



**GEOLOGICAL SURVEY OF CANADA**  
**OPEN FILE 3005**

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**Biogeochemical survey over kimberlites  
in the Kirkland Lake area,  
northeastern Ontario**

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**M.B. McClenaghan and C.E. Dunn**

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# Biogeochemical Survey Over Kimberlites in the Kirkland Lake Area, Northeastern Ontario

Geological Survey of Canada  
Open File 3005

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## INTRODUCTION

In 1992, the Geological Survey of Canada began a four year project in the Kirkland Lake area of northeastern Ontario designed to increase knowledge of the genesis of kimberlite, the principal host rock for diamonds, to improve techniques for kimberlite exploration and to evaluate the potential for the discovery of additional kimberlite occurrences in the region. Part of this project included the study of the geochemical and mineralogical character of known kimberlitic intrusions and determining associated geochemical signatures in various sample media that are routinely used in mineral exploration (e.g., till, humus, soil and vegetation).

Most bedrock in the Kirkland Lake area is covered by glacial sediments, from a few metres to 100 m thick. By applying a combination of geophysical and drift prospecting methods several kimberlite pipes and dikes have been discovered in the Kirkland Lake area within the last 10 years (Brummer et al., 1992a; McClenaghan, 1993).

This report describes the geochemical results for tree tissue samples that were collected over two kimberlite pipes and one kimberlite dike in the Kirkland Lake area: the Diamond Lake and C14 pipes and the Buffonta dike. Pin cherry twigs, balsam fir twigs, black spruce twigs and black spruce bark samples were collected in order to evaluate their effectiveness in detecting the presence of kimberlite beneath the glacial sediments and to evaluate their potential use in diamond exploration. A series of overburden holes were subsequently drilled by the GSC on the two kimberlite pipes to determine the glacial stratigraphy of each site and to examine dispersal patterns in till down-ice. These results will be published at a later date. Biogeochemical data will be compared to geochemical results from till and soil on which the plants were living.

## Location and Access

The Kirkland Lake kimberlite field is in northeastern Ontario, approximately 10 km to the north and east of Kirkland Lake and 100 km southeast of Timmins (Figure 1). The Diamond Lake pipe is the most easterly in the cluster, located at 48°06'20"N and 79°45'30" W, in the southwest corner of McVittie Township. It underlies the east bank of the Misema River and is accessed via the Fork Lake Road, running north from Highway 66. The Buffonta kimberlite dike is located in central Garrison Township at 48°28'02"N and 79°56'52" W on the old Buffonta Mines property, just west of the old Buffonta pit. The property is accessed via a gravel road, extending southeast from Highway 101. The C14 kimberlite pipe is located in south central Clifford Township, at 48°16'30"N and 79°48'W. The property is accessed via an old logging road running east from Highway 564, towards Kennedy Lake.

## Geology

The Kirkland Lake kimberlite field is in the western part of the Archean Abitibi Greenstone Belt and is underlain by a typical assemblage of greenstone rocks dominated by mafic and felsic metavolcanics. Kimberlitic intrusions were emplaced in the area during the Late Jurassic, approximately 155 to 160 Ma (Brummer et al., 1992b) and consist of tuffisitic kimberlite breccia.

The Diamond Lake area is underlain by two kimberlite pipes, the north pipe is approximately 150 m in diameter and the south pipe is approximately 50 m diameter (Figure 2). The pipes intrude metasedimentary rocks, mainly greywacke and conglomerate. The bedrock surface is covered by a thick sequence of glaciofluvial sand and gravel of the Misema River Esker, on average 40 m thick (Averill and McClenaghan, 1994).

The Buffonta area (Figure 3) is underlain by mafic volcanic rocks and the Garrison monzonite stock (Jensen, 1982). Gold mineralization, with minor galena, molybdenite,

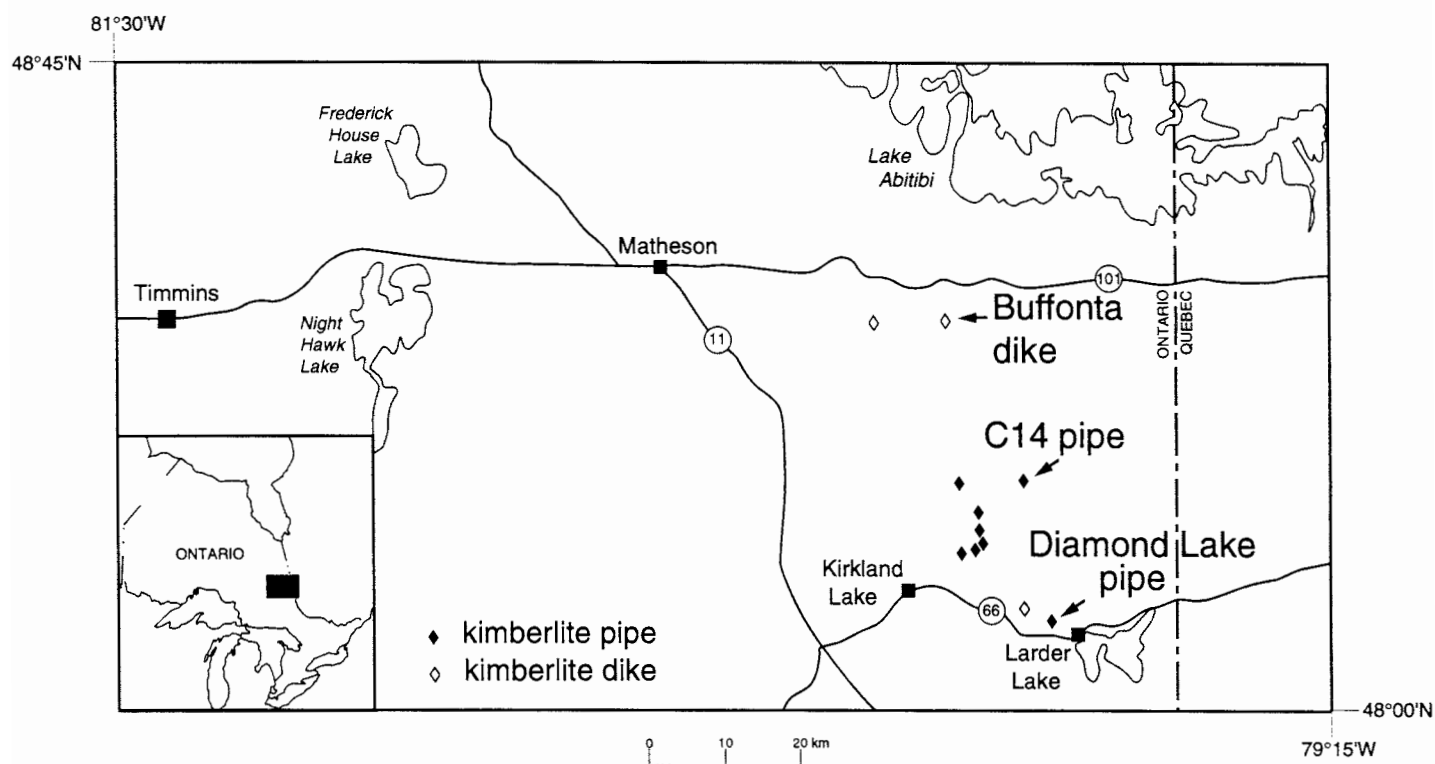


Figure 1. Location of the C14, Diamond Lake and Buffonta kimberlite intrusions in the Kirkland Lake kimberlite field, northeastern Ontario.

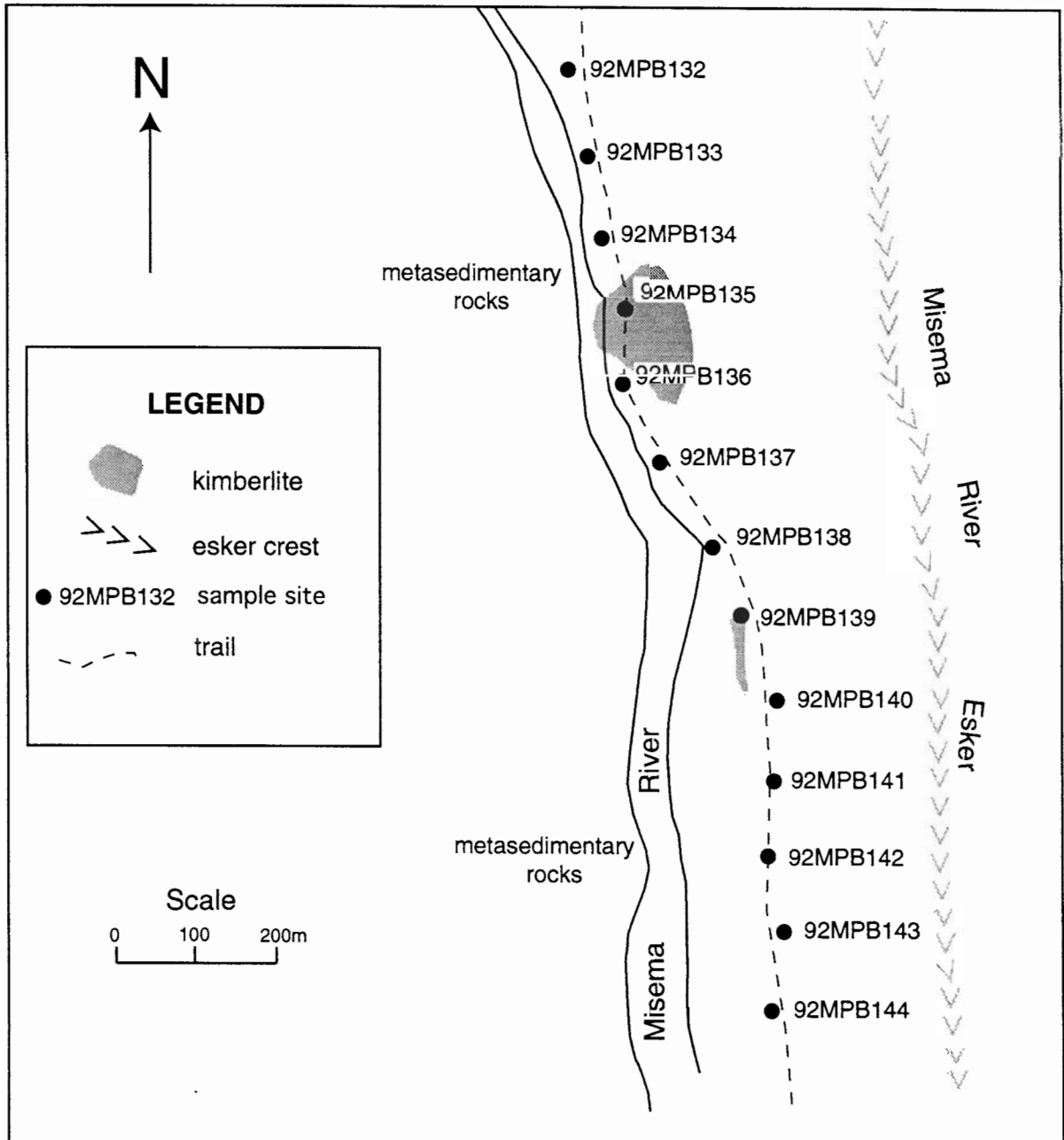


Figure 2. Diamond Lake bedrock geology and location of balsam fir sample sites.



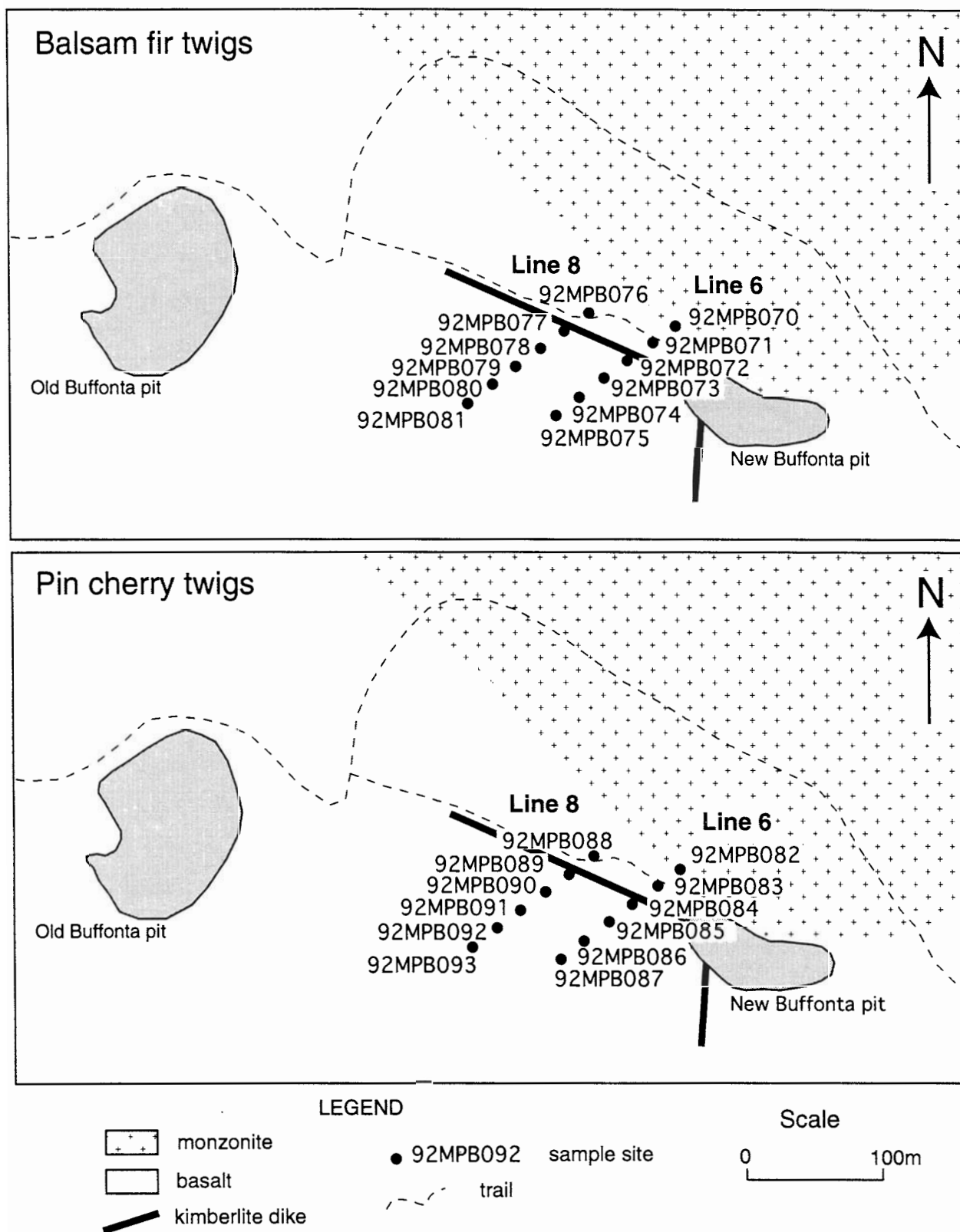


Figure 3. Buffonta bedrock geology and location of pin cherry and balsam fir sample sites.

argentite and chalcopyrite, occurs in quartz veins hosted by foliated volcanic rocks within the 1 km wide contact metamorphic aureole of the stock (Bath, 1990). The Buffonta kimberlite dike has intruded one of several northwestward shear zones related to the earlier intrusion of the Garrison stock. The dike is approximately 1 m wide where it subcrops and consists of kimberlitic breccia with angular quartz vein and pyritized felsic intrusive fragments within a kimberlite matrix (Barron and Barnett, 1993). On the west side of the new Buffonta pit, the dike has intruded along the margin of a 0.4 m wide quartz vein. Bedrock is covered by a thin blanket (up to 3 m) of Matheson Till.

The C14 pipe is approximately 200 m in diameter and intrudes felsic metavolcanic rocks (Figure 4). Mafic intrusive rocks lie 50 m to the south (Jensen, 1975). Several mineralized occurrences of pyrite, chalcopyrite, gold, sphalerite, molybdenite and galena which occur in felsic intrusive and felsic volcanic rocks northeast of the pipe may explain some of the biogeochemical metal enrichment in this area (Jensen, 1975). The C14 pipe is covered by approximately 20 m of glaciolacustrine clay and silt overlying 5 m of Matheson Till. Mafic intrusive rocks south of the pipe are covered by a thin, discontinuous veneer of Matheson Till (Figure 4).

## METHODS

### Sample Collection

Tree tissues were collected along transects over the kimberlite bodies during a two day period in August, 1992. The composition of forest cover was different over each kimberlite. At each location tissues of the dominant species were collected: twigs of balsam fir (*Abies balsamea*) at Diamond Lake; twigs and outer bark of black spruce (*Picea mariana*) at the C14 pipe; and twigs of both balsam fir and pin cherry (*Prunus pennsylvanica*) at Buffonta.

Samples of twig and foliage were snipped using standard anvil-type, teflon-coated, garden pruning snips, and placed in heavy duty brown paper hardware bags

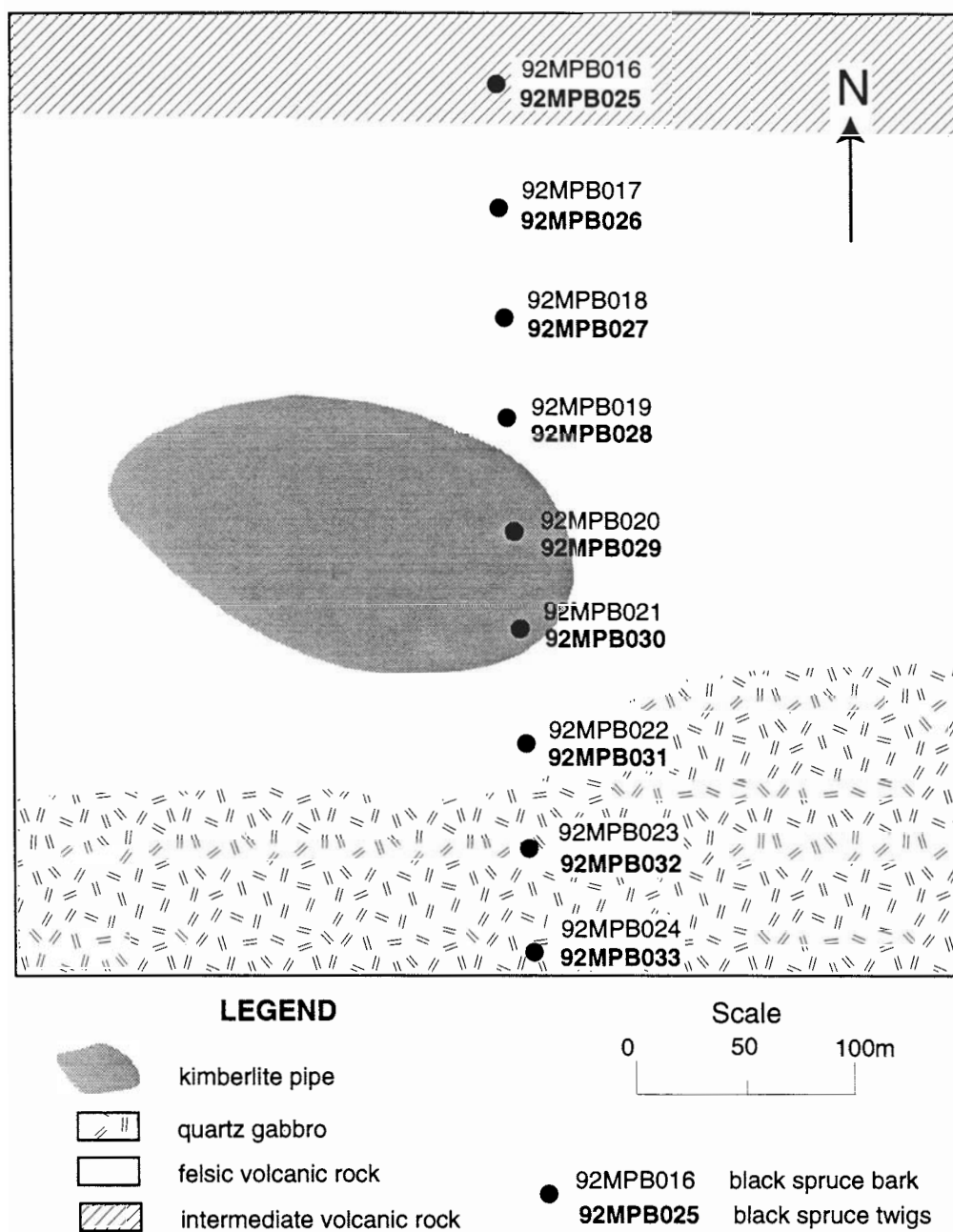


Figure 4. C14 bedrock geology and location of black spruce sample sites.

(approximately 25 x 35 cm) and secured with masking tape. Usually 5 to 7 twigs, each comprising 5 to 7 years of growth, provided the required amount of material (approximately 200 g fresh weight). Within the survey area this amount of growth was commonly 35 to 40 cm of twig. Where growth was more spindly 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 program 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 of the twig rather than its woody tissue. If this ratio changes substantially, then variations in element content may be attributable to mixing thick with thin twigs, providing false anomalies. For the Kirkland Lake surveys the twig diameter at most locations was approximately 5 mm where twigs were 5 to 7 years old.

There are fewer variables that need to be considered during collection of black spruce bark. The only factor of importance is that only the loose, dead tissue comprising the scaly outer bark should be collected because its composition is substantially different from that of the inner bark. Most heavy metals accumulate in tree extremities (outer bark, twig ends and tree tops). Approximately 50 g of bark scales was scraped from each spruce tree using a hardened steel paint scraper and either a large hardware bag or a dust-pan to collect the scrapings. The bark scales were then placed into standard 'kraft' paper soil bags. More details of sampling procedures and precautions are given in Dunn *et al.* (1993), and Brooks *et al.* (1995).

At Diamond Lake, balsam fir twigs were collected from 13 sample sites spaced 100 m apart along a 1200 m north to south transect (Figure 2). At the Buffonta property, pin cherry and balsam fir twigs were collected from 12 sites at 30 m intervals along two transects (Lines 6 and 8, Figure 3). At the C14 pipe, black spruce bark and twig samples

were collected along a 400 m transect over the kimberlite from nine sites spaced at 50 m intervals (Figure 4). Sample locations are listed in Appendix A.

### **Sample Preparation and Analysis**

Samples were left to dry for several weeks in a greenhouse, after which foliage was separated from the twigs because there are differences in the composition of the two tissue types (lower levels of most heavy and base metals in the foliage). The ratio of foliage to twig may vary substantially among sample locations, therefore if twigs are not separated from foliage some false anomalies may be generated which are simply a function of different ratios of twig to foliage.

Approximately 50 g of dry twig or bark was weighed into aluminum trays. The trays were placed in a pottery kiln, and the temperature slowly raised (over 2 - 3 hours) to 470 C. After a further 12 hours no charcoal remained, and the tissues were reduced to approximately 1 g of ash. Ash yields for individual samples are listed in Appendix A. Half was weighed accurately and compacted into small polyethylene vials for INAA (instrumental neutron activation analysis) of 35 elements at Activation Laboratories Ltd., Ancaster, Ontario. Lower detection limits for elements relevant to this study are listed in Table 1 and the analytical results are listed in Appendix B.

The remaining half of the ash sample was submitted for multi-element analysis by ICP-ES (inductively-coupled plasma emission spectrometry), following an aqua regia digestion, at Acme Analytical Laboratories Ltd., Vancouver, B.C.. Relevant elements are listed in Table 1 and the results are listed in Appendix C. For most elements in plant ash this extraction is near 'total', although for some (e.g. Al, B, Na, K) it is only partial. Analytical precision was good for most elements, such that the relative element distribution patterns are meaningful even if the absolute concentrations are only partial.

Table 1. Analytical methods and lower detection limits

Element	Method	Method	Lower Detection Limit
Ag ppm	ICP-ES		0.2 ppm
Al%	ICP-ES		0.02%
As ppm		INAA	0.5 ppm
Au ppb		INAA	5 ppb
B ppm	ICP-ES		1 ppm
Ba ppm		INAA	100 ppm
Be ppm	ICP-ES		0.3 ppm
Br ppm		INAA	1 ppm
Ca %		INAA	0.10%
Ce ppm		INAA	1 ppm
Cd ppm	ICP-ES		0.2 ppm
Co ppm		INAA	1 ppm
Cr ppm		INAA	1 ppm
Cs ppm		INAA	0.5 ppm
Cu ppm	ICP-ES		1 ppm
Fe %		INAA	0.05%
K %		INAA	0.01%
La ppm		INAA	0.1 ppm
Li ppm	ICP-ES		2 ppm
Mg %	ICP-ES		10%
Mn ppm	ICP-ES		1 ppm
Mo ppm	ICP-ES		2 ppm
Na ppm		INAA	100 ppm
Ni ppm	ICP-ES		1 ppm
P %	ICP-ES		10%
Pb ppm	ICP-ES		1 ppm
Rb ppm		INAA	20 ppm
Sb ppm		INAA	0.1 ppm
Sc ppm		INAA	0.1 ppm
Sr ppm		INAA	300 ppm
Th ppm		INAA	0.1 ppm
Ti %	ICP-ES		0.01%
V ppm	ICP-ES		2 ppm
Zn ppm		INAA	20 ppm

Ash standard samples and duplicate splits of field samples were inserted at random intervals to monitor analytical quality control. Results for standards and duplicates are listed in Appendix D.

## RESULTS

For each element, profile plots for the Diamond Lake, Buffonta and C14 areas were combined in one diagram to compare concentrations between areas and between tree species. Data for Diamond Lake are plotted from north to south starting with sample 92MPB132 (Figure 2). Data for Buffonta are plotted from northeast to southwest along lines 6 and 8, beginning with samples 92MPB070/082 (Figure 3) and 92MPB076/088 (Figure 3), respectively. C14 data are plotted from north to south, starting with samples 92MPB016/025 (Figure 4). Seven samples, not analyzed by ICP-ES because of insufficient volume, are represented on the plots by small black dots. Values reported as less than detection limit were assigned values of half the detection limit for constructing the profile plots. Plots are presented in Appendices E (INAA) and F (ICP-ES).

### Differences among species and tissue types

Every species of plant and tissue type has a different requirement for, and tolerance to metals: for example, the composition of balsam fir is different from that of black spruce, and the composition of black spruce twigs differs from that of its bark. Some are able to concentrate high levels of certain metals, whereas others create barriers to metal uptake at low concentrations. The profile plot of As concentration (Appendix E) shows that at the C14 pipe black spruce concentrates more As in bark than in twigs; conversely there are higher concentrations of Au in the twigs than the bark.

Of the species and tissues discussed in this report, the relative sensitivity and ability of each to accumulate base and heavy metals is: black spruce twigs > black spruce bark > balsam fir twigs > pin cherry twigs. There are exceptions to this pattern (e.g. As and Sb

are higher in the spruce bark than the twigs; Ba and Sr are higher in the pin cherry twigs than in the balsam fir twigs, etc.). Some metals (e.g. Au) may have volatilized from the pin cherry during the ashing process: this species contains cyanogenic glycosides with which Au may combine to volatilize as a Au cyanide below the ashing temperature of 470°C. Except for Br which is partially lost during ashing, other element losses due to volatilization are insignificant.

These differences in element accumulation show the importance of being consistent in the collection of a single species, tissue type, and amount of growth (as discussed earlier) within a survey area unless it can be established that a normalization factor among species/tissues can be applied. For the present study the element distribution patterns over each kimberlite body should be considered separately, because it is the element distribution *patterns* which are of more significance than the absolute values. The exception is balsam fir twigs which were collected at two locations (Diamond Lake and Buffonta), and therefore their absolute values can be compared.

### **Element Variations Over Kimberlite**

Brief notes are provided on each element in the order of maps in Appendix E (INAA), followed by those in Appendix F (ICP-ES). The data are compared to normal or background values for balsam fir twigs and black spruce bark defined by Dunn et al. (1989) and Dunn et al. (1992).

### ***Elements Determined by INAA***

#### **Arsenic (As)**

Weak response except for spruce bark over the intermediate volcanic rocks at C14 and very subtle enrichment over the kimberlite.



**Gold (Au)**

Unusually high concentrations in most balsam fir samples from Buffonta, and also in the spruce from C14. Background levels in these species are usually <10 ppb Au in ash.

**Barium (Ba)**

Balsam fir is enriched in Ba relative to its usual concentrations of 1000 - 1500 ppm Ba in twigs. The high concentrations in samples from Buffonta suggest local enrichment of Ba in the substrate.

**Bromine (Br)**

Some Br always volatilizes during ashing, but there is commonly residual Br enrichment in vegetation from zones of Au enrichment. At C14, relatively high concentrations occur in spruce twigs also enriched in Au.

**Calcium (Ca)**

Calcium is a basic 'building block' element in plants (much as silica is in most rocks). Variations in the study areas are of no exploration significance. Calcium levels in spruce bark suggest enrichment of carbonates in the substrate in the area of the C14 pipe.

**Cerium (Ce)**

Normal background concentrations.

**Cobalt (Co)**

Normal background concentrations, except weak enrichment in association with Au over the C14 kimberlite, and increasing Co concentrations southward along the Diamond Lake profile, perhaps reflecting progressive enrichment in base metals.

**Chromium (Cr)**

Usual background levels. Weak enrichment in spruce twigs over the C14 kimberlite.

**Cesium (Cs)**

1 - 3 ppm Cs is common in twigs and bark of conifers. Weak enrichment associated with Au enrichment in vegetation is common (cf. C14).

**Iron (Fe)**

Normal range of concentrations.

**Potassium (K)**

Normal range of concentrations. Potassium is a 'building block' element essential to plants.

**Lanthanum (La)**

Normal range of concentrations

**Sodium (Na)**

Normal range in concentrations.

**Rubidium (Rb)**

Background concentrations are commonly in the range of 200 - 300 ppm Rb in conifer twigs, therefore there is enrichment at Diamond Lake and C14. A biogeochemical study of the Sturgeon Lake kimberlite in Saskatchewan noted enrichment of Rb in aspen twigs near the kimberlite (Dunn, 1993).

**Antimony (Sb)**

Normal background concentrations except for elevated levels at C14.

**Scandium (Sc)**

Commonly, scandium closely follows Fe in plants. The distribution patterns of the two elements are very similar for Diamond Lake, Buffonta and C14.

**Samarium (Sm)**

Concentrations are close to those typical of these species, and distribution patterns closely follow those of the other rare earth elements (cf. La, Ce).

**Strontium (Sr)**

High concentrations of Sr occur in the pin cherry, whereas in the fir and spruce the levels are typical for these species. Note the Sr enrichment over the Diamond Lake, Buffonta and C14 kimberlites. Studies in Saskatchewan (Dunn, 1993) recorded relatively high Sr concentrations in several plant species growing adjacent to kimberlite.

**Thorium (Th)**

Normal background concentrations.

**Zinc (Zn)**

Concentrations are usually about 2000 ppm Zn in balsam fir twigs (Dunn et al., 1989) and 1500 ppm Zn in black spruce bark (Dunn et al., 1992). There is, therefore, some enrichment in the areas surveyed, notably at Buffonta. Above the C14 pipe the black spruce twigs are enriched in Zn. There is progressive enrichment of Zn southward along the Diamond Lake transect.

***Elements Determined by ICP-ES*****Silver (Ag)**

Typical background levels of silver in conifer twigs and bark are <1 ppm Ag. Consequently, the Ag content of spruce twigs at the C14 pipe is strongly anomalous, and indicates enrichment of Ag in the substrate.

**Aluminum (Al)**

Normal range of concentrations.

**Boron (B)**

Normal range of concentrations. Boron is an essential element for plant metabolism.

**Beryllium (Be)**

Plants usually contain <0.2 ppm Be, and 1 ppm Be is uncommon. Several sites over and adjacent to kimberlite at Diamond Lake and Buffonta are enriched in Be. Two samples of the kimberlite dike at Buffonta yielded 2 ppm Be.

**Cadmium (Cd)**

Background concentrations in conifer twigs and bark are typically <3 ppm Cd in ash. Cadmium is highly mobile in the surficial environment and high concentrations in plant ash commonly occur over base metal (especially Zn) enrichment in the substrate. The profile of Cd in balsam fir twigs at Diamond Lake suggests progressive base metal enrichment toward the south. At Buffonta the balsam fir data indicate similar base metal enrichment, especially over the kimberlite.

**Copper (Cu)**

Normal range of concentrations, except at C14 where the spruce twigs indicate Cu enrichment over and around the pipe.

**Lithium (Li)**

Normal range of concentrations

**Magnesium (Mg)**

Normal range of concentrations except unusually low levels in spruce bark at C14.

**Manganese (Mn)**

Normal range in concentrations, except for unusually low levels in spruce bark at C14. Several of the kimberlite sites have relatively low concentrations of Mn, which is in accord with biogeochemical data obtained from the Sturgeon Lake kimberlite in Saskatchewan (Dunn, 1993).

**Molybdenum (Mo)**

None of the species collected are particularly sensitive to the presence of Mo. Levels of a few ppm Mo are common. Weak enrichment over the kimberlite at Buffonta may indicate traces of molybdenite in the substrate.

**Nickel (Ni)**

Background levels of Ni in conifer twigs and bark are typically <50 ppm in ash, except over mafic and ultramafic rocks where concentrations may be substantially higher. Over the Sturgeon Lake kimberlite, Ni concentrations in dogwood twigs were substantially higher than in the surrounding area (Dunn, 1993), although other species did not show this trend. Weak enrichment occurs in balsam fir at Buffonta.

### **Phosphorus (P)**

Normal concentrations of this essential element in conifer twigs are <2% P. There is notable enrichment at Buffonta which may reflect the typically enhanced concentrations of P associated with kimberlites.

### **Lead (Pb)**

Lead concentrations in conifer twigs are mostly <200 ppm. Concentrations in spruce from the vicinity of the C14 pipe suggest Pb enrichment in the substrate.

### **Titanium (Ti)**

Normal range of concentrations.

### **Vanadium (V)**

Normal range of concentrations.

## **SUMMARY**

1. Biogeochemical transects across the three kimberlite bodies show that of the species and tissues collected, their relative sensitivity and ability to accumulate base and heavy metals is: black spruce twigs > black spruce bark > balsam fir twigs > pin cherry twigs. There are, however, some exceptions to this pattern.

2. Strontium and rubidium are enriched in most tissues from sites over and adjacent to the kimberlites. This observation is in accord with results obtained from a biogeochemical study of the Sturgeon Lake kimberlite in Saskatchewan. Most other elements in the plant tissues did not show sufficient geochemical contrast to provide consistent help in locating the kimberlite bodies. The element enrichments/depletions over each kimberlites were:

a) **Diamond Lake:** *Balsam fir twigs*- Sr, Rb, Be, Mo, (Mn depletion);

b) **Buffonta:** *Balsam fir twigs* - Sr, Rb, Be, Mo, (Mn depletion), Au, Cr,

Na, Cd, Ni, Al;

*Pin Cherry twigs* - Sr, Rb, Au;

c) **C14:** *Black spruce twigs* - Sr, Rb, (Mn depletion), Au, Cr, Na, Cd, Co,

Cu, Ba, Cs, REE, Zn;

*Black spruce bark* - Sr, Ba, Zn.

3. Gold is enriched in balsam fir twigs from Buffonta and in spruce twigs and bark from C14. At the C14 pipe there is coincident enrichment of Ag, As, Sb and, to a lesser degree, Cu and Br.

4. At Diamond Lake there is a progressive southward increase in Cd, Zn, and Co, and to a lesser degree Pb, Ni, Cr, V, Fe, Sc, Mn and REE.

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## REFERENCES

- Averill, S.A. and McClenaghan, M.B.  
1994: Distribution and character of kimberlite indicator minerals in glacial sediments, C14 and Diamond Lake kimberlite pipes, Kirkland Lake, Ontario; Geological Survey of Canada, Open File 2819, 46p.
- Bath, A.C.  
1990: Mineral occurrences, deposits and mines in the Black River-Matheson area; Ontario Geological Survey, Open File Report 5735, 1883p.
- Barron, K.M. and Barnett, R.L.  
1993: A kimberlite-kamafugite transition? Kalsilite-bearing kimberlite from the New Buffonta Gold Mine, Kirkland Lake area, northeastern Ontario; in Mid-Continent Diamonds, ed. K.P.E. Dunne, GAC-MAC Symposium Volume, Edmonton, Alberta, May 17-18, 1993, p. 37-45.
- Brooks, R.R., Dunn, C.E., and Hall, G.E.M.  
1995: *Biological Systems in Mineral Exploration and Processing*. Ellis-Horwood Ltd., Hemel Hempstead, U.K., 538 p.
- Brummer, J.J., MacFadyen, D.A. and Pegg, C.C.  
1992a: Discovery of kimberlites in the Kirkland Lake area, Northeastern Ontario, Part I: Early surveys and surficial geology; *Exploration and Mining Geology*, v.1, p. 339-350.
- Brummer, J.J., MacFadyen, D.A. and Pegg, C.C.  
1992b: Discovery of kimberlites in the Kirkland Lake area, Northeastern Ontario, Part II: Kimberlite discoveries, sampling, diamond content, ages and emplacement, v.1, p. 351-370.
- Dunn, C.E.  
1993: Diamondiferous kimberlite in Saskatchewan, Canada - a biogeochemical study. *Journal Geochemical Exploration*. v. 47, p. 131-141.
- Dunn, C.E., Adcock, S.W., and Spirito, W.A.  
1992: Reconnaissance biogeochemical survey, southeastern Cape Breton Island, Nova Scotia: Part 1 - Black spruce bark. Geological Survey of Canada, Open File 2558, approx. 200 p.
- Dunn, C.E., Banville, R.M.P., and Adcock, S.W.  
1989: Reconnaissance biogeochemical survey, eastern Nova Scotia. Geological Survey of Canada, Open File 2002, approx. 200 p.
- Dunn, C.E., Hall, G.E.M., and Scagel, R.  
1993: Applied biogeochemical prospecting in forested terrain. (Short Course Notes) Association of Exploration Geochemists, Ottawa, 192 p.
- Jensen, L.S.  
1975: Geology of Clifford and Ben Nevis Townships; Ontario Geological Survey, Geoscience Report 132, 55p.



Jensen, L.S

1982: Precambrian geology of the Magusi River area, NTS 32D/5, Cochrane and Timiskaming Districts, Ontario; Ontario Geological Survey, Map P.2434, scale 1:63 360

McClenaghan, M.B.

1993: Location of known kimberlite bedrock, float and indicator minerals in drift in the Kirkland Lake area; Geological Survey of Canada, Open File Map 2626.

Thomson, J.E.

1941: Township of McVittie, Timiskaming District, Ontario; Ontario Department of Mines, Map 50b.