CHEMICAL CHARACTERISTICS OF KIMBERLITE INDICATOR MINERALS FROM THE DRYBONES BAY AREA (NTS 85I/4), NORTHWEST TERRITORIES

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INTRODUCTION

This Open File presents the mineral chemistry and other chemical characteristics of kimberlite indicator minerals from the Drybones Bay area, N.W.T. (Fig. 1). As part of the ongoing Yellowknife EXTECH program, a GSC surficial geology study in 1999 undertook regional till sampling in the Yellowknife and Drybones Bay areas. Detailed till sampling was also undertaken in the Drybones Bay area in view of the presence of the diamondiferous Drybones kimberlite. This is part of a glacial dispersal study which is currently focussing on an area approximately 4 km southeast of Drybones Bay, in a region informally called Mud Lake (Fig. 2). This report supercedes Open File D3861 (Kerr et al., 2000) which presented the preliminary counts of suspected kimberlite indicator minerals, as well as counts of gold grains and gold geochemical data for till samples in the Yellowknife and Drybones Bay area, N.W.T.

REGIONAL SETTING

Bedrock geology

The bedrock in the Drybones Bay area constitutes part of the southern Slave Structural Province of the Canadian Shield, and it outcrops throughout all of the study area. Archean granitoid rocks (granodiorite, tonalite, granite) predominate, although metasediments (schists) of the Yellowknife Supergroup are present in the most southern regions along Great Slave Lake (Henderson, 1985). A kimberlite pipe was discovered in 1994 in Drybones Bay, approximately 45 km southeast of Yellowknife, and remains the only kimberlite discovered to date along the southwestern margin of the Slave Craton. Water depth in the bay averages 38 m, and the kimberlite is overlain by 67-77 m of lake bottom sediments. The Drybones kimberlite is intruded into the Archean granitoids, and has yielded preliminary dates of about 441-485 Ma (Kretschmar, 1997). It is approximately 900 m long by 400 m wide. Its normal-polarity magnetic expression is subtle in comparison with the host granites. The kimberlite is a large complex intrusion consisting of 2 or 3 separate phases with 7 distinct lithotypes forming a crater facies, diatreme facies and a thin basal facies; each lithotype is diamond-bearing. Mineralogy consists of abundant olivine, ilmenite, pyrope and chromite in a matrix of serpentine, clays, calcite and chlorite (Kretschmar, 1997).

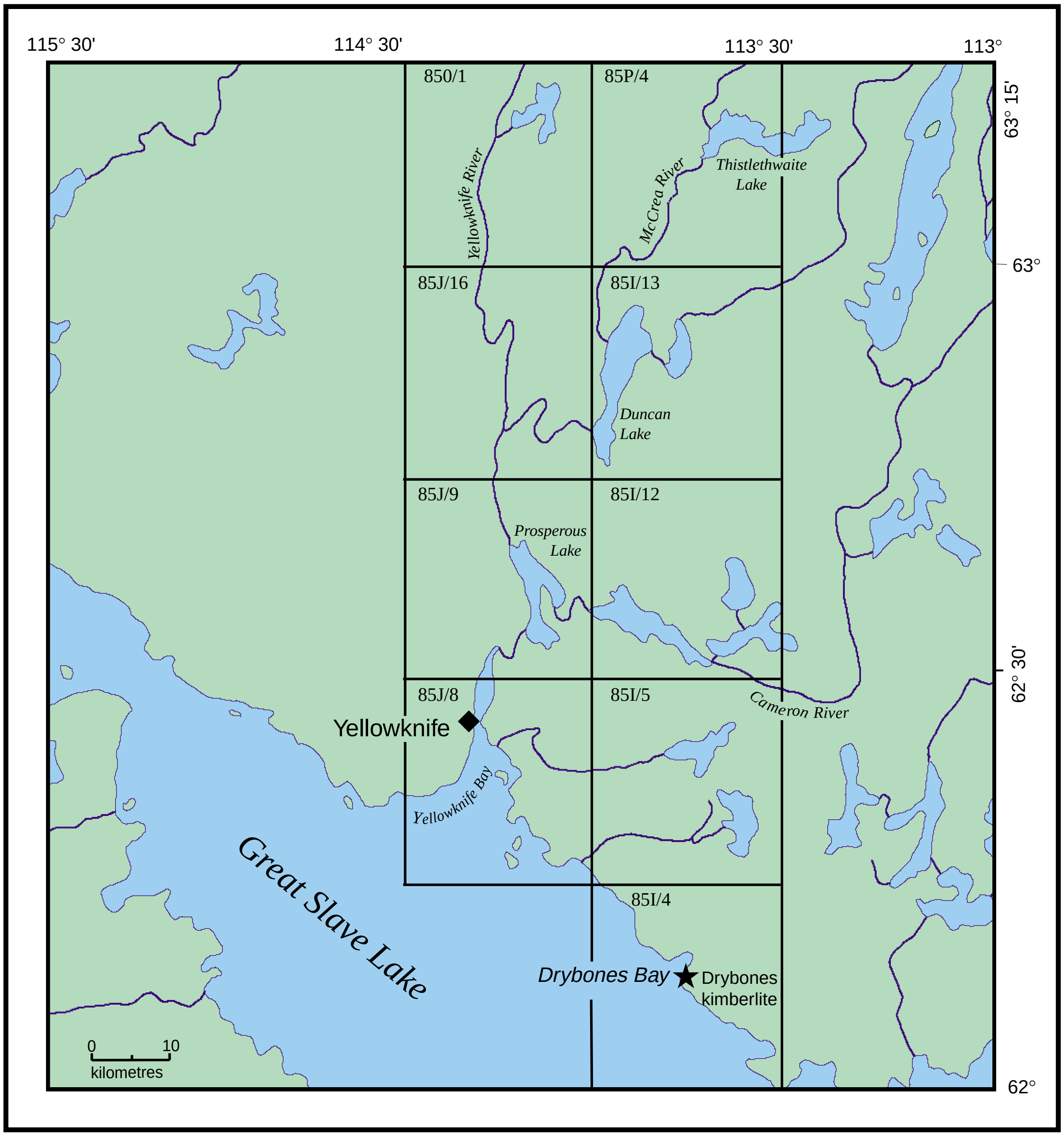

Figure 1. Location map of the Drybones Bay area, within NTS 85I/4, NWT.

Figure 2. Aerial view of the Mud Lake area, Drybones Bay, NWT.

Surficial geology

Much of the terrain in the Drybones Bay area is generally of low relief and < 180 m a.s.l. The landscape consists mainly of bare to boulder-strewn outcrops with glacial sediments overlain by organics in topographic lows between outcrops. Till is the prevalent surficial sediment in the study area. It is a loosely compact, stony, matrix-supported diamicton, with the matrix ranging from coarse to fine sand with minor amounts of silt. Clasts of various lithologies range in size from small pebbles to large boulders, and are subangular to subrounded. It is generally <2 m thick, and forms a discontinuous veneer over bedrock outcrops. Glaciofluvial sediments are relatively uncommon, and consist of fine sand to cobbles in the form of eskers, kames and subaqueous outwash. Glaciolacustrine deposits consist of poorly to moderately sorted coarse to fine sand, silt and clay estimated to be up to 20 m thick, with variable amounts of pebbles, cobbles and boulders, occurring preferentially in topographic lows. Stratigraphically, these sediments may overlie till, outwash and bedrock. Glaciolacustrine deposits are associated with glacial Lake McConnell which inundated the area during deglaciation. Organic sediments consist of peat formed by the accumulation of fibrous, woody and mossy vegetative matter. Peat is up to 1 m thick or more in bogs and other wetlands underlain by fine-grained glaciolacustrine sediments. Sedges, shrubs and open forests of stunted black spruce grow on these sediments. Yellowknife lies within the zone of discontinuous permafrost, where permafrost is localized or absent (Wolfe, 1998).

Glacial history

The last glacial episode to affect the study area was the Late Wisconsin glaciation, which reached its maximum extent about 18 000 years ago. During this period, the Laurentide Ice Sheet advanced to the southwest and eventually retreated towards the northeast. The Yellowknife region was ice covered to about 11 000 BP and became ice-free by about 10 000 BP (Dyke and Prest, 1987). Ice flow indicators relate to ice movement towards the southwest (Fig. 3), representing the last phase of ice flow which occurred prior to and during deglaciation. Minor variations in local ice flow are likely the result of topographically controlled bedrock highs and lows as the ice sheet thinned and receded. Glacial Lake McConnell, a large ice marginal lake, formed along the western margin of the retreating ice, and occupied the combined basins of Great Bear, Great Slave and Athabasca

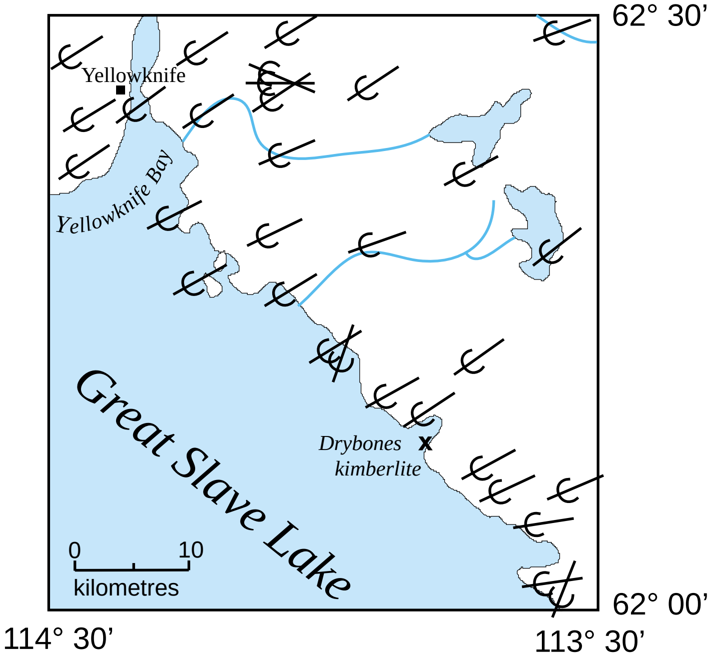

Figure 3. Summary of regional ice flow in the Drybones Bay area.

lakes, up to an elevation of 280 m (Craig, 1965). Below the limit of inundation by glacial Lake McConnell, there is evidence of widespread washing of till, lake sediments, glaciofluvial deposits and bedrock by wave action which occurred as lake levels fell. Following subareal exposure, some areas experienced fluvial activity and erosion. Great Slave Lake reached its present level of 157 m a.s.l. by about 8 500 BP (Vanderburgh and Smith, 1988).

METHODS

Sample collection and processing

In the field, till was collected to obtain representative samples of this surficial material. All samples were taken from shallow hand-dug pits at depths ranging between 20 and 70 cm. No preconcentration was done in the field although an attempt was made to remove most of the large pebbles by hand. Four regional till samples weighing approximately 10 kg each were collected in the Drybones Bay/Mud Lake area (99KKA6050K, 99KKA6057K, 99KKA6059K, and 99KKA6060K). A 10 kg till sample (99KKA6058K) was taken immediately down-ice (west) of the Drybones kimberlite in order to characterize the kimberlite indicator mineral assemblage associated with till. An additional 25 till samples (99MLT01 to 25) weighing approximately 20 to 30 kg were obtained as part of a detailed till sampling program in the Drybones Bay/Mud Lake area.

Samples were processed at Overburden Drilling Management Ltd., Nepean, Ontario (Fig. 4). A 5 to 25 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. All fractions have been archived. Note that for samples MLT 4 and 5, only 50% and 80% of the concentrate respectively was examined randomly, due to the large number of grains.

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

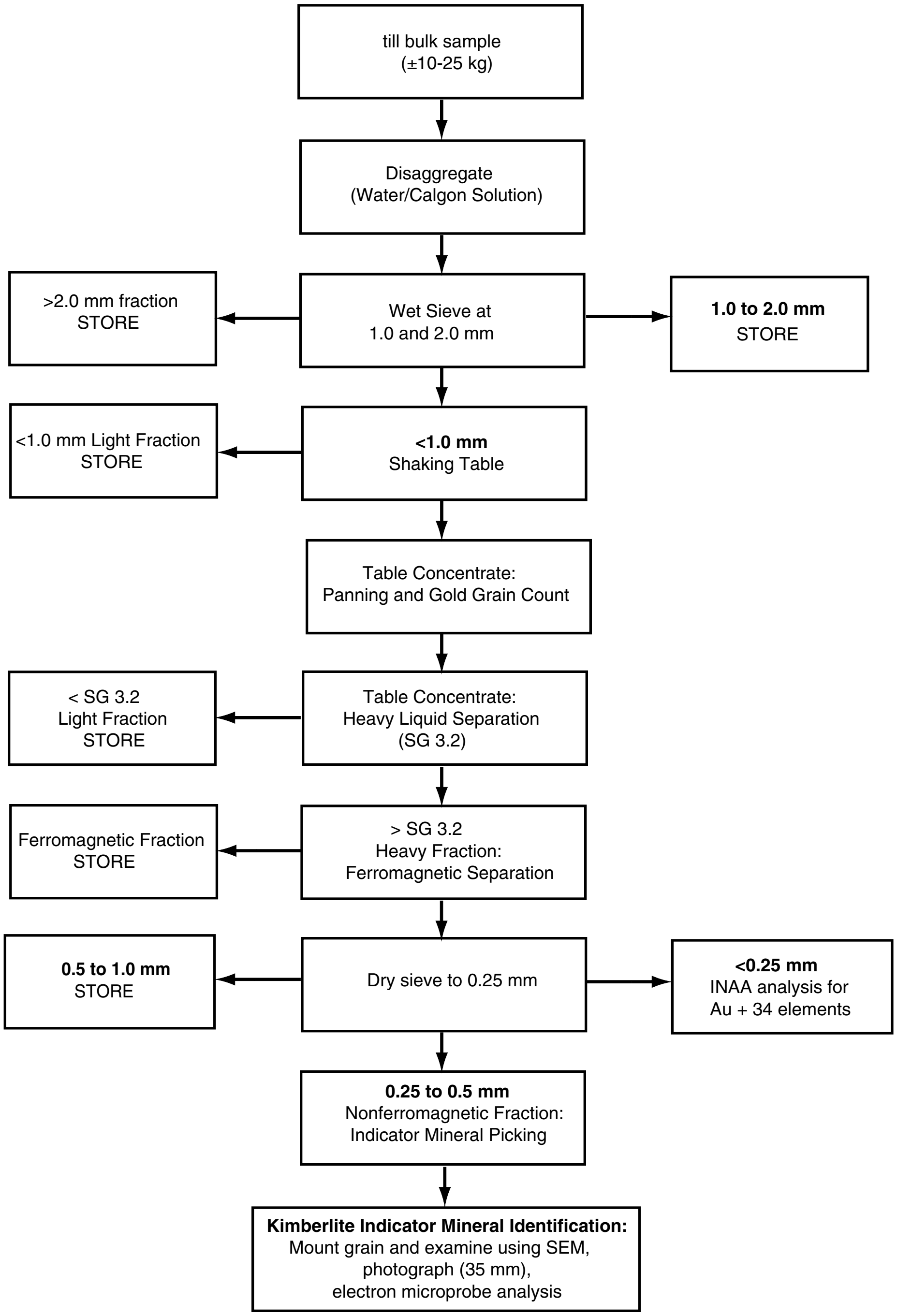

Figure 4. Sample processing flow diagram for till sample preparation at Overburden Drilling Management Ltd. Processing includes preparation of heavy mineral concentrates for gold grain counting, kimberlite indicator mineral picking by I. & M. Morrison Geological Services, and microprobing by GSC.

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. Some of 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 shape). For all samples, the nonferromagnetic heavy mineral concentrates in the 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. 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. Minerals identified in the picking stage included pyrope garnet, eclogitic garnets, Cr-diopside, ilmenite and chromite. Note that in some samples, time and financial constraints did not permit the probing of the entire picked fraction.

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, following methods similar to those reported by Stirling and Pringle, (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.

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 end members (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 end member 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 in Table 2) 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_2O_3 while some other authors have used a 0.5 wt.% Cr_2O_3 cutoff (Fipke, 1989; Thorleifson et al. 1994).

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.

Table 1. Mineral classification

Almandine	< 21 wt.% MnO <	Spessartine
Almandine	< 15 wt.% MgO <	**Pyrope**
Almandine	< 17 wt.% CaO <	Grossular
Andradite	< 11 wt.% Al_2O_3 <	Grossular
Andradite	< 2 wt.% TiO_2 <	Melanite
Pyrope	< 15 wt.% Cr_2O_3 + 17 wt.% CaO <	Uvarovite
Pyrope	< 2 wt.% Cr_2O_3 <	**Cr-Pyrope**
Andradite	< 2 wt.% Cr_2O_3 <	Cr-Andradite
LoCr-Diopside	< 1 wt.% Cr_2O_3 <	**Cr-Diopside**
Cr-Diopside	< 1.40 wt.% Cr_2O_3<	**HiCr-Diopside**
Chromite	< Cr_2O_3/Al_2O_3 = 1.5 <	**Cr-Spinel**
Chromite	< 11 wt.% MgO + Cr_2O_3/Al_2O_3 <1.5 <	**Magnesio-chromite**
Chromite	< 3 wt.% TiO_2 <	**Ti-Chromite**
Rutile	< 15 wt.% FeO_{tot} <	Fe-Rutile
Ilmenite	< 5 wt.% MgO <	**Mg-Ilmenite**
Ilmenite	< 53 wt.% FeO_{tot} <	Ilmenite (altered)
Ti-Magnetite	< 18 wt.% TiO_2 <	Ilmenite (altered)
Hematite	< 2 wt.% TiO_2 <	Ti-Magnetite

CHEMICAL CHARACTERISTICS OF SOME KIMBERLITE INDICATOR MINERALS

Pyrope garnet

Pyrope is chemically characterized by a high MgO content (>13 wt.% MgO) and varying amounts of Cr_2O_3 ranging from < 1 up to 15 wt. %. Pyropes with > 2 wt.% Cr_2O_3 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_2O_3 ratio. Kimberlites that contain pyropes in the subcalcic harzburgite field (essentially "G10" garnets) are potentially diamondiferous (Gurney, 1984; Gurney and Moore, 1993; Fipke, 1989). Low-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_2O_3 as well as diagnostic amounts of Na_2O (> 0.08%) and TiO_2 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_2O_3 values (up to 6 wt.%, Stephens and Dawson, 1977). They overlap at the lower end of the Cr_2O_3 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_2O_3 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 probabaly derived from other bedrock sources. Characteristically emerald green Cr-diopsides with high Cr_2O_3 (>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 prep).

Ilmenite

Mg-rich ilmenites with > 5 wt.% MgO (also called picroilmenites) are characteristic of kimberlites (Mitchell, 1973; Haggerty, 1975). Ilmenites from other ultrabasic rocks (with the possible exception of carbonatites) or from crustal rocks, which are much more common, usually have MgO < 3 or 4 wt.%. Samples with high MgO and Cr_2O_3 indicate good diamond preservation potential (Gurney, 1984).

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.% Cr_2O_3 to (magnesio-)chromites with > 60 wt.% Cr_2O_3. Similar to Cr-diopsides, the Cr_2O_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.% Cr_2O_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 .

KIMBERLITE INDICATOR MINERALS IN THE DRYBONES BAY AREA

The majority of the 1700 analyzed grains listed in Table 2 are ilmenites (both low-Mg, i.e regional ilmenites (n=590), and high-Mg or low-Mg/high Cr kimberlitic ilmenites, including Mn-ilmenites (n=474)). There are only 31 chromites. The analyzed silicates are dominantly garnet, most of which are mantle derived Cr-pyropes (n=504), the others are crustal almandines and spessartines (n=14). Only three Cr-diopsides were found. Other minerals analyzed in this study were picked because they resembled potential Mg-ilmenite: black Fe-rutile (n=15) and rutile (n=55). Fe-rutile and rutile may represent altered ilmenite or a mixture of ilmenite – rutile – hematite. The remainder of the oxides grains are hematite (n=12). In addition to minerals listed in Table 2, olivine grains were recovered (n=4): 2 grains from MLT-2 and I grain from each of MLT-9 and 13.

Most ilmenites have low totals and low TiO_2 , which might be due to either analytical problems or strong oxidation/alteration. All ilmenites were plotted in a MgO vs. Cr_2O_3 - diagram (Fig. 5). Several populations are visible in this figure: regional ilmenites have low Cr (close to 0) and up to 3 wt.% MgO. Another population has similar MgO values (< 4 wt.%) but higher Cr_2O_3 (‡ 0.47 wt.%) and contains appreciable MnO (up to 4 wt.%). This population grades into a thick cluster of kimberlitic ilmenites with comparatively low MgO (4 to 7 wt.%) and variable Cr_2O_3 (increasing with increasing MgO). These medium-Mg-ilmenites are found dominantly in samples MLT4, 5, 6 and 6059K (Fig. 6). A second population of kimberlitic ilmenites has higher MgO (7 to 11 wt.%) and Cr_2O_3 values that increase at the low end of their MgO-spectrum, overlapping with the medium-MgO kimberlitic ilmenites at 6 to 8 wt.% MgO. These high-MgO ilmenites are found exclusively in sample 6058K (the Drybones kimberlite till sample). Both kimberlitic ilmenite population define the lower part of a parabola (Haggerty, 1975) with low Cr_2O_3 in the center which increases at the low and/or the high end of the MgO spectrum up to 4 wt.% Cr_2O_3. It is not clear whether the Mn-ilmenite population (low MgO, > 0.47 wt.% Cr_2O_3) is separate from the medium-Mg ilmenite population or if they form a continuum (they occur in the same proportions in the same samples and the medium Mg-ilmenites also contain similar amounts of MnO). Although such low-MgO, Mn-bearing ilmenites are unusual in kimberlites, they do occur (Mitchell, 1986), and can be considered here as kimberlitic due to their comparatively high Cr_2O_3 and Nb contents.

Sample	**m-gar**	alm	spess	**CD**	**chro**	**Mg-ilm**	**Mn-ilm**	ilm	Fe-rut	rut	hem	TOTAL
MLT1	**11**					**3**		4				18
MLT2				**1**		**1**	**1**	21				24
MLT3								10				10
MLT4	**105**				**6**	**35**	**21**	90	3	15	7	282
MLT5	**100**				**3**	**48**	**11**	66	2	11	3	244
MLT6	**41**				**5**	**23**		45		8		222
MLT7				**1**		**1**		3		1		6
MLT8	**4**					**11**	**1**	26			1	43
MLT9	**5**		1			**1**	**1**	17	1			26
MLT10	**2**							20				22
MLT11	**2**							5				7
MLT12	**1**					**1**		24				26
MLT13							**1**	21		1		23
MLT14								1				1
MLT15								11	1			12
MLT16								6				6
MLT17								7				7
MLT18	**27**		7	**1**		**7**	**2**	65		2		111
MLT19								5				5
MLT20	**2**							5	1			8
MLT21	**1**							6				7
MLT22								12				12
MLT23	**1**							10				11
MLT24	**1**							6				7
MLT25								13				13
6050K								24				24
6057K								2				2
6058K	**103**	1	3		**8**	**192**		5				312
6059K	**100**	1	1		**8**	**97**	**16**	52	6	17	1	299
6060K					**1**			8	1			10
Total	**506**	2	12	**3**	**31**	**420**	**54**	590	15	55	12	1700

Table 2. Heavy minerals and kimberlite indicator minerals (in bold type) in till samples from the Drybones Bay area: 0.25-0.5 mm fraction.

m-gar=mantle garnets (Cr-pyrope+2 almadine)
alm= regional almadine
spess=spessartine
CD=Cr-diopside
chro=chromite
Mg-ilm=Mg-ilmenite

Mn-ilm=Mn-ilmenite
ilm=regional ilmenite
Fe-rut=Fe-rutile
rut=rutile
hem=hematite

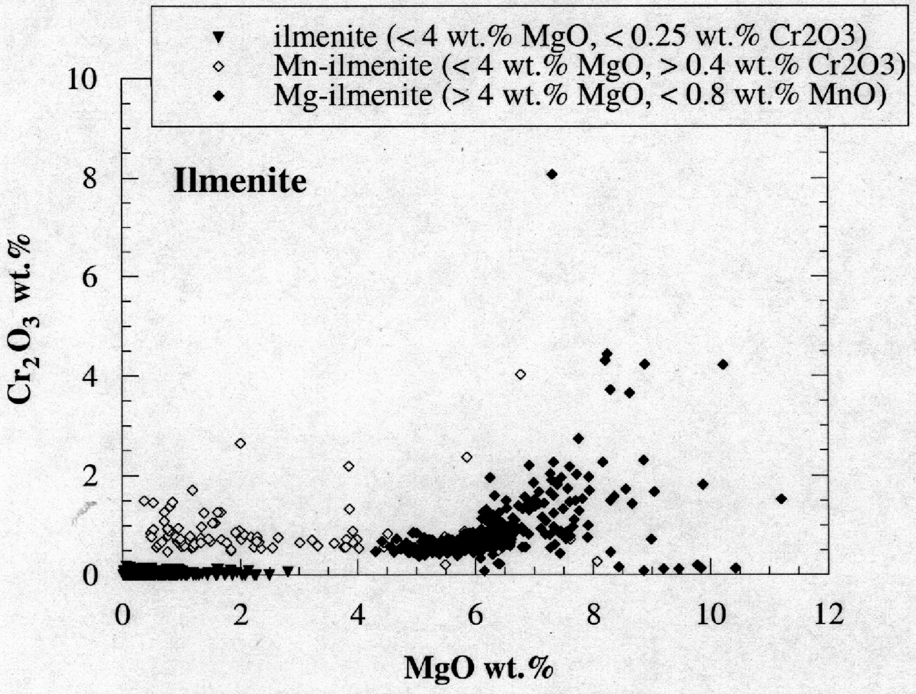

Figure 5. Cr2O3 vs MgO plot for ilmenites, Mn-ilmenites, and Mg-ilmenites from □ the Drybones Bay area.

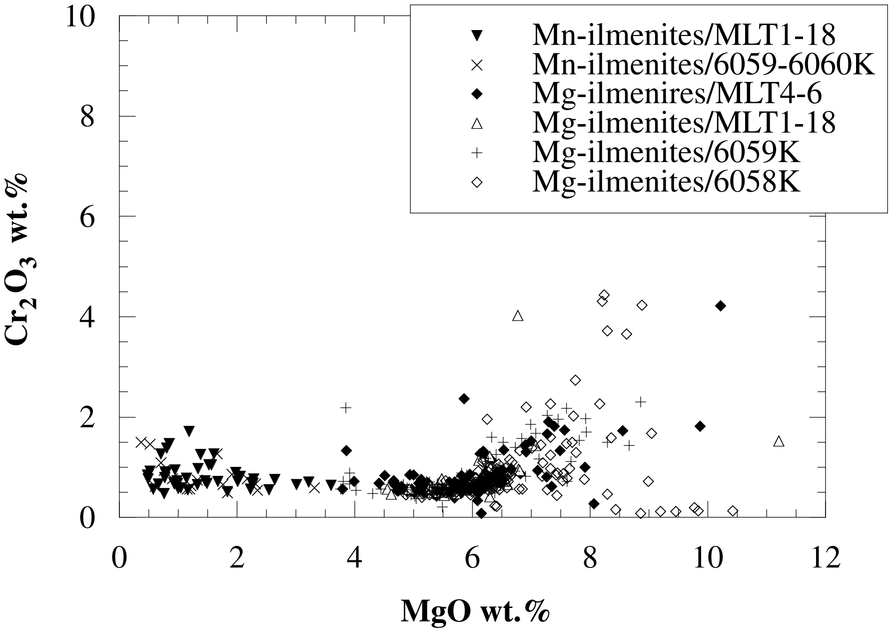

Figure 6. Cr2O3 vs MgO plot for Mn-ilmenites and Mg-ilmenites according to sample number from the Drybones Bay area.

The ilmenite compositions define three or four different populations, two of which are clearly kimberlitic, indicating that indicator minerals of at least two kimberlites appear in the heavy mineral concentrates. One is represented by sample 6058K (Drybones kimberlite) and the other by samples MLT4, 5 6 and 6059K (Mud Lake area). The latter samples have, for kimberlites, unusual ilmenite compositions characterized by comparatively low MgO (from 0.25 to 8 wt.%) and MnO values up to 4 wt.%. The rutiles and Fe-rutiles encountered in the same samples are considered alteration products of kimberlitic Mg-ilmenites since they contain appreciable Cr and Nb.

The chromites plot in an area typical for kimberlitic chromites; although Kretschmar (1997) reported chromites with diamond-inclusion chemistry from the Drybones kimberlite, none of the grains from this study fall into the fields of diamond intergrowths or diamond inclusions (Fig. 7). A greater number of chromite grains may be required for additional microprobe studies.

The garnets are concentrated in samples MLT4, 5, 6 and 6058K and 6059K (Fig. 8). The mantle garnets were divided according to rock type (Fig. 9) using cluster analysis (a macro devised by G. Palidwor, 1994). Most garnets were labeled harzburgitic (corresponding to G10 in Dawson & Stephen's (1975) classification) due to their high Cr_2O_3 and low FeO contents , however, their CaO levels are too high to be derived from harzburgites (which are depleted in CaO and hence lack cpx). They are more likely to come from cpx-bearing parageneses such as wehrlites or pyroxenites, however, very little cpx was recovered from the heavy mineral concentrates. Kretschmar (1997) also reported high Ca and Cr pyrope populations. Only a few very Cr-rich (dunitic) garnets fall into the subcalcic field of garnets coexisting with diamonds (Sobolev, 1977) and only an additional few fall below the 85% line of Gurney (1984). No megacryst garnets (TiO_2-rich , Cr-poor pyropes with 4 to 5 wt.% CaO) were found and the only two eclogitic/ pyroxenitic garnets (found in sample 6058K) are from non-diamondiferous eclogite or pyroxenite (Schulze, 1999).

The few Cr-rich and CaO-poor garnets point to the existence of potentially diamond-bearing depleted harzburgite or dunite in the mantle assemblage sampled by the kimberlite(s). However, the low MgO and (inferrred) high Fe_2O_3 (indicative of oxidizing conditions) of most ilmenites indicates that the diamonds might not have survived the ascent to the surface.

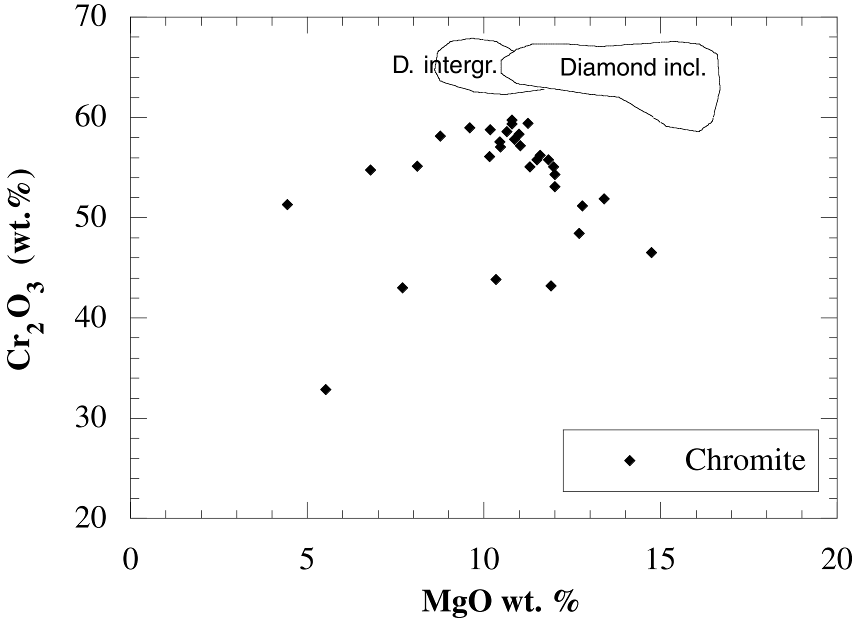

Figure 7: Cr2O3 vs MgO plot for chromites from the Drybones Bay area.

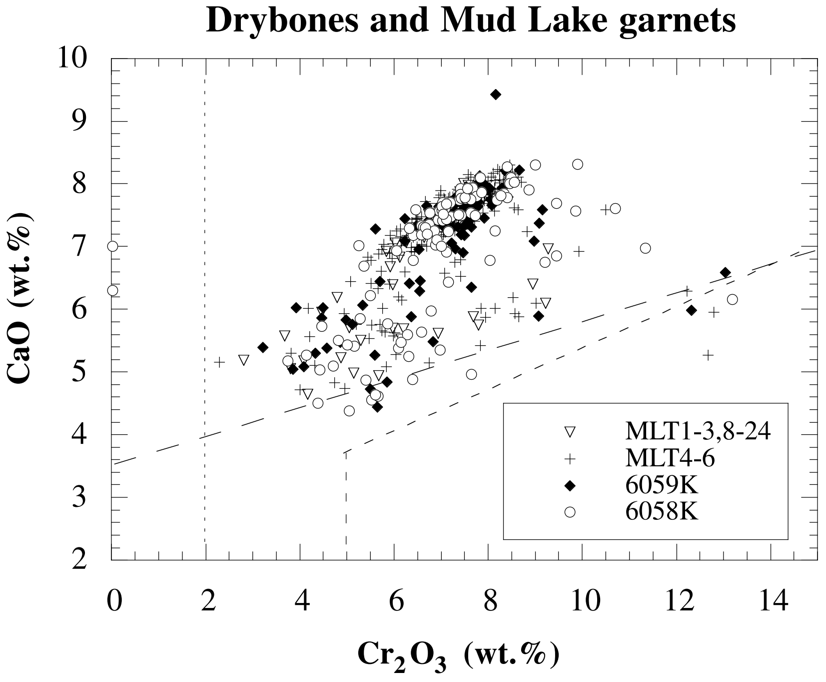

Figure 8: CaO vs Cr2O3 plot for garnets according to sample number from the
 Drybones Bay area

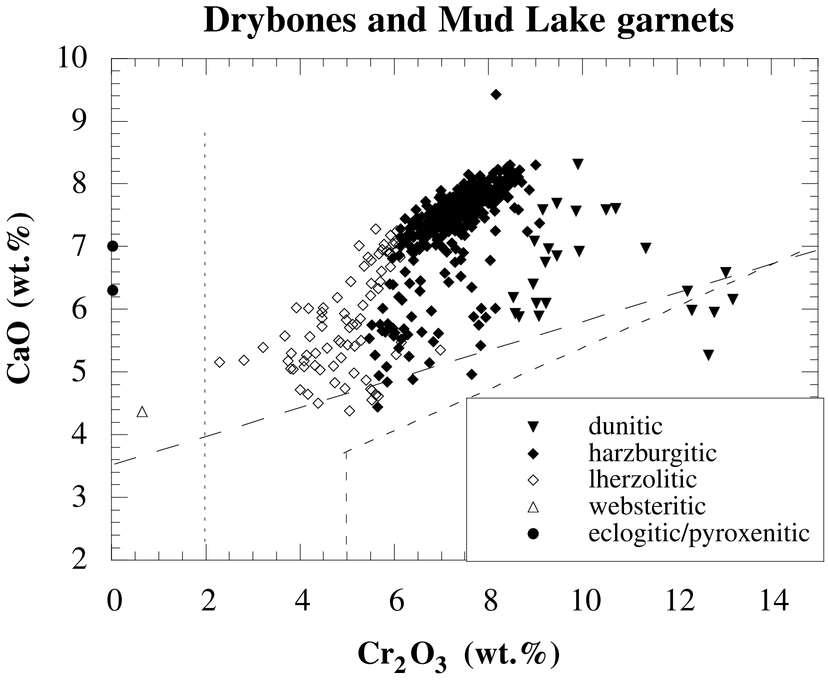

Figure 9: CaO vs Cr2O3 plot for mantle garnets divided according to rock type from the Drybones Bay area.

The only three Cr-diopsides found are Cr-rich (0.5 to 1.33 wt.% Cr_2O_3) with high MgO (100Mg/(Mg+Fe) = 88 to 92), typical of mantle-derived cpx occurring in kimberlites.

Although Kretschmar (1997) reported olivine to be the most abundant macrocryst mineral, few grains were recovered in this study. Olivine serpentinization is complete in the uppermost strata of the volcaniclastic tuff, and this weathered material was likely eroded and incorporated into the till, as opposed to relatively fresh material from the deeper diatreme facies.

CONCLUSIONS

Till sampling is effective as a kimberlite exploration tool. Electron microprobe studies have shown that indicator minerals of at least two distinct kimberlites appear in the heavy mineral concentrates recovered from till samples in the Drybones Bay area. Clearly, the sample from site 6058K located immediately down-ice (west) of the Drybones kimberlite, relates to this diamondiferous pipe. The MLT sample series, more specifically MLT4, 5, 6 and 6059K in the Mud Lake area, 4 km southeast of Drybones Bay, relate to an undiscovered kimberlite(s).

The relatively large number of indicator minerals recovered in the Mud Lake till samples is indicative of close proximity to their kimberlitic source, in view of the regional background of 0 grains. Ice flow patterns suggest a source likely a short distance up-ice (east/northeast) of these samples because indicator grains originating from the kimberlite(s) would be transported southwestward in till. However, additional till sampling is required to further define the source in view of the possibility that the till may have been reworked briefly by the waters of glacial Lake McConnell, accounting for the lack of a typical linear dispersal train.

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REFERENCES

Craig, B.G.

1965: Glacial Lake McConnell, and the surficial geology of parts of Slave River and Redstone River map-areas, District of Mackenzie; Geological Survey of Canada, Bulletin 122, 33 p.

Dawson J.B., and Stephens, W.E.

1975: Statistical classification of garnets from kimberlite and associated xenoliths; Journal of Geology, v. 83, p. 589-607.

Deer, W.A., Howie, R.A., and Zussman, J.

1978: Rock forming minerals. Vol. 2A, Single-chain silicates, second edition, Longmans, London, 668 p.

Deer, W.A., Howie, R.A. and Zussman, J.

1997: Rock-forming Minerals, Vol. 1A Orthosilicates, second edition; The Geological Society, London, 919 p.

Dyke, A.S. and Prest, V.K.

1987: Paleogeography of northern North America 11 000 - 8 400 years ago; Geological Survey of Canada, Map 1703A, 3 sheets, scale 1:12 500 000.

Fipke, C.E. (ed.)

1989: The development of advanced technology to distinguish between diamondiferous and barren diatremes; Geological Survey of Canada, Open File Report 2124, 559 p. and 2 microfiche appendices.

Griffin, W.L., Ryan, C.G., Gurney, J.J., Sobolev, N.V., and Win, T.T.

1994: Chromite macrocrysts in kimberlites and lamproites: geochemistry and origin; in Kimberlites, Realated Rocks and mantle Xenoliths, Proceedings of the Fifth International Kimberlite Conference, Araxa, Brazil, 1991, H.O.A. Meyer and O.H. Leonardos, eds. CPRM Special Publication 1A, p. 366-377.

Gurney, J.J.

1984: A correlation between garnets and diamonds, in Kimberlite Occurrence and Origins; in A basis for Conceptual Models in Exploration, J.E. Glover and P.G. Harris, eds., University of Western Australia, Publication 8, p. 376-383.

Gurney, J.J. and Moore, R.O.

1993: Geochemical correlation between kimberlitic indicator minerals and diamonds; in Diamonds: Exploration, Sampling and Evaluation, Short Course Proceedings, Prospectors and Developers Association of Canada, p. 147-171.

Haggerty, S.E.

1975: The chemistry and genesis of opaque minerals in kimberlites; Physics and chemistry of the Earth's Interior, v. 9, p. 195-307.

Henderson, J.B.

1985: Geology, Yellowknife - Hearne Lake, District of Mackenzie, Northwest Territories; Geological Survey of Canada, Map 1601A, scale 1: 250 000.

Kerr, D.E., Smith, D., and Wilson, P.

2000: Anomalous kimberlite indicator mineral and gold grain abundances, Drybones Bay and Yellowknife area, Northwest Territories; Geological Survey of Canada, Open File D3861.

Kretschmar, U.

1997: Drybones Bay kimberlite: summary and exploration update; Exploration Overview 1996, NWT Geology Division, Indian and Northern Affairs Canada, Yellowknife, p. 3-27 to 3-28.

LeMaitre, R.W.

1982: Numerical Petrology - Statistical Interpretation of Geo-chemical data; developments in Petrology 8, Elsevier Science Publishing, Amsterdam, New York, 281 p.

McCandless T.E., and Gurney, J.J.

1989: Sodium in garnet and potassium in clinopyroxene: criteria for classifying mantle xenoliths; in Kimberlites and Related Rocks, vol. 2, Edited by J. Ross, Geological Society of Australia, Vol. 14, p. 827-832.

McClenaghan, M.B., Kjarsgaard, I.M., Stirling, J.A.R., Pringle, G. and Crabtree, D.
1993: Chemistry of kimberlite indicator minerals in drift from the Kirkland Lake area, northeastern Ontario; Geological Survey of Canada, Open File 2761, 375 p.

McClenaghan, M.B., Kjarsgaard, B., Kjarsgaard, I.M., and Paulen, R.
In prep: Mineralogy and geochemistry of the Paddie kimberlite and associated glacial sediments, New Liskeard, Ontario, Geological Survey of Canada, Open File XXXX.

Mitchell, R.H.
1973: Magnesium ilmenite and its role in kimberlite petrogenesis; Journal of Geology, v. 81, p. 301-311.

Mitchell, R.H.
1986: Kimberlites: mineralogy, geochemistry, and petrology; Plenum Publishing Corporation, New York, 442 p.

Palidwor, G.
1994: A paragenetic classification system for garnets from mantle xenoliths and kimberlites; Unpublished Bachelor's Thesis, University of Ottawa. 35 p.

Pouchou, J.L., and Pichoir, F.
1984: An new model for quantitative X-ray microanalysis; La Recherche Aerospatiale, vol. 3, p. 167-192.

Schulze, D.J.
1995: A guide to the recognition and significance of kimberlite indicator minerals; in Diamonds-theory and exploration, Geological Association of Canada, Short Course 20, p. 1-39.

Schulze, D.J.

1999: The significance of eclogitic and Cr-poor megacryst garnets in diamond exploration; Exploration and Mining Geology, v.6, p.349-366.

Sobolev, N.V.

1977: Deep seated inclusions in kimberlites and the problem of the composition of the upper mantle; American Geophysical Union, Washington, 279 p.

Stephens, W.E, and Dawson, J.B.

1977: Statistical comparison between pyroxenes from kimberlites and their associated xenoliths; Journal of Geology, v. 85, p. 433-449.

Stirling, J.A., and Pringle, G.J.

1996: Tools of investigation: the electron microprobe and scanning lectron microscope; in Searching for diamonds in Canada, Edited by A.N. Lecheminant, D.G. Richardson, R.N.W. DiLabio, and K.A. Richardson, p. 47-53. Geological Survey of Canada, Open File 3228, 268 p.

Thorleifson, L.H., Garrett, R.G. and Matile, G.

1994: Praire kimberlite study - indicator mineral geochemistry; Geological Survey of Canada, Open File 2875.

Vanderburgh, S. and Smith, D.G.

1988: Slave River delta: geomorphology, sedimentology and Holocene reconstruction; Canadian Journal of Earth Sciences, vol. 25, p. 1990-2004.

Willis, J.P.

1993: Course on the theory and practice of XRF spectrometry; University of Western Ontario, p. 5-17 to 5-24.

Wolfe, S.A.

1998: Living with frozen ground. A field guide to permafrost in Yellowknife, Northwest Territories; Geological Survey of Canada, Miscellaneous Report 64, 71 p.