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Chemical Variability in Vegetation Samples from the Area of the Osborne Cu-Zn Deposit, Snow Lake, Manitoba

by M.A.F. Fedikow

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Hon. James E. Downey
Minister

David Tomasson
Deputy Minister

Geological Services

W.D. McRitchie
Director

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ABSTRACT

Twig samples that represent eight year's growth were collected from the north, south, east and west sides of black spruce (*Picea mariana*), jack pine (*Pinus banksiana*), tamarack (*Larix laricina*), birch (*Betula papyrifera*) and poplar (*Populus tremuloides*) to examine trace and major element peripheral variability. Twig and needle/leaf sample results, based on NAA and ICP-AES analyses, document the absence of ore-related element variation about the tree's periphery. Observed variations are attributed to flux occurring at or near the effective lower limit of detection (LLD) of the analytical method, and to spurious single sub-sample anomalies. Peripheral sampling can alleviate geochemical "noise" during vegetation geochemical programs without significantly increasing sampling time.

An investigation examining the use of cattails (*Typha latifolia*) as a vegetation geochemical sampling medium indicates high contrast Zn anomalies in cattail stalks between anomalous and background sites.

TABLE OF CONTENTS

FIGURES

TABLES

INTRODUCTION

A vegetation geochemical survey designed to examine the chemical variability in twig and needle/leaf samples from the periphery of common vegetation types was conducted in September 1991. These samples were collected from a small, well-drained area about 1 km west of the Osborne Lake Cu-Zn deposit (Fig. 1); as well, a suite of cattail (*Typha latifolia*) samples was collected from the general area of the Osborne deposit. Cattails were collected to test their effectiveness in scavenging and storing various ore and ore-related elements in their tissues.

The hypothesis being tested in the chemical variability study is whether ore and ore-related elements are deposited in vegetation tissues or bio-objects (Kovalevsky, 1984) as a result of root specific nutrient supply. That is, will twigs collected from the north side of a black spruce tree contain higher Au, Cu, Pb, Zn, etc. than either the south, east or west sides of the tree if the north side root system accesses a substrate that contains high concentrations of these metals. The substrate may contain portions or the entirety of a glacially-derived heavy metal dispersion fan. Root specific nutrient supply possibility was suggested by Brooks (1982) and has potentially dire consequences during an exploration-oriented vegetation geochemical survey. An anomaly in vegetation could be missed by sampling only one branch from one location on a tree.

This survey was approached in the manner of an exploration-oriented survey, *i.e.*, by collecting single branches from the periphery on the north, south, east and west sides of the available vegetation during routine sampling. Five vegetation types were sampled: black spruce (*Picea mariana*), jack pine (*Pinus banksiana*), tamarack (*Larix laricina*), birch (*Betula papyrifera*) and poplar (*Populus tremuloides*).

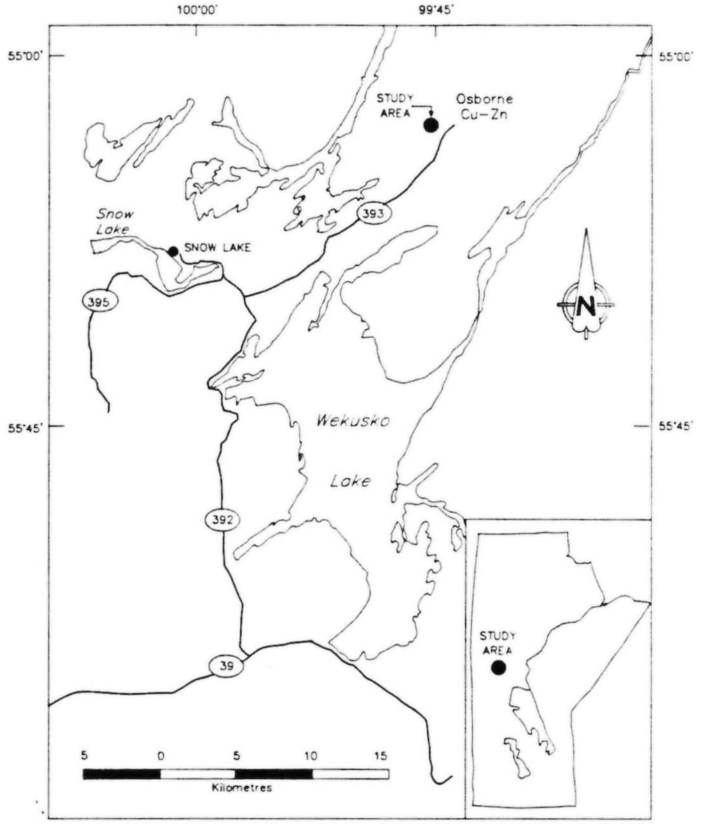

Figure 1: Location map for the study area.

SAMPLE COLLECTION, PREPARATION AND ANALYSIS

Single branches from the north, south, east and west sides were collected from each of the various species in an area approximately 100 m^2. Each branch represents a single sample, one of four collected from each species. The branches represent 8 year's growth as determined by growth node and ring counts. Accordingly, constant diameter of the sample branches was maintained (*cf.* Dunn, 1992).

Cattails were sampled from the general area of the Osborne deposit and in environments where considerable contamination could be expected, as well as from a "background" location. A cattail sample consists of a brown, tubular head, characterized by the upper 10-15 cm of the plant, and a stalk, the lower 30-40 cm. Two or three cattails were collected at each site, depending on availability, and the heads and stalks bulked to give a single sample.

Samples were stored in pre-labelled paper sample bags for 3 weeks to dessicate. Subsequently, needles of black spruce, jack pine and tamarack were separated from the branches and placed in separate sample bags. Birch and poplar leaves were separated from the branches and also stored in separate, labelled sample bags. Cattail heads and stalks were also placed into separate sample bags.

Samples were forwarded to the Geological Survey of Canada (Ottawa) and ashed at 470°C under the supervision of C.E. Dunn. Sample ashes (approximately 0.2500 g) were encapsulated and forwarded to Activation Laboratories Ltd. (Ancaster, Ontario) for neutron activation analysis (NAA); a second split of ash was sent to Barringer Laboratories (Toronto) for analysis by inductively coupled argon plasma atomic emission spectroscopy (ICP-AES).

RELATIVE ABUNDANCES AND GEOCHEMICAL PARTITIONING

Rigid conclusions regarding the relative abundance of elements in the various species sampled as well as the geochemical partitioning between twigs and needles cannot be made on the basis of this small sample population. The general patterns observed, however, are briefly discussed and also summarized in Tables 1 and 2.

Ore-related elements appear to be concentrated in different tissues/organs of the species represented in this brief study. Au and As are generally highest in tamarack needles. An analysis of 138 ppb Au in birch twigs and one of 43 ppb Au in poplar leaves are probably spurious and are discussed in a later section ("Peripheral Variability"). Pb and Zn are concentrated in birch twigs and Cu in tamarack twigs.

Interestingly, cattail stalks, collected from contaminated/anomalous substrate, contain significant Zn concentrations (Table 3, 750-1100 ppm; Table 4), and compared to Zn concentrations in background/non-contaminated cattail stalks, indicate a high-contrast Zn anomaly.

Table 1: Trace and major element comparison between the various organs (bio-objects) of species sampled for this study. Abbreviations as follows: BST-black spruce twigs, BSN-black spruce needles; JPT-jack pine twigs, JPN-jack pine needles; Tt-tamarack twigs, TN-tamarack needles; BT-birch twigs, BL-birch leaves; PT-poplar twigs, PL-poplar leaves. Data shown are ranges of analyses of 4 samples for each organ. LLD = Lower limit of detection. Cu* and Pb* analyzed by ICP-AES, all others by NAA.

	Au(ppb)	As(ppm)	Ba(ppm)	Br(ppm)	Ca(%)	Fe(%)	K(%)	Na(ppm)
Black Spruce (*Picea mariana*)								
BST	<5-10	3.4-4.3	1800-2100	21-44	20.6-22.4	0.29-0.41	14.5-21.4	1060-1390
BSN	<5	1.3-2.6	1400-1500	14-21	20.5-22.5	0.12-0.17	9.59-11.9	231-311
Jack Pine (*Pinus banksiana*)								
	Au(ppb)	As(ppm)	Ba(ppm)	Br(ppm)	Ca(%)	Fe(%)	K(%)	Na(ppm)
JPT	9-29	4.1-7.1	160-220	65-82	14.8-16.2	0.41-0.52	21.0-23.0	1140-1380
JPN	<5-7	10-14	<100	130-160	15.0-17.2	0.23-0.27	18.1-20.6	458-712
Tamarack (*Larix laricina*)								
	Au(ppb)	As(ppm)	Ba(ppm)	Br(ppm)	Ca(%)	Fe(%)	K(%)	Na(ppm)
Tt	<5-8	2.4-4.3	2100-2700	94-150	16.6-18.2	0.25-0.28	19.7-22.3	689-780
TN	16-79	9.2-11.0	1400-1700	250-330	10.2-13.4	0.15-0.23	15.7-17.5	281-382
Birch (*Betula papyrifera*)								
	Au(ppb)	As(ppm)	Ba(ppm)	Br(ppm)	Ca(%)	Fe(%)	K(%)	Na(ppm)
BT	<5-9	1.9-3.4	620-670	23-33	27.8-30.8	0.09-0.12	6.94-9.7	507-621
BL	6-138	6.8-8.1	340-440	14-17	24.3-25.9	0.09-0.10	7.96-10.2	338-363
Poplar (*Populus tremuloides*)								
	Au(ppb)	As(ppm)	Ba(ppm)	Br(ppm)	Ca(%)	Fe(%)	K(%)	Na(ppm)
PT	<5	<0.5-1.4	150-190	10-16	28.8-30.8	0.06-0.07	7.25-8.5	147-214
PL	<5-43	0.9-1.3	86-110	43-46	20.3-22.8	0.08-0.10	8.99-10.5	167-256

Black Spruce (*Picea mariana*)

	Ni(ppm)	Rb(ppm)	Sr(ppm)	La(ppm)	*Cu(ppm)	*Pb(ppm)	Zn(ppm)	Ash(%)
BST	<50-53	27-32	2000-2300	2.7-4.5	179-198	15-23	3700-3800	2.5-3.1
BSN	<50	15-21	2000-2200	0.7-1.3	46-57	6-12	3800-4000	4.2-4.8

Jack Pine (*Pinus banksiana*)

	Ni(ppm)	Rb(ppm)	Sr(ppm)	La(ppm)	*Cu(ppm)	*Pb(ppm)	Zn(ppm)	Ash(%)
BST	<50-67	33-52	<300-750	3.5-4.4	102-287	58-75	2700-3000	0.9-1.3
BSN	<50-82	29-39	<300	1.4-2.5	87-104	44-60	3000-3200	2.5-2.6

Tamarack (*Larix laricina*)

	Ni(ppm)	Rb(ppm)	Sr(ppm)	La(ppm)	*Cu(ppm)	*Pb(ppm)	Zn(ppm)	Ash(%)
Tt	<50-85	150-200	2700-3000	1.6-2.0	262-308	51-64	2300-2500	1.7-1.8
TN	<50	70-84	1800-2800	0.8-1.2	66-77	33-42	960-1100	4.7-4.9

Birch (*Betula papyrifera*)

	Ni(ppm)	Rb(ppm)	Sr(ppm)	La(ppm)	*Cu(ppm)	*Pb(ppm)	Zn(ppm)	Ash(%)
BT	<50	50-62	940-1100	1.3-1.5	148-187	58-75	6300-7300	2.1
BL	<50	26-47	<300-710	0.8-0.9	57-68	24-33	4400-4800	4.5-6.0

Poplar (*Populus tremuloides*)

	Ni(ppm)	Rb(ppm)	Sr(ppm)	La(ppm)	*Cu(ppm)	*Pb(ppm)	Zn(ppm)	Ash(%)
PT	<50	17-24	920-1000	0.5-0.8	96-112	2-9	4000-4600	4.0-5.3
PL	<50	12-25	<300	0.7-0.8	46-61	23-33	4000-6000	8.4-9.2

Black Spruce (*Picea mariana*)

	Ce(ppm)	Sm(ppm)	Eu(ppm)	Yb(ppm)	Cr(ppm)	Cs(ppm)	Sc(ppm)	
BST	6-8	0.4-0.6	<0.02-0.17	0.22-0.35	6-8	<0.5-0.9	0.9-1.1	
BSN	<3-3	0.1-0.2	<0.02	<0.05-0.09	<1-5	<0.5-0.7	0.3-0.4	

Jack Pine (*Pinus banksiana*)

	Ce(ppm)	Sm(ppm)	Eu(ppm)	Yb(ppm)	Cr(ppm)	Cs(ppm)	Sc(ppm)	
JPT	5-9	0.6-0.7	<0.02-0.17	0.22-0.34	7-24	<0.5-1.1	1.2-1.4	
JPN	<3-5	0.2-0.4	<0.02-0.19	<0.05-0.25	6-12	<0.5-1.4	0.5-0.8	

Tamarack (*Larix laricina*)

	Ce(ppm)	Sm(ppm)	Eu(ppm)	Yb(ppm)	Cr(ppm)	Cs(ppm)	Sc(ppm)	
Tt	<3-4	0.2-0.3	<LLD	<0.05-0.26	<1-8	1.1-1.3	0.6	(all samples)
TN	<3-5	0.1-0.2	<LLD	<0.05-0.25	<1-6	<0.5-1.2	0.2-0.3	

Birch (*Betula papyrifera*)

	Ce(ppm)	Sm(ppm)	Eu(ppm)	Yb(ppm)	Cr(ppm)	Cs(ppm)	Sc(ppm)	
BT	<3-3	0.1-0.2	<LLD	<0.05	<1-3	<0.5-1.1	0.2-0.3	
BL	<3	0.1	<LLD	<0.05-0.08	2-4	<0.5-1.1	0.2-0.3	

Poplar (*Populus tremuloides*)

	Ce(ppm)	Sm(ppm)	Eu(ppm)	Yb(ppm)	Cr(ppm)	Cs(ppm)	Sc(ppm)	
PT	<LLD	<LLD	<LLD	<LLD	2-3	<0.5	0.1-0.2	
PL	<3-4	<LLD	<LLD	<LLD	1-3	<0.5	0.1-0.2	

Table 2: Relative abundances of chemical elements in vegetation samples collected during the peripheral variability study. Tabled data based on the analysis of 4 twig and 4 needle samples from each species.

Species	Organ	Elements Concentrated
Black Spruce	Twigs	Ce
(*Picea mariana*)	Needles	-
Jack Pine	Twigs	Fe, K, Na, La, Pb, Ce, Sm, Yb
(*Pinus banksiana*)	Needles	As
Tamarack	Twigs	Ba, Rb, Sr, Cu
(*Larix laricina*)	Needles	Au, As, Br
Birch	Twigs	Pb, Zn
(*Betula papyrifera*)	Leaves	(138 ppb Au)*
Poplar	Twigs	Ca
(*Populus tremuloides*)	Leaves	(43 ppb Au)*

* - probable spurious result

Table 3: Location and description of cattail (*Typha latifolia*) sampling sites

A: represents contaminated or anomalous site
B: represents noncontaminated or background site

Site Number	Sample Number	Location and Description
1A	02001 (stalk) 02002 (head)	10 m from base of ore-loading dock in ditch with red-brown water
2A	02003 (stalk) 02004 (head)	edge of Osborne tailings pond; 8-9 cm red-brown water
3A	02035 (head) 02036 (stalk)	310 m downstream from Osborne waste dumps along edge of Osborne Creek; moderate drainage; no ponded water
4A	02039 (head) 02040 (stalk)	edge of Osborne tailings retention pond; 10-15 cm red-brown water, adjacent to pumphouse
5B	02037 (head) 02038 (stalk)	2.8 km south of Herblet Lake access road adjacent to Provincial Road 393; in ditch with 2-3 cm ponded water

Table 4: **Summary of geochemical data for, cattail (*Typha latifolia*) heads and stalks. Anomalous sites are represented by ranges in elemental concentrations in samples 02001, 02002, 02003, 02004, 02035, 02036, 02039 and 02040. Ba, Br, Na, Ni, Rb, Sr, La, Cu, Pb and Zn in ppm, others as indicated. Ag, As, Cr, Cs, Hf, Hg, Ir, Sb, Sc, Se, Sn, Th, U, W, Ce, Nd, Sm, Eu, Tb, Yb and Lu were ineffective or below LLD. Cu* and Pb* analyzed by ICP-AES, all others by NAA.**

Cattail (*Typha latifolia*)	Organ	Sample No.	Au (ppb)	Ba	Br	Ca (%)	Fe (%)	K (%)	Na
Anomalous	Head	see	<5-10	<100-160	410-770	6.1-8.3	<0.05-0.11	27.0-37.4	4400-8370
	Stalk	notes	<5	<100-280	620-1200	11.0-12.9	<0.05-0.23	21.7-33.3	10045-65300
Background	Head	02037	<5	<100	150	7.1	0.10	30.7	4450
	Stalk	02038	<5	<100	310	13.5	0.06	30.0	10200

Cattail (*Typha latifolia*)	Organ	Sample No.	Ni	Rb	Sr	La	Cu*	Pb*	Zn	Ash (%)
Anomalous	Head	see	<50-110	47-270	<300-650	<0.1-0.4	106-231	53-58	510-790	3.9-4.8
	Stalk	notes	<50	<15-110	<300-740	0.6-1.8	32-95	32-112	750-1100	5.1-7.7
Background	Head	02037	<50	64	<300	0.4	126	51	380	4.4
	Stalk	02038	<50	37	<300	0.3	24	35	140	7.6

BLACK SPRUCE (*Picea mariana*)

With the possible exception of K in twigs, there are no indications of trace or major element variability in branches and twigs collected about the periphery of the tree. Although some variation is noted for Cs in needles (BST-<0.5-0.9 ppm; BSN-,0.5-0.7 ppm) these analyses are very close to the detection limit. A similar observation is made for Eu in twigs: a single high analysis of 0.17 ppm (LLD = 0.02 ppm) was recorded from twigs on the east side of the tree; the remainder of the twig and needle analyses are <LLD.

JACK PINE (*Pinus banksiana*)

Unlike black spruce bio-objects, the needles and twigs of the jack pine indicate some peripheral chemical variability at the sampling site. In twigs, Au varies from 9 to 29 ppb with two samples at 13 ppb. Although 29 ppb is not an extraordinarily high Au analysis, it conceivably represents a low-contrast anomaly if compared to a background of 9 to 13 ppb. Chromium in twigs demonstrates a similar peripheral variation in terms of the order of magnitude: the range in concentration is 7 to 24 ppm with two samples at 10 ppm. Cu analyses for 3 of 4 peripheral twigs samples range from 102 to 287 ppm. Sr analyses range from <300 ppm to 750 ppm in twigs; analyses for Ni in twigs and needles in three of four samples are <LLD (*i.e.* <50 ppm), however, the fourth twig and needle samples contain 67 and 82 ppm, respectively. Eu contents of twigs (0.17 ppm Eu) and needles (0.19 ppm Eu) from the south side of the tree are distinct from the rest of the twig and needle samples, which are <LLD. The variation in Yb concentrations in needles is similar to that for Eu: needles on the east side contain 0.25 ppm, whereas samples from the north and south side contain <0.05 ppm.

TAMARACK (*Larix laricina*)

Tamarack bio-objects are generally chemically homogeneous about the periphery of the tree sampled, with the possible exception of Au in needles. The range for Au in the needles is 16 to 79 ppb based on analyses of 16, 18, 54 and 79 ppb. The range in concentration and the absolute concentration of Au are considerably higher for needles than for twigs. These Au concentrations represent the highest observed in this survey, with the exception of a single analysis of 138 ppb in birch leaves. A range of 0.1 to 130 ppb Au has been documented in needles of larch (*Larix dahurica*) from the former U.S.S.R., by Brooks (1982) (*cf.* Table 3.2 in Dunn, 1992). The variable Au results from the tamarack needles in this survey are distributed about the tree as follows:

north side, 79 ppb;
south side, 16 ppb;
east side, 54 ppb;
west side, 18 ppb;

Tamarack twigs and needles are marked by variable Yb contents (twigs <0.05-0.26 ppm; needles <0.05-0.25 ppm). A duplicate analysis of a south side tamarack twig indicates the above-noted variability may be an artifact of the analytical process when concentrations are close to the LLD. The duplicate analysis indicates <0.05 ppm Yb and 0.25 ppm Yb in the same sample.

BIRCH (*Betula papyrifera*)

The single highest Au analysis obtained from this survey is 138 ppb in birch leaves (sample 04692, south side of tree). This result is in stark contrast to the analyses of the remainder of the leaf and twig samples (leaves = 6, 8, 10 and 138 ppb; twigs = <5, <5, 9 and 9 ppb), and accordingly, is probably suspect. Possible peripheral variation is noted for Cs (leaves = ≤0.5, 0.5, 0.6 and 1.1 ppm; twigs = ≤0.5, 0.5, 0.6 and 1.1 ppm) and Sr in leaves (three samples at <300 ppm, one sample = 710 ppm), although these variations are also close to the limits of detection of the analytical method.

POPLAR (*Populus tremuloides*)

A single high Au result of 43 ppb was recorded from the leaves on the south side of the tree. Once again, as in the case of the birch leaves, this analysis would appear to be suspect compared to the remainder of the leaf and twig samples (all <5 ppb). Some variability for As in twigs, albeit near the lower limit of detection, is observed (1.4, 1.1, <0.5 and 1.4 ppm).

CATTAIL STUDY

CATTAIL (*Typha latifolia*)

Many of the chemical elements determined in ashed samples of cattail heads and stalks are below the limits of detection in most, if not all, samples. These elements include:

Au, Ag, As, Cs, Cr, Sr, Ta, Th, Hf, Hg, Ir, Ni, Se, Sn, U, Ce, Nd, Sm, Eu, Tb, Yb and Lu.

A clear preference of Br, Ca, Na and Co for the stalks and Cu, Rb, Zn and Mo for the heads is apparent in the background sample:

	Cu	Br*	Ca	Na	Co	Ta	Rb	Zn	Mo
Stalk	24	310	13.5	10200	7	<0.5	37	140	10
Head	126	150	7.1	4450	3	0.9	64	380	17

(all analyses in ppm)

Au is effectively near or <LLD for all samples; ash is highest in the stalk (7.6 *vs.* 4.4%).

Significant differences exist between the chemistry of the anomalous samples as compared to background samples. These differences probably result from the variable nature of the geochemical environment from which they were collected. Locations and descriptions of cattail sampling sites are given in Table 3. Ba, Br, K, Na, Rb, Sr, Cu, Co and Zn are all higher in heads and stalks of the anomalous samples; La, Fe and Pb are higher in stalks of the anomalous samples. Interestingly, there is virtually no difference in the ash percentages between anomalous and background cattail heads and stalks which suggests that airborne particulate contamination does not explain the chemical differences between anomalous and background samples. Higher concentrations of Mo (17 ppm-head; 10 ppm-stalk) is documented in the background sample. The ore-related elements Cu, Pb, Co, Fe, Zn and As are highest in anomalous samples when the sample was collected from standing, red-brown water representing drainage from the Osborne Cu-Zn dumps. This observation probably represents the effects of the high acidity and trace element content of the environment in which the cattails are growing.

* Br is volatilized during sample ashing and, accordingly, the values recorded in this survey represent residual Br

DISCUSSION

This brief study indicates that significant variation of trace element abundances about the periphery of a tree, representing a comparison between single branches collected from the north, south, east and west, is probably not present. The small number of samples in this study precludes a definitive statement; however, in elements above the LLD there is little variation. Single sample anomalies, such as the 138 ppb Au in a birch leaf sample and 43 ppb Au in a poplar leaf sample, are considered spurious inasmuch as the other three leaf samples from the same trees are <LLD. Spurious results are probably not attributable to contamination from airborne particulate and/or drainage from the Osborne mine dumps. Variation in elements close to the LLD are also considered insignificant.

The relatively high Au and As concentrations in tamarack needles and Cu in the tamarack twigs indicates the potential for the use of this species in Au and Cu exploration. Although a high Zn contrast was observed for cattail stalks, the contaminated/anomalous samples were collected from areas considered to be at the extreme end of contamination. Whether natural contamination from an oxidizing base metal deposit can be monitored in the same manner as anthropogenic contamination remains to be demonstrated.

CONCLUSIONS

1. Variation of ore-related trace elements is probably absent from the periphery of the vegetation species sampled.
2. The collection of twigs and needles, as well as bark, from the periphery of a tree and subsequent homogenization before analysis would nominally increase sample collection and preparation time, but would alleviate any possible concerns regarding peripheral variation or "geochemical noise".
3. Cattail stalks may offer promise as vegetation geochemical sampling media in the search for base metals. If an opportunity arises to test this media away from anthropogenic contamination, it should be undertaken.

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APPENDIX I: Geochemical Analyses For the Peripheral Variability Study

Note: Cu* and Pb* analysed by ICP-AES, all others by NAA. All analyses undertaken on ashed samples. All concentrations in ppm unless otherwise indicated. BST-black spruce twigs, BSN-black spruce needles; JPT-jack pine twigs, JPN-jack pine needles; Tt-tamarack twigs, TN-tamarack needles; BT-birch twigs, BL-birch leaves; PT-poplar twigs, PL-poplar leaves. Only elements with significant variation above the lower limit of detection are provided.

Species	Organ	Sample	Cu*	Pb*	Zn	Au (ppb)	As	Sb	Ba	Br	Ni	Sc	Co	Cr (%)	Cs
Black Spruce	BST(north)	02013	179	23	3800	<5	4.3	0.4	2100	37	<50	1.1	4	6	<0.5
(*Picea mariana*)	BSN(north)	02014	50	7	3800	<5	1.6	0.2	1400	18	<50	0.3	1	<1	<0.5
	BST(south)	02015	198	15	3700	6	3.8	0.3	1800	44	53	0.9	3	6	<.05
	BSN(south)	02016	57	12	3900	<5	1.6	0.5	1400	21	<50	0.4	2	5	0.7
	BST(east)	02017	194	21	3700	10	4.7	0.3	1900	21	<50	1.0	3	8	0.9
	BSN(east)	02018	57	6	3900	<5	2.6	0.3	1400	14	<50	0.3	1	2	<0.5
	BST(west)	02019	187	16	3800	<5	3.4	0.5	2000	29	<50	1.2	4	7	0.7
	BSN(west)	02020	46	6	4000	<5	1.3	0.1	1500	15	<50	0.4	2	5	<0.5

Sample	La	Fe (%)	Na	Sr (%)	K (%)	Rb	Ca (%)	Ash (%)	Ce	Sm	Eu	Yb
02013	3.4	0.38	1140	2300	17.2	32	20.6	3.1	6	0.5	<0.02	0.28
02014	0.7	0.13	231	2000	9.9	17	22.0	4.3	<3	0.1	<0.02	<0.05
02015	2.7	0.29	1060	2000	20.9	28	22.0	2.5	5	0.4	<0.02	0.22
02016	1.0	0.14	29	2100	11.9	21	22.5	4.2	<3	0.1	<0.02	<0.05
02017	3.1	0.33	1070	2100	21.4	27	20.6	2.8	7	0.4	0.17	0.22
02018	0.9	0.12	274	2200	10.4	15	21.2	4.4	<3	0.2	<0.02	<0.05
02019	4.5	0.41	1390	2200	14.5	28	22.4	2.6	8	0.6	<0.02	0.35
02020	1.3	0.17	311	2100	9.6	20	20.5	4.8	3	0.1	<0.02	0.09

Species	Organ	Sample	Cu*	Pb*	Zn	Au (ppb)	As	Sb	Ba	Br	Ni	Sc	Co	Cr	Cs
Jack Pine	JPT(north)	02005	287	75	3000	9	4.1	0.5	180	65	<50	1.2	6	10	0.9
	JPN(north)	02006	na	na	3000	<5	10	0.5	<100	130	<50	0.5	6	7	<0.5
(Pinus	JPT(south)	02007	102	58	3000	13	7.1	0.4	220	54	<50	1.2	6	10	1.1
banksiana)	JPN(south)	02008	104	60	3200	6	11	0.3	70	130	<50	0.6	5	6	1.4
	JPT(east)	02009	235	75	2800	13	6.2	0.6	160	82	<50	1.4	7	24	<0.5
	JPN(east)	02010	87	44	3100	6	14	0.5	<100	160	<50	0.8	6	12	<0.5
	JPT(west)	02011	na	na	2700	29	6.4	0.5	210	79	67	1.2	7	7	0.7
	JPT(west)	02012	91	46	3100	7	11	0.3	<100	150	82	0.5	6	9	<0.5

Sample	La	Fe (%)	Na	Sr	K (%)	Rb	Ca (%)	Ash (%)	Ce	Sm	Eu	Yb
02005	3.5	0.41	1340	370	23.0	52	14.9	0.9	5	0.67	<0.03	0.22
02006	1.4	0.23	458	<300	19.9	29	15.0	2.6	3	0.2	<0.02	<0.05
02007	3.7	0.45	1360	680	21.0	39	15.2	1.2	6	0.6	0.17	0.29
02008	1.7	0.27	712	<300	20.6	39	15.4	2.6	5	0.2	0.19	<0.05
02009	4.4	0.52	1380	<300	22.1	52	14.8	1.2	7	0.7	<0.03	0.34
02010	2.5	0.26	632	<300	18.1	39	16.9	2.5	5	0.4	<0.02	0.25
02011	3.8	0.45	1140	750	21.8	33	16.2	1.3	9	0.6	<0.02	0.29
02012	1.5	0.24	497	<300	18.4	30	17.2	2.6	<3	0.2	<0.02	0.25

Species	Organ	Sample	Cu*	Pb*	Zn	Au (ppb)	As	Sb	Ba	Br	Ni	Sc	Co	Cr	Cs
Tamarack	Tt(north)	02025	262	53	2300	6	2.8	0.3	2700	94	67	0.6	16	5	1.1
(*Larix laricina*)	TN(north)	04697	77	39	1100	79	9.2	<0.1	1700	330	<50	0.3	18	6	1.0
	Tt(south)	02026	308	51	2350	6	2.4	0.3	2100	150	85	0.6	17	8	1.3
	TN(south)	04700	68	33	1000	16	11	0.2	1400	300	<50	0.3	16	2	<0.5
	Tt(east)	02027	297	64	2500	8	3.3	0.2	2400	140	63	0.6	18	5	1.2
	TN(east)	04699	68	42	1100	54	11	0.2	1600	300	<50	0.3	16	<1	0.8
	Tt(west)	02028	281	54	2500	<5	4.3	0.3	2500	110	<50	0.6	18	<1	1.2
	TN(west)	04701	66	40	960	18	11	0.2	1500	250	<50	0.2	15	4	1.2

Sample	La	Fe (%)	Na	Sr	K (%)	Rb	Ca (%)	Ash (%)	Ce	Sm	Eu	Yb
02025	2.0	0.26	780	2700	19.7	150	17.5	1.8	<3	0.3	<0.02	0.21
04697	1.1	0.23	382	2800	15.7	84	13.4	4.8	<3	0.2	<0.04	0.25
02026	1.6	0.28	711	2800	20.3	190	16.6	1.7	<3-5	0.2-0.3	<0.03	<0.05-0.25
04700	1.2	0.23	336	1000	17.5	81	12.0	4.8	5	0.2	<0.04	<0.05
02027	1.9	0.25	715	2900	22.3	200	17.2	1.8	4	0.3	<0.03	0.26
04699	1.0	0.20	353	2300	16.4	84	11.6	4.9	3	0.2	<0.04	<0.05
02028	1.8	0.27	689	3000	21.9	170	18.2	1.8	<3	0.2	<0.02	0.17
04701	0.8	0.15	281	2000	15.9	70	10.2	4.7	<3	0.1	<-.-4	<0.05

Species	Organ	Sample	Cu*	Pb*	Zn	Au (ppb)	As	Sb	Ba	Br	Ni	Sc	Co	Cr	Cs
Birch	BT(north)	02021	161	58	7300	9	2.6	<0.1	670	33	<50	0.3	6	<1	1.1
	BL(north)	04685	68	24	4400	10	7.0	0.2	340	16	<50	0.2	4	4	1.1
(Betula	BT(south)	02022	148	75	6600	9	1.9	0.1	640	32	<50	0.3	6	<1	0.6
papyrifera)	BL(south)	04692	57	25	4800	138	8.1	0.2	440	17	<50	0.2	4	2	0.6
	BT(east)	02023	154	64	6300	<5	2.6	0.4	630	23	<50	0.2	6	3	<0.5
	BL(east)	04688	68	31	4400	8	7.5	0.2	410	14	<50	0.3	4	3	<0.5
	BT(west)	02024	187	58	7200	<5	3.4	<0.1	620	23	<50	0.2	6	3	0.5
	BL(west)	04687	67	33	4500	6	6.8	0.2	410	15	<50	0.2	4	4	0.5

Sample	La	Fe	Na (%)	Sr	K (%)	Rb	Ca (%)	Ash (%)	Ce	Sm	Eu	Yb
02021	1.4	0.11	621	940	9.6	57	29.2	2.1	3	0.2	<0.02	<0.05
04685	0.8	0.10	347	<300	8.4	29	23.7	5.3	<3	0.1	<0.02	<0.05
02022	1.5	0.12	507	950	6.9	62	30.0	2.1	<3	0.2	<0.02	<0.05
04692	0.8	0.09	338	<300	7.9	26	25.9	6.0	<3	0.1	<0.02	<0.05
02023	1.4	0.09	529	1100	8.3	52	27.8	2.1	<3	0.2	<0.02	<0.05
04688	0.9	0.11	353	<300	10.2	47	23.8	4.5	<3	0.1	<0.02	<0.05-0.08
02024	1.3	0.10	549	1100	9.2	50	29.3	2.1	<3	0.1	<0.02	<0.05
04687	0.8	0.10	363	710	8.8	36	24.3	5.5	<3	0.1	<0.02	<0.05

Species	Organ	Sample	Cu*	Pb*	Zn	Au (ppb)	As	Sb	Ba	Br	Ni	Sc	Co	Cr	Cs
Poplar	PT(north)	02031	103	9	4200	<5	1.4	0.1	180	13	<50	0.2	5	2	<0.5
	PL(north)	04682	58	24	5000	<5	0.9	0.1	110	45	<50	0.1	18	3	<0.5
(*Populus*	PT(south)	02032	112	2	4300	<5	1.1	<0.1	150	10	<50	0.2	5	2	0.5
tremuloides)	PL(south)	04691	61	23	6000	43	0.9	<0.1	88	43	<50	0.2	20	3	<0.5
	PT(east)	02033	96	3	4600	<5	<0.5	<0.1	150	16	<50	0.2	4	3	<0.5
	PL(east)	04683	49	25	4800	<5	1.3	<0.1	96	46	<50	0.2	18	2	<0.5
	PT(west)	02034	100	6	4000	<5	1.4	<0.1	190	13	<50	0.1	4	3	<0.5
	PL(west)	04684	46	33	4000	<5	1.2	0.1	86	45	<50	0.2	18	1	<0.5

Sample	La	Fe (%)	Na	Sr	K (%)	Rb	Ca (%)	Ash (%)	Ce	Sm	Eu	Yb
02031	0.6	0.07	147	970	7.9	17	30.8	5.3	<3	<0.1	0.08	<0.05
04682	0.7	0.09	167	<300	10.5	25	21.4	9.2	<3	<0.1	<0.02	<0.05
02032	0.6	0.07	194	920	7.5	20	28.8	4.7	<3	<0.1	<0.01	<0.05
04691	0.8	0.08	213	<300	8.9	19	22.8	9.0	<3	<0.1	<0.02	<0.05
02033	0.8	0.07	214	1000	7.2	17	29.7	4.3	<3	<0.1	<0.02	<0.05
04683	0.8	0.08	231	<300	8.9	17	21.7	9.2	4	0.1	<0.02	<0.05
02034	0.5	0.06	183	1000	8.5	24	29.0	4.0	<3	<0.1	<0.01	<0.05
04684	0.8	0.11	256	<300	9.1	12	20.3	8.4	<3	<0.1	<0.02	<0.05

APPENDIX II: Geochemical Data - Cattail (*Typha latifolia*) Study

Note: Cu* and Pb* analyzed by ICP-AES, all others by INAA. All analyses undertaken on ashed samples. All concentrations in ppm unless otherwise indicated.

Species	Organ (ppb)	Sample	Cu*	Pb*	Zn	Au (ppb)	As	Sb	Mo	Ba	Br	Ni	Ta
Cattail	Head	02002	188	58	550	10	<0.6	<0.1	<2	<100	410	<50	<0.5
(*Typha latifolia*)	Stalk	02001	59	44	750	<5	<0.8	<0.1	<2	<100	740	<50	<0.5
	Head	02004	231	54	790	<5	<0.7	0.3	<2	<100	770	11	0.7
	Stalk	02003	66	39	1000	<5	2.9	<0.1	<2	200	1200	<50	<0.5
	Head	02035	106	53	520	<5	<0.8	<0.1	<2	130	690	<50	<0.5
	Stalk	02036	32	39	1100	<5	<0.8	0.2	8	230	620	<50	<0.5
	Head	02037	126	51	380	<5	<0.5	<0.1	17	<100	150	<50	<0.5
	Stalk	02038	24	35	140	<5	<0.5	<0.1	10	<100	310	<50	0.9
	Head	02039	230	58	790	<5	<0.7	<0.1	<2	160	600	<50	<0.5
	Stalk	02040	95	43	1000	<5	<0.8	0.2	<2	280	770	<50	<0.5

Sample	Co	Cr	Cs	La	Fe (%)	Na	Sr	K (%)	Rb	Ca (%)	Ash (%)
02002	48	5	<0.5	0.3	0.08	8370	650	33.5	47	6.3	4.4
02001	46	8	<0.5	0.7	0.08	65300	740	25.8	<15	11.0	7.7
02004	27	<1	<0.5	<0.1	0.11	4260	<300	37.4	260	6.1	3.9
02003	22	<1	0.9	0.6	0.23	10045	<300	31.3	98	12.0	6.9
02035	25	6	<0.5	0.4	0.08	6190	<300	27.0	370	6.8	4.8
02036	22	<1	<0.5	1.8	<0.05	58600	<300	21.7	110	12.9	5.1
02037	3	<1	<0.5	0.4	0.10	4450	<300	30.7	64	7.1	4.4
02038	7	<1	<0.5	0.3	0.06	10200	<300	30.5	37	13.5	7.6
02039	27	<1	<0.5	<0.1	<0.05	4400	<300	36.4	270	8.3	4.6
02040	32	<1	<0.5	1.1	0.17	10500	<300	33.3	110	12.3	5.9