SEDIMENTARY GEOLOGY INVESTIGATIONS

Biogeochemical Investigations in Northern Saskatchewan: Preliminary Data on Tungsten, Gold, Platinum, Rare Earths and Uranium

by Colin E. Dunn

I. OVERVIEW

The aims of the biogeochemical program are threefold:

1) To determine the distribution and concentrations of elements in common plant species in unmineralized areas, thus establishing background values; and near zones of known mineralization to determine whether anomalous values are detectable. As part of the study, consideration is given to metal uptake under a variety of environmental conditions and over a range of common rock types.
2) To investigate the use and usefulness of biogeochemical methods for mineral exploration on both regional and local scales.
3) To develop new exploration methods that are easy to undertake, rapid to perform and low in cost.

The overall intention is to provide an effective additional tool to an exploration program that above all must be practical, and which can be used in conjunction with other more traditional exploration methods. With the current state of the art, biogeochemistry should not and must not be used without careful consideration given to the geology, hydrogeology, soils, topography and any local environmental peculiarities such as the possibility of contamination by airborne material.

Studies conducted in 1983 consisted of three two-week periods, during which the author and one assistant visited areas of known uranium, gold, platinum and rare-earth element mineralization (Fig. 1). In each area sampling was extended from the mineralized areas into 'background' regions. Two of the studies (gold and uranium) were more regional in nature, and were conducted in an attempt to delineate relatively auriferous and uraniferous bedrock, respectively.

Included in the following accounts is a study conducted in 1982 over presumed tungsten mineralization. Data from this study became available early in 1983 and provided some basic information upon which the 1983 field program was developed.

A standard sample preparation procedure is now adopted for the vegetation analysis for most elements. This involves drying samples in a microwave oven to remove all moisture, followed by separation of leaves (or needles) from twigs. The separated plant organs are then placed in aluminum trays and ashed in a pottery kiln at 475°C for 24 hours. Unless stated otherwise all analyses quoted in the ensuing accounts are concentrations in ashed material prepared in the above manner.

II. TUNGSTEN

Studies have shown that plants can absorb moderately high concentrations of tungsten. Kovalevskii (1966) found tungsten to be concentrated in plants growing in a permafrost region of the USSR. Dekate (1967) found plants growing over a mineralized zone in India to contain 2 to 18 times as much tungsten as the background value of 2.7 ppm W. Quin et al. (1974) found up to 300 ppm W in the ash of beech trees growing over scheelite deposits in New Zealand. Further studies have shown encouraging results for tungsten prospecting using plants (Kovalevskii 1978), humus (Toverud, 1979), and plant saps (Zaguzin et al., 1981).

In the light of these results an area in northern Saskatchewan was chosen for study in order to determine which plant species (if any) accumulated tungsten.

Christie (1953, p. 115) reported that "a considerable amount of scheelite ($CaWO_4$)" was present in a radioactive occurrence known as the Radiore Zone No. C1 (Beck, 1969). Since no follow-up work on this discovery has been published, a few days were spent during July 1982 collecting soils, rocks and vegetation over the area. A brief account of the survey is given in Dunn (in press).

The occurrence lies 1.2 km south of the west end of Collier Lake, 10 km east of Uranium City (Fig. 1). Pitchblende occurs along an east-striking fault zone in quartz-feldspar-hornblende gneiss and in fractures striking 060° and 340°. Eldorado Nuclear Ltd. mined the occurrence for uranium in recent years. Examination of the pit, surrounding outcrop and drill core failed to locate any scheelite. A night survey of the area with

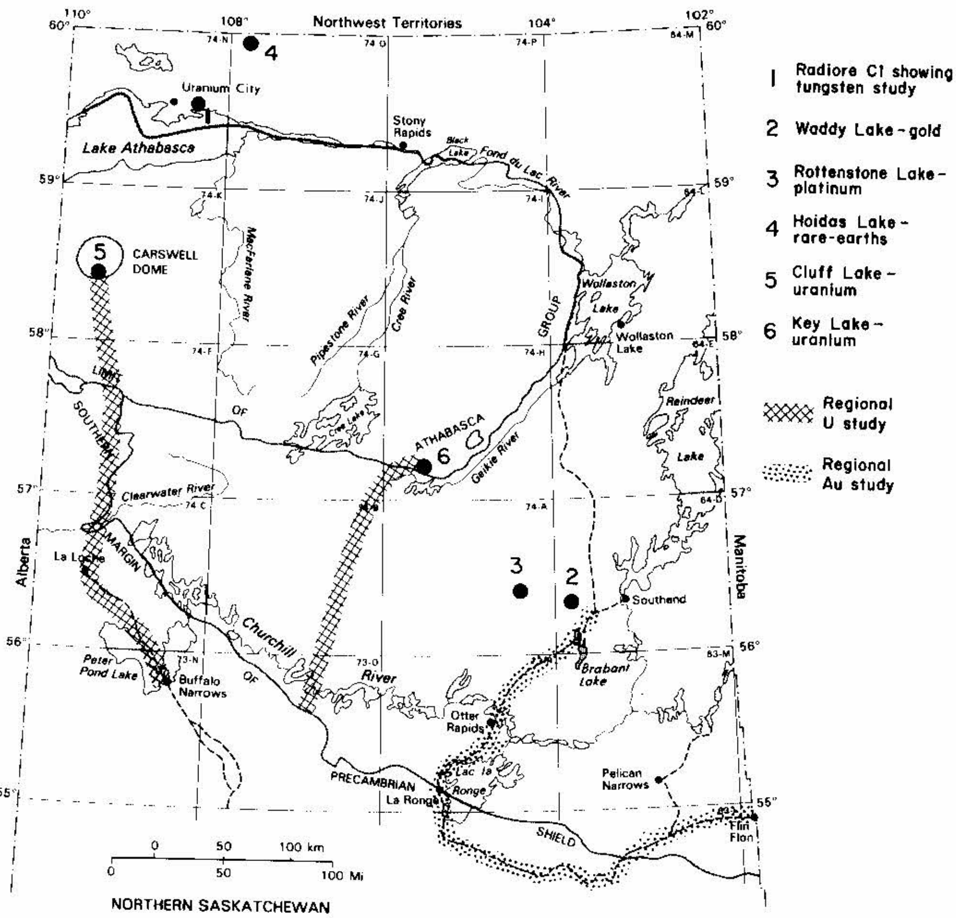

Figure 1 - Location map of areas studied.

an ultraviolet lamp showed some calcite fluorescence and spectacular green fluorescence of uranium minerals on joint planes, but no sign of the bluish-white fluorescence characteristic of scheelite. Thus the survey was restricted to the collection of samples from 33 sites over an area of 200 by 250 m.

A forest fire burned over part of the area approximately 12 years ago, so the forest is dominated by young jack pine (Pinus banksiana), birch (Betula sp.) and alder (Alnus sp.), with some black spruce (Picea mariana), labrador tea (Ledum groenlandicum) and juniper (Juniperus sp.). Immature podzols are present between outcrops of mildly radioactive gneisses.

Sixteen sample media were prepared by the procedures outlined in Section I (this paper), providing over 300 samples for analysis. Of these, 130 samples were selected for tungsten (W), gold (Au), uranium (U), arsenic (As), antimony (Sb), molybdenum (Mo) and samarium (Sm) analysis by neutron activation. This choice of elements was to provide background data on those that could be determined along with tungsten for low extra cost, and to help determine suitable sample media for the following year's research program.

Results

Tungsten

Table 1 summarizes the data obtained for W. Concentrations were close to normal background levels in all samples, and the mean W content of the rocks was 2 ppm (equal to the Clarke for this element). No single sample site yielded all the sample media considered in this study. However, it does appear from considering different permutations of samples that the twigs of black spruce, labrador tea and jack pine tend to concentrate W more strongly than all other plant parts (Table 1). Although no W mineralization was discovered, the biogeochemical survey has indicated the most

Table 1 - Tungsten in Rocks and Vegetation from the Vicinity of a Reported Scheelite ($CaWO_4$) Showing in the Radiore Cl Uranium Zone, 10 km east of Uranium City (130 Samples Comprising 16 Sample Media)

Sample Medium	n	Tungsten (ppm)	
		Range	Mean
Rocks (granitic gneiss)	21	<.7 - 6.7	2.0
Twigs (black spruce)	13	<.7 - 3.5	2.0
Twigs (labrador tea)	4	<.7 - 3.9	1.7
Twigs (jack pine)	5	<.7 - 2.0	.7
Needles and leaves of above and all leaves and twigs of alder, birch, willow, juniper	78	<.7 - 1.0	<.7
B_F horizon soils (-80 mesh)	9	<.7 - 0.8	<.7

suitable sample media for a W survey in this environment. Consideration should also be given to the trunks of the trees (cf. Quin et al., 1974); however, few trees in the study area were sufficiently mature to test the W uptake of the tree trunks.

Other elements

Table 2 shows the maximum values obtained for each sample medium, and gives a broad guide as to the relative sensitivity of the plants to the presence of several elements. In view of the erratic distribution of some plant species, and the low populations of other species, it must be emphasized that these preliminary data serve only as a crude indication of the plants' abilities to accumulate elements. Noteworthy concentrations are Au and Mo in alder, and U in twigs of spruce and jack pine. The unusually high U concentrations are attributed to the presence of readily leachable uranium in the joints and fractures. Spruce twigs appear more effective at concentrating As, Sb and Sm than the other sample media.

III. GOLD

Studies have shown that gold is absorbed by many plants (see review article by Boyle, 1979). Impressive case histories of successful biogeochemical surveys for gold by Baker (Tasmania), Curtin and King (USA), Erdman (USA), Riese and Arp (USA), and Hoffman and Brooker (Canada), amongst others, were presented at a recent symposium in Los Angeles and are currently in press (Carlisle et al., in press).

Studies in Saskatchewan indicate that gold is concentrated in forest litter near gold mineralization (Dunn, 1980), and is preferentially absorbed by alder (*Alnus rugosa*) in the Uranium City area (see Section II, this paper).

These results inspired the initiation of a regional biogeochemical survey for gold in an attempt to delineate relatively auriferous areas which could subsequently be investigated in greater detail. During the course of other surveys during May 1983, alder twigs were collected at 20 sites (some near known gold mineralization and others at presumed 'background' sites). This group of samples comprised the material for a small-scale orientation survey. At each site, the most recent 50 cm of alder twig growth was collected, generally representing 2 to 3 years growth. Since the survey was conducted in May, no leaves had sprouted. All samples were dried, a split ashed, and analyses done separately by neutron activation on dried and ashed material. All ashed samples were analyzed for Au and As, and selected samples of dried material were analyzed for Au, As and Sb. Many replicates and standards were inserted with each batch of samples submitted for analysis, and they attest to the excellent precision and accuracy obtained. Results show that no Au volatilized during ashing, because data corresponded closely after recalculating the data back to a dry weight basis.

Table 2 - Maximum Concentrations of Elements in Rocks, Soils and Ashed Vegetation from the Vicinity of the Radiore C1 Uranium Zone, 10 km east of Uranium City

Sample Medium	n	Maximum Concentrations[1]					
		U (ppm)	As (ppm)	Au (ppb)	Mo (ppm)	Sb (ppm)	Sm (ppm)
Rocks	21	0.5-28[2]	3.3	< 20	3	.8	12.0
A_0 soil	27	1.9-19	NA[3]	NA	NA	NA	NA
B_1 soil	9	1.7-4.3	2.0	< 20	< 2	< .2	3.6
Spruce twigs	13	75-291	4.1	< 20	< 10	1.2	7.1
Spruce needles	14	2-25	1.1	< 20	< 8	.3	.8
Alder twigs	25	1-33	.2	60	274	.8	3.2
Alder leaves	25	0.5-15	.7	200	146	.6	2.6
Jack pine twigs	5	30-147	2.0	60	< 10	1.0	2.3
Jack pine needles	5	7-47	.9	20	28	.9	1.3
Birch twigs	7	11-99	1.5	50	< 2	< .2	1.6
Birch needles	7	0.9-9	.9	20	< 2	.4	< .2
Lab. tea twigs	4	7-56	1.7	70	14	1.1	2.5
Lab. tea leaves	4	4-11	1.2	40	7	< .2	.5
Juniper twigs	2	14 & 20	< .3	< 20	< 10	.3	.8
Juniper leaves	2	7 & 16	< .3	< 20	52	.3	.4
Willow twigs	2	1.7 & 2.7	< .3	< 20	24	< .2	1.4
Willow leaves	2	0.7 & 1.5	< .3	< 20	24	.3	.9

[1]Except for uranium, the lowest concentration of elements in all sample media was below detection limit (i.e. approximately 0.3 ppm As, 20 ppb Au, 2 ppm Mo, 0.2 ppm Sb and 0.2 ppm Sm).
[2]Values from surface outcrop; samples from the pit that was mined for uranium yielded up to 4680 ppm U.
[3]NA = not analyzed

Arsenic concentrations in ashed samples ranged from 0.2 to 6.7 ppm, but did not show a consistent pattern of enhanced values where Au levels were higher. In the dried samples As ranged from 0.02 to 0.34 ppm and Sb from < 0.01 to 0.04 ppm. It appears that little or no As was lost during ashing. It was anticipated that Sb would volatilize, so ashed samples were not analyzed for this element.

Results

Orientation Survey

Table 3 summarizes the concentrations of Au found in ashed alder twigs. The data show that, in the Cluff Lake (Carswell Structure) and Box granite (Uranium City) vicinities (Fig. 1), the mean Au concentrations are appreciably higher than in the other three test areas. The wide range of concentrations observed in each area is attributed to the random sampling and the local concentrations of Au. At Cluff Lake two samples were from soils known to contain Au. In the Box granite area samples were not collected from near the disused Box Mine (Au) but rather from around a nearby lake (Vic Lake) without knowledge of the bedrock Au content at each site. A sample of forest litter from beneath one alder at Cluff Lake had in its ash less than half the Au content of the ashed twigs.

Cones from one alder contained more Au than twigs of the same shrub, yet at another site the opposite occurred. Unashed samples of cones and twigs returned very similar values.

Table 3 - Gold Concentrations in Ashed Twigs of Alder (Alnus rugosa), Orientation Survey, May 1983 (Random Sampling)

Location	n	Gold (ppb)	
		Range	Mean
Cluff Lake area (auriferous soils)	4	25-386	152
Box granite (auriferous bedrock)	6	17-217	79
Key Lake Road	3	9-55	38
Anglo-Rouyn copper mine	6	7-29	17
South of La Ronge (above Cretaceous Sandstones)	1		15

Regional Survey

The above orientation survey was sufficient to show a positive response of Au uptake by alder twigs in areas of known mineralization, and encouraged a program of more widespread sampling during a seven-day period in early August.

Alder samples were collected about 50 m from the roadside at 2 km intervals from Lac la Ronge to Brabant Lake (Fig. 1). Black spruce twigs were collected at every second site (4 km), since spruce also shows a tendency to concentrate Au. Data on these samples are not yet available. From Brabant Lake the sampling interval was reduced to 1 km for 18 km northwestward to the Komis Au deposit by Waddy Lake. Detailed sampling was conducted in the vicinity of the Komis mineralization.

In addition, samples were collected at 20 km intervals eastward from La Ronge across Cretaceous sandstones and Ordovician carbonates to the Precambrian terrain near Flin Flon, and over known Au mineralization in that area. The 176 sites visited provided about 240 samples which (when separated into leaves, twigs, etc.) produced nearly 500 samples for analysis. To date, Au and As values have been received for 100 samples.

Fig. 2 shows the regional distribution of Au in ashed alder twigs sampled from the northern end of Lac la Ronge, across to Stanley Mission and northward past Otter Lake. The most striking feature is the consistently high Au concentrations, from 20 to 130 ppb, that occur in the Glennie Lake Domain. Samples from the La Ronge Domain rarely yield more than 10 ppb Au. The reason for this is unknown, but two possibilities are offered. Either:

1) the extensively sheared Glennie Lake Domain is generally more auriferous than the La Ronge Domain; certainly numerous Au showings are known just north of Lac la Ronge; or
2) the traces of Au within the Glennie Lake Domain are present in a form (in the bedrock or soils) that is more readily accessible to absorption by the alder roots than in the La Ronge Domain.

Further investigation seems warranted.

Samples collected in the vicinity of the Komis Au deposit yield much lower Au concentrations than expected. Table 4 shows Au in bedrock, various size fractions of soil, and several parts of alder shrubs rooted at these two sites. Arsenic was at or below the detection limit of 1 ppm in all vegetation samples; its content in the bedrock was not determined. The Au content of the granodiorite, from within a few centimetres of the andesite, is surprisingly high (3600 ppb), and there is a marked tendency for Au to concentrate in the coarse fraction of the soils. The high Au content of the forest litter is considered to be mainly contained in adhering soil particles rather than the organic debris. This conclusion is supported by the high Au content of a gritty sample of forest litter from site A. Clearly the alders are showing very little tendency to absorb the abundance of Au present in the bedrock and soils. Perhaps this is due to the inorganic nature of the soils, and the lack of organic acids normally available in the humus layer to aid in mobilizing Au and transporting it into the plants; a few years ago the outcrop was washed clean, and the sparse vegetation has not had time to add an appreciable organic fraction to the new mechanically derived soil. It seems that careful consideration should be given to the nature and maturity of the soil when interpreting Au biogeochemical data.

Two alder samples collected from the vicinity of the Rio Au occurrence near Flin Flon contained 25 and 45 ppb Au in their twigs, and 20 and 65 ppb in the leaves. Arsenic contents ranged from 9 to 17 ppm. Another Au occurrence in the vicinity of Wekach Lake near Flin Flon yielded 65 and 230 ppb Au in alder twigs, and 85 and 160 ppb in the leaves. In general, studies showed that the Au content of leaf ash in August was slightly lower than that of twig ash. Preliminary results suggest that during the growing season the Au content of twigs increases, whilst that of the leaves decreases.

The potential use of alder twigs in delineating auriferous zones seems promising, provided careful consideration is given to the soils in which they are growing. The latest 50 cm of twig growth appears to be a practical amount to collect.

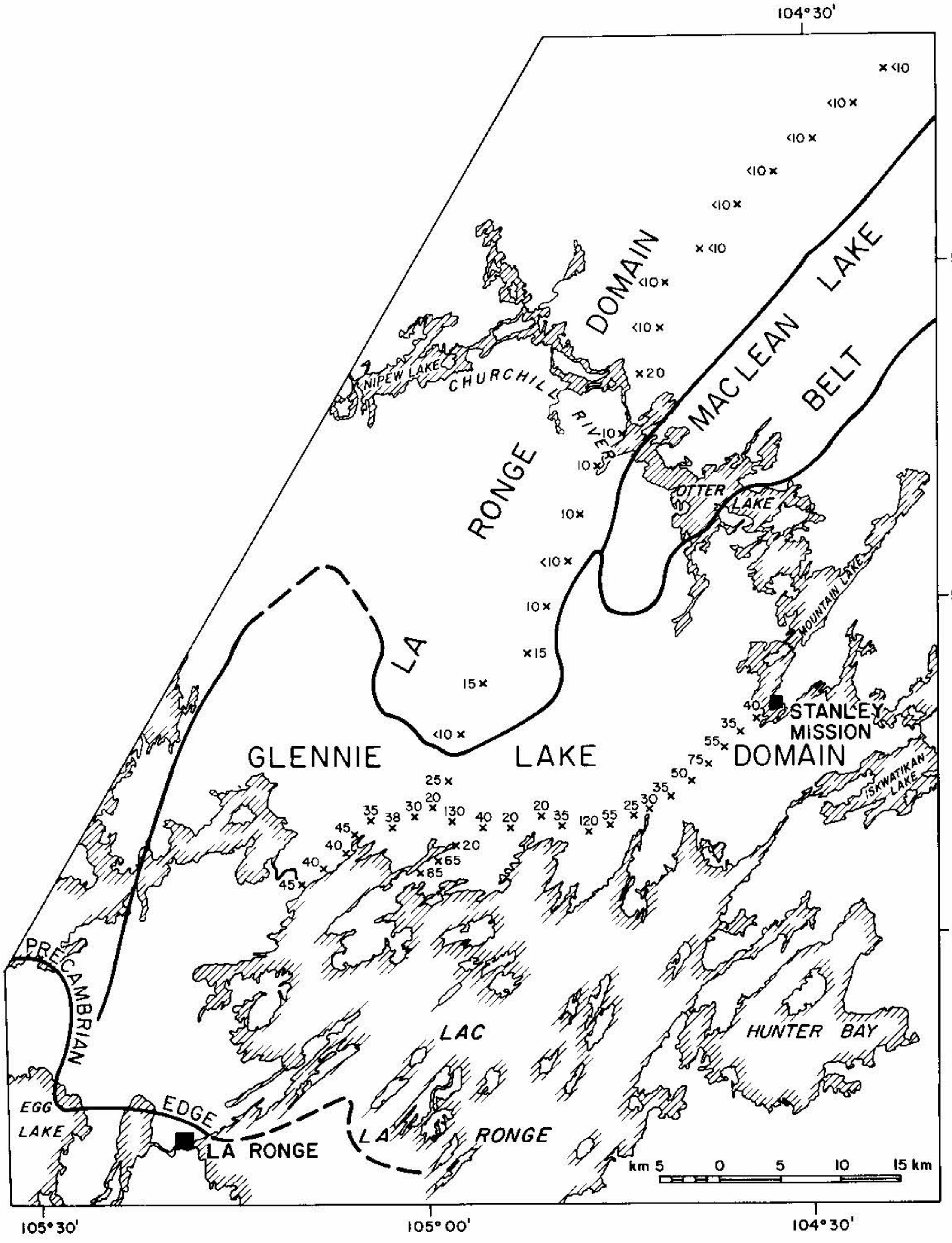

Figure 2 - Distribution of gold in the ash of alder twigs (ppb).

Table 4 - Gold Content of Bedrock, Soils, Forest Litter and Alder Shrubs Rooted in a Fracture in Andesite, Adjacent to a Pluton of Granodiorite, Komis Deposit, Waddy Lake; Alder at Site A was 1.5 m High, That at Site B was 1.0 m High

Sample Medium	Au (ppb)	
	Site A	Site B
Andesite	950	1220
Granodiorite	-	3600
Soil (-10 to -40 mesh)	910	4700
Soil (-40 to -80 ")	500	2600
Soil (-80 to -200 ")	290	1550
Soil (less than -200 mesh)	405	1100
Forest litter	250	410
Forest litter (gritty)	1500	-
Alder twigs (latest 50 cm growth)	20	20
Alder leaves (on latest 50 cm growth)	10	<10
Alder twigs (growth from 50 to 100 cm from tip of twig)	35	35
Alder leaves (on growth from 50 to 100 cm from tip of twig)	25	-
Alder stems (growth from 100 to 150 cm from tip of twig)	<10	-
Alder twigs (dead)	15	-
Alder stems (dead)	35	-

IV. PLATINUM

A search of the world literature indicates that the only publication on platinum biogeochemistry is that by Fuchs and Rose (1974). They analyzed the ash of twigs from four trees in the Stillwater Complex of Montana and found concentrations of 12 to 56 ppb Pt. A presentation at a symposium in Los Angeles (Feb. 1983) entitled "Organic Matter, Biological Systems and Mineral Exploration" showed that plants growing over the platiniferous Marensky Reef in South Africa contain up to 1500 ppb Pt in dry leaves (P.J. Petersen); a second study (Riese and Arp, in press) found 3000 ppb Pt in ashed twigs of Douglas Fir above platiniferous zones in the Stillwater Complex.

In Saskatchewan platinum has been recorded from several ultramafic bodies. Two occurrences, Rottenstone (Fig. 1), and Nicholson near Uranium City, were selected as biogeochemical test sites to determine the distribution of Pt, Pd and Au in a variety of common plants. Data from the Rottenstone area are reported here.

The Rottenstone Deposit

The Rottenstone Lake (Hall showing) Ni-Cu-Pt-Pd deposit consists of about 50 percent sulphides disseminated in a body of pyroxene-rich rock that is surrounded by gneissose metasediments (Richards and Robinson, 1966). According to these authors the body has an average thickness of 8 m and dips 30° to the east, rising as far above the average land surface as it does below it. It has been surmised that the pyroxenite body occurs as a raft (i.e. a roof pendant) within the migmatitic complex (cf. Gilboy, 1975). The sulphides are mainly pyrrhotite (FeS), violarite (Ni_2FeS_4) and chalcopyrite ($CuFeS_2$). Platinum occurs as minute grains of sperrylite ($PtAs_2$).

The deposit was mined from 1965 until the ore was exhausted in 1968. Thus, 15 years have elapsed during which the vegetation could become re-established.

Three days at the end of May were spent in the area collecting vegetation and bedrock from 22 sites in the vicinity of the worked-out deposit and two sites on a mineralized zone of similar appearance (the Tremblay-Olsen showing), 2.5 km to the southwest.

Samples were collected at intervals of approximately 100 m along four lines spaced 200 m apart (Fig. 3). Twigs of black spruce (Picea mariana) were collected at all sites (latest ten years of growth). In addition, labrador tea (Ledum groenlandicum), jack pine (Pinus banksiana), shrub alder (Alnus sp.), willow (Salix sp.) and birch (Betula sp.) were collected at selected sites.

Preliminary Results

Six boulders of ore-grade rock were analyzed for precious metals to provide a general comparison with the vegetation samples. It should be noted, however, that no vegetation sample was found rooted in or close to a boulder of high-grade ore. Concentrations in those rocks were 1200 to 3600 ppb Pt, 3500 to 6900 ppb Pd, 20 to 67 ppb Rh, and 210 to 340 ppb Au.

Data have been received for Pt, Pd and Au concentrations in all samples of spruce twigs (n = 24) and spruce needles (n = 24). One analysis is available for each of labrador tea twigs, birch twigs, willow twigs and spruce trunk. Table 5 shows the concentrations in these species from a single locality, thereby permitting direct comparison of the relative uptake of the

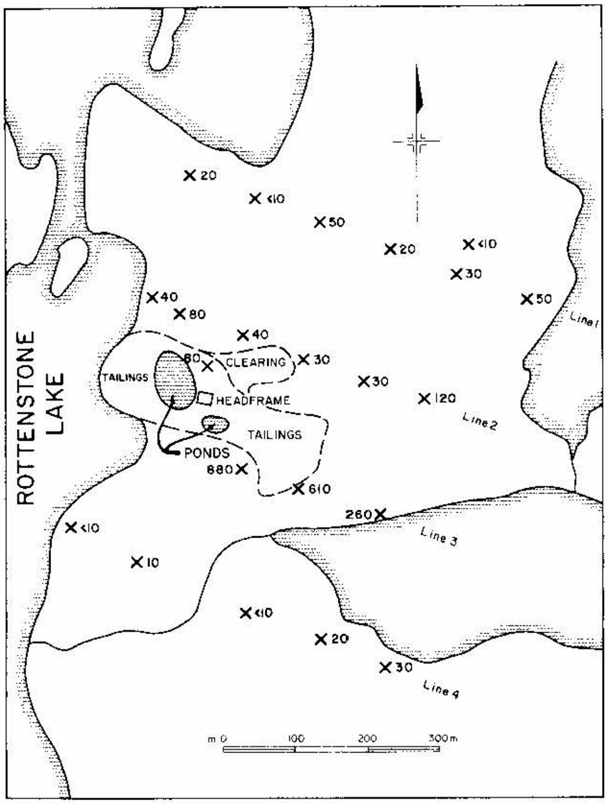

Figure 3 - Sketch map of platinum (ppb) in the ash of black spruce twigs, Rottenstone mine area.

precious metals by the plants. Clearly, the black spruce and labrador tea twigs, and jack pine trunk are more effective at concentrating Pt and Pd than the other plant parts. The high concentration of Au in the spruce trunk is of interest and worth further investigation.

High concentrations of precious metals are present in the twigs of black spruce growing down drainage from the tailings debris (line 3 on Figs. 3, 4 and 5). In addition there are fairly high values of Pt and Pd on the ridge that occurs immediately north of the old mine (line 2), and at two sites along line 1 where Pt concentrations are 50 ppb. Gold values are only anomalous at two sites north of the mine, where 68 and 76 ppb Au are recorded along line 1. It appears that background values in the spruce twigs are about 2 ppb Au, 10 ppb Pt and 10 ppb Pd.

The biogeochemical results are encouraging since they indicate that in this heavily forested terrain it may be possible to use the vegetation to provide a 'window' through the glacial cover in order to assess the precious metal potential of the underlying bedrock.

Table 5 - Concentrations of Platinum, Palladium and Gold in Plants from a Test Site on Disturbed Ground Above the Worked-out Rottenstone Mine. All Samples from Within a 5 by 5 m Area.

	Pt (ppb)	Pd (ppb)	Au (ppb)
Black spruce twigs	80	120	9
Black spruce needles	10	10	<2
Black spruce trunk	70	62	460
Jack pine twigs	50	52	62
Jack pine needles	20	17	<2
Jack pine trunk	70	120	23
Labrador tea stems	80	170	60
Birch twigs	<10	7	18
Willow twigs	<10	3	<2

V. RARE-EARTH ELEMENTS (REE)

Near Hoidas (previously known as Lane Lake) and Nisikkatch Lakes in northernmost Saskatchewan (Fig. 1), high concentrations of REE (locally 12 percent) occur in several outcrops of radioactive allanite (Hogarth, 1957). The country rock is predominately pink granulite and felsic gneiss containing variable amounts of biotite and amphibole. The allanite occurrences are erratically distributed over a distance of 10 km, but are associated with zones of fracturing and shattering that conform to the regional strike of about 045°. Associated with the allanite are apatite, carbonate (calcite and barite), hyalophane (Ba-feldspar) and amphibole. The radioactivity of the allanite is due to thorium (up to 4000 ppm); uranium concentrations are generally about 50 to 100 ppm.

In trying to define the extent of the mineralization, the radioactive component of the rocks has been a useful guide to near-surface outcrop. Background scintillometer counts are 20 to 30 cps; over most outcrops counts are 60 to 120 cps, rising to 2000 cps in trenches above rich mineralization at the south end of Hoidas Lake. However, the radioactivity of the allanite is variable, making exploration difficult for possible mineralization beneath muskegs, soils and glacial cover. Cliff faces have been blasted in recent years in an attempt to uncover mineralization, but inspection of these fresh surfaces shows only small blebs of allanite with halos of radiation-damaged minerals.

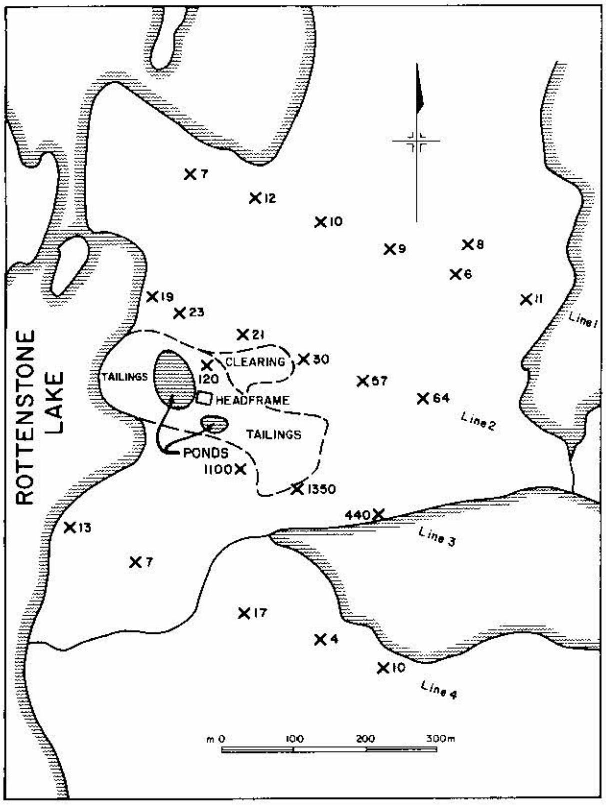

Figure 4 - Sketch map of palladium (ppb) in the ash of black spruce twigs, Rottenstone mine area.

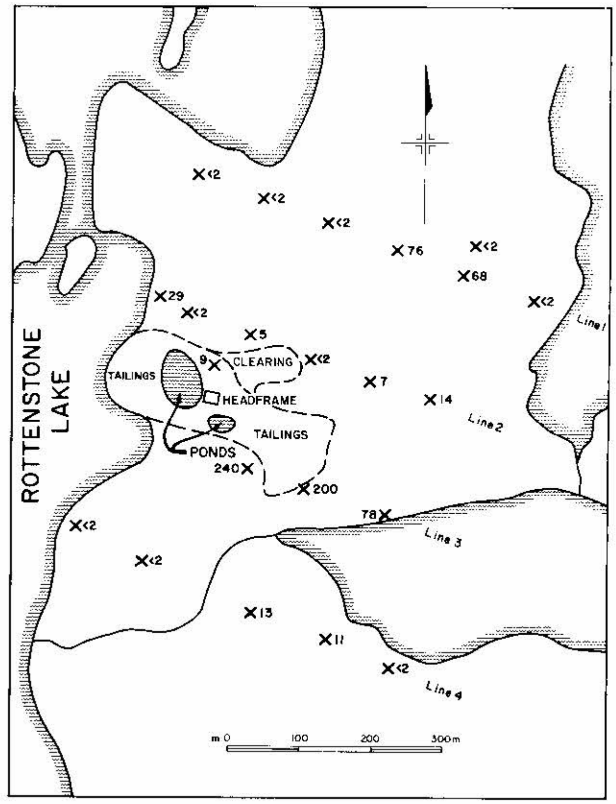

Figure 5 - Sketch map of gold (ppb) in the ash of black spruce twigs, Rottenstone mine area.

The vegetation is a possible medium that may aid in outlining mineralization in the area. It was shown long ago that some plants are capable of concentrating the rare-earths (Robinson et al., 1938). Studies of vegetation growing above REE-rich pegmatites in Finland have indicated that mosses and lichens can concentrate REE, but the uptake by trees is relatively low (Yliruokanen 1975). No studies have been made on the uptake by plants of metals from the Hoidas Lake type of mineralization, so during a five-day period in mid-June of 1983 a biogeochemical orientation survey was made of the Hoidas Lake zones of mineralization. The purpose was to determine which parts of the common species were most sensitive to this type of mineralization, and to ascertain if any biogeochemical sample medium might be used as an aid to exploration. An additional reason for choosing this area was that it provided a test site with a wide range of elements, hence was suitable for examining the relative uptake of many elements into a variety of plants.

Earlier studies (see Section II, this paper) indicated that the twigs of black spruce have a tendency to collect samarium. In light of this observation, and the chemical coherency of the REE, black spruce twigs (latest 10 years growth) were collected at all sites. At selected sites additional samples included spruce trunk and cones; birch trunk, bark, twigs and leaves; labrador tea twigs, leaves and roots; willow twigs and leaves; alder twigs and leaves; jack pine twigs, bark, trunk and cones; and moss.

Samples were collected at 60 sites, providing about 240 samples for analysis following the sample preparation procedure outlined in Section I (this paper). Most samples were from dry flat woodland in the vicinity of a series of allanite outcrops near the north end of Hoidas Lake (Fig. 6). Ten lines normal to the strike of the mineralization were sampled. Lines were 25 m apart and the sample interval along each line was 20 m.

The "Rare earth mineral exploration package" offered by Nuclear Activation Services Ltd. was chosen as the most suitable and cost-effective method of analysis for this study. This package offers neutron activation analysis for the rare-earth

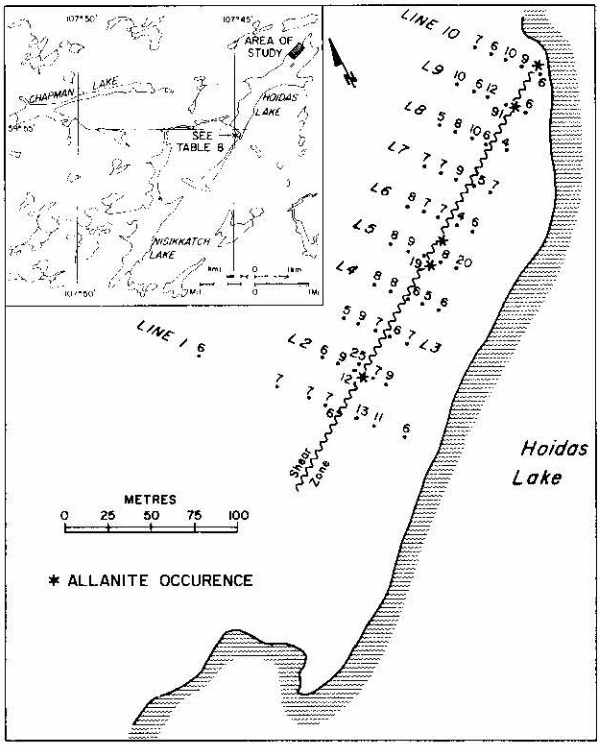

Figure 6 - Lanthanum (ppm) in the ash of black spruce twigs, allanite mineralization at north end of Hoidas Lake.

elements lanthanum (La), cerium (Ce), samarium (Sm) and lutetium (Lu). This suite of elements is sufficient to obtain a broad indication of the ability of the plants to accumulate the 15 elements which comprise the rare-earths. In addition scandium (Sc), thorium (Th) and uranium (U) analyses were obtained. At a later date analyses will be available for Eu, Yb, Br, Au, Rb, Ba, Cs, Sr, As, Sb, Mo, Zn, Ta, Na, K, Ca, Cr, Fe, Co, Ni, Hf and W. Some of these may be useful pathfinder elements for the type of mineralization under investigation.

Results

Analysis of the allanite shows that it contains up to 6 percent La, 5 percent Ce, 0.3 percent Sm, but only 6 ppm Lu. In addition to the Th and U mentioned above, there is up to 2 percent Ba, 0.7 percent Sr and 800 ppm Pb.

The sensitivity of the black spruce twigs to the presence of REE is low. Fig. 6 shows that La concentrations are 6 to 8 ppm, except within a few metres of allanite outcrop where concentrations are 2 to 3 times this value and in one case reach 91 ppm La (Ce and Sm concentrations of this sample were correspondingly high). Cerium concentrations are generally 50 percent higher than La, whereas Sm is commonly below 1 ppm. Thorium values are consistently low (less than 3 ppm) and show no tendency for enrichment. Similarly, U concentrations rarely exceed 1 ppm, indicating that no readily leachable U is accessible to the plants.

Table 6 shows the concentrations of some elements in the ash of black spruce twigs and needles collected along line 5 (Fig. 6). The scintillometer reading taken at the base of each tree trunk is given for comparison,

Table 6 - Concentrations of Elements in the Latest 10 Years Growth of Ashed Black Spruce (Picea mariana) Twigs and Needles, Profile (Line 5 on Fig. 6) across Zone of Massive Radioactive Allanite (Located at Sample Site No. 27), Northwest End of Hoidas Lake

Site No.	Scint. Reading (cps)	Element Concentration (ppm)													
		U		Th		Sc		La		Ce		Sm		Lu	
		T[1]	N[1]	T	N	T	N	T	N	T	N	T	N	T	N
25	26	1.2	.1	2.9	<.5	2.3	<.5	20	2.8	31	5	1.6	.2	.07	<.02
26	29	1.3	.1	1.8	<.5	2.0	<.5	8	0.5	14	<1	1.0	.1	.09	<.02
27	60	1.0	.1	2.1	<.5	1.2	<.5	19	3.3	28	5	1.1	.2	.05	<.02
28	120	2.3	.1	2.1	.8	1.8	<.5	9	1.0	16	3	1.5	.3	.06	.02
29	26	2.3	.1	1.9	<.5	2.4	<.5	9	0.9	15	3	1.0	.1	.05	<.02
R28[2]	55	1.2		6		ND		47		ND		ND		ND	

[1] T = twig; N = needle
[2] Felsic granulite collected 30 cm from tree site no. 28.
ND = not determined

along with the U, Th and La concentrations of a rock from the most radioactive site (no. 28). The table shows that the twigs contain consistently higher concentrations of each element than the corresponding needles. The U and Th show no clear response to increased radioactivity, although a trace more Th is present in the needles at site 28. It should be noted also that the surface rock from this site (R28) does not have anomalous concentrations of U and Th. The tree at site 27 was growing 2 m away from a trench containing massive allanite. Again Th and U values are not enhanced, but both La and Ce values are elevated (in twigs and needles). However, at site 25 similar concentrations are present in twigs from a malformed tree. It is not known if these values are due to the presence of allanite near the roots of that tree, or to some other factor. In view of the generally elevated REE values in spruce twigs near allanite occurrences (Fig. 6), it seems possible that allanite may be present at this site.

The above indicates that the spruce twigs do show a weak response to allanite mineralization. However, analysis of other vegetation shows that the spruce is not the most sensitive sample medium for this type of mineralization. At site 27 twelve additional "bio-objects" (to use the term of Kovalevskii, 1979) were analyzed, and the resulting data (Table 7) clearly show that birch and labrador tea accumulate much greater concentrations of REE than spruce. The same is true of the willow and moss, but their environment was different from the other species in that they were growing in an old trench into allanite; the willow was a young shrub (50 cm high), and the moss that encrusted the rocks was thoroughly washed but could have retained some small inorganic particles. Similarly, the high values obtained from the labrador tea roots may be in part due to adhering soil particles. An important aspect of the data in the table is that the trunks (stripped of bark) of both the spruce and birch gave relatively high REE values, indicating that the REE enter the trees via the roots and are not the result of airborne dust adhering to the plant surfaces.

To provide a comparison with site 27, data are given in Table 8 for plants collected above a rich occurrence of allanite on the top of a hill at the south end of Hoidas Lake. The plants were collected from a site about 10 m in diameter, within which radioactivity varied from 100 to 540 cps at the base of the plants. The data show that, unlike site 27, there is not much difference in the concentrations of REE in spruce and birch, but jack pine and especially alder have much greater concentrations. The trunks of the spruce, birch and jack pine have high concentrations of REE, thereby confirming the observation at site 27 that the elements are absorbed internally, not externally.

Table 7 - Concentrations of Elements in Plants Growing Within 5 m of a Trenched Occurrence of Massive Radioactive Allanite (Associated with Hyalophane and Apatite), Site No. 27, Northwest End of Hoidas Lake

Description	Element Concentration (ppm)						
	U	Th	Sc	La	Ce	Sm	Lu
Spruce twig	1.0	2.1	1.2	19	28	1.1	.05
Spruce twig (top of tree)	1.3	1.6	1.4	21	28	1.3	.03
Spruce needle	0.1	< 0.5	0.1	3	5	0.2	< .02
Spruce trunk	0.1	2.2	0.2	39	37	1.0	< .02
Spruce bark	0.2	0.9	0.2	24	30	1.1	.02
Birch twigs	0.4	< 0.5	0.3	182	117	5.5	.02
Birch leaf	0.1	3.5	0.3	37	39	2.4	.02
Birch bark (outer)	1.0	14	1.1	102	189	6.6	.08
Birch bark (inner)	0.1	2.5	0.1	27	23	0.9	< .01
Birch trunk	0.3	< 0.5	0.1	142	98	4.8	.02
Labrador Tea twig	2.8	2.3	0.7	194	227	8.3	.04
Labrador Tea root	3.9	4.7	0.7	139	170	7.3	.04
Willow twig	0.2	0.7	0.2	142	123	4.0	.04
Moss	19	14	1.1	820	1000	52	.11

Table 8 - Concentrations of Elements in Plants Growing Above an Outcrop of Massive Radioactive Allanite, South End of Hoidas Lake

Description	Scint. Reading (cps)	Element Concentration (ppm)						
		U	Th	Sc	La	Ce	Sm	Lu
Birch twig	400	0.1	2.0	0.1	56	40	2.0	<.02
Birch leaf	400	0.2	1.1	0.2	14	19	0.9	.03
Birch bark	400	0.3	2.4	0.1	33	39	2.0	<.01
Birch trunk	400	0.3	<0.5	<0.1	75	42	2.3	.02
Labrador tea root	540	0.8	4.4	0.9	67	97	6.2	<.04
Labrador tea stem	540	0.7	2.2	0.8	15	25	1.3	.05
Alder twig	540	0.3	<0.5	0.3	353	360	13	.03
Alder leaf	540	1.1	2.1	0.7	275	311	22	.06
Alder leaf (duplicate)	540	1.2	1.7	0.6	278	325	22	.06
Spruce twig	100	1.1	2.4	1.7	50	65	2.9	.06
Spruce twig (top of tree)	100	1.1	1.7	1.4	43	60	2.5	.06
Spruce Bark	100	0.2	0.9	0.2	24	30	1.1	.02
Spruce trunk	100	0.3	0.8	0.1	105	109	2.7	<.02
Spruce cones	100	0.9	2.6	0.8	10	18	0.9	.03
Spruce twig (young tree growing in trench)	400	1.1	2.9	1.3	84	118	4.7	.04
Jack-pine twig	200	0.8	0.8	0.9	138	142	3.7	.03
Jack pine needles	200	0.4	0.4	0.3	60	81	4.1	.02
Jack pine trunk	200	<0.1	<0.5	0.1	276	250	5.2	.03
Jack pine bark	200	0.2	1.0	0.1	178	165	4.4	<.02
Jack pine cone	200	1.1	2.5	1.0	17	26	1.4	.03

Conclusions

The thorium- and rare-earth-rich allanite mineralization in the vicinity of Hoidas Lake is reflected in the vegetation as follows:

1) Thorium concentrations up to 4000 ppm in bedrock show no enrichment in any biogeochemical sample medium. Uranium concentrations of 50 to 100 ppm that are typical for the allanite (with 2 ppm U in surrounding rocks) show no tendency to be absorbed by the plants. The uranium must be structurally bound into the crystal lattices and not readily leached, and is therefore not available for uptake by plant roots.

2) Lanthanum and cerium concentrations in ashed twigs of black spruce above felsic granulites are generally about 6 to 8 ppm and 10 to 12 ppm, respectively. Concentrations of 2 to 3 times these levels occur in the immediate vicinities of allanite mineralization near the north end of Hoidas Lake; however, above mineralization at the south end of Hoidas Lake concentrations are considerably higher.

3) Twigs concentrate rare-earths appreciably more than the needles in all species studied.

4) Tree trunks tend to concentrate the rare-earths, whereas cones tend to be depleted relative to the rest of the tree.

5) Highest rare-earth concentrations were found in a moss and labrador tea roots (both of which may have had adhering inorganic particles), and the leaves and twigs of alder.

6) Samarium enrichment generally follows that of La and Ce, but lutetium shows very little geochemical relief. This indicates that the plants perform a natural fractionation of the rare-earth elements.

7) It is considered that plants may provide useful information to aid in the exploration for rare-earth elements associated with the type of mineralization occurring in the Hoidas Lake area. Only one rare-earth (La or Ce) need be sought. It is unfortunate that alder is uncommon in this environment, since it appears to accumulate the rare-earths more than other species. The trunks of spruce, jack pine and birch contain relatively high concentrations, although twigs of spruce or birch are more practical to

collect. Enhanced values of rare-earths in the plants can only be expected within a few metres of mineralization. Investigation of associated elements may reveal pathfinder elements with much larger dispersion halos.

VI. URANIUM

Regional studies of the distribution of uranium in plants throughout northern Saskatchewan have revealed a large biogeochemical anomaly near Wollaston Lake, and anomalous concentrations in the Uranium City and Cluff Lake areas (Dunn, 1981, 1982a, b).

During late May these studies were extended to include the areas 1) around Uranium City in northern Saskatchewan, 2) from Buffalo Narrows to Cluff Lake in northwestern Saskatchewan and 3) from Pinehouse to Key Lake in north-central Saskatchewan. Results from these traverses are plotted on Fig. 7, and those from another traverse, from La Ronge to Southend, will be available at a later date.

The data represent U concentrations in the ash of the latest ten years growth of black spruce (Picea mariana) twigs. Northward from Buffalo Narrows rocks beneath the glacial till are Cretaceous sands and sandstones, which overlap sandstones of the Athabasca Group at about latitude 58°N. All samples contain background concentrations of 1 to 2 ppm U. Fifteen kilometres south of Cluff Lake the concentration increases to 5 ppm U. Samples of spruce growing in mineralized till, about 300 m south of the worked-out 'D' zone of U mineralization, contain from 73 to 187 ppm U (Fig. 8). Slightly lower values occur 1.5 km southeast of the 'D' zone in an area underlain by Athabasca Group sandstone. Immediately south of the 'D' zone concentrations increase to 946 ppm. One sample from this vicinity was divided into two portions, one of which was thoroughly washed prior to analysis. The unwashed portion had 469 ppm U, and two samples of the washed portion yielded 557 and 559 ppm U. The implication is that the dust on the unwashed portion diluted the U value obtained from the ashed twig, and that airborne dust in this uraniferous vicinity tends to reduce U concentrations in plant ash rather than increase them.

The rocks underlying the Pinehouse/Key Lake road are metasediments of the Mudjatik Domain. The U level of the ashed spruce twigs is higher than those along the Cluff Lake road, generally ranging from 3 to 5 ppm. Close to the uranium mineralization at Key Lake, values reach a maximum of 24 ppm (Fig. 9). Extensive preparation of the ground for mining the uranium has left no trees close to the orebodies. In 1976 samples of the most recent 20 cm of jack pine and black spruce twigs were collected above the Deilmann orebody (Walker, 1979), and yielded from 0.5 to 8.5 ppm U. Concentrations of up to 162 ppm U were encountered over a boulder train a few kilometres to the south.

The biogeochemical response to uranium mineralization is much more subdued in the Key Lake area than in either the Wollaston or Cluff Lake areas (cf. Dunn, 1982a). The reason for this difference is uncertain. It may be due to a lower degree of hydrologic dispersion of U near Key Lake than in the other areas, and the fact that the surface sediments at Key Lake are being constantly remobilized by the wind (i.e. sand dunes have developed since removal of the vegetation).

Around Uranium City samples were collected from easily accessible locations and from a few sites farther afield. Concentrations in excess of 10 ppm U occur in samples over a zone of approximately 8 by 20 km, with the eastern limit still undefined (Fig. 10).

VII. SUMMARY

Biogeochemical studies were conducted for a variety of elements over known mineralization and in areas with no known mineralization. New data are available for the distribution of elements in common plant species of the boreal forest, and the relative sensitivities of these plants and their organs to various types of mineralization. The main observations are summarized as follows:

1. Tungsten: The reported scheelite occurrence of the Radiore Cl zone near Uranium City could not be found visually or geochemically. Either the report was a misidentification of the mineral, or the occurrence has been removed during uranium mining operations. The study showed that conifer and labrador tea twigs tend to concentrate tungsten traces more than other plant parts.

2. Gold: Alder twigs show a tendency to concentrate gold. Enhanced gold values were found over auriferous soils at Cluff Lake, and in the Flin Flon area. The mineralized zone at Waddy Lake was not clearly defined, perhaps due to the extreme immaturity of the soil. Regional surveys defined the Glennie Lake Domain as biogeochemically more auriferous than the La Ronge Domain.

3. Platinum: Plants sampled in the vicinity of the worked-out platiniferous nickel deposit at Rottenstone Lake showed that the twigs of the conifers and labrador tea are more effective at concentrating platinum and palladium than the other plant parts. Slight enrichments of precious metals occur to the north of the old mine where contamination

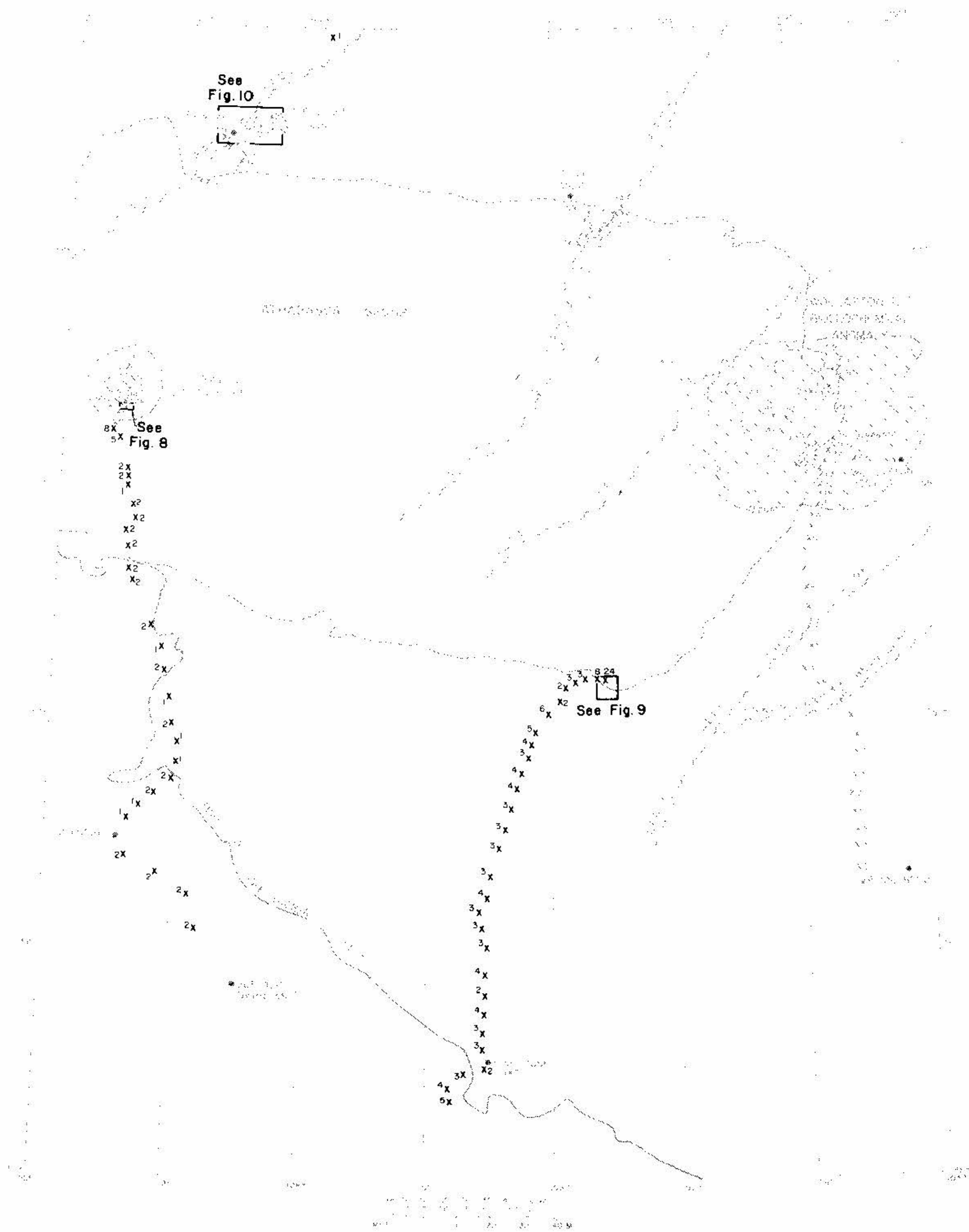

Figure 7 - Distribution of uranium in the ash of black spruce twigs. Grey numbers indicate values published previously; black numbers indicate new data (ppm).

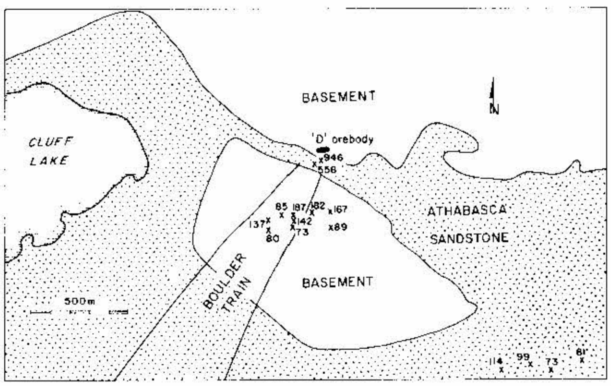

Figure 8 - Uranium in the ash of black spruce twigs, near Cluff Lake. Above the basement to the north of the 'D' zone, concentrations are generally 5 to 8 ppm U.

from mine-workings is unlikely. One spruce trunk yielded an unusually high gold concentration.

4. Rare-earths: The uptake of rare-earths in plants growing close to massive rare-earth rich radioactive allanite varies greatly from one species to the next. Twigs of black spruce contain approximately three times background levels of lanthanum and cerium above some mineralized zones, and higher contents above others. Relatively high concentrations of these elements occur in alder twigs, birch twigs, and trunks of jack pine, black spruce and birch. Samarium tends to follow lanthanum and cerium, but the low levels of lutetium show very little biogeochemical relief.

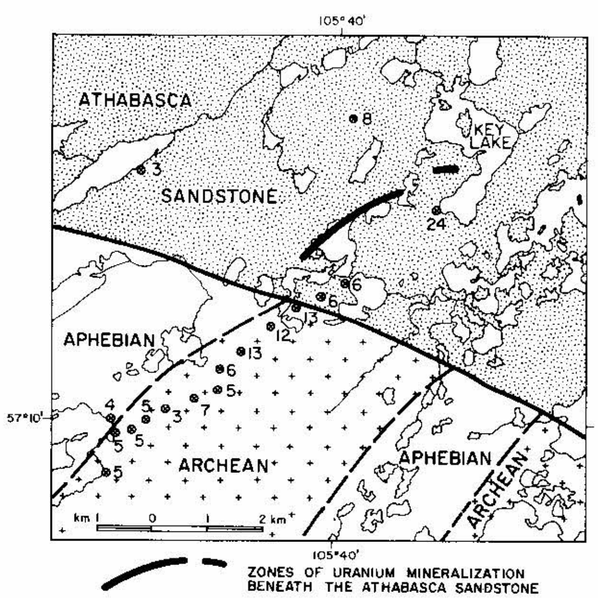

Figure 9 - Uranium in the ash of black spruce twigs, near Key Lake (ppm).

5. Uranium: A continuation of studies on the regional distribution of uranium in ashed black spruce twigs shows that levels are 1 to 2 ppm above Cretaceous sediments along the Cluff Lake road, whereas the levels are 3 to 5 ppm above metasediments of the Mudjatik Domain from Pinehouse to Key Lake. An elongate area around Uranium City, measuring 8 by 20 km and open to the east, contains over 10 ppm U (up to 290 ppm) in all samples analyzed. Studies conducted near zones of mineralization at Cluff Lake and Key Lake showed enhanced values of uranium in the plants, although values at Key Lake were an order of magnitude lower than those at Cluff Lake.

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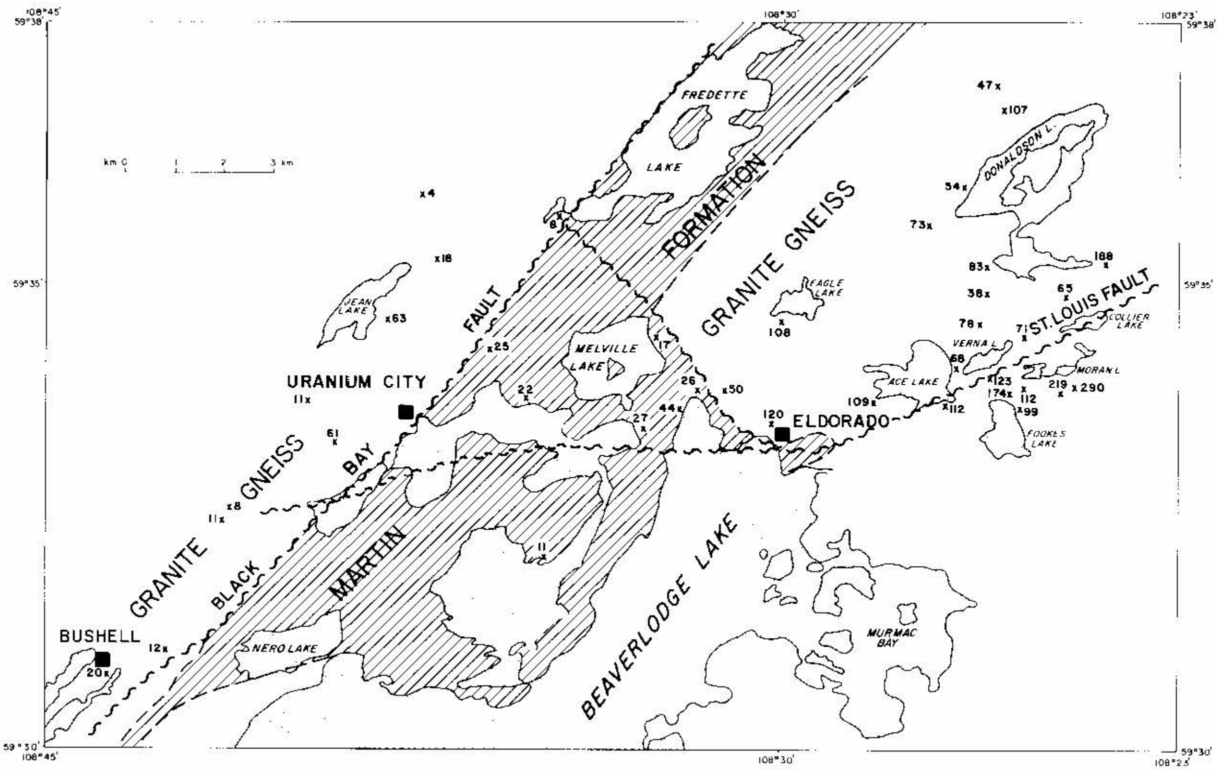

Figure 10 - Uranium in the ash of black spruce twigs, Uranium City.

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