se are essential for some plants and for human health. Selenium occurs in combination with many compounds, some of which break down to release volatile chemical species of Se during the ashing process. Consequently, it is probable that the Se content of the bark ash does not represent the total content of the dry tissue. Despite this, the residual Se commonly bears a significant relationship to zones of Au mineralization. This was particularly notable in southeastern Nova Scotia (Dunn, 1988), and some association with Au is apparent in the southwest (site #1006-1010; and to the northwest of Liverpool). It appears that Se in the ash of spruce bark may act as a pathfinder for Au mineralization.

### **Tin (Sn)**

Tin was determined by INAA and as part of a routine scan of elements by ICP-ES. Analysis by INA has poor sensitivity and yields variable detection levels because of spectral interferences from other elements. The data listings show that detection limits range from 50 - 310 ppm (.005 % - .031 % Sn), and that for most samples the detection level was approximately 100 ppm Sn. However, for the few samples that were enriched in tin, the reproducibility of the data was good - for example, sample #1076 yielded 0.16% Sn in both splits (p. A11).

Tin analysis by ICP-ES provides a substantially lower determination limit (2 ppm Sn) than by INAA, but the aqua regia digestion and the simultaneous determination of Sn from the ICP-ES scan provides data that are much lower, indicating that the acid leach is only partial. For example the sample quoted above (#1076) that yielded 0.16% (1600 ppm) Sn by INAA yielded only 10 ppm Sn by ICP-ES, although the *precision* was excellent, with 10 ppm obtained in both sample splits. Because of the great difference in sensitivity of the two methods, only the map of Sn determined by INAA is presented.

### **Strontium (Sr)**

INAA has poor sensitivity to traces of Sr, and analytical precision is inferior to that 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.

Strontium is known to be essential for some plant species, but its general essentiality still needs confirmation. It performs a function similar to Ca in plants, and may be incorporated into their structural components. However, interactions between Ca and Sr are complex and, as demonstrated by the distribution maps for these elements, they do not closely follow one another. Correlation matrices of spruce bark data show that Sr distribution is largely independent of other elements, but that there is a weak association with Ca, Ba, and Zn.

### **Tantalum (Ta)**

Bark rarely contains more than 1 ppm Ta in ash, therefore, the larger dots on the Ta distribution map indicate sites of unusual enrichment, especially in association with the East Kemptville tin deposits. The statistics show (p. B22) that Ta enrichments are greater in samples collected over the plutons than from samples collected over the Cambro-Ordovician sediments. Studies conducted by the senior author have disclosed Ta-rich mineral phases within the structure of bark from Ta deposits in Manitoba, attesting to the accumulation of Ta by absorption through the root systems.

### **Thorium (Th)**

Thorium has low solubility and is not essential for plant growth. Its concentration in plant ash is typically < 2 ppm Th, and even over zones of Th-rich mineralization (e.g. allanite with > 5000 ppm Th in northern Saskatchewan) only a few ppm accumulate in the tissues (Dunn and Hoffman, 1986). The map of Th distribution shows that some of the highest Th contents in the bark are from samples collected near the margins of plutons.

### **Uranium (U)**

Although  $U_3O_8$  has high solubility, it rarely exceeds concentrations of more than 2 ppm in plant ash. There are a number of notable exceptions, particularly in northern Saskatchewan where enrichments in spruce twigs are locally more than three orders of magnitude (Dunn, 1983). Uranium-rich phases of granite commonly give rise to concentrations of a few ppm U in spruce bark ash, as shown by the cluster of dots around the mineralization at East Kemptville.

### **Tungsten (W)**

The detection limit for W by INAA is 2 ppm in ash, which is above the usual concentrations in tree tissues. This accounts for the simple pattern of W distribution on the map, except for the area of enrichment associated with the mineralization at East Kemptville.

### **Zinc (Zn)**

Because Zn is essential for carbohydrate and protein metabolism, differences of a few 100 ppm Zn in ash are probably related 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.

### **Rare-Earth Elements (REE)**

Because of their chemical coherence, these elements are considered as a single group. INAA can be used to readily determine lanthanum (La), cerium (Ce), neodymium (Nd), samarium (Sm), europium (Eu), terbium (Tb), ytterbium (Yb), and lutetium (Lu). Of these elements, only Tb consistently yields concentrations below the detection level of 0.5 ppm and therefore no map of Tb is included. Maps of these elements show very similar distribution

patterns, with relatively high concentrations over the White Rock Formation. However, no sample yielded an unusually high concentration of any of the REE, and in general they closely follow Fe in the spruce bark. The median concentrations of the REE are substantially higher in samples collected over the plutonic rocks than those from over the Meguma metasediments.

### ***Distribution Maps of Elements Determined by ICP-ES***

#### **Aluminium (Al)**

All dry vegetation samples were placed in Al trays for ashing, therefore a certain amount of contamination from this source is inevitable. However, the wide range in Al concentrations, the high levels of Al in the samples, and the similarity of Al distribution patterns to those of Fe suggest that areas of *relative* Al enrichment are significant. The aqua regia extraction used is not 'total', but good precision was obtained for duplicate samples. Tests undertaken to compare data obtained on the ash internal standard (V2) by ICP-ES (aqua regia digestion) with some INAA data (determinations for short-lived isotopes) indicate that the acid digestion releases approximately 50% of the Al.

#### **Boron (B)**

Borosilicate test tubes were used for the acid digestion of the ash samples, from which the analysts suggest 5 - 10 ppm B may be released. This is an insignificant amount in comparison with the concentrations of B present in the ash. Tests indicate that the analytical procedure used provides data which represent about 50% of the true concentrations of B in the samples. Precision, however, is excellent.

Boron is an element that is essential for plant growth, and it is believed to play an important role in the translocation of sugars. In general, B uptake is low from Ca-rich soils, but because the study area is not noted for its Ca enrichment there is no obvious relationship between the distribution patterns of these two elements. The median concentrations of B (p.B35) show little variation from one substrate to the next.

### **Beryllium (Be)**

Russian workers have found that conifer bark is effective in concentrating Be in the vicinity of Be mineralization (Kovalevskii, 1978). Only a few ppm Be is present in soils, and because it is a non-essential element to plant growth (in high concentrations it is toxic), its presence in the substrate is reflected in the spruce bark by anomalies of only a few ppm. The map of Be distribution shows clearly the relative enrichment around East Kemptville; weak enrichment occurs in the western part of the survey area. Analytical precision is extremely good to the 0.5 ppm Be level.

### **Cadmium (Cd)**

Although there is a strong geochemical association between Cd and Zn in many geochemical environments, this is not evident in plant tissues because of the *requirement* that plants have for Zn but not for Cd. However, Cd is extremely easily absorbed by plants and may therefore be expected to reflect relative Cd concentrations in the soils and groundwaters whether they are due to mineral deposits or environmental contamination. Cd can be captured by a variety of organic compounds in cell walls and therefore not all of it will be transported to the tree extremities.

### **Copper (Cu)**

Data obtained by ICP-ES from the aqua regia leach are both precise and accurate (see Figure 1). Copper plays a fundamental role in a plant's metabolism. It assists in such processes as respiration, photosynthesis, nitrogen fixation and valence changes, and is present in many micro-components of plants (small and large molecules, chloroplasts, mitochondria etc.). As a consequence, the 'background' concentration of Cu in ash of the bark is high compared to many trace elements, with a median value of 170 ppm Cu.

The interpretation of Cu distribution patterns in tree tissues should be approached with caution, since laboratory studies report numerous antagonistic and synergistic interactions with both major and minor elements. These are reviewed briefly by Kabata-Pendias and Pendias (1984). However, despite the essentiality of Cu and the complex metabolic roles that it may play, substantial differences among the survey samples are more likely to reflect major differences of Cu in the substrate than the relatively small differences attributable to

micronutrient functions.

### **Lithium (Li)**

Lithium commonly follows Rb and Cs in nature. In spruce bark it is less abundant than Rb but enriched with respect to Cs. It is not known to be essential to plant metabolism. Its high solubility (except where firmly bonded to clay minerals) causes Li enrichment in soils and waters to be readily reflected in plant tissues. This is strongly apparent in the East Kemptville area.

### **Magnesium (Mg)**

Magnesium is a macronutrient which plays several important roles in plant health, including photosynthesis and numerous enzymic reactions. From a biogeochemical prospecting perspective, major differences in Mg concentrations in plants can indicate significant differences in the underlying lithology, but smaller differences are not known to be of value in delineating zones of mineralization.

### **Manganese (Mn)**

Red and black spruce contain considerably more Mn than most other species. Manganese is an essential element which is readily taken up by plants, especially where the acidity of the ground is high. In acidic environments there is a Mn/Fe antagonism, which is extended to elements with a broad affinity for Fe.

### **Nickel (Ni)**

The presence of Ni may assist in the translocation of nitrogen in some plants, but its general essentiality is unproven. When in solution, Ni is readily taken up by plants, therefore it may be expected that the Ni content of the bark may be positively correlated with Ni concentrations in groundwaters.

INAA has low sensitivity to Ni (detection limit of 50 ppm Ni in ash). In contrast, excellent precision and accuracy are obtained by ICP-ES down to the minimum level (13 ppm) recorded for this data set. Although there is a relative abundance of Ni in the western part of the study area, the statistical analysis of the data shows similar background (i.e. median) values

for samples on all underlying formations.

### **Phosphorus (P)**

Phosphorus plays a vital role in plant energy metabolism, and it is extremely important as a structural part of many organic compounds. Its uptake by trees may be antagonized by excess Ca but, from the maps showing distribution patterns of Ca and P, this antagonism is not apparent in the red spruce bark. Similarly, high levels of P may influence the uptake of numerous trace metals, although this effect appears to be subordinate to the over-riding effect of the chemistry of the substrate.

### **Lead (Pb)**

Despite the known toxic effects of Pb, it occurs naturally in all plants, and in small traces Pb may even be an essential element (Broyer et al., 1972). It is taken up mainly by root hairs and stored as a pyrophosphate in cell walls. Kovalevskii (1979) showed that in Dahurian larch, which is chemically similar in many respects to red spruce, there is a strong correlation between the Pb content of soil and that of bark. As a result of these processes, the natural background levels of Pb in the spruce bark ash are high (median of 376 ppm Pb), and local concentrations of over 2000 ppm Pb occur in the southern part of the survey area. The reason for the high levels of Pb from coastal samples is unknown: a possible explanation may be that Pb in the soil forms complexes with salt from the sea spray and is being more readily absorbed by the tree roots as a Pb chloride.

### **Titanium (Ti)**

The essentiality of Ti for plant growth is uncertain, but it may play a role in photosynthesis. The ICP-ES analysis is probably not 'total', although it is likely that most of the Ti in the ash goes into solution during the aqua regia digestion. There is a wide range in Ti content of the ash samples, with highest median concentrations occurring in trees growing over the Barrington Passage Tonalite and the White Rock Formation.

## **Vanadium (V)**

Although V is present in all of the bark samples, its essentiality for plants other than green algae has not been proven. Soluble V is easily taken up by roots, and it may play a similar role to Mo in fixing nitrogen. The maps of Mo and V show similar distribution patterns, and there are broad similarities with the Sb and Pb maps.

## **Other Elements**

Each sample was analyzed for iridium and mercury. All Ir analyses showed concentrations of less than 2 ppb, indicating that no obvious platinum-group elements occur 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). In our experience these concentrations rarely exceed 100 ppb Hg, whereas remote from mineralization concentrations are < 20 ppb Hg.

## **Notes on the Biogeochemical Data Listings (Appendices A and B)**

Appendix A lists field data and all analytical data obtained for the spruce bark ash. Appendix B provides some simple statistical analyses 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 Tables 5 and 6.

## **Acknowledgements**

The co-operation, assistance, and advice provided by personnel of the Nova Scotia Dept. of Natural Resources (NSDNR) are greatly appreciated. In particular we thank P.J. Rogers (NSDNR) for his active support throughout this study.

Table 5: Abbreviations Used in Appendix A

|                            |  |
|----------------------------|--|
| RS                         | Replicate Status; an integer (1 or 2) that follows the Site ID and indicates two splits from the same sample.  |
| Map Sheet                  | 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. |
| Zone, Easting and Northing | The Universal Transverse Mercator (UTM) zone followed by easting and northing co-ordinates in metres.  |
| Bark                       | The coarseness of the bark collected (i.e. Fine (F), Medium (M) or Coarse (C)).  |
| Slope                      | 0 = flat ground<br>1 = slight incline followed by downward compass direction<br>(e.g. 1N = slight downward incline to the north)<br>2 = moderate incline<br>3 = steep incline        |
| Forest Type                | Type of vegetation cover and degree of surface water saturation.   |

Table 6: Abbreviations Used in Appendix B

|                  |  |
|------------------|--|
| Rock Type        | Underlying bedrock lithology (derived from published geological maps):<br><br>DCg - Devono-Carboniferous granite<br>DCt - Devono-Carboniferous tonalite (Barrington Passage)<br>OSw - Ordovician-Silurian White Rock Formation<br>COh - Cambro-Ordovician Halifax Formation<br>COg - Cambro-Ordovician Goldenville Formation |
| N<br>dl<br>Cum % | N = number of samples<br>dl = determination limit<br>Cum % - cumulative frequency (as a percentage)  |

## References

- Bidwell, R.G.S., 1979. Plant Physiology. Second edition, MacMillan Publ. Co., Inc., NY.
- Bjorklund, A. and Gustavsson, N., 1987. Visualization of geochemical data on maps: new options. Jour. Geochem. Explor., **29**: 89-103.
- Bolviken, B., Bergstrom, J., Bjorklund, A., Kontio, M., Lehmuspelto, P., Lindholm, T., Magnusson, J., Otteson, R.T., Steenfelt, A., and Volden, T., 1986. Geochemical atlas of northern Fennoscandia, scale 1:4 million. Geological Surveys of Finland, Norway and Sweden, 20pp, 155 maps.
- Broyer, T.C., Johnson, C.N., and Paull, R.E., 1972. Some aspects of lead in plant nutrition. Plant Soil, **36**: 301.
- Chukhrov, F.V., Churikov, V.S., Ermilova, L.P., and Kalentchuk, G.E., 1979. Background levels of copper and zinc in common plants from various regions of the Soviet Union. J. Geochem. Explor., **12**: 79-86.
- Coker, W.B. et al. (in preparation). Till geochemistry, Contwoyto Lake and Yathkyed Lake, N.W.T. G.S.C. Open File.
- Dunn, C.E., 1983. Uranium biogeochemistry of the NEA/IAEA Athabasca test area. In: Uranium Exploration in Athabasca Basin, Saskatchewan, Canada (Ed. E.M. Cameron). Geol. Surv. Can., Paper 82-11: 127-132.
- Dunn, C.E., 1986. Gold exploration in northern Saskatchewan by biogeochemical methods. Can. Inst. Mining, Spec. Vol. **38**: 418-434.
- Dunn, C.E., 1988. Reconnaissance level biogeochemical surveys for gold in Canada: *in* Prospecting in Areas of Glaciated Terrain - 1988 (Eds. D.R. MacDonald and K.A.

Mills). Can. Inst. Mining, Geology Division, Halifax, N.S: 433-438.

Dunn, C.E., 1990. Reconnaissance level biogeochemical surveys for gold in Canada. Trans. Inst. Min. Metall. (Section B: Appl. earth sci.), **98**: B153-161.

Dunn, C.E., 1991. Assessment of biogeochemical mapping at low sample density. Trans. Inst. Min. Metall. (Section B: Appl. earth sci.), **100**: B130-133.

Dunn, C.E., and Hoffman, E., 1986. Multi-element study of vegetation from a zone of rare-earth rich allanite and apatite in northern Saskatchewan, Canada. Applied Geochem., **1**: 375-381.

Dunn, C.E., and Scagel, R.F., 1989. Tree top sampling from a helicopter - a new approach to gold exploration. J. Geochem. Explor., **34**: 255-270.

Dunn, C.E., Banville, R.M.P., and Adcock, S.W., 1989. Reconnaissance biogeochemical survey, eastern Nova Scotia. Geol. Surv. Canada, Open File 2002.

Dunn, C.E., Coker, W.B., and Rogers, P.J., 1991. Reconnaissance and detailed geochemical surveys for gold in eastern Nova Scotia using plants, lake sediment, soil, and till. J. Geochem. Explor., **40**: 143-163.

Giles, P.S., 1985. A major post-Visean sinistral shear zone - new perspectives on Devonian and Carboniferous rocks of southern Nova Scotia: *in* Guide to the Granites and Mineral Deposits of Southwestern Nova Scotia (Ed. A.K. Chatterjee and D.B. Clarke). N.S. Dept. Mines and Energy, Paper 85-3: 233-248

Horovitz, C.T., 1988. Is the major part of the periodic system really inessential for life? J. Trace Elem. Electrolytes Health Dis., **2**: 135-144.

Kabata-Pendias, A., and Pendias, H., 1984. Trace Elements in Soils and Plants. CRC Press, Inc., Boca Raton, Florida, 315pp.

- Keppie, J.D., 1979. Geological map of the Province of Nova Scotia, Nova Scotia Dept. Mines and Energy, Published Map, scale 1:500 000.
- Kouba, J., 1978. Datum considerations for test adjustments of Canadian primary horizontal networks: *in* Proceedings of the second international symposium on problems related to the redefinition of the North American geodetic networks, p55-62. U.S. National Oceanic and Atmospheric Administration.
- Kovalevskii, A.L., 1978. Biogeochemical halos of ore deposits. *Int. Geol. Reviews*, **20**: 548-562.
- Kovalevskii, A.L., 1979. Biogeochemical Exploration for Mineral Deposits. Amerind Publ. Co. Pvt. Ltd., New Delhi, 136 pp.
- Kovalevskii, A.L., 1986. Mercury-biogeochemical prospecting for mineral deposits. *Biogeochemistry*, **2**: 211-220.
- LRIS, no date. Explanation of control survey data terms [booklet available from LRIS, 120 Water Street, Summerside, P.E.I. C1N 1A9]
- McClenaghan, M.B., DiLabio, R.N.W. and Laurus, K.A.\* (1992). Till geochemistry and clast lithology data for the Mira-Framboise area, southeastern Cape Breton Island, Nova Scotia. G.S.C. Open File 2533.
- Reynolds, P.H., Zentilli, M. and Muecke, G.K., 1981. K-Ar and  $^{40}\text{Ar}/^{39}\text{Ar}$  geochronology of granitoid rocks from southern Nova Scotia: its bearing on the geological evolution of the meguma zone of the Appalachians. *Can. Jour. Earth Sci.*, **18**: 386-394.
- Rogers, H.D., 1985. Geology of the igneous-metamorphic complex of Shelburne and eastern Yarmouth counties, Nova Scotia: *in* Current Research, Part A. *Geol. Surv. Can.*, Paper 85-1A: 773-777.

- Rogers, P.J., and Dunn, C.E., 1989. Regional biogeochemical surveys for gold in eastern Nova Scotia, Canada. Nova Scotia Dept. Mines Energy, Rep. Activities 1988, Rep. 89-1: 71-78.
- Rogers, P.J., and Dunn, C.E., in preparation. Vegetation chemistry applied to mineral exploration in eastern Nova Scotia.
- Sangster, A.L., 1990. Metallogeny of the Meguma Terrane, Nova Scotia: *in* Mineral Deposit Studies in Nova Scotia, Vol. 1 (Ed. A.L. Sangster), Geol. Surv. Can., Paper 90-8: 115-162.
- Stea, R.R., 1982. Pleistocene geology and till geochemistry of south central Nova Scotia (Sheet 6). Nova Scotia Dept. Mines and Energy, Map 82-1.
- Stea, R.R., and Grant, D.R., 1982. Pleistocene geology and till geochemistry of southwestern Nova Scotia (Sheets 7 and 8). Nova Scotia Dept. Mines and Energy, Map 82-10.
- Taylor, F.C., 1967. Reconnaissance geology of the Shelburne map area, Queens, Shelburne, and Yarmouth counties, Nova Scotia. Geol. Surv. Can. Memoir 349; 83 p.
- Thorleifson, L.H. and Kristjansson, F.J., 1990. Geochemical, mineralogical and lithological analyses of glacial sediments for gold, base metal, and kimberlite exploration, Beardmore-Geraldton area, district of Thunder Bay, northern Ontario. G.S.C Open File 2266.
- Warren, H.V., Delavault, R.R., and Barakso, J., 1964. The role of arsenic as a pathfinder in biogeochemical prospecting. Econ. Geol., **59**: 1381-1389.