



GEOLOGICAL SURVEY OF CANADA
OPEN FILE 3344

Reconnaissance biogeochemical survey of
southwestern Cape Breton Island, Nova Scotia,
using balsam fir twigs
(NTS 11F/14, and parts of 11F/10, 11, 15)

C.E. Dunn, R.G. Balma

1997

COOPERATION

COOPERATION
AGREEMENT ON
MINERAL DEVELOPMENT

ENTENTE DE
COOPÉRATION SUR
L'EXPLOITATION MINÉRALE

Contribution to Canada-Nova Scotia Cooperation Agreement on Mineral Development (1992-1995), a subsidiary agreement under the Economic and Regional Development Agreement.

Contribution à l'Entente de coopération Canada-Nouvelle-Écosse sur l'exploitation minérale (1992-1995), entente auxiliaire négociée en vertu de l'Entente Canada-Nouveau-Brunswick de développement économique et régional.

Canada

Nova Scotia

Province of
Nova Scotia



GEOLOGICAL SURVEY OF CANADA
OPEN FILE 3344

Reconnaissance biogeochemical survey of
southwestern Cape Breton Island, Nova Scotia,
using balsam fir twigs
(NTS 11F/14, and parts of 11F/10, 11, 15)

C.E. Dunn, R.G. Balma

1997



Natural Resources
Canada

Ressources naturelles
Canada

Canada

COOPERATION

COOPERATION
AGREEMENT ON
MINERAL DEVELOPMENT

ENTENTE DE
COOPÉRATION SUR
L'EXPLOITATION MINÉRALE

Contribution to Canada-Nova Scotia Cooperation Agreement on Mineral Development (1992-1995), a subsidiary agreement under the Economic and Regional Development Agreement.

Contribution à l'Entente de coopération Canada-Nouvelle-Écosse sur l'exploitation minérale (1992-1995), entente auxiliaire négociée en vertu de l'Entente Canada-Nouveau-Brunswick de développement économique et régional.

Canada

Nova Scotia



Province of
Nova Scotia

CONTENTS

INTRODUCTION 1

CREDITS 2

SURVEY DESCRIPTION AND METHODOLOGY 3

 SCOPE OF SURVEY 3

 SAMPLE COLLECTION 3

 SAMPLE PREPARATION AND ANALYSIS 4

 ANALYTICAL QUALITY CONTROL 4

GEOLOGY 13

 BEDROCK GEOLOGY 13

 MINERALIZATION 13

 QUATERNARY DEPOSITS..... 17

MAP PRODUCTION AND DATA HANDLING 18

ELEMENT DISTRIBUTION MAPS..... 19

 TRANSPARENT OVERLAYS..... 22

 DISTRIBUTION MAPS OF ELEMENTS DETERMINED BY INAA..... 22

Gold (Au) 22

Arsenic (As)..... 22

Barium (Ba) 24

Bromine (Br) 24

Calcium (Ca)..... 24

Cerium (Ce): see Lanthanum and other Rare Earth Elements 24

Cobalt (Co) 24

Chromium (Cr)..... 25

Cesium (Cs)..... 25

Europium (Eu): See Lanthanum and other Rare Earth Elements..... 25

Hafnium (Hf)..... 25

Potassium (K)..... 26

Lanthanum (La) and other Rare Earth Elements [REE]..... 26

Lutetium (Lu):See Lanthanum and other Rare Earth Elements 26

Molybdenum (Mo)..... 26

Sodium (Na) 26

Neodymium (Nd): See Lanthanum and other Rare Earth Elements..... 26

Rubidium (Rb)..... 26

Antimony (Sb)..... 27

Scandium (Sc) 27

Selenium (Se) 27

Samarium (Sm): See Lanthanum and other Rare Earth Elements 27

Strontium (Sr)..... 27

Thorium (Th)..... 28

Uranium (U)..... 28

Ytterbium (Yb): See Lanthanum and other Rare Earth Elements 28

Zinc (Zn)..... 28

 DISTRIBUTION MAPS OF ELEMENTS DETERMINED BY ICP-ES 28

Aluminum (Al)..... 28

Boron (B) 29

Cadmium (Cd)..... 29

Copper (Cu) 29

Lithium (Li) 30

Magnesium (Mg) 30

Manganese (Mn) 30

Nickel (Ni) 30

Phosphorus (P) 31

Lead (Pb) 31

Vanadium (V) 31

 OTHER ELEMENTS: (TUNGSTEN, SILVER, BERYLLIUM)..... 31

NOTES ON THE BIOGEOCHEMICAL DATA LISTINGS..... 32

ACKNOWLEDGEMENTS 32

REFERENCES 34

FIGURES

Fig. 1: Survey Area with Respect to NTS Map Sheets..... Facing p.1

Fig. 2: Map Showing Geological Units and Metallic Mineral Occurrences..... 14

Fig. 3: Digital Elevation Map Showing Main Physiographic Divisions 16

Fig. 4: Plot of Scores for Factor 4 (Au, Br, K) from factor analysis of data set.....23

TABLES

Table 1: Mean and Standard Deviation for Standard V6c Analyzed by INA 5

Table 2: Mean and Standard Deviation for Standard V6c Analyzed by ICP-ES 5

Table 3: Standard V6c - concentrations in ash determined by INAA 6

Table 4: Standard V6c - concentrations in ash determined by ICP-ES..... 7

Table 5: Laboratory Duplicates - concentrations in ash determined by INAA 8

Table 6: Laboratory Duplicates - concentrations in ash determined by ICP-ES 10

Table 7: Determination Limits for Elements Analyzed by INAA 12

Table 8: Determination Limits for Elements Analyzed by ICP-ES 12

Table 9: Mean concentrations of elements in balsam fir twig ash from surveys in Nova Scotia: Determinations
by INAA.....20

Table 10: Mean concentrations of elements in balsam fir twig ash from surveys in Nova Scotia: Determinations
by ICP-ES.....21

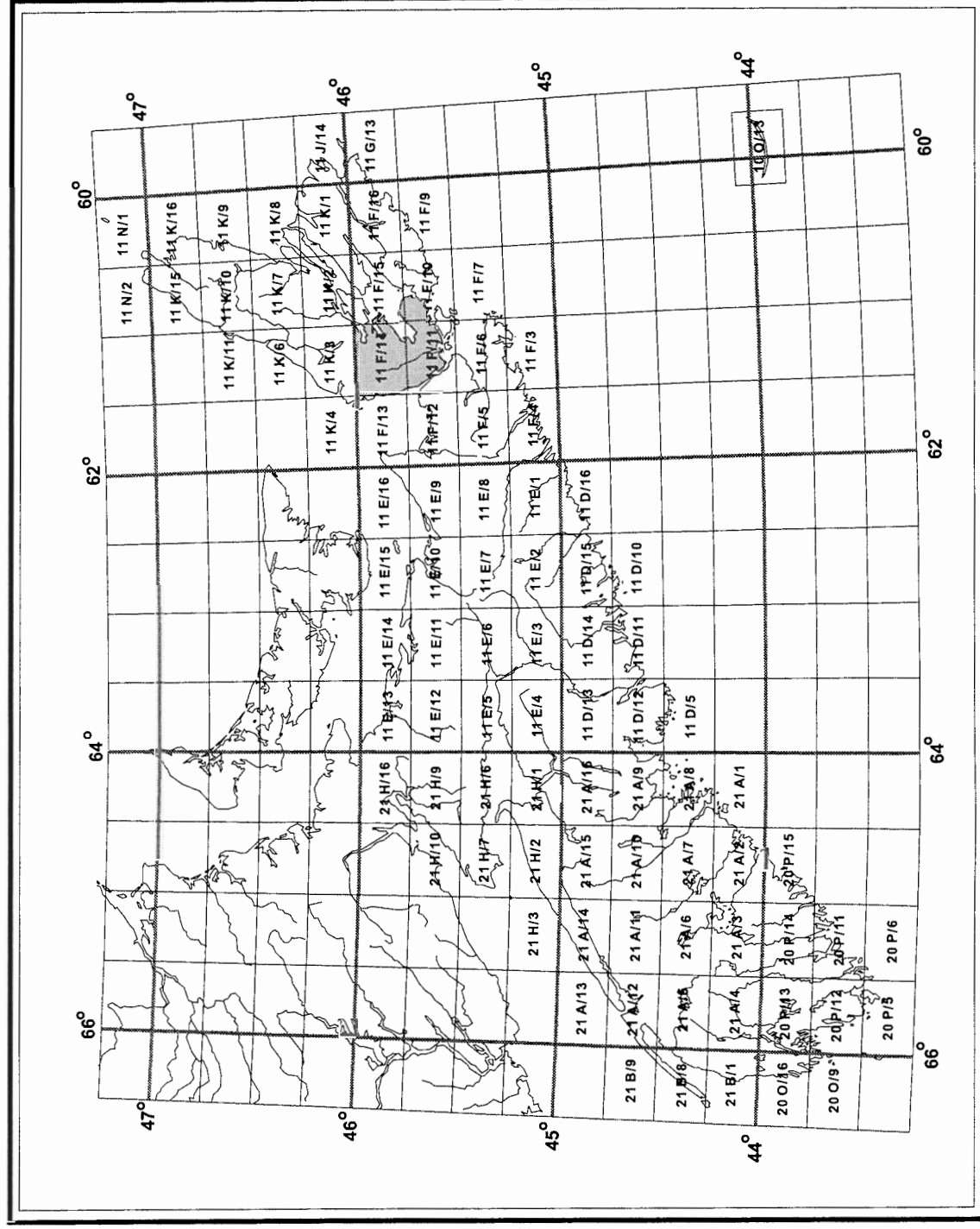
Table 11: Abbreviations used in Appendix A 33

Table 12: Abbreviations used in Appendix B 33

Appendix A - Data Listings (Field and Analytical)..... A1

Appendix B - Statistical Summary B1

Appendix C - Element Distribution Maps and Overlay of Sample Sites, with Geological Contacts, Mineral
Occurrences and Main Communities; Colour Geology and Sample Location..... in envelope



RECONNAISSANCE BIOGEOCHEMICAL SURVEY OF SOUTHWESTERN CAPE BRETON ISLAND, NOVA SCOTIA, USING BALSAM FIR TWIGS

C.E.Dunn and R.G. Balma

ABSTRACT

Samples of balsam fir twigs were collected from 365 locations within a 1600 sq. km area of southwestern Cape Breton Island. Once stripped of their needles, the twigs were reduced to ash by controlled ignition and analysed by instrumental neutron activation for 36 elements. Of these, 28 elements were in sufficient concentration to be detected and quantified. A second portion of each ash sample was digested in aqua regia and the solution analysed by inductively coupled plasma emission spectrometry for approximately 30 elements. Data for 11 of these elements were sufficiently concentrated and precise to be added to the data set provided in this report.

In general, element concentrations in the balsam fir twigs are similar to those reported from surveys of similar magnitude elsewhere in Nova Scotia. Median concentrations of Au are higher than in other parts of the province, although no unusually high levels were found. Data analysis indicates a zone northward from Port Hastings where relatively high concentrations of Au occur in association with Br and K. Relatively high levels of the alkali metals Rb and Cs characterise the Craguish Hills. High concentrations of Ba, Cr, and Ni occur in a synclinal structure of clastic rocks comprising the Mabou Group, in the River Denys Lowlands. Along North Mountain, especially in the vicinity of the Lime Hill sphalerite occurrence, notable enrichment of Zn occurs with weak enrichment of Pb.

INTRODUCTION

This Open File contains data from a reconnaissance biogeochemical survey in southwestern Cape Breton Island (Fig. 1), conducted in June, 1995, by the Geological Survey of Canada under the Canada - Nova Scotia Co-operation Agreement on Mineral Development (1992 - 1995). Field observations, data listings, statistical summaries, a geological and sample location map, and element distribution maps are presented. The maps show element concentrations in the ash of twigs from balsam fir (*Abies balsamea*). Instrumental neutron activation analysis (INAA) was used for determining 36 elements, of which 28 were in sufficient concentration to be detected and quantified. In addition data are included for 11 elements determined by inductively coupled plasma emission spectrometry (ICP-ES). All data reported are concentrations in ash remaining after controlled ignition at 470°C. For balsam fir and other coniferous trees, reduction to ash is a concentration process with little or no loss of elements except for a few 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. Since 1987 reconnaissance biogeochemical surveys of similar magnitude to that reported here, also using balsam fir twigs, were conducted in other parts of Nova Scotia. Results were published as Open File reports (Dunn *et al.*, 1989; Dunn *et al.*, 1994a, 1994b; and Dunn *et al.*, 1996), and interpretative accounts are given in Dunn (1988, 1990), Rogers and Dunn (1989, 1993), and Dunn *et al.* (1991).

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

The Zn example illustrates that biogeochemical data should be interpreted with caution and the text notes provided for each element should be considered when evaluating results. Biogeochemistry is a complex science involving the interaction of organic and inorganic processes that are controlled by many physicochemical parameters. However, despite 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 groundwater.

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; Toll-free 1-888-252-4301
Fax: (613) 943-0646
Internet: gsc_bookstore@gsc.NRCan.gc.ca

The data will be supplied on an MS-DOS (IBM-PC) 3.5" 1.44 Mb diskette which can be read by any DBASE-compatible software, and as an ASCII comma-delimited file.

CREDITS

Survey design, direction, and sampling methodology: C.E.Dunn, in collaboration with G.E.M. Hall who planned and implemented a simultaneous hydrogeochemical survey.

Field party leader: R.G. Balma.

Sub-party leaders: P. Lombard (NSDNR), P. James and K. Slough, assisted by T.L. Hearty, L. Young, P. Pelchat, K. Simpson and J. Adams.

Sample Preparation: undertaken and supervised by T. Hearty, with the assistance of L. Young.

Data Management: R.G. Balma and W.A. Spirito.

Computer Programming: S.W.Adcock developed a program for the data and statistical listings presented in Appendices A and B.

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

Inductively-Coupled Plasma Emission Spectrometry: by contract to Acme Analytical Laboratories Ltd., Vancouver, B.C.

SURVEY DESCRIPTION AND METHODOLOGY

SCOPE OF SURVEY

During a three week period in June, 1995, balsam fir twig samples were collected from 365 sites within a 1600 km² area of south-western Cape Breton Island (Fig. 1). Samples were collected on as even a grid as was practically possible, attaining an average sample density of approximately 1 site per 4.5 km². In general, samples were collected at 2 km intervals along driveable roads and tracks, with some helicopter support for access to 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. Samples were located by using 1:50,000 NTS (National Topographic Survey) maps.

SAMPLE COLLECTION

The most common tree species in the survey area are balsam fir (*Abies balsamea*), white spruce (*Picea glauca*), and black spruce (*Picea mariana*). Earlier studies involving the chemical analysis of twigs from these species and the outer bark of the spruce indicated that each was sensitive to a particular range of elements, and that outer bark from black spruce had generally the highest concentrations of many trace metals. However, within the survey area black spruce is not evenly distributed, and therefore balsam fir was selected as the sample medium. The selection of balsam fir had the added advantage that comparative data were available for this species from other reconnaissance biogeochemical surveys conducted in Nova Scotia.

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 (less than 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 is commonly a 35 - 40 cm length of twig. The range of age in twigs from each site is given in the data listings (Appendix A). At a few sites where growth was more spindly (e.g. dense forest) and annual growth increments were shorter approximately 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 among sample locations, so if twigs are not separated from needles some false biogeochemical anomalies may be generated which are simply a function of different twig to needle ratios. Approximately 50 g of dry twigs was 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 36 elements. Maps are provided for 28 of these elements. Of the remaining 8 elements, concentrations were all, or mostly, below the determination levels (in parentheses) for Ag (2 ppm), Hg (1 ppm), Ir (2 ppb), Sn (50 ppm), Ta (0.5 ppm), and Tb (0.5 ppm). Reproducibility of data for W and Ni by INAA was poor at the low levels present (mostly <2 ppm W and 50 ppm Ni), therefore maps of W and Ni determinations by INAA are not presented.

Of the remaining ash sample, 0.25 g was submitted for aqua regia digestion and multi-element analysis by ICP-ES analysis. For most elements this extraction is near 'total', although for some (e.g. Al, B) it is only partial. However, the analytical precision was good for most elements, such that the element distribution patterns of relative concentrations 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 (V6c), 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 the standard ash sample are given in Tables 1 (INAA) and 2 (ICP-ES). Tables 3 and 4 contain the raw data from which these calculations were made. Tables 5 and 6 list the analytical data obtained by the two analytical methods on the duplicate pairs. With few exceptions the reproducibility of analytical data is excellent for most elements, attesting to the skills of the analysts and the good sample homogeneity. In house repeat ICP-ES analyses by Acme Laboratories indicated extremely good and consistent precision, suggesting that samples with some variation between analytical pairs probably have some heterogeneity.

Tables 7 and 8 show the determination (detection) limits quoted for each element by the analytical laboratories. Where concentrations in the survey samples were below determination limits, a value of half the limit was used for statistical calculations.

Table 1: Mean and Standard Deviation for Standard V6c Analyzed by INA (n=19)

Element			Mean	Standard Deviation
Arsenic	As	ppm	7.2	1.1
Gold	Au	ppb	17	5.2
Barium	Ba	ppm	381	24
Bromine	Br	ppm	12	1.1
Calcium	Ca	%	15.2	1.0
Cerium	Ce	ppm	39	1.6
Cobalt	Co	ppm	8.2	0.8
Chromium	Cr	ppm	68	3.5
Cesium	Cs	ppm	0.8	0.28
Europium	Eu	ppm	0.75	0.06
Iron	Fe	%	1.67	0.09
Hafnium	Hf	ppm	4.8	0.34
Potassium	K	%	3.48	0.27
Lanthanum	La	ppm	20	0.81
Lutetium	Lu	ppm	0.26	0.03
Molybdenum	Mo	ppm	4.8	1.1
Sodium	Na	ppm	10758	485
Neodymium	Nd	ppm	20	1.7
Rubidium	Rb	ppm	43	4.3
Antimony	Sb	ppm	1.1	0.07
Scandium	Sc	ppm	4.2	0.16
Samarium	Sm	ppm	2.9	0.11
Strontium	Sr	ppm	868	154
Thorium	Th	ppm	2.8	0.28
Uranium	U	ppm	1.3	0.23
Ytterbium	Yb	ppm	1.61	0.10
Zinc	Zn	ppm	722	24

Note: Statistics for Se are omitted because >90% of samples had concentrations below the determination limit of 2 ppm.

Table 2: Mean and Standard Deviation for Standard V6c Analyzed by ICP-ES (n=19)

Element			Mean	Standard Deviation
Aluminum	Al	%	1.12	0.06
Boron	B	ppm	154	14
Cadmium	Cd	ppm	3.0	0.16
Copper	Cu	ppm	132	18
Lithium	Li	ppm	7.1	1.9
Magnesium	Mg	%	2.04	0.10
Manganese	Mn	ppm	735	62
Nickel	Ni	ppm	69	4.1
Phosphorus	P	%	0.623	0.054
Lead	Pb	ppm	180	10
Vanadium	V	ppm	25	1

Table 3: Standard V6c - Concentrations in Ash Determined by INAA

Au ppb	As ppm	Ba ppm	Br ppm	Ca pct	Ce ppm	Co ppm	Cr ppm	Cs ppm	Eu ppm	Fe pct	Hf ppm	K pct	La ppm	Lu ppm	Mo ppm	Na ppm	Nd ppm	Rb ppm	Sb ppm	Sc ppm	Se ppm	Sm ppm	Sr ppm	Th ppm	U ppm	Yb ppm	Zn ppm
5*	0.5	10	1	0.2	3	1	1	0.5	0.01	0.05	0.5	0.05	0.1	0.05	2	10	5	5	0.1	0.1	2	0.1	300	0.1	0.1	0.05	20
10	7.3	380	11	18.0	38	8	65	0.8	0.64	1.65	4.6	3.41	20.0	0.26	5	10800	18	45	1.1	4.2	<2	2.9	850	3.2	1.1	1.42	700
16	11.0	360	13	15.1	40	9	71	0.8	0.71	1.68	4.6	3.40	21.0	0.26	5	10500	21	46	1.2	4.2	<2	3.1	820	3.1	0.9	1.64	720
14	7.2	400	12	15.6	40	8	70	0.6	0.78	1.68	4.9	3.50	20.0	0.28	5	10900	20	47	1.1	4.2	<2	2.9	850	2.8	1.2	1.66	720
12	7.3	400	11	14.9	42	9	74	0.7	0.86	1.89	5.1	3.56	21.0	0.30	6	10800	23	40	1.0	4.4	<2	2.9	1100	3.1	1.3	1.76	710
16	7.1	380	11	13.7	38	8	75	0.8	0.79	1.74	4.8	3.58	18.0	0.32	7	10100	19	41	1.0	4.1	<2	2.6	900	2.3	0.8	1.70	700
18	6.5	400	12	15.9	39	7	70	0.8	0.72	1.66	4.9	3.27	21.0	0.25	5	11200	19	38	1.1	4.3	<2	3.0	560	3.2	1.4	1.64	790
16	7.6	350	12	14.7	38	7	69	0.8	0.68	1.54	4.8	3.58	20.0	0.23	3	10600	20	38	1.1	4.1	<2	2.9	750	2.6	1.5	1.61	690
14	7.0	380	12	15.6	39	8	70	<0.5	0.70	1.67	5.0	3.90	20.0	0.27	5	10800	18	43	1.1	4.1	<2	2.9	840	2.9	1.4	1.61	740
17	7.4	360	11	14.7	38	7	70	1.0	0.74	1.57	5.1	3.12	19.0	0.25	5	10600	18	42	1.1	4.0	<2	2.8	840	3.0	1.1	1.45	700
12	6.2	370	14	16.6	39	8	70	0.9	0.67	1.65	4.4	3.47	20.0	0.24	4	10600	20	51	1.0	4.1	<2	3.0	770	2.9	1.5	1.62	720
34	6.7	390	13	15.5	41	9	66	0.7	0.79	1.70	4.9	4.03	19.0	0.28	4	11500	23	41	1.1	4.4	<2	2.8	1000	2.6	1.5	1.61	730
16	7.6	380	12	15.1	40	9	69	0.9	0.84	1.76	4.9	3.98	20.0	0.27	4	10900	20	45	1.2	4.3	<2	2.8	900	2.7	1.6	1.64	730
16	8.1	390	12	15.0	42	9	65	1.0	0.85	1.79	5.3	3.14	20.0	0.31	7	11700	21	38	1.2	4.5	<2	2.9	750	2.9	1.4	1.67	740
25	5.3	390	12	14.9	40	9	65	1.5	0.80	1.68	5.1	3.15	20.0	0.28	6	11600	22	34	1.1	4.3	<2	2.8	560	2.9	1.2	1.66	760
17	7.1	340	11	15.6	39	7	61	<0.5	0.69	1.54	4.2	3.71	19.0	0.24	4	10500	20	41	1.0	4.0	<2	3.0	900	2.5	1.3	1.60	700
13	6.8	440	14	14.6	38	9	70	0.9	0.74	1.70	5.5	3.38	20.0	0.26	4	10100	22	50	1.0	4.1	<2	2.9	1100	2.8	1.2	1.75	710
17	7.3	410	13	13.3	39	9	70	1.2	0.73	1.69	4.5	3.31	19.0	0.24	4	10100	18	43	1.1	4.0	<2	2.8	950	2.5	1.1	1.35	720
16	6.7	360	14	16.0	36	8	68	0.7	0.73	1.57	4.9	3.36	19.0	0.23	4	10900	19	46	1.0	4.1	<2	2.9	960	2.5	1.6	1.55	720
16	7.2	350	11	14.4	36	8	63	0.9	0.71	1.56	4.2	3.33	19.0	0.24	5	10200	18	45	1.0	3.9	<2	2.8	1100	2.3	1.1	1.56	720

* first row of data shows determination limits

Table 4: Standard V6c - Concentrations in Ash Determined by ICP-ES

Al	B	Cd	Cu	Li	Mg	Mn	Ni	P	Pb	V
pct	ppm	ppm	ppm	ppm	pct	ppm	ppm	pct	ppm	ppm
0.01*	2	0.2	1	2	0.01	1	1	0.001	3	2
1.09	166	3.0	133	9	1.96	673	67	0.682	191	25
1.26	184	3.4	140	12	2.22	755	78	0.742	193	28
0.95	133	3.1	110	5	1.82	629	61	0.551	163	24
1.14	173	3.2	129	7	2.10	787	73	0.690	194	26
1.13	170	3.4	126	5	2.10	876	71	0.701	183	25
1.11	143	2.9	129	6	2.12	692	66	0.643	179	25
1.13	142	3.0	129	7	2.10	709	71	0.637	178	26
1.16	157	3.1	176	5	2.08	780	70	0.585	179	24
1.10	138	3.0	125	4	2.01	708	64	0.559	184	24
1.07	136	2.9	128	6	1.99	673	70	0.549	170	25
1.11	146	2.9	126	8	2.04	734	67	0.586	172	25
1.18	149	3.2	126	9	2.07	736	70	0.647	179	25
1.15	156	2.9	181	8	2.10	809	69	0.590	194	24
1.14	166	3.0	137	7	2.09	747	70	0.591	200	25
1.13	150	3.0	123	8	2.02	711	69	0.633	172	25
1.07	139	2.9	118	7	1.89	682	61	0.594	169	24
1.17	160	3.1	132	9	2.10	843	71	0.654	176	26
1.09	156	3.1	127	8	1.96	727	70	0.624	175	25
1.06	153	2.8	121	5	1.92	700	64	0.587	171	24

* first row of data shows determination limits

Table 5: Laboratory Duplicates - Concentration in Ash Determined by INAA

Vial Number	Au ppb 5*	As ppm	Ba ppm	Br ppm	Ca pct	Ce ppm	Co ppm	Cr ppm	Cs ppm	Eu ppm	Fe pct	Hf ppm	K pct	La ppm	Lu ppm	Mo ppm	Na ppm	Nd ppm	Rb ppm	Sb ppm	Sc ppm	Se ppm	Sm ppm	Sr ppm	Th ppm	U ppm	Yb ppm	Zn ppm
AL95/424	<5	1.1	2500	71	22.9	6	4	19	1.8	<0.03	0.16	0.9	26.60	1.9	<0.05	<2	1660	<5	200	0.4	0.5	<2	0.3	<300	0.2	<0.1	<0.05	1800
AL95/425	<5	1.0	2500	77	21.1	6	5	16	1.9	<0.03	0.15	<0.5	26.20	2.0	0.06	<2	1690	<5	180	0.4	0.5	<2	0.3	<300	<0.1	<0.1	0.29	1800
AL95/434	14	3.4	2300	30	15.0	23	7	32	1.6	0.48	1.11	3.2	19.90	13.0	0.26	<2	5640	17	100	0.5	4.0	<2	2.2	3500	3.1	1.1	1.35	1200
AL95/435	18	2.9	2200	28	15.5	23	6	30	2.2	0.39	0.98	2.9	20.10	12.0	<0.05	<2	5450	13	120	0.4	3.8	<2	2.0	3300	2.5	<0.1	1.04	1200
AL95/462	10	1.9	5600	27	20.5	<3	7	19	<0.5	<0.03	0.13	<0.5	25.20	1.6	<0.05	<2	1560	<5	170	0.3	0.3	<2	0.2	<300	0.1	<0.1	<0.05	1600
AL95/463	13	0.9	5200	27	18.7	<3	7	26	1.5	<0.03	0.14	<0.5	21.70	1.5	<0.05	<2	1510	<5	130	0.2	0.3	<2	0.2	340	<0.1	<0.1	0.21	1500
AL95/488	8	1.5	3300	50	17.3	<3	8	16	0.8	<0.04	0.12	<0.5	29.00	1.3	<0.05	<2	2500	<5	180	0.3	0.2	<2	0.2	750	<0.1	<0.1	<0.05	2900
AL95/489	8	1.0	3000	50	16.3	<3	7	13	<0.5	<0.03	0.11	<0.5	26.90	1.2	<0.05	<2	2240	12	160	0.5	0.2	<2	0.2	700	<0.1	<0.1	<0.05	2700
AL95/500	25	<0.5	1700	24	15.8	4	2	18	<0.5	<0.03	0.15	<0.5	24.50	1.3	0.05	<2	1100	<5	60	0.3	0.3	<2	0.2	860	<0.1	0.5	<0.05	1900
AL95/501	23	1.5	1700	23	17.1	<3	2	19	1.0	<0.03	0.18	<0.5	25.40	1.4	<0.05	<2	1210	<5	71	0.3	0.3	<2	0.2	1200	0.2	<0.1	<0.05	1900
AL95/540	17	2.3	5200	31	19.6	12	7	13	1.1	<0.03	0.44	2.0	24.80	5.9	0.09	<2	5190	8	150	0.6	1.4	<2	0.8	1200	1.1	<0.1	0.52	1700
AL95/541	18	1.8	5100	34	19.2	11	5	15	1.2	<0.03	0.45	2.3	22.70	6.2	0.08	<2	5070	<5	130	0.4	1.4	<2	0.8	1100	0.9	<0.1	0.48	1600
AL95-544	14	2.2	1200	49	22.2	10	5	26	1.0	0.14	0.43	1.3	24.10	5.3	0.08	<2	2980	7	170	0.6	1.4	<2	0.8	<300	1.1	<0.1	0.42	1800
AL95-545	19	1.7	1300	51	20.1	10	5	25	2.0	<0.02	0.48	1.4	25.80	5.7	0.08	<2	3080	<5	160	0.6	1.5	<2	0.9	<300	1.1	0.5	0.44	1900
AL95/583	13	<0.5	2200	33	23.0	3	4	8	<0.5	0.09	0.14	<0.5	24.70	1.7	<0.05	<2	2090	<5	47	0.2	0.3	<2	0.2	710	<0.1	<0.1	<0.05	2000
AL95/584	<5	1.1	2200	30	22.9	<3	4	9	<0.5	<0.02	0.11	1.0	25.80	1.5	<0.05	<2	2080	<5	47	0.4	0.3	<2	0.2	940	0.3	<0.1	0.17	2000
AL95/606	30	6.0	3100	38	10.7	50	15	37	2.7	1.02	1.44	5.3	17.80	25.0	0.41	2	8390	26	110	0.6	5.3	3	4.6	770	4.7	1.6	2.28	1200
AL95/607	30	4.7	2900	37	11.5	49	14	36	1.9	1.08	1.49	5.3	16.20	24.0	0.38	<2	7860	27	97	0.6	5.2	<2	4.6	<300	4.7	1.4	2.45	1100
AL95/627	21	1.1	3600	33	27.9	6	4	18	1.2	<0.03	0.22	<0.5	18.70	2.8	<0.05	<2	2130	<5	210	0.6	0.4	<2	0.3	670	<0.1	<0.1	0.18	1900
AL95/628	27	1.9	3500	34	25.9	<3	4	20	<0.5	<0.03	0.19	<0.5	17.20	3.0	0.08	<2	2080	<5	170	0.4	0.5	<2	0.3	1300	0.3	<0.1	0.20	2000
AL95/643	12	0.8	960	29	15.6	3	4	60	0.7	<0.02	0.13	<0.5	28.70	0.9	<0.05	<2	6350	<5	93	0.3	0.4	<2	0.1	1200	0.2	<0.1	0.16	1600
AL95/644	15	<0.5	950	33	15.1	<3	5	59	<0.5	<0.03	0.18	<0.5	29.10	1.0	<0.05	<2	6490	<5	100	0.2	0.5	<2	0.1	1100	0.4	<0.1	<0.05	1600

* first row of data shows determination limits

Table 5 (cont'd): Laboratory Duplicates - Concentration in Ash Determined by INAA

Vial Number	Au ppb 5*	As ppm 0.5	Ba ppm 10	Br ppm 1	Ca pct 0.2	Ce ppm 3	Co ppm 1	Cr ppm 1	Cs ppm 0.5	Eu ppm 0.01	Fe pct 0.05	Hf ppm 0.5	K pct 0.05	La ppm 0.1	Lu ppm 0.05	Mo ppm 2	Na ppm 10	Nd ppm 5	Rb ppm 5	Sb ppm 0.1	Sc ppm 0.1	Se ppm 2	Sm ppm 0.1	Sr ppm 300	Th ppm 0.1	U ppm 0.1	Yb ppm 0.05	Zn ppm 20	
AL95/670	<5	2.7	2800	45	17.1	5	9	52	1.0	<0.03	0.26	<0.5	27.90	1.9	<0.05	<2	2450	<5	290	0.5	0.7	<2	0.3	830	<0.1	<0.1	<0.1	0.17	2000
AL95/671	<5	2.4	2800	43	16.6	5	9	49	0.9	<0.03	0.25	<0.5	25.90	1.7	<0.05	<2	2250	<5	280	0.4	0.7	<2	0.2	1200	<0.1	<0.1	<0.1	0.24	1900
AL95/683	16	2.7	1900	43	19.7	11	7	25	<0.5	0.20	0.42	0.7	22.60	4.8	0.06	<2	2860	<5	160	0.8	1.2	<2	0.8	800	0.7	<0.1	0.24	2000	
AL95/684	7	1.6	1400	28	16.9	5	3	15	0.8	0.06	0.21	<0.5	23.10	2.5	<0.05	<2	1090	<5	160	0.3	0.6	<2	0.3	770	0.2	<0.1	0.17	2300	
AL95/690	12	2.5	1400	57	21.8	8	6	52	1.5	<0.02	0.45	0.8	23.70	4.5	<0.05	<2	5140	<5	140	0.8	1.2	<2	0.6	770	0.5	<0.1	0.32	2400	
AL95/691	15	3.2	1400	54	22.5	11	6	48	1.2	<0.02	0.37	0.7	23.70	3.9	0.06	<2	5000	<5	150	0.9	1.1	<2	0.6	<300	0.9	<0.1	0.34	2300	
AL95/712	8	1.9	1900	26	17.6	6	5	12	<0.5	<0.03	0.36	0.8	21.20	3.2	0.09	<2	2860	<5	120	0.3	1.1	<2	0.5	940	0.3	<0.1	0.30	1500	
AL95/713	8	1.9	2000	29	16.4	7	5	14	0.6	<0.03	0.37	<0.5	25.30	3.3	<0.05	<2	2900	<5	100	0.3	1.2	<2	0.5	1000	0.4	<0.1	0.20	1500	
AL95/727	7	1.0	740	19	19.3	<3	3	32	<0.5	<0.02	0.12	<0.5	18.10	1.0	<0.05	<2	2070	<5	100	0.2	0.2	<2	<0.1	300	<0.1	0.4	<0.05	960	
AL95/728	7	1.0	730	20	20.1	<3	3	33	<0.5	<0.02	0.10	<0.5	18.20	1.0	<0.05	<2	2170	9	110	1.4	0.2	<2	0.2	430	<0.1	<0.1	<0.05	940	
AL95/753	6	1.4	380	31	19.8	<3	3	12	0.8	<0.03	0.14	<0.5	24.90	1.6	<0.05	<2	1320	<5	350	0.2	0.4	<2	0.2	<300	<0.1	<0.1	<0.05	1400	
AL95/754	8	1.1	330	30	19.3	3	2	10	1.0	<0.03	0.17	0.5	21.70	1.7	<0.05	<2	1350	<5	330	0.4	0.4	<2	0.2	<300	<0.1	<0.1	<0.05	1300	
AL95/774	16	<0.5	5400	49	20.9	<3	5	10	0.9	<0.03	<0.05	<0.5	15.50	1.5	<0.05	<2	3600	<5	72	0.3	0.2	<2	<0.1	1100	<0.1	0.7	<0.05	2500	
AL95/775	24	<0.5	5300	44	18.7	<3	4	13	<0.5	<0.03	0.09	<0.5	15.20	1.2	<0.05	<2	3700	<5	86	0.2	0.2	<2	0.1	1100	<0.1	<0.1	<0.05	2300	
AL95/783	7	1.6	2100	20	15.5	8	5	18	0.9	0.17	0.29	0.9	17.80	4.0	0.08	<2	3980	<5	130	0.4	0.9	<2	0.7	890	0.4	<0.1	0.29	1400	
AL95/784	10	1.9	2300	22	17.1	6	5	14	<0.5	<0.02	0.26	<0.5	16.90	3.2	0.06	<2	4760	<5	120	0.4	0.8	<2	0.5	1000	0.5	<0.1	0.34	1400	
AL95/797	<5	1.6	1300	24	12.6	19	10	48	1.4	0.41	1.00	2.1	14.70	9.5	0.13	<2	7900	7	140	0.4	3.4	<2	1.5	1200	2.1	0.8	0.68	1300	
AL95/798	<5	1.3	1300	29	11.8	16	9	52	1.4	0.29	0.93	2.1	14.40	8.8	0.12	<2	7530	<5	150	0.4	3.2	<2	1.5	1300	1.9	0.7	0.67	1200	
AL95/821	9	<0.5	1800	22	13.9	<3	3	13	3.3	<0.02	0.12	<0.5	26.00	1.3	<0.05	<2	1690	<5	240	0.3	0.3	<2	0.2	760	<0.1	<0.1	0.06	1700	
AL95/822	9	0.6	1800	23	13.8	<3	3	13	3.5	<0.02	0.12	0.6	24.10	1.2	<0.05	<2	1620	<5	250	0.3	0.3	<2	0.2	870	<0.1	0.2	<0.05	1700	

* first row of data shows determination limits

Table 6: Laboratory Duplicates - Concentration in Ash Determined by ICP-ES

Packet Number	Al pct 0.01*	B ppm 2	Cd ppm 0.2	Cu ppm 1	Li ppm 2	Mg pct 0.01	Mn ppm 1	Ni ppm 1	P pct 0.001	Pb ppm 3	V ppm 2
ICP95-424	0.27	366	5.6	126	<2	2.48	16401	21	2.584	60	6
ICP95-425	0.28	375	5.6	126	<2	2.52	16615	21	2.598	60	6
ICP95-434	1.04	257	6.6	133	11	2.13	10410	72	3.274	41	13
ICP95-435	1.02	260	6.4	133	12	2.11	10331	71	3.258	40	12
ICP95-462	0.42	243	13.5	145	<2	2.04	16749	40	1.829	27	4
ICP95-463	0.44	250	14.9	148	<2	2.08	17243	40	1.841	30	3
ICP95-488	0.48	317	10.6	154	2	2.51	18281	34	2.734	35	5
ICP95-489	0.50	327	10.8	161	<2	2.54	18548	32	2.874	39	4
ICP95-500	0.18	242	6.7	131	<2	1.75	35997	12	4.545	51	8
ICP95-501	0.20	248	7.2	133	<2	1.76	35919	13	4.580	48	9
ICP95-540	0.81	259	10.8	167	3	2.51	22427	73	2.845	36	7
ICP95-541	0.79	261	10.5	167	3	2.48	22466	73	2.800	40	6
ICP95-544	0.48	292	11.1	126	3	2.00	24770	23	1.921	41	9
ICP95-545	0.46	280	10.4	120	2	1.91	23674	19	1.825	40	7
ICP95-583	0.30	272	20.6	140	<2	2.44	11974	73	1.595	27	2
ICP95-584	0.30	272	20.1	138	<2	2.39	11618	69	1.562	26	2
ICP95-606	1.43	215	6.5	102	15	1.61	47874	35	1.105	71	19
ICP95-607	1.44	214	6.3	103	15	1.60	47789	36	1.112	73	20
ICP95-627	0.73	263	16.0	157	<2	2.28	17064	39	1.751	76	14
ICP95-628	0.67	248	14.9	145	2	2.14	15918	35	1.647	71	13

* first row of data shows determination limits

Table 6 (cont'd): Laboratory Duplicates - Concentration in Ash Determined by ICP-ES

Packet Number	Al pct 0.01*	B ppm 2	Cd ppm 0.2	Cu ppm 1	Li ppm 2	Mg pct 0.01	Mn ppm 1	Ni ppm 1	P pct 0.001	Pb ppm 3	V ppm 2
ICP95-643	0.77	275	6.1	157	<2	2.76	8425	37	3.378	18	2
ICP95-644	0.75	265	6.1	154	<2	2.73	8342	37	3.371	16	1
ICP95-670	0.50	303	8.7	129	2	2.64	36762	14	2.066	43	9
ICP95-671	0.49	296	8.6	125	2	2.55	35494	13	1.998	48	10
ICP95-683	0.34	397	9.9	156	3	2.24	26553	19	1.318	118	20
ICP95-684	0.38	236	12.5	121	<2	1.86	50115	13	1.741	61	13
ICP95-690	0.41	309	7.9	136	<2	1.91	29496	21	1.288	99	25
ICP95-691	0.38	303	7.8	134	<2	1.86	28770	21	1.261	101	24
ICP95-712	0.59	307	13.7	161	3	2.97	28524	45	2.433	41	15
ICP95-713	0.60	309	13.7	163	<2	2.98	28645	46	2.450	43	15
ICP95-727	0.26	219	3.7	131	<2	2.43	4294	7	1.995	29	2
ICP95-728	0.24	211	3.6	126	3	2.31	4066	7	1.939	25	3
ICP95-753	0.32	267	6.4	140	<2	1.79	7403	14	1.989	36	4
ICP95-754	0.33	274	6.3	146	<2	1.82	7553	14	2.058	36	4
ICP95-774	0.83	216	14.9	121	2	3.29	24492	30	1.826	43	4
ICP95-775	0.85	221	15.8	125	<2	3.33	24804	31	1.821	41	4
ICP95-783	0.72	268	5.8	153	5	2.80	19021	48	1.985	77	9
ICP95-784	0.58	282	5.2	157	4	3.05	21478	42	1.955	73	7
ICP95-797	0.88	173	4.2	123	6	3.05	16132	31	1.384	25	12
ICP95-798	0.85	179	4.2	120	5	3.04	16168	30	1.399	28	12
ICP95-821	0.28	219	18.2	134	<2	2.75	24254	18	1.809	32	4
ICP95-822	0.28	212	17.7	133	<2	2.70	23944	19	1.780	28	4

* first row of data shows determination limits

Table 7: Determination Limits for Elements Analyzed by INA

Element		Units of Measure	Determination Limit
Gold	Au	ppb	5
Barium	Ba	ppm	10
Bromine	Br	ppm	1
Calcium	Ca	%	0.2
Cerium	Ce	ppm	3
Cobalt	Co	ppm	1
Chromium	Cr	ppm	1
Cesium	Cs	ppm	0.5
Europium	Eu	ppm	0.01
Iron	Fe	%	0.05
Hafnium	Hf	ppm	0.5
Potassium	K	%	0.05
Lanthanum	La	ppm	0.1
Lutetium	Lu	ppm	0.05
Molybdenum	Mo	ppm	1
Rubidium	Rb	ppm	5
Sodium	Na	ppm	10
Neodymium	Nd	ppm	5
Antimony	Sb	ppm	0.1
Scandium	Sc	ppm	0.1
Selenium	Se	ppm	2
Samarium	Sm	ppm	0.1
Strontium	Sr	ppm	300
Thorium	Th	ppm	0.1
Uranium	U	ppm	0.1
Tungsten	W	ppm	1
Ytterbium	Yb	ppm	0.05
Zinc	Zn	ppm	20

Table 8: Determination Limits for Elements Analyzed by ICP-ES

Element		Units of Measure	Determination Limit
Silver	Ag	ppm	0.3
Aluminum	Al	pct	0.01
Boron	B	ppm	2
Beryllium	Be	ppm	0.2
Cadmium	Cd	ppm	0.2
Copper	Cu	ppm	1
Lithium	Li	ppm	2
Magnesium	Mg	%	0.01
Manganese	Mn	ppm	1
Nickel	Ni	ppm	1
Phosphorus	P	%	0.001
Lead	Pb	ppm	3
Vanadium	V	ppm	2

GEOLOGY

BEDROCK GEOLOGY

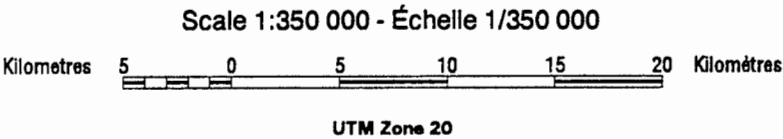
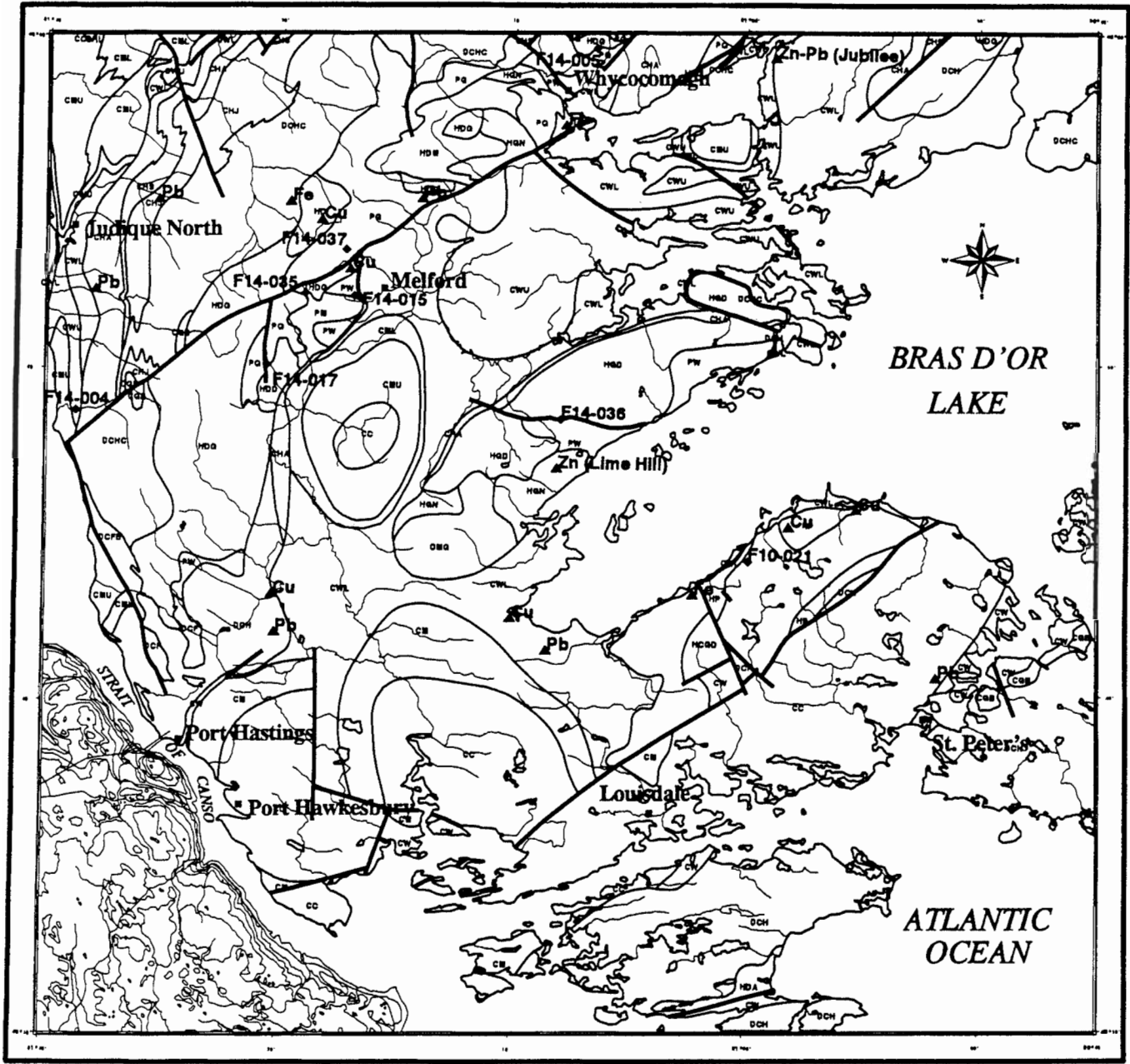
Figure 2 shows the geological contacts of the stratigraphic units and locations of mineral occurrences. The geology, with sample numbers, is shown also on the large coloured geological map provided in the envelope. This map is a simplified digital compilation after Lynch *et al.*, 1995.

The geology of the area is complex, with rocks ranging in age from Helikian to Carboniferous that have been faulted and folded. The Precambrian rocks have been metamorphosed up to amphibolite-grade gneiss, schist, calc-silicate, marble, wacke and quartzite. These comprise the George River Group of Hadrynian to Helikian age. Late Hadrynian to Lower Paleozoic intrusions range in composition from granite to diorite, and form much of the high ground (see digital elevation map, Fig. 3). Basalt and andesite flows occurred during the late Devonian and comprise the Fisset Brook Formation. Overlying the volcanic flows are the early Carboniferous Craignish, Judique, Strathlorne and Ainslie formations of the Horton Group. These formations are dominated by a generally fining-upward sequence of clastic sediments, with periodic incursions of conglomerates and, in the Strathlorne Formation, the deposition of minor micritic limestone. The overlying Windsor Group of the Visean Stage is dominated by carbonates with minor siltstone, and intercalations of evaporite sediments. During the Namurian Stage deposition was mostly siltstone with variable amounts of dolomite, together making up the Mabou Group. After the intrusion of some small plugs of gabbro and diabase, cross-bedded medium to coarse clastic sediments of the Westphalian-Stephanian Cumberland Group were deposited with minor coal, siltstone and shale.

Subsequently, the area has been faulted and folded to give rise to the present association of juxtaposed formations of different age, and several synclinal basins, notably in the centre of the survey area, occupying valleys between significant north-easterly-trending ridges of granodiorite. These features stand out clearly on the digital elevation map (Fig. 3).

MINERALIZATION

Several metallic mineral occurrences are reported in the survey area (Fig. 2, from Gregory *et al.*, 1979, and Nova Scotia Mineral Occurrence Database: NSDNR, 1996). Most are Precambrian in age, and associated with carbonates of the George River Group. Of note is the Lime Hill sphalerite showing on the western shore of Bras d'Or Lake, comprising more than 2 million tonnes of ore grading 2.5% zinc (Chatterjee, 1977; Justino and Sangster, 1987, Hill, 1987). Just east of the survey area, a few kilometres east of Whycocomagh, is the Jubilee Zn/Pb deposit, containing >500,000 tonnes combined Zn/Pb grading >6%, and hosted by carbonates of the Windsor Group (Hein *et al.*, 1988). Other showings are of Pb, Cu, Fe, and a few reports of minor concentrations of disseminated gold. Details of these occurrences are provided in the NSDNR (1996) digital database. The Au occurrences are all prefixed with either F10 or F14 and are summarised in the Table comprising part of Fig. 2.



Gold Occurrence Number	Gold Occurrence Name and Category	Mineralization	Style of Mineralization
F10-021	Campbell Mountain (Cu)	Au, Ag, Cu	Quartz Vein
F14-004	Craigmore (Au)	Au	Not reported
F14-005	Whycocomagh (Au)	Au, As, Cu	Disseminated
F14-015	Melford	Au, Fe	Not reported
F14-017	Glendale Road (As)	Au, As, Cu, Fe, Pb, Zn	Not reported
F14-035	River Denys Road (As)	Au, As	Disseminated; Fracture Fillings; Pods
F14-036	Kennedy's Big Brook (Fe)	Au, As, Ag, Co, Cu, Fe, Sb	Disseminated; Massive
F14-037	Glen Brook (Diogenes Brook) (Fe)	Au, As, Fe	Disseminated; Fracture Fillings

Fig. 2: Map showing geological units and metallic mineral occurrences.

Base metal locations from Gregory *et al.*, 1979. Gold occurrences (described in Table) from NSDNR (1996)

BEDROCK GEOLOGY

Legend to Fig. 2 (see also large map in envelope for details)

CARBONIFEROUS

WESTPHALIAN-STEPHANIAN

CUMBERLAND GROUP

- CC** cross-bedded and trough cross-bedded white medium sand arkose, minor siltstone, shale, and coal, equivalent to *Port Hood Formation*
- CCPHL** *Lower Port Hood Formation*: channelized sandstone deposits, siltstone, shale

NAMURIAN

- CGB** gabbro, diabase

MABOU GROUP

- CMU** Upper member including *Pomquet Formation*: red and green siltstone and sandstone, minor conglomerates
- CML** Lower member including *Hastings Formation*: shale and siltstone, dolomitic siltstone, and thin stromatolitic dolostone beds
- CM** undifferentiated Mabou Group

WISEAN

WINDSOR GROUP

- CWU** Upper member including *Herbert River* limestone: red siltstone and sandstone with intercalated shallow marine limestone, dolostone, gypsum and halite
- CWL** Lower member: limestone variably dolomitic and fossiliferous, red siltstone and thick units of gypsum and halite
- CW** undifferentiated Windsor Group

LATE DEVONIAN TO CARBONIFEROUS

FAMENNIAN-TOURNAISIAN

HORTON GROUP

- CHA** *Ainslie Formation*: cross-bedded sandstone and conglomerate, siltstone, mostly fluvialite deposits
- CHS** *Strathlorne Formation*: grey and red siltstone, sandstone, micritic limestone, conglomerate with carbonate clasts
- CHJ** *Judique Formation*: red cross-bedded medium to coarse sand, lithic arkose, sandstone, minor conglomerate
- DCHC** *Craignish Formation*: dominantly conglomerate with red and grey sandstone, thick and thinly bedded, alluvial fan facies
- DCH** undifferentiated Horton Group
- DCFB** *Fisset Brook Formation*, basalt member: vesicular porphyritic basalt and andesite, with minor interbedded redbed siltstone and conglomerate
- DCF** *Fisset Brook Formation*: vesicular basalt, rhyolite, red siltstone, sandstone, conglomerate

ORDOVICIAN

- OMG** monzogranite

HADRYNIAN-CAMBRIAN

- HCGD** medium grained granodiorite (includes Capelin Cove pluton)

LATE HADRYNIAN

- HGN** gneiss

- HGD** granodiorite

PRINGLE MOUNTAIN GROUP

- HP** varied basaltic to rhyolitic lapilli tuff and ash tuff, minor rhyolite flows

HELIKIAN-HADRYNIAN**GEORGE RIVER GROUP**

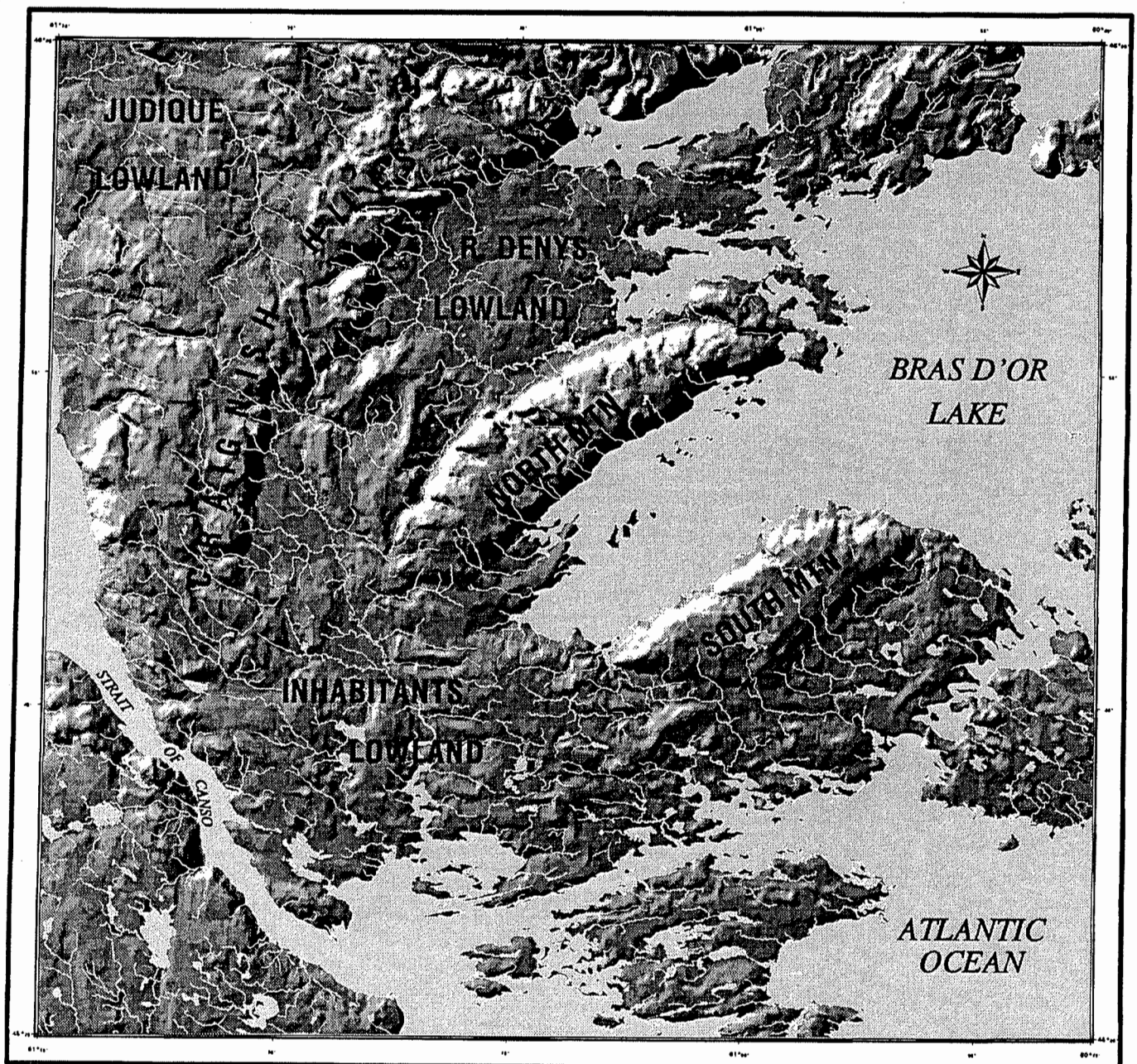
PG	limestone, marble, dolostone, calc-silicate rock, quartzite, feldspathic arenite, wacke, minor mafic metavolcanic rocks
PM	marble, calc-silicate rock, gneiss, minor quartzite
PQ	quartzite, psammitic schist, quartzofeldspathic gneiss, minor calc-silicate rock and amphibolite
PW	biotite and chlorite schist, metawacke, marble, dolostone calc-silicate rock, quartzite, gneiss, schist, mafic metavolcanic rocks, amphibolite

POLLETS COVE RIVER GROUP

HD	monzonite, diorite, gabbro
----	----------------------------

UNCERTAIN AGE

HDM	mylonitic granite, diorite, and mylonitic gneiss, biotite-garnet schist
HDG	medium grained variably foliated granite
HDD	diorite
HDA	amphibolite



Scale 1:350 000 - Échelle 1/350 000

Kilometres 5 0 5 10 15 20 Kilomètres

Transverse Mercator Projection
Scale Factor 1, Central Meridian 61°10', Latitude of Origin 45°30'

Fig. 3: Digital Elevation Map Showing Main Physiographic Divisions

QUATERNARY DEPOSITS

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

Grant (1994) describes the Quaternary geology of Cape Breton Island in detail. His comprehensive study shows that 90 percent of the survey area is covered with a veneer or thin blanket of Wisconsinan till interspersed with numerous rock outcrops (Grant, 1994, Fig. 40). His map shows three categories of till, differentiated according to thickness and morphological features. Grant's text description assigns source rocks to the tills and identifies four principal categories:

- a) reddish, silt/clay tills derived mainly from Carboniferous shale;
- b) reddish brown, sandy tills derived mainly from Carboniferous sandstone;
- c) brown, sandy, stony tills derived by mixture of Carboniferous conglomerate and Precambrian crystalline rocks;
- d) grey and brown, stony, sandy tills derived mainly from crystalline rocks.

Approximately 80 percent of the survey area has a surface till underlain by one or more tills of differing lithology and texture. Grant (1994) notes that 'the till sequence, together with various cross-cutting glacial erosional features, documents a succession of several local and regional ice-flows from different directions various cohesive silty tills with a high proportion of transported stones occur on the sedimentary rock lowlands'. The southern part of the study area experienced an early phase of ice movement toward the northeast, followed by dominant flow over the entire area toward the northwest. Later there were minor and more local phases to the southeast, the northeast, and finally toward the southwest.

In addition to the till layers there are local glaciolacustrine and glaciofluvial deposits, and a succession of post-glacial sediments (fluvial, colluvial and organic deposits) creating a high level of complexity to the surficial regime. Clearly these sediments have had a bearing on the chemical signatures of the vegetation. The relative influence of each successive is difficult to assess, especially since tree roots may locally penetrate one sediment layer to extract nutrients from another. Despite these complications regional patterns of element distributions emerge which provide insight to the geochemistry of the surficial environment. These patterns may provide focus for further study whether oriented toward exploration or environmental concerns.

MAP PRODUCTION AND DATA HANDLING

The transparent geological overlay map provided in the pocket, and the large coloured sample location map are digitised computer-plotted compilations based upon the map of Lynch *et al.*, 1995. The digital geology base for this study was created by digitally clipping the appropriate area from the digital base map. The resulting topologically consistent base contains 30 units.

The maps for this report (with the exception of Fig. 1) were all drawn using a Transverse Mercator (TM) projection, using the North American Datum 1927 (NAD27). Figure 1 is part of a Digital Chart of the World (DCW) 1 : 1,000,000, which is a non-projected (geographic Latitude/Longitude) compilation.

The coastline, drainage and roads for the page size maps (1 : 350 000 scale) were obtained in AutoCad DXF digital format from Geomatics Canada of the Department of Natural Resources Canada. The digital base for these maps was produced by splicing together four 1 : 50,000, NAD27, Universal Transverse Mercator (UTM) Zone 20, digital bases (11F/14, 11F/15, 11F/11, 11F/10) and then clipping the appropriate sub-area. The colour insert base was produced by clipping the study area from a 1 : 250 000 NAD27, UTM Zone 20, ARC/INFO export file (E00) of Cape Breton bedrock geology produced by the Geological Survey of Canada (Lynch *et al.*, 1995).

The proportional dot maps were generated using AML (ARC/INFO Macro Language). The macro, with its corresponding input menu, prompts the user to input percentile break points and an appropriate scaling exponent for each element to be mapped. Proportional dots are then generated, using the ARC/INFO SPOTSIZE, POINTSPOT and SPOT commands, with the user specifying an appropriate minimum and maximum dot size. For the purposes of this Open File, analytical values for a particular element that were greater than or equal to the 98th percentile were plotted at the maximum dot size; values less than the 98th percentile were scaled according to the user defined exponent. Exponents for individual elements were carefully chosen to provide the best view of the analytical data. Accordingly, care should be exercised when attempting to compare different elements plotted with different exponents. 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.

A digital elevation map of south-western Cape Breton Island is provided (Fig. 3, and transparent overlay in envelope) for additional assistance in interpreting the element distribution maps. This map was produced from Digital Terrain Elevation Data (DTED) provided by CCRS (Canada Centre for Remote Sensing). Complete elevation coverage for the survey area was obtained by merging 1° x 1° DTED tiles, and then clipping the appropriate sub-area. The resulting cell size was approximately 97 x 97m, with a horizontal circular error (CE) of less than 130 m and a vertical linear error (LE) of less than ±30 m. ARC/INFO's GRID module was used to perform the raster compilation and to create the shaded relief map.

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 summaries in Appendix B.

For determinations by INAA the first element listed is Au, because of its common interest, after which elements are arranged alphabetically by chemical symbol. For determinations by ICP-ES, elements are arranged alphabetically by chemical symbol.

Since the present study is the fifth of its kind in Nova Scotia using balsam fir twigs, Tables 9 and 10 are provided for comparison with data from different parts of the province. Surveys were conducted between 1987 and 1995 using the same sampling methods, and all sample preparation was conducted in the GSC laboratory of the senior author. The INAA data in Table 9 are summarised as median values of element data sets, all provided by the same analytical laboratory (Activation Laboratories) under consistent analytical conditions. The ICP-ES data in Table 10 also show median concentrations, and were all obtained on an aqua regia digestion of ash samples. No ICP-ES data were obtained for samples from the first survey (Open File 2002). Min-En Laboratories, Vancouver, provided data given in Open Files 2757 and 2758. Data in the remaining two Open Files were provided by Acme Analytical Laboratories, Vancouver. Throughout the entire analytical program one standard ash sample of conifer tissues has been inserted within each batch of 20 samples to ensure consistency in analytical accuracy. GSC standard 'V2' was used for the early surveys and when that was exhausted it was superseded by 'V6c'.

These Tables show that there is remarkable consistency in median concentrations of many elements, and they provide a clear assessment of 'background' concentrations across the province. In the following comments with respect to individual elements, reference can be made to these tables to assess the magnitude of local concentrations of elements.

Table 9: Mean concentrations of elements in balsam fir twig ash from surveys in Nova Scotia: Determinations by Instrumental Neutron Activation Analysis (INAA)

		OF 3344 ¹ Southwest Cape Breton Island n=365	OF 2758 ² Southeast Cape Breton Island n=491	OF 2002 ³ Southeast Nova Scotia n=593	OF 3221 ⁴ Central Nova Scotia n=786	OF 2757 ⁵ Southwest Nova Scotia n=455
Au	ppb	12	5	7	8	<5
As	ppm	1.8	2.7	2.3	3.3	2.7
Ba	ppm	2000	1500	1100	2500	1300
Br	ppm	30	33	19	33	30
Ca	%	16.9	16.2	15.2	18.7	18.4
Ce	ppm	5	6	8	7	6
Co	ppm	4	5	5	5	3
Cr	ppm	18	14	23	17	6
Cs	ppm	1.0	1.6	2.7	1.5	2.7
Eu	ppm	<0.01	<0.01	0.06	<0.01	<0.01
Fe	%	0.24	0.39	0.34	0.32	0.28
Hf	ppm	0.6	0.7	0.9	0.9	0.6
K	%	23.4	20.3	22.2	23.6	20.8
La	ppm	2.6	3.3	4.1	4.5	3.2
Lu	ppm	<0.05	0.06	<0.05	0.06	<0.05
Na	ppm	2460	3020	2920	1945	3135
Nd	ppm	<5	<5	<5	<5	<5
Rb	ppm	160	170	260	250	270
Sb	ppm	0.4	0.6	0.4	0.6	0.6
Sc	ppm	0.7	1.0	0.9	0.9	0.8
Se	ppm	<2	<2	<2	<2	<2
Sm	ppm	0.4	0.5	0.6	0.6	0.5
Sr	ppm	780	1100	860	980	1400
Ta	ppm	<0.5	<0.5	<0.5	<0.5	<0.5
Th	ppm	0.3	0.6	0.7	0.6	0.5
U	ppm	<0.1	<0.1	<0.5	<0.1	<0.1
W	ppm	<1	<1	<1	<1	<1
Yb	ppm	0.22	0.28	0.34	0.31	0.26
Zn	ppm	1900	1900	2000	2100	2000
Ash	%	2.10	2.12	2.08	2.00	2.00
Yield						

1

This study

2

Dunn, et al., 1994b

3

Dunn, et al., 1989

4

Dunn, et al., 1996

5

Dunn, et al., 1994a

Table 10: Mean concentrations of elements in balsam fir twig ash from surveys in Nova Scotia: Determinations by ICP-ES after aqua regia digestion

	OF 3344 ¹ Southwest Cape Breton Island n=365	OF 2758 ² Southeast Cape Breton Island n=491	OF 2002 ³ Southeast Nova Scotia n=593	OF 3221 ⁴ Central Nova Scotia n=786	OF 2757 ⁵ Southwest Nova Scotia n=455
Ag ppm	<0.3	0.6	-	0.5	1.5
Al %	0.53	0.71	-	0.66	0.57
B ppm	262	221	-	368	222
Be ppm	<0.2	<0.2	-	0.3	<0.2
Cd ppm	8.6	7.9	-	8	5.5
Cu ppm	148	165	-	166	164
Ga ppm	-	<2	-	-	3.5
Li ppm	2	<2	-	3	<2
Mg %	2.63	3.43	-	3.87	3.42
Mn %	2.08	2.68	-	2.03	1.11
Mo ppm	1*	2	-	<1	2
Ni ppm	29	62	-	53	38
P %	2.24	3.56	-	2.34	2.84
Pb ppm	48	134	-	57	113
Sr ppm	545	-	-	586	-
Ti ppm	-	106	-	-	83
V ppm	8	25	-	23	28

* Determined by INAA (quality of ICP-ES data was inadequate)

1

2

3

4

5

This study

Dunn, et al., 1994b

Dunn, et al., 1989

Dunn, et al., 1996

Dunn, et al., 1994a

TRANSPARENT OVERLAYS

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 coloured map, Appendix C), and to relate their positions to main communities, bedrock geology and mineral occurrences. A second transparent overlay is a digital elevation map, showing roads, streams and topographic features.

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 Au enrichment in soils, groundwater and near surface rocks. Background levels of Au in the ash of balsam fir twigs are commonly less than 5 ppb Au. In the survey area the median concentration (an estimate of background) of 12 ppb Au is appreciably higher than the median for Au in other survey areas of Nova Scotia, suggesting that south-west Cape Breton Island is a 'geochemical province' of weak gold enrichment. Median values (11 - 13 ppb) are similar for the five basic categories of rock adopted for broad classification of the survey area (Appendix B, p. B1, and Table 12).

Balma (1997), as part of his thesis, undertook a factor analysis of the analytical data set in an attempt to identify a factor in which Au is a dominant component. He found that the fourth factor, which accounted for 5.9% of the data variation, had factor loadings >0.5 for Au, Br, and K. The Au/Br association is of interest in that it has been noted in biogeochemical studies near zones of Au mineralization from elsewhere in Canada (Dunn, 1986; Dunn and Hoffman, 1986). Thus, by mapping the factor scores associated with factor four, it is possible to identify those areas where this association is dominant and, by inference, the areas where biogeochemical data indicate preferred areas for Au exploration (Fig. 4).

Arsenic (As)

Arsenic is renowned 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 median concentration of 1.8 ppm As is lower than elsewhere in Nova Scotia (Table 9). The statistics sheet (Appendix B, p.B2) shows that samples from terrain underlain by extrusive rocks (Fisset Brook Formation and Pringle Mountain Group) and metamorphic rocks of the George River Group have relatively low background concentrations of As (1.2 ppm). In general the western half of the survey area has slightly more arsenic than the east, especially in areas of clastic sediments of the Cumberland and Mabou groups.

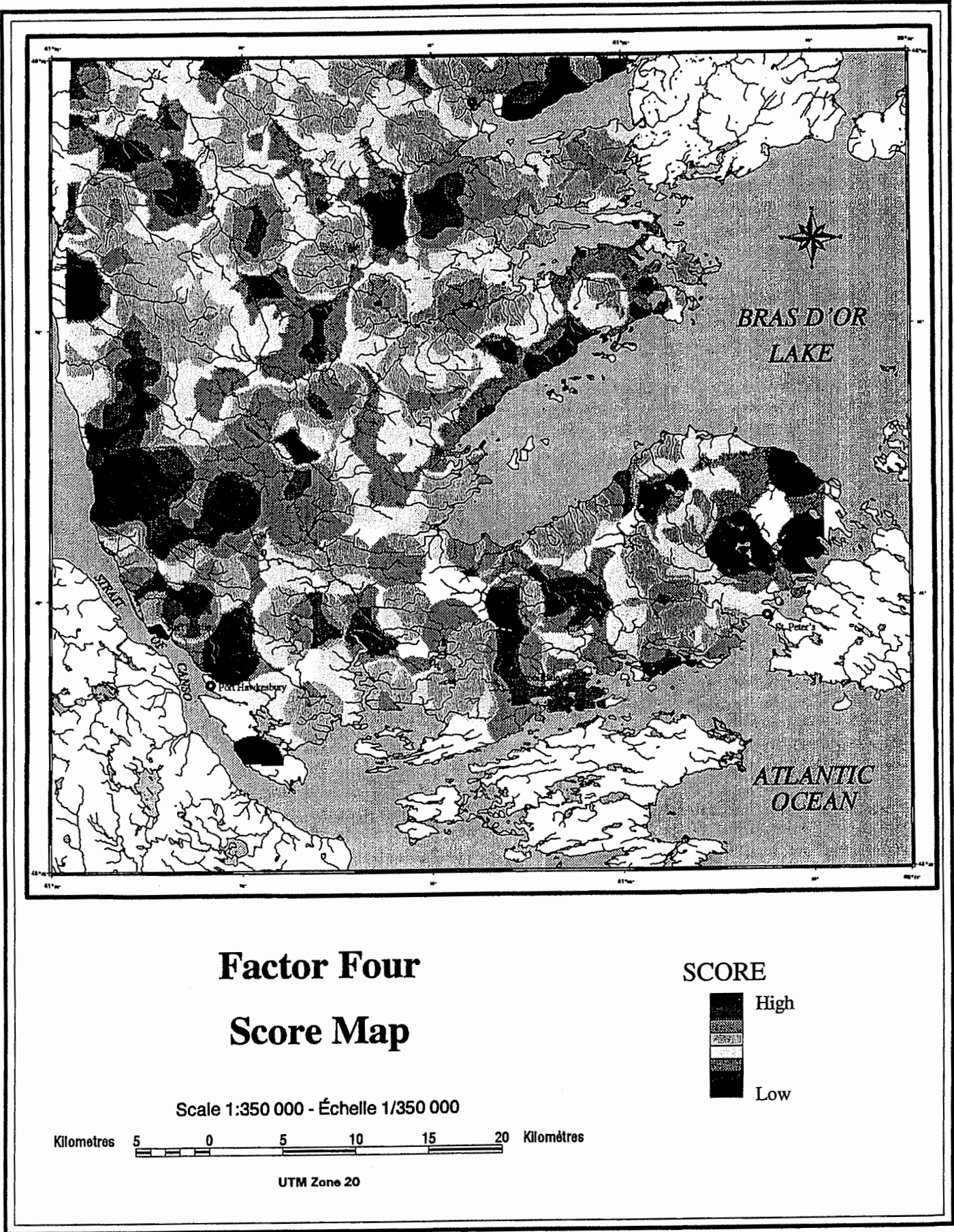


Fig. 4: Plot of scores for Factor 4 (Au, Br, K) from factor analysis of data set

Barium (Ba)

All samples yielded substantially more barium than the INAA detection limit of 10 ppm Ba. Balsam fir twigs commonly contain approximately 1000 ppm Ba. In the survey area the median of 2000 ppm Ba attests to the relative enrichment of Ba in southwestern Cape Breton Island. Highest concentrations (maximum of 6600 ppm Ba) occur in areas with clastic and chemical sediments (carbonates and evaporites) of the Cumberland and Mabou groups, and clastic sediments of the Horton Group in the northwestern part of the survey area. There is a notable area of enrichment associated with the synclinal structure (Fig. 3) in the River Denys Lowland.

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 occur in many forms as complexes within plants. Some Br complexes volatilise during the ashing process, causing losses of up to 90 percent of the Br contained within the plant tissues. The median value of 30 ppm Br is in close accord with Br concentrations in balsam fir twig ash from elsewhere in Nova Scotia (Table 9). As discussed above (section on 'Gold'), in some environments there is a Au/Br association in plant ash from zones of mineralization (Dunn, 1986). Within the survey area some of highest concentrations of Br occur near sites of Au enrichment in twigs, approximately 10 km north of Port Hastings. A second area with high Br is located a few km south of Whycocomagh near a site yielding moderate enrichment of Au.

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. For example a statistical analysis of multi-element data sets commonly reveals a strong association of Ca with Ba and Zn, although within the survey area this association is not apparent. The statistical summary of the Ca data (p. B5) shows there is little variation among trees growing over different substrates except for enrichment over rocks of the George River Group.

Cerium (Ce): see Lanthanum and other Rare Earth Elements

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 commonly have approximately 5 ppm Co. Within the survey area the median content of Co in the balsam fir twigs is 4 ppm. Most sites with above background concentrations of Co (maximum 15 ppm) occur in the south, between St. Peter's and Port Hastings

Chromium (Cr)

Chromium is a non-essential element for which precise INAA data are obtained at low ppm levels. The median concentration of 18 ppm Cr is similar to that for balsam fir from elsewhere in Nova Scotia (Table 9). However, there are zones of unusual enrichment (maximum of 100 ppm Cr) associated with the synclinal structure of clastic sediments comprising the Mabou Group (River Denys Lowland) and foliated granite lying to the west (Craignish Hills). Most Cr in rocks is structurally incorporated in crystal lattices of spinel group minerals and it is not readily released to tree roots from these sources. Usually, it is only where a source of weakly bound Cr is present (e.g. Cr mica, serpentinized ultramafic rocks, or the rare Cr carbonate) that concentrations such as those found here are encountered. The source of the Cr is unknown.

Cesium (Cs)

This alkali metal performs no known essential function in plant tissues, and is usually present at less than 3 ppm Cs in conifer twig 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 in two areas underlain by felsic intrusive rocks in the east-central (Hadrynian granodiorite, North Mountain [Fig. 3]) and north-eastern (Hadrynian gneiss, Craignish Hills [Fig. 3]) parts of the survey area. Comparison of the maps of Cs and Rb shows that elsewhere in the survey area there is a greater level of partitioning of these metals.

Europium (Eu): See Lanthanum and other Rare Earth Elements

Iron (Fe)

Iron is essential for photosynthesis and is a major constituent of chlorophyll. In addition, there is a residual content of Fe that reflects the composition of the substrate. Statistical analysis of the data (p. B11) shows that, compared to other lithological groups, Fe concentrations are appreciably lower (0.15% Fe) over metamorphic rocks of the George River Group, and extrusive rocks of the Fisset Brook Formation and the Pringle Mount Group.

Hafnium (Hf)

Hafnium it is not known to play an essential role in plant metabolism, yet the ash of conifer twigs commonly contains 1 ppm Hf. Hafnium levels are usually higher where Fe concentrations are high because the two elements are associated in plants. This is the dominant association, although Zr may also control the uptake of Hf by plants due to the close geochemical affinities of these elements.

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. The ranges of concentrations present are normal levels for conifer twigs (Table 9). There is relative enrichment of K in fir twigs from trees on foliated granite forming the Craguish Hills (Fig. 3), probably because of the potassic feldspar in the bedrock.

Lanthanum (La) and other Rare Earth Elements [REE]

Because of their chemical coherence the rare earth elements are considered as a separate group. Data provided by the low cost multi-element INAA package used in this study includes determinations of the rare earth elements lanthanum (La), cerium (Ce), neodymium (Nd), samarium (Sm), europium (Eu), terbium (Tb), ytterbium (Yb), and lutetium (Lu). Of these rare earths, only Tb consistently yields concentrations below the detection level (0.5 ppm) and is excluded from the data listings and discussion. Maps of REE show very similar distribution patterns, with concentrations generally higher in the east than the west. No sample yielded an unusually high concentration of any of the REE, and in general they closely follow Fe.

Lutetium (Lu): See Lanthanum and other Rare Earth Elements

Molybdenum (Mo)

Molybdenum is required in trace amounts by most plants for nitrogen fixation and nitrate reduction. Concentrations are usually <2 ppm Mo in the ash of conifer twigs, although over highly alkaline soils the trees are able to absorb Mo more readily, and therefore slightly higher levels may be expected. Within the survey area Mo concentrations are not exceptional, with only a few isolated occurrences of Mo up to 6 ppm.

Sodium (Na)

Median concentrations of Na are similar over the differing rock substrates, except for a moderate deficiency over rocks of the metamorphosed rocks of the George River Group. Local enrichment occurs a few kilometres north of Port Hastings in an area yielding some of the highest Au levels of the survey area.

Neodymium (Nd): See Lanthanum and other Rare Earth Elements

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, resulting in different distribution patterns for the two elements. Cesium is also involved in this competition, and in trees is more closely associated with Rb than K, especially where they grow on alkali-rich granites (cf. maps of Cs and Rb distributions). Background levels of Rb in balsam fir twigs

are commonly around 250 ppm, although compared to the rest of Nova Scotia there is relative depletion throughout much of southern Cape Breton Island (Table 9). In the survey area highest concentrations (maximum of 940 ppm Rb) occur as a north-easterly belt of enrichment in the north, coincident with felsic intrusive rocks of Hadrynian age that form the Craguish Hills.

Antimony (Sb)

Excellent analytical precision is obtained for Sb by INAA down to sub-ppm levels in ash. Although Sb in soluble forms can be taken up readily by plants, it is considered a non-essential element (Kabata-Pendias and Pendias, 1984) and it is usually present in sub-ppm amounts (Table 9). Throughout the survey area, antimony is present at levels close to usual background concentrations for balsam fir, reaching a maximum of only 1.9 ppm Sb.

Scandium (Sc)

Data on the essentiality of Sc in biologic systems are inconclusive (Horovitz, 1988). If required at all, Sc is needed only in 'ultra-trace' amounts, and therefore its presence in twigs is controlled essentially by the chemistry of the substrate and by the distribution of other elements. In the survey area Sc shows the usual high correlation with Fe that is found in plants.

Selenium (Se)

Traces of Se are essential for some plants. 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 is not proportional to the total content of the dry tissue. Analytical precision by INAA at low ppm levels of Se is poor. As a result, anomalies are mostly isolated and bear no relationship to known mineralization within the survey area.

Samarium (Sm): See Lanthanum and other Rare Earth Elements

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 well above detection limits in all samples, such that the areas of Sr enrichment depict significant regional variations.

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. In the survey area highest concentrations occur in association with sediments of the Mabou Group (maximum of 5800 ppm Sr - site #2033).

Thorium (Th)

Thorium has low solubility and is not essential for plant growth. Its concentration in plant ash is typically < 1 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). Relative to the rest of the survey area, there is relative enrichment (maximum of 4.7 ppm Th) over sediments of the Mabou and Cumberland groups.

Uranium (U)

Although U_3O_8 has high solubility, it rarely exceeds concentrations of more than 2 ppm in plant ash, and background concentrations are commonly <0.1 ppm U (Table 9). 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). No significant enrichment of U occurs within the survey area.

Ytterbium (Yb): See Lanthanum and other Rare Earth Elements

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, in the survey area there is a range in concentration from 960 - 4200 ppm Zn indicating that the regional pattern of Zn distribution is reflecting broad differences across the area. Spatial patterns of Zn concentrations are not confined to any single stratigraphic formation, however there are two north-easterly-trending zones of Zn enrichment which are mostly over the rocks of Hadrynian age that form the Craignish Hills and North Mountain. Some of the highest concentrations occur in the general vicinity of the Lime Hill zinc deposit (see Fig. 2).

DISTRIBUTION MAPS OF ELEMENTS DETERMINED BY ICP-ES

Aluminum (Al)

All dry vegetation samples were placed in Al trays for ashing, therefore some contamination from this source is inevitable. However, the amount of Al contributed from this source is small compared to the concentrations (typically more than 0.5%) that occur in the ash of conifer twigs. The aqua regia extraction used for releasing metals from ash into solution is not 'total' for Al, but good precision was obtained for duplicate samples (Table 6). Tests undertaken to compare data obtained on an ash 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. Highest concentrations of Al in the survey area are mostly over clastic sediments of the Cumberland and Mabou groups.

Boron (B)

Borosilicate test tubes were used for the acid digestion of the ash samples. This digestion may release 5 - 10 ppm B from the borosilicate, but this is insignificant in comparison with the hundreds of ppm B present in the ash. Tests indicate that the analytical procedure provides data, which represent about 50% of the true concentrations of B in the samples. Precision, however, is excellent (Table 6).

Boron is essential for plant growth, and it is believed to play an important role in the translocation of sugars. Within the survey area the median and range of B concentrations are typical for balsam fir (Table 10), and there are no significant enrichments. Some of the highest concentrations occur over carbonates and evaporites of the Windsor Group in the northeastern part of the survey area (River Denys Lowland).

Cadmium (Cd)

Although there is a strong geochemical association between Cd and Zn in many geochemical environments, commonly this is not evident in plant tissues because of the *requirement* that plants have for Zn but not for Cd. However, Cd is easily absorbed by plants and may therefore be expected to reflect relative Cd concentrations in the soils and groundwater. Absolute concentrations differ among plant species because Cd can be captured by a variety of organic compounds in cell walls and therefore not all will be transported to the tree extremities. The Cd content of samples from extrusive rocks and metamorphic rocks of the George River Group is lower than elsewhere in the survey area. Although concentrations are locally high (maximum of 52.5 ppm Cd) there are no obvious trends in Cd distributions.

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 it 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 twigs (median 148 ppm Cu for this study) 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. Kabata-Pendias and Pendias (1984) review these briefly. However, despite the essentiality of Cu and the complex metabolic roles that it may play, substantial differences among survey samples are more likely to reflect significant differences in the Cu content of the substrate than the relatively small differences attributable to micronutrient functions. Within the present survey area the range in Cu concentrations is quite small (99 - 244 ppm) and not diagnostic of any significant concentration of Cu in the substrate. No clear trends are apparent, except perhaps for a weak association with Zn,

following a north-easterly trend in association with rocks of Hadrynian age in the north (Craignish Hills).

Lithium (Li)

Lithium commonly follows Rb and Cs in nature. In balsam fir twigs it is less abundant than Rb but slightly 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. There are no notable concentrations of Li in the survey area. Highest concentrations (maximum of 15 ppm Li) are in trees growing over clastic sediments of the Mabou and Cumberland groups.

Magnesium (Mg)

Magnesium is a macronutrient that plays several important roles in plant health, including photosynthesis and numerous enzyme 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. Table 10 shows that the median Mg concentration in southwest Cape Breton is appreciably lower than elsewhere in the province, perhaps reflecting a relative paucity of mafic to ultramafic rocks and dolomite. Highest concentrations occur in trees growing over rocks of the George River Group (maximum of 4.84% Mg).

Manganese (Mn)

Manganese is highly enriched in balsam fir twigs. 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. Statistics on p. B35 show that trees from sites overlying the clastic sediments and intrusive rocks (mostly granitic), which generate relatively acidic soils, contain the highest concentrations of Mn.

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, plants readily take up Ni, therefore it may be expected that the Ni content of the twigs is positively correlated with Ni concentrations in groundwater. INAA has low sensitivity to Ni (detection limit of 50 ppm Ni in ash). In contrast, excellent precision (Table 6) and accuracy are obtained by ICP-ES down to the minimum level (7 ppm Ni) recorded for this data set. In general, Ni concentrations in balsam fir from southwest Cape Breton Island are lower than those from other areas of Nova Scotia that have been surveyed (Table 10). Nickel concentrations are highest (maximum of 142 ppm Ni) in trees growing over sediments of the Cumberland and Mabou groups to the east of

Port Hastings, and also in the centre of the survey area where enrichments are coincident with high levels of Cr.

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 antagonised by excess Ca which, by comparing maps showing distribution patterns of Ca and P, appears to take place in the balsam fir twigs because most sites with high Ca have low P. 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. Phosphorus levels are quite low in comparison with those in balsam fir from other parts of the province (Table 10).

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. On average, Pb concentrations in the survey area are lower than those found in balsam fir from other parts of Nova Scotia (Table 10). Some of the highest concentrations occur along North Mountain

Vanadium (V)

The essentiality of V for plants other than green algae has not been proven. Roots easily take up soluble V, and it may play a similar role to Mo in fixing nitrogen. Vanadium concentrations in southwest Cape Breton Island are substantially lower than concentrations in other parts of Nova Scotia. Table 10 shows that the median value of 8 ppm V is only a third of that found elsewhere. The distribution of V is different from all other elements determined, except for a coincidence with Ni enrichment near Port Hawkesbury and Port Hastings. Most samples with concentrations greater than 20 ppm V are from trees growing on clastic sediments of the Cumberland Group.

OTHER ELEMENTS: (TUNGSTEN, SILVER, BERYLLIUM)

Tungsten (W) - The detection limit for W by INAA is 1 ppm in ash, which is above the usual concentrations in tree tissues, and analytical precision at this level is poor.

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 sub-ppm concentrations present within the study area (and most natural environments) the inhibiting effect of Ag on the uptake of other elements is insignificant.

Beryllium (Be) - There is usually less than 2 ppm Be in soils, and because it is a non-essential element for plant growth (in high concentrations it is toxic), its presence in the

substrate is reflected in the balsam fir twigs by concentrations of mostly less than 0.2 ppm Be.

NOTES ON THE BIOGEOCHEMICAL DATA LISTINGS

(APPENDICES A and B)

Appendix A contains lists of 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 by lithology. Abbreviations used in the appendices are explained in Tables 11 and 12.

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 Paul Lombard and two of his assistants for undertaking some of the sampling, and Dr. P.J. Rogers (formerly NSDNR) for his active support throughout this study. Thanks, too, to Martin McCurdy for his review of this report. This project is a contribution to a Canada-Nova Scotia Co-operation Agreement on Mineral Development (1992-1995).

Table 11: Abbreviations Used in Appendix A

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
Land Class	Land Classification: type of vegetation cover and degree of surface water saturation. First letter: D = dry; M = moist; W = wet Second letter: O = open; M = moderately dense; D = dense Third letter: W = woodland; B = bog
Rock Unit	Abbreviation used on large coloured map

Table 12: Abbreviations Used in Appendix B

Rock Type	<p>In view of the many different bedrock units in the survey area, rock types have been broadly grouped according to lithology, derived from published geological maps, mostly that of Lynch <i>et al.</i>, 1995:</p> <p>Clast. sed. - Clastic sediments; mostly sandstone, siltstone and some coal Chem. sed. - Chemical sediments; i.e. carbonates and evaporites Int. rock - Intrusive rocks; mostly granite and granodiorite Ext. rock - Extrusive rocks; mostly basalt and andesite Meta. G.R. - Metamorphic rocks of the George River Group</p>
N dl Cum %	<p>N = number of samples dl = determination limit Cum % - cumulative frequency (as a percentage)</p>

REFERENCES

- Balma, R.G., 1997. Biogeochemical Prospecting for Gold: Southwest Cape Breton Island, Nova Scotia. Unpublished B.A. (Hon.) thesis, Dept. Geography, Carleton University, Ottawa, 75 pp.
- Bidwell, R.G.S., 1979. Plant Physiology. Second edition, MacMillan Publ. Co., Inc., NY.
- Broyer, T.C., Johnson, C.N., and Paull, R.E., 1972. Some aspects of lead in plant nutrition. *Plant Soil*, **36**: 301.
- Chatterjee, A.K., 1977. Copper-zinc deposit at McMillan Brook, Victoria County, Cape Breton Island. Nova Scotia Dept. of Mines and Energy, Report of Activities 1976, Report 77-1, 79-90
- 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., 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., Adcock, S.W., and Spirito, W.A., 1994a. Reconnaissance biogeochemical survey of south-western Nova Scotia: Part 2 - balsam fir twigs (Parts of NTS 20 O,P, 21 A,B). *Geol. Survey Canada, Open File* **2757**, 142 pp + maps.
- Dunn, C.E., Adcock, S.W., and Spirito, W.A., 1994b. Reconnaissance biogeochemical survey of south-eastern Cape Breton Island, Nova Scotia: Part 2 - balsam fir twigs (parts of NTS 11F,G,J,K). *Geol. Survey Canada, Open File* **2758**, 146pp + maps.
- Dunn, C.E., Balma, R.G., and Spirito, W.A., 1996. Reconnaissance biogeochemical survey, central Nova Scotia (parts of NTS 11D,E, and 21A,H): Part 1 - balsam fir twigs. *Geol. Survey Canada, Open File* **3221**, 164 pp + maps.
- 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.
- Grant, D.R., 1994. Quaternary geology, Cape Breton Island, Nova Scotia. *Geol. Survey Canada, Bulletin* **482**, 159 pp.
- Gregory, D.J., Chatterjee, A.K., and Lyttle, M.A., 1979. *Metallic Mineral Occurrences in Nova Scotia*. Nova Scotia Dept. of Mines and Energy (compilation plotted on map by Keppie. 1979)

- Hein, F.J., Graves, M.C., and Ruffman, A., 1988. The geology of the Jubilee zinc-lead deposit, Victoria County, Cape Breton Island, Nova Scotia. Geological Survey of Canada Open File 1891, 135 pp, 11 sheets.
- Hendrix, D.L. and Higinbotham, N., 1974. Heavy metals and sulphhydryl reagents as probes of ion uptake in pea stem. *In: Membrane Transport in Plants*, Springer Verlag, Berlin, 412 pp.
- Hill, J.R., 1987. A preliminary report on geology and on mineral occurrences in Precambrian carbonate rocks, Cape Breton Island, Nova Scotia. *In: Current Research, Part A*, Geol. Survey Canada, Paper 87-1A: 533-542.
- 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.
- Justino, M.F., and Sangster, A.L., 1987. Geology in the vicinity of the Lime Hill zinc occurrence, southwestern Cape Breton Island, Nova Scotia. *In: Current Research, Part A*, Geol. Survey Canada, Paper 87-1A 555-561.
- 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, Map, scale 1:500 000.
- Lynch, G., Barr, S.M., Houlahan, T., and Giles, P., 1995. Geological compilation, Cape Breton Island, Nova Scotia. Geol. Survey Canada, Open File **3159**, map scale 1:250,000.
- NSDNR (Nova Scotia Dept. Natural Resources), 1996. Nova Scotia Mineral Occurrence Database. Digital Product DP1, v.1. Nova Scotia Dept. of natural Resources, Library, P.O. Box 698, Halifax, Nova Scotia, B3J 2T9
- 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., 1993. Vegetation chemistry applied to mineral exploration in eastern Nova Scotia. *J. Geochem. Explor.*, **48**: 71-95.
- 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.