



GEOLOGICAL SURVEY OF CANADA

OPEN FILE 3221

RECONNAISSANCE BIOGEOCHEMICAL SURVEY CENTRAL NOVA SCOTIA (Parts of NTS 11D,E, and 21A,H) PART 1 - BALSAM FIR TWIGS

C.E. Dunn, R.G. Balma, W.A. Spirito

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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/Nouvelle-Écosse de développement économique et régional.

Canada

Nova Scotia

Province of
Nova Scotia

C.E. Dunn, R.G. Balma, W.A. Spirito

1996

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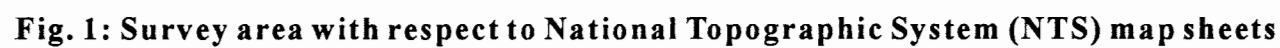
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RECONNAISSANCE BIOGEOCHEMICAL SURVEY
CENTRAL NOVA SCOTIA
PART 1 - BALSAM FIR TWIGS

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INTRODUCTION

This Open File contains data from a reconnaissance biogeochemical survey in central Nova Scotia (Fig. 1), conducted in May and June, 1994, by the Geological Survey of Canada under the Canada - Nova Scotia Cooperation Agreement on Mineral Development (1993 - 1996). This is the first of two Open Files of biogeochemical data from central Nova Scotia. The second will present data from the analysis of spruce bark.

Field observations, data listings, statistical summaries, a geology 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 14 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, the ashing process concentrates the elements 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. In 1987 and 1993 reconnaissance biogeochemical reconnaissance 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 interpretative accounts are given in Dunn (1988, 1990), Rogers and Dunn (1989), Dunn *et al.* (1991), and Rogers and Dunn (1993).

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 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, to 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 Fax: (613) 943-0646

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. James and K. Slough, assisted by T. Hearty, L. Young, W. Spirito, and P. Pelchat.

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

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

Digital Cartography: R.G. Balma

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 four week period, commencing mid-May, 1994, vegetation samples were collected from approximately 925 sites within a 5600 km² area of central Nova Scotia (Fig. 1). This report presents data from the 786 sites at which balsam fir twig samples were collected. Samples were collected on as even a grid as was practically possible, attaining an average sample density of approximately 1 site per 7 km². Agricultural and cultural developments in the northern part of the survey area precluded sample collection at some locations. In general, samples were collected at 2 km intervals along driveable roads and tracks, with some helicopter support for accessing remote areas. Three trucks were used, each with a crew of two. At each sample location vegetation samples were selected from a site at least 50 m from a highway, or 10 m from a little-used track.

Sample Locations

Samples were located in the field from 1:50,000 NTS (National Topographic System) maps, supplemented by 1:10,000 LRIS (Land Registration Information Service) maps. The 1:10,000 maps use the Nova Scotia modified transverse Mercator (MTM) projection, in conjunction with the ATS77 datum (Kouba, 1978; LRIS, no date). The ATS77 datum is a precursor and very similar to the North American Datum 1983 (NAD83). The NTS 1:50,000 maps use the NAD27 datum and the usual UTM (Universal Transverse Mercator) projection. The UTM Eastings and Northings presented in the data listings are all in UTM Zone 20.

Sample Collection

An orientation survey of the area conducted in July, 1993, showed that the most common species are balsam fir (*Abies balsamea*), red spruce (*Picea rubens*), and black spruce (*Picea mariana*). 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, but that outer bark from the red and black spruce had generally higher concentrations of trace metals than the other tissues that were collected. At most sample stations outer bark of red or black spruce, and twigs of balsam fir were collected. Data from analysis of the spruce bark will be compiled for a second Open File release.

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 four 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 commonly 35 - 40 cm length of twig. The range of age in twigs from each site is given in the data listings (Appendix A). 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 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 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 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 Mo and Ni by INAA was poor at the low levels present (mostly <2 ppm Mo and <50 ppm Ni), therefore maps of Mo and Ni determinations by INAA are not presented. Instead there are maps of Mo and Ni determined by ICP-ES, because this is the preferred method for these elements at the concentrations present in the samples. 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 (0.5 g) was submitted for multi-element ICP-ES analysis, following an aqua regia digestion. 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 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 (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 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. In Tables 3-6 the first row of data shows the determination limits. 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.

Table 1: Mean And Standard Deviation For Standard V6c Analyzed By INAA
(n=49)

Element			Mean	Standard Deviation
Arsenic	As	ppm	7.9	0.7
Gold	Au	ppb	16	3
Barium	Ba	ppm	423	25
Bromine	Br	ppm	12	2
Calcium	Ca	%	16.4	1.2
Cobalt	Co	ppm	9	1
Chromium	Cr	ppm	70	3
Cesium	Cs	ppm	1.3	0.5
Iron	Fe	%	1.85	0.10
Hafnium	Hf	ppm	5.4	0.3
Potassium	K	%	3.83	0.80
Rubidium	Rb	ppm	47	6
Sodium	Na	ppm	11555	540
Antimony	Sb	ppm	1.2	0.1
Scandium	Sc	ppm	4.6	0.2
Selenium	Se	ppm	1	0.4
Strontium	Sr	ppm	964	189
Thorium	Th	ppm	3.2	0.3
Uranium	U	ppm	1.4	0.3
Tungsten	W	ppm	*	*
Zinc	Zn	ppm	795	44

Rare Earth Elements			Mean	Standard Deviation
Lanthanum	La	ppm	21.6	1.1
Cerium	Ce	ppm	43	3
Neodymium	Nd	ppm	23	2
Samarium	Sm	ppm	3.2	0.2
Europium	Eu	ppm	0.87	0.07
Ytterbium	Yb	ppm	1.80	0.15
Lutetium	Lu	ppm	0.31	0.02

* all below determination limit of 1 ppm

Table 2: Mean and Standard Deviation for Standard V6c Analyzed by ICP-ES
(n=50)

Element			Mean	Standard Deviation
Silver	Ag	ppm	0.3	0.2
Aluminum	Al	%	1.22	0.07
Boron	B	ppm	180	19
Beryllium	Be	ppm	0.2	0.1
Cadmium	Cd	ppm	3.2	0.4
Copper	Cu	ppm	132	19
Lithium	Li	ppm	8	3
Magnesium	Mg	%	3.33	0.25
Manganese	Mn	ppm	773	90
Molybdenum	Mo	ppm	6	2
Nickel	Ni	ppm	80	7
Phosphorus	P	%	0.669	0.043
Lead	Pb	ppm	182	27
Strontium	Sr	ppm	576	29
Vanadium	V	ppm	30	2

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

Au ppb 5*	As ppm	Ba ppm	Br ppm	Ca %	Ce ppm	Co ppm	Cr ppm	Cs ppm	Eu ppm	Fe %	Hf ppm	K %	La ppm	Lu ppm	Na ppm	Nd ppm	Rb ppm	Sb ppm	Sc ppm	Se ppm	Sm ppm	Sr ppm	Th ppm	U ppm	W ppm	Yb ppm	Zn ppm
	0.5	10.0	1	0.2	3	1	1	0.5	0.01	0.05	0.5	0.05	0.1	0.05	10	5	5	0.1	0.1	2	0.1	300	0.1	0.1	1	0.05	20
18	7.2	430	11	14.8	38	9	67	1.9	0.82	1.75	5.0	3.71	21.0	0.27	10900	20	45	1.2	4.3	<2	3.3	1000	3.0	1.1	<1	1.61	780
15	7.4	410	13	16.5	39	9	66	2.1	0.82	1.75	5.3	3.14	22.0	0.31	11000	22	43	1.2	4.3	<2	3.2	1400	3.0	1.4	<1	1.71	780
14	7.7	440	10	16.8	40	10	68	2.2	0.85	1.76	5.5	3.25	20.0	0.34	11900	22	48	1.2	4.4	<2	3.0	1000	3.1	1.4	<1	1.81	780
18	7.3	410	10	14.7	40	9	67	1.8	0.69	1.81	4.6	3.55	20.0	0.29	10800	23	44	1.1	4.4	<2	3.4	830	2.6	<0.1	<1	1.48	720
16	5.8	380	9	15.3	43	9	72	1.8	0.74	1.89	5.0	3.51	21.0	0.29	10700	27	46	1.2	4.5	<2	3.6	830	2.6	0.9	<1	1.61	730
14	7.5	440	10	15.0	47	9	71	1.7	0.88	1.82	5.3	4.29	21.0	0.31	11400	21	39	1.2	4.6	<2	3.1	1200	3.2	1.5	<1	1.76	800
14	7.1	410	10	16.5	42	9	67	2.4	0.84	1.74	5.2	3.96	20.0	0.29	11800	24	50	1.1	4.4	<2	2.9	930	2.9	1.3	<1	1.61	740
21	8.0	390	9	17.3	40	8	69	2.0	0.78	1.65	5.0	3.38	20.0	0.30	10900	20	45	1.3	4.3	<2	3.0	890	3.1	1.4	<1	1.79	790
17	7.6	380	11	15.7	39	7	68	2.2	0.77	1.65	5.1	3.53	20.0	0.27	10700	23	51	1.0	4.1	<2	2.9	590	3.0	1.9	<1	1.69	730
15	7.8	420	15	15.9	41	9	70	1.2	0.77	1.96	5.8	3.87	21.0	0.35	11500	24	39	1.1	4.7	3	3.0	700	3.1	1.2	<1	1.78	800
18	7.3	390	13	15.2	43	9	75	1.3	0.91	1.95	5.3	3.70	21.0	0.32	11100	23	48	1.2	4.6	<2	3.2	930	3.4	1.1	<1	1.88	760
14	7.1	400	12	14.2	42	9	80	1.5	0.87	1.90	5.3	3.99	21.0	0.29	10700	21	49	1.0	4.5	<2	2.9	970	2.8	1.2	<1	1.80	750
12	7.5	410	12	14.4	44	8	69	1.1	0.84	1.75	4.6	3.74	21.0	0.29	11200	23	39	1.2	4.4	<2	3.2	1100	2.8	1.2	<1	1.64	760
14	7.6	430	12	14.8	47	10	70	<0.5	0.90	2.03	5.7	4.04	22.0	0.31	11600	20	50	1.1	4.7	3	3.3	980	3.7	1.3	<1	1.89	840
16	7.5	430	10	15.3	41	9	65	1.3	0.90	1.99	5.6	4.30	21.0	0.33	10900	22	45	1.0	4.5	<2	2.9	1000	2.9	1.2	<1	1.59	780
14	7.7	450	13	15.5	44	10	70	1.2	0.91	1.83	5.5	3.66	22.0	0.33	12000	25	64	1.1	4.8	<2	3.3	1000	3.0	1.5	<1	1.84	850
10	8.1	450	13	14.6	46	9	69	1.1	0.94	1.74	5.4	3.78	21.0	0.33	11500	22	66	1.2	4.8	<2	3.2	1100	3.1	1.7	<1	1.90	870
14	7.6	440	13	15.3	43	9	69	1.1	0.86	1.83	5.4	3.61	21.0	0.34	12600	24	45	1.2	4.9	<2	3.1	970	3.5	1.7	<1	1.65	770
13	7.6	460	12	16.3	46	10	71	1.3	0.86	1.88	5.7	4.10	22.0	0.33	12600	24	41	1.2	4.9	<2	3.2	950	3.3	1.7	<1	1.83	820
21	7.8	360	12	14.5	39	9	65	0.9	0.73	1.74	5.2	3.09	19.0	0.29	11800	21	38	1.1	4.4	2	2.9	1000	2.9	1.0	<1	1.65	700
18	7.2	480	12	16.8	42	9	66	1.3	0.83	1.78	6.0	3.98	21.0	0.35	12100	22	40	1.2	4.7	<2	3.1	1100	3.3	1.6	<1	1.76	780
14	8.2	430	13	16.7	45	9	69	0.8	0.87	1.92	5.8	3.43	21.0	0.31	11500	26	40	1.3	4.8	<2	3.2	970	3.2	1.6	<1	1.85	860
16	7.9	450	13	18.1	47	8	75	0.9	0.93	1.92	5.7	3.67	22.0	0.28	12000	24	52	1.3	4.7	<2	3.3	910	3.3	1.4	<1	1.89	800
17	7.6	420	13	17.4	48	9	75	1.1	0.89	1.90	5.5	3.75	21.0	0.34	12500	25	47	1.2	4.7	<2	3.4	940	3.2	2.0	<1	2.11	840
17	10.0	430	12	18.9	48	9	67	0.7	0.92	1.95	5.6	5.59	21.0	0.36	12500	24	44	1.3	4.8	<2	3.4	930	3.4	1.7	<1	2.31	880

* first row of data shows determination limits

Table 3 (cont'd): Standard V6c - Concentrations in Ash Determined by INAA

Au ppb 5*	As ppm 0.5 10.0	Ba ppm	Br ppm	Ca %	Ce ppm	Co ppm	Cr ppm	Cs ppm	Eu ppm	Fe %	Hf ppm	K %	La ppm	Lu ppm	Na ppm	Nd ppm	Rb ppm	Sb ppm	Sc ppm	Se ppm	Sm ppm	Sr ppm	Th ppm	U ppm	W ppm	Yb ppm	Zn ppm
			1	0.2	3	1	1	0.5	0.01	0.05	0.5	0.05	0.1	0.05	10	5	5	0.1	0.1	2	0.1	300	0.1	0.1	1	0.05	20
12	8.5	470	12	18.0	43	9	72	0.8	0.88	1.96	5.8	3.20	23.0	0.33	12400	21	54	1.3	4.7	<2	3.5	1100	3.4	1.6	<1	1.84	820
17	8.2	430	13	14.6	42	8	70	1.4	0.90	1.90	5.6	4.27	23.0	0.33	12000	20	47	1.2	4.7	<2	3.5	990	3.0	1.3	<1	1.78	830
15	8.7	410	16	17.0	44	9	73	1.1	0.83	1.85	5.3	4.82	23.0	0.31	11900	24	64	1.2	4.6	<2	3.4	880	3.6	1.4	<1	2.05	830
16	7.4	410	14	15.3	47	10	69	1.1	0.95	1.71	5.5	4.81	21.0	0.31	10500	26	49	1.1	4.7	<2	3.8	950	3.0	1.2	<1	1.82	770
17	7.6	430	12	17.5	44	10	72	1.1	0.91	1.86	5.6	3.78	22.0	0.32	11900	26	46	1.2	4.8	<2	3.4	1300	3.4	1.4	<1	1.81	840
17	8.0	390	13	16.0	41	9	66	0.8	0.88	1.83	5.2	3.33	21.0	0.31	11300	21	46	1.2	4.7	<2	3.0	1200	2.9	1.3	<1	1.72	770
17	6.6	420	12	16.3	42	9	68	1.3	0.91	1.84	5.4	3.93	21.0	0.31	11700	22	49	1.2	4.7	<2	3.1	930	3.0	1.6	<1	1.89	780
17	8.7	440	12	17.3	44	10	72	0.9	0.87	1.86	5.5	3.51	22.0	0.32	11700	24	48	1.3	4.8	<2	3.2	630	3.3	1.2	<1	1.99	850
16	9.2	430	11	17.2	46	10	71	0.7	0.98	2.03	5.6	5.53	22.0	0.34	11800	21	43	1.4	4.8	<2	3.3	910	3.2	1.9	<1	1.91	810
15	8.8	440	13	17.1	48	10	71	1.1	0.91	1.88	6.0	4.14	24.0	0.33	11700	26	45	1.2	4.9	<2	3.4	1100	3.7	1.5	<1	1.81	820
14	8.3	430	12	17.4	45	9	71	1.3	0.81	1.78	5.5	4.33	22.0	0.27	11300	22	45	1.2	4.4	<2	3.2	1100	3.3	1.3	<1	1.69	760
15	8.5	380	11	17.2	45	8	70	0.8	0.84	1.81	5.6	4.09	22.0	0.30	11400	25	51	1.2	4.5	<2	3.2	920	3.2	1.4	<1	1.88	740
17	8.5	420	12	17.1	44	8	73	0.9	0.86	1.78	5.6	3.60	21.0	0.32	11400	23	46	1.2	4.5	<2	3.2	900	3.1	1.4	<1	1.72	730
17	8.6	430	10	17.7	45	8	73	2.4	0.83	1.78	5.8	3.08	22.0	0.31	11600	26	47	1.2	4.4	<2	3.2	390	3.3	1.7	<1	1.83	790
13	7.3	410	13	17.4	41	8	73	0.9	0.75	1.74	5.1	4.25	21.0	0.25	11200	26	52	1.1	4.5	<2	3.1	960	3.1	1.3	<1	1.77	790
19	8.6	420	13	18.0	44	9	69	1.1	0.91	1.81	5.2	3.51	22.0	0.31	11200	23	54	1.2	4.4	<2	3.2	790	3.3	1.4	<1	1.99	770
32	7.5	380	13	17.3	43	8	72	0.9	0.80	1.71	5.5	3.41	21.0	0.32	11000	24	37	1.1	4.4	<2	3.2	410	3.0	1.2	<1	1.75	730
19	8.6	410	12	17.5	46	8	72	1.3	0.88	1.79	5.5	<0.38	23.0	0.27	11500	26	55	1.2	4.5	<2	3.4	960	3.4	1.3	<1	1.75	810
17	7.8	450	15	17.1	46	11	75	1.1	0.94	1.93	5.2	3.68	24.0	0.35	11200	25	45	1.3	5.1	<2	3.3	1200	3.2	1.4	<1	1.82	850
16	7.9	430	14	16.0	46	10	71	0.9	0.81	1.88	5.0	3.19	22.0	0.31	11400	21	47	1.4	4.8	<2	3.1	970	3.3	1.5	<1	1.77	850
16	8.2	440	15	16.3	46	9	73	1.2	0.91	1.91	5.2	4.99	22.0	0.33	11800	25	47	1.3	4.9	<2	3.3	1100	3.9	1.6	<1	1.82	780
18	7.6	440	13	16.7	48	9	71	1.1	0.88	1.84	5.0	3.79	23.0	0.32	11700	25	46	1.3	4.7	<2	3.3	1100	3.5	1.5	<1	1.76	830
13	8.0	460	12	17.7	46	10	73	1.3	1.09	2.08	5.5	4.28	24.0	0.33	12500	23	45	1.2	5.1	<2	3.5	1100	3.7	1.4	<1	2.07	830
17	7.5	440	13	17.0	47	10	72	0.8	0.97	1.94	5.6	5.40	22.0	0.32	11900	27	46	1.3	4.9	<2	3.2	1100	3.3	1.7	<1	1.70	840

* first row of data shows determination limits

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

Ag ppm 0.1*	Al ppm 0.01	B ppm 2	Be ppm 0.2	Cd ppm 0.2	Cu ppm 1	Li ppm 2	Mg % 0.01	Mn ppm 1	Mo ppm 1	Ni ppm 1	P % 0.001	Pb ppm 3	Sr ppm 1	V ppm 2
0.7	1.22	188	<0.2	2.7	124	8	3.33	755	9	81	0.672	173	610	30
<0.1	1.15	168	<0.2	2.9	111	14	3.07	720	6	76	0.635	170	576	28
0.2	1.27	177	0.3	2.9	131	6	3.44	780	9	80	0.678	167	613	32
0.1	1.24	176	<0.2	2.9	117	6	3.28	744	6	82	0.661	165	605	30
0.6	1.22	171	<0.2	3.2	125	9	3.31	644	8	81	0.660	170	594	31
0.3	1.31	168	<0.2	3.3	124	16	3.38	792	5	78	0.701	160	607	31
<0.1	1.26	161	<0.2	3.1	116	12	3.34	778	3	80	0.687	170	595	31
0.5	1.22	146	<0.2	3.0	179	6	2.98	749	6	72	0.642	162	597	30
0.3	1.29	146	<0.2	2.8	121	5	3.03	757	9	74	0.649	170	596	30
0.3	1.20	159	<0.2	2.7	115	<2	3.16	717	4	74	0.635	151	568	30
0.2	1.28	168	<0.2	3.0	117	11	3.35	748	10	78	0.662	165	591	31
0.5	1.28	167	<0.2	2.9	118	<2	3.24	748	6	75	0.654	156	597	29
0.5	1.18	166	<0.2	2.9	119	<2	3.04	707	7	74	0.626	143	564	29
0.4	1.21	168	<0.2	2.8	119	5	3.16	731	8	91	0.648	164	580	29
1.0	1.28	169	<0.2	3.5	134	15	3.30	757	8	80	0.684	176	596	32
0.2	1.29	179	<0.2	3.0	133	6	3.37	835	5	82	0.696	161	617	31
0.1	1.27	171	<0.2	3.3	132	10	3.38	787	2	82	0.695	178	616	32
0.4	1.22	174	<0.2	2.6	122	12	3.30	689	7	79	0.646	167	586	28
0.6	1.23	175	<0.2	3.0	120	17	3.22	725	9	105	0.643	169	580	28
0.4	1.20	154	<0.2	2.4	112	<2	3.00	687	9	75	0.597	164	566	28
0.3	1.21	138	<0.2	2.9	125	6	2.99	762	5	73	0.629	161	577	30
<0.1	1.15	187	<0.2	3.4	119	8	3.25	686	6	76	0.637	250	571	29
0.7	1.18	186	0.2	3.2	131	7	3.42	749	6	87	0.662	240	588	30
0.5	1.08	162	<0.2	3.5	104	6	3.07	675	5	73	0.611	233	527	28
0.4	1.13	167	0.2	3.3	116	8	2.97	659	5	68	0.612	229	532	28

* first row of data shows determination limits

Table 4 (cont'd): Standard V6c - Concentrations in Ash Determined by ICP-ES

Ag ppm 0.1*	Al ppm 0.01	B ppm 2	Be ppm 0.2	Cd ppm 0.2	Cu ppm 1	Li ppm 2	Mg % 0.01	Mn ppm 1	Mo ppm 1	Ni ppm 1	P % 0.001	Pb ppm 3	Sr ppm 1	V ppm 2
0.1	1.08	176	<0.2	3.1	107	9	3.12	698	5	77	0.617	228	549	28
0.1	1.16	177	<0.2	3.3	131	9	3.22	707	6	79	0.645	239	562	29
0.4	1.08	170	<0.2	3.4	106	8	2.80	621	5	67	0.596	226	508	27
<0.1	1.07	169	<0.2	3.1	115	8	3.03	669	6	74	0.607	230	552	27
0.3	1.07	167	<0.2	3.4	116	8	2.95	650	6	71	0.598	229	527	28
<0.3	1.30	196	0.4	3.1	140	7	3.69	814	3	86	0.709	174	555	30
0.4	1.14	200	0.3	3.4	142	7	3.40	852	6	83	0.672	166	533	29
<0.3	1.18	204	0.3	3.7	173	6	3.53	1099	4	83	0.716	172	558	29
0.4	1.16	208	0.3	4.0	169	7	3.71	1023	5	87	0.722	189	590	32
0.5	1.18	218	0.2	4.8	153	7	3.79	906	8	91	0.787	197	600	33
0.5	1.25	206	0.4	3.5	140	9	3.53	833	9	79	0.706	167	561	30
<0.3	1.28	200	0.2	3.0	136	8	3.60	784	6	86	0.682	154	646	32
<0.3	1.22	192	0.2	3.1	145	5	3.39	802	5	79	0.681	157	541	30
<0.3	1.26	212	0.5	3.4	157	7	3.60	920	5	82	0.727	174	551	30
<0.3	1.18	188	0.3	3.4	137	6	3.35	820	5	78	0.663	180	516	27
0.4	1.29	194	0.4	3.3	183	6	3.68	783	5	84	0.727	191	580	31
<0.3	1.20	184	0.3	3.4	160	6	3.37	752	5	76	0.680	169	548	30
0.3	1.36	205	0.4	3.6	149	8	3.85	845	8	89	0.749	204	591	32
<0.3	1.22	194	0.4	2.8	158	8	3.54	886	7	89	0.707	180	573	30
<0.3	1.29	201	0.3	3.3	139	7	3.56	784	6	84	0.723	183	611	31
0.3	1.26	196	0.2	3.4	142	6	3.58	757	7	84	0.712	189	576	31
<0.3	1.21	211	0.4	3.9	130	7	3.42	817	7	83	0.689	162	553	30
<0.3	1.21	179	0.3	3.1	116	5	3.21	850	7	82	0.634	164	591	32
<0.3	1.30	185	0.3	3.4	131	6	3.29	792	7	86	0.660	169	597	34
<0.3	1.31	209	0.4	3.9	157	6	3.73	817	3	86	0.736	172	583	32

* first row of data shows determination limits

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

Vial Number	Au ppb 5*	As ppm	Ba ppm	Br ppm	Ca %	Ce ppm	Co ppm	Cr ppm	Cs ppm	Eu ppm	Fe %	Hf ppm	K %	La ppm	Lu ppm	Na ppm	Nd ppm	Rb ppm	Sb ppm	Sc ppm	Se ppm	Sm ppm	Sr ppm	Th ppm	U ppm	W ppm	Yb ppm	Zn ppm
AL94/1402 AL94/1403	<5 6	1.7 1.3	1600 1900	84 84	14.2 17.3	3 3	6 7	2 2	0.8 <0.5	0.14 <0.02	0.15 0.17	0.8 0.6	22.20 25.90	3.1 3.3	<0.05 <0.05	1010 1110	<5 <5	180 230	0.3 0.3	0.4 0.4	<2 <2	0.3 0.3	830 1200	0.3 <0.1	<0.1 <0.1	<1 <1	0.17 0.19	1500 1700
	29 29	2.2 2.2	1900 1800	61 59	16.9 17.7	5 6	10 10	8 4	3.3 2.8	<0.02 <0.02	0.23 0.26	0.7 0.8	24.40 25.60	5.5 5.6	<0.05 <0.05	2250 2300	<5 <5	360 380	0.6 0.7	0.6 0.6	<2 <2	0.4 0.4	1200 860	0.5 0.2	<0.1 0.4	<1 <1	0.23 0.22	2000 2000
AL94/1451 AL94/1452	21 14	7.4 7.5	2900 2900	49 48	10.6 10.7	15 18	5 6	12 13	3.5 3.3	0.20 0.40	0.72 0.70	1.7 1.7	27.50 26.40	8.6 8.2	0.12 0.12	3540 3520	9 8	440 440	0.6 0.6	2.1 2.0	<2 <2	1.2 1.2	800 590	1.7 1.8	<0.1 0.9	<1 <1	0.77 0.64	1800 1700
	22 23	3.2 2.4	330 330	39 43	13.7 13.6	5 <3	3 3	5 6	5.5 6.5	<0.03 <0.03	0.29 0.29	<0.5 <0.5	27.60 24.00	3.0 2.9	<0.05 0.05	1610 1530	<5 <5	310 300	0.4 0.4	0.7 0.6	<2 <2	0.4 0.4	450 <300	0.3 <0.1	<0.1 <0.1	<1 <1	0.20 <0.05	2200 2100
AL94/1495 AL94/1496	14 11	15.0 15.0	1800 1800	27 27	10.5 11.1	49 49	13 12	35 32	2.3 2.5	0.79 0.92	2.20 2.11	4.2 4.0	20.20 17.30	23.0 23.0	0.39 0.36	4340 4440	24 27	190 170	0.9 0.8	6.1 6.2	<2 <2	4.5 4.5	<300 620	3.9 4.0	1.3 1.6	<1 <1	2.08 1.97	1400 1400
	7 8	3.1 2.8	4600 4600	35 36	17.7 18.7	9 8	8 9	4 6	2.4 3.0	<0.02 <0.02	0.26 0.30	1.2 1.3	25.50 26.10	4.4 4.2	0.06 0.05	1670 1810	7 <5	270 280	0.4 0.6	0.9 0.9	<2 <2	0.6 0.6	1200 1100	0.6 0.5	<0.1 <0.1	2 <1	0.30 0.25	1600 1600
AL94/1563 AL94/1564	<5 6	2.6 2.3	4200 3800	23 22	26.0 21.8	6 5	8 6	3 2	2.2 1.8	<0.03 <0.03	0.25 0.22	<0.5 <0.5	23.60 25.60	3.0 3.2	<0.05 <0.05	1790 1570	<5 <5	490 480	0.5 0.5	0.6 0.5	<2 <2	0.3 0.3	770 710	0.1 <0.1	<0.1 <0.1	<1 <1	<0.05 0.28	2000 1900
	7 11	2.4 2.3	1900 2100	23 22	20.6 22.6	6 6	4 4	5 5	7.8 7.6	0.21 <0.02	0.31 0.32	1.1 <0.5	24.80 27.40	3.8 3.9	0.06 <0.05	1190 1390	<5 <5	750 780	0.5 0.5	0.8 0.8	<2 <2	0.5 0.5	660 550	0.3 0.6	<0.1 <0.1	<1 <1	0.21 0.30	1700 1800
AL94/2329 AL94/2330	20 16	6.4 6.8	1200 1200	18 17	16.4 16.3	7 7	4 4	10 7	13.0 13.0	<0.03 <0.03	0.35 0.32	0.8 1.0	16.20 16.50	5.4 5.1	<0.05 0.06	1550 1520	<5 <5	580 530	0.6 0.6	0.9 0.9	<2 3	0.5 0.5	1100 1100	0.4 0.4	<0.1 <0.1	<1 <1	0.18 0.25	2300 2300
	14 15	3.8 3.3	3300 3200	72 74	16.4 15.9	5 4	8 7	5 <1	<0.5 0.8	<0.03 <0.03	0.18 0.14	0.7 <0.5	33.00 36.60	3.1 3.1	<0.05 <0.05	1730 1680	<5 <5	130 140	0.7 0.6	0.3 0.4	<2 <2	0.3 0.3	680 520	<0.1 <0.1	<0.1 <0.1	<1 <1	0.16 <0.05	2000 2000
AL94/2388 AL94/2389	7 12	2.2 2.1	4500 4600	60 58	23.5 24.1	4 <3	8 9	37 41	0.7 <0.5	<0.03 <0.03	0.16 0.19	<0.5 <0.5	21.30 22.40	1.7 2.0	<0.05 0.05	4380 4490	<5 <5	47 59	0.4 0.4	0.4 0.4	<2 5	0.2 0.3	630 940	<0.1 0.5	<0.1 <0.1	<1 <1	<0.05 0.14	1600 1700
	19 23	19.0 20.0	2400 2500	40 32	12.4 13.4	55 52	17 17	41 41	3.3 3.2	1.22 1.11	2.48 2.48	4.5 4.1	16.30 15.80	32.0 32.0	0.43 0.47	5770 5730	34 24	210 230	1.5 1.7	6.4 6.4	2 <2	5.1 5.2	1300 1100	5.0 4.9	1.7 1.7	<1 <1	2.42 2.75	2200 2100
AL94/2492 AL94/2493	6 <5	20.0 19.0	3400 3200	25 27	16.3 16.5	60 56	11 11	40 40	2.0 2.1	1.25 1.17	1.70 1.70	8.4 8.4	15.70 15.60	27.0 26.0	0.58 0.56	4170 4120	31 30	130 130	0.8 0.9	4.7 4.9	<2 <2	4.2 4.1	580 650	5.5 5.5	1.9 2.3	4 <1	3.28 3.22	1800 1800

* first row of data shows determination limits

* first row of data shows determination limits

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

Vial Number	Au ppb	As ppm	Ba ppm	Br ppm	Ca %	Ce ppm	Co ppm	Cr ppm	Cs ppm	Eu ppm	Fe %	K %	La ppm	Lu ppm	Na ppm	Nd ppm	Rb ppm	Sb ppm	Sc ppm	Se ppm	Sm ppm	Sr ppm	Th ppm	U ppm	W ppm	Yb ppm	Zn ppm
	5*	0.5	10.0	1	0.2	3	1	1	0.5	0.01	0.05	0.05	0.1	0.05	10	5	5	0.1	0.1	2	0.1	300	0.1	0.1	1	0.05	20
AL94/2534	6	2.1	2800	37	24.0	6	3	20	1.5	<0.03	0.38	1.0	5.1	<0.05	1700	<5	99	0.6	1.0	<2	0.6	570	0.8	<0.1	<1	0.42	2200
AL94/2535	<5	3.3	2900	55	23.9	5	4	25	1.4	0.19	0.46	1.5	5.7	0.07	1800	<5	120	0.4	1.1	<2	0.6	1100	0.8	<0.1	<1	0.59	2300
AL94/2605	12	5.0	2200	67	22.1	11	9	31	<0.5	<0.03	0.44	<0.5	5.3	0.09	2840	<5	38	0.8	1.3	<2	0.7	1200	1.0	<0.1	<1	0.49	1200
AL94/2606	15	5.1	2300	62	23.9	10	9	30	1.0	0.11	0.48	1.2	5.4	0.09	2970	<5	57	0.7	1.3	<2	0.8	1200	1.1	<0.1	<1	0.49	1300
AL94/2624	<5	2.1	2700	77	23.6	11	5	25	<0.5	<0.04	0.53	1.6	5.9	0.16	2270	<5	52	0.4	1.4	<2	1.0	470	0.9	0.8	<1	0.64	1800
AL94/2625	<5	2.7	2800	66	24.6	16	6	29	0.9	<0.04	0.55	1.8	7.2	0.12	2090	<5	57	0.4	1.5	<2	1.1	710	1.1	0.7	<1	0.51	1900
AL94/2638	6	3.0	2900	50	20.2	7	6	49	<0.5	<0.02	0.38	1.0	4.7	0.08	1860	<5	210	0.8	1.0	<2	0.6	580	0.6	<0.1	<1	0.50	3000
AL94/2639	<5	3.4	2900	50	20.0	11	6	38	1.3	0.19	0.35	<0.5	4.9	<0.05	1940	8	190	0.9	0.9	<2	0.6	300	0.6	<0.1	<1	0.35	2900
AL94/2667	7	1.8	4200	24	23.2	7	3	17	<0.5	<0.02	0.23	1.0	3.2	<0.05	1390	<5	220	0.4	0.6	<2	0.5	980	0.2	<0.1	<1	0.17	2700
AL94/2668	6	1.4	4100	24	22.9	7	3	15	0.7	<0.02	0.27	<0.5	3.4	0.05	1430	6	210	0.4	0.6	<2	0.5	660	0.5	0.5	<1	0.23	2700
AL94/2681	<5	5.2	2100	28	15.7	41	8	41	1.6	0.93	1.55	4.7	19.0	0.32	4100	19	150	0.9	4.4	<2	3.2	510	3.5	0.9	<1	1.85	2000
AL94/2682	<5	6.5	2000	27	16.7	40	8	44	1.7	0.91	1.64	4.8	20.0	0.34	4170	24	150	0.9	4.5	<2	3.3	550	3.5	1.4	<1	1.80	2000
AL94/2705	<5	5.6	4500	36	17.8	35	8	33	2.0	0.77	1.31	2.8	16.0	0.27	4320	21	130	0.6	4.1	<2	3.1	1200	3.4	<0.1	<1	1.45	1900
AL94/2706	<5	6.8	4500	31	18.6	36	8	38	1.7	0.75	1.32	3.1	18.0	0.29	4580	20	130	0.6	4.3	<2	3.2	1100	3.0	1.5	<1	1.64	1900
AL94/2730	10	9.3	6000	34	21.9	7	7	24	1.4	<0.03	0.34	<0.5	4.5	<0.05	1990	<5	220	0.8	1.0	<2	0.5	1400	0.9	0.2	<1	0.21	2000
AL94/2731	6	11.0	6200	30	23.8	7	7	24	0.9	<0.03	0.32	<0.5	4.8	<0.05	1880	<5	210	0.7	1.0	<2	0.6	1600	0.8	<0.1	<1	0.27	2100
AL94/2746	<5	4.7	2500	43	22.2	7	6	25	3.1	<0.03	0.49	0.7	6.6	0.08	2360	<5	350	0.8	1.3	<2	0.8	2700	0.8	<0.1	<1	0.49	3000
AL94/2747	9	5.3	2500	37	21.6	9	5	25	3.5	<0.03	0.44	1.2	7.1	0.07	2290	<5	350	0.9	1.2	6	0.7	2400	0.6	<0.1	<1	0.56	3000
AL94/2767	6	2.9	5500	37	23.3	5	3	16	<0.5	<0.03	0.21	1.4	3.4	0.08	1210	<5	110	0.3	0.6	<2	0.4	620	0.5	<0.1	<1	0.31	1800
AL94/2768	9	2.1	5800	38	21.9	4	2	16	<0.5	0.20	0.27	<0.5	3.3	<0.05	1290	<5	120	0.3	0.7	<2	0.4	440	0.4	<0.1	<1	0.15	1800
AL94/2797	50	4.1	2300	39	21.1	13	9	6	1.5	<0.02	0.33	<0.5	9.4	<0.05	2250	7	360	0.7	1.0	<2	0.8	1100	0.7	<0.1	<1	0.30	2100
AL94/2798	21	3.7	2200	37	20.0	10	7	4	1.4	<0.02	0.34	1.0	9.1	0.06	2110	<5	310	0.7	0.9	<2	0.8	790	0.8	<0.1	<1	0.33	2000
AL94/2814	14	3.0	1700	25	21.2	5	4	22	7.5	<0.02	0.29	1.1	8.0	<0.05	2570	<5	600	0.9	0.8	<2	0.5	960	0.7	<0.1	<1	0.34	2000
AL94/2815	6	2.9	1700	26	20.1	9	4	24	7.9	<0.02	0.33	0.8	8.5	0.05	2630	7	590	0.9	0.8	<2	0.5	1100	0.6	0.6	<1	0.31	2200
AL94/2817	9	5.6	1000	24	17.8	26	15	40	1.8	0.49	0.90	2.2	15.0	0.21	3800	12	220	0.7	2.4	<2	2.3	980	2.7	0.8	<1	1.21	1300
AL94/2818	6	2.1	2200	21	20.0	8	6	21	2.5	0.20	0.29	<0.5	6.2	<0.05	1530	<5	490	0.5	0.8	<2	0.7	840	0.8	0.4	<1	0.38	2100

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

Vial Number	Au ppb	As ppm	Ba ppm	Br ppm	Ca %	Ce ppm	Co ppm	Cr ppm	Cs ppm	Eu ppm	Fe %	Hf ppm	K %	La ppm	Lu ppm	Na ppm	Nd ppm	Rb ppm	Sb ppm	Sc ppm	Se ppm	Sm ppm	Sr ppm	Th ppm	U ppm	W ppm	Yb ppm	Zn ppm	
AL94/2837	11	4.9	2700	17	23.7	16	4	19	1.0	0.31	0.59	2.0	18.60	8.5	0.12	2580	<5	92	0.4	1.7	<2	1.3	780	1.4	<0.1	<1	<1	0.56	1600
AL94/2838	9	4.0	2700	16	22.0	16	4	18	0.6	0.31	0.58	1.8	19.40	8.3	0.10	2540	9	81	0.4	1.6	<2	1.3	700	1.3	<0.1	<1	<1	0.65	1600
AL94/2858	15	2.6	6000	24	20.4	4	3	23	1.3	<0.03	0.23	1.4	24.50	2.9	<0.05	993	<5	230	0.4	0.7	<2	0.3	710	<0.1	<0.1	<1	0.21	1600	
AL94/2859	<5	3.6	6100	26	19.5	7	3	26	0.7	<0.03	0.25	1.2	23.70	2.8	0.06	937	<5	250	0.4	0.7	<2	0.4	870	0.4	<0.1	<1	0.29	1700	
AL94/2884	<5	2.5	2500	29	17.7	8	5	18	1.9	<0.03	0.49	1.6	22.90	5.8	0.09	1640	<5	190	0.7	1.4	<2	0.8	590	1.1	<0.1	<1	0.49	2900	
AL94/2885	10	3.5	2600	31	18.8	10	5	18	1.8	<0.03	0.50	1.3	26.90	5.4	0.07	1680	<5	170	0.6	1.4	<2	0.8	980	0.9	<0.1	<1	0.63	3000	
AL94/2896	<5	7.5	6000	26	15.3	33	6	34	1.9	0.57	1.35	4.7	28.10	17.0	0.31	2510	24	210	0.9	3.9	<2	2.8	1100	3.5	1.1	<1	1.78	2600	
AL94/2897	12	7.2	5800	25	14.6	33	6	32	2.4	<0.03	1.25	4.6	24.10	16.0	0.29	2440	20	170	0.9	3.8	<2	2.6	920	3.1	1.4	<1	1.51	2300	
AL94/2925	8	5.6	3400	32	15.3	22	5	33	2.6	0.38	0.98	3.1	19.00	12.0	0.22	3160	<5	360	0.7	2.8	3	1.8	1100	2.4	0.8	<1	1.24	2800	
AL94/2926	11	5.3	3500	33	15.8	25	5	37	2.8	0.54	1.01	3.1	19.00	11.0	0.20	3130	12	360	0.9	2.9	<2	1.8	1100	2.5	<0.2	<1	1.18	2800	
AL94/2944	8	6.7	3300	41	15.6	39	8	37	1.4	0.67	1.70	5.3	24.40	17.0	0.40	4790	22	88	0.9	4.7	<2	2.9	680	3.9	1.0	<1	1.81	1700	
AL94/2945	7	6.2	3100	39	14.0	35	7	35	1.2	0.76	1.60	5.3	23.40	17.0	0.35	4840	21	86	1.0	4.7	<2	2.8	730	3.7	1.3	<1	1.90	1600	
AL94/2976	<5	2.2	790	28	21.2	<3	3	7	13.0	0.16	0.21	<0.5	30.60	2.6	<0.05	2140	<5	790	3.6	0.6	<2	0.3	980	0.4	<0.1	<1	<0.05	1900	
AL94/2977	6	2.2	910	25	20.3	<3	3	8	13.0	<0.03	0.21	<0.5	30.60	2.4	<0.05	2040	<5	770	4.0	0.5	<2	0.2	1500	<0.1	<0.1	<1	<0.05	1900	
AL94/2986	6	2.1	1600	24	18.7	14	4	21	1.6	0.26	0.48	0.8	26.70	6.8	0.09	2400	<5	150	0.6	1.4	<2	0.9	1100	1.0	<0.1	<1	0.46	2100	
AL94/2987	15	3.2	1600	38	18.4	12	4	23	1.9	0.32	0.52	1.1	27.40	6.9	0.09	2640	<5	160	0.7	1.5	<2	0.9	960	0.9	<0.1	<1	0.51	2200	
AL94/6049	<5	1.7	3500	25	31.5	5	5	9	0.6	<0.02	0.21	<0.5	18.50	2.4	<0.05	2140	<5	190	0.4	0.6	<2	0.3	670	0.6	<0.1	<1	0.09	2100	
AL94/6050	6	1.0	3400	22	29.3	<3	5	8	0.6	<0.02	0.17	0.7	20.40	2.2	0.07	2150	<5	200	0.4	0.6	<2	0.3	660	<0.1	<0.1	<1	0.29	2100	

* first row of data shows determination limits

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

Packet Number	Ag ppm 0.1*	Al ppm 0.01	B ppm 2	Be ppm 0.2	Cd ppm 0.2	Cu ppm 1	Li ppm 2	Mg % 0.01	Mn ppm 1	Mo ppm 1	Ni ppm 1	P % 0.001	Pb ppm 3	Sr ppm 1	V ppm 2
ICP94/1402	1.9	0.32	349	<0.2	3.0	90	3	3.60	35941	<1	56	1.479	40	651	42
ICP94/1403	2.1	0.33	353	<0.2	2.8	93	3	3.65	36603	<1	58	1.502	44	664	42
ICP94/1426	2.4	0.47	457	<0.2	4.0	159	4	3.40	38997	<1	70	2.077	51	795	71
ICP94/1427	1.7	0.48	457	0.3	4.5	161	5	3.28	44349	1	74	2.137	70	881	78
ICP94/1495	0.5	1.40	175	<0.2	5.2	93	21	3.12	7056	1	52	1.884	38	365	18
ICP94/1496	0.5	1.47	199	<0.2	6.0	106	23	3.23	7252	1	57	2.013	37	389	19
ICP94/1535	1.4	0.60	315	0.4	11.0	118	5	3.13	20983	<1	40	1.912	66	608	19
ICP94/1536	<0.1	0.61	315	0.5	12.6	121	5	2.85	26002	1	29	1.950	75	681	22
ICP94/1563	<0.1	0.58	364	0.3	10.6	156	3	3.92	19638	1	51	2.284	41	561	35
ICP94/1564	1.0	0.76	330	0.3	8.6	149	4	4.14	15725	<1	43	2.144	35	498	32
ICP94/1569	0.6	0.58	358	0.4	2.1	118	4	3.92	6711	1	34	1.731	37	499	18
ICP94/1570	0.6	0.57	347	0.4	2.2	115	4	3.83	6601	1	35	1.683	41	490	18
ICP94/2329	0.4	0.89	363	0.3	18.7	125	2	5.59	50332	<1	121	2.871	58	846	68
ICP94/2330	0.7	0.89	376	0.3	19.0	130	<2	5.73	51094	<1	126	2.952	75	855	68
ICP94/2364	0.1	0.49	291	0.2	1.6	163	<2	4.13	12114	<1	172	2.922	17	384	9
ICP94/2365	<0.1	0.49	298	0.5	1.5	166	<2	4.24	12302	<1	176	3.001	24	392	10
ICP94/2408	0.4	1.45	239	<0.2	7.5	143	18	2.39	23886	4	83	1.476	80	613	39
ICP94/2409	0.3	1.43	241	0.3	7.5	141	25	2.37	23653	2	85	1.459	73	603	37
ICP94/2492	0.2	1.15	233	<0.2	6.6	105	23	2.80	12134	<1	41	1.247	62	303	35
ICP94/2493	0.3	1.10	228	<0.2	6.5	105	14	2.77	12075	<1	42	1.248	64	301	33
ICP94/2534	<0.1	0.57	297	0.4	12.7	142	<2	3.54	17779	1	81	2.995	28	665	23
ICP94/2535	<0.1	0.58	302	0.3	12.2	144	<2	3.66	18048	<1	89	3.100	28	674	24
ICP94/2605	0.2	0.61	261	<0.2	8.4	143	19	3.34	5787	<1	86	2.482	42	819	31
ICP94/2606	0.2	0.59	254	<0.2	7.7	138	8	3.20	5619	<1	81	2.398	41	794	30
ICP94/2624	0.1	0.50	269	0.2	2.9	159	<2	3.11	3832	<1	32	2.227	49	304	22
ICP94/2625	<0.1	0.54	276	0.9	3.4	180	12	2.85	4418	11	28	2.417	48	341	22

* first row of data shows determination limits

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

Packet Number	Ag ppm 0.1*	Al ppm	B ppm	Be ppm	Cd ppm	Cu ppm	Li ppm	Mg %	Mn ppm	Mo ppm	Ni ppm	P %	Pb ppm	Sr ppm	V ppm
ICP94/2638	<0.3	0.37	369	<0.2	7.0	194	4	4.44	31338	6	40	2.330	126	342	25
ICP94/2639	<0.3	0.35	379	0.2	5.9	197	3	4.70	26220	<1	44	2.221	97	282	23
ICP94/2667	<0.3	0.45	456	0.2	13.7	156	3	3.83	24037	<1	21	2.479	57	378	14
ICP94/2668	<0.3	0.45	462	0.2	13.1	160	3	3.85	24192	1	19	2.517	54	384	14
ICP94/2681	<0.3	1.09	299	0.3	7.2	156	15	3.21	17190	4	35	1.408	97	287	29
ICP94/2682	<0.3	1.08	298	0.4	7.3	158	16	3.20	17081	2	38	1.396	95	290	29
ICP94/2705	<0.3	0.99	284	0.4	7.6	146	7	3.65	19516	8	26	1.512	83	702	20
ICP94/2706	<0.3	0.92	298	0.4	6.8	149	17	4.02	16047	3	29	1.473	65	582	19
ICP94/2730	<0.3	0.55	389	<0.2	9.7	180	2	3.30	17104	8	23	1.756	77	946	26
ICP94/2731	<0.3	0.50	372	0.2	5.8	183	2	3.50	13735	3	22	1.641	47	778	22
ICP94/2746	<0.3	0.92	403	<0.2	16.6	195	<2	4.33	14637	1	51	2.243	98	1254	50
ICP94/2747	<0.3	0.92	417	0.2	17.3	197	2	4.43	14960	<1	52	2.285	91	1266	52
ICP94/2767	<0.3	0.29	511	<0.2	9.4	163	<2	3.71	12827	7	106	2.364	45	459	10
ICP94/2768	<0.3	0.27	506	0.2	6.7	165	<2	3.68	12551	5	108	2.352	35	467	8
ICP94/2797	<0.3	0.70	347	0.5	7.6	134	<2	4.17	42002	2	98	1.655	56	665	109
ICP94/2798	<0.3	0.74	362	0.5	8.4	140	<2	4.46	43990	2	108	1.740	58	703	115
ICP94/2814	<0.3	0.50	427	0.2	6.6	167	2	5.15	20522	1	75	2.379	64	825	119
ICP94/2815	<0.3	0.51	432	0.3	6.7	172	2	5.26	20472	2	78	2.500	65	834	122
ICP94/2817	<0.3	1.74	361	0.5	9.0	183	9	4.12	23123	1	446	1.930	85	674	43
ICP94/2818	<0.3	0.74	366	0.4	11.2	171	4	4.21	33085	<1	116	2.000	56	598	40
ICP94/2837	<0.3	0.44	360	0.3	4.2	184	6	4.53	5712	<1	24	1.960	24	467	10
ICP94/2838	<0.3	0.45	360	0.4	4.0	184	5	4.56	5747	<1	24	1.979	22	467	11
ICP94/2858	<0.3	0.32	321	<0.2	7.3	160	<2	3.58	24984	2	54	2.684	39	528	16
ICP94/2859	<0.3	0.36	343	<0.2	8.6	161	2	3.81	28736	2	62	2.950	43	536	18
ICP94/2884	0.3	0.86	388	0.3	25.1	172	3	4.46	25702	5	98	2.577	77	582	31
ICP94/2885	<0.3	0.84	380	0.6	23.0	170	3	4.35	25724	5	100	2.584	64	564	29

* first row of data shows determination limits

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

Packet Number	Ag ppm 0.1*	Al ppm 0.01	B ppm 2	Be ppm 0.2	Cd ppm 0.2	Cu ppm 1	Li ppm 2	Mg % 0.01	Mn ppm 1	Mo ppm 1	Ni ppm 1	P % 0.001	Pb ppm 3	Sr ppm 1	V ppm 2
ICP94/2896	<0.3	1.16	324	0.8	15.4	218	13	3.30	10948	10	126	2.971	40	576	16
ICP94/2897	<0.3	1.14	328	0.7	16.7	212	15	3.32	11192	<1	126	2.933	30	567	18
ICP94/2925	<0.3	1.01	367	0.6	16.9	254	6	3.01	73056	<1	88	3.014	74	872	34
ICP94/2926	<0.3	1.03	362	0.7	15.0	254	6	2.97	71924	<1	79	3.006	84	867	28
ICP94/2944	<0.3	0.88	241	0.2	3.8	135	12	3.32	10192	<1	39	2.343	72	304	24
ICP94/2945	<0.3	0.90	252	0.4	3.5	142	15	3.05	11934	<1	38	2.472	79	364	27
ICP94/2976	<0.3	0.62	429	0.3	6.9	188	5	3.51	24044	3	50	3.201	13	764	11
ICP94/2977	<0.3	0.57	389	0.3	4.5	166	8	3.16	22031	<1	51	2.913	29	705	8
ICP94/2986	<0.3	0.07	18	0.3	3.4	10	<2	0.16	1485	17	6	0.113	13	62	4
ICP94/2987	<0.3	0.05	15	0.3	2.5	7	<2	0.14	1425	16	2	0.100	<3	56	3
ICP94/6049	<0.3	0.33	322	<0.2	6.4	128	<2	3.04	26539	<1	6	1.525	48	388	14
ICP94/6050	<0.3	0.33	326	<0.2	8.4	134	4	3.07	26656	4	6	1.510	45	387	13

* first row of data shows determination limits

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 determination limit was used for statistical calculations.

For Mn (ICP-ES) one sample exceeded an upper determination limit of 10%. For this sample a value of 99,999 ppm was used for statistical calculations.

Table 7: Determination Limits for Elements Analyzed by INAA

Element		Units of Measure	Determination Limit
Arsenic	As	ppm	0.5
Gold	Au	ppb	5
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
Iron	Fe	%	0.05
Hafnium	Hf	ppm	0.5
Potassium	K	%	0.05
Rubidium	Rb	ppm	5
Sodium	Na	ppm	10
Antimony	Sb	ppm	0.1
Scandium	Sc	ppm	0.1
Selenium	Se	ppm	2
Strontium	Sr	ppm	300
Thorium	Th	ppm	0.1
Uranium	U	ppm	0.1
Tungsten	W	ppm	1
Zinc	Zn	ppm	20

Rare Earth Elements		Units of Measure	Determination Limit
Lanthanum	La	ppm	0.1
Cerium	Ce	ppm	3
Neodymium	Nd	ppm	5
Samarium	Sm	ppm	0.1
Europium	Eu	ppm	0.01
Ytterbium	Yb	ppm	0.05
Lutetium	Lu	ppm	0.05

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

Element		Units of Measure	Determination Limit
Silver	Ag	ppm	0.1
Aluminum	Al	%	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
Molybdenum	Mo	ppm	1
Nickel	Ni	ppm	1
Phosphorus	P	%	0.001
Lead	Pb	ppm	3
Strontium	Sr	ppm	1
Vanadium	V	ppm	2

Fig. 2: Geological Contacts, with Metallic Deposits and Occurrences, and Main Locations Referred to in Text

BEDROCK GEOLOGY
Legend

CRETACEOUS

EK red and gray clay, kaolin, silica sand, lignite

LATE TRIASSIC

Fundy Group

LT UNDIVIDED LATE TRIASSIC

LTW Wolfville Formation: red conglomerate, arkose, sandstone, shale

CARBONIFEROUS

Pictou Group

LCSV Scotch Village Formation: grey sandstone, shale

Canso Group

CWB Watering Brook Formation: mudstone, shale, gypsum, anhydrite, halite

Windsor Group

ECW UNDIVIDED WINDSOR GROUP

ECWC Murphy Road & Green Oaks Formations: sandstone, siltstone, limestone, dolostone, anhydrite, gypsum

ECWB Wentworth Station, Miller Creek & MacDonalds Road Formations: siltstone, limestone, dolostone

ECWA White Quarry, Macumber, Stewiacke, Carrolls Corner, Meaghers Grant (stippled) & Gays River Formations: anhydrite, gypsum, halite, siltstone, limestone, dolostone, shale

Horton Group

ECH UNDIVIDED HORTON GROUP

ECC Cheverie Formation: sandstone, siltstone, shale, arkose, conglomerate

ECCN Craignish Formation: arenite, siltstone, sandstone

ECHB Horton Bluff Formation: sandstone, shale, dolomite, conglomerate

ECS Strathlorne Formation: siltstone, shale, dolomite, conglomerate

CAMBRIAN

Meguma Group

COG Goldenville Formation: greywacke, slate

COH Halifax Formation: slate, siltstone, rare limestone at base

PLUTONIC ROCKS

DCG Granite

DCGT Granitoid

DCMG Monzo-granite

DGD Granodiorite

Reference: Keppie, J.D., 1979. Geological Map of the Province of Nova Scotia, Department of Mines and Energy, Nova Scotia; Scale 1:500 000.

GEOLOGY

Bedrock and Mineralization

Figure 2 shows the geological contacts of the stratigraphic or lithologic units with mineral deposits and occurrences. The geology, with sample numbers, is shown also on the large, coloured geological map provided in the envelope.

The oldest rocks to outcrop in the survey area are the Cambro-Ordovician Meguma Group comprising turbidites (Goldenville Formation) and slates (Halifax Formation). These were intruded by plutons of felsic to intermediate composition during the Devonian to early Carboniferous periods. This plutonism, notably the South Mountain Batholith in the southwest of the survey area, gave rise to folding and faulting, accompanied by regional greenschist to amphibolite grade metamorphism (Taylor, 1967). Keppie (1979) considered that the major folds of the Meguma Group formed at ca. 370 Ma, in the early stages of the Acadian Orogeny.

During the Carboniferous Period clastic sediments of the Horton Group were deposited, which were succeeded by carbonates and evaporites of the Windsor Group. These sediments were overlain by evaporites of the Canso Group and capped with sandstones and shales of the Pictou Group (Scotch Village Formation). Downwarping into three major southwest-northeast striking synclines has preserved many lithological elements of the Carboniferous in the Kennetcook, Shubenacadie and Musquodoboit basins (Fig. 2). Triassic sediments of the Fundy Group are preserved in the north along the shore of the Bay of Fundy. No rocks of Jurassic age occur in the survey area, but around and to the east of Shubenacadie recent seismic studies (S. Pullan, GSC), substantiated by a drilling program conducted by the Nova Scotia Dept. of Natural Resources (R. Stea), have found more extensive early Cretaceous clastic sediments than had previously been known (R.N. DiLabio, personal communication, 1996).

Many gold occurrences have been reported (Fig. 2) and a few have been worked (e.g. Caribou, Moose River, Oldham, Mt. Uniacke, Rawdon Hills). There are a few base metal deposits (notably Pb at Gays River), and many manganese, iron and evaporite deposits in the Walton area.

Digital Geological Base Map Compilation

The transparent geological overlay map provided in the pocket, and the coloured 1:130000 sample location map are digitized computer-plotted compilations derived primarily from the Geological Map of the Province of Nova Scotia (Keppie, 1979). Minor modifications have been made to update certain units, in particular the early Cretaceous clastic sediments around Shubenacadie.

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 21 geological units.

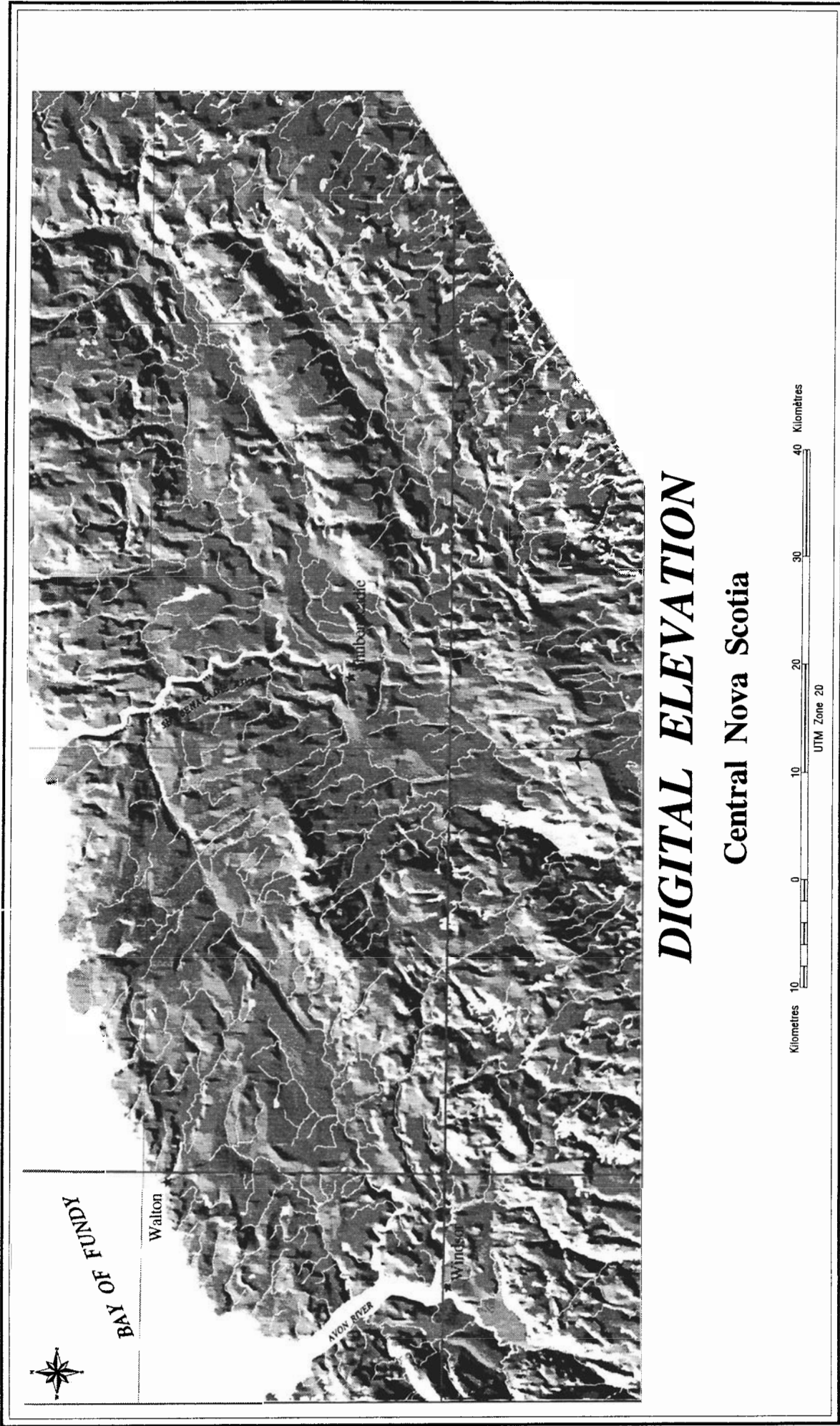


Fig. 3: Digital Elevation Map of Survey Area Showing Drainage Systems (white).

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.

Results of the earliest mapping of the surficial geology in the Shubenacadie area were published by Hughes (1957). Subsequently, Stea and Fowler (1979) published a series of maps of Pleistocene cover in Nova Scotia. Map No. 4, which covers the western half of the present survey area, shows that there is an extensive cover of Lawrencetown Till, mostly only a few metres thick. This till is overlain by patches of Rawdon Till up to 100 km² in extent (Rawdon Hills area), Granite Till (southwest of survey area), Quartzite Till (marginal to the Granite Till), and local narrow elongate deposits of outwash till. Recently, more detailed studies have been undertaken which indicate four main phases of ice movement: southeastward (East Milford Till); southward from a centre over Prince Edward Island (Hants Till [equivalent to much of the Lawrencetown Till]); northeastward from an ice divide near the south shore of Nova Scotia, modifying the Hants Till; and westward, depositing the Rawdon Till (Stea and Fowler, 1981; Stea and Finck, 1984; Stea, Graves and Rogers, 1988; Stea, 1994; McClenaghan and DiLabio, in prep., and M.B. McClenaghan, personal communication, 1996).

MAP PRODUCTION AND DATA HANDLING

The maps are all drawn using the Universal Transverse Mercator projection (NAD27 datum), 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 ESRI's ARC/INFO software. Computations were performed on UNIX workstations, with output to a 600 dpi 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 Remote Sensing Sector (SMRSS) of the Department of Natural Resources, Canada. The digital hydrography base was produced by splicing together four 1:250 000 digital bases (21H, 11E, 21A, 11D) and then clipping the appropriate sub-area. This hydrography was then merged with the digital geology base (Keppie, 1979), supplied by NSDNR, to produce the large, 1:130 000 colour map.

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 Central Nova Scotia 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 SMRSS. Complete elevation coverage for the survey area was obtained by merging six 1° x 1° DTED tiles, and then clipping the appropriate sub-area. The resulting cell size was approximately 93x93 m, 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 summary 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. Exceptions are the rare earth elements (REE) which are 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 colour map in envelope), 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. 2. 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, groundwaters and near surface rocks. Background levels of Au in the ash of balsam fir twigs are commonly less than 5 ppb Au. 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 analyses is poor. In general, Au concentrations in the study area are low (median 8 ppb). Around the Rawdon Hills there are scattered sites yielding moderate concentrations of Au. Local clusters of sites with relative Au enrichment occur near the Gays River Pb/Zn mine (Windsor Group sediments), and over Meguma Group sediments west of the airport, at the southern end of Shubenacadie Grand Lake. In this area one site yielded 182 ppb Au on the east side of the lake (Fig. 4a), but most of the gold-rich samples were confined to a 6 km x 2 km zone on the west side of Shubenacadie Grand Lake, generally following the east-west strike of the underlying Goldenville Formation. As an initial follow-up, balsam fir needles from several of the Au-rich twigs were retrieved from archive storage and analyzed. The data confirmed the enrichment of Au at these sites, yielding up to 410 ppb Au. All potential sources of contamination during sample collection and preparation were examined, and none could be found. Consequently, the following year (June, 1995) a follow-up survey was conducted that involved the collection of balsam fir and red spruce from 90 sites, and a few water, rock and till samples. The twigs (some with needles) yielded lower concentrations of Au than in the previous year (perhaps because of a wetter spring in 1995), but data confirmed that there are sites in the vicinity of Golden and Sandy Lakes at which twigs of both species locally have relative enrichment of Au (Fig. 4b), Ag and As. Concentrations reached maxima of 35 ppb Au in balsam fir twigs, and 47 ppb Au and 5 ppm Ag in red spruce twigs (Dunn and Balma, 1995). The few rock and till samples obtained were processed by M-Tech Inc. (Halifax) to extract gold grains. The maximum yield was six grains in the -60 mesh fraction of a crushed 1.5 kg boulder of Goldenville greywacke. Of 11 one litre samples of stream water from the area that were analyzed for Au, only one yielded a concentration above the determination limit of 0.2 ppt Au (G.E.M. Hall, personal communication, 1995). Balsam fir data from detailed sampling of this area in 1995 are included with the digital data listings provided on the diskette available from the address on p.2.

At this time the source of the gold anomalies is unknown, and the inconsistent nature of the vegetation anomalies warrants further investigation. It is noteworthy that some of the sites of gold enrichment in the trees lie close to the axes of the Au-bearing Oldham Anticline, and the Shubenacadie Anticline (Fig. 4). It is also of interest that a few kilometres north of this area is the recently discovered Steve's road gold deposit. Furthermore, Nova Scotia's only full time gold miner, Edgar Horne, steadily extracts gold from quartz veins near Renfrew, 10 kilometres north of the detailed study area (Durstling et al., 1994).

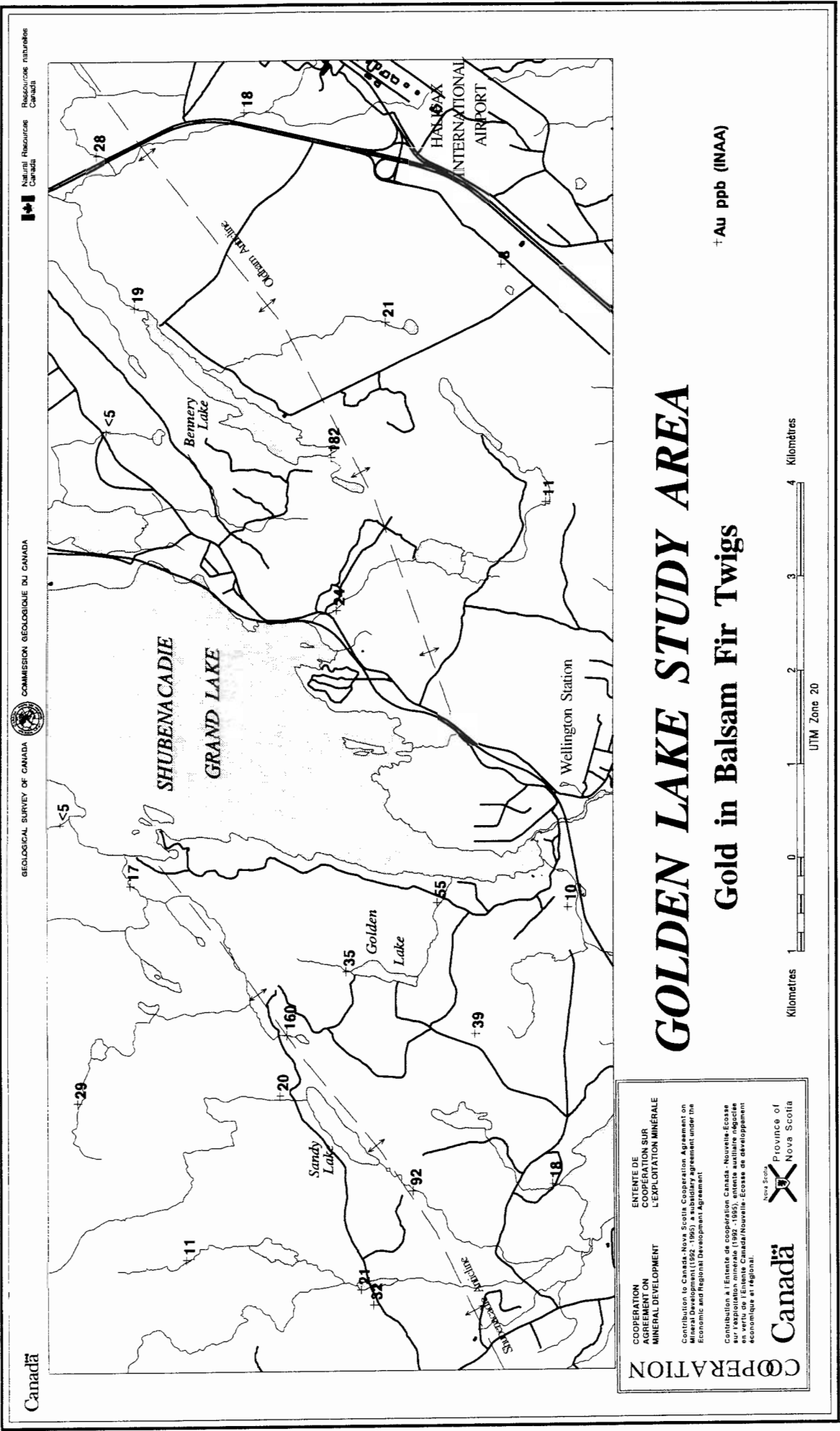


Fig. 4a: Gold in balsam fir twigs (1994 survey). Detail of Au distribution map in envelope (Appendix C). Axes of Oldham and Shubenacadie anticlines from Faribault et al., (1908 & 1909).

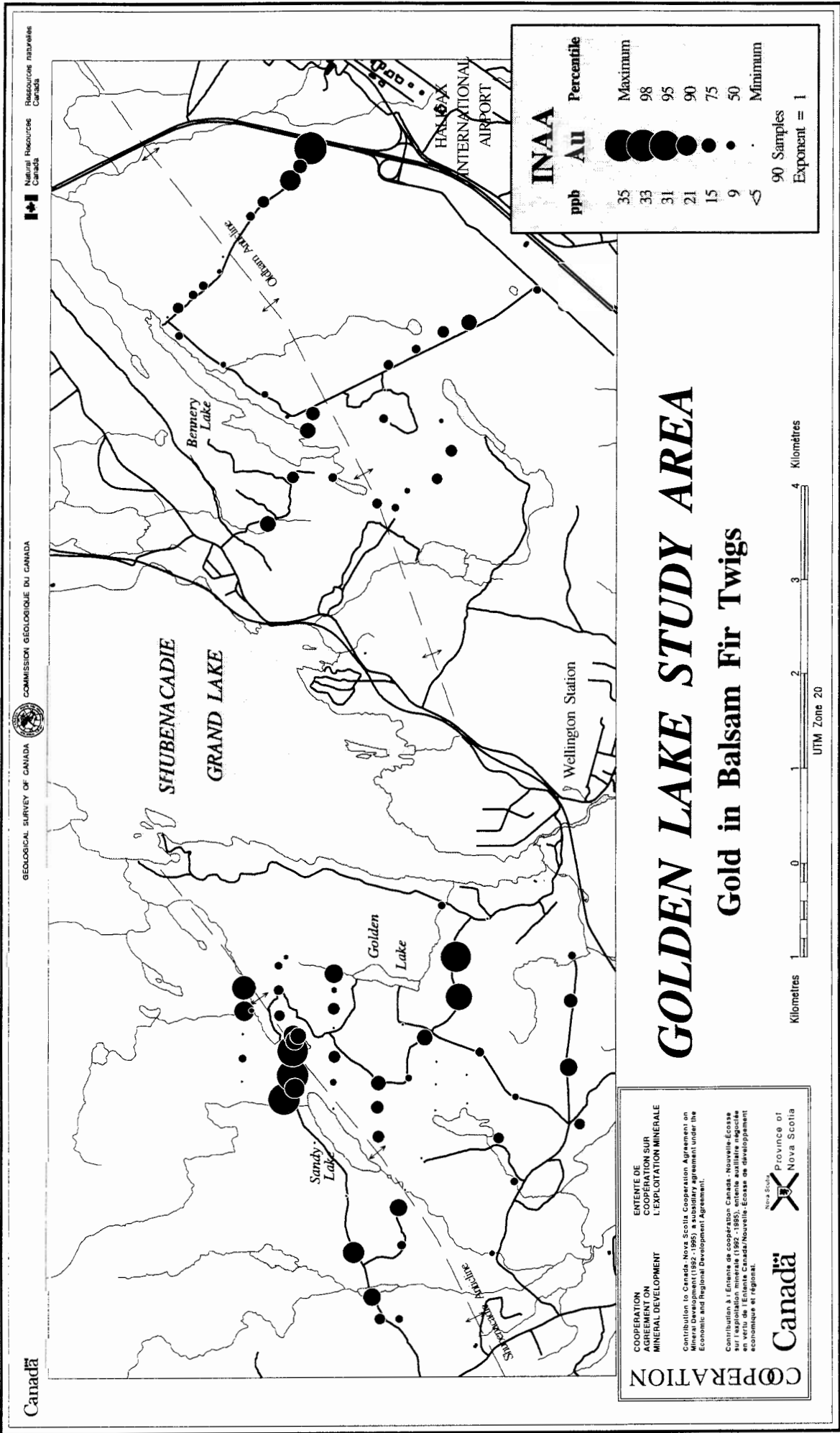


Fig. 4b: Gold in balsam fir twigs (some with needles) - detailed survey in 1995. Axes of Oldham and Shubenacadie anticlines from Faribault et al., (1908 & 1909).

Arsenic (As)

Arsenic is renowned for its toxicity, yet plants (especially Douglas-fir) 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. Zones of relative As enrichment occur near west of Shubenacadie Grand Lake, near sites of Au enrichment at Sandy Lake (Fig. 4) and Uniacke; north-east of the airport, near gold mineralization at Oldham; at Gays River; in the vicinity of the Caribou Gold Mines; and at scattered localities around the Rawdon Hills. Weak enrichment of As is present, too, at several sites just south of Walton along the northern limb of the Kennetcook syncline, over rocks of the Windsor Group near their contact with the underlying clastic sediments of the Horton Group.

The statistics sheets (Appendix B) show that balsam fir from the Goldenville, Halifax, and Scotch Village (Pictou Group) formations are generally slightly more enriched in both As (p.B2) and Au (p.B1) than trees on the other formations.

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, but some unusually high concentrations occur within the map area, locally up to 12,000 ppm in samples from the Walton area. The generally high levels of Ba in twigs from sites underlain by Carboniferous sediments reflects the bedrock enrichment in Ba which, as would be expected, is highest near the evaporitic sediments of the Walton area where barite is mined.

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 volatilize during the ashing process, causing losses of 30 - 90 percent of the Br contained within the plant tissues. In some environments there is a Au/Br association in plant ash from zones of mineralization (Dunn, 1986). Within the survey area some of the highest concentrations of Br occur near sites of Au enrichment in twigs, west of Shubenacadie Grand Lake. High concentrations also occur near the Horton/Windsor contact at the western end of the Kennetcook syncline.

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.

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 5 ppm. Plant tissues commonly contain elevated levels of Co over ultramafic rocks, and it has been observed that some plants exhibit Co enrichment in the vicinities of gold mineralization in northern Saskatchewan (Dunn, 1986). The map of central Nova Scotia shows no significant enrichment of Co, but slightly elevated concentrations around the Rawdon Hills.

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 of values for balsam fir twigs (10 - 20 ppm Cr). Samples from sites underlain by sediments of the Windsor Group and Halifax Formation are locally unusually enriched in Cr, yielding maximum concentrations of 160 ppm near the margins of the Shubenacadie basin.

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 at the eastern end of the survey area near the contact between Meguma Group sediments and Devonian-Carboniferous granitoid rocks. Concentrations in samples growing on the granitoid rocks reach a maximum of 37 ppm Cs, and the median concentration (6 ppm) is four times greater than the median for all samples. For comparison, balsam fir from close to the Cs-rich rocks at East Kemptville were found to contain up to 59 ppm Cs (Dunn *et al.*, 1994a)

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. Statistical analysis of the data (p. B9) shows Fe concentrations are generally similar in trees growing over different substrates, with highest concentrations (maximum of 2.48% Fe) over rocks of the Windsor Group, and lowest (maximum of 0.33% Fe) over the granitoids in the east.

Hafnium (Hf)

Ash of conifer twigs commonly contains 1 - 2 ppm Hf. Hafnium levels are usually higher where Fe concentrations are high because the two elements are commonly associated in plants. The concentration of Hf in plants may also be correlated with Zr, due to their close geochemical affinities.

Potassium (K)

Potassium has no structural role in plants, but it serves a number of catalytic roles and is required in large amounts (Bidwell, 1979). It is very important in the overall metabolism of plants. The range of concentrations present are normal levels for conifer twigs. There is relative enrichment of K in fir twigs from trees from the eastern part of the survey area and around the northern limb of the Kennetcook basin.

Sodium (Na)

The effect of salt-spray from the Bay of Fundy is evident from coastal samples near Walton. Elsewhere Na concentrations are relatively high over Windsor Group sediments (notably at the eastern end of the Shubenacadie basin), and depleted over the granitoids.

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, being more closely associated with Rb than K in the trees (cf. maps of Cs and Rb distributions). Background levels of Rb in balsam fir twigs are commonly 200 ppm. Balsam fir twigs from over the Devonian-Carboniferous plutons contain a median concentration of 395 ppm Rb in ash. Enrichment of the alkali metals occurs over and to the south of the Rawdon Hills, and in the east.

Antimony (Sb)

Excellent analytical precision is obtained for Sb by INAA down to sub-ppm levels in ash. 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. In general, Sb levels are close to the usual background for balsam fir, except for two areas: Rawdon Hills, and over Meguma sediments and granitoid rocks in the east. By comparing the distribution patterns of Sb, Au and As, it appears that the Sb is not associated with Au mineralization. The zones of Sb enrichment appear to be more closely linked to some zones of copper enrichment.

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 twigs is controlled

essentially by the chemistry of the substrate and by the distribution of other elements. In particular, there is a high correlation between Sc and Fe.

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.

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. Highest concentrations occur in association with evaporite rocks of the Windsor Group. In addition there are Sr enrichments in trees growing on Meguma Group rocks in the east and in the southwest.

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). Highest concentrations occur in trees from the Windsor Group (maximum of 5.5 ppm Th) and the Halifax Formation (maximum of 5.2 ppm Th), each representing a concentration an order of magnitude above background levels.

Uranium (U)

Although U_3O_8 has high solubility, it rarely exceeds concentrations of more than 2 ppm in plant ash. There are a number of notable exceptions, particularly in northern Saskatchewan where enrichments in spruce twigs are locally more than three orders of magnitude (Dunn, 1983). Within the survey area the highest concentrations are from samples over the Windsor Group.

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. There are, however, several zones where multiple samples are weakly enriched in W (e.g. around the Musquodoboit basin).

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 690 - 4100 ppm Zn indicating that the regional pattern of Zn distribution is reflecting broad differences across the area, although it is not confined to any single stratigraphic formation.

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 (0.5 ppm) and therefore no map of Tb is included. Maps of these elements 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.

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 0.5 ppm Ag in the balsam fir twigs is a typical background level. Of note is a zone of multi-site enrichment of Ag at the northeastern end of the Rawdon Hills. A second cluster of anomalous values occurs in the far northeast corner of the survey area, and another south of Walton. There is weak Ag enrichment at several sites east of Shubenacadie, and west of Shubenacadie Grand Lake near sites of Au enrichment.

Aluminum (Al)

All dry vegetation samples were placed in Al trays for ashing, therefore a certain amount of contamination from this source is inevitable. 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 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. Sites of relative enrichment of Al are scattered throughout the survey area.

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 100s 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.

Boron 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, perhaps accounting for the slightly lower B levels in trees from the carbonate-rich Windsor Group. Most of the highest concentrations occur over Meguma, Pictou and Horton sediments in the east.

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 less than 1 ppm Be. The map of Be distribution clearly shows the relative enrichment in a few areas (e.g. near Walton), but because there appears to be a slight drift in analytical determinations of Be in the standard sample (Table 4) interpretation of the data should be treated with caution. It is unlikely that the subtle variations in Be content are of significance.

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 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 will be transported to the tree extremities. There is relative enrichment of Cd in samples from over sediments of the Meguma and Horton groups, especially around the Rawdon Hills and in the northeast.

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 166 ppm) 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 significant differences in the Cu content of the substrate than the relatively small differences attributable to micronutrient functions. This is particularly true in the eastern part of the survey area where there is relative Cu enrichment over sediments of the Horton and Meguma groups.

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. Of note are the relatively high concentrations of Li in trees growing over clastic sediments of the Scots Valley Formation (Pictou Group) and, to a lesser degree, the Windsor Group (p. B35).

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. Of note are the relatively high concentrations in many samples in the south where underlying rocks are Meguma greywackes and slates.

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. The many Mn occurrences in the Walton area are not reflected in the trees because of the alkaline nature of the substrate. Locally there is in excess of the upper limit of determination of Mn - 10% in ash. Statistics on p. B37 show that trees from sites overlying the Halifax slates contain the highest concentrations of Mn.

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 able to absorb Mo more readily, and therefore slightly higher levels may be expected. There are generally higher levels of Mo in the northeastern part of the survey area, mostly in and

around the Shubenacadie basin. Spatially related to this area there is enrichment of Cu near the margins of this basin.

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 (6 ppm) recorded for this data set. There is a relative abundance of Ni in samples from the southwestern end of the Rawdon Hills, and to a lesser degree at sites in the northeast where some Cu enrichment occurs.

Phosphorus (P)

Phosphorus plays a vital role in plant energy metabolism, and it is extremely important as a structural part of many organic compounds. Its uptake by trees may be antagonized by excess Ca which, from the 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. There are some broad similarities between the distribution patterns of P, Cu and Sb.

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 southwestern Nova Scotia and southeastern Cape Breton Island (Dunn *et al.*, 1994a,b), and from comparison of median values there is very little difference according to underlying lithology. However, maximum values are higher because of the high levels near the Gays River mine (maximum of 2120 ppm Pb).

Vanadium (V)

Although concentrations of V are above detection levels 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. The distribution of V is different from all other elements determined, with a marked concentration in the southern part of the survey area. At many of these sites there is relative enrichment of Mg.

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 group or formation; all intrusions are grouped together because they are all Devono-Carboniferous in age, and range in composition from granite to monzo-granite). Abbreviations used in the appendices are explained in Tables 9 and 10.

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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, Geoff Day and Dave Gallagher, for undertaking some of the sampling, and Dr. P.J. Rogers (NSDNR) for his active support throughout this study.

Table 9: 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/S = Bog, Swamp; F = Farmland; L = Logged
Rock Unit	See legend alongside large coloured map

Table 10: Abbreviations Used in Appendix B

Rock Type	Underlying bedrock lithology (derived from published geological maps - see large coloured map): EK Early Cretaceous (clastic sediments) LT Late Triassic (clastic sediments) LCSV Late Carboniferous Scotch Village Formation (clastic sediments) EC Early Carboniferous Windsor Group (mostly carbonates and evaporites) H Early Carboniferous Horton Group (clastic sediments) COG Cambro-Ordovician Meguma Group - Goldenville Formation (turbidites) COH Cambro-Ordovician Meguma Group - Halifax Formation (slates) DC Devono-Carboniferous felsic plutons
N dl Cum %	N number of samples dl determination limit Cum % cumulative frequency (as a percentage)

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