



**GEOLOGICAL SURVEY OF CANADA**  
**OPEN FILE 2758**

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**Reconnaissance biogeochemical survey  
southeastern Cape Breton Island, Nova Scotia:  
Part 2 – balsam fir twigs  
(Parts of NTS 11 F,G,J,K)**

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

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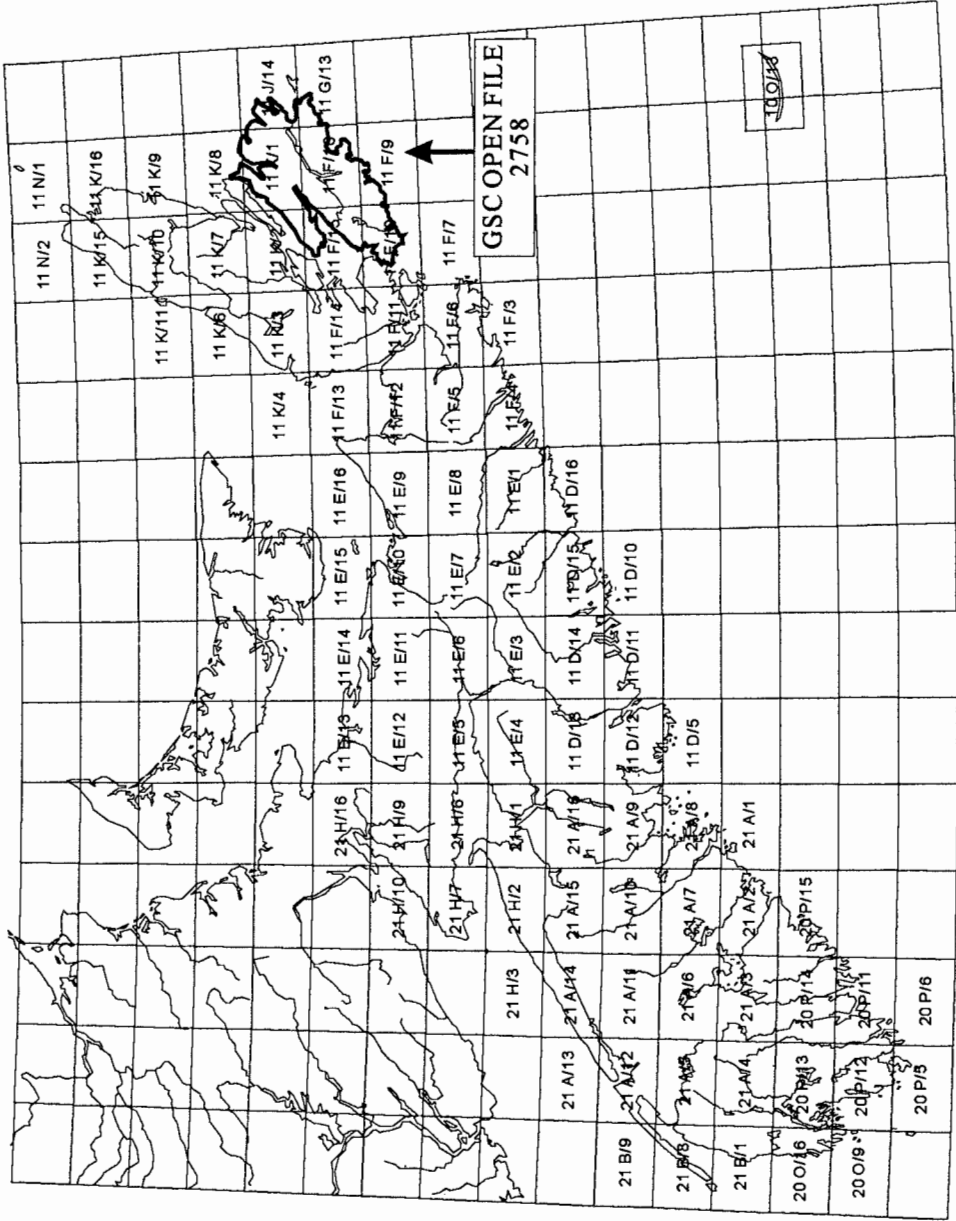
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Survey area with respect to National Topographic System (NTS) map sheets

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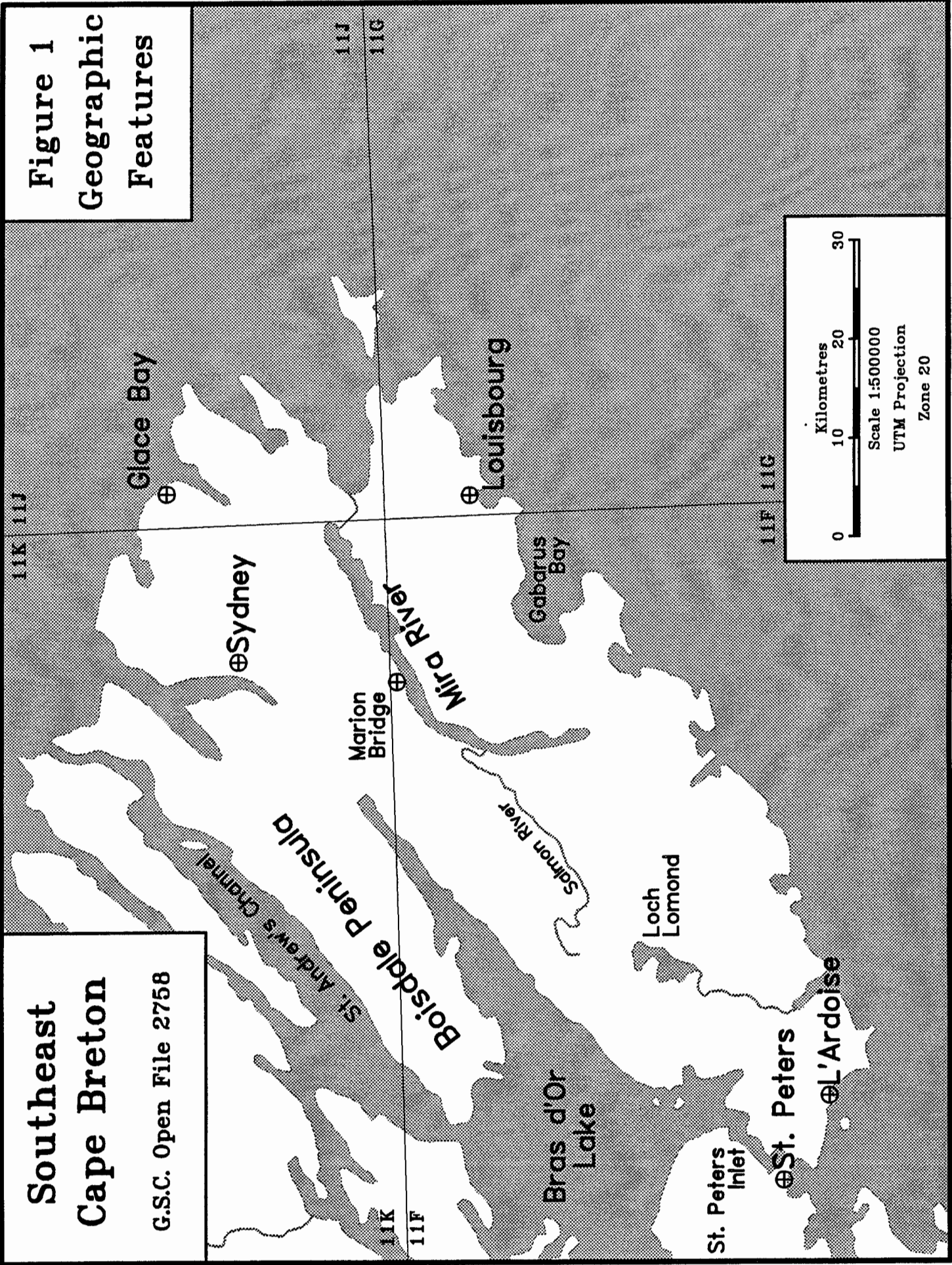
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Reconnaissance Biogeochemical Survey - SE Cape Breton Island, Nova Scotia: Balsam Fir Twig

# RECONNAISSANCE BIOGEOCHEMICAL SURVEY, SOUTHEASTERN CAPE BRETON ISLAND, NOVA SCOTIA: PART 2 - BALSAM FIR TWIGS

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

## INTRODUCTION

This Open File contains data from a reconnaissance biogeochemical survey in southeastern Cape Breton Island. The survey was conducted in late May to mid-June, 1991, by the Geological Survey of Canada under the Canada - Nova Scotia Cooperation Agreement on Mineral Development (1990 - 1992). It represents the second of a series of biogeochemical Open Files of different tree tissues from several species in the same area. The first report on this area (Dunn et al., 1992a) dealt with results from the analysis of outer bark from black spruce (*Picea mariana*).

Field observations, data listings, statistical summaries, a geology and sample location map, and element distribution maps are presented. The maps show concentrations in the ash of balsam fir (*Abies balsamea*) twigs of 29 elements determined by instrumental neutron activation analysis (INAA), and of 16 elements determined by inductively-coupled plasma emission spectrometry (ICP-ES). The data are reported as 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, using the same sample medium (balsam fir twigs), 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.). In May, 1991 another survey was undertaken in southwestern Nova Scotia. Two Open File reports from that area have been published that deal with bark from red spruce and balsam fir twigs (Dunn et al., 1992b; Dunn et al., 1994).

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.

The Zn example illustrates that biogeochemical data should be interpreted with caution and



the text notes for each element are provided for assistance. Biogeochemistry is a complex science involving the interaction of organic and inorganic processes that are controlled by many physicochemical parameters. Despite 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.

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

GSC Bookstore  
Geological Survey of Canada  
601 Booth St.  
Ottawa  
Ontario, K1A 0E8 Tel: (613) 995-4342 Fax: (613) 943-0646

The data will be supplied on MS-DOS (IBM-PC) 3.5" 1.44 Mb diskette, 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:** E.H.W. Hornbrook, C. Logan, and S. Alvarado, assisted by W.A. Spirito, R.D. Cardinal, S. Lambert, K. Ruhland and S. Phaneuf.

**Sample Preparation:** undertaken and supervised by R.D. 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 UNIX workstation 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 late in May, 1991, tree tissue samples were collected from approximately 550 sites within a 4000 km<sup>2</sup> area of southeastern Cape Breton Island. Balsam fir was present at 495 of these sites providing an average density of 1 per 8 km<sup>2</sup>. The

sampling grid was irregular because of difficulty in accessing some areas. Where available, samples were collected at 2 km intervals along driveable roads and tracks, with helicopter access to a few remote sites. 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 in order to minimize the risk of roadside contamination.

### Sample Locations

The 1:10000 LRIS (Land Registration Information Service) maps were used for the field work. The only exceptions were a few sites for which the 1:10000 maps were not available at the time of the survey. 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 NAD27 datum. A program (CONV27) was purchased from LRIS to convert MTM coordinates to UTM coordinates, based on the NAD27 datum.

### Sample Collection

An orientation survey of the area conducted in October, 1990, showed that the most common species are balsam fir (*Abies balsamea*), black spruce (*Picea mariana*), white spruce (*Picea glauca*), 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 black spruce bark had generally higher concentrations of trace metals than the other tissues that were collected. The chemistry of white spruce is appreciably different from that of black spruce (Dunn, 1991), therefore samples from the two species could not be interchanged. White spruce has a lower content than black spruce of many trace elements (especially those associated with Fe), and in most parts of the survey area white spruce is the less common of the two species (except around Bras d'Or Lake, and especially on the Boisdale Peninsula - Fig. 1)). Consequently, black spruce bark was selected as one of the principal sample media, but in addition samples of tamarack bark, and the twigs of black spruce, balsam fir and tamarack were collected at sites where they were available. Data from the black spruce bark have been published (Dunn et al., 1992a); data for the other species will be presented in future open file releases.

At each sample location 200 - 250 g of fresh twigs and needles were snipped from balsam fir using standard anvil-type, teflon-coated, garden pruning snips. Twig samples were placed in heavy-duty brown paper hardware bags (approximately 25 x 35 cm) and secured with masking tape. There are seasonal variations in the chemistry of twigs, therefore the survey was completed as quickly as possible (three weeks).

Usually 5 - 7 twigs, each comprising 5 - 7 years of growth, provided the required amount of material. Within the survey area this amount of growth was a 35 - 40 cm length of twig. Where growth was more spindly (e.g. dense forest) and annual growth increments were shorter, up to 10 years of growth was collected. Although there is annual variation in the metal uptake and

storage of many chemical elements (some accumulating near the twig ends), the over-riding factor for consideration in a biogeochemical sampling programme is the *diameter* of the twig. It is important to maintain a consistent ratio of twig bark to twig wood, because many of the heavy metals are located in the bark, and not in the woody tissue of the twig. If this ratio changes substantially, then variations in element content may be attributable to mixing thick with thin twigs, providing false anomalies. For the balsam fir survey the twig diameter at most locations was approximately 5 mm where twig growth was 5 - 7 years old.

### Sample Preparation and Analysis

After the samples were air-dried for several weeks in a greenhouse, the needles were separated from the twigs. Balsam fir needles have a different chemical composition from the twigs (lower levels of most heavy and base metals in the needles). The ratio of needle to twig may vary substantially among sample locations, so if twigs are not separated from needles some false anomalies may be generated which are simply a function of different twig to needle ratios.

Approximately 50 g of dry twigs were weighed into 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 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 31 of these elements - concentrations of Ag, Hg, Ir, and Tb were all below the detection levels of 2 ppm, 1 ppm, 2 ppb, and 0.5 ppm, respectively). 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 +/- 10 percent.

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 good for most elements, such that the relative element distribution patterns are meaningful even if the absolute concentrations are only partial.

### Analytical Quality Control

Included within each block of 20 samples prepared for analysis there was one standard ash sample (V5), and one duplicate ash sample. These provided controls on accuracy and precision, respectively. Data on mean values and standard deviations obtained for each element in a standard ash sample are given in Tables 1 and 2. Tables 3 and 4 contain the raw data from which these determinations were made. Tables 5 and 6 list the analytical data obtained on the duplicate pairs; graphical representation of the data for three elements determined by INAA (Au, As, Zn), and three determined by ICP-ES (Ni, Cu, and Pb) is presented in Figure 2. Reproducibility is good

for these elements, with the exception of Au at low concentrations in a few pairs of samples. Tables 7 and 8 show the determination (detection) limits quoted for each element by the analytical laboratories, and the substitution values used for statistical calculations where analyses were below these levels.

Table 1: Mean and Standard Deviation for Standard V5  
Analyzed by INA (N=24)

Element			Mean	Standard Deviation
Gold	ppb	Au	20	13
Arsenic	ppm	As	8.0	0.7
Barium	ppm	Ba	415	34
Bromine	ppm	Br	27	3
Calcium	%	Ca	16.9	1.2
Cobalt	ppm	Co	9	1
Chromium	ppm	Cr	23	3
Cesium	ppm	Cs	4.7	0.4
Iron	%	Fe	1.1	0.1
Hafnium	ppm	Hf	1.7	0.2
Potassium	%	K	2.4	0.4
Sodium	ppm	Na	4122	219
Rubidium	ppm	Rb	46	5
Antimony	ppm	Sb	2.0	0.1
Scandium	ppm	Sc	2.0	0.2
Selenium	ppm	Se	*	*
Strontium	ppm	Sr	1254	254
Tantalum	ppm	Ta	1.1	0.2
Thorium	ppm	Th	1.6	0.2
Uranium	ppm	U	0.6	0.3
Tungsten	ppm	W	*	*
Zinc	ppm	Zn	1975	126
Lanthanum	ppm	La	18.4	0.8
Cerium	ppm	Ce	25	2
Neodymium	ppm	Nd	13	3
Samarium	ppm	Sm	1.9	0.1
Europium	ppm	Eu	0.37	0.05
Ytterbium	ppm	Yb	0.71	0.07
Lutetium	ppm	Lu	0.13	0.01

\* all below determination limit

**Table 2: Mean and Standard Deviation for V5  
Analyzed by ICP-ES (N=23)**

Element			Mean	Standard Deviation
Silver	ppm	Ag	1.5	0.2
Aluminum	ppm	Al	10309	558
Boron	ppm	B	171	8
Beryllium	ppm	Be	0.4	0.1
Cadmium	ppm	Cd	10.0	0.6
Copper	ppm	Cu	193	11
Gallium	ppm	Ga	7	1
Lithium	ppm	Li	5	2
Magnesium	ppm	Mg	23507	1025
Manganese	ppm	Mn	2837	323
Molybdenum	ppm	Mo	4	0.3
Nickel	ppm	Ni	41	7
Phosphorus	ppm	P	15688	830
Lead	ppm	Pb	367	17
Titanium	ppm	Ti	197	22
Vanadium	ppm	V	28	1

\* all below determination limit

Reconnaissance Biogeochemical Survey - SE Cape Breton Island, Nova Scotia: Balsam Fir Twigs

Table 3: Standard V5 - concentrations in ash determined by INAA

Au	As	Ba	Br	Ca	Co	Cr	Cs	Fe	Hf	K	Na	Rb	Sb	Sc	Se	Sr	Ta	Th	U	W	Zn	La	Ce	Nd	Sm	Eu	Yb	Lu
ina ppb	ina ppm	ina ppm	ina ppm	ina %	ina ppm	ina ppm	ina ppm	ina %	ina ppm	ina %	ina %	ina ppm	ina ppm	ina ppm	ina ppm	ina ppm	ina ppm	ina ppm	ina ppm	ina ppm	ina ppm	ina ppm	ina ppm	ina ppm	ina ppm	ina ppm	ina ppm	ina ppm
16 15	6 7.7	440 440	25 27	17.1 17.2	11 10	23 21	5.1 4.5	1.19 1.24	2.2 1.8	2.75 2.5	4350 4340	45 39	2.1 2.1	2.4 2.2	<2 <2	1100 1300	0.9 1.4	1.6 1.5	0.4 0.6	<1 <1	2100 2000	19 19	24 23	15 12	1.9 1.8	0.34 0.4	0.82 0.79	0.12 0.13
16 80	8.4 10	400 440	27 33	16 20.3	8 9	19 25	4.5 4.9	1.18 1.13	1.7 1.4	2.4 2.79	4200 4010	44 51	2 2.1	1.9 2	<2 <2	780 1100	0.7 1.3	1.4 1.9	0.8 0.6	<1 <1	2000 2000	19 19	26 27	16 15	2 1.9	0.38 0.38	0.69 0.84	0.13 0.12
15 17	8.6 8.6	380 400	22 27	17.4 17.7	8 8	20 24	4.5 4.6	1.04 1.04	1.6 1.4	3.12 2.51	3880 4000	43 45	1.9 2	1.8 1.9	<2 <2	1000 1200	1 0.8	1.5 1.5	0.6 0.7	<1 <1	1800 1900	19 18	26 26	14 11	1.9 1.8	0.34 0.29	0.76 0.59	0.12 0.09
16 22	8.3 7.8	420 510	29 30	17.2 17.3	9 11	23 25	4.8 5.2	1.04 1.2	1.9 1.9	2.79 2.52	4220 4280	46 55	2 2.2	2 2.2	2 <2	1000 1600	1.2 1.2	1.7 1.5	0.7 0.5	<1 <1	2100 2100	19 19	27 27	14 10	1.8 2	0.4 0.44	0.76 0.81	0.12 0.12
14 17	7.8 8.2	400 400	24 25	18.1 17.9	8 9	23 23	4.5 4.7	1.06 1.08	1.6 1.7	2.51 2.51	3600 4050	55 46	2 2	1.9 1.9	<2 <2	1100 960	1.1 0.8	1.6 1.5	0.6 0.7	<1 <1	1900 1900	18 18	27 27	13 15	1.8 1.9	0.39 0.37	0.68 0.7	0.15 0.14
21 19	8.1 8	420 430	25 25	17 16.3	10 9	24 23	4.8 4.1	1.1 1.13	1.8 1.7	2.76 2.42	4240 4200	51 43	2 2	2 1.9	<2 <2	1500 1300	1.3 1	1.8 1.5	0.5 <0.1	<1 <1	2200 2000	20 18	25 26	12 12	1.8 1.8	0.37 0.31	0.74 0.63	0.13 0.14
22 19	8.4 7.1	450 410	24 32	16.8 17.7	9 10	20 26	4.6 5.2	1.12 1.16	1.9 1.6	2.32 2.21	4300 4350	46 51	2 1.8	2 2	<2 <2	1400 1500	1 1.1	1.8 1.4	0.4 0.6	<1 <1	2100 2000	18 18	26 26	<5 14	1.8 1.9	0.46 0.38	0.81 0.76	0.13 0.14
18 18	7.5 8.4	390 450	24 26	16.1 16.5	9 10	23 23	4.6 5.1	1.07 1.1	1.7 1.5	2.09 2.36	4000 4110	45 37	1.9 2.2	1.9 2	<2 <2	1400 1800	1.1 1	1.6 1.4	0.6 0.8	<1 <1	2000 2100	18 19	24 24	12 15	1.8 1.9	0.41 0.41	0.62 0.65	0.14 0.13
19 14	8.6 7.2	410 430	28 29	16.7 15.2	10 9	26 22	5 3.9	1.16 1.04	2.1 2.1	1.54 1.79	4380 4510	39 50	2.1 1.9	2.1 1.9	<2 <2	1500 1400	1.7 1	1.6 1.5	0.6 0.5	<1 <1	2100 1900	19 18	25 25	15 13	2 2	0.38 0.35	0.75 0.63	0.13 0.14
14 18	6.3 7	410 370	27 23	18.2 15.6	9 7	24 18	5.4 3.9	1.17 1.02	1.9 1.5	2.1 2.07	3870 3710	50 41	1.9 1.7	1.8 1.7	<2 <2	1000 960	1 1	1.5 1.1	1.3 0.8	<1 <1	1900 1700	18 16	26 24	15 14	2 1.7	0.25 0.36	0.64 0.6	0.12 0.12
11 23	7.2 8	410 400	26 31	15.6 15.7	9 10	17 25	4.4 5.3	1.07 1.17	1.7 1.7	3.29 2.58	4110 4200	42 42	1.9 2.1	1.9 2.2	<2 <2	1300 1500	1.1 0.9	1.6 1.6	0.5 0.8	<1 <1	1900 2100	18 19	25 22	13 10	2 1.9	0.34 0.38	0.69 0.69	0.13 0.15
20 26	8.9 8.6	420 330	28 26	15.3 17.7	10 8	25 31	3.9 4.7	1.42 1	1.5 1.6	1.95 2.4	4080 3960	43 51	2 1.9	2 1.8	<2 <2	1400 1000	0.8 1	1.5 1.5	0.7 <0.1	<1 <1	1800 1800	18 17	21 25	12 10	1.8 1.8	0.35 0.35	0.75 0.75	0.12 0.14

Reconnaissance Biogeochemical Survey - SE Cape Breton Island, Nova Scotia: Balsam Fir Twigs

Table 4: Standard V5 - concentrations in ash determined by ICP-ES

Ag icp ppm	Al icp %	B icp ppm	Be icp ppm	Cd icp ppm	Cu icp ppm	Ga icp ppm	Li icp ppm	Mg icp %	Mn icp %	Mo icp ppm	Ni icp ppm	P icp %	Pb icp ppm	Ti icp ppm	V icp ppm
1.3	10340	172	0.5	9.3	192	7	5	23470	2514	4	72	15310	364	196	27
1.5	11080	161	0.4	9.5	180	8	5	23060	2813	4	40	15660	365	239	28
1.3	9440	162	0.6	8.5	179	6	<2	21560	2451	4	36	14330	335	194	26
1.7	9970	169	0.5	10.5	183	9	6	22750	2861	4	37	14910	355	222	27
1.2	9820	162	0.2	10	182	5	3	22780	2521	4	38	15130	365	184	26
1.8	10340	165	0.4	10	189	6	<2	23250	3195	4	38	15460	363	224	28
1.6	9860	163	0.2	9.9	183	6	5	22480	2676	4	36	14930	348	198	27
1.5	10510	177	0.4	10.3	201	6	5	23630	2682	4	40	15440	362	241	29
1.4	9680	164	0.3	9.7	186	6	6	22640	3422	3	41	15220	340	187	27
1.3	10170	163	0.3	9.7	193	5	5	23030	3437	4	40	15400	358	229	28
1.4	11250	182	0.6	10.2	203	6	7	23830	2531	4	43	15920	374	192	28
1.2	9590	163	0.5	9.5	181	7	4	22250	2759	4	38	14660	344	183	26
1.5	10320	176	0.3	10.7	198	9	5	23930	3342	4	41	16540	382	190	28
1.4	9610	162	0.4	9.5	185	8	5	22410	2297	4	39	14570	358	176	26
1.6	10320	174	0.4	9.8	195	8	4	23950	2989	4	43	16060	373	190	28
1.5	11670	188	0.5	10.9	215	8	6	26280	2856	4	43	18110	409	202	30
1.6	10310	172	0.4	10.7	190	7	6	23470	2564	4	38	16220	373	174	27
1.8	10770	178	0.4	10.9	204	7	6	24760	2745	4	40	16430	386	208	29
1.8	10290	176	0.4	10.1	194	9	6	23840	2607	4	41	15880	378	166	28
1.4	10370	170	0.5	10	191	9	3	23890	2906	4	40	15660	371	195	28
1.6	11010	183	0.5	10.2	203	8	6	24930	3129	5	44	16300	393	207	29
1.5	10110	181	0.4	9.9	198	5	6	24180	2729	4	40	16170	368	164	27
1.5	10280	179	0.4	10	216	6	5	24310	3232	4	42	16520	388	169	28

Reconnaissance Biogeochemical Survey - SE Cape Breton Island, Nova Scotia: Balsam Fir Twigs

Table 5: Laboratory Duplicates - concentrations in ash determined by INAA

Vial Number	Au	As	Ba	Br	Ca	Co	Cr	Cs	Fe	Hf	K	Na	Rb	Sb	Sc	Se	Sr	Ta	Th	U	W	Zn	La	Ce	Nd	Sm	Eu	Yb	Lu	
	ina	ina	ina	ina	ina	ina	ina	ina	ina	ina	ina	ina	ina	ina	ina	ina	ina	ina	ina	ina	ina	ina	ina	ina	ina	ina	ina	ina	ina	ina
	ppb	ppm	ppm	ppm	%	ppm	ppm	ppm	%	ppm	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
AL91/2408	<5	3.4	2800	39	15.9	9	15	1.2	0.41	1	21.6	5130	240	0.5	1.2	<2	1600	<0.5	0.7	<0.2	<1	2100	3.2	<3	<5	0.5	0.08	0.38	<0.05	
AL91/2409	14	1.4	2600	65	14.5	9	15	1.1	0.43	1.1	26.9	4690	280	0.7	1.2	<2	1300	<0.5	0.9	<0.2	<1	2000	3.1	7	<5	0.5	<0.03	0.46	0.12	
AL91/2434	<5	9.8	1500	38	11	9	38	2.1	1.75	4.3	13.6	4370	120	1.1	4.7	<2	880	<0.5	3.7	0.7	<1	1100	17	31	18	3.3	0.74	1.69	0.36	
AL91/2435	15	10	1400	47	11.7	9	39	1.8	1.8	4.8	16.1	4460	100	1.2	4.6	<2	1300	1.2	3.6	1.3	<1	1200	17	32	19	3.3	0.79	1.77	0.38	
AL91/2484	7	11	1700	46	18.4	4	11	3.9	0.43	<0.5	15.8	1830	130	0.6	1.2	5	1300	<0.5	0.5	<0.1	<1	1800	3.9	7	<5	0.7	<0.03	0.39	0.07	
AL91/2485	<5	2.9	1500	27	18.6	3	12	4.8	0.49	<0.5	13.7	2220	140	0.7	1.3	<2	1100	<0.5	0.6	<0.1	<1	1900	4.1	9	<5	0.8	<0.02	0.37	<0.05	
AL91/2507	<5	4	3300	39	20.5	4	11	1.7	0.38	0.6	23	1880	180	0.5	0.7	<2	900	<0.5	0.4	<0.2	<1	2500	3	5	6	0.4	<0.03	<0.05	<0.05	
AL91/2508	<5	4	3100	40	19.1	4	20	1.6	0.52	<0.5	23.9	2270	170	0.5	0.8	<2	1000	<0.5	<0.1	<0.2	<1	2300	3.2	5	10	0.5	<0.03	0.27	<0.05	
AL91/2528	<5	4.9	2300	20	20.5	4	89	2.6	1.32	2.9	12.9	6180	110	0.6	2.5	<2	600	1	2.4	4	<1	1800	12	21	14	1.9	0.44	1.18	0.17	
AL91/2529	7	6.4	2200	20	19.8	4	91	2.6	1.28	2.7	17.3	5840	110	0.6	2.4	<2	480	0.9	2.4	4.2	<1	1700	11	21	13	1.9	0.42	0.91	0.2	
AL91/2554	7	4.4	930	22	16.7	3	18	1.7	0.5	1.1	22.7	2070	120	1.5	1.1	<2	630	<0.5	1	<0.1	<1	1400	4.8	10	<5	0.9	0.2	0.5	0.07	
AL91/2555	6	4.1	980	23	17.6	2	17	1.3	0.48	1	18.9	2030	130	1.4	1.1	<2	530	<0.5	0.7	<0.1	<1	1400	4.4	7	<5	0.8	0.17	0.47	0.05	
AL91/2575	10	3.1	1700	29	20.5	3	15	2	0.45	1.2	14.2	2460	140	0.8	1.2	<2	770	<0.5	1	<0.1	<1	1600	4.2	9	<5	0.8	0.17	0.3	0.07	
AL91/2576	10	3.1	1400	29	20.9	3	12	1.2	0.45	0.7	13.7	1990	130	0.7	1.2	<2	810	<0.5	1	<0.1	<1	1700	3.9	10	7	0.7	0.28	0.44	0.06	
AL91/2598	9	2.1	710	32	13.6	5	13	6.3	0.71	1.7	21.1	6670	200	0.7	2.7	<2	830	<0.5	1.4	<0.1	<1	2300	6.4	10	6	1.1	0.26	0.67	0.15	
AL91/2599	7	2.4	670	35	13.9	6	15	4.4	0.73	1.8	20.6	6690	150	0.7	2.6	<2	900	<0.5	1.8	0.4	<1	2200	6.6	11	<5	1.1	0.22	0.55	0.14	
AL91/2626	7	3.3	720	32	18.5	3	15	3.2	0.31	<0.5	22.6	3160	300	0.7	0.8	3	1000	<0.5	0.6	<0.1	<1	2600	2.8	7	<5	0.5	<0.02	0.27	0.06	
AL91/2627	<5	2.3	660	67	16.4	3	18	2.3	0.34	<0.5	20.6	3730	280	0.5	0.7	<2	810	<0.5	0.6	<0.1	<1	2400	2.7	5	<5	0.5	<0.02	0.2	<0.05	
AL91/2647	<5	1.9	1500	32	19.7	3	14	1.5	0.27	<0.5	23	1950	170	0.4	0.6	<2	740	<0.5	0.4	<0.1	<1	1700	2.2	5	<5	0.3	<0.03	0.14	<0.05	
AL91/2648	5	1.9	1500	34	18.8	4	13	1.5	0.26	<0.5	24.1	1840	150	0.5	0.5	<2	690	<0.5	0.1	<0.1	<1	1800	2	4	10	0.3	<0.03	0.17	<0.05	
AL91/2673	7	2.9	590	67	18	6	21	<0.5	0.32	<0.5	22.3	2160	110	0.5	0.8	<2	1200	<0.5	0.5	<0.1	<1	1700	3.3	7	<5	0.6	<0.02	0.14	0.06	
AL91/2674	<5	2.3	670	64	17.9	6	19	<0.5	0.34	0.6	20.1	2330	110	0.6	0.9	4	1000	<0.5	0.5	<0.1	<1	1900	3.8	7	<5	0.6	<0.02	0.3	0.08	
AL91/2693	7	1.5	860	25	14.7	3	7	2.4	0.16	<0.5	20.3	2260	450	0.2	0.3	<2	1500	<0.5	<0.1	<0.1	<1	2000	1.2	<3	<5	0.2	<0.03	<0.05	<0.05	
AL91/2694	<5	1.2	870	25	15	3	9	3.6	0.14	<0.5	22.3	2160	450	0.3	0.4	<2	1400	<0.5	0.5	<0.1	<1	2100	1.1	3	<5	0.2	<0.03	<0.05	<0.05	



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Table 5 (cont'd): Laboratory Duplicates - concentrations in ash determined by INAA

Vial Number	Au ina ppb	As ina ppm	Ba ina ppm	Br ina ppm	Ca ina %	Co ina ppm	Cr ina ppm	Cs ina ppm	Fe ina %	Hf ina ppm	K ina %	Na ina %	Rb ina ppm	Sb ina ppm	Sc ina ppm	Se ina ppm	Sr ina ppm	Ta ina ppm	Th ina ppm	U ina ppm	W ina ppm	Zn ina ppm	La ina ppm	Ce ina ppm	Nd ina ppm	Sm ina ppm	Eu ina ppm	Yb ina ppm	Lu ina ppm
AL91/2711	11	3.3	1700	20	20.8	6	12	2	0.56	1.6	15.7	3750	240	0.6	1.5	<2	1400	<0.5	0.9	0.6	<1	1400	3.7	8	<5	0.6	<0.03	0.53	0.11
AL91/2712	10	3.9	1800	20	20.5	7	15	2.5	0.58	1.6	14.6	3880	250	0.6	1.5	<2	1200	<0.5	0.9	<0.1	<1	1400	4.2	9	6	0.7	<0.03	0.45	0.1
AL91/2726	<5	1.7	1400	24	18.4	3	10	1.9	0.25	<0.5	22.5	2900	220	0.8	0.6	<2	1000	<0.5	0.3	<0.1	<1	1600	2.3	7	<5	0.3	<0.02	0.2	0.05
AL91/2727	<5	2	1300	24	19.5	3	8	1.8	0.23	<0.5	23.4	2440	240	0.8	0.5	<2	1200	<0.5	0.2	<0.1	<1	1600	2.1	4	<5	0.3	<0.02	0.19	<0.05
AL91/2750	<5	2.1	2000	34	16.9	5	25	1	0.6	2	25.4	3260	300	0.3	1.5	<2	920	1.1	1.1	<0.1	<1	1800	5.5	13	10	1	0.28	0.53	0.1
AL91/2751	<5	2.6	2000	36	16	5	26	1.4	0.59	1.9	25.9	3300	320	0.4	1.4	<2	810	0.9	1	<0.1	<1	1600	5.3	12	<5	1	<0.02	0.57	0.11
AL91/2774	<5	3.8	1500	40	17.4	8	25	1.7	0.96	2.7	16.6	4310	150	0.7	3.3	<2	970	<0.5	2.2	0.7	<1	1600	13	21	15	2.2	0.49	0.97	0.21
AL91/2775	<5	2.9	1500	38	15.6	8	22	1.5	1	1.9	18.2	4190	130	0.6	3.2	<2	1400	<0.5	2.1	<0.1	<1	1600	13	24	15	2.2	0.45	1.06	0.18
AL91/2798	<5	0.9	1700	26	14.6	4	12	1.9	0.32	<0.5	25.1	3490	230	0.5	0.9	<2	2000	0.8	0.6	<0.1	<1	1700	2	4	<5	0.3	<0.03	0.18	<0.05
AL91/2799	<5	1.6	1600	27	13.7	4	10	1.5	0.3	<0.5	24.2	3550	240	0.5	0.9	<2	2100	<0.5	0.4	<0.1	<1	1600	1.9	3	<5	0.3	<0.03	0.31	<0.05
AL91/2815	<5	2.1	1400	27	12.2	5	12	1	0.61	1.7	17.7	5440	230	0.3	2	<2	980	<0.5	1.7	<0.1	<1	1500	7.1	18	8	1.3	0.36	0.71	0.15
AL91/2816	<5	2.4	1500	25	14.3	6	13	2.1	0.59	2.2	20.5	7970	280	0.5	2	<2	450	<0.5	1.5	<0.1	<1	1800	7.4	17	9	1.4	0.26	0.65	0.13
AL91/2835	<5	7.1	1400	19	16.4	8	22	1.6	1.09	1.3	15.3	4620	150	0.9	3.6	<2	890	<0.5	1.7	0.9	<1	1900	9	23	11	1.8	0.29	0.73	0.17
AL91/2836	8	8	1500	20	15.6	8	21	2	1.11	1.7	16	4930	180	0.8	3.6	<2	1000	<0.5	1.6	<0.1	3	1900	8.6	20	16	1.8	0.51	0.61	0.1
AL91/2842	6	4.3	4500	27	17.4	3	25	1.4	0.89	1.6	14.4	7310	150	1	1.5	<2	1000	0.9	1	<0.1	<1	1900	5.5	11	11	1.1	0.05	0.55	0.1
AL91/2843	<5	3.9	4600	28	18.2	3	23	1.5	0.96	1.8	16.1	7770	160	1.1	1.6	<2	1000	<0.5	1.1	<0.1	<1	1900	5.6	12	<5	1.1	<0.03	0.42	0.08
AL91/2863	<5	0.9	3300	21	19	2	8	<0.5	0.22	1.1	16.4	2260	110	0.2	0.9	<2	620	<0.5	0.5	<0.1	<1	1900	3.4	7	<5	0.6	<0.02	0.33	<0.05
AL91/2864	5	1.5	3300	22	19.5	3	8	0.6	0.27	1	14.8	2100	110	0.3	0.8	<2	550	<0.5	0.7	<0.1	<1	2000	3.3	6	<5	0.6	<0.02	0.19	<0.05
AL91/2886	6	3.5	1200	36	21.9	4	15	1.8	0.34	<0.5	18.2	3790	82	0.6	0.8	<2	1300	<0.5	<0.1	<0.1	<1	2000	2.6	4	<5	0.4	<0.02	0.25	0.09
AL91/2887	6	2.2	1200	26	22.2	4	14	1.6	0.39	<0.5	18.9	4040	80	0.4	0.9	<2	1600	<0.5	0.5	<0.1	<1	2000	2.6	5	<5	0.4	0.12	0.17	<0.05
AL91/2919	12	2.1	1800	99	14.6	7	11	13	0.58	<0.5	23.8	3720	220	0.6	1.8	3	1600	1.1	0.9	<0.1	<1	2600	4.4	7	<5	0.7	0.23	0.51	0.08
AL91/2920	<5	2.9	1800	100	14.5	6	14	13	0.65	1	20.6	3630	210	0.8	1.8	<2	1400	<0.5	0.5	<0.1	<1	2400	4.3	8	<5	0.7	0.27	0.36	0.06
AL91/2942	8	11	2800	19	21	9	38	5.7	1.72	1.1	10.2	3940	97	1.7	2	2	930	0.6	1.3	0.6	<1	1600	6.4	15	<5	1.2	<0.02	0.7	0.11
AL91/2943	8	11	2800	22	20.9	8	36	7.8	1.5	1.4	12	3260	81	1.6	1.9	<2	1100	0.9	1.3	0.6	<1	1600	5.9	13	<5	1.1	<0.03	0.61	0.11

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Table 6: Laboratory Duplicates - concentrations in ash determined by ICP-ES

Packet Number	Ag icp ppm	Al icp %	B icp ppm	Be icp ppm	Cd icp ppm	Cu icp ppm	Ga icp ppm	Li icp ppm	Mg icp %	Mn icp %	Mo icp ppm	Ni icp ppm	P icp %	Pb icp ppm	Ti icp ppm	V icp ppm
ICP91/2408	0.7	10190	230	<0.2	11.9	212	3	<2	32700	24387	2	74	50260	124	92	20
ICP91/2409	0.5	8760	223	<0.2	2.9	194	<2	2	30410	21390	3	64	54570	115	87	19
ICP91/2434	<0.2	16530	156	<0.2	2.5	107	4	9	25150	25711	3	58	20780	151	353	39
ICP91/2435	0.2	16790	155	0.2	2.6	107	6	<2	26870	26066	3	60	20500	153	367	40
ICP91/2484	1.1	5440	205	<0.2	<0.2	145	3	<2	39660	13403	<2	30	23920	148	145	29
ICP91/2485	1.4	5760	196	0.3	<0.2	141	5	<2	37590	12513	2	29	22490	141	168	30
ICP91/2507	0.9	8220	233	<0.2	26.7	146	<2	2	40290	28430	3	74	40260	213	85	30
ICP91/2508	0.8	7920	204	<0.2	14.6	152	<2	2	35740	24398	2	68	37350	185	91	28
ICP91/2528	1.5	10960	174	0.3	6.5	119	<2	<2	46010	7782	3	24	19740	753	217	39
ICP91/2529	1.7	10990	164	0.4	7.2	113	<2	61	43190	7344	2	22	18200	733	235	38
ICP91/2554	<0.2	4970	135	<0.2	5.4	132	<2	<2	28640	85600	3	114	21530	215	120	24
ICP91/2555	<0.2	5440	139	<0.2	5.7	131	<2	6	28010	89900	4	116	20750	225	151	26
ICP91/2575	0.9	5460	215	<0.2	4.6	150	<2	<2	29500	20838	2	40	24140	162	116	26
ICP91/2576	0.9	6390	243	<0.2	6	160	<2	<2	27070	21082	3	45	23930	145	129	26
ICP91/2598	1	11330	227	<0.2	5.4	173	<2	7	38930	21721	2	51	38000	100	242	29
ICP91/2599	0.9	10930	214	<0.2	4.3	166	<2	7	37890	21848	<2	51	36190	97	245	29
ICP91/2626	0.6	7690	235	<0.2	9.7	149	<2	<2	37950	29056	2	68	30160	143	74	30
ICP91/2627	0.2	8070	242	<0.2	6.9	146	<2	2	35900	26513	5	75	31250	195	77	34
ICP91/2647	<0.2	3070	272	<0.2	5.7	152	<2	<2	35020	54300	2	80	36350	160	71	26
ICP91/2648	<0.2	2890	244	<0.2	7.5	152	<2	<2	36030	65200	2	94	42680	137	51	23
ICP91/2673	<0.2	3980	197	<0.2	1.2	139	<2	<2	24600	72800	3	107	26190	208	115	30
ICP91/2674	<0.2	3290	201	<0.2	<0.2	125	<2	<2	22750	62325	9	106	25110	207	95	32
ICP91/2693	<0.2	5570	195	<0.2	8.5	167	<2	<2	42080	37841	<2	96	55650	95	39	18
ICP91/2694	<0.2	5500	187	<0.2	7.9	158	<2	<2	42120	38285	<2	95	54860	97	38	18

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Table 6 (cont'd): Laboratory Duplicates - concentrations in ash determined by ICP-ES

Packet Number	Ag icp ppm	Al icp %	B icp ppm	Be icp ppm	Cd icp ppm	Cu icp ppm	Ga icp ppm	Li icp ppm	Mg icp %	Mn icp %	Mo icp ppm	Ni icp ppm	P icp %	Pb icp ppm	Ti icp ppm	V icp ppm
ICP91/2711	0.3	6920	187	<0.2	16.5	126	5	<2	31770	34114	2	65	24800	154	166	23
ICP91/2712	0.2	7410	196	<0.2	17.9	132	3	2	33970	37336	2	68	26340	164	180	25
ICP91/2726	<0.2	6060	219	<0.2	11.7	178	<2	<2	23730	47727	3	84	50790	175	86	27
ICP91/2727	<0.2	5610	224	<0.2	9.2	154	<2	<2	26040	57600	2	83	47920	151	68	24
ICP91/2750	0.8	8570	190	<0.2	<0.2	157	8	2	37670	16164	<2	39	30330	88	161	20
ICP91/2751	1.1	8300	179	<0.2	<0.2	154	8	2	37540	14565	<2	36	28660	81	152	19
ICP91/2774	<0.2	9520	245	<0.2	10.5	185	<2	2	30450	80917	2	115	30080	170	227	31
ICP91/2775	<0.2	9410	237	<0.2	11	188	<2	2	30090	70100	2	116	29680	168	222	31
ICP91/2798	1.3	6140	238	<0.2	2.4	191	6	<2	43700	15238	<2	39	59590	107	97	18
ICP91/2799	1.3	6220	239	<0.2	2.4	195	5	<2	44010	14874	<2	35	60410	110	101	18
ICP91/2815	1.3	10690	228	<0.2	10.4	179	9	4	33400	19843	<2	46	46800	116	270	28
ICP91/2816	1.1	10780	229	0.2	12.8	171	9	4	27080	13915	2	36	46410	96	196	23
ICP91/2835	1.4	12270	180	<0.2	12.9	235	9	6	34920	20932	3	40	30170	136	453	35
ICP91/2836	1.4	13320	191	<0.2	15.4	248	9	6	37110	22054	2	40	31820	155	502	37
ICP91/2842	1.6	4940	231	<0.2	8.2	221	10	4	33200	13770	3	27	23080	363	220	31
ICP91/2843	1.8	4530	216	<0.2	9	208	11	3	31420	12642	3	26	21530	361	198	30
ICP91/2863	0.9	6630	166	<0.2	12	131	11	<2	26000	16358	2	49	27410	70	97	16
ICP91/2864	0.9	6760	171	<0.2	12.1	133	11	<2	26770	16958	2	51	28000	72	97	16
ICP91/2886	0.7	6190	199	<0.2	17.5	124	12	<2	24280	31048	3	55	21710	157	67	24
ICP91/2887	0.7	6340	203	<0.2	18.2	126	12	<2	24670	42100	3	56	22360	160	67	24
ICP91/2919	0.9	8550	204	<0.2	5.7	177	<2	3	51030	24430	<2	55	37800	106	169	26
ICP91/2920	0.9	8080	194	<0.2	6.5	173	<2	3	49830	23911	<2	52	36420	95	159	25
ICP91/2942	<0.2	7190	188	<0.2	14	179	<2	5	20450	71000	5	105	29040	281	139	35
ICP91/2943	<0.2	7130	199	<0.2	13.8	193	<2	5	20050	66700	5	106	34630	266	126	34

Table 7: Determination Limits and Substitution Values for Elements Analysed by INA

Element		Units of Measure	Determination Limit	Substitution Value
Gold	Au	ppb	5	2.5
Arsenic	As	ppm	0.5	0.25
Barium	Ba	ppm	10	*
Bromine	Br	ppm	1	*
Calcium	Ca	%	0.2	*
Cobalt	Co	ppm	1	*
Chromium	Cr	ppm	1	*
Cesium	Cs	ppm	0.5	0.25
Iron	Fe	%	0.05	*
Hafnium	Hf	ppm	0.5	0.25
Potassium	K	%	0.05	*
Sodium	Na	ppm	10	*
Rubidium	Rb	ppm	5	*
Antimony	Sb	ppm	0.1	0.05
Scandium	Sc	ppm	0.1	*
Selenium	Se	ppm	2	1
Strontium	Sr	ppm	300	150
Tantalum	Ta	ppm	0.5	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	*
Lanthanum	La	ppm	0.1	0.05
Cerium	Ce	ppm	3	1.5
Neodymium	Nd	ppm	5	2.5
Samariam	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

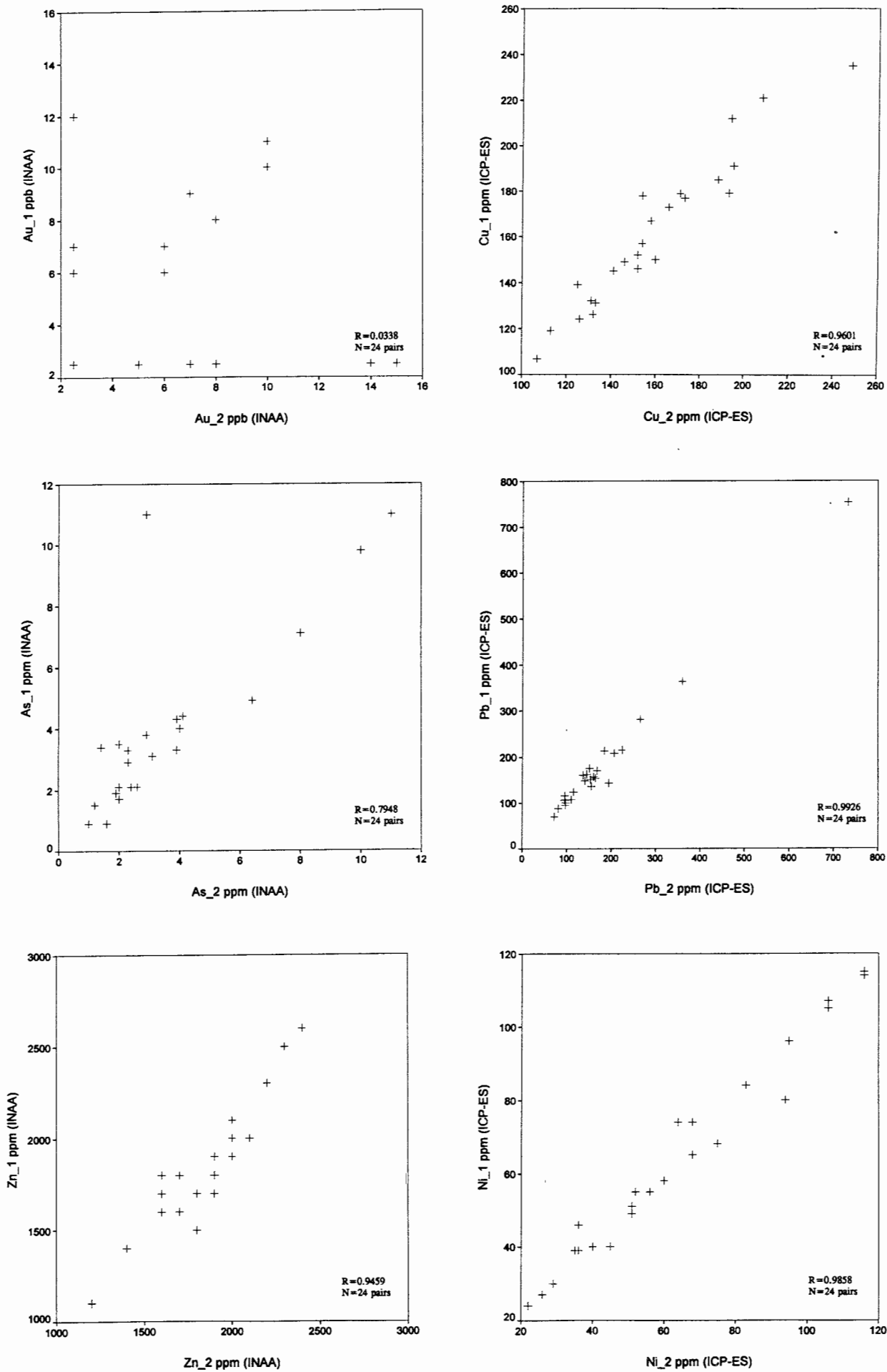
\* all values above the determination limit

Table 8: Determination Limits and Substitution Values for Elements Analysed by ICP-ES

Element		Units of Measure	Determination Limit	Substitution Value
Silver	Ag	ppm	0.2	0.1
Aluminum	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	*
Gallium	Ga	ppm	2	1
Lithium	Li	ppm	2	1
Magnesium	Mg	ppm	10	*
Manganese	Mn	ppm	1	*
Molybdenum	Mo	ppm	2	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

**Fig. 2: Scatterplots of analytical duplicate pairs for Au, As, Zn by INAA and Cu, Pb, and Ni by ICP-ES**



## GEOLOGY

### Bedrock and Mineralization

The geology of southeast Cape Breton Island is very complex. The area is heavily faulted, and correlating stratigraphic units is very difficult (c.f. Barr and Raeside, 1989; Keppie, 1990).

The late Precambrian rocks have been divided into three major groups. Weeks (1954) identified the George River Group and Fourchu Group. Barr et al. (1989) re-assigned part of the Fourchu Group to a new unit, which they termed the Main-à-Dieu sequence. The George River Group is a metasedimentary sequence of quartzites and marbles. The Fourchu Group is a predominantly metavolcanic sequence, with minor metasediments. It outcrops in a series of fault-bounded blocks, with a pronounced northeast-southwest orientation. The Main-à-Dieu sequence is distinguished from adjacent Fourchu Group rocks by a predominant sedimentary component and weaker cleavage.

Overlying the Precambrian rocks is a sequence of sedimentary and minor volcanic rocks of late Precambrian to Ordovician age. South of Marion Bridge, Barr et al. (1992) identified two distinct sequences separated by a major fault running along the Mira River. The Devonian-Carboniferous L'Ardoise Block is an allochthonous sedimentary unit. The poorly exposed McAdam Lake Formation is of similar age and lithology.

Carboniferous sediments occur throughout the area. Gibling et al. (1987) recognised two fining-upward megasequences. The Horton, Windsor and Canso Groups comprise the lower sequence. The coal-bearing Morien Group comprises the upper sequence.

Plutonic rocks occur throughout the area. The majority of the plutons are late Precambrian to Cambrian in age. The Salmon River, Gillis Mountain and Deep Cove plutons are Devonian. Compositionally, the larger plutons are acidic (granite, granodiorite), and the smaller plutons range from acidic to basic (gabbro).

There are three large abandoned mines in the area - the Mindamar Mine at Stirling (Zn-Pb-Cu massive sulphide deposit), the Yava Mine on the Salmon River (sandstone-hosted Pb; Sangster and Vaillancourt, 1990; MacDonald et al., 1991) and the Coxheath Mine (porphyry Cu; Oldale, 1967). Other notable deposits include the polymetallic Cu-Mo prospects at Deep Cove, Blue Mountain and Gillis Mountain (Macdonald, 1989), and the Copper Shaft Cu-Bi occurrence. Northeast of Loch Lomond there are several open pits producing celestite ( $\text{SrSO}_4$ ) - e.g. the Kaiser deposit. Locations of these mineral occurrences are shown on the colour overlay for the element distribution maps.

## 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:

- Barr, S.M., Macdonald, A.S. and White, C.E. (1988). The Fourchu Group and associated granitoid rocks, Coxheath Hills, East Bay Hills, and southwestern Stirling and coastal belts, southeastern Cape Breton Island, Nova Scotia. GSC Open File 1759.
- Barr, S.M., Macdonald, A.S. and White, C.E. (1989). Geological maps of the coastal and Stirling belts, southeastern Cape Breton Island, Nova Scotia. GSC Open File 1988.
- Barr, S.M., O'Reilly, G.A. and O'Beirne, A.M. (1982). Geology and geochemistry of selected granitoid plutons of Cape Breton Island. N.S. Dept. Mines and Energy, Paper 82-1.
- Barr, S.M. and Setter, J.R.D. (1984). Geological map of the Boisdale Peninsula, central Cape Breton Island. N.S. Dept. Mines and Energy, Map 84-2.
- Barr, S.M. and Setter, J.R.D. (1986). Petrology of granitoid rocks of the Boisdale Peninsula, central Cape Breton Island, Nova Scotia. N.S. Dept. Mines and Energy, Paper 84-1.
- Boehner, R.C. and Giles, P.S. (1986). Geological map of the Sydney Basin, Cape Breton Island. N.S. Dept. Mines and Energy, Map 86-1.
- Boehner, R.C. and Prime, G. (1985). Geology, Loch Lomond basin and Glengarry half graben. N.S. Dept. Mines and Energy Map 85-2.
- 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.
- Keppie, J.D., Dostal, J. and Murphy, J.B. (1979). Petrology of the late Precambrian Fourchu Group in the Louisbourg area, Cape Breton Island. N.S. Dept. Mines, Paper 79-1.
- Keppie, J.D. and Smith, P.K. (1978). Age of igneous rocks along the Lennox Passage - St. Peters lineament, southern Cape Breton Island. N.S. Dept. Mines Paper 78-2.
- Macdonald, A.S. (1989). Metallogenic studies, southeastern Cape Breton Island. N.S. Dept. Mines and Energy Paper 89-1.
- Smith, P.K. (1978). Geology of the Giant Lake area, southeastern Cape Breton Island, Nova Scotia. N.S. Dept. Mines, Paper 78-3.
- Weeks, L.J. (1954). southeast Cape Breton Island, Nova Scotia. GSC Memoir 277.
- Weeks, L.J. (1958). Mira map sheet. GSC Map 1056A.
- Weeks, L.J. (1954). Framboise map sheet. GSC Map 1037A.



## 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.

Grant (1988) and MacDonald et al. (1991) recognize four periods of Wisconsinan ice flow in the study area. The oldest was toward the south, followed by flows to the east, then north, and finally toward the south once more. Most of the survey area is covered by a veneer of sandy and silty red or grey tills. Recent work by McClenaghan et al. (1992) presents comprehensive summaries of till geochemical data and pebble lithologies within approximately 50% of the biogeochemical survey area.

## 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 SPARCMAP geochemical mapping software used by the Applied Geochemistry Subdivision of the GSC. Computations were performed on a UNIX workstation, 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 Natural Resources Canada. For the small scale maps, the digital data were purchased from the National Atlas Information Service (NAIS). These data were derived from 1:2 000 000 scale original maps. Features are accurate to about 200 m. This led to some samples which were collected near lakes or the ocean being plotted in the water. The 1:125 000 map was plotted from data purchased from the Canada Centre for Geomatics. These data were derived from the 1:250 000 NTS map sheets, and therefore are much more accurate than the NAIS data. They contain too much detail to be useful as base maps at a scale of 1:500 000.

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

The dot maps are based on a method first developed by Bjorklund and Gustavsson (1987). It was used as the primary data presentation method for 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).

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

Interpretation of the element distribution maps requires some consideration of the role of chemical elements in plant function. Some comments are given in this section to assist in this interpretation. These notes deal first with those elements determined by INAA, followed by those determined by ICP-ES. This sequence is the same as the element listings in Appendix A and the statistical summary in Appendix B.

For determinations by INAA, elements are arranged alphabetically by chemical symbol, except for the rare earth elements (REE) arranged in order of increasing atomic weight - i.e. La, Ce, Nd, Eu, Sm, Yb, as is conventional for REE listings. For determinations by ICP-ES, elements are arranged alphabetically by chemical symbol.

### Transparent Overlay

A transparent overlay at the same scale as the element distribution maps is provided to help locate individual samples (identified by sample number on the folded 1:250 000 scale colour map), and to relate their positions to main communities, bedrock geology, mineral deposits and showings. Detailed geology is provided as a large colour map, and additional place names are shown on Fig. 1.

## ***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 balsam fir twigs are commonly less than 5 ppb Au, as occurs in this data set. Because of the low (ppb) traces of Au that are present, the precision of the INAA on duplicate pairs is not as good as that of most other elements determined by this method, and at concentrations below 10 ppb Au the reproducibility of the analyses is poor. In general, Au concentrations in the study area are low, but local clusters of samples with Au enrichment occur at a few locations, notably over Carboniferous Morien Group sediments southeast of Sydney and around the abandoned Stirling mine. Highest concentrations (> 50 ppb Au) occur on the east side of Lac Bras d-Or, and at an isolated location 10 km southeast of Sydney. Relative enrichment of Au occurs at several sites along a northeasterly trend through the Yava deposit, close to the contact between sediments of the Windsor and Morien groups.

### **Arsenic (As)**

Arsenic is renowned for its toxicity, yet some tree species can accumulate extraordinary amounts without exhibiting any visible harmful effects (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. Of note is the relative enrichment of As in samples from over the Morien Group, indicating either elevated levels in the bedrock or contamination from the industry on the east coast around Glace Bay.

### **Barium (Ba)**

All samples yielded substantially more barium than the INAA detection limit of 10 ppm Ba. Balsam fir twigs commonly contain 1000 ppm Ba, but concentrations within the map area range up to 6700 ppm. Highest concentrations occur mostly in samples from over the Carboniferous sediments (p. B4), with notable regional enrichment over the northwestern half of the survey area.

### **Bromine (Br)**

Bromine is a volatile element, present in most, if not all terrestrial plants, but it is not known to be an essential element. It can be complexed in many forms within plants. Some complexes volatilize during the ashing process, causing losses of 30 - 90 percent of the Br contained within the plant tissues. Samples with highest Br content occur in the southeastern half of the survey area over Lower Palaeozoic and Hadrynian rocks. Studies elsewhere (Dunn, 1986) have noted that where there is gold mineralization there is sometimes enrichment of Br in plant ash, indicating that a stable Br compound is retained.

### **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 twigs may influence the distribution of some trace elements (e.g. Zn, Ba). The median Ca content of twig samples from trees growing over Morien Group rocks is slightly lower than elsewhere in the study area.

### **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 (Kabata-Pendias and Pendias, 1984), 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). Throughout southeastern Cape Breton Island the Co concentrations in balsam fir are generally low, with the median value at only 5 ppm Co, and the 98th percentile at 11 ppm Co. Clusters of relative Co enrichment occur over sediments of the Morien Group to the east of Glace Bay, and south of Loch Lomond in the southwestern part of the study area near the contact between Devonian-Carboniferous clastic sediments and Fourchu Group volcanoclastic rocks.

### **Chromium (Cr)**

Chromium is a non-essential element for which precise INAA data are obtained at low ppm levels. Concentrations are mostly within the normal range for balsam fir twigs of 10 - 20 ppm Cr (median value for southeastern Cape Breton of 15 ppm Cr). A northeasterly trend of strong Cr enrichment (up to 99 ppm Cr) occurs in the centre of the study area at the contact between sedimentary rocks of Carboniferous age (Morien and Windsor groups) and an older pluton to the south. This linear trend of metal enrichment is apparent for several elements, notably Fe, Pb, U, Th, Sc, Hf, REE and, to a lesser degree, Au.

### **Cesium (Cs)**

This alkali metal performs no known essential function in plant tissues, and conifer twig ash usually contains less than 3 ppm Cs. The median value for this data set is only 1.6 ppm Cs. Clusters of samples with Cs enrichment (up to 140 ppm Cs) occur over the Proterozoic and Cambro-Ordovician sediments and volcanic rocks in the centre of the study area. There is a close geochemical affinity between Cs and Rb in most rock types, but in plant tissues the two elements behave differently. Consequently, there are appreciable differences between the distribution patterns shown in the Cs and Rb maps.

### **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 shows similar distribution to that of Cr, U, Th, REE, Sc, Hf and to a lesser extent Al, Ta, Pb,

As and Au. This suite of elements is characteristic of the 'iron factor' commonly found in plant tissues (Dunn, in press). There is notable Fe enrichment in balsam fir on Morien Group sediments.

### **Hafnium (Hf)**

The content of Hf in the ash of conifer twigs is commonly 1 - 2 ppm Hf, except for higher values where the Fe concentration is high due to the strong association that Hf commonly has with Fe. This geochemical coherence is evident from the maps of both Hf and Fe.

### **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 important in the overall metabolism of plants.

The high concentrations present in balsam fir twigs (median of 20.3%) are normal levels. In environments where there is an abundance of K (e.g. K-rich clays or felsic rocks), trees may concentrate unwanted amounts in their tissues. No such K-enrichment is evident from the map of K distribution.

### **Sodium (Na)**

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

### **Rubidium (Rb)**

Although Rb may substitute for K in rock-forming minerals, there is an antagonism between K and Rb in plants (Kabata-Pendias and Pendias, 1984). This results from their competition for the same binding sites, thereby causing different distribution patterns for the two elements. Background levels of Rb in the ash of balsam fir twigs are normally close to 200 ppm and several hundred ppm is not uncommon. Clusters of relative enrichment occur near Mira River and 20 km east of St. Peters, mostly over pre-Carboniferous rocks.

### **Antimony (Sb)**

Excellent analytical precision is obtained by INAA for sub-ppm levels of Sb. 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, and at less than 1 ppm Sb in the ash of balsam fir twigs. Clusters of samples with very weak enrichment of Sb (98th percentile of only 1.7 ppm) occur mostly over rocks of the Morien Group.

### **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 conifer twigs is controlled essentially by the chemistry of the substrate and by the distribution of other

elements. The near perfect correlation between Sc and Fe commonly found in plant tissues is apparent from a comparison of the Fe and Sc maps, although there appears to be some partitioning of these elements over Morien Group rocks near Glace Bay.

### **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 twig ash does not represent the total content of the dry tissue, although the residual Se commonly bears a significant relationship to zones of Au mineralization. This was particularly notable in southeastern Nova Scotia (Dunn, 1988). The dominant feature of the Se map is the relative enrichment that occurs in samples from the eastern part of the survey area.

### **Strontium (Sr)**

Strontium is 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.

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 the determination level of 300 ppm Sr in all but three samples. Concentrations of approximately 1000 ppm Sr are common for the ash of balsam fir twigs, and the median value for this data set is 1100 ppm Sr. Unusual enrichment of Sr (maximum of 11000 ppm) occurs in samples from over sedimentary rocks of the Windsor Group.

### **Tantalum (Ta)**

Conifer twigs rarely contain more than 1 ppm Ta in ash. Within the survey area the median value for the data set is below the determination limit for Ta (0.5 ppm), and the 95th percentile is 1.0 ppm Ta. Sites that exhibit weak Ta enrichment are clustered over rocks of the Cambro-Ordovician Kelvin Glen Group near the Mira River. There is a broad similarity in the distribution patterns of Ta and Fe.

### **Thorium (Th)**

Thorium has low solubility and is not essential for plant growth. Its concentration in plant ash is typically < 2 ppm, 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 a pronounced northeasterly trend of relative Th enrichment extending from Loch Lomond to Glace Bay in samples from sites close to the

contact between sedimentary rocks of the Windsor and Morien groups, and the older 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 three orders of magnitude greater (Dunn, 1983). In southeastern Cape Breton 75 percent of samples yielded less than the determination limit of 0.1 ppm U. The few samples that yielded more than 1 ppm U indicate a similar distribution pattern to those of Th and Fe.

### **Tungsten (W)**

The detection limit for W by INAA is 2 ppm in ash, which is above the usual concentration in tree tissues. Furthermore, the analytical precision at low levels of W concentration is poor. This accounts for the 'spotty' appearance of isolated W enrichments which do not follow any clear trends.

### **Zinc (Zn)**

Zinc is essential for carbohydrate and protein metabolism, therefore 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 almost 5000 ppm Zn indicating that the regional pattern of Zn distribution is reflecting broad differences across the area. Most of the highest Zn concentrations are clustered near the abandoned Stirling mine and to the southwest.

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

Because of their chemical coherence, these elements are considered as a separate 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, which closely parallel those of Fe, Cr, U, Th, Sc, Hf and to a lesser extent Al, Ta, Pb, As and Au. Relatively high concentrations occur over rocks of the Morien Group to the southeast of Glace Bay.

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

### **Silver (Ag)**

Silver is not known to be essential to plant life, and can become toxic to plants by substituting for K in membranes and thereby inhibiting the absorption of other cations by roots (Hendrix and Higinbotham, 1974). However, at the few ppm concentrations present within the

study area (and most natural environments) the inhibiting effects of Ag on the uptake of other elements is insignificant. The 50th percentile value of 0.6 ppm Ag in the balsam fir twigs is normal for plant ash, and substantially lower than the 50th percentile in the same sample medium from southwestern Nova Scotia. The maps of Ag distribution shows that many of the higher concentrations occur in the northeastern part of the Boisdale peninsula, near the Coxheath mine, and associated with volcanic rocks of the Fourchu Group along the southern shore of Bras D'Or Lake and around the Stirling Mine. The highest concentration (15.6 ppm Ag at site 3019) is an isolated single element anomaly, at the southern end of the Mira River.

### **Aluminum (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 and the high levels of Al in the samples 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 an ash internal standard 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.

There is close similarity to the distribution pattern of Fe (and Fe-related elements - see section on iron), with one of the more notable trends being northward from Louisbourg.

### **Boron (B)**

Borosilicate test tubes were used for the acid digestion of the ash samples, from which analytical tests indicate that 5 - 10 ppm B may be released. This is an insignificant amount in comparison with the 100s ppm 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 few samples were from carbonate terrain. The range of B concentrations is normal for the ash of balsam fir twigs.

### **Beryllium (Be)**

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 balsam fir twigs by sub-ppm levels in ash. Analytical precision is good to the 0.5 ppm Be level, but only 3 samples yielded Be concentrations above this level. The two clusters of samples with very weak Be enrichment occur at locations where there are elevated levels of Al, probably reflecting the characteristic geochemical affinity of the two elements.



### **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. Absolute concentrations differ among plant species because Cd can be captured by a variety of organic compounds in cell walls and therefore not all Cd is transported to tree extremities.

Within the survey area there are some high concentrations of Cd, especially over sedimentary rocks of the Windsor Group. Cadmium enrichment occurs at the Stirling and Yava deposits, and high levels elsewhere may be indicative of base metal enrichment in the substrate.

### **Copper (Cu)**

Data obtained by ICP-ES from the aqua regia leach are both precise and accurate. Copper plays a fundamental role in plant metabolism. It assists in 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 balsam fir twigs (median value of 164 ppm Cu) is high compared to many trace elements.

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. Only two isolated sites yielded anomalous levels of Cu - 911 ppm Cu at site 3038 (5 km south of the Kaiser celestite occurrence), and 1585 ppm Cu at site #3067, approximately 30 km west of St. Peters. Clusters of samples with relatively high Cu concentrations occur south of the Stirling deposit and around the Coxheath mine.

### **Gallium (Ga)**

There are few data available on the biogeochemistry of Ga, and the accuracy of the data obtained by ICP-ES on the present samples is uncertain. However the precision is adequate, and some distinct regional patterns of distribution are apparent, with notable enrichment in the northwestern half of the survey area. Highest concentrations (up to 72 ppm Ga) occur in samples from over the clastic sedimentary rocks of L'Ardoise Block in the southwest.

### **Lithium (Li)**

Lithium commonly follows Rb and Cs in nature. In plant tissues it is usually less

abundant than Rb but enriched with respect to Cs. It is not known to be essential to plant metabolism, and its high solubility (except where firmly bonded to clay minerals) causes Li enrichment in soils and waters to be readily reflected in plant tissues. Most of the samples with relative enrichment in Li occur in the east and are coincident with anomalous levels of Al, and some with Be. The sample with the highest Li content (61 ppm at site #2022) yielded <2 ppm in a second split of the ash.

### **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. The statistical analysis of the data shows there to be no appreciable difference in the Mg content of the twigs from trees growing over different rock types.

### **Manganese (Mn)**

Manganese is highly enriched in balsam fir twigs. Locally there is up to 12% Mn in ash from samples in the survey area. It 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. There is a general antipathetic relationship of Mn to Fe throughout the survey area.

### **Molybdenum (Mo)**

Molybdenum in trace amounts is required by most plants for nitrogen fixation and nitrate reduction. Concentrations are usually <2 ppm Mo in conifer twigs, although over highly alkaline soils the trees are more readily able to absorb Mo and therefore slightly higher levels may be expected. No notable enrichment of Mo is apparent, although there is relative enrichment over clastic sediments of the Morien Group in the northeast.

### **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 twigs is 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 (14 ppm) recorded for this data set. Concentrations of Ni are moderately high in the southwest over clastic sediments of L'Ardoise Block and to the northeast of Mira River (clastic rocks of the Morien Group).

## **Phosphorus**

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, and 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). Local clusters of samples with anomalous concentrations of Pb occur in the northeastern part of the survey area (southwest of Sydney); as a linear trend in the vicinity of the Yava deposit (reinforcing the findings of Fortescue and Hornbrook, 1969); and around the abandoned Stirling mine. In general, samples from over the Windsor and Morien groups are relatively enriched in Pb.

## **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 broad similarity between the distribution patterns of Ti, Fe, and Fe-related elements.

## **Vanadium (V)**

Although V is detectable in all of the twig 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. There is a similarity between the distribution patterns of V and Fe. Relative enrichment of V occurs near Louisbourg.

## **Other Elements**

Each sample was analyzed for iridium and mercury. All Ir analyses showed concentrations of less than 2 ppb, suggesting a lack of platinum-group element enrichment in the area. All Hg analyses yielded 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 suggested 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 field data and all analytical data obtained for the balsam fir twig 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 9 and 10.

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Table 9: 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.
Twig Min Age Twig Max Age	The minimum age of each length of twig collected. The maximum age of each length of twig collected.
Slope	0 = flat ground 1 = slight incline followed by downward compass direction (e.g. 1N = slight downward incline to the north) 2 = moderate incline 3 = steep incline
Forest Type	Type of vegetation cover and degree of surface water saturation.

Table 10: Abbreviations Used in Appendix B

Rock Type	Underlying bedrock lithology (derived from published geological maps):  ign - igneous plutons Cm - Carboniferous Morien Group Cw - Carboniferous Windsor and Canso Groups Ch - Carboniferous Horton Group D-C - Devono-Carboniferous C-O - Cambro-Ordovician Hmd - Hadrynian Main-à-Dieu Group Hf - Hadrynian Fourchu Group
N dl Cum %	N = number of samples dl = determination limit Cum % - cumulative frequency (as a percentage)

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