



## GEOLOGICAL SURVEY OF CANADA

### OPEN FILE 3768

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# Regional distribution and chemistry of kimberlite indicator minerals, northern Contwoyto Lake map area, Nunavut (NTS 76E, north half)

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Contribution to the Slave NATMAP Project/  
Contribution au Projet de la Province des Esclaves du CARTNAT

**1999**

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**Regional distribution and chemistry of kimberlite indicator minerals,  
northern Contwoyto Lake map area (NTS 76E, N/2),  
Northwest Territories, Nunavut**

## **INTRODUCTION**

### **Purpose**

The Quaternary geology component of the Slave Province National Mapping Program was designed to provide a regional framework for geologic interpretation, environmental management, and drift prospecting. In 1996, Terrain Sciences Division of the Geological Survey of Canada mapped the surficial geology of the north half of the Contwoyto Lake map area (Kerr et al. 1997a, b). The project involved helicopter-assisted ground work including surficial geology mapping using air photos at a scale of 1:60 000, till sampling, and measuring of ice flow indicators. Twenty five ~10-kg samples were collected from the Contwoyto Lake area for kimberlite indicator mineral and gold grain analyses. An additional 112 1-kg samples were collected for geochemical analysis. This report documents the results from the electron microprobe analysis of potential kimberlite indicator minerals from the heavy mineral concentrates from the 25 samples, and shows distributions and concentrations of kimberlite indicator minerals in the area. Till geochemistry results and gold grain data are published as GSC Open File 3654 (Kerr and Knight, 1998). Distribution and chemical characteristics of kimberlite indicator minerals from the extreme southwest part of northern Contwoyto Lake (4 samples) and south half of the Contwoyto Lake map area (23 samples) can be found in Ward et al. (1996a). The text of this document in Word 6.0/95 format and the tabular data in Excel 3.0 format are available on diskette from the GSC bookstore. Digital files of figures are not included on the diskette.

### **Location and physiography**

The Contwoyto Lake map area, NTS 76E, (Figure 1) lies in the north-central District of Mackenzie. Elevations range from 445 m (Contwoyto Lake) to 580-640 m in the Peacock and Willingham Hills in the northernmost region of the area. The terrain northwest and east of Contwoyto Lake is generally between 480 and 520 m, whereas much of the area south of the lake is < 500 m. Local relief is variable, commonly between < 10 m and 20 m in areas of outcrop and till cover, although relief > 100 m may occur in rocky areas of the Peacock and Willingham Hills. Contwoyto Lake is on the divide between two drainage systems; its southern outlet is the Contwoyto River which flows into the Back River. The northern outlet drains into Kathawachaga Lake and the Burnside River. Numerous small lakes occupy glacially scoured bedrock basins, as well as isolated depressions in till plains. Most drainage ways are shallow; few streams and rivers have cut into bedrock or surficial sediments, with the exception of a few unnamed streams which have incised glaciofluvial sediments. The map area lies north of treeline in the zone of continuous permafrost, and contains sparse clumps of low birch, alder, and tundra heath vegetation.

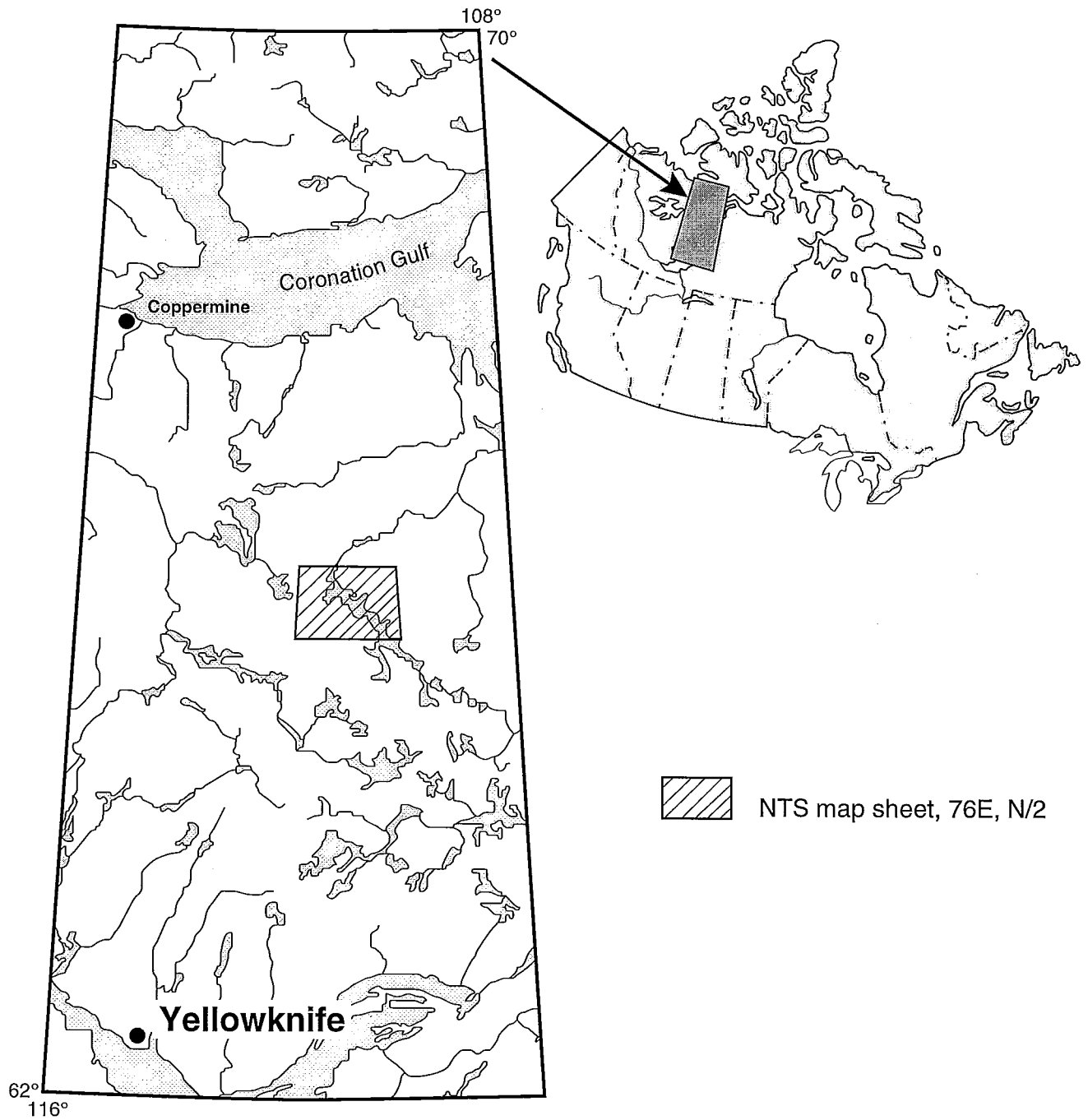


Figure 1. Location map of the Contwoyto Lake map area.

## REGIONAL GEOLOGY

### Bedrock geology

Archean rocks outcrop throughout much of the map area (King et al. 1992) and are part of the Slave Geological Province. They consist of supracrustal rocks of the Yellowknife Supergroup and younger granitoid rocks (Figure 2). The Yellowknife Supergroup contains metaturbidites (some with iron formation), and intermediate to felsic metavolcanic rocks, including rocks of the Central Volcanic Belt (Gebert and Jackson, 1994). These are intruded by widespread granitoid rocks consisting of granite, gabbro, diorite, tonalite, and gneissic rocks. Proterozoic sedimentary rocks occur only in the north-central map area (Peacock Hills) and include argillite, siltstone, greywacke, quartzite and minor dolomite. Gabbro sills are also restricted to the north-central map area. The region is cross-cut by a variety of diabase dykes of which the northwest-trending Proterozoic Mackenzie swarm is most prominent.

A number of important mineral deposits occur in the northern Contwoyto Lake area, notably the iron formation hosted Lupin gold deposit, and the smaller Butterfly gold occurrence, both associated with Yellowknife Supergroup metaturbidites. These rocks also host many gold showings southwest of Contwoyto Lake. The Gondor volcanogenic Cu-Zn  $\pm$  Pb deposit is associated with Yellowknife Supergroup metavolcanics, as are some Cu-Mo gossans.

The central part of the Slave Province is currently the focus of diamond exploration. Numerous diamondiferous kimberlites, dating approximately 97 Ma to 52 Ma (Pell, 1995a, 1996), occur in the Winter Lake-Lac de Gras-Aylmer lake area to the south. Those occurring in the Contwoyto Lake map area include Ranch Lake, Torrie, Sputnik, Eddie, and Suzie pipes (Pell, 1995b), Jericho (172 Ma, Cookenboo, 1997), Rush and Muskox (Armstrong, 1988), and Contwoyto 1. However, the exact number and locations of kimberlites in the northern half of the Contwoyto Lake map sheet have not been published yet (G.N.W.T., 1997; Armstrong, 1998). Other than those shown in Figure 2, unreported or undiscovered kimberlites likely lie within the map area.

### Surficial Geology

#### *Nature of Deposits*

Notes on the glacial geology of the area have been published by Craig (1960), Blake (1963), Tremblay (1976) and Kerr et al. (1995a). Preliminary maps based on limited field work of the northern 3/4 of the Contwoyto map area were undertaken by Hart et al. (1989). Recently, a map of the surficial geology of the northern Contwoyto Lake map area, compiled at a scale of 1:125 000, has been published (Kerr et al. 1997b).

The area is a glaciated landscape, and till is the most extensive glacial deposit. Only one stratigraphic unit of till is recognized, and it is attributed to Late Wisconsin Laurentide ice. The till sheet has been divided into 3 units based on thickness and surface morphology: veneer (thin: <2 m), blanket (thicker: 2 to 10 m), and hummocky (thickest: 5 to 20+ m). Till veneers and blankets

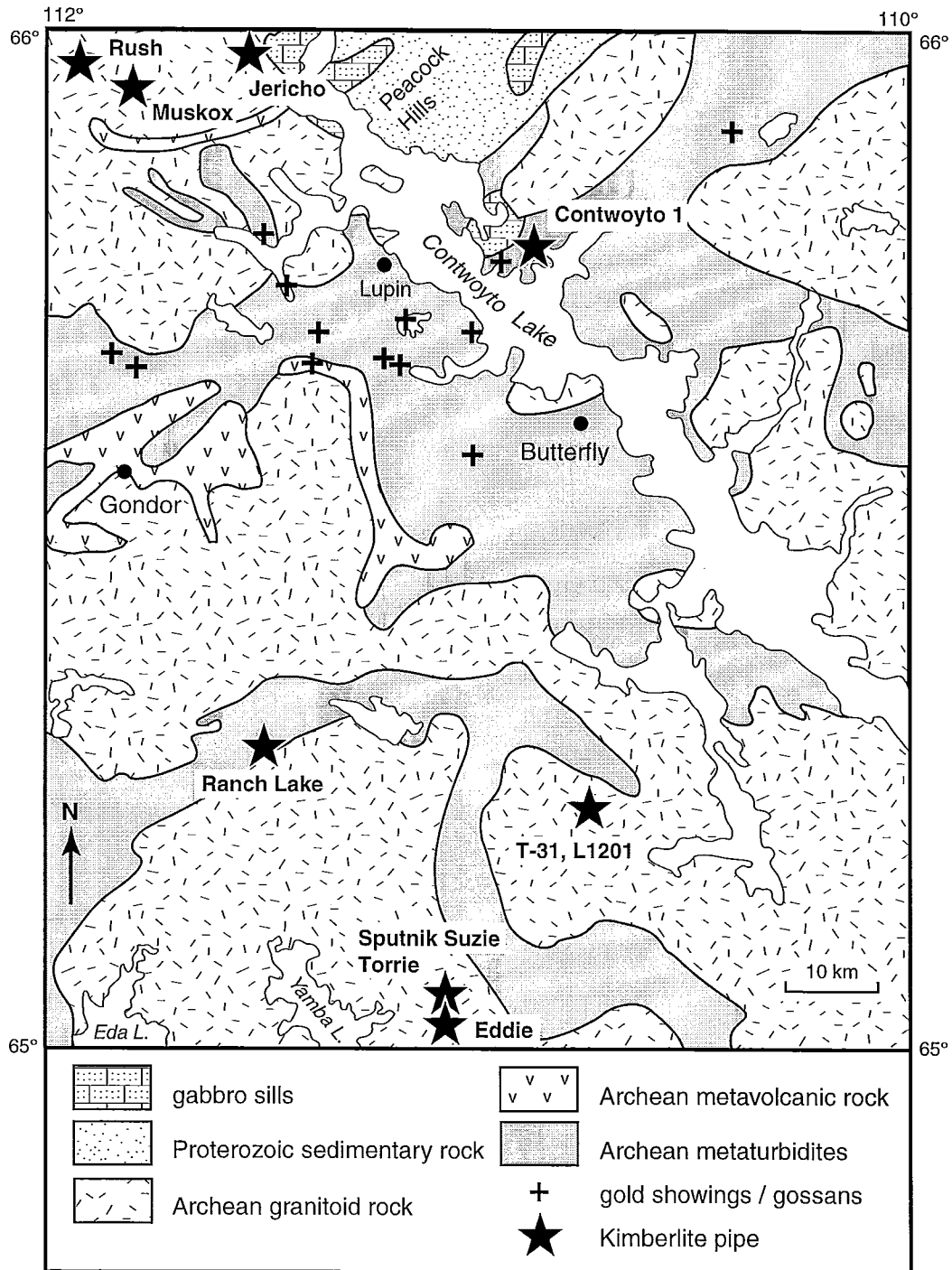


Figure 2. Simplified bedrock geology of the Contwoyto Lake map area.

are pervasive throughout the area. Till veneers commonly have a bouldery surface, while blankets have a range of boulder concentrations. Hummocky till forms two broad belts in the southwest and northeast regions, and contains linear, bouldery zones where the till has been extensively winnowed by meltwater. Locally, hummocky till forms irregular mounds a few metres high and ridges ranging in length from tens of metres to over 3 km. Till is a matrix-supported diamicton, with the matrix ranging from silty sand to sand. The upper 0.5 to 1 m of the till has been extensively modified by frost churning and solifluction due to the thawing of the active layer in summer. Surficial organics have been incorporated to depths of 50-60 cm, and primary deposition features such as layers or lenses have commonly been cryoturbated.

Glaciofluvial deposits are limited in extent and are predominantly in the form of subglacially formed eskers, outwash terraces and related kames. The largest glaciofluvial complexes primarily lie within the belts of hummocky till and till blanket, and trend west and northwest, in the southwest map area, and north, in the northeast regions. Meltwater corridors of bare washed rock flank many esker ridges and terraces or connect esker segments. Small isolated kames occur throughout the map area.

Isolated beaches and wave-cut terraces indicate that glacial lake levels associated with Contwoyto Lake were higher than present during and immediately after deglaciation. These features are best developed along the central and southern shorelines bordering Contwoyto Lake, and are up to 35 to 40 m above present lake level. Glaciolacustrine deposits such as blanket silts and sands are rare, although areas of organic deposits in low-lying areas around Contwoyto Lake and other smaller surrounding lakes could be underlain by fine grained glaciolacustrine material. Within the glacial lake basin, the main surface deposit is till that has been winnowed to various degrees, and consequently may have a sandy matrix. Stream deposits are rare because the relief is low, and no major rivers flow through the area.

### *Glacial history*

The area lies within the central part of the Keewatin Sector of the Laurentide Ice Sheet (Dyke and Prest, 1987; Dyke and Dredge, 1989), west of the M'Clintock Ice Divide, which was prominent during the Late Wisconsin maximum (18 000 - 13 000 BP). At its maximum, the northern margin of Keewatin Sector ice extended north of the Arctic coast and as far west as Mackenzie Valley. From 13 000 BP, the ice divide shifted eastwards into the District of Keewatin, where it remained until about 7 000 years ago. Radiocarbon dates on marine shells beyond the boundaries of this map area suggest that the ice margin lay near the present coast of Coronation Gulf about 9 000 to 10 000 year ago (Kerr, 1994). A radiocarbon date from twigs in an esker on hummocky till terrain southeast of the map area suggests that most of the Contwoyto Lake area was deglaciated by about 8500 BP (TO-4241; Dredge et al. 1996a), although there may have been a late ice remnant in the area of hummocky till. Morainal ridges and non-oriented rim ridges



composed of till are present in the northeast regions of hummocky till, and may reflect the position of former crevasses in the ice or the front of ice lobes during recession.

A glacial lake developed in the Contwoyto Lake basin as the ice receded. The lake occupied the glacioisostatically depressed area in front of the southeastward retreating ice sheet. Either the active ice front, or stagnant ice in areas now covered by hummocky till, dammed the lake. The range of lake levels, indicated by the elevation of beaches from 10 to 40 m above the present lake, points to a gradual reduction in lake level. Westward and northward drainage channels are found at the north end of the lake. Evidence of lacustrine outlets also exists in the south half of the Contwoyto Lake map area, southwest of Fry Inlet, as well as the Kathawachaga Lake (76 L) and Mara River (76 K) map areas to the north.

#### *Ice flow directions*

Directions and sequences of ice flow and glacial transport of materials can be determined by the relative age of striations, the orientation of glacially moulded till and bedrock forms, and the orientation of eskers. At a few locations in the eastern study area, isolated striae (1 in Figure 3) record an early SW flow. Although the westerly extent of this event is not presently known, a similar SW striae pattern is recorded in the eastern regions of the south half of the Contwoyto Lake map area (Ward et al. 1996a). Striae in the northeast quadrant are likely associated with this same event.

In the eastern study area, a subsequent NW ice flow (2 in Figure 3), which gradually shifts to a WNW flow in the western map area (2 in Figure 3), is inferred from cross-cutting relationships of striae. The youngest flow is defined by large-scale ice flow indicators (drumlins and crag-and-tails) and striae (3 in Figure 3). This last, dominant flow varies considerably in direction, and is responsible for the creation of all current glacial landforms in the study area. Ice movement ranges from WNW to NW in the southwest quadrant, and NW along the entire length of Contwoyto Lake. In the central and southeast regions, flow gradually shifts from NW to NNW and NNE, north of Contwoyto Lake. In the easternmost regions, a NW flow predominates.

#### *Glacial transport distances*

Studies of lithologies of the pebble-sized clasts (2 to 6 cm) in till indicate that pebble dispersal trains are traceable for considerable distances. The expected distribution pattern of Proterozoic pebbles is one of sharply decreasing clast concentration down-ice of the source rock and bedrock contact. However, because of different ice flow directions over time, the predicted pattern of clast-content attenuation is not as evident. The pebble distribution map of frequency % (Figure 4) illustrates that the early SW flow transported clasts across the north end of Contwoyto Lake. Concentrations of 20 to 25% occur as much as 18 to 35 km down-ice (SW) of the source, and generally decrease to <10% approximately 25 to 42 km down-ice from the nearest source outcrops. The highest concentrations (up to 96%) of Proterozoic clasts occur in areas underlain

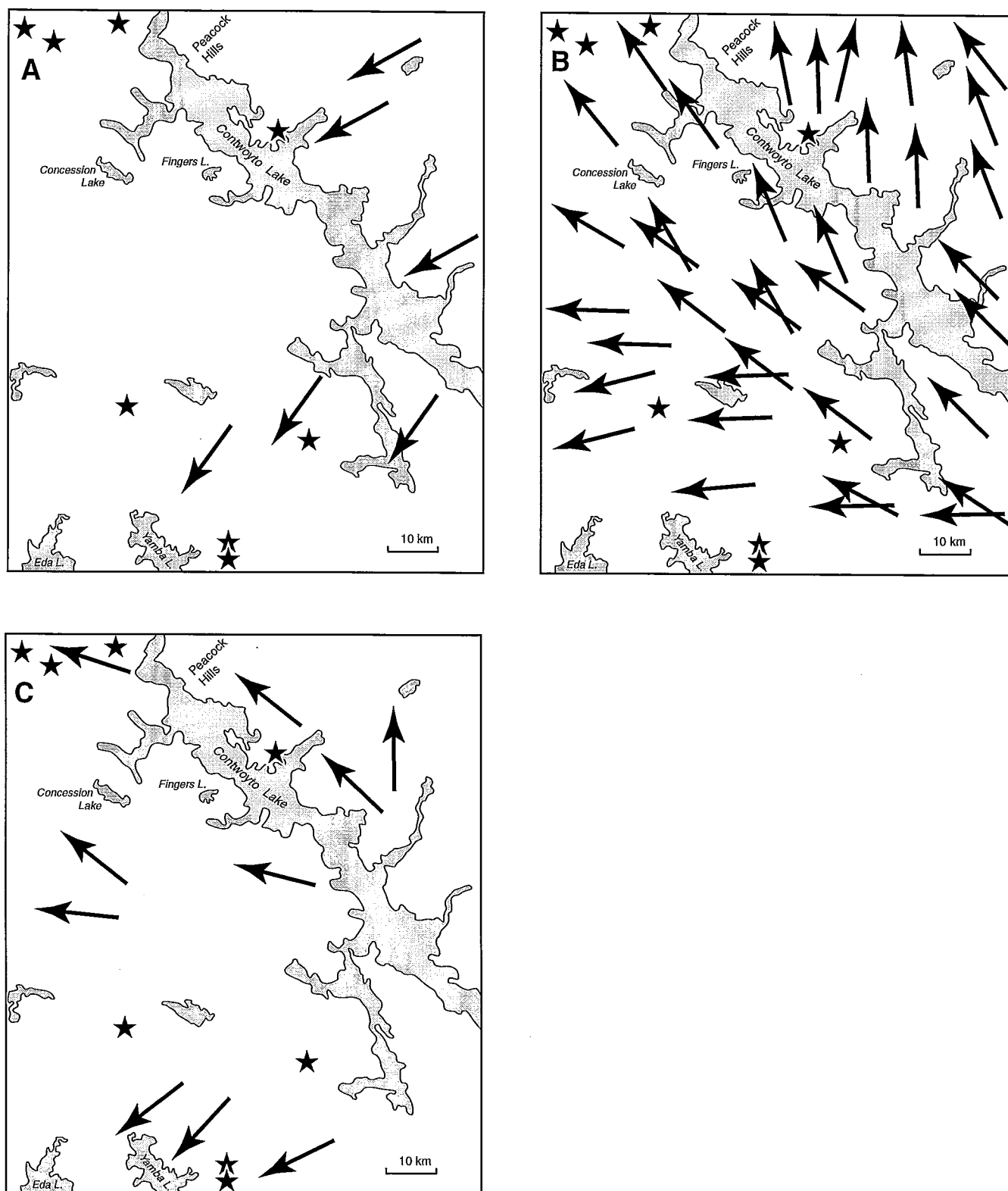


Figure 3. Sequence of ice flows in the Contwoyto Lake map area, from A) oldest to C) youngest. Kimberlites indicated by star symbol.

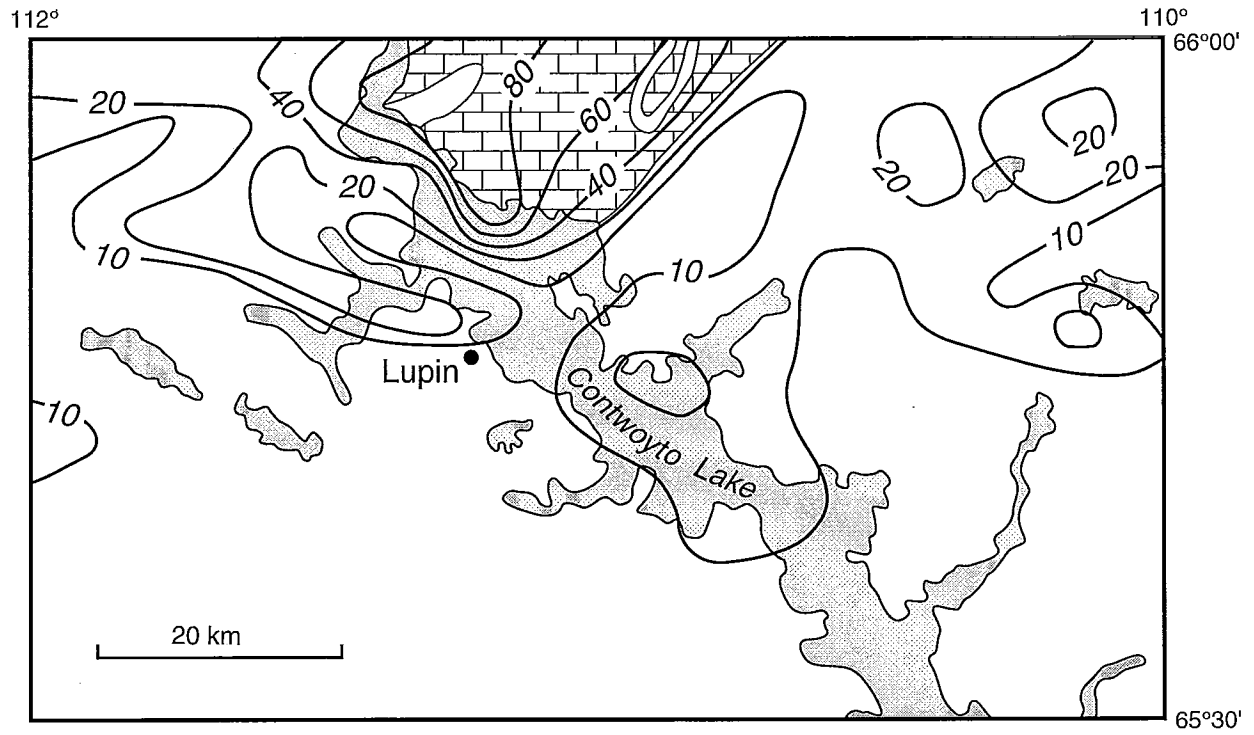


Figure 4. Distribution of Proterozoic pebbles in till. Proterozoic sedimentary rock is shown.

by Proterozoic bedrock. The greatest values are in the western region of Proterozoic terrain. Subsequent NW and the last dominant NNW ice flows are responsible for the dispersal train in the northwest corner of the study area. Northwest of the southeast contact between Proterozoic and granitoid bedrock, Proterozoic pebbles increase in concentration up to 80%, as dilution by granitoid and metaturbidites pebbles decreases.

The distribution of pebbles in the northeast quadrant of the map area may also be evidence of an early SW flow, from Proterozoic bedrock 40 km to the northeast. It is unlikely that they relate to bedrock sources at the north end of Contwoyto Lake as this would require a southeasterly ice movement. The possibility exists however that some of the pebbles may be associated to preexisting Proterozoic outcrops which were completely eroded during the last glaciation, or alternatively to unmapped bedrock covered by surficial sediments.

## **METHODS**

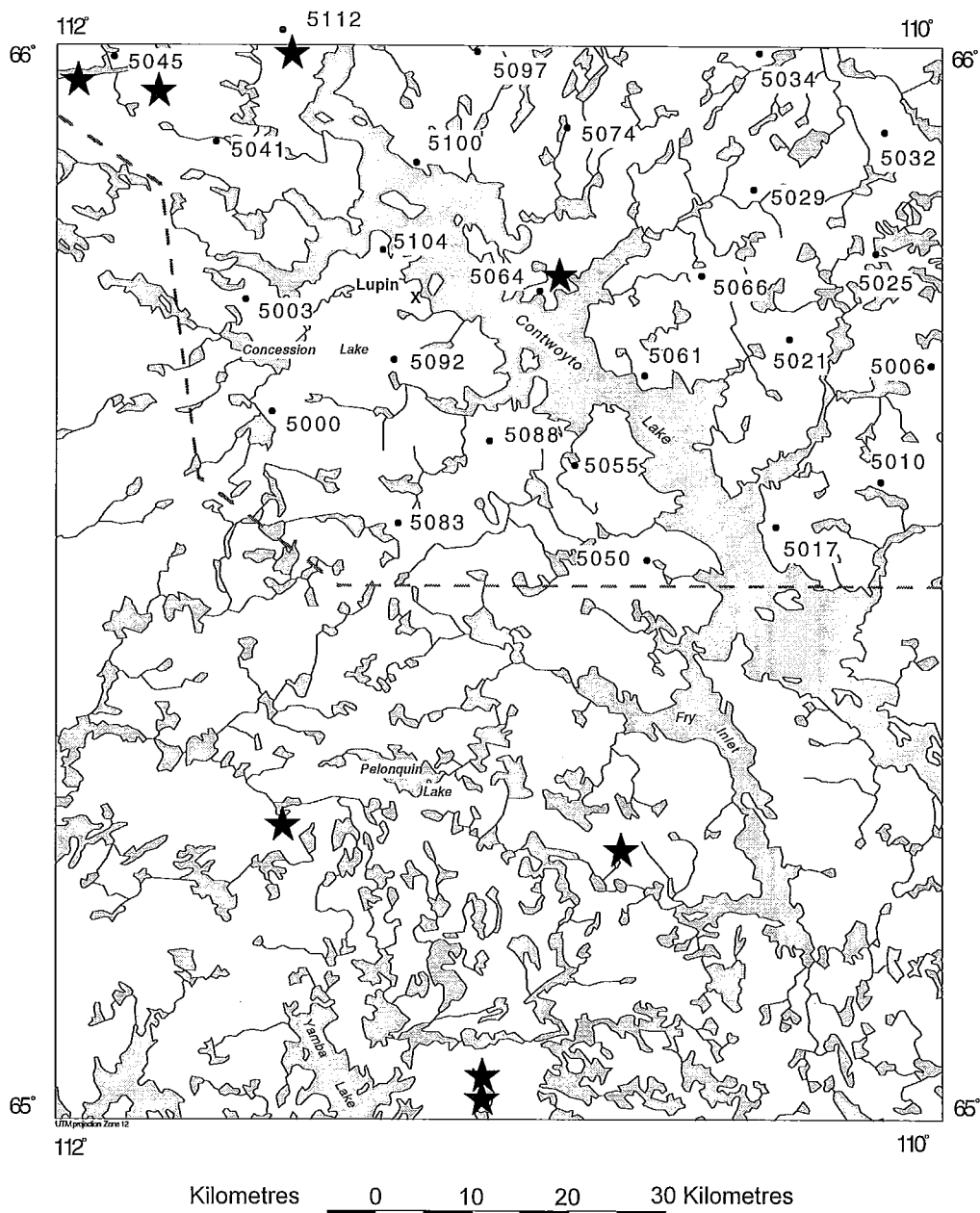
### **Sample Collection and Processing**

In the field, ~10-kg samples were taken from mudboils in till to obtain unoxidized representative till material. All samples were taken from shallow hand-dug pits from depths ranging from 20 to 80 cm. This depth corresponds to a position well below the soil layer, but above the base of the active layer. Sample locations are shown on Figure 5, and their UTM coordinates are listed in Appendix 1. No preconcentration was done in the field although an attempt was made to remove most of the pebbles by hand.

Samples were processed at Overburden Drilling Management Ltd., Nepean, Ontario. A 10 kg split from each bulk sample was disaggregated and screened with the <1.0 mm fraction being run across a shaking table twice. The preconcentrate was then further refined using methylene iodine diluted with acetone at specific gravity of 3.2 to separate light and heavy mineral fractions. The heavy mineral fraction was further split into a nonferromagnetic and a ferromagnetic fraction using a hand magnet. The ferromagnetic fraction was archived and the nonferromagnetic fraction was sieved to <0.25, 0.25-0.5, and 0.5-1.0 mm. A detailed flow chart of this same processing method used in previous studies can be found in Kerr et al. (1995b). All fractions have been archived. Sample processing weights of selected size fractions are listed in Appendix 2.

### **Indicator Mineral Picking**

Certain minerals, when found in glacial sediments, are useful indicators of the presence of kimberlite. Several features make these minerals ideal kimberlite indicator minerals; they are far more abundant in kimberlite than diamonds, they occur almost exclusively in kimberlite, they can withstand extreme crushing and grinding during glacial transport, and they are visually and chemically distinct. The most commonly used kimberlite indicator minerals are Cr-pyrope (purple colour, kelyphitic rims), eclogitic garnet (orange-red), Cr-diopside (pale to emerald green), Mg-ilmenite (black, conchoidal fracture), and chromite (reddish-black, irregular to octahedral crystal



**Figure 5**  
**Sample location map. Sample numbers**  
**have a "96KKA" prefix. Area south of dashed**  
**line relates to Open File 3386 (Ward et al., 1996a).**

Contwoyto Lake (76E, N/2)

★ kimberlite pipe

shape), although in rare cases, diamond is abundant enough to be its own indicator.

For all samples, the nonferromagnetic heavy mineral concentrates in the 0.5 mm-1.0 mm and 0.25-0.5 mm fractions were sent to I. & M. Morrison Geological Services, Delta B.C. for visual selection of potential kimberlite indicator minerals. In total, five fractions were examined for each sample of the two size fractions. The medium sand fraction (0.25-0.5 mm) is highlighted because it was shown to contain more kimberlite indicators than either finer or coarser sand fractions in analyses from the Lac de Gras area (Ward et al. 1995, 1996b). Minerals identified in this study included pyrope garnet exhibiting orange peel texture and remnant kelyphitic rims, chrome diopside, ilmenite and olivine.

### **Electron Microprobe Analysis**

Picked potential kimberlite indicator mineral grains were mounted in 25 mm epoxy mounts and polished at Lakefield Research, Lakefield, Ontario. Color photographs and Scanning Electron Microscope (SEM) backscatter images were taken of each epoxy mount to help identify each grain. The grains were analyzed using the electron microprobe facilities at the Geological Survey of Canada, using methods similar to those reported by Ward et al. (1995) and Stirling et al. (1996).

The analyses were done with a four-spectrometer wavelength-dispersive Cameca SX50 electron microprobe. The raw data were processed with the Cameca PAP program (Pouchou and Pichoir, 1984). Grains were analyzed using an automated run of approximately 24 hours. The dead time correction formula (Willis, 1993) has been changed for this SX50 to achieve linearity at higher count rates.

The grains were analyzed using the GSC "GARNET" routine. This routine was developed by the Geological Survey of Canada in order to analyze the major elements required to identify the potential mineral species to be encountered in this study using a minimum of probe time. The standards and operating conditions are given in Appendix 4.1. The calculated detection limits and counting times are given in Appendix 4.2.

### **MINERAL IDENTIFICATION**

The analyzed grains were classified on the basis of their chemical composition. Theoretical chemical compositions of mineral end-members (LeMaitre, 1982, Table A13) were used to calculate cut-off values (at approximately 50:50 mol %) for members of binary solid solution series. These cut-off values are shown in Table 1. For analyses with low totals and for minerals that contain substantial amounts of more than two endmembers (which is the case for most garnets and spinels), these cut-off values were lowered accordingly. In equivocal cases molar fractions of the critical oxides were calculated in order to assess the endmember with the highest percentage, after which the mineral would subsequently be named.

In addition, prefixes were added to some of the indicator minerals (bold print) to highlight

elevated contents of petrogenetically critical elements associated with kimberlite, such as Mg, Cr, and Ti. Cutoff values for their oxides (Table 1) were based on the range of chemistry typical of indicator minerals in the Slave Province and might differ from those used by other authors. For instance, Cr-diopside was defined at >1 wt.% Cr<sub>2</sub>O<sub>3</sub> while some other authors have used a 0.5 wt.% Cr<sub>2</sub>O<sub>3</sub> cutoff (Fipke, 1989; Thorleifson et al. 1994). Microprobe data are included as Appendix 5 in this report, and users are encouraged to examine and reclassify the minerals according to their own criteria.

Table 1. Mineral classification

Almandine	< 21 wt.% MnO <	Spessartine
Almandine	< 15 wt.% MgO <	<b>Pyrope</b>
Almandine	< 17 wt.% CaO <	Grossular
Andradite	< 11 wt.% Al <sub>2</sub> O <sub>3</sub> <	Grossular
Andradite	< 2 wt.% TiO <sub>2</sub> <	Melanite
<b>Pyrope</b>	< 15 wt.% Cr <sub>2</sub> O <sub>3</sub> + 17 wt.% CaO <	Uvarovite
<b>Pyrope</b>	< 2 wt.% Cr <sub>2</sub> O <sub>3</sub> <	<b>Cr-Pyrope</b>
Andradite	< 2 wt.% Cr <sub>2</sub> O <sub>3</sub> <	Cr-Andradite
<b>LoCr-Diopside</b>	< 1 wt.% Cr <sub>2</sub> O <sub>3</sub> <	<b>Cr-Diopside</b>
<b>Cr-Diopside</b>	< 1.40 wt.% Cr <sub>2</sub> O <sub>3</sub> <	<b>HiCr-Diopside</b>
<b>Chromite</b>	< Cr <sub>2</sub> O <sub>3</sub> /Al <sub>2</sub> O <sub>3</sub> = 1.5 <	<b>Cr-Spinel</b>
<b>Chromite</b>	< 11 wt.% MgO	<b>Magnesio-chromite</b>
	+ Cr <sub>2</sub> O <sub>3</sub> /Al <sub>2</sub> O <sub>3</sub> < 1.5 <	
<b>Chromite</b>	< 3 wt.% TiO <sub>2</sub> <	<b>Ti-Chromite</b>
Rutile	< 15 wt.% FeO <sub>tot</sub> <	Fe-Rutile
Ilmenite	< 6 wt.% MgO <	<b>Mg-Ilmenite</b>
Ilmenite	< 53 wt.% FeO <sub>tot</sub> <	Ilmenite (altered)
Ti-Magnetite	< 18 wt.% TiO <sub>2</sub> <	Ilmenite (altered)
Hematite	< 2 wt.% TiO <sub>2</sub> <	Ti-Magnetite

Additional information on the mineral grains (color, specific gravity, magnetic susceptibility) were used to improve or confirm identification. Problems in identifying and labelling the minerals properly included low totals in a few analysis caused by insufficient grain area at the surface of the polished mount, inhomogeneities within the grain, or the presence of elements in the mineral not analyzed by the microprobe routine (eg. Zr, REE, S). Enlarged color prints as well as SEM backscatter images of the grain mounts were used to aid mineral identification and to recognize possible inhomogeneities, intergrowths or exsolutions within individual grains. In most cases, minerals could still be labelled in spite of low totals.

## CHEMICAL CHARACTERISTICS OF SOME INDICATOR MINERALS

### Pyrope garnets

Pyrope is chemically characterized by a high MgO content (>13 wt.% MgO) and varying amounts of Cr<sub>2</sub>O<sub>3</sub> ranging from < 1 to up to 15 wt. %. Pyropes with > 2 wt.% Cr<sub>2</sub>O<sub>3</sub> were labelled

Cr-pyropes. Pyropes are exceedingly rare in upper crustal rocks and are found mainly in peridotites, kimberlites and lamproites (Deer et al. 1997). They are therefore one of the most important kimberlite indicator minerals. Aside from crustal xenocrysts, garnets in kimberlite form three major petrogenetically and compositionally different groups: pink to purple (rarely green) peridotitic garnets (Ti-poor Cr-pyropes), deep red megacryst garnets (Cr-poor, Ti-rich pyropes) and orange eclogitic garnets (pyrope-almandine-grossular mixtures with minor amounts of Ti and Na).

The composition of pyropes can be used to evaluate the diamond potential of kimberlites since diamonds are associated with Ca-poor (subcalcic), Cr-diopside free garnet harzburgite and group I eclogites (Gurney, 1984; Gurney and Moore, 1993; Fipke, 1989; McCandless and Gurney 1989). Cr-pyropes from subcalcic garnet harzburgite can be differentiated from other sources, including garnet lherzolite, by their CaO vs Cr<sub>2</sub>O<sub>3</sub> ratio. Kimberlites that contain pyropes in the subcalcic harzburgite field (essentially "G10" garnets) are potentially diamondiferous (Gurney, 1984; Gurney and Moore, 1993; Fipke, 1989). Lo-Cr titanian megacryst garnets, although most closely related to kimberlite, are not in themselves an indicator for diamond potential.

Eclogitic garnets are difficult to differentiate from other orange garnets. A combination of low FeO (< 25 wt%), high MgO and/or CaO, low MnO and Cr<sub>2</sub>O<sub>3</sub> as well as diagnostic amounts of Na<sub>2</sub>O (> 0.08) and TiO<sub>2</sub> are typical for garnets from diamondiferous group I eclogites. Optically, orange eclogitic garnets are easily confused with orange almandine-spessartine garnets or staurolite of crustal origin, deep red rutile can be mistaken for megacryst garnets and pink to purple quartz, and spinels are mistaken for peridotitic garnets.

### **Cr-diopside**

Pale green to emerald green chrome diopside is an important kimberlite indicator mineral, originating from mantle xenoliths (lherzolites and wehrlites) as well as megacrysts (clinopyroxene-ilmenite intergrowths). Kimberlites contain diopsides with a wide range of Cr<sub>2</sub>O<sub>3</sub> values (up to 6 wt.%, Stephens and Dawson, 1977). They overlap at the lower end of the Cr<sub>2</sub>O<sub>3</sub> spectrum (< 1.5 wt.%) with diopside compositions in other ultrabasic rocks (compare Table 52, Deer et al. 1978), making discrimination between kimberlitic and other diopsides on the basis of chrome content difficult. Studies of diopside compositions in till samples from the Kirkland Lake area (McClenaghan et al. 1993) have shown that Cr-diopsides with Cr<sub>2</sub>O<sub>3</sub> contents up to 1.4 wt.% can be found in varying abundances in samples that contain no other reliable kimberlite indicator minerals and thus are probably derived from other bedrock sources. Characteristically emerald green Cr-diopsides with high Cr<sub>2</sub>O<sub>3</sub> (>1.4 wt.%), however, indicate the presence of mantle derived garnet lherzolite or pyroxenite which are typically found in kimberlites or lamproites (McClenaghan et al. in press).

Diopsides, therefore, have been divided into LoCr-diopsides (< 1.0 wt.% Cr<sub>2</sub>O<sub>3</sub>), which



might have different bedrock sources including kimberlite, Cr-diopsides (1.0 - 1.4 wt.%  $\text{Cr}_2\text{O}_3$ ), which are probably from kimberlites, and HiCr-diopsides ( $> 1.4$  wt.%  $\text{Cr}_2\text{O}_3$ ) which are likely kimberlitic unless peridotitic bodies are present in the sampled area. Cr-diopsides and HiCr-diopsides, or LoCr-diopsides that occur in samples together with Cr-pyropes (and or Mg-ilmenite) are likely to be derived from kimberlites. LoCr-diopsides and Cr-diopsides without other indicator minerals may be from other ultrabasic bodies.

### **Ilmenite**

Mg-rich ilmenites with  $> 5$  wt.% MgO (also called picroilmenites) are characteristic for kimberlites (Mitchell, 1973; Haggerty, 1975). Ilmenites from other ultrabasic rocks (with the possible exception of carbonatites) or crustal rocks, which are much more common, usually have  $\text{MgO} < 3$  or 4 wt.%. Samples with high MgO and  $\text{Cr}_2\text{O}_3$  indicate good diamond preservation potential (Gurney, 1989).

### **Chromite**

Deep reddish brown to black chromites occur in a variety of basic and ultrabasic rocks, including kimberlite. They can have a wide compositional range, from Cr-spinels with  $< 20$  wt.%  $\text{Cr}_2\text{O}_3$  to (magnesio-)chromites with  $> 60$  wt.%  $\text{Cr}_2\text{O}_3$ . Similar to Cr-diopsides, the  $\text{Cr}_2\text{O}_3$  contents of kimberlitic and non-kimberlitic chromites overlap. Differentiation is possible using trace element composition, but proton microprobe analysis is required (Griffin et al. 1994). Chromites can be used to evaluate diamond potential of a kimberlite.

Chromium-rich and magnesium-rich chromites ( $> 62.5$  wt.%  $\text{Cr}_2\text{O}_3$ ,  $> 12-17$  wt.% MgO) in kimberlite are considered to be strong diamond indicators, as they have been found as inclusions in diamonds (Fipke, 1989; Gurney and Moore, 1993). Chromite chemistry therefore is often used to assess diamond potential of kimberlites. Schulze (1995), however, notes that the compositional range of chromites actually coexisting with diamonds is not restricted to these ranges, which is known as the "diamond inclusion field".

### **Olivine**

Olivine is the most abundant mineral making up the macrocryst suite of kimberlites (Mitchell, 1986). Unfortunately, olivine is also a common constituent of a wide range of other basic and ultrabasic rocks and is not unique to kimberlite. However, it has been used as a kimberlite indicator mineral in the glaciated terrain of Canada (Fipke et al. 1995; McClenaghan et al. in press). Olivine is also the most abundant mineral in the upper mantle (main component of peridotite) and a phenocryst phase in kimberlite. Olivine from kimberlite and peridotite is MgO-rich (close to the forsterite endmember of the olivine solid solution series) and as such colourless to pale yellow or pale green. Its chemistry is characterized by high mg-values ( $100 \text{ Mg}/(\text{Mg}+\text{Fe}^{2+})$ ) between 84 and

95 and notable traces of NiO, both of which enable us to distinguish between peridotitic, kimberlitic and basaltic olivines, although some overlaps occur (Deer et al. 1997). Typical mg-values for peridotitic olivines are between 88 and 95, with NiO 0.25

## **KIMBERLITE INDICATOR MINERALS IN THE NORTHERN CONTWOYTO LAKE AREA**

A summary of the minerals identified in the 0.25 to 0.5 mm and 0.5 to 1.0 mm fractions of each sample containing potential kimberlite indicators in the northern Contwoyto Lake map area is given in Table 2. Microprobe analyses are listed in Appendix 5. Out of the 25 bulk till samples, 12 samples contained a total of 28 kimberlite indicator minerals: 13 Cr-pyrope, 5 HiCr-diopside, 7 Cr-diopside, and 3 Mg-ilmenite. Other minerals analyzed in this study were picked because they resembled kimberlite indicator minerals: black ilmenite (12) and rutile (2) were picked as potential Mg-ilmenite or chromite.

Compared to results of kimberlite indicator analyses from till in the Lac de Gras map area, the northern Contwoyto Lake map area has considerably fewer kimberlite indicator minerals in till. For instance, the Lac de Gras map area has a total of 2037 indicators in 80 till samples (Ward et al. 1995), and Winter Lake map area has 256 indicators in 49 till samples (Kerr et al. 1995b). However in comparison to other surrounding map areas, the northern Contwoyto Lake map area has either comparable numbers or more: Point Lake map area (Dredge et al. 1996b) has 45 in 47 till samples, while southern Contwoyto Lake map area has 36 in 27 till samples (Ward et al. 1996a), the Napaktulik Lake map area has 25 in 43 till samples (Kerr et al. 1996), and the Aylmer Lake map area has only 16 indicators in 61 till samples (Dredge et al. 1995).

Figure 6 shows the regional distribution for the total number of indicator minerals in the 0.25-0.5 mm size fraction of 10-kg till samples. Because many sites in the northern Contwoyto Lake map area contained no kimberlite indicator mineral grains in this size fraction, as is the case in the south half of 76 E, background values can be considered to be zero, and the presence of any indicator minerals in this area should be considered anomalous.

Three out of twenty five sites had between 1 and 19 kimberlite indicators in the 0.25-1.0 mm fraction per 10 kg sample, with the remaining 20 sites being barren. These 3 sites occur in the north-central and northwestern regions of the map area, overlying Proterozoic sediments and granite. Northwestward ice flows are dominant in the area where indicator minerals were found. The sample containing the highest number of indicator minerals (96KKA5045) lies only a few km northwest of, i.e., down-ice, from the Muskox kimberlite. The second richest sample (96KKA5112) lies about 1 km down-ice of the Jericho kimberlites. The remaining sample (96KKA 5100) is 20 km down-ice of the Contwoyto 1 kimberlite.

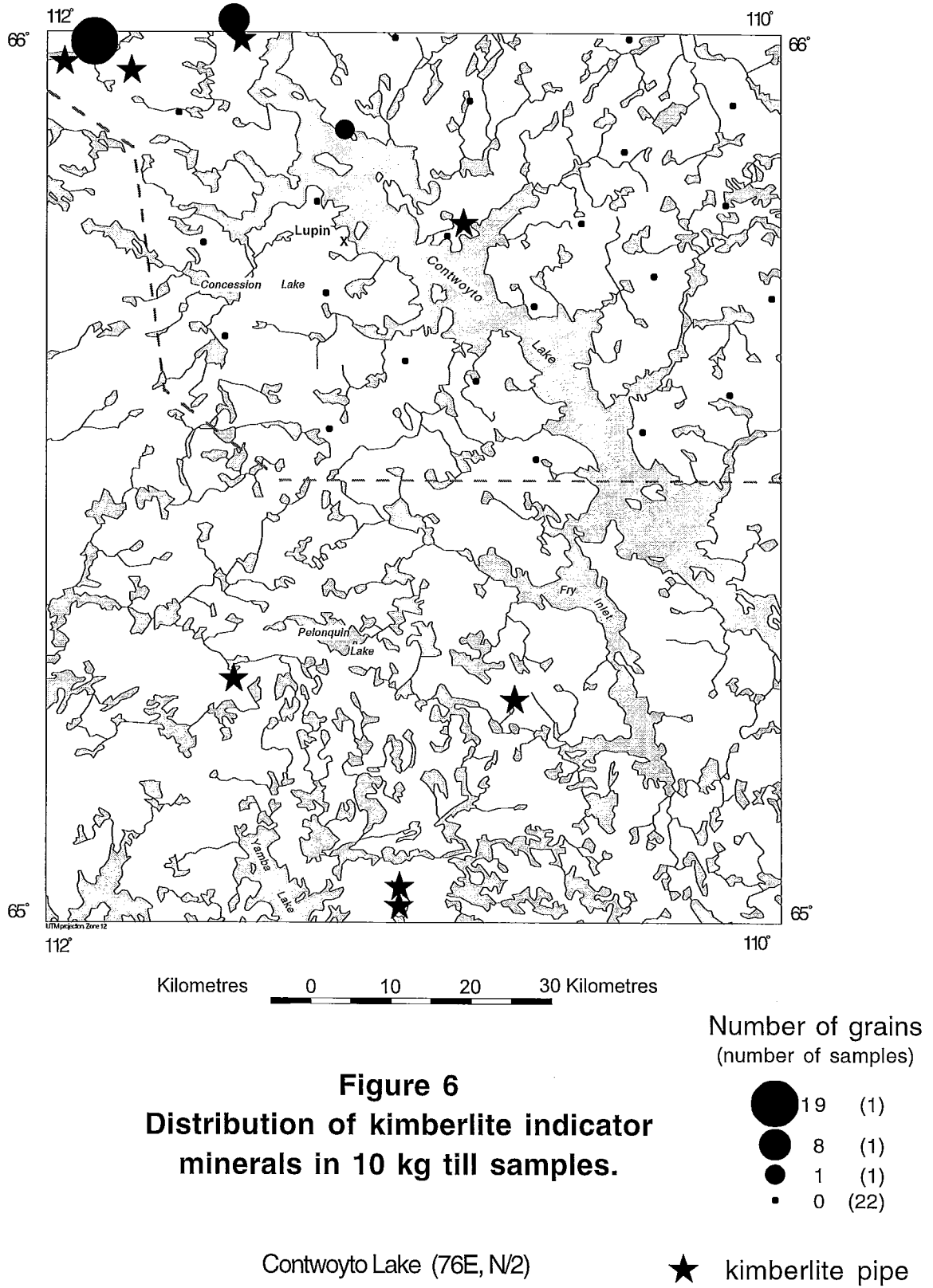
A total of 13 pyrope garnets were recovered. Figure 7 indicates that the majority of pyropes are from lherzolitic sources and probably derived from kimberlites; two pyropes have subcalcic "G10" compositions. Though data are limited, a comparison of pyrope grains from

Table 2. Heavy minerals and kimberlite indicator minerals (in bold type) in till samples from the northern Contwoyto Lake map area:  
0.25 to 0.5 mm fraction; 0.5 to 1 mm fraction in ().

Sample	n	pyr	LCD	CD	HCD	diop	enst	oliv	rut	ilm	Mg-il	zr	epi	TKIM
96KKA5000	3								2			1		0
96KKA5003	1					1								0
96KKA5032	3									3				0
96KKA5045	31	7	9	5(1)	5		1	1		(1)	1			19
96KKA5050	2									1			1	0
96KKA5061	1												1	0
96KKA5066	1		1											0
96KKA5074	2		1					1						0
96KKA5083	1									1				0
96KKA5092	2									2				0
96KKA5100	2									(1)	(1)			1
96KKA5112	20	5(1)	5	1		(2)		2		3	1			8
total	69	13	16	7	5	3	1	4	2	12	3	1	2	28

n=number of grains microprobed  
pyr=pyrope  
LCD=LoCr-diopside  
CD=Cr-diopside  
HCD=HiCr-diopside  
diop=diopside  
enst=enstatite  
oliv=olivine

rut= rutile  
ilm=ilmenite  
Mg-il=Mg-ilmenite  
zir=zircon  
epi=epidote  
TKIM=Total no. of kimberlite indicator grains



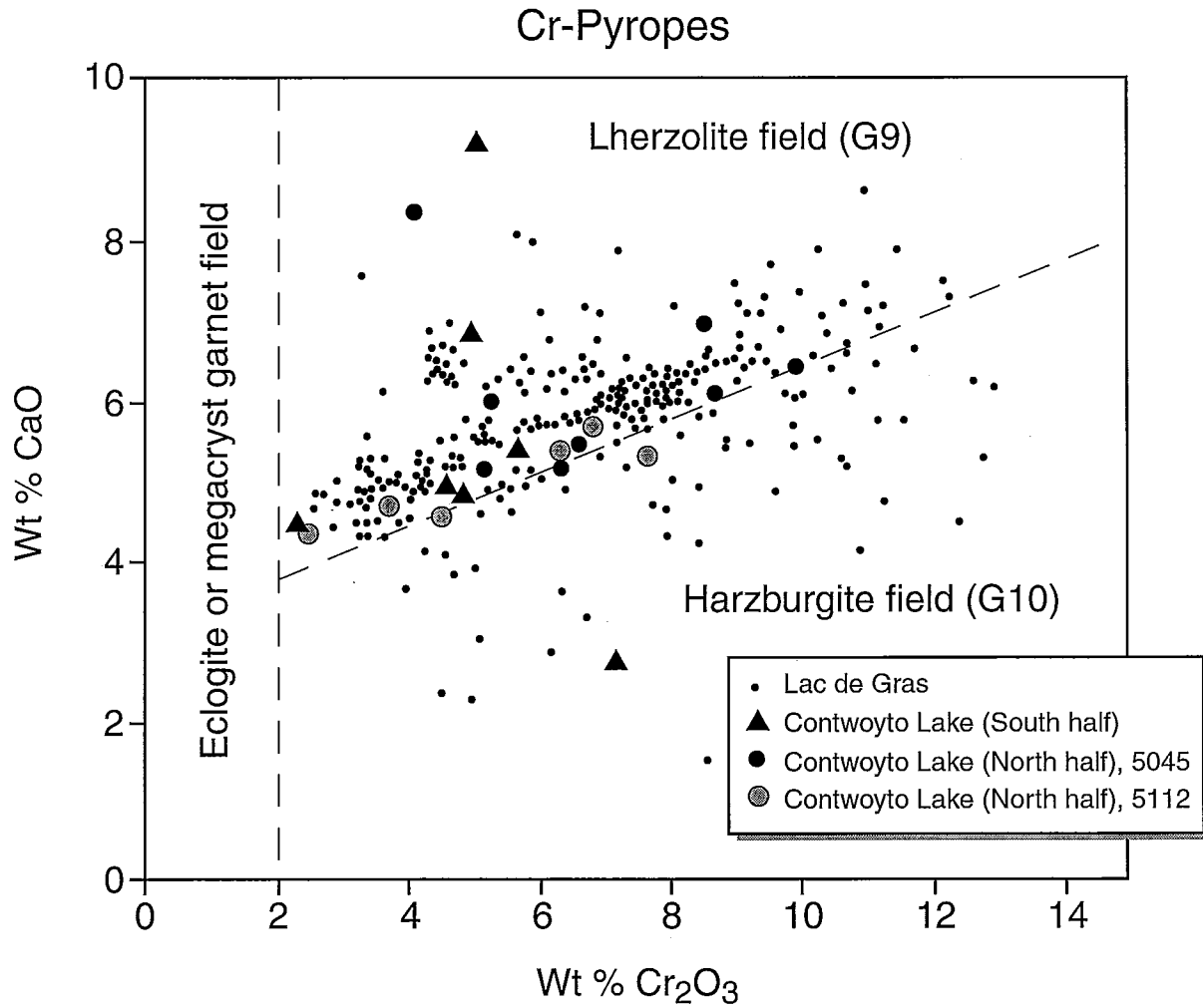


Figure 7. CaO vs Cr<sub>2</sub>O<sub>3</sub> plot for pyropes from the Contwoyto Lake map area. Results from till in the south half of Contwoyto Lake and Lac de Gras areas are shown for comparison.

samples 5045 and 5112 with pyrope from the southern Contwoyto Lake map area suggests that pyrope composition from site 5112 may resemble more closely compositions associated to samples found in the southern Contwoyto Lake area (generally lower CaO and Cr<sub>2</sub>O<sub>3</sub> wt %). Pyrope from site 5045 appear to have slightly higher CaO and Cr<sub>2</sub>O<sub>3</sub> wt % values. Figure 8 shows the distribution of pyropes in the study area. Pyropes at sites 5045 and 5112 are down-ice of the Muskox and Jericho kimberlites respectively.

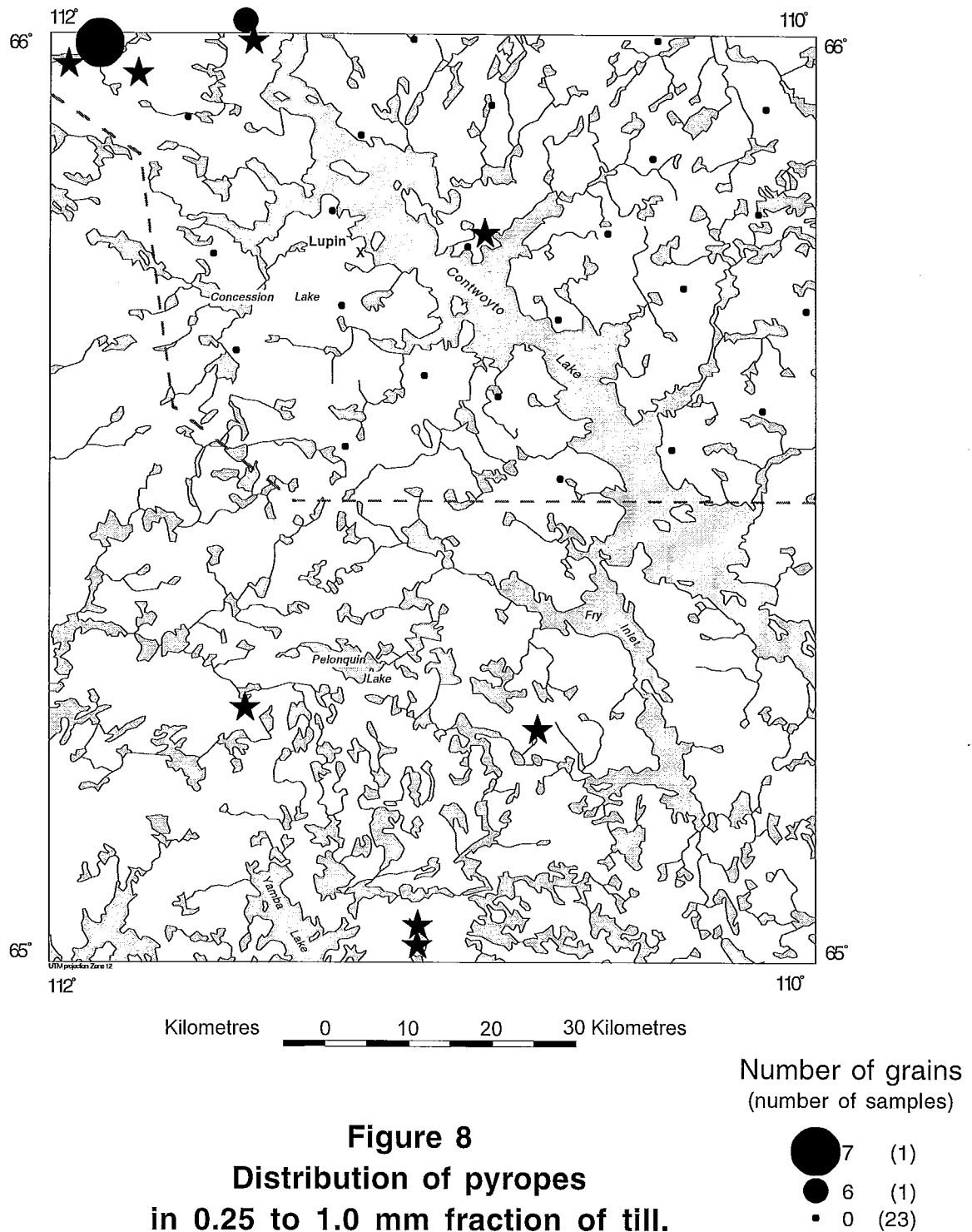
Figure 9 shows the distribution of the most common kimberlite indicator minerals in the northern Contwoyto Lake area: Cr-diopsides and HiCr-diopsides. They lie in the northwest quadrant of the map area, occurring down-ice of the Muskox and Jericho kimberlites. The combination of Cr-diopsides with HiCr-diopside and pyropes (site 5045), and Cr-diopsides with pyropes (site 5112) suggests that these grains likely originate from kimberlite.

Of 15 ilmenites identified, the majority (12) were regional ilmenites from non-kimberlitic sources with MgO < 6.0 wt.%. Mg-rich ilmenites with > 6 wt.% are characteristic for kimberlite (Mitchell, 1973; Haggerty, 1975); a total of 3 such Mg-ilmenites were identified (Figures 10, 11). Samples with high MgO and Cr<sub>2</sub>O<sub>3</sub> indicate good diamond potential. The small number of Mg-ilmenites recovered in this study limits interpretation although Figure 11 suggests that Mg-ilmenites from the Contwoyto Lake, Napaktulik Lake (86l) and Lac de Gras map areas may all have slightly different compositions which may be characteristic of each pipe or individual kimberlite clusters in each map area. It is probable that Mg-ilmenites from samples 5045 and 5112 are derived from the Muskox and Jericho kimberlites respectively. The Mg-ilmenite recovered from sample 5100 may be associated with the Contwoyto 1 kimberlite in the up-ice direction, although minor changes in ice-flow directions preclude assigning a source with certainty.

Olivine is one of the most abundant minerals in heavy mineral concentrates from Contwoyto Lake till samples in the 0.25-0.5 mm size fraction (Appendix 3). Only a small percentage of these grains (26) have been analyzed by microprobe and they exhibit a very limited chemical variation: Mg-values vary from 91.2 to 92.3, and NiO from 0.12 to 0.15. Olivine occurs together with pyrope, Cr-diopside and Mg-ilmenite in samples 5045 and 5112, as well as 5074. Due to overlapping ranges, it remains unclear if the olivines are derived from peridotite xenoliths or olivine phenocrysts from the kimberlite.

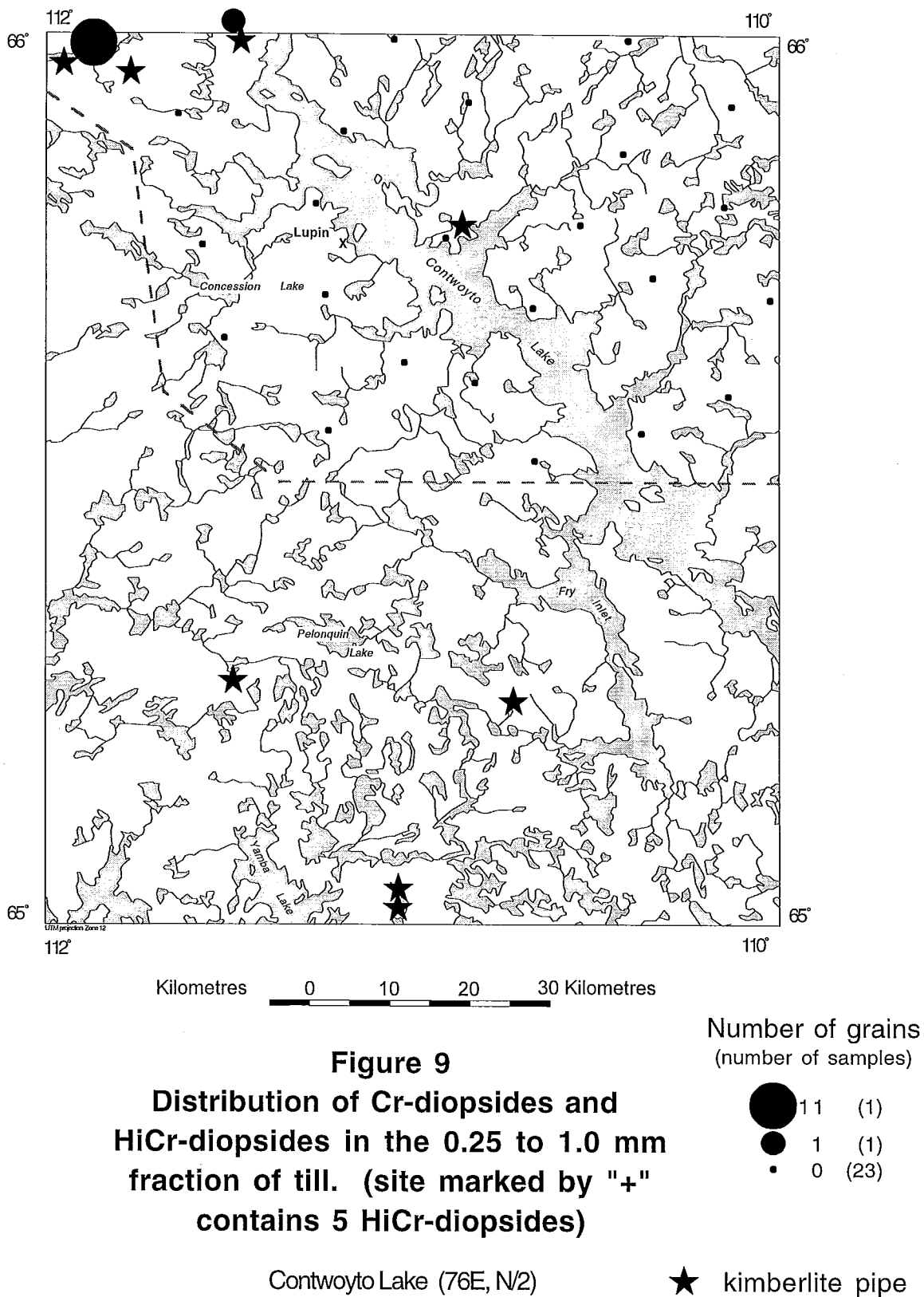
## CONCLUSIONS

It is interesting to note that despite the relatively low kimberlite indicator grain counts and regional sampling density of approximately 1 sample/175 km<sup>2</sup>, the presence of three out of four known kimberlites in the sampling area were detected in the till sampling program, even though the location of the kimberlite sources were not known when the samples were taken (with the exception of Jericho). This indicates that till sampling is effective as a reconnaissance kimberlite exploration tool. Clearly, samples from sites 5045 and 5112 related to the Muskox and

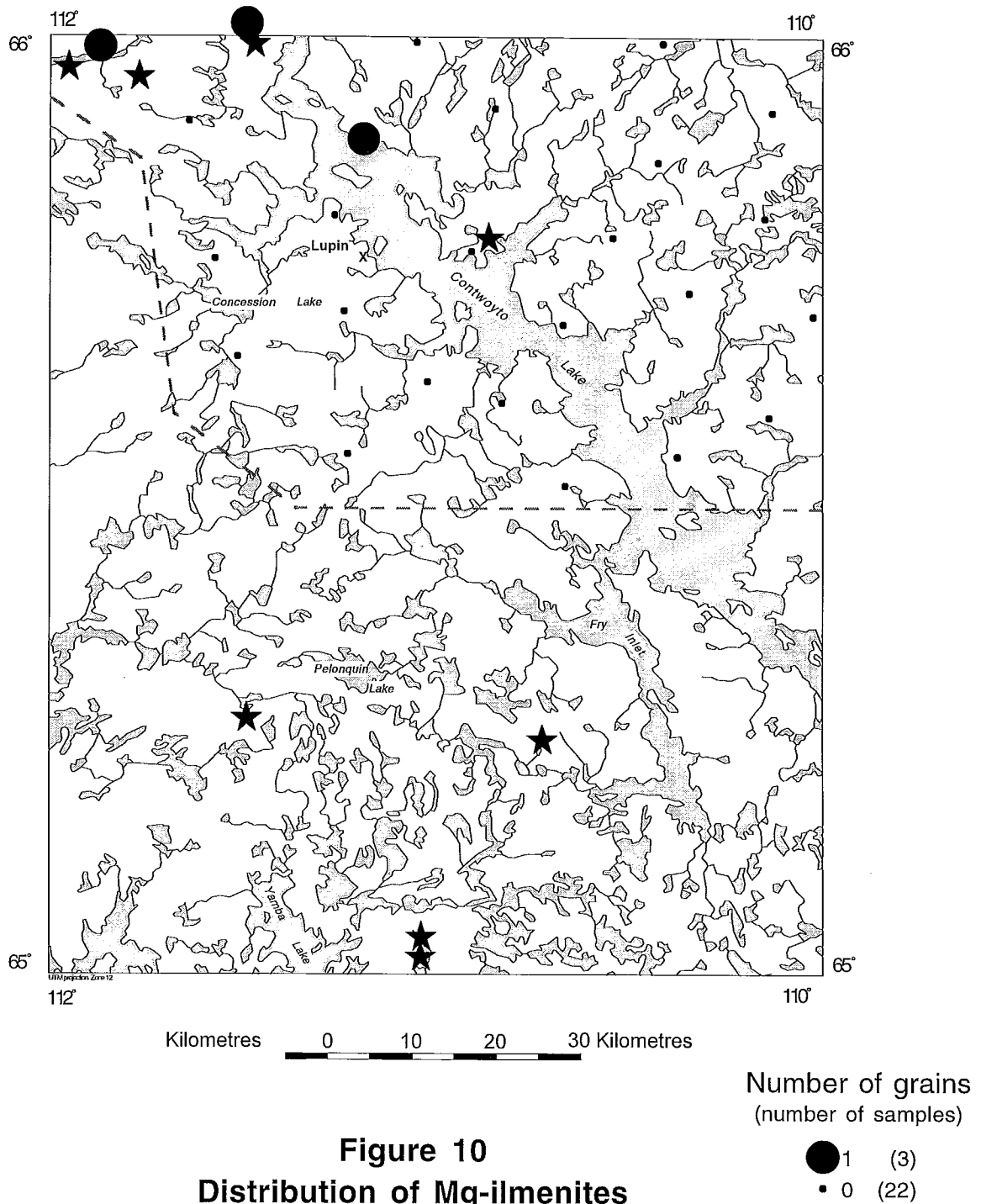


Contwoyo Lake (76E, N/2)

★ kimberlite pipe







Contwoyo Lake (76E, N/2)

★ kimberlite pipe

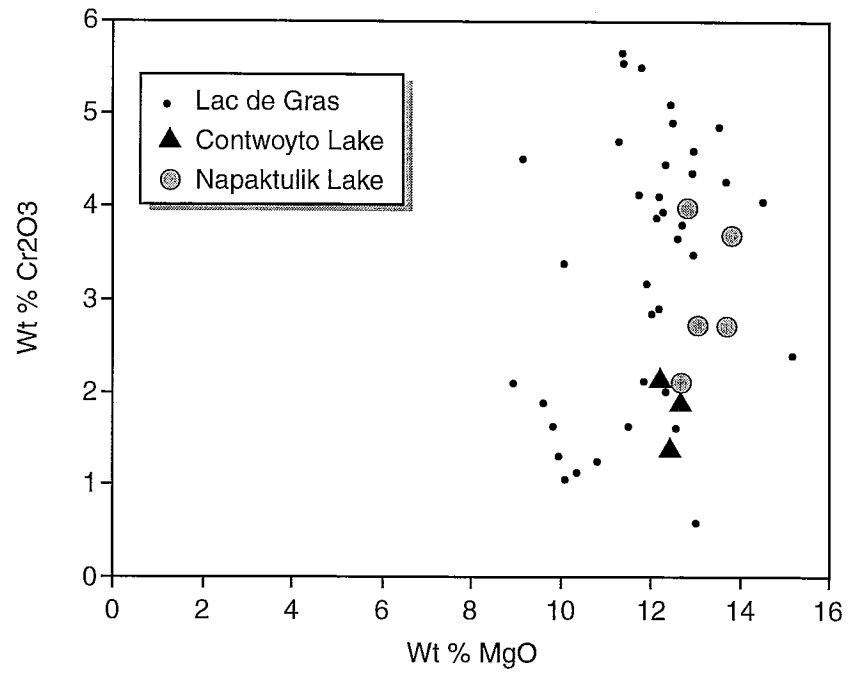


Figure 11.  $\text{Cr}_2\text{O}_3$  vs  $\text{MgO}$  plot for all Mg-ilmenites in till from the Contwoyto Lake area. Results from till in the Lac de Gras and Napaktulik Lake areas are shown for comparison.

Jericho kimberlites respectively as they occur down-ice of these pipes.

The relatively small number of indicators restricted to the northeast of Contwoyto Lake itself are unlikely to have originated from known kimberlites in the southern Contwoyto Lake map area (Ranch Lake, Torrie, T-31 and LI201 pipes). Ice flow patterns suggest that indicators originating from these sources would be transported west-northwestward within the south-central region of the Contwoyto Lake map area, and not northward across Contwoyto lake proper. Site 5100 contains a transported grain that may form part of a diluted north-northwest tail of a dispersal train originating from the Contwoyto 1 kimberlite.

A cursory examination of till geochemistry (Kerr and Knight, 1998) with respect to trace elements that are commonly associated with kimberlites (including Ba, Ce, Cr, La, Mg, Ni and Sr) revealed no obvious elevated concentrations of these elements down-ice of the kimberlites.

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## Appendix 1. UTM sample locations

Sample	Easting	Northing
96 KKA 5000	476240	7281870
96 KKA 5003	473570	7293519
96 KKA 5006	544737	7287006
96 KKA 5010	539730	7274810
96 KKA 5017	528874	7269968
96 KKA 5021	530069	7289538
96 KKA 5025	538889	7298547
96 KKA 5029	526247	7304970
96 KKA 5032	539615	7311095
96 KKA 5034	526664	7319157
96 KKA 5041	470655	7309840
96 KKA 5045	460322	7318807
96 KKA 5050	515430	7266430
96 KKA 5055	507835	7276200
96 KKA 5061	515067	7285618
96 KKA 5064	504110	7294278
96 KKA 5066	520965	7295960
96 KKA 5074	506904	7311219
96 KKA 5083	489294	7270222
96 KKA 5088	498880	7278710
96 KKA 5092	488926	7287158
96 KKA 5097	497550	7319090
96 KKA 5100	491271	7307559
96 KKA 5104	487810	7298555
96 KKA 5112	477555	7321368

Appendix 2. Sample processing weights (\* M.I. = Methylene Iodine)

Sample Number	Material	Amount Processed kg	Table feed ( $<1$ mm) kg	Total M.I.* Concentrate g	M.I.* Lights		Mag g	Non-mag		Concentrate examined	
					g	g		g	g	Non-mag	
										0.25-0.5 mm	0.5-1 mm
96 KKA 5000	Till	11.00	8.50	594.3	527.7	8.7	57.9	7.4		g	g
96 KKA 5003	Till	9.10	6.90	705.5	654.9	7.1	43.5	5.7			2.8
96 KKA 5006	Till	9.30	6.80	467.2	440.0	6.3	20.9	2.9			1.4
96 KKA 5010	Till	9.60	6.65	590.3	555.5	7.2	27.6	4.7			1.8
96 KKA 5017	Till	8.45	5.50	837.2	801.6	5.5	30.1	6.2			2.1
96 KKA 5021	Till	8.20	5.75	680.3	654.7	5.7	19.9	3.4			1.7
96 KKA 5025	Till	10.15	6.35	738.7	678.1	8.5	52.1	7.5			3.9
96 KKA 5029	Till	9.60	6.90	346.7	302.6	6.2	37.9	3.6			1.5
96 KKA 5032	Till	11.75	8.80	849.2	806.1	5.5	37.6	5.1			3.2
96 KKA 5034	Till	10.10	3.30	249.4	237.6	2.0	9.8	1.6			1.7
96 KKA 5041	Till	8.85	7.00	784.3	732.8	8.4	43.1	4.6			2.9
96 KKA 5045	Till	9.45	6.60	268.2	244.7	5.9	17.6	2.5			1.5
96 KKA 5050	Till	10.80	8.05	657.2	573.1	9.0	75.1	8.3			4.2
96 KKA 5055	Till	9.00	8.05	486.4	412.2	5.6	68.4	2.3			1.4
96 KKA 5061	Till	9.05	6.55	481.4	441.4	6.5	33.5	3.8			2.1
96 KKA 5064	Till	9.90	7.20	660.3	609.5	10.2	40.6	5.9			3.3
96 KKA 5066	Till	9.85	5.80	596.0	542.9	12.4	40.7	6.6			4.3
96 KKA 5074	Till	9.70	5.55	624.1	589.4	6.8	27.9	4.1			3.4
96 KKA 5083	Till	10.15	7.60	442.5	393.9	3.0	45.6	6.3			4.0
96 KKA 5088	Till	7.95	6.95	328.5	276.2	5.0	47.3	1.2			0.6
96 KKA 5092	Till	9.05	6.05	617.8	561.7	10.2	45.9	9.1			5.5
96 KKA 5097	Till	9.35	6.60	406.7	356.3	15.8	34.6	5.1			3.4
96 KKA 5100	Till	9.85	6.60	430.9	396.8	6.8	27.3	5.0			2.7
96 KKA 5104	Till	8.80	7.45	360.3	324.9	4.9	30.5	3.1			1.5
96 KKA 5112	Till	10.05	7.05	735.5	647.6	14.8	73.1	13.0			6.9



Appendix 3. Number of grains picked and probed (0.25-1 mm fraction)

Sample Number	Indicator Minerals											
	Pyrope		Mg-Ilmenite		Chromite		Chrome diopside		Zircon		Olivine	
	#picked	#probed	#picked	#probed	#picked	#probed	#picked	#probed	#picked	#probed	#picked	#probed
96 KKA 5000	0	0	0	0	2	2	0	0	1	1	0	0
96 KKA 5003	0	0	0	0	0	0	1	1	0	0	0	0
96 KKA 5006	0	0	0	0	0	0	0	0	0	0	0	0
96 KKA 5010	0	0	0	0	0	0	0	0	0	0	0	0
96 KKA 5017	0	0	0	0	0	0	0	0	0	0	0	0
96 KKA 5021	0	0	0	0	0	0	0	0	0	0	0	0
96 KKA 5025	0	0	0	0	0	0	0	0	0	0	0	0
96 KKA 5029	0	0	0	0	0	0	0	0	0	0	0	0
96 KKA 5032	0	0	0	0	3	3	0	0	0	0	0	0
96 KKA 5034	0	0	0	0	0	0	0	0	0	0	0	0
96 KKA 5041	0	0	0	0	0	0	0	0	0	0	0	0
96 KKA 5045	7	7	2	2	0	0	20	20	1	1	1	1
96 KKA 5050	0	0	1	1	0	0	0	0	0	0	1	0
96 KKA 5055	0	0	1	0	0	0	0	0	2	0	20	0
96 KKA 5061	0	0	0	0	0	0	0	0	0	0	1	0
96 KKA 5064	0	0	0	0	0	0	0	0	0	0	0	0
96 KKA 5066	0	0	0	0	0	0	1	1	0	0	0	0
96 KKA 5074	0	0	0	0	0	0	1	1	0	0	1	1
96 KKA 5083	0	0	0	0	0	0	1	1	0	0	0	0
96 KKA 5088	0	0	0	0	0	0	0	0	0	0	0	0
96 KKA 5092	0	0	2	2	0	0	0	0	0	0	0	0
96 KKA 5097	0	0	0	0	0	0	0	0	0	0	0	0
96 KKA 5100	0	0	2	2	0	0	0	0	0	0	0	0
96 KKA 5104	0	0	0	0	0	0	0	0	0	0	0	0
96 KKA 5112	7	7	4	4	0	0	6	6	3	3	2	2

## Appendix 4.1 Operating conditions and standards for the major element routine "GARNET".

## SUMMARY OF CONDITIONS IN GARNET.EXP AND GARNET.PHY

Cosecant of the take off angle: 1.556

Total number of elements : 11

Number of analyzed elements :10

## CALIBRATION DATA :

	SPC	XTAL	POS.	+BG. OFFSET	-BG. OFFSET	BG SLOPE	PK-BG C/s/nA	SIGMA	PK_TIMs	%REQ. ACCUR	BG_TIM ms
Na	1	PC0	26848	2500	-2500	0.00	1517.62	0.7	10	0.1	5000
K	3	PET	42757	1000	0	1.00	294.38	0.6	10	0.5	5000
Fe	4	LIF	48081	1050	0	1.00	333.18	0.3	10	0.1	5000
Mg	2	TAP	38516	1000	0	1.00	1155.93	0.2	10	0.1	5000
Si	2	TAP	27732	1500	0	1.00	1312.58	0.5	10	0.1	5000
Ca	3	PET	38389	2000	0	1.00	370.99	0.4	10	0.1	5000
Mn	4	LIF	52201	1200	0	1.00	435.75	0.2	10	0.5	4627
Ti	3	PET	31426	1000	0	1.00	803.96	0.1	10	0.1	5000
Cr	3	PET	26193	1000	0	1.00	366.95	0.1	10	0.1	5000
Al	2	TAP	32468	1000	0	1.00	1372.19	0.1	10	0.1	5000

## STANDARD DATA:

	STD	WT	LINE	kV	BEA M
Na	NACL7	0.3930	Ka	20.0	20.0
K	KBR7	0.3290	Ka	20.0	20.0
Fe	MAG1	0.7236	Ka	20.0	20.0
Mg	MGO1	0.6032	Ka	20.0	20.0
Si	QTZ1	0.4674	Ka	20.0	20.0
Ca	WOL1	0.3432	Ka	20.0	20.0
Mn	MN	1.0000	Ka	20.0	20.0
Ti	RUT	0.5895	Ka	20.0	20.0
Cr	CHR1	0.2504	Ka	20.0	20.0
Al	COR1	0.5290	Ka	20.0	20.0

NACL7	Na	0.3930	Cl	0.6070							
KBR7	K	0.3290	Br	0.6710							
MAG1	Fe	0.7236	O	0.2764							
MGO1	Mg	0.6032	O	0.3968							
QTZ1	Si	0.4674	O	0.5326							
WOL1	Ca	0.3432	Fe	0.0030	Mn	0.0012	Si	0.2399	O	0.4127	
MN	Mn	1.0000									
RUT1	Ti	0.5895	Fe	0.0050	Nb	0.0050	O	0.4005			
CHR1	Cr	0.2504	Al	0.0762	Fe	0.2985	Mg	0.0434	Ti	0.0054	V 0.0012
	Mn	0.0015	Ni	0.0012	Si	0.0011	O	0.3211			
COR1	Al	0.5290	O	0.4710							

Appendix 4.2. Counting times for the sample and the calculated minimum detection limits (MDL) for the major element routine "garnet".

ELEMENT	TIME (s)	MDL (ppm)	MDL (oxide wt.%)
Na	10	300	0.040
Si	10	80	0.017
K	10	200	0.024
FE	10	400	0.051
AL	10	100	0.019
CA	10	200	0.028
MN	10	400	0.052
MG	10	200	0.033
TI	10	200	0.033
CR	10	200	0.029

Appendix 5. Electron microprobe data for grains run using the GSC GARNET program.

Mount	Grain	Sample	Colour	Mineral	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	TOTAL
T739	1	96KKA5000K	black	Rutile	0.04	99.29	0.08	0.19	0.17	0.00	0.02	0.00	0.00	0.01	99.80
T739	2	96KKA5000K	black	Zircon	36.51	0.03	0.04	0.00	0.04	0.00	0.00	0.01	0.12	0.01	36.76
T739	3	96KKA5000K	black	Rutile	0.09	99.89	0.14	0.00	0.22	0.01	0.01	0.01	0.00	0.00	100.36
T739	4	96KKA5003K	clear	Diopside	54.11	0.08	0.72	0.31	3.89	0.10	16.08	23.54	0.89	0.01	99.75
T739	5	96KKA5032K	black	Ilmenite	0.03	50.15	0.04	0.03	46.89	1.75	0.11	0.00	0.02	0.00	99.04
T739	6	96KKA5032K	black	Ilmenite	0.06	51.01	0.06	0.00	47.22	0.50	0.49	0.00	0.00	0.00	99.35
T739	7	96KKA5032K	black	Ilmenite	0.07	50.73	0.08	0.12	48.06	0.89	0.04	0.00	0.02	0.01	100.02
T739	8	96KKA5045K	pink	Cr-Pyrop	40.47	0.14	15.47	10.00	7.52	0.42	19.57	6.31	0.00	0.00	99.89
T739	9	96KKA5045K	pink	Cr-Pyrop	40.72	0.21	18.85	6.28	7.53	0.45	20.15	5.21	0.00	0.00	99.41
T739	10	96KKA5045K	pink	Cr-Pyrop	40.98	0.02	20.03	5.16	7.96	0.53	19.87	5.14	0.00	0.00	99.71
T739	11	96KKA5045K	pink	Cr-Pyrop	40.50	0.04	19.23	5.20	8.65	0.56	18.77	6.02	0.00	0.00	98.97
T739	12	96KKA5045K	pink	Cr-Pyrop	41.33	0.72	17.83	6.44	7.68	0.33	20.31	5.39	0.01	0.22	100.24
T739	13	96KKA5045K	clear	Olivine	40.95	0.04	0.03	0.06	8.03	0.13	50.64	0.02	0.00	0.00	99.91
T739	14	96KKA5045K	pink	Cr-Pyrop	40.71	0.45	16.22	8.69	7.43	0.40	19.85	6.06	0.00	0.00	99.80
T739	15	96KKA5045K	pink	Cr-Pyrop	40.62	0.03	16.68	8.51	7.18	0.33	19.02	7.01	0.00	0.01	99.40
T739	16	96KKA5045K	green	HiCr-Diopside	54.70	0.24	1.93	2.53	2.54	0.11	17.10	18.31	2.24	0.06	99.76
T739	17	96KKA5045K	green	HiCr-Diopside	54.53	0.29	2.05	1.94	3.35	0.16	16.67	18.38	2.41	0.01	99.80
T739	18	96KKA5045K	green	HiCr-Diopside	54.62	0.16	2.11	3.73	2.12	0.13	15.83	17.61	3.06	0.01	99.37
T739	19	96KKA5045K	green	Cr-Diopside	55.08	0.26	1.94	1.35	3.18	0.13	17.26	19.12	2.04	0.04	100.41
T739	20	96KKA5045K	green	Cr-Diopside	55.03	0.19	2.60	1.00	2.91	0.08	16.23	19.73	2.19	0.02	99.98
T739	21	96KKA5045K	green	HiCr-Diopside	55.32	0.22	1.88	1.68	2.76	0.14	17.84	18.72	1.76	0.03	100.36
T739	22	96KKA5045K	green	Cr-Diopside	54.62	0.29	1.87	1.22	3.05	0.08	16.81	20.00	1.69	0.04	99.68
T739	23	96KKA5045K	green	HiCr-Diopside	54.60	0.25	1.88	1.55	2.99	0.13	16.89	19.54	1.78	0.01	99.62
T739	24	96KKA5045K	green	Cr-Diopside	54.74	0.26	1.97	0.92	3.32	0.12	16.78	20.28	1.62	0.00	100.00
T739	25	96KKA5045K	green	Cr-Diopside	54.07	0.27	1.93	1.24	3.33	0.09	16.98	18.83	1.82	0.04	98.61
T739	26	96KKA5045K	green	Cr-Diopside	53.53	0.33	2.06	1.08	3.24	0.09	16.58	19.91	1.80	0.05	98.67
T739	27	96KKA5045K	green	Cr-Diopside	54.38	0.32	1.89	0.94	3.26	0.10	16.84	20.46	1.53	0.04	99.77
T739	28	96KKA5045K	green	Cr-Diopside	54.81	0.23	1.90	0.93	3.17	0.11	16.80	20.59	1.56	0.03	100.12
T739	29	96KKA5045K	green	Cr-Diopside	54.78	0.25	1.91	0.90	3.18	0.10	16.69	20.20	1.62	0.04	99.66
T739	30	96KKA5045K	green	Cr-Diopside	53.75	0.29	1.97	0.82	3.20	0.10	16.53	20.12	1.79	0.05	98.62
T739	31	96KKA5045K	green	Cr-Diopside	53.86	0.24	2.00	0.61	3.10	0.14	16.70	20.59	1.55	0.02	98.79
T739	32	96KKA5045K	green	Cr-Diopside	54.05	0.23	1.93	0.97	3.13	0.08	16.43	20.14	1.67	0.03	98.66
T739	33	96KKA5045K	green	Cr-Diopside	53.76	0.18	1.31	0.85	2.92	0.09	16.56	21.47	1.45	0.02	98.61
T739	34	96KKA5045K	green	Cr-Diopside	55.16	0.23	1.91	0.56	3.05	0.09	16.59	21.23	1.48	0.04	100.36

Appendix 5. Electron microprobe data for grains run using the GSC GARNET program.

Mount	Grain	Sample	Colour	Mineral	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	TOTAL
T739	35	96KKA5045K	colorless	Enstatite	56.99	0.11	0.67	0.57	5.74	0.14	34.67	0.55	0.14	0.01	99.57
T739	36	96KKA5050K	black	Ilmenite	0.05	53.88	0.08	0.00	45.62	0.20	0.58	0.01	0.00	0.00	100.42
T739	37	96KKA5050K	colorless	Epidote	37.69	0.12	26.72	0.01	8.11	0.19	0.06	23.71	0.00	0.01	96.62
T739	38	96KKA5061K	colorless	Epidote	37.73	0.09	26.27	0.03	8.77	0.25	0.08	23.59	0.00	0.01	96.83
T739	39	96KKA5066K	green	Cr-Diopside	54.09	0.05	1.25	0.56	2.22	0.12	17.34	23.31	0.41	0.02	99.37
T739	40	96KKA5074K	green	Cr-Diopside	54.29	0.30	1.86	0.79	3.33	0.06	17.42	19.39	1.82	0.05	99.31
T739	41	96KKA5083K	black	Ilmenite	0.05	51.13	0.09	0.03	47.11	0.54	0.49	0.01	0.00	0.00	99.46
T739	42	96KKA5092K	black	Ilmenite	0.06	50.36	0.04	0.00	47.44	0.41	0.19	0.00	0.02	0.02	98.54
T739	43	96KKA5092K	black	Ilmenite	0.10	47.69	0.03	0.02	48.38	1.24	1.12	0.00	0.00	0.03	98.60
T739	44	96KKA5112K	black	Mg-Ilmenite	0.07	52.90	0.51	1.30	31.83	0.26	12.42	0.00	0.00	0.00	99.29
T739	45	96KKA5112K	black	Ilmenite	0.07	50.58	0.02	0.02	47.40	1.10	0.04	0.01	0.00	0.02	99.27
T739	46	96KKA5112K	black	Ilmenite	0.13	51.17	0.07	0.00	47.00	0.59	0.08	0.01	0.00	0.00	99.05
T739	47	96KKA5112K	black	Ilmenite	0.11	50.95	0.07	0.08	47.21	1.42	0.07	0.01	0.00	0.01	99.92
T739	48	96KKA5112K	pink	Cr-Pyropite	40.98	0.04	18.56	6.76	7.53	0.37	19.67	5.65	0.00	0.00	99.56
T739	49	96KKA5112K	pink	Cr-Pyropite	41.21	0.33	19.92	4.42	7.88	0.35	20.79	4.58	0.00	0.00	99.49
T739	50	96KKA5112K	pink	Cr-Pyropite	41.74	0.21	21.84	2.43	8.07	0.39	21.08	4.32	0.00	0.00	100.08
T739	51	96KKA5112K	pink	Cr-Pyropite	41.11	0.21	20.77	3.79	7.49	0.43	20.88	4.67	0.00	0.01	99.38
T739	52	96KKA5112K	pink	Cr-Pyropite	40.63	0.20	17.88	7.70	7.14	0.41	20.38	5.39	0.00	0.00	99.73
T739	53	96KKA5112K	pink	Cr-Diopside	54.87	0.29	2.02	1.12	3.70	0.12	17.19	18.86	1.78	0.05	100.01
T739	54	96KKA5112K	pink	Cr-Diopside	54.81	0.29	2.02	0.50	3.56	0.08	16.69	19.93	1.74	0.01	99.63
T739	55	96KKA5112K	pink	Cr-Diopside	54.55	0.24	1.91	0.50	3.27	0.08	17.02	20.43	1.49	0.02	99.51
T739	56	96KKA5045K	black	Ilmenite	0.09	51.87	0.06	0.00	47.16	0.57	0.16	0.00	0.00	0.00	99.90
T739	57	96KKA5045K	black	Mg-Ilmenite	0.07	52.51	0.55	2.10	31.51	0.29	12.20	0.03	0.00	0.01	99.28
T739	58	96KKA5045K	green	Cr-Diopside	54.81	0.22	1.88	1.30	3.22	0.09	17.11	19.35	1.68	0.03	99.69
T739	59	96KKA5074K	colorless	Olivine	39.87	0.05	0.04	0.06	8.42	0.12	50.30	0.05	0.00	0.01	98.91
T739	60	96KKA5100K	black	Ilmenite	0.08	49.97	0.06	0.00	48.24	0.57	0.07	0.00	0.00	0.00	98.99
T739	61	96KKA5100K	black	Mg-Ilmenite	0.27	53.11	0.49	1.88	30.15	0.31	12.60	0.02	0.00	0.02	98.84
T739	62	96KKA5112K	pink	Cr-Pyropite	40.76	0.68	17.92	6.34	6.97	0.35	20.55	5.29	0.02	0.00	98.87
T739	63	96KKA5112K	green	Cr-Diopside	54.69	0.22	2.00	0.78	3.59	0.13	17.50	18.68	1.74	0.03	99.36
T739	63	96KKA5112K	green	Cr-Diopside	54.50	0.22	2.01	0.91	3.65	0.11	17.38	18.67	1.76	0.03	99.24
T739	64	96KKA5112K	green	Cr-Diopside	54.42	0.27	1.92	0.95	3.61	0.15	17.30	18.48	1.75	0.04	98.90
T739	65	96KKA5112K	colorless	Olivine	40.94	0.00	0.02	0.05	7.60	0.12	50.77	0.02	0.00	0.01	99.54
T739	66	96KKA5112K	colorless	Olivine	40.54	0.03	0.01	0.08	8.67	0.15	50.38	0.05	0.00	0.01	99.93