VIIIth
International
KIMBERLITE
conference

Northern Ontario Field Trip Guidebook

29 June - 5 July 2003

Prepared for the VIIIth International Kimberlite Conference

NORTHERN ONTARIO FIELD TRIP GUIDEBOOK

Guidebook Prepared for the VIIIth International Kimberlite Conference,
Northern Ontario Field Trip
June 29 –July 5, 2003

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Geological Survey of Canada

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NORTHERN ONTARIO FIELD TRIP ITINERARY

Sunday June 29, 2003

Participants meet at Pearson International Airport, Toronto, for 17:35 flight to Sault Ste. Marie.

Monday June 30, 2003
Day 1. Sault Ste. Marie to Wawa

Depart Sault Ste Marie at 6:30 AM

Scenic stop en route to Wawa along Lake Superior

Wawa area ; Sandor diamondiferous lamprophyre occurrence

Wawa area; diamond-bearing volcaniclastic rocks Pele Mountain (Moet and Mumm occurrences) and Band-Ore (area B and Engagement Zone) properties

Tuesday July 1 , 2003
Day 2. Wawa to Chapleau

Depart Wawa at 7:30 AM. See Appendix 1a, b.

Wawa area; Nicholson dyke

Wawa area, olivine monchiquite dyke

Wawa area; lamprophyre dykes at the Parkhill, Darwin, and Surluga Mines

Dalton area; lamprophyre dykes at the Fletch and East C occurrences;

Wednesday July 2, 2003
Day 3. Chapleau to Buffonta to Kirkland Lake

Depart Chapleau at 7:00 AM

Transect across the Kapuskasing Structural Zone from Chapleau to Foleyet

Stop 1. Transition from vertical to horizontal structures, at amphibolite grade

Stop 2. Amphibolite to granulite transition

Stop 3. Granulite grade straight gneiss,

Stop 4. Granulites at 10 kbar, with well developed metamorphic modal layering

Stop 5. Ivanhoe Fault (west side); brittle faults and psuedotachylite

Buffonta kimberlite

Kimberlite boulders in Munro esker

Thursday July 3, 2003
Day 4. Lake Timiskaming area

Leave Quality Inn New Liskeard at 7:30 AM

McLean kimberlite

Triple B and Seed kimberlite s

Peddie kimberlite

Friday July 4, 2003
Day 5. New Liskeard to Sudbury

Leave Quality Inn New Liskeard at 9:00 AM

Examine drill core from 96-1, 95-2, and MR6 kimberlites

Examine drill core from Troika and Border kimberlites

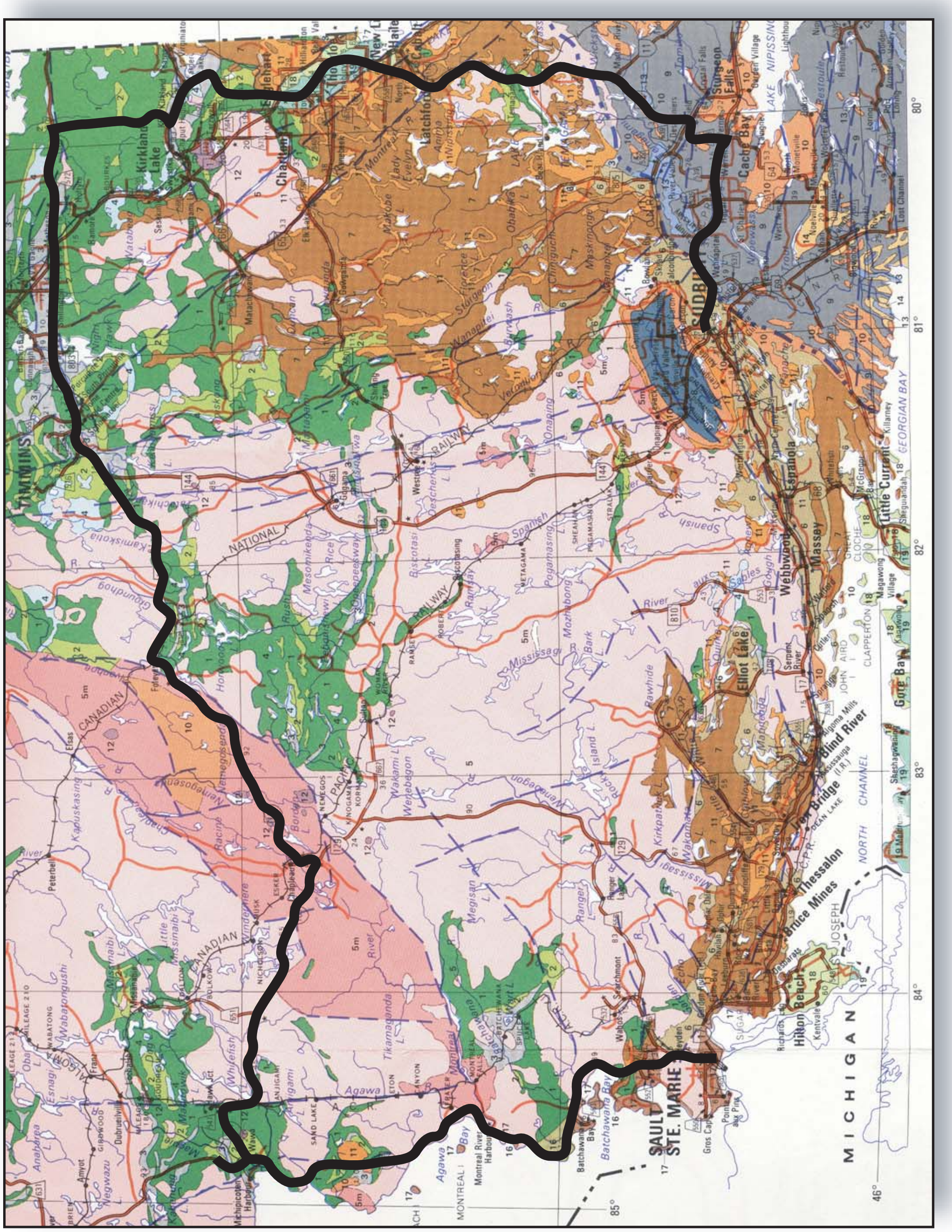
Kimberlite boulders in Sharp Lake pit

Saturday July 5, 2003
Day 6. Sudbury

Depart Ramada Inn at 9:00

Examine Victor, Surtaq, Wemindji kimberlite at DeBeers' warehouse

Delegates to pack samples


TIMMINS
Kirkland Lake
Chapleau
SUDBURY
Sturgeon Falls
Cache Bay
LAKE NIPISSING
GEORGIAN BAY
Killarney
Little Current
Espanola
Webbwood
Massey
Elliot Lake
Blind River
Iron Bridge
Thessalon
Bruce Mines
Hilton Beach
Gore Bay
NORTH CHANNEL
SAULT STE. MARIE
MICHIGAN
CANADIAN NATIONAL RAILWAY
CANADIAN PACIFIC
Mississagi R.
Spanish
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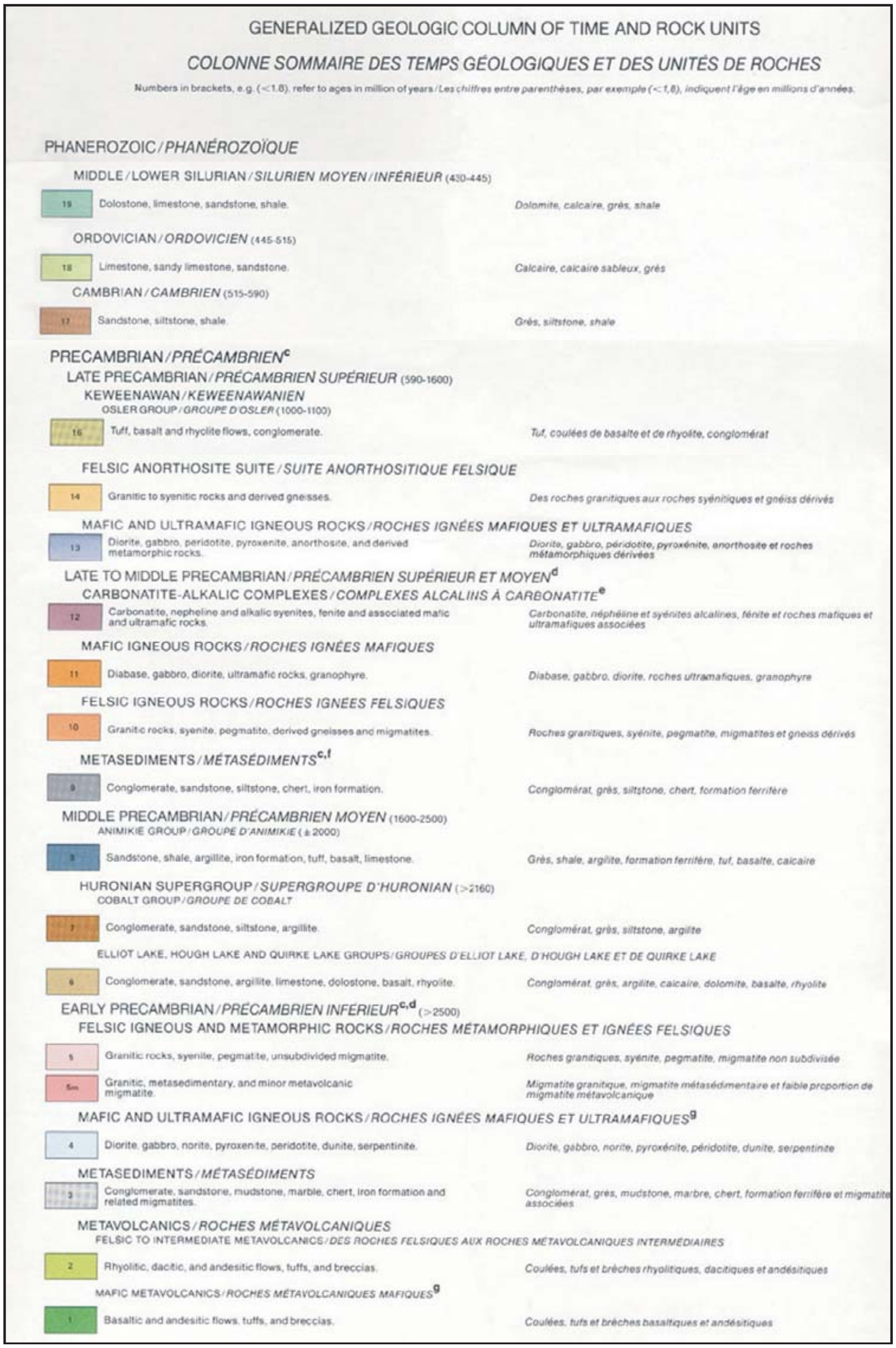

GENERALIZED GEOLOGIC COLUMN OF TIME AND ROCK UNITS

COLONNE SOMMAIRE DES TEMPS GÉOLOGIQUES ET DES UNITÉS DE ROCHES

Numbers in brackets, e.g. (<1.8), refer to ages in million of years/*Les chiffres entre parenthèses, par exemple (<1,8), indiquent l'âge en millions d'années.*

PHANEROZOIC/*PHANÉROZOÏQUE*

MIDDLE/LOWER SILURIAN/*SILURIEN MOYEN/INFÉRIEUR* (430-445)

19	Dolostone, limestone, sandstone, shale.	*Dolomite, calcaire, grès, shale*

ORDOVICIAN/*ORDOVICIEN* (445-515)

18	Limestone, sandy limestone, sandstone.	*Calcaire, calcaire sableux, grès*

CAMBRIAN/*CAMBRIEN* (515-590)

17	Sandstone, siltstone, shale.	*Grès, siltstone, shale*

PRECAMBRIAN/*PRÉCAMBRIEN*[c]

LATE PRECAMBRIAN/*PRÉCAMBRIEN SUPÉRIEUR* (590-1600)

KEWEENAWAN/*KEWEENAWANIEN*

OSLER GROUP/*GROUPE D'OSLER* (1000-1100)

16	Tuff, basalt and rhyolite flows, conglomerate.	*Tuf, coulées de basalte et de rhyolite, conglomérat*

FELSIC ANORTHOSITE SUITE/*SUITE ANORTHOSITIQUE FELSIQUE*

14	Granitic to syenitic rocks and derived gneisses.	*Des roches granitiques aux roches syénitiques et gnéiss dérivés*

MAFIC AND ULTRAMAFIC IGNEOUS ROCKS/*ROCHES IGNÉES MAFIQUES ET ULTRAMAFIQUES*

13	Diorite, gabbro, peridotite, pyroxenite, anorthosite, and derived metamorphic rocks.	*Diorite, gabbro, péridotite, pyroxénite, anorthosite et roches métamorphiques dérivées*

LATE TO MIDDLE PRECAMBRIAN/*PRÉCAMBRIEN SUPÉRIEUR ET MOYEN*[d]

CARBONATITE-ALKALIC COMPLEXES/*COMPLEXES ALCALINS À CARBONATITE*[e]

12	Carbonatite, nepheline and alkalic syenites, fenite and associated mafic and ultramafic rocks.	*Carbonatite, néphéline et syénites alcalines, fénite et roches mafiques et ultramafiques associées*

MAFIC IGNEOUS ROCKS/*ROCHES IGNÉES MAFIQUES*

11	Diabase, gabbro, diorite, ultramafic rocks, granophyre.	*Diabase, gabbro, diorite, roches ultramafiques, granophyre*

FELSIC IGNEOUS ROCKS/*ROCHES IGNÉES FELSIQUES*

10	Granitic rocks, syenite, pegmatite, derived gneisses and migmatites.	*Roches granitiques, syénite, pegmatite, migmatites et gneiss dérivés*

METASEDIMENTS/*MÉTASÉDIMENTS*[c,f]

9	Conglomerate, sandstone, siltstone, chert, iron formation.	*Conglomérat, grès, siltstone, chert, formation ferrifère*

MIDDLE PRECAMBRIAN/*PRÉCAMBRIEN MOYEN* (1600-2500)

ANIMIKIE GROUP/*GROUPE D'ANIMIKIE* (±2000)

8	Sandstone, shale, argillite, iron formation, tuff, basalt, limestone.	*Grès, shale, argilite, formation ferrifère, tuf, basalte, calcaire*

HURONIAN SUPERGROUP/*SUPERGROUPE D'HURONIAN* (>2160)

COBALT GROUP/*GROUPE DE COBALT*

7	Conglomerate, sandstone, siltstone, argillite.	*Conglomérat, grès, siltstone, argilite*

ELLIOT LAKE, HOUGH LAKE AND QUIRKE LAKE GROUPS/*GROUPES D'ELLIOT LAKE, D'HOUGH LAKE ET DE QUIRKE LAKE*

6	Conglomerate, sandstone, argillite, limestone, dolostone, basalt, rhyolite.	*Conglomérat, grès, argilite, calcaire, dolomite, basalte, rhyolite*

EARLY PRECAMBRIAN/*PRÉCAMBRIEN INFÉRIEUR*[c,d] (>2500)

FELSIC IGNEOUS AND METAMORPHIC ROCKS/*ROCHES MÉTAMORPHIQUES ET IGNÉES FELSIQUES*

5	Granitic rocks, syenite, pegmatite, unsubdivided migmatite.	*Roches granitiques, syénite, pegmatite, migmatite non subdivisée*
5m	Granitic, metasedimentary, and minor metavolcanic migmatite.	*Migmatite granitique, migmatite métasédimentaire et faible proportion de migmatite métavolcanique*

MAFIC AND ULTRAMAFIC IGNEOUS ROCKS/*ROCHES IGNÉES MAFIQUES ET ULTRAMAFIQUES*[g]

4	Diorite, gabbro, norite, pyroxenite, peridotite, dunite, serpentinite.	*Diorite, gabbro, norite, pyroxénite, péridotite, dunite, serpentinite*

METASEDIMENTS/*MÉTASÉDIMENTS*

3	Conglomerate, sandstone, mudstone, marble, chert, iron formation and related migmatites.	*Conglomérat, grès, mudstone, marbre, chert, formation ferrifère et migmatite associées*

METAVOLCANICS/*ROCHES MÉTAVOLCANIQUES*

FELSIC TO INTERMEDIATE METAVOLCANICS/*DES ROCHES FELSIQUES AUX ROCHES MÉTAVOLCANIQUES INTERMÉDIAIRES*

2	Rhyolitic, dacitic, and andesitic flows, tuffs, and breccias.	*Coulées, tufs et brèches rhyolitiques, dacitiques et andésitiques*

MAFIC METAVOLCANICS/*ROCHES MÉTAVOLCANIQUES MAFIQUES*[g]

1	Basaltic and andesitic flows, tuffs, and breccias.	*Coulées, tufs et brèches basaltiques et andésitiques*

KIMBERLITES AND ULTRABASIC ROCKS OF THE WAWA, CHAPLEAU, KIRKLAND LAKE, AND LAKE TIMISKAMING AREAS

B.A. Kjarsgaard[1], M.B. McClenaghan[1], D.R. Boucher[2], and K. Kivi[3]

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3. Kennecott Canada Exploration Inc., 309 South Court St., Thunder Bay, ON P7B 2Y1

DRIFT PROSPECTING FOR KIMBERLITE

In Canada, glacial erosion is the principal means by which kimberlite and its associated minerals have been dispersed, from a few tens of metres to tens of kilometres down-ice. Postglacial weathering has had little impact on kimberlite debris in the glacial sediments, thus boulder tracing, indicator mineral methods, and trace element geochemistry of the fine fraction of till, collectively referred to as "drift prospecting" methods, can be used to detect the presence of kimberlite within areas covered by glacial sediment.

Till, glaciofluvial sand, and kimberlite boulders are the glacial sediments most commonly used for indicator mineral surveys, while till is the only medium that is suitable for geochemical surveys. Till is a freshly crushed, first-cycle unsorted mixture of rock and mineral fragments, from boulder to clay sized, transported by glaciers, and plastered onto bedrock or released by melting at the base or surface of the glacier. Glaciofluvial sand results from recycling of till by glacial meltwater in subglacial streams and is sampled from eskers, outwash and moraines, or beaches formed on these deposits. Kimberlite boulders, produced by direct glacial erosion of kimberlite, can be deposited down-ice within, and on top of till and within eskers (e.g. Baker, 1982; Brummer et al., 1992a). For indicator mineral recovery and examination, at least 10 kg (~5 litres) of glacial sediment are required.

The unique mineralogy of kimberlites enables the application of indicator mineral methods in glaciated terrain. Characteristics that make these minerals useful indicators in glacial sediments include: an abundance in kimberlite that is far greater than diamonds; distinct visual and chemical properties; sizes in the sand range (0.25 to 2.0 mm) for easy picking; sufficient density to be concentrated by gravity methods; and, durability to survive preglacial weathering as well as subsequent glacial transport (Dummett et al., 1987; Averill, 2001). In glaciated terrain, all kimberlite indicator minerals typically survive long distance glacial transport and are little affected by degradation or physical breakdown. Variations in relative abundance of indicator minerals in individual kimberlites control the relative amounts of indicator minerals in glacial sediments down-ice.

Use of till geochemistry in kimberlite exploration is increasing because of its versatility (regional- and local-scale surveys), initial low cost, as compared to indicator mineral methods, and quick turn around time. The discrimination afforded by the till geochemistry is based on the unusual major and trace element composition of kimberlites. Important kimberlite pathfinder elements that provide good contrast in till geochemical surveys include Ni, Cr, Ba, Co, Sr, Rb, Nb, Mg, Ta, Ca, Fe, K, Ti, and LREE, the combination of which will depend on kimberlite composition as well as that of the surrounding bedrock (McClenaghan and Kjarsgaard, 2001).

HISTORY OF DIAMOND EXPLORATION IN NORTHEASTERN ONTARIO

Introduction

The following section is adapted from Kjarsgaard and Levinson (2002). The possibility of diamonds occurring in Canada was raised over a century ago by Professor W. H. Hobbs (1899), who was the first person to make a convincing argument that diamonds in the Great Lakes states were transported by glaciers from a specific region in Canada (the James Bay Lowland; Figure 1). Isolated discoveries of diamonds were reported in the eastern U.S. (e.g., North Carolina) as early as the 1840s, but diamonds found in the Great Lakes states from 1876 onward are the only ones of significance from a Canadian perspective. Nevertheless, serious diamond exploration did not begin until the 1960s, and major kimberlite discoveries were not made until the 1980s. In the 60 years following the publication of the Hobbs (1899) article, many additional diamond discoveries in glacial drift were reported in the Great Lakes states (e.g., Blatchley, 1903; Hausel, 1995), mostly in Indiana and Illinois, for a total of 81 diamond discoveries by 1967 (Gunn, 1968). Blue (1900) suggested that the diamonds might originate from carbonaceous slates in northern Ontario (e.g., in the Sudbury area). Blatchley (1903) and Kunz (1931) were favorably inclined toward two Canadian sources for the Great Lakes states diamonds: the James Bay area and the north shore of Lake Superior. Bell (1906) favoured multiple sources in the Lake Superior–Lake Huron region, but rejected the James Bay Lowland because of the great distance from the diamond occurrences. There are also at this time brief reports of diamonds being sought, unsuccessfully, by survey parties during construction of the Transcontinental Railroad, immediately north of the Great Lakes (Kunz, 1906). Satterly (1949a) reported the first occurrence of kimberlite in Canada: two thin dykes (the largest 15 cm wide) that were intersected during drilling for gold in Michaud Township, near Kirkland Lake, Ontario, in 1946 .

Kjarsgaard, B.A., McClenaghan, M.B., Boucher, D.F., and Kivi, K.
2003: Kimberlites and Ultrabsic Rocks of the Wawa, Chapleau, Kirkland Lake, and Lake Timiskaming Areas; in VIIIth International Kimberlite Conference, Northern Ontario Field Trip Guidebook, B.A. Kjarsgaard (ed.); p. 1-37.

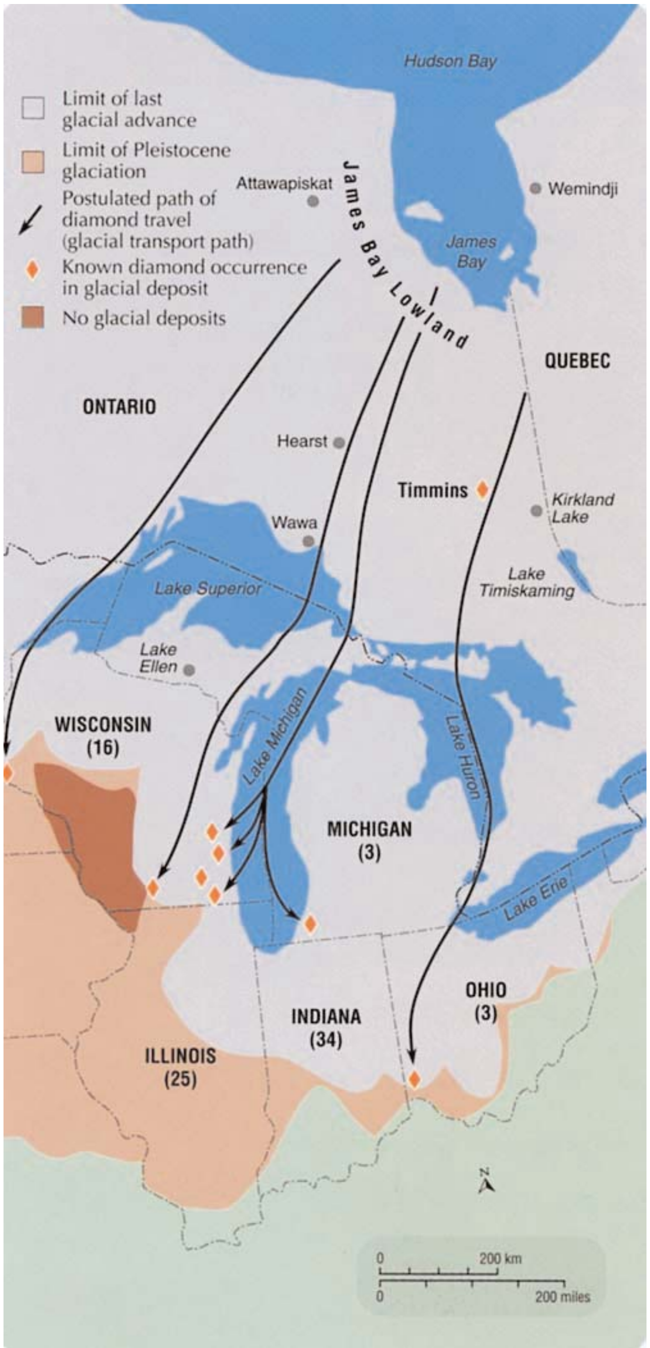


Figure 1. Early evidence of possible diamond-bearing kimberlites in Canada is found in the occurrence of isolated diamonds in the glacial deposits in the Great Lakes states. The diamonds are generally believed to have originated from the James Bay Lowland of Ontario. This map of the region shows the limit of Pleistocene glaciation and the last glacial advance, the number of known diamond occurrences in each state (e.g., Indiana, 34), and the paths that the diamonds may have taken from their presumed source(s) in the James Bay Lowland. The location is shown of the first authenticated diamond found (in 1971) in glacial deposits in eastern Canada: the 0.25 ct Jarvie diamond near Timmins. The kimberlites at Lake Ellen, Michigan have been suggested, but never confirmed, as a possible source of the diamonds in the Great Lakes states. Adapted from Kjarsgaard and Levinson (2002).

Exploration Activity

The 1960s ushered in the modern era of diamond exploration in Canada, with the sudden appearance of several diamond exploration programs by two companies in particular: De Beers (South Africa) and Selco Exploration Co. (the Canadian subsidiary of Selection Trust, a British company). Both companies were experienced diamond explorers internationally, but were new to North America. In 1960, De Beers rehired Canadian geologist Dr. Mousseau Tremblay, who had left the company only the year before to return to Canada (Duval et al., 1996). Dr. Tremblay had several years of diamond exploration experience in East Africa, including the area around the Williamson (Mwadui) mine in Tanganyika (now Tanzania). In addition, studies related to diamond exploration were undertaken by various federal and provincial geological surveys.

Initial efforts to find diamonds in Canada were concentrated up-ice of the Great Lakes diamond discoveries. In 1961, De Beers' first sediment sampling program was carried out north of the Great Lakes, while during the same year Tom Skimming of Selco published his first assessment work report on their Moose River Basin sampling project. Both De Beers and Selco found kimberlite indicator minerals (including pyrope garnet) at 20 locations over a large area (~10,000 km^2) in the Lowlands, but no kimberlite or diamonds (Brummer, 1978). Work by the Ontario Department of Mines in 1966 (Brown et al., 1967) also confirmed the presence of indicator minerals (Kong et al., 1999). The activities of all three groups supported the suggestion of Hobbs (1899) that the James Bay Lowland might be the source of the Great Lakes diamonds.

In the early 1960s, De Beers followed a trail of indicator minerals in an esker (and glacial till) to the Guigues pipe (Lake Timiskaming area) in Quebec. This was the first kimberlite pipe found as a result of geologic exploration rather than by accident. However, the absence of diamonds in a multi-tonne sample of glacial material immediately "down-ice" of the kimberlite precluded drilling or sampling the kimberlite itself (M. Tremblay, pers. comm., 1998). Early exploration in the Kirkland Lake–Lake Timiskaming area of Ontario (and adjacent parts of Quebec) was at least in part due to the 1946 discovery of thin kimberlite dykes in a gold mine near Kirkland Lake (Satterly, 1949a). In addition, government-funded studies in this area in the early to mid-1960s demonstrated the validity of esker sampling for kimberlite indicator minerals (Lee, 1965; Lee and Lawrence, 1968).

In late 1971, a 0.255 ct diamond was found by Reno Jarvi while sampling an esker near Timmins, Ontario (Brummer, 1978, 1984; *see* Fig. 1). Its primary source has never been located, but this was the first authenticated diamond to be found in glacial drift in Canada — almost a century after the 1876 discovery of the first diamond found in glacial material in the Great Lakes states (Hobbs, 1899). Recovery of the Jarvi diamond on the "down-ice" path taken by glaciers from the James Bay Lowland helped maintain interest in northeastern Ontario. It also gave further importance to sampling eskers. In the 1970s, the Ontario government further encouraged diamond exploration in the James Bay Lowland by conducting extensive reconnaissance surveys, which revealed various areas with unusual concentrations of diamond indicator minerals. These areas overlapped those explored by industry in the 1960s (Wolfe et al., 1975; Brummer, 1978).

In 1978, the innovative Kirkland Lake Initiatives Program (KLIP) started. The Ontario government supported this four-year project to stimulate exploration and mining for gold, base metals, and diamonds (summarized by Brummer et al., 1992a; Sage, 1993). Maps were published of areas with anomalous concentrations of diamond indicator minerals and geophysical (e.g., aeromagnetic) anomalies, starting in 1979. These data helped stimulate the mining companies to renew exploration for diamonds in the early 1980s.

In the Lake Timiskaming area, De Beers drill tested the Guigues pipe (previously identified in the 1960s, but not drilled) in 1981 and the Bucke pipe in 1983. Also in 1983, De Beers drill tested the A-4, AM-47, and B-30 kimberlite pipes in the Kirkland Lake kimberlite field. In 1984, De Beers drilled the Morrisette Creek kimberlite, and in 1985 the Gravel kimberlite in the Lake Timiskaming area, bringing to seven the number of kimberlite pipes it had discovered in the Kirkland Lake/Lake Timiskaming area. For the first time, a major kimberlite field was discovered by design by a diamond exploration company. Additional kimberlites were found in this area by Falconbridge Ltd. in 1984 and 1987, Homestake in 1987, and Lac Minerals in 1987 (Sage, 1996). However, the diamonds recovered were small (the largest 0.17 ct), and the best grade reported for any kimberlite was 0.02 ct per tonne (Brummer et al., 1992b).

From 1979 to 1982, Selco, joined by Esso Minerals Canada in 1982, explored part of the James Bay Lowland north of Hearst, Ontario. They used airborne magnetic reconnaissance surveying to delineate potential kimberlite bodies, followed by more detailed ground geophysical surveying (Janse et al., 1989; Reed and Sinclair, 1991). Although the 45 alnöite bodies identified were of no economic interest, this represents the first large-scale geophysical survey in Canada to find a field of "kimberlite-like" pipes. In 1984, De Beers started an annual regional survey program north of the area explored by Selco and Esso in the James Bay Lowland. The combination of stream sediment sampling for indicator minerals and airborne magnetic surveys led them to the Attawapiskat River area (Kong et al., 1999; *see* Fig. 3 in Webb, 2003, this guidebook). Drilling in 1988 and 1989 confirmed 16 kimberlites, ranging from 0.4–15 ha (1–37 acres), 15 of which contained diamonds.

In Ontario in the 1990s, five diamond-bearing kimberlites were found in the Kyle Lake area of the James Bay Lowland (Janse, 1995), but the one with the best grade is too deeply buried to be considered economic at this time. In the adjacent Attawapiskat kimberlite field (*see* Fig. 1 in Webb, 2003, this guidebook), the evaluation of the De Beers' Victor kimberlite began in 1998. The Victor kimberlite comprises two pipes that coalesce at the present surface with an area of ~15 ha. With a quoted ore value of $94/tonne (Robertson, 2002), Victor has the potential to host Canada's first diamond mine outside the NWT. However, it is in a remote area, the grade is highly variable, and the geology is complex (Wood, 2002).

Additional kimberlites and other diamond-bearing rocks have been found over the last ten years in the Wawa, Chapleau, Kirkland Lake, and Lake Timiskaming areas. These are described in more detail in this guidebook.

WAWA AREA

Quaternary Geology of the Wawa Region

The Wawa region was glaciated during the Quaternary resulting in a rolling landscape with abundant bedrock outcrop and a thin (<1 m) cover of glacial sediments over most of the region with thicker glacial and postglacial deposits along some bedrock channels and river valleys. The Quaternary geology of the region is summarized below from Morris (2001) and Morris et al. (1998).

During the Late Wisconsinan, central Canada was covered by the Laurentide Ice Sheet, which in the Wawa region flowed mainly to the southwest (Fig. 2). As the ice sheet thinned towards the end of glaciation, bedrock topography channeled ice flow westward along some bedrock valleys (Fig. 2). Much of the region's overburden consists of a discontinuous till veneer (<1 m) that was deposited by this southwest ice flow and drapes the bedrock surface. Till is a poorly sorted mixture of boulder- to clay-size material that has been eroded, transported, and deposited directly by the glacier, with little or no sorting by water. As is typical of a shield-derived till, in the Wawa area it has a sand-rich matrix and is locally derived. Distance of glacial transport from local bedrock sources is <5 km and commonly <200 m.

Glaciofluvial outwash and coarse-grained glaciolacustrine sediments are restricted to bedrock controlled valleys and broad flat lowlands. A large deposit of ice-contact stratified drift (sand and gravel), consisting of a west-trending belt of moraines and south-trending eskers, straddles Highway 101, east of Wawa. This belt narrows to the west and northwest and appears to represent the westward extension of the Chapleau II moraine, originally described by Boissonneau (1968). These sediments are mostly of local provenance, however, a small component is derived from the Paleozoic carbonate rocks in the Hudson Bay Lowland, 300 km to the northeast.

The glacial and post-glacial lake history associated with the Lake Superior basin includes seven prominent lake stages, from oldest to youngest: Minong, post-Minong (or Dorion), Houghton, Nipissing, Algoma, Sault, and sub-Sault (Farrand and Drexler, 1985). Three substages of Minong (I, II, III) and four sub-stages of post-Minong (I, II, III, IV) are recorded in the Wawa area by prominent terraces of glaciolacustrine sediments along the Michipicoten and Magpie river valleys just south and southwest of Wawa. Also during Post Minong, a barrier bar derived from the reworking of glaciolacustrine material formed across the southwest end of Wawa Lake. The town of Wawa is built on this bar. Successively lower stages of river flow have incised through these glaciolacustrine deltaic sediments, leaving a series of spectacular river terraces along the Magpie and Michipicoten river valleys west and southwest of Wawa. The surface of the highest river terrace is 33 m above the present river level.

Since deglaciation, alluvial deposits (stream sediments) consisting of fine- to coarse-grained sand with minor amounts of gravel have been deposited in streams and rivers

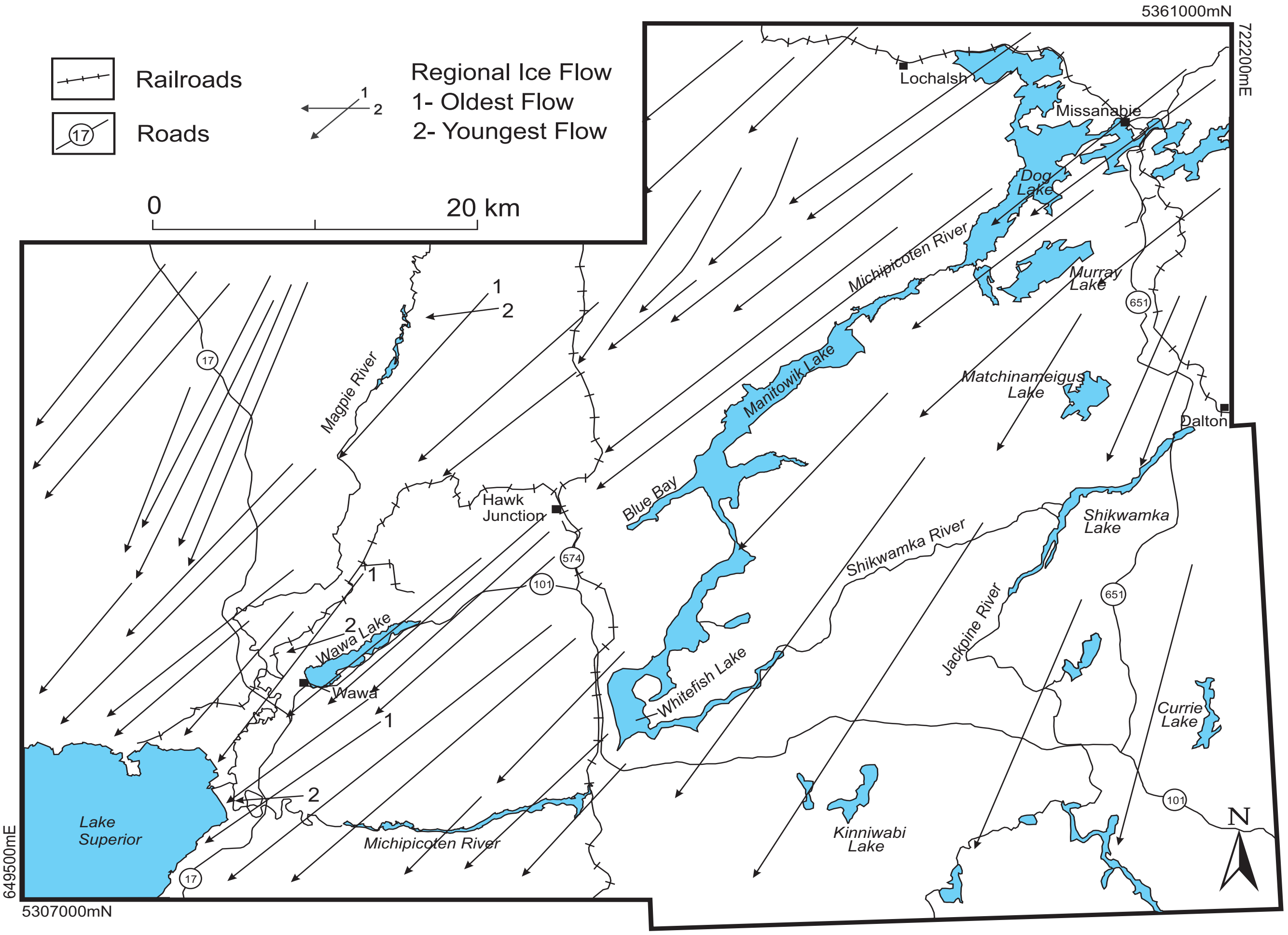


Figure 2. Regional ice flow patterns for the Wawa area. The dominant ice transport direction was to the southwest (1). At the end of glaciation, localized ice flow towards the west (2) occurred along some bedrock controlled valleys (from Morris, 2001).

from the reworking of till, glaciofluvial, or glaciolacustrine deposits. Large expanses of alluvium occur in the southern reaches of the Magpie River valley below Steephills Fall dam, the Michipicoten River valley below High Falls dam, the Doré River, and smaller rivers and creeks west and east of the Doré River.

Drift Prospecting for Diamonds in the Wawa Area

The Ontario Geological Survey conducted a regional-scale stream sediment (modern alluvium) sampling program for kimberlite indicator minerals over a 3800 km^2 area centred on Wawa in response to the 1993 diamond discovery, to assess the potential of the region to host kimberlite (Morris et al. 1994, 1997, 1998). The sampling program was successful in that it demonstrated the usefulness of stream sediments as a kimberlite exploration sampling medium in glaciated terrain and identified anomalous concentrations of Cr-pyrope, Cr-diopside, Mg-ilmenite (Fig. 3) and chromite in stream sediments, the sources of some of which have yet to be fully explained. On a property-scale, stream sediment sampling for kimberlite indicator minerals has been used by prospectors and junior exploration companies to follow-up anomalies identified by the Ontario Geological Survey's regional survey and to test the potential of specific properties to host kimberlite. One such survey (Kaminsky et al., 2002) led to the discovery of kimberlitic rocks just east of Whitefish Lake (Fig. 4).

Till mineralogy and geochemistry have been used to explore for the indicator mineral-poor lamprophyre dyke rocks similar to the Sandor occurrence. Thomas and Gleeson (2000) demonstrated that elevated concentrations of Ni, Cr, Ba, Co, V, Ca, Fe, and Mg in the <0.177 mm (-80 mesh) fraction of till combined with elevated concentrations of actinolite, chromite, and ilmenite clearly outlined the areas underlain by the known dykes as well as other areas where dykes likely occur.

With the discovery of diamonds in Archean volcanic/intrusive breccias in the Wawa region, drift exploration methods have shifted to boulder tracing. It is an effective exploration medium for these rocks because: 1) it is inexpensive; 2) the overburden cover is thin and boulders will be locally derived (<100 m); 3) the breccias have a visually distinct physical appearance that is readily identified in boulders.

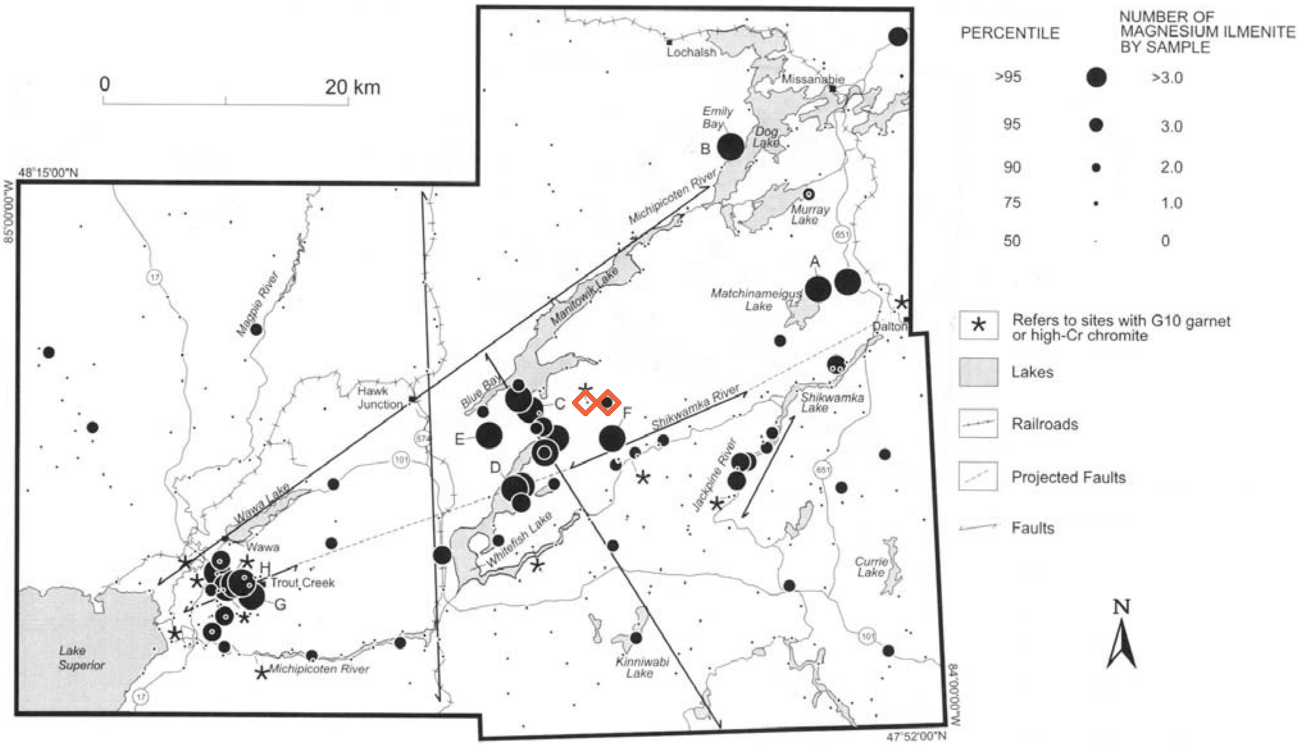


Figure 3. Distribution of Mg-ilmenite in regional stream sediment samples collected by the Ontario Geological Survey in the Whitefish Lake-Kinniwabi Lake area, 30 km east of Wawa (modified from Morris et al., 1997). Location of kimberlites 115 and 121 discovered in 1997 indicated by red diamonds.

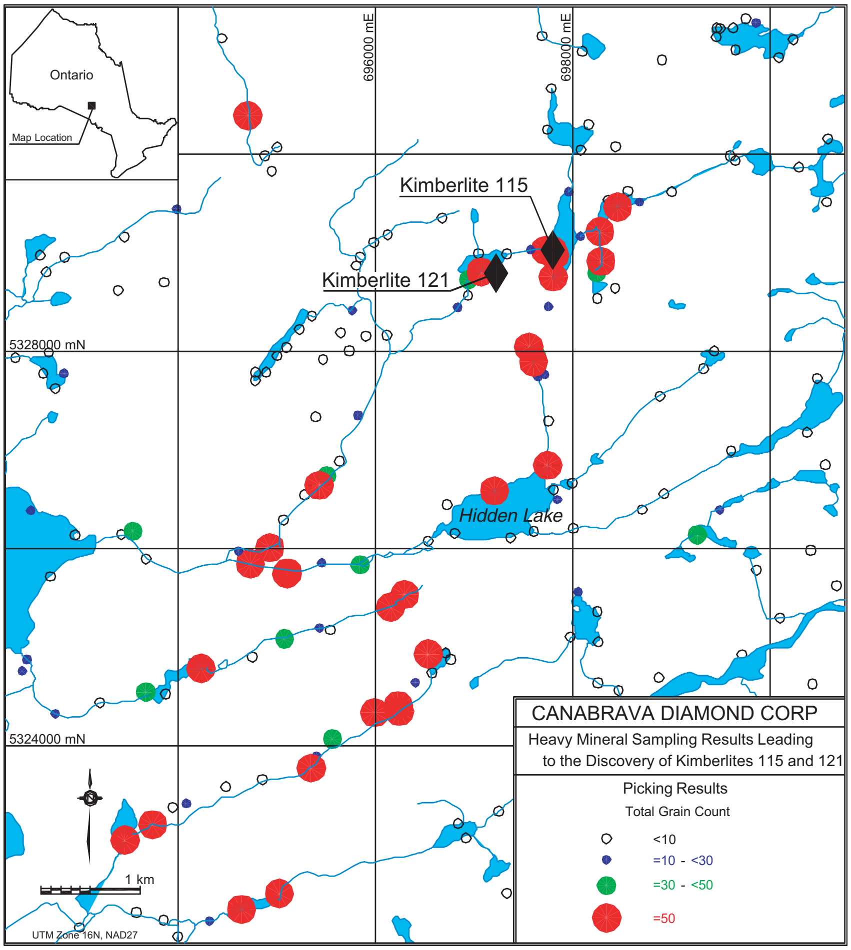


Figure 4. Distribution of kimberlite indicator minerals in stream sediment samples collected by Canabrava Diamond Corp. in the Hidden Lake area, 35 km east of Wawa that lead to the discovery of kimberlites 115 and 121 (unpublished data from Canabrava Diamond Corp.)

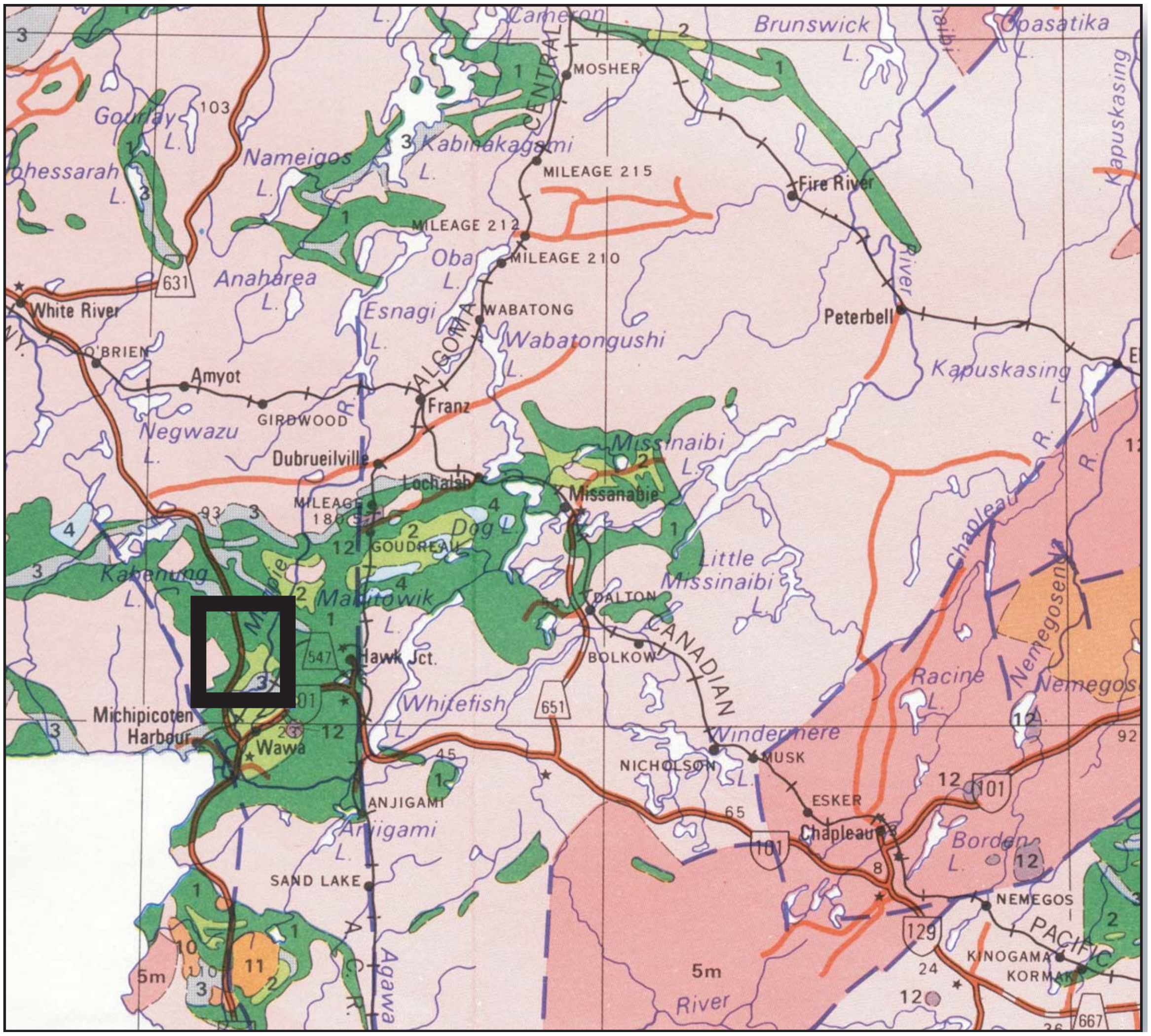


Figure 5. Simplified bedrock geology (from Ontario Ministry of Natural Resources Geological Highway Map of Northern Ontario) of the Wawa area. Box indicates area of field trip stops on the first day.

Bedrock Geology of the Wawa Area

The following is adapted from Heather et al. (1995). Archean bedrock of the Michipicoten greenstone belt in the Wawa area (Fig. 5) is a stratigraphically and structurally complex assemblage of volcanic, sedimentary, and plutonic rocks metamorphosed to greenschist and amphibolite facies. To the east it is bordered by the Wawa gneiss domain, comprised of tonalitic gneiss with granite and pegmatite intrusions. Tonalite gneiss in the Wawa domain has been dated by U-Pb zircon at 2920 Ma (Moser, 1993) and constitutes the oldest known rocks in the Wawa area. Mafic volcanic rocks and gneissic rocks in the Hawk Lake sequence (Turek et al., 1992) on the eastern edge of the Michipicoten greenstone belt range in age from 2889 to 2881 Ma. These older volcanic and gneissic rocks are inferred to be basement to the younger (2750 – <2690 Ma) volcanic rocks of the Michipicoten greenstone belt.

The younger volcanic rocks are comprised of two cycles, ca. 2750 to 2720 and 2700 to 2670 Ma based on U-Pb zircon age determinations on felsic volcanic rocks capping the cycles, and syn-volcanic intrusions. Each cycle consists of a tholeiitic basalt base (with minor andesite) capped by calc-alkaline dacite and rhyolite associated with high level tonalitic intrusions. The older cycle is termed the Wawa assemblage, and the younger cycle the Catfish assemblage. The youngest cycle is conformably overlain by younger sedimentary rocks (e.g. conglomerate, sandstone, greywacke, banded iron formation). Structural development of the Michipicoten greenstone belt is complex. Early structures include thrusts, recumbent folds, and cleavage. Later superimposed upright folds are accompanied by steep cleavages. The latest structures are steep northwest-southeast trending shear zones, which are host to numerous gold showings, and are associated with coarse clastic deposits inferred to be correlative with the Timiskaming Group. Rocks in the Michipicoten greenstone belt were metamorphosed at greenschist to lower amphibolite facies (0.2–0.3 GPa; Studmeister, 1983).

Diamond-bearing Archean Rocks of the Wawa Area

Discovery and initial studies

The original discovery of diamonds in the Wawa area was made in 1995 by Sandor Surmacz and Marcelle Hauseux (Saminex) in rock outcrops along the Trans Canada Highway in Lalibert Township (Fig. 6, 7). Micro- and macro-diamonds were recovered from two separate dykes, described as being of ultramafic composition and diatreme-like in character. The dykes, which contained six diamonds, are referred to as the Sandor occurrence. In 1996, Ron Sage of the Ontario Geological Survey initiated a preliminary study of the Sandor occurrence, and suggested these dyke rocks are lamprophyres and meet the definition of a spessartite (Sage, 2000). A sample of the Sandor occurrence was dated at 2703±42 Ma, which led Sage (2000) to conclude that these dykes were emplaced into the Catfish assemblage volcanic stratigraphy, near the conclusion of the deposition of the older, lower mafic volcanic package and prior to the deposition of the younger, upper felsic volcanic package. Subsequent exploration on the claim block has led to the discovery of additional lamprophyres (locally termed 'sandorite') that contain diamonds (Fig. 6, 8). Subsequently, three different lamprophyre emplacement styles are recognized: hypabyssal dykes, subvolcanic breccias, and volcanic rocks.

Dyke rocks contain a matrix that is either actinolite-rich (60–85% actinolite) or is biotite-rich, with sub-equal proportions of quartz, albite, plagioclase, and biotite (Burns, 2002). The dyke rocks also contain rounded to elliptical inclusions that are completely altered to actinolite plus talc, and range in size from <30 to 100 cm in size. Subvolcanic intrusive breccias are narrow dykes. Groundmass mineralogy is dominated by actinolite with variable proportions of mica, albite, and pargasite microphenocrysts (Burns, 2002). Variable proportions of highly altered xenoliths are present in these breccias. The volcanic lamprophyric rocks are typically matrix supported, with a high proportion of country rock fragments. The matrix is massive actinolite, with mica phenocrysts that are variably altered to chlorite. Clast supported breccias, and lapilli tuff and ash tuff units are observed in these volcaniclastic rocks.

Archean diamond-bearing volcaniclastic rocks

The following section has been compiled from abstracts presented by Walker (2002) on the Pele Mountain claim block, and Kivi (2003) and Lefebvre et al. (2003) on the Band-Ore claim block.

In an area to the southeast of the Sandor outcrop (Fig. 9–12), within the Catfish assemblage of the Michipicoten greenstone belt, a number of diamond-bearing volcaniclastic rocks have been discovered. These rocks range in composition from mafic to ultramafic and plot in the alkaline to subalkaline field on a total alkalis versus silica diagram. Field relationships indicate the diamond-bearing volcaniclastic rocks are intercalated with mafic to felsic lava flows, pillow basalts, and related volcaniclastic sediments. A variety of different diamond-bearing volcaniclastic rocks are recognized in the area, including pyroclastic rocks (lapilli tuffs and ash tuffs; Fig. 13), as well as heterolithic debris flows (Fig. 14). Dykes of similar composition to the diamond-bearing volcaniclastics crosscut the Catfish assemblage volcanic rocks. Upper and lower crustal xenoliths as well as altered mantle xenoliths are observed in the volcaniclastic rocks.

Lefebvre et al. (2003) report that both the volcaniclastic and dyke rocks contain oscillatory zoned hornblende phenocrysts of variable composition (the Ca-amphiboles edenite, pargasite, magnesi-hornblende, and tschermakite) and also biotite phenocrysts. The mineral assemblage of the groundmass in the dyke rocks and the volcaniclastic rocks is dominated by actinolite, with variable proportions of epidote, titanite, quartz, feldspar, biotite, hornblende, and chlorite. These mineral assemblages are typical of mafic rocks that have undergone greenschist to lower amphibolite grade metamorphism.

Lamprophyric Dyke Rocks in the Wawa and Dalton Areas

A variety of mantle xenolith bearing, Proterozoic lamprophyric dyke rocks of broadly variable composition occur in the region between Wawa and Chapleau (Appendix 1a, b). A number of these locales will be visited on the second day of the field trip. Mitchell and Janse (1982) describe in detail a set of a harzburgite-bearing olivine monchiquite dykes, in a roadcut 8 km south of Wawa on Highway 17 (Fig. 15). At this locality are two 1 metre wide and one 3 metre wide dykes, which parallel each other, striking 060º, and cut a small granodiorite stock. The widest dyke contains variable proportions of olivine and mica, suggested to be the result of multiple intrusions (Mitchell and Janse, 1982), or alternately, this is a result of flowage differentiation. These olivine monchiquite dykes are part of a bifurcating, en echelon dyke system. The mineralogy of the dyke consists of olivine phenocrysts, in a groundmass of titaniferous aluminous pyroxene, titaniferous phlogopite, analcite, calcite, and spinel (Mitchell and Janse, 1982). The mantle xenoliths at this locality have sampled fragments of the mantle from 50 to 90 km depth. (Mitchell and Janse, 1982). The lamprophyric dykes at the Parkhill and Darwin Mines, and the Nicholson dyke have a number of macroscopic similarities, and also differences. Dykes at the Parkhill and Darwin Mines contain abundant ilmenite megacrysts; the Nicholson dyke has a variable, but high content of mantle peridotite xenoliths.

In the Dalton area, a number of lamprophyric dykes (Fig. 16, 17), which contain mantle peridotite xenoliths, have recently been discovered. The following description of the East C (EC) dyke is adapted from the detailed petrographic description and electron microprobe analyses of Barnett (2000). The modal mineralogy of the EC locality is olivine (55%), phlogopite (30%), chromite and Ti-magnetite (5%), calcite (5%), clinopyroxene (<5%), and apatite (<1%). Large olivine crystals are abundant, with occasional large phlogopite laths. These macrocrysts are set in a groundmass of olivine, phlogopite, acicular clinopyroxene, zoned spinels (chromite cores rimmed by Cr, Ti magnetite), calcite, and apatite. Olivine cores typically have Mg# 93 to 94, with olivine rims as iron rich as Mg# 83. Phlogopite crystals are strongly zoned, with low Ti, high Ba Mg-rich cores and

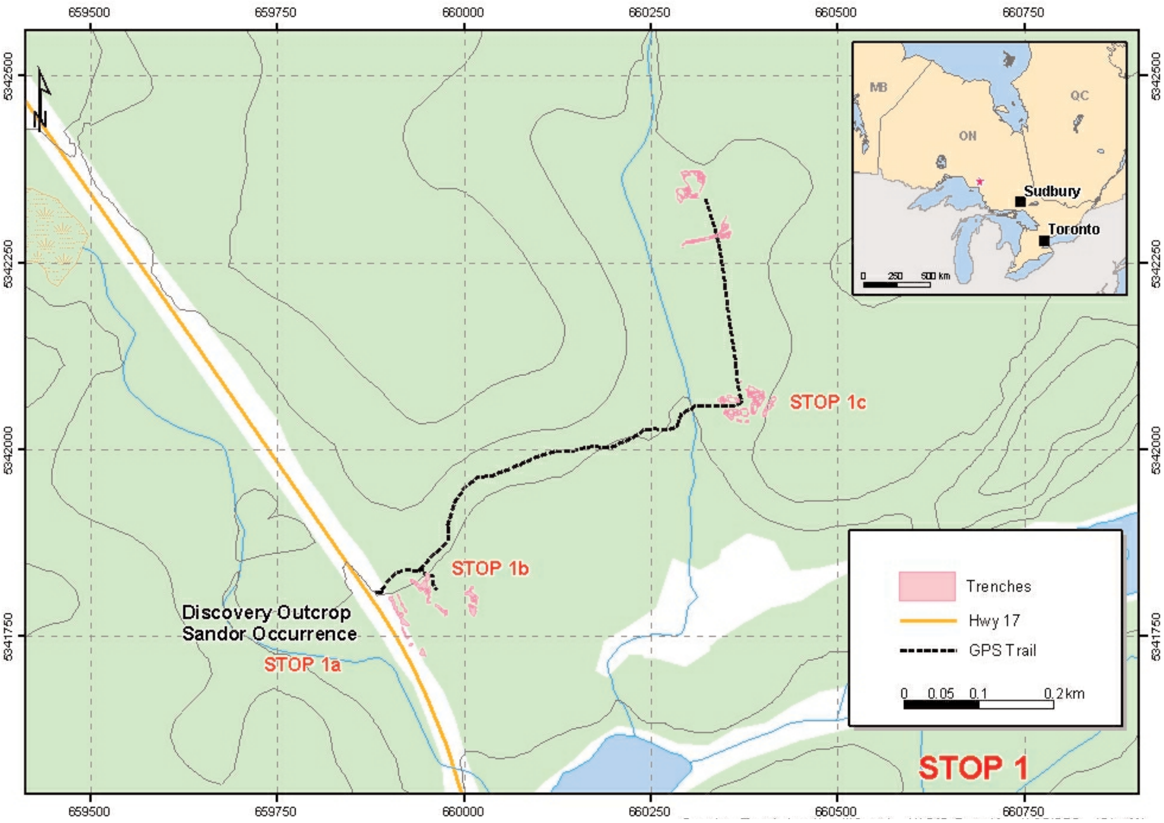


Figure 6. Location map of trenches of diamond-bearing rocks on the Spider Resources Inc. property north of Wawa (field trip stop 1).

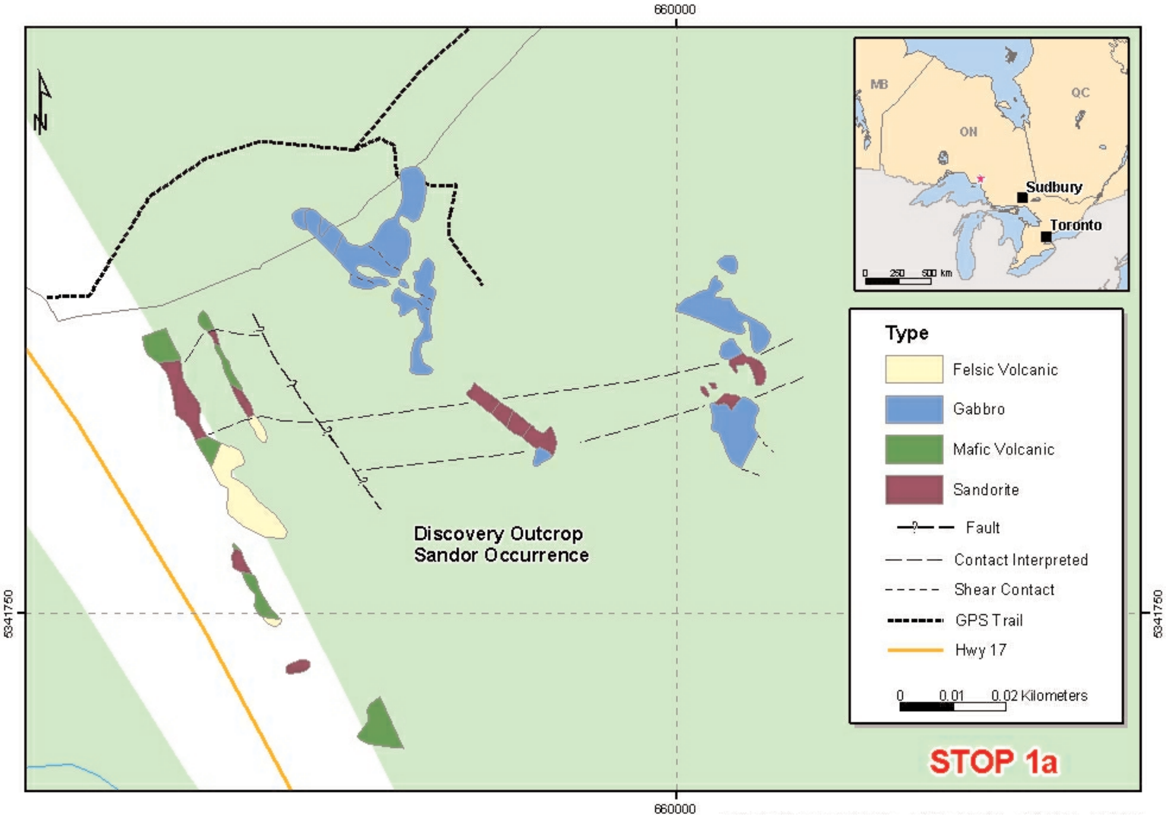


Figure 7. Detailed geology of the discovery outcrop along the Trans-Canada Highway on the Spider Resources Inc. property (field trip stops 1a and 1b).

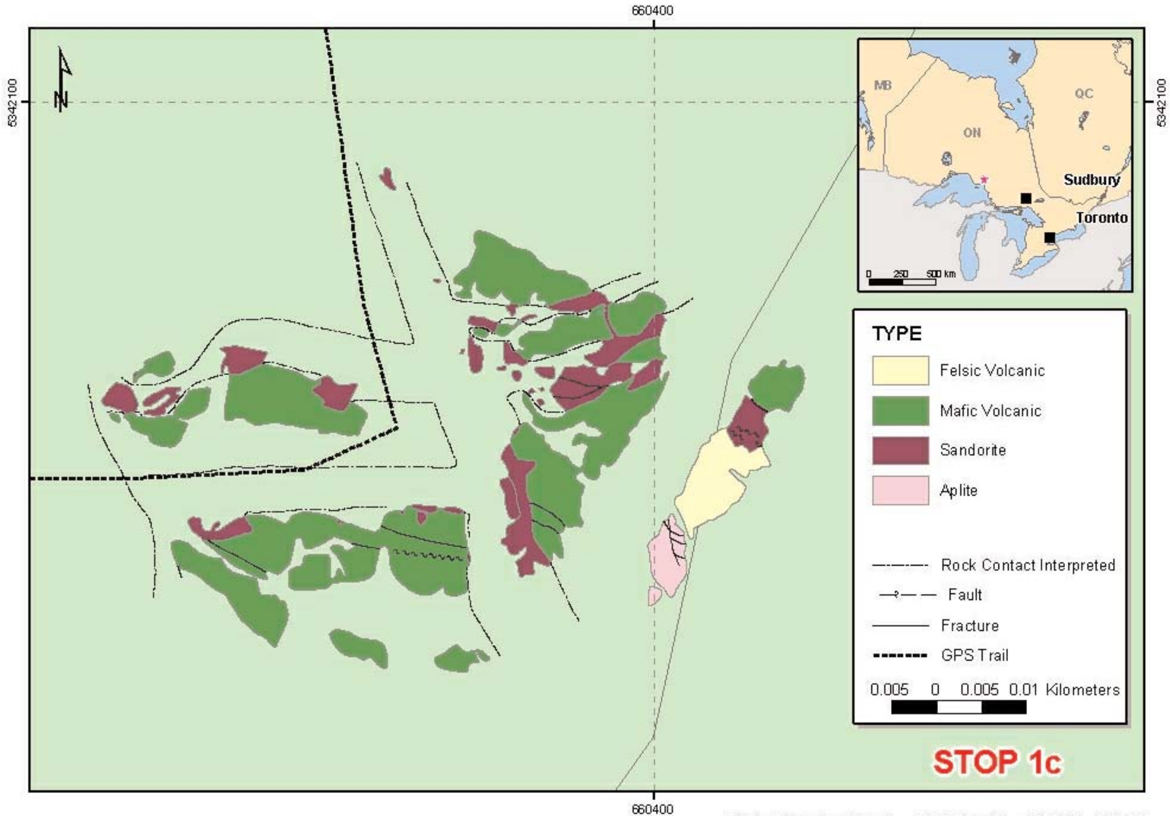


Figure 8. Detailed geology of field trip stop 1c on the Spider Resources Inc. property.

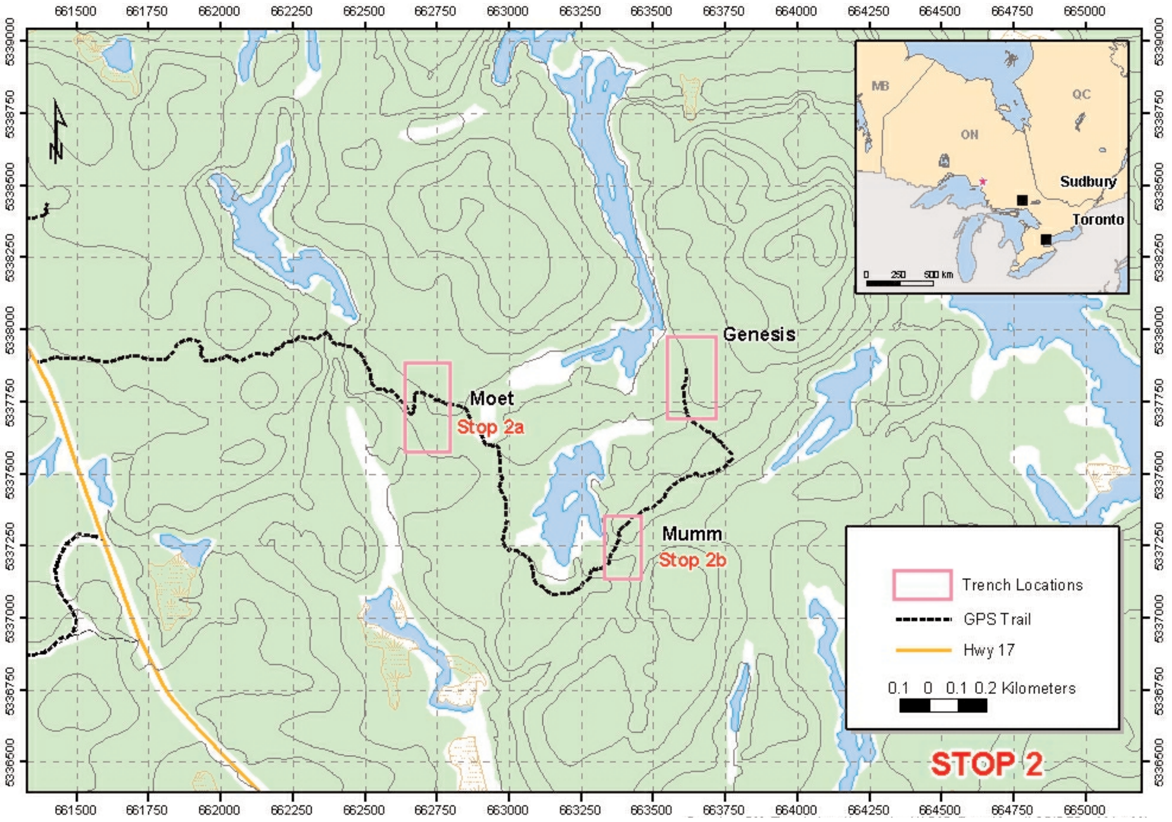


Figure 9. Location map of trenches of diamond-bearing rocks on the Pele Mountain Resources property north of Wawa (field trip stop 2).

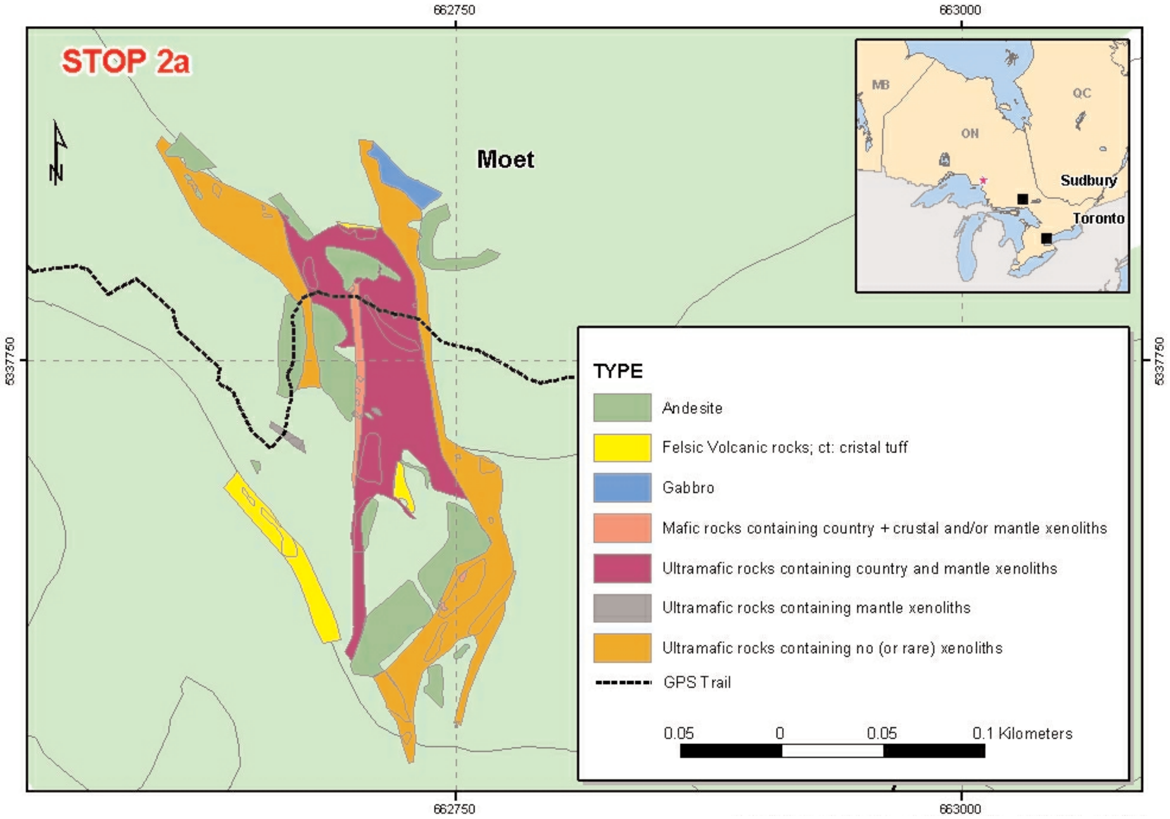


Figure 10. Detailed geology of the Moet locality (field trip stop 2a) on the Pele Mountain Resources property north of Wawa.

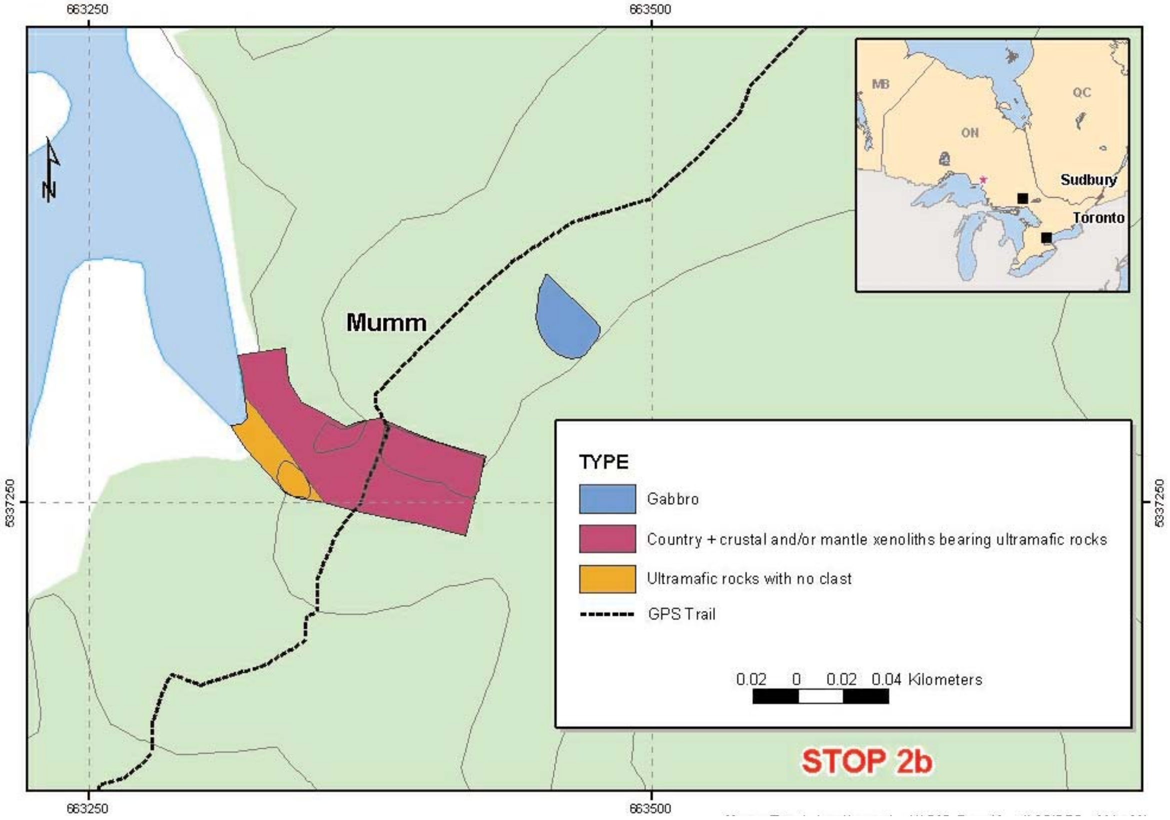


Figure 11. Detailed geology of the Mumm locality (field trip stop 2b) on the Pele Mountain Resources property north of Wawa.

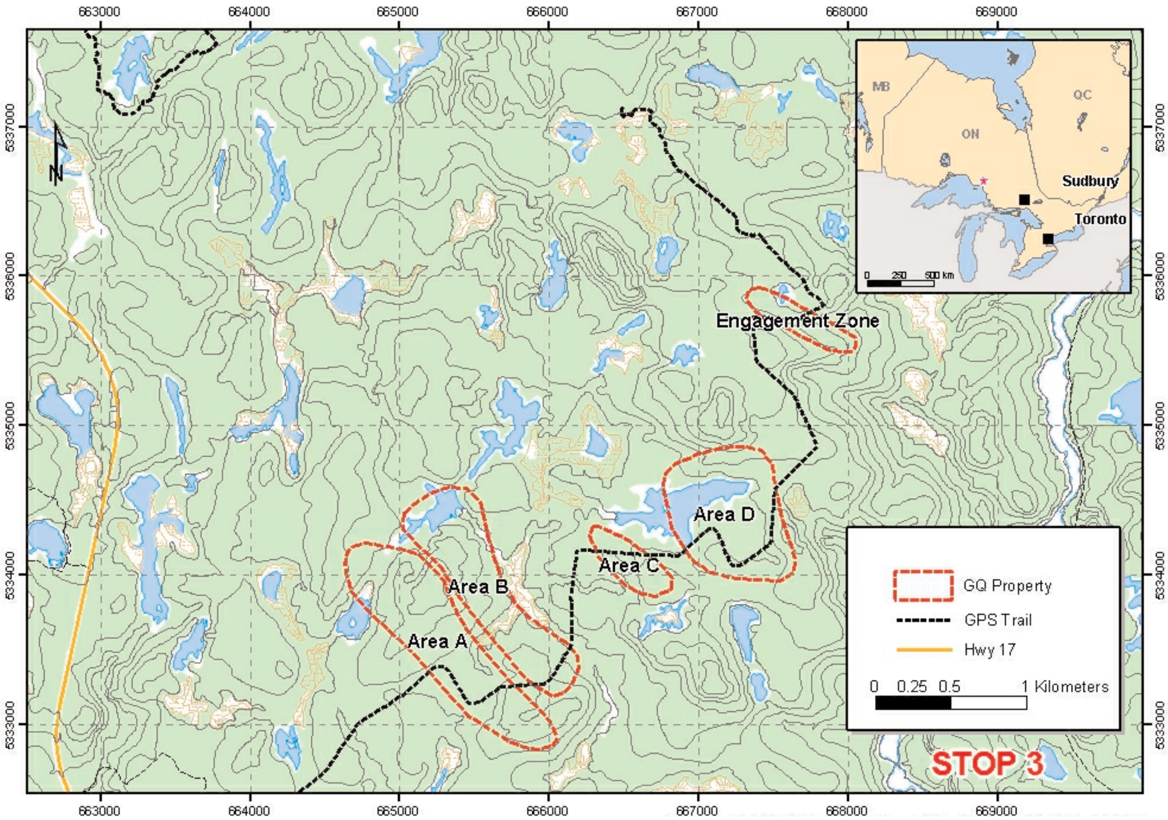


Figure 12. Location map of trenches of diamond-bearing rocks on the Band Ore Resources Ltd. property north of Wawa (field trip stop 3).

Figure 13. Diamond-bearing Archean lapilli tuff, Moet occurrence, Wawa.

Figure 14. Diamond-bearing Archean debris flow, Moet occurrence, Wawa.

tetraferriphlogopite rims. Clinopyroxene crystals are diopside, with Ti- and Al-enriched rims. Spinel grains have chromite cores (>62 wt.% Cr_2O_3 with >11 wt.% MgO), with thin Cr, Ti magnetite rims. A variety of peridotitic xenolith types are reported from these dykes.

KAPUSKASING STRUCTURAL ZONE

The following section is adapted from Percival, in Heather et al. (1995). The Chapleau block, of the Kapuskasing Structural Zone, is the widest, most accessible and most thoroughly studied part of the Kapuskasing structure (Fig. 18). Rock types include mafic gneiss and paragneiss, interpreted to be of supracrustal origin. Intrusive rocks of the Chapleau block include tonalite and diorite sheets, and anorthosite. Four sets of structures are recognized in the Chapleau block, with D1 layering in gneiss and paragneiss predating tonalite intrusion, and D4 constrained to be older than 2582 Ma, based on the age dating of pegmatites that cut D4 shears. Ductile deformation (phases 1–4) was broadly synchronous with high grade metamorphism, which varies from upper amphibolite to granulite facies within the Chapleau block.

The transition from early, steep fabrics to later, shallow, flat-lying fabrics of the Kapuskasing structural zone is well

Figure 15. Mantle xenolith-bearing monchiquite dyke, Highway 17 roadcut south of Wawa.

illustrated in the roadcut on the first stop on Day 3 (Fig. 19). Here early upright fabrics in an amphibolite grade (~6 kbar) foliated to gneissic tonalite (crystallization age of 2675±2 Ma; Moser, 1993) are overprinted by gently dipping shear zones which developed after leucosome formation at 2661±1 Ma (Moser, 1993). Further to the east, at stop 2, the amphibolite to granulite transition can be observed in mafic gneisses with flat lying structures. Thermobarometry on garnet – clinopyroxene – hornblende – plagioclase – quartz assemblages yield conditions of ~7 kbar and 700 ^{o}C. At stop 3, granulite grade tonalite straight gneisses (Fig. 20) are cut by 1144 Ma lamprophyre dykes which contain spinel peridotite xenoliths. The dykes are inferred to be related to either the Lackner Lake or Nemegosenda alkali silicate/carbonatite complexes, located south and north of the highway, respectively. At stop 4, metamorphic modal layering is well developed on a 2 to 5 cm scale with amphibole-poor and amphibole-rich bands. Mafic migmatites in this area record P-T conditions of ~10 kbar and 750 ^{o}C. The Kapuskasing structure is terminated on its eastern side by the Ivanhoe Lake fault zone. Here well developed cataclasite and pseudotachylite can be observed (Day 3, stop 5), related to uplift (~17 km) of the Kapuskasing zone at 1.9 Ga.

QUATERNARY GEOLOGY OF THE KIRKLAND LAKE-LAKE TIMISKAMING REGION

Quaternary Geology

The Quaternary geology of the Kirkland Lake-Lake Timiskaming region is known from federal and provincial government surficial mapping (Baker, 1985; Veillette, 1996) and exploration overburden drilling for gold and, in recent years, kimberlites. The topography and surficial sediments are the result of the Wisconsinan (80–10 ka BP) glaciation during which time the region was covered by the Laurentide Ice Sheet. Glacial and proglacial sediments that were deposited vary in thickness from <1 to 30 m, and up to 60 m overlying some kimberlites (Fig. 21).

Striated bedrock records ice-flow patterns across the region (Veillette, 1986a; McClenaghan et al., 1995; Veillette and McClenaghan, 1996; McClenaghan and Veillette, 2001) and outcrops exposed mainly along forest access roads provide excellent sites to examine striae. In the vicinity of the Kirkland Lake kimberlite field, glacial flow was towards the west and southwest during the main phase of the Laurentide Ice Sheet (Fig. 22), then south, and finally southeast during deglaciation. In the Lake Timiskaming region, striations record evidence of three major ice-flow phases (Fig. 22). The oldest flow (Phase 1) was towards the southwest. This flow likely was associated with the main phase of the Laurentide ice sheet. During deglaciation, ice flow shifted southward (Phase 2). During final deglaciation of the area, local ice tongues from the main ice sheet occupied the structural depressions of the Montreal River and Lake Timiskaming, giving rise to ice flow towards the southeast (Phase 3). All phases of ice flow are associated with erosion, and transportation and deposition of till.

Figure 16. Carbonatite dyke cutting kimberlitic dyke, Fletch North occurrence, Dalton area.

Figure 17. Block from the EC kimberlitic dyke, Dalton area.

Unweathered till deposits in the region are generally olive grey, have a silty sand matrix, and contain between 5 and 20% clasts. Where the till is thin, it is generally more locally derived. A large dispersal train of Paleozoic limestone clasts in till derived from bedrock around upper Lake Timiskaming trends south-southwest across the area

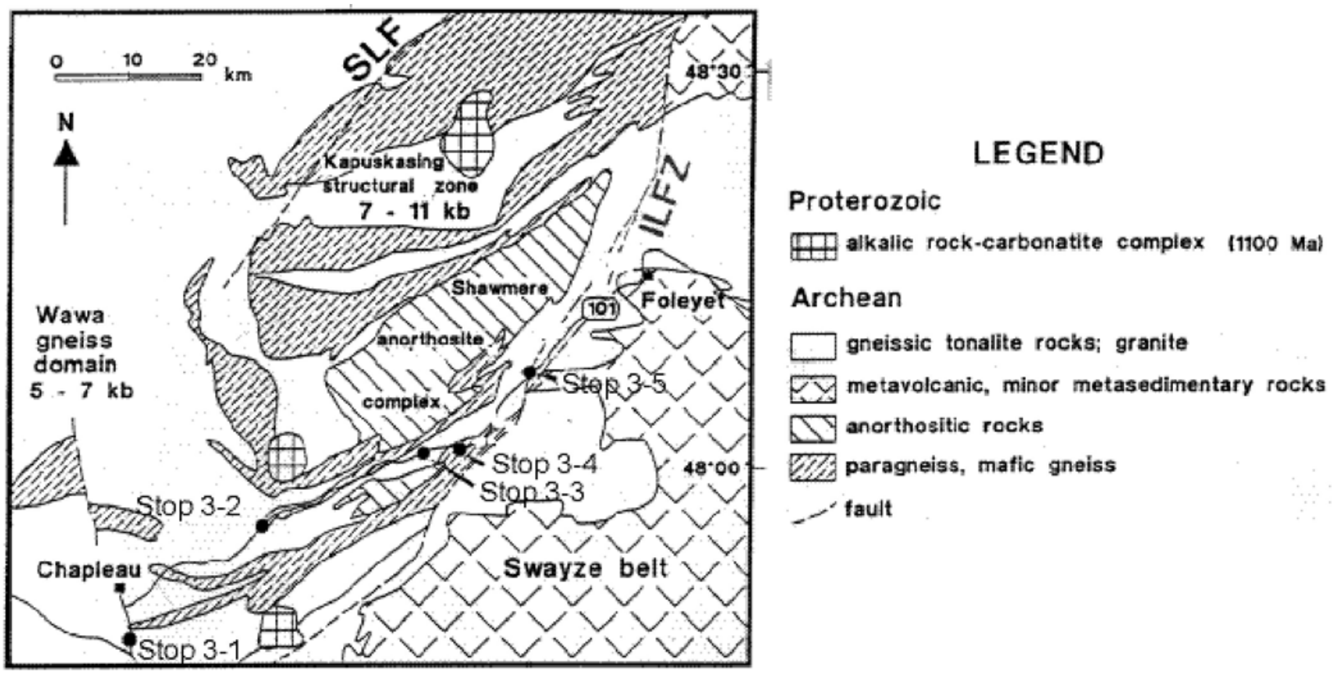


Figure 18. Location of field trip stops (Day 3) across the Kapuskasing Structural Zone (adapted from Percival, in Heather et al., 1995).

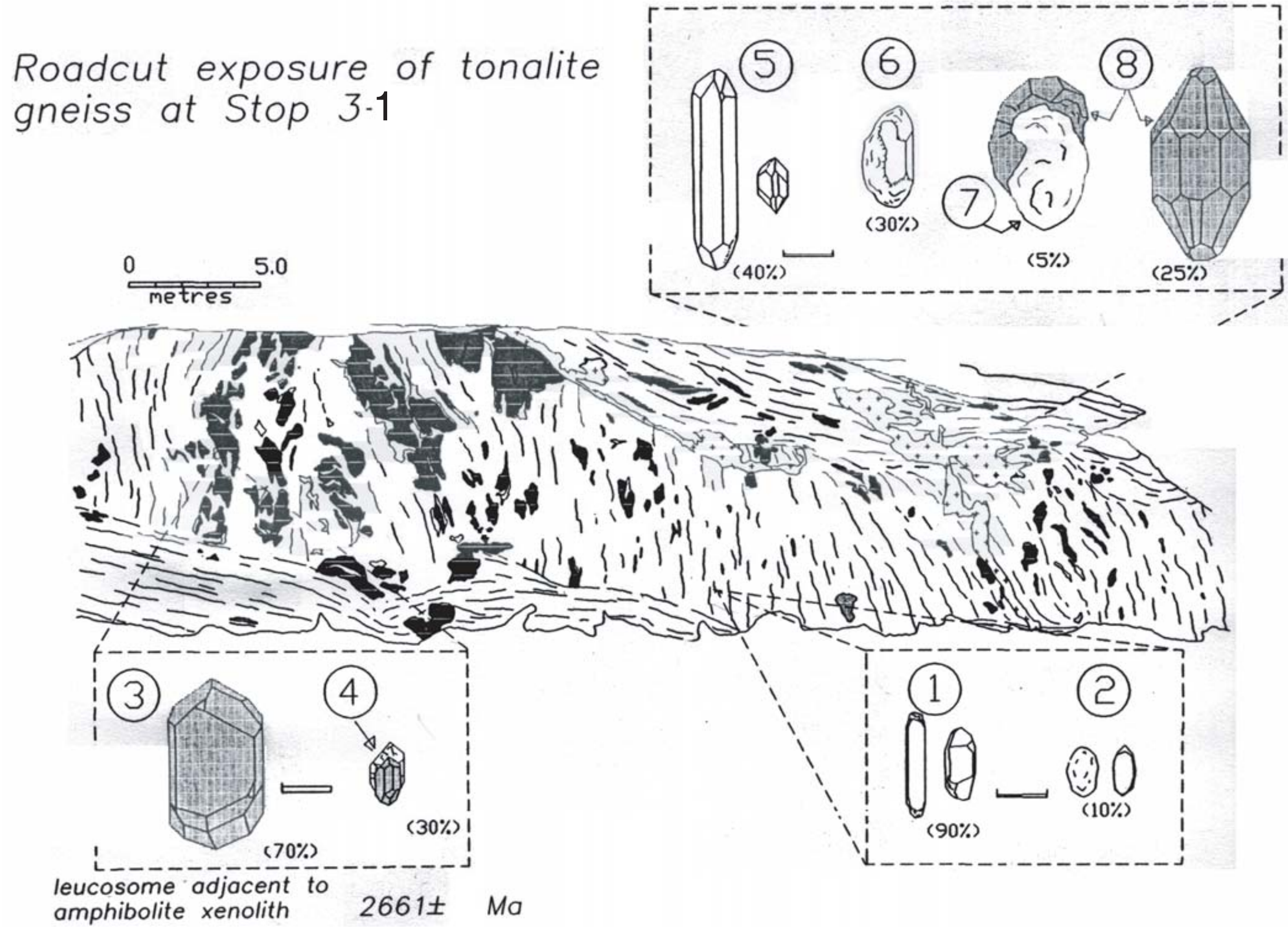


Figure 19. Line drawing of outcrop, Day 3, Stop 1, illustrating early, steep foliation in tonalite gneiss and flat lying structures (shear zones) at the top and bottom of the outcrop. Sketches of different zircon types and the corresponding sample locations on the outcrop are also shown (adapted from Moser, in Heather et al., 1995).

Figure 20. Tonalitic straight gneiss within the Kapuskasing structural zone (Day 3, stop 3).

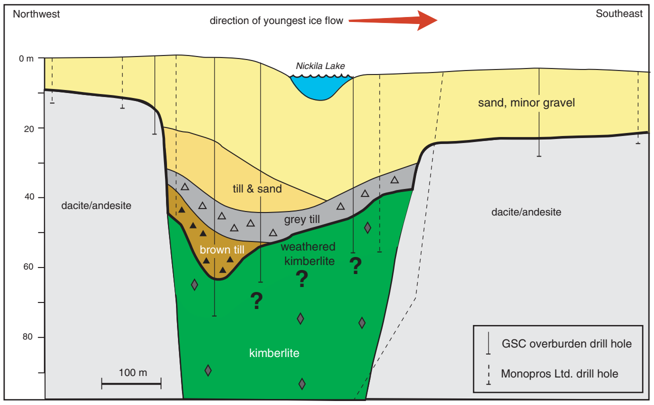


Figure 21. Plan view and cross-section of the B30 kimberlite, Kirkland Lake, Ontario showing the deep level of kimberlite erosion below the surrounding bedrock surface, and a thick cover of glacial sediment masking the bedrock depression (from McClenaghan et al., 1996).

(Veillette, 1996), but has been truncated in its proximal part by the last southeast ice flow (Veillette, 1989, 1996). Discontinuous patches of carbonate-rich till occur up to 35 km south of the outlier.

During deglaciation, glaciofluvial sediments, in the form of sand and gravel, were deposited near the terminus of the ice sheet in the south-trending eskers (Baker, 1985; Veillette, 1986a, 1996). The Munro Esker, the largest esker in the region, is in places 40 km wide and up to 350 m thick (Hobson and Grant, 1967). It extends southward for more than 275 km, crossing the Kirkland Lake kimberlite field and terminates 25 km to the south.

During retreat of the Late Wisconsinan Ice Sheet, glacial Lake Barlow covered the Kirkland Lake-Lake Timiskaming region. This lake was the southern of two connected ice-contact glacial lakes (the other being Lake Ojibway) that covered northern Ontario and western Quebec from about 10.1 to 8.0 ka BP (Vincent and Hardy, 1979; Vincent et al., 1987; Veillette, 1988, 1989, 1996). Fine grained glaciolacustrine sediments (mostly varved silt and clay) were deposited on the lake bottom up to a maximum of 30 m, covering bedrock, till and, in places, glaciofluvial deposits. The approximate life span of both lakes (2000 years) and average rate of glacial retreat during this time (450 m/year) was deduced from varve chronology. Both lakes drained eastward through the Ottawa River until the ice sheet broke apart about 8.0 ka BP. Lake Ojibway drained abruptly northward into the Tyrell Sea in the Hudson Bay Lowland raising sea level approximately 30 cm (Veillette, 1994). Since this time, surficial sediments have been exposed to normal postglacial weathering and soil forming processes.

In the Kirkland Lake and New Liskeard areas, weathered kimberlite is more susceptible to glacial erosion than the surrounding bedrock, thus many kimberlites are found in low or swampy ground, or in bedrock depressions covered by thin (<1 m) to thick (>50 m) glacial sediments. Glacial erosion has removed varying amounts of the preglacially weathered kimberlite, and in some cases, the hard competent kimberlite below. For example, glacial erosion of the Peddie, McLean, and Seed kimberlites near Lake Timiskaming removed preglacially weathered kimberlite, leaving a polished striated subcropping surface. In contrast, glacial erosion of the B30 kimberlite, near Kirkland Lake (Fig. 1), was much less vigorous and left a >10 m cap of soft and highly weathered dark green clay-rich kimberlite (McClenaghan et al., 1996). The thickness of remaining preglacially weathered kimberlite will influence the geophysical signature of the kimberlite.

Kimberlite Drift Prospecting History

Kirkland Lake has long been the focus of gold exploration since the discovery of the world class gold camp in 1906, while silver and cobalt have been the focus of exploration in the Lake Timiskaming area since 1903. Since the early 1960s, both areas have also been explored for kimberlites, using geophysical and drift prospecting methods. The first published account of kimberlite indicator minerals (other than diamond) in glacial sediments in Canada is from the Munro Esker just south the Kirkland Lake kimberlite field.

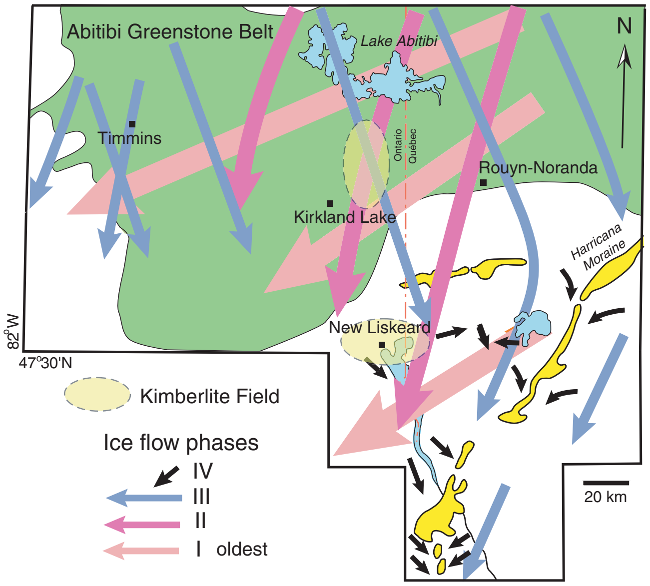


Figure 22. Main ice flow phases across the Kirkland Lake and Lake Timiskaming areas (modified from Veillette and McClenaghan, 1996).

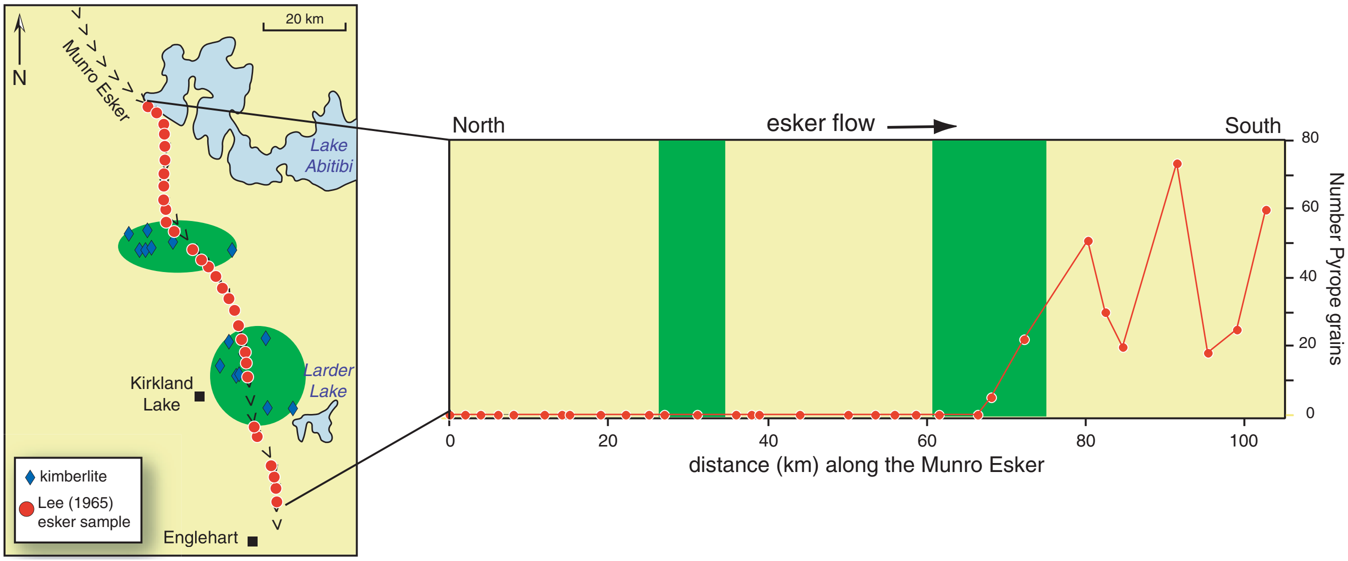


Figure 23. Visual abundance of pyrope in the 0.5 to 1.23 mm fraction of sand samples collected along a 100 km segment of the Munro Esker near Kirkland Lake by the Geological Survey of Canada (adapted from Lee, 1965). The location of kimberlites subsequently discovered is also shown by the blue diamonds Note pyropes appear in esker sediments just south of the southern kimberlite cluster.

Lee (1965) noted the presence of pyrope along a 35 km segment of the Munro Esker just south of what is known today as the Kirkland Lake kimberlite field (Fig. 23). Since the 1980's, numerous kimberlite boulders have been found in poorly sorted pebble to boulder gravel units exposed in active gravel pits along the Munro Esker, as well the Misema River and Sharp Lake eskers (Baker, 1982; Brummer et al., 1992a; McClenaghan et al., 2002a). Both glacial (striation orientations) and glaciofluvial (esker trends) transport directions must be considered when attempting to determine the source of kimberlite boulders or indicator minerals in eskers in the region. Kimberlite boulders may have been glacially transported by the last phase of ice flow prior to being incorporated into the meltwater drainage system of the glacier. Boulders were transported as fresh, competent fragments of kimberlite, deposited in glaciofluvial sediments, and subsequently suffered chemical weathering in the last 8000 years since deglaciation. Because the boulders have been so severely weathered, they crumble easily and it is therefore rare to find kimberlite boulders in gravel pits in which pit faces are not fresh. Many kimberlite boulders in the local eskers cannot be matched to known kimberlites, which suggest that there are more kimberlites yet to be discovered (McClenaghan et al., 2002a).

Between 1979 and 1982, prior to the discovery of kimberlite pipes in the Kirkland Lake region, the Ontario Geological Survey (OGS) sampled till in 171 overburden drill holes and 200 backhoe trenches, directed mainly at gold exploration. Pyrope (Fig. 24) and Cr-diopside were recognized in glacial sediments recovered at several sites (Fortescue et al., 1984) and this information aided in the discovery of several of the kimberlites near Kirkland Lake (Pegg et al., 1990; Brummer et al., 1992a, b). Pyrope appears in glacial sediments in the general area subsequently found to contain seven kimberlite pipes and its presence continues for another 30 to 40 km down-ice. Prior to, and since then, several regional-scale indicator mineral sampling programs have been carried out across the region by industry (e.g. Fig. 25) and government (McClenaghan et al., 1993; Allan, 2001; McClenaghan et al., 2001; Reid, 2002). Most of the known kimberlites have distinct dispersal trains that were identified using indicator minerals (McClenaghan et al., 1995, 1996, 1998, 1999, 2002b, 2003). For example, down-ice of the Bucke and Gravel kimberlites in the Lake Timiskaming field, a large fan-shaped glacial dispersal train extends more than 10 km to the south (Fig. 25) along the directions of the Phase 2 and 3 ice flows. In contrast, glacial dispersal from the Peddie kimberlite, 4 km southeast, is detectable for only 500 m down-ice (southeast; McClenaghan, 2002b).

BUFFONTA KIMBERLITE

The Buffonta property is located at 48°28'N and 79°56'W, (UTM 577000, 5369800 NAD27) in south-central Garrison Township, 35 km north of Kirkland Lake (Fig. 26). The property is reached from the northwest by a gravel road, which joins Highway 101 near Perry Lake. Two open pits have been excavated on the property (Fig. 27), the first was excavated in 1981 and is referred to as the old Buffonta pit. The kimberlite dykes are exposed in the walls of a second, smaller open pit, located 350 m southeast of the first pit, which was excavated in 1990 and 1991.

The Buffonta property is in the western part of the Archean Abitibi Greenstone Belt and is underlain by mafic metavolcanic rocks (Fig. 27) and the Garrison monzonite stock (Jensen, 1982; Bath, 1990). Gold mineralization was first discovered on the Buffonta property 75 years ago (Satterly, 1949b) and it has been explored and mined intermittently ever since. Bedrock in the area was mapped by Satterly (1949b) and Jensen (1982).

Kimberlite on the Buffonta property was first reported by Gajaria (1987; *in* Bath, 1990) from intersections in diamond drill holes. In 1991, two kimberlite dykes were exposed (Fig. 28) during the excavation of the new Buffonta pit. Barron and Barnett (1993) confirmed the rock as a kimberlite by

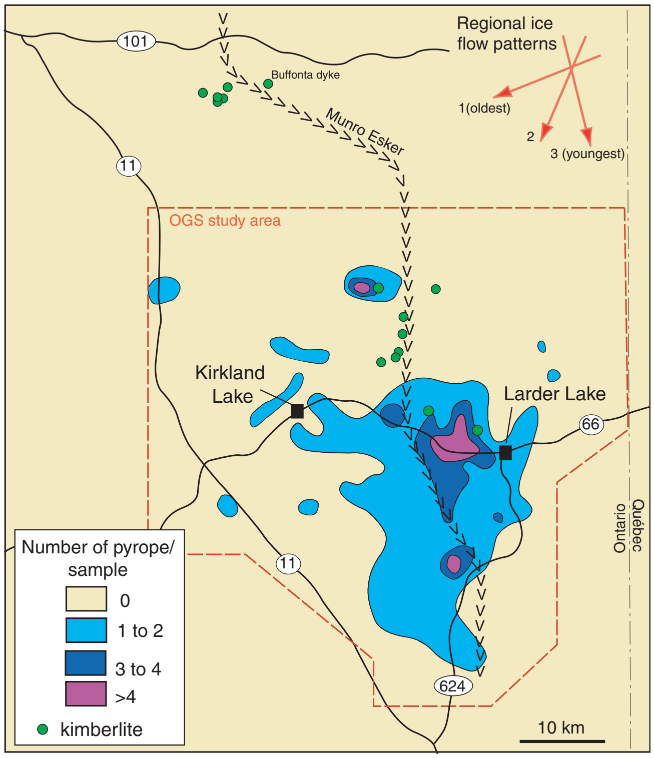


Figure 24. Distribution of pyrope in till and glaciofluvial sediment samples collected by the Ontario Geological Survey (1979–1984) and location of the subsequently discovered kimberlites (modified from Brummer et al., 1992a; kimberlite locations from Zalnieriunas and Sage, 1995). Pyrope grains have been dispersed by three phases of ice to the southwest, then to the south, and finally to the southeast.

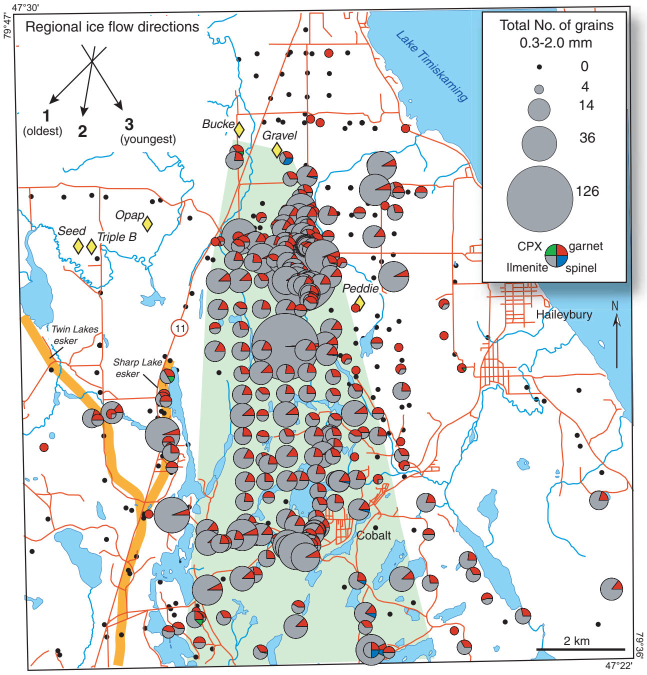


Figure 25. Fan-shaped dispersal train (shaded green) of visually identified kimberlite indicator minerals in the 0.3 to 2.0 mm fraction of surface till and glaciofluvial sediment samples down-ice of the Bucke and Gravel kimberlites, Lake Timiskaming kimberlite field (unpublished data from De Beers Canada Exploration Inc., 2003). Location of known kimberlites indicated by yellow diamonds.

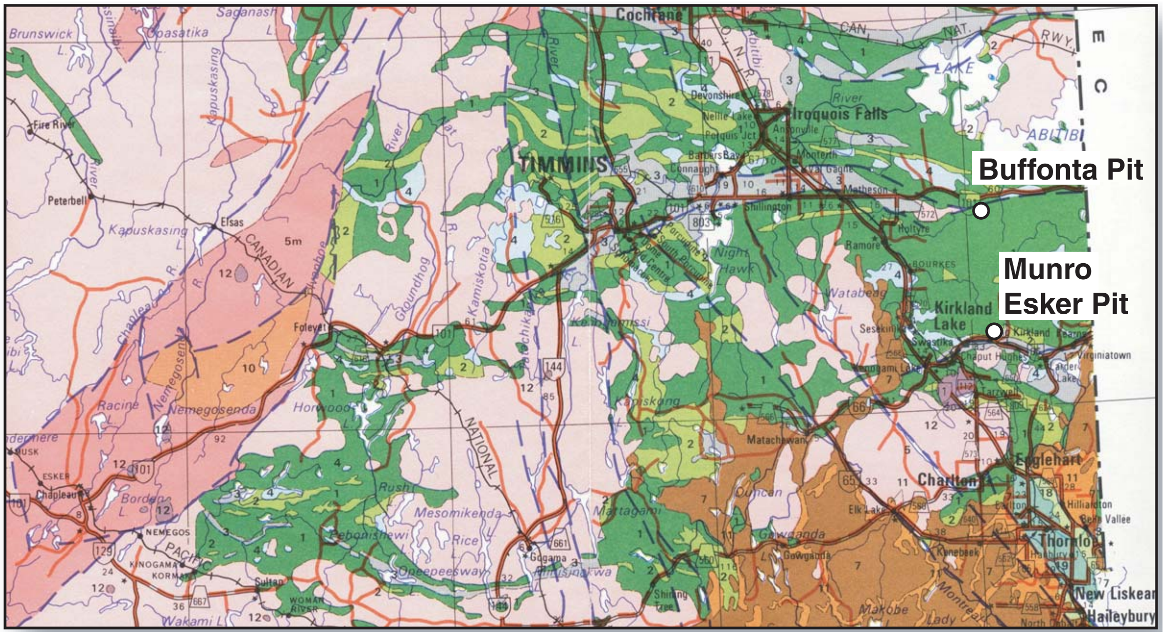


Figure 26. Location of the Buffonta pit and the Munro esker pit to be visited on the field trip.

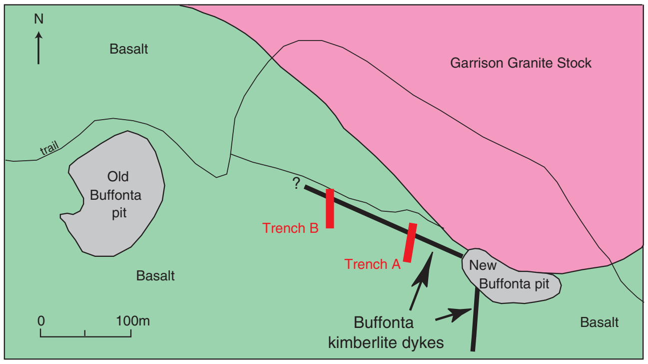


Figure 27. Detailed geology map of the Buffonta pit, illustrating the location of the two kimberlite dykes and two trenches excavated on the NNW trending dyke.

Figure 28. Photo of south striking kimberlite dyke in southwest wall of the Buffonta pit.

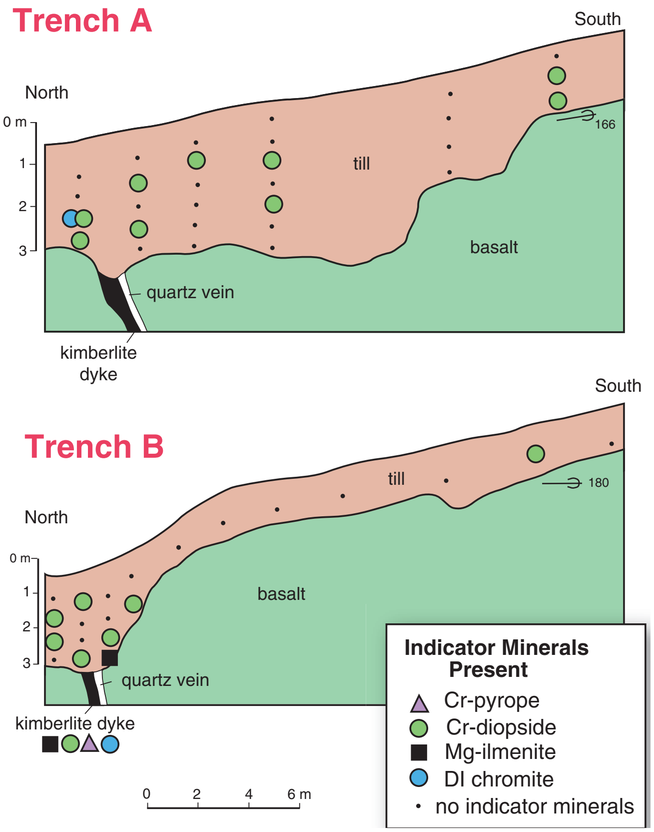


Figure 29. Detailed cross section through trench A and B, Buffonta kimberlite.

Figure 30. Weathered kimberlite in the Buffonta spoil heap.

geochemical and mineralogical methods. The two dykes intrude mafic volcanic rocks within the mineralized metamorphic aureole around the Garrison Stock. They have intruded along near-vertical shear zones in the host basalt. One dyke strikes north northwest, the other dyke strikes almost due south (Fig. 27, 28). Both are approximately 1 m wide. The north-northwest striking kimberlite dyke is a hypabyssal breccia comprising fragments of angular vein quartz and pyritized felsic intrusive rocks within a kimberlite matrix (Barron and Barnett, 1993) and has intruded along the edge of a 0.4 m wide quartz vein (Fig. 29). The subcropping surface of the kimberlite dyke is weathered sufficiently so that it may be excavated easily with a hand shovel. The south striking dyke is massive, and generally free of host rock inclusions. Numerous pieces of this kimberlite can be found in the spoil heaps from the gold mining operation (Fig. 30). It is unclear what the relationship between the two dykes is, as the open pit has flooded.

The kimberlite consists of macrocrysts of olivine and phlogopite, in a groundmass of olivine, phlogopite, calcite, perovskite, spinel, apatite, and serpentine. Microprobe studies reported by Barron and Barnett (1993) indicate that zonation

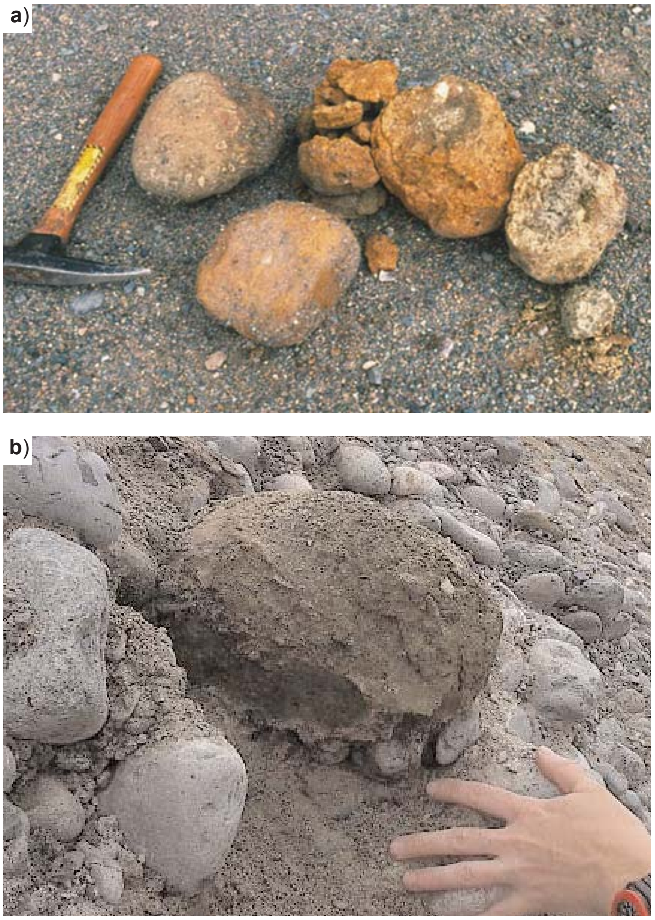


Figure 31. Kimberlite boulders from the Highway 66 gravel pit on the Munro Esker near Kirkland Lake: a) highly weathered orange cobbles; and, b) moderately weathered green kimberlite boulder in situ in pebble to cobble gravel.

trends in spinel are consistent with magmatic trend 1 of Mitchell (1986). Based on the mineral assemblage and spinel zonation trends, the Buffonta kimberlite is an archetypal (Group I) kimberlite. The Buffonta kimberlite is unusual however, in containing 10 to 30 µm kalsilite grains in the groundmass. U-Pb perovskite radiometric age determinations on the Buffonta dyke are somewhat enigmatic. Two perovskite populations are present in the Buffonta kimberlite; Type 1: large brown octahedral grains; Type 2: small irregular tan grains. Type 1 grains have a distinctly older age (153.4 Ma) than the Type 2 grains (145.9 Ma) (Heaman and Kjarsgaard, 2000). A possible interpretation is that the younger (146 Ma) kimberlite breccia incorporated older (153 Ma) hypabyssal kimberlite, although this idea has not been tested.

MUNRO ESKER

Over the past 30 years, numerous kimberlite boulders and cobbles have been found in gravel pits in two eskers that cross the Kirkland Lake kimberlite field (Baker, 1982; Brummer et al., 1992a; McClenaghan et al., 2002a). Kimberlite boulders are easily identified by their distinct light green or orange colour and typically high degree of weathering (Fig. 31a, b). They are commonly found in fresh faces of active gravel pits in matrix-supported, poorly sorted pebble to small boulder gravel. A selection of kimberlite boulders and cobbles from the eskers in the Kirkland Lake area was examined by the Geological Survey of Canada to determine their indicator mineralogy and to attempt to identify their kimberlite sources up-stream/up-ice. Determining the source of the boulders is significant to kimberlite exploration because boulders with indicator mineral compositions that are different from the known kimberlites indicate the presence of as yet undiscovered kimberlite(s) in the region.

Both glacial (striation orientations) and glaciofluvial (esker trends) transport directions must be considered when attempting to determine the source of kimberlite boulders in eskers in the Kirkland Lake region. Kimberlite boulders may have been glacially transported by the last phase of ice flow to the southeast prior to being incorporated into the meltwater drainage system of the glacier. Boulders were transported as fresh, competent fragments of kimberlite, deposited in glaciofluvial sediments, and subsequently suffered chemical weathering in the last 8000 years since deglaciation. Because the boulders have been so severely weathered, they crumble easily and it is therefore rare to find kimberlite boulders in gravel pits in which pit faces are not fresh.

Nine boulders were collected from two active gravel pits in the Munro Esker; one pit on the north side of Highway 66 (which will be visited as a field trip stop) and a second pit 6 km to the north on the east side of Victoria Lake (Victoria Lake pit). Of these nine boulders, six from the Victoria Lake and Highway 66 pits (Fig. 32) are likely derived from one

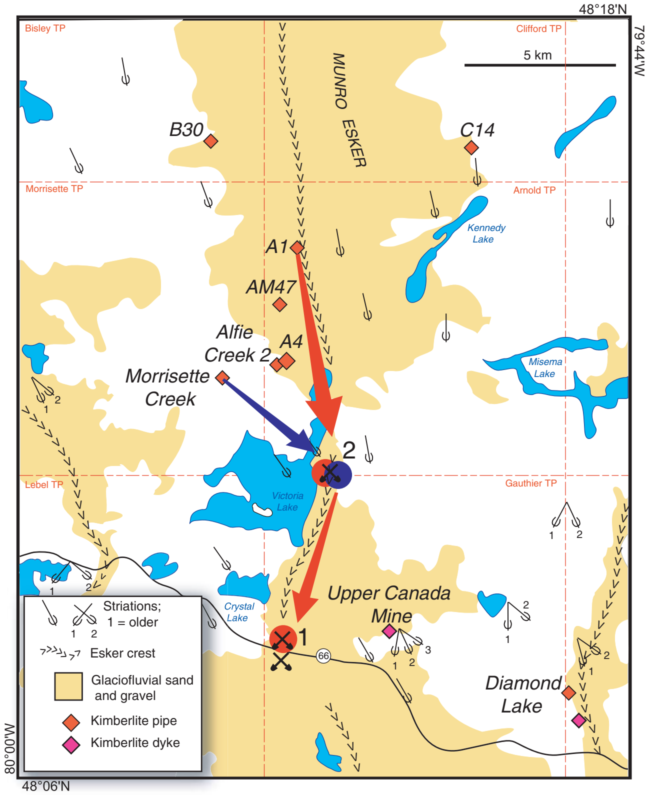


Figure 32. Distribution of glaciofluvial sand and gravel deposits of the Munro Esker, and location of gravel pits containing known kimberlite boulders: 1) Highway 66 pit; and 2) Victoria Lake pit. Possible glacial and glaciofluvial transport paths for kimberlite boulders are highlighted with the red and blue arrows (modified from McClenaghan et al., 2002a).

kimberlite source. They display similar relative abundances of indicator minerals and the following mineral chemical characteristics: 1) Mg-ilmenite has a narrow range of MgO (10–13 wt.%) and <1.2 wt.% Cr_2O_3; 2) chromite is abundant and exhibits a MAC-AMC compositional trend; 3) populations of crustal almandine garnet, eclogitic Mg-almandine garnet, megacryst suite Ti-Cr pyrope garnet, lherzolite Cr-pyrope garnet and low Ca/low Cr pyrope garnet are observed; 4) two populations of Cr-diopside are observed, one being very Mg-rich and of peridotitic origin, the other with lower Mg-number and thought to be of crustal xenocryst origin; and, 5) olivine is abundant, and of both kimberlitic and peridotitic origin, with possible crustal xenocrystic olivine in two of the samples. Their mineral chemistry is most similar to that of the Morrisette Creek kimberlite, approximately 5 km up-ice (northwest) of the Victoria Lake gravel pit. If the boulders are indeed from the Morrisette Creek kimberlite, they underwent two stages of transport: 1) glacial transport by late-stage southeast-flowing ice; and then, 2) transport in glacial meltwaters flowing east or southeast into the Munro Esker drainage system, and deposited in poorly sorted gravel at the Victoria Lake pit or carried further south to the Highway 66 pit. An alternate possible source for these boulders is a hitherto unknown kimberlite northwest to northeast of the Victoria Lake pit.

The three other kimberlite boulders examined have very different mineral chemistry and relative abundances. Mineral chemistry for two of the boulders (from the Victoria Lake pit) do not match published mineral chemistry data for kimberlites from the Kirkland Lake area, and are likely derived from two different and unknown kimberlites northwest to northeast of the Victoria Lake pit. Mg-ilmenite and garnet compositions of the third boulder (from the Highway 66 pit) are very similar to those from the A1 kimberlite, which underlies the Munro Esker approximately 10 km north (upstream) of the pit.

BEDROCK GEOLOGY IN THE NEW LISKEARD AREA

The locations of the kimberlites in the Lake Timiskaming kimberlite field are shown in Figure 33. The bedrock geology in the southern part of the Lake Timiskaming kimberlite field is shown in Figure 34. The main Archean geological elements are volcanic rocks (predominantly basalts), and metaconglomerates of the Timiskaming Formation. Paleoproterozoic diamictites and argillites of the Gowganda and Lorraine Formation (Young and Nesbitt, 1999) are the dominant lithology of the area. All of these units are cut by Paleoproterozoic Nipissing diabase sills (Lightfoot et al., 1993), and Mesoproterozoic diabase dykes. Paleozoic carbonate rocks of the Ferrar Formation limestone are part of the Lake Timiskaming outlier (Grant and Owsiacki, 1987).

MCLEAN KIMBERLITE

The McLean kimberlite is located at 47°29'10"N and 79°45' 30"W (UTM Zone 17, Easting 593600, Northing 5256000, NAD27) in Bucke Township, 6 km southwest of the town of New Liskeard. The kimberlite is on the McLean Farm, south of South Wabi Creek, in a wooded area 300 m west of the natural gas pipeline right of way (Fig. 35).

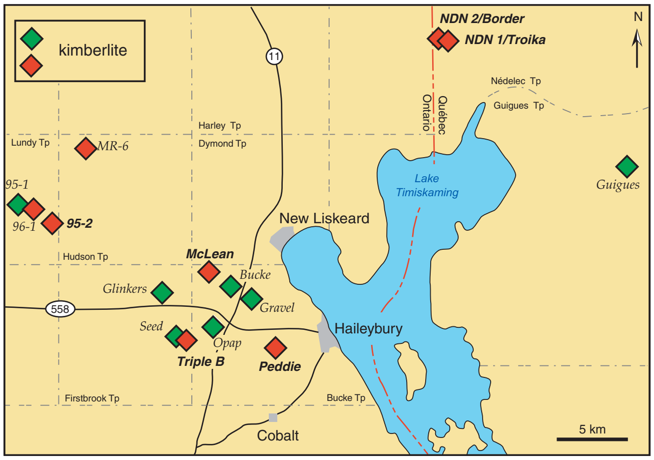


Figure 33. Location of the kimberlites to be examined in the field, and kimberlites for which drill core will be examined, in the Lake Timiskaming kimberlite field.

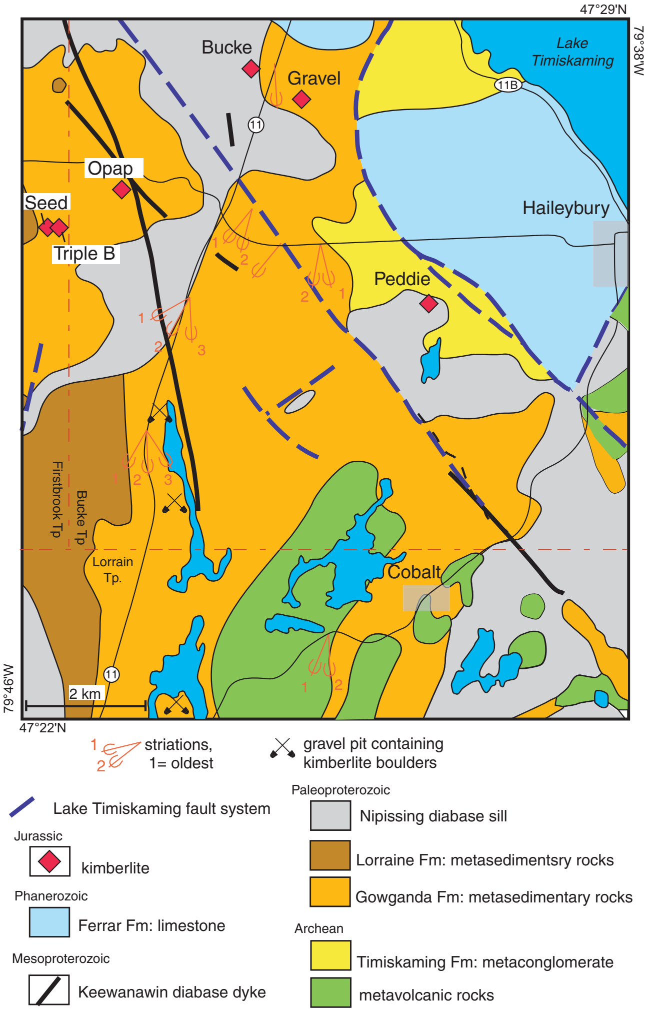


Figure 34. Bedrock geology in the area of the Lake Timiskaming kimberlite field.

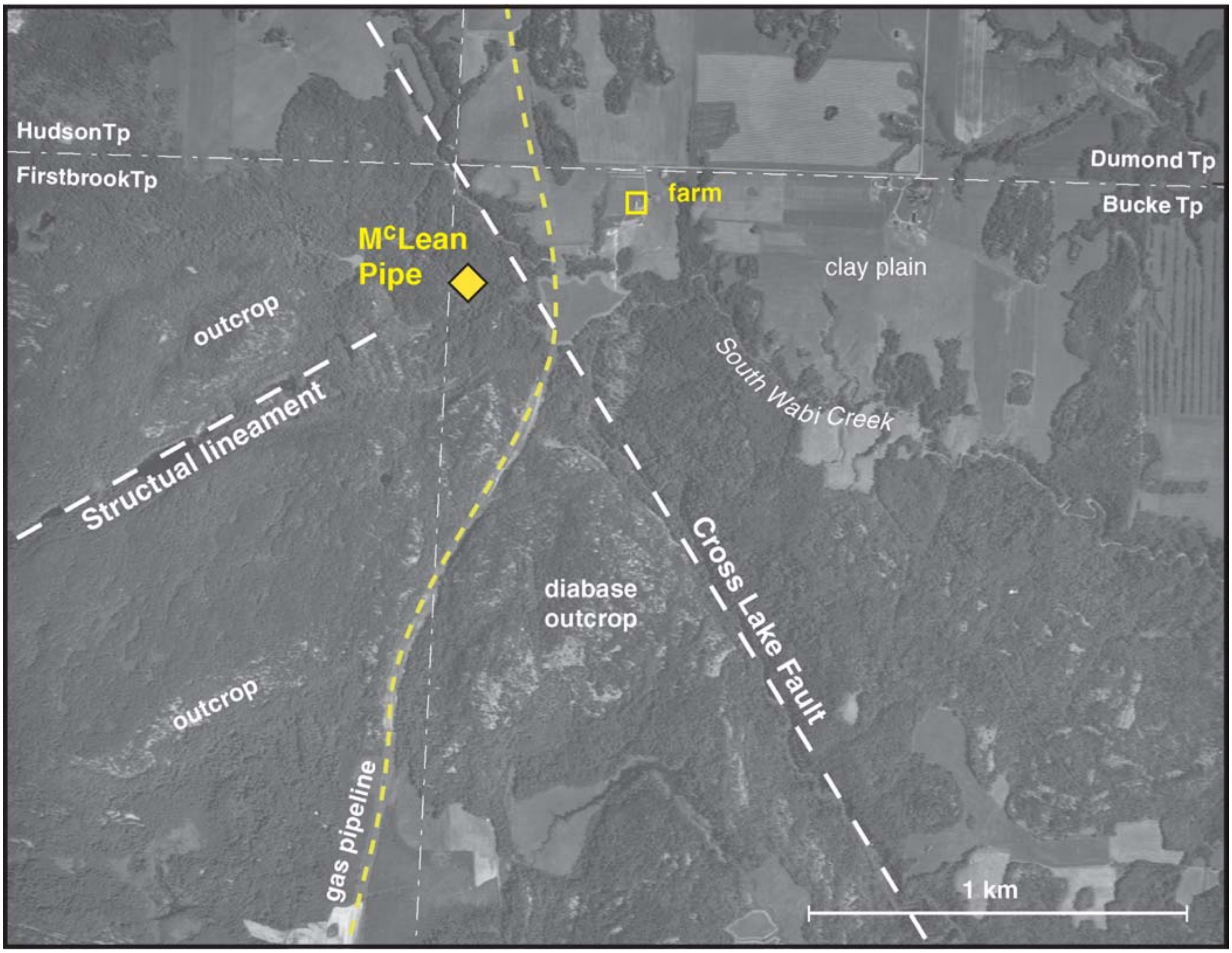


Figure 35. Air photo showing the location of the McLean kimberlite and significant bedrock structural features (Veillette, 1986b; Card and Lumbers, 1975).

The McLean kimberlite is located adjacent to (within 150 m of) the Cross Lake Fault, and appears to be directly on an unnamed structural lineament which trends at 045° (Fig. 35). It is suspected that the Bucke and Gravel kimberlites (Fig. 33) also lie along the Cross Lake Fault (Sage, 2000). The McLean kimberlite outcrops adjacent to a small ephemeral stream on the southeast side of the body (Fig. 36). It intrudes the Paleoproterozoic Firstbrook Member of the Gowganda Formation (Fig. 37). Rocks of the Firstbrook Member are comprised dominantly of thin- to medium-bedded argillite/siltstone, with minor wacke and arenite. Paleoproterozoic Nipissing diabase sills intrude the Gowganda Formation, and form extensive areas of outcrop and cliffs just to the south (Fig. 35). The McLean kimberlite is characterized by a circular, negative isomagnetic anomaly (Fig. 38) approximately 150 m in diameter (Sage, 2000).

A radiometric age of 141.9±2.8 Ma was determined by the U-Pb perovskite technique for the McLean kimberlite (Heaman and Kjarsgaard, 2000). This age suggests the McLean kimberlite is contemporaneous with the Guigues kimberlite in western Quebec (142.3±6.6 Ma), and lies in the middle of the age range of the eight Lake Timiskaming kimberlites dated so far, which vary from 155.4±1.5 Ma (Bucke) to 133.9±1.5 Ma (Glinker) in age (Heaman and Kjarsgaard, 2000).

From drill core studies it is known that the McLean kimberlite is a multi-phase intrusion that consists of diatreme and hypabyssal kimberlite (Sage, 1996, 2000; Hodder, 2002). The kimberlite sampled at the surface is a hypabyssal aphanitic kimberlite, which is characterized by a scarcity of megacrysts, xenoliths, and phenocrysts (Fig. 39). Burgers et al. (1998) describe the McLean kimberlite as a hypabyssal “porphyritic” spinel-rich calcite monticellite kimberlite and note a paucity of olivine macrocrysts. The hypabyssal aphanitic kimberlite is here termed a spinel monticellite calcite kimberlite, and in the drill core the diatreme kimberlite is best classified as a spinel calcite serpentine kimberlite.

The McLean kimberlite is covered by up to 0.3 m of grey, silty sand till, which is overlain by up to 3 m of glaciolacustrine silt (Fig. 40). Striations on kimberlite surfaces in Pits 1 and 9 indicate that ice flowed toward 212 to 218°. On the southeast edge of the kimberlite, small pockets of postglacially weathered kimberlite were observed. A sample of fresh aphanitic kimberlite contained approximately 1 g of

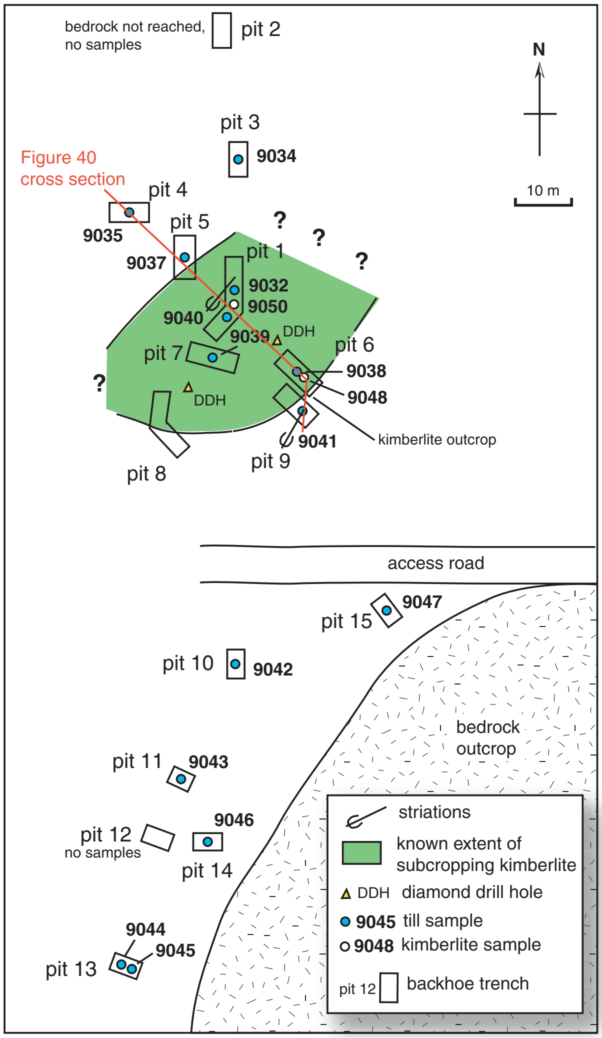


Figure 36. Location of backhoe trenches and till samples around the McLean kimberlite.

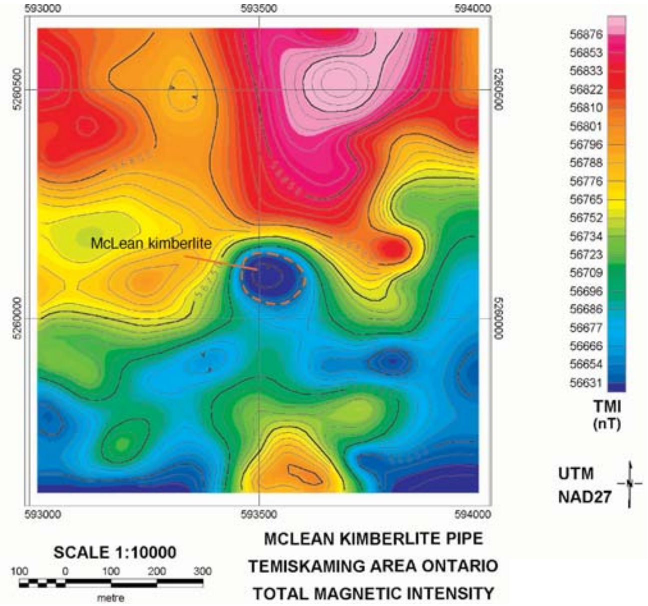


Figure 38. Airborne magnetic survey showing the negative magnetic anomaly associated with the McLean kimberlite. Likely extent of the kimberlite outlined by red dashed line. (unpublished data from MPH Consulting Ltd. and Sudbury Contact Mines Ltd., 2003).

Figure 37. Contact between the Jurassic-age McLean kimberlite (background) and Paleoproterozoic Firstbrook Member metasediments (foreground) in pit 9. Note more resistant ledge in the metasediments, due to the formation of a contact aureole.

Figure 39. Photo of polished hand specimen of aphanitic hypabyssal kimberlite which caps the McLean kimberlite.

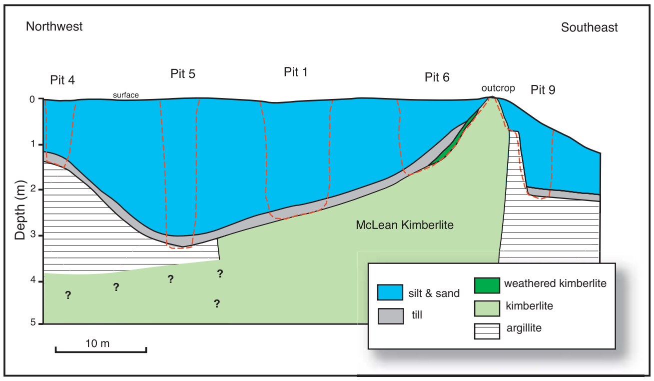


Figure 40. Schematic northwest-southeast cross section over the McLean kimberlite showing glacial sediment thickness and sample locations (not all samples shown).

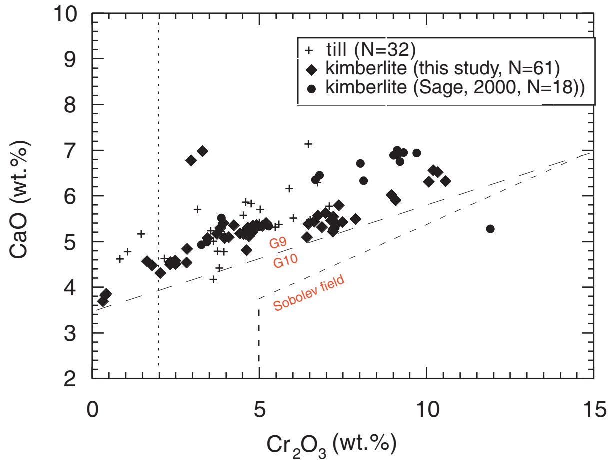
heavy minerals/kg of sample, of which 20% of the heavy minerals are ferromagnetic. In contrast, weathered kimberlite sample 9048 contains 24 g of heavy minerals/kg of sample, of which 90% of the heavy minerals are feromagnetic.

Garnet grains from the McLean kimberlite and surrounding till samples can be assigned to two different groups: 1) megacryst garnets (n=5), and 2) peridotitic garnets (n=83), including lherzolitic, harzburgitic and wehrlitic garnets, and garnets from sheared (metasomatized) lherzolites (Fig. 41a). Garnets from sheared/metasomatized lherzolites are similar in composition to megacryst garnets (e.g. high TiO_2) but have higher Cr_2O_3 (>3.5 wt.%; Fig. 41a). The peridotitic garnet population contains only two grains that plot below the 85% line of Gurney (1984), one of which (from Sage, 2000) is sufficiently subcalcic to plot in Sobolev's (1973) field for subcalcic garnets associated with diamonds (Fig. 41a). A comparison of the grains from till samples and the McLean kimberlite shows that the till contains garnets that are generally more CaO rich and do not exceed >6.5 wt.% Cr_2O_3, whereas the kimberlite contains more Cr-rich pyropes (up to 11 wt.% Cr_2O_3).

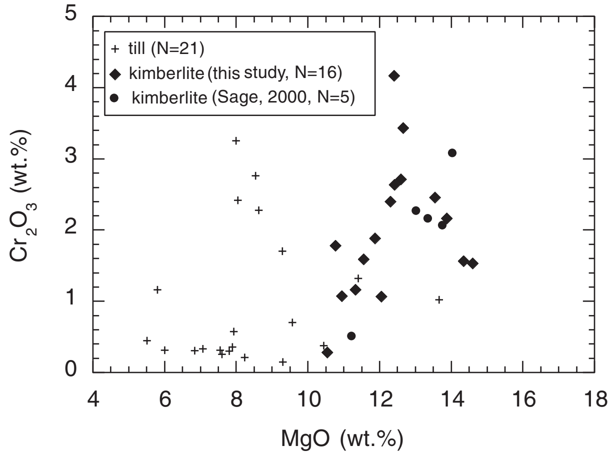
Mg-ilmenite (>5.0 wt.% MgO) is most abundant in the fresh aphanitic kimberlite sample, but is absent in the weathered kimberlite. Mg-ilmenite in till ranges from 5.5 to 13.7 wt.% MgO, with Cr_2O_3 contents up to 3.29 wt.% (Fig. 41b), whereas the McLean kimberlite is characterized by Mg-ilmenite with 10.5 to 14.6 wt.% MgO and Cr_2O_3 up to 4.17 wt.%. Comparison of ilmenite from the kimberlite and till shows almost mutually exclusive compositional fields (Fig. 41b). Only three grains from till samples overlap with the compositional field of McLean kimberlite ilmenite. Ilmenite in the till samples show two separate trends: 1) low (<0.7 wt.%) Cr_2O_3 and low (5–10 wt.%) MgO; and, 2) a parabolic trend represented by grains from samples ranging from 3.3 wt.% Cr_2O_3 at about 8 wt.% MgO to 1 wt.% Cr_2O_3 at 14 wt.% MgO, where they overlap with the Mg-ilmenite from the McLean kimberlite.

In contrast to garnet and Mg-ilmenite, which are far more abundant in the kimberlite compared to the till samples, chromite occurs in similar abundances in till and kimberlite samples (due to its a relative scarcity in the kimberlite). Chromite grains have a comparatively narrow range of Cr_2O_3, having concentrations from 40 to 63 wt.% Cr_2O_3 with the exception of a few outliers at lower Cr_2O_3 levels

a) garnet



b) Mg-ilmenite



c) chromite

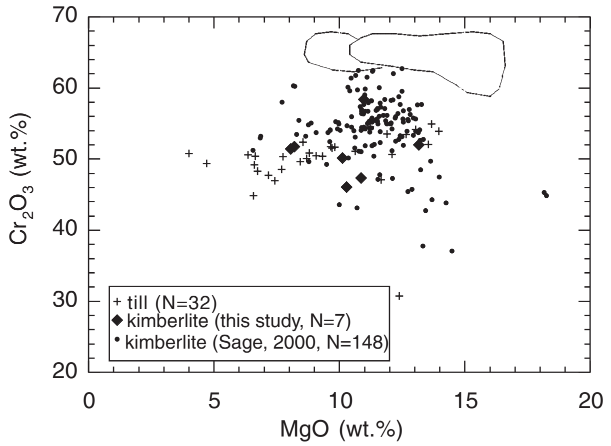


Figure 41. a) Bivariate plot of Cr_2O_3 versus CaO for garnet from the McLean kimberlite from McClenaghan et al. (2003) and from Sage (2000), along with garnet from till samples . Sobolev field is from Sobolev et al. (1973, 1993), dashed diagonal line separating G9 and G10 garnets is from Gurney (1984), dashed vertical line at 2 wt.% Cr_2O_3 is from Fipke et al. (1995); **b)** Bivariate plot of MgO versus Cr_2O_3 for Mg-ilmenite from the McLean kimberlite from McClenaghan et al. (2003) and from Sage (2000), along with Mg-ilmenite from till samples; **c)** Bivariate plot of MgO versus Cr_2O_3 for chromite from the McLean kimberlite from McClenaghan et al. (2003) and from Sage (2000), along with chromite from till samples. Diamond inclusion and intergrowth fields are from Fipke et al. (1995).

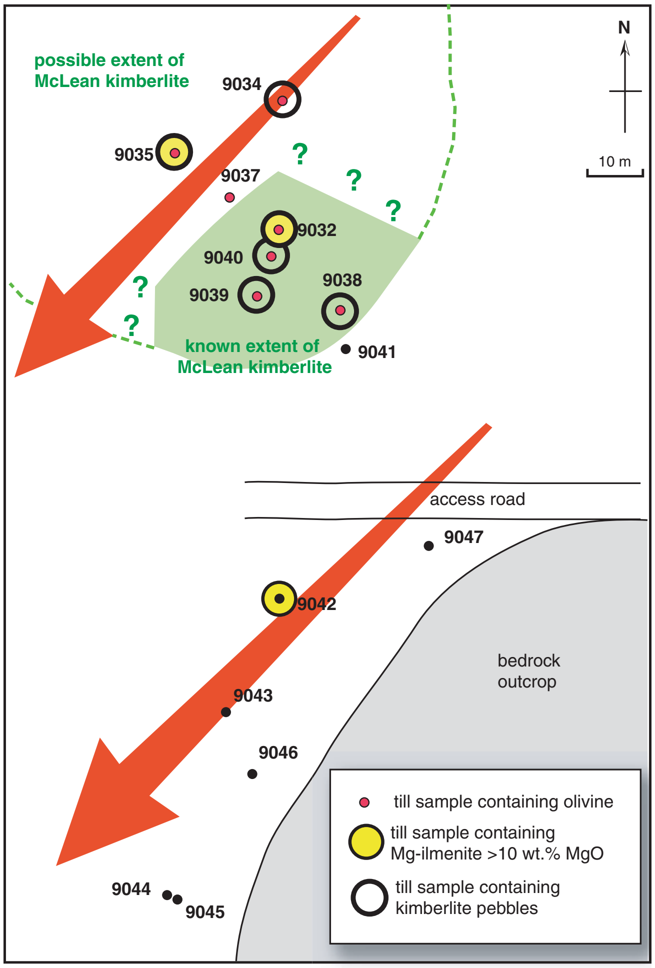


Figure 42. Known and possible extent of subcropping McLean kimberlite and local southwest-trending (218°) ice flow paths (red arrows).

(Fig. 41c). Comparison of the kimberlite and the till samples (Fig. 41c) shows that the kimberlite chromite grains have a narrower compositional range than chromite in till, which have lower MgO levels, indicating a trend towards Fe_2CrO_4 (chromite *sensu stricto*) + Fe_3O_4 (magnetite) at the expense of Mg_2AlO_4 (spinel *sensu stricto*). None of the chromite grains contain sufficient MgO and Cr_2O_3 to plot in the diamond inclusion field defined by Fipke et al. (1995), although chromite grains recovered from the McLean kimberlite drill core by Sage (2000) straddle the boundaries of both the diamond intergrowth and inclusion fields.

Due to the aphanitic nature of the kimberlite sampled at the surface, both the fresh and weathered kimberlite samples from the McLean pipe are indicator mineral poor compared to other kimberlites in the region (Sage, 1996, 2000; McClenaghan et al., 1999, 2003). Among the few indicator minerals recovered from McLean, garnet and Cr-diopside far outnumber Mg-ilmenite and chromite. Olivine, however, is by far the most abundant (>10000 grains) in the fresh kimberlite. Sage (2000) also reports finding few pyrope garnet and Mg-ilmenite and abundant olivine in a 3 kg drill core sample of hypabyssal kimberlite from the McLean pipe. In addition, he recovered numerous grains of chromite that overlap with compositions of chromite analyzed in this study and extend towards slightly more Cr_2O_3 rich compositions.

Due to the scarcity of indicator minerals in the McLean kimberlite, glacial dispersal of indicator minerals is short (<50 m). Till sampled to the south of the McLean kimberlite contains kimberlite indicator minerals that are distinctly different in composition from those of the McLean kimberlite, which suggests another kimberlite source(s) up-ice (northeast). Some of the chromite, Cr-diopside, and all of the MgO-poor ilmenite in till are not from kimberlite, but most likely from regional mafic or ultramafic rocks. Pyrope garnet and Mg-ilmenite, however, have compositions that indicate that they are from the McLean kimberlite further up-ice or from some other unknown kimberlite source up-ice.

The subcrop of McLean kimberlite delineated with backhoe trenching is small (30 x 40 m) compared to its likely extent (100 m across) indicated by the pipe's magnetic signature (Fig. 38). The presence of kimberlite indicator minerals and kimberlite pebble in till samples north of the known subcrop (Fig. 42) indicate that the Mclean kimberlite likely subcrops just north of sample 9034. If this is true, then argillite country rock in pits 3, 4, and 5 (sample sites 9034, 9035, and 9037; Fig. 36, 42) was not penetrated by the kimberlite in this part of the intrusion or may be xenoliths within the kimberlite.

SEED AND TRIPLE B KIMBERLITES

The Seed kimberlite was discovered in 1995 by Consolidated Pine Channel Gold Corp. using airborne and ground magnetic surveys. In 2001, shallow trenches were excavated into the Seed kimberlite by the Geological Survey of Canada. Also in 2001, the Triple B kimberlite (to the southeast of the Seed kimberlite) was discovered by the Geological Survey of Canada, using trenching to evaluate a shallow magnetic target. In 2002, additional trenching was undertaken on the Triple B kimberlite. The following is adapted from McClenaghan and Kjarsgaard (in press).

The Seed kimberlite is located at latitude 47°26'30"N, longitude 79°41"W (UTM Zone 17, NAD27, Easting 593010, Northing 5256250) and the Triple B kimberlite is located 270 m to the southeast (Fig. 33, 34, 43). Both kimberlites are on the west side of the natural gas pipeline, north

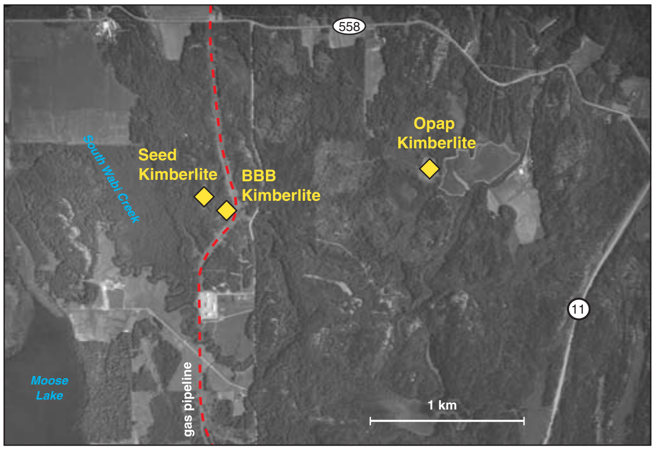


Figure 43. Aerial photograph showing the location of the Seed and Triple B kimberlites. Ontario Ministry of Natural Resources Air Photo No. 89-4716-36-64 (1989).

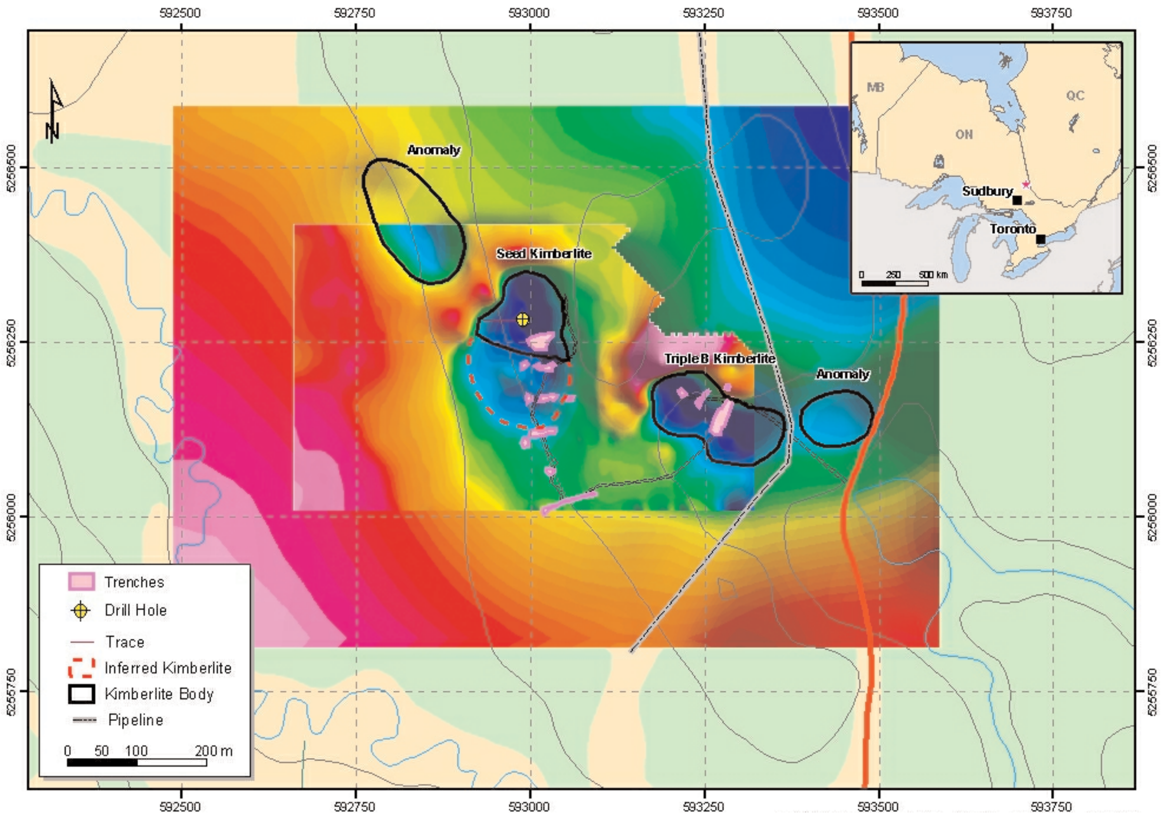


Figure 44. Airborne magnetic survey showing the negative magnetic anomalies associated with the Seed and Triple kimberlites, as well as two untested negative magnetic anomalies nearby outlined by thick black lines. Location of GSC trenches indicted in pink (unpublished data from De Beers, 2003).

of South Wabi Creek, in the northeast part of Firstbrook Township. They are in a recently logged part of Mr. Jeff Seed's farm.

The bedrock geology in the vicinity of the kimberlites consists of Paleoproterozoic rocks of the Firstbrook Member of the Gowganda Formation (Fig. 34; Johns and Van Steenburgh, 1984). Paleoproterozoic Nippising diabase sills intrude the Gowganda Formation, and form extensive areas of outcrop further to the east and north (Fig. 34). Locally, rocks of the Firstbrook Member are comprised of red to cream/buff coloured, thinly to medium-bedded, siltstone, and argillite. The Triple B kimberlite is intrusive into argillites of the Firstbrook Member. Host rock intrusive relationships for the Seed kimberlite were not observed in the excavations, but it is also inferred to intrude rocks of the Firstbrook Member. However, a backhoe pit just southwest of the Seed kimberlite encountered diabase, suggesting the Seed kimberlite may be, in part, intrusive into Nippising diabase.

Seed kimberlite

The Seed kimberlite has a strong negative magnetic response (Fig. 44). The outline of the kimberlite, indicated by the thick black line, is based on the geology of the subcropping bedrock surface exposed in GSC trenches. However, the geophysical anomaly is much larger than this outline, which likely indicates the kimberlite body is more extensive at depth (red dashed line).

From studies on drill core, Burgers et al. (1998) described the Seed kimberlite as having variable textures, including transitional pelletal tuffisitic diatreme, globular segregationary hypabyssal and segregationary hypabyssal. Sage (2000) described the Seed kimberlite as a pervasively altered hypabyssal kimberlite. The kimberlite subcrop which was excavated is a pelletal textured kimberlite breccia (>15% clasts larger than 4 mm), with the clasts dominantly argillite and limestone, with minor diabase (Fig. 45). Burgers et al. (1998) describe the mineralogy of the hypabyssal Seed kimberlite as a phlogopite and monticellite-bearing calcite kimberlite. McClenaghan and Kjarsgaard (in press) noted a serpentine-rich matrix, with microcrystalline diopside forming

Figure 45. Photograph of Seed diatreme kimberlite breccia.

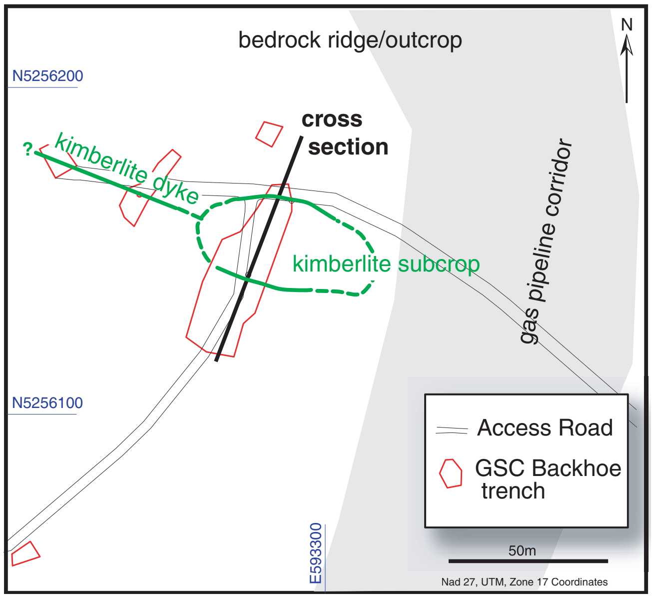


Figure 46. Location of trenches, till, and kimberlites sample sites over the Triple B kimberlite. Kimberlite subcrop outlined in green: known subcrop (solid line), inferred subcrop from geophysical data (dashed line).

at the margins of the pelletal lapilli, i.e. the hallmarks of diatreme kimberlite. A radiometric age of 153.7±1.8 Ma was determined by the U-Pb perovskite technique for the Seed kimberlite (Heaman and Kjarsgaard, 2000). This age suggests the Seed kimberlite is amongst the oldest of the eight Lake Timiskaming field kimberlites dated so far, which vary from 155.4±1.5 Ma (Bucke) to 133.9±1.5 Ma (Glinker) in age (Heaman and Kjarsgaard, 2000).

Triple B kimberlite

The geology of the Triple B kimberlite is quite variable. At the northern contact of the main kimberlite body (Fig. 46, 47) with the Firstbrook argillite (Fig. 48), there is hypabyssal aphanitic kimberlite (about 20-30 cm in width), which contains small (<1 mm) olivine phenocrysts, and is almost completely devoid of olivine macrocrysts. Over 5 m, there is a transition (with increasing olivine macrocryst content) from aphanitic kimberlite to 'normal' looking (i.e. macrocrystic) olivine-rich hypabyssal kimberlite (Fig. 49). Approximately 13 m from the north contact, there is a significant increase in country rock clasts (limestone and argillite), pelletal lapilli are observed, and the matrix is serpentine-rich. Ilmenite and garnet macrocrysts are noticeably abundant in hand samples. This rock is termed a diatreme kimberlite microbreccia (Fig. 49). Approximately 16 m south of the northern contact, there is a sharp break, south of which the kimberlite is completely altered (Fig. 49, 50). The southern contact of the main Triple B body was not determined, although ground geophysics and trenching suggest the subcropping kimberlite in the trench is 30 m in width. A narrow kimberlite dyke trending approximately 310° subcrops and was uncovered in two backhoe pits (Fig. 46). This dyke is a hypabyssal phlogopite spinel calcite kimberlite, based on petrographic observations. Ilmenite and garnet macrocrysts are noticeably abundant in hand samples of the dyke. The Triple B kimberlite has a strong negative magnetic response (Fig. 44). The outline of the kimberlite, indicated by the thick black line (Fig. 44), is based on the geology of the subcropping bedrock surface exposed in GSC trenches. A radiometric age for the Triple B kimberlite has not yet been determined.

A schematic cross section across the Triple B kimberlite showing glacial sediment thickness is illustrated in Figure

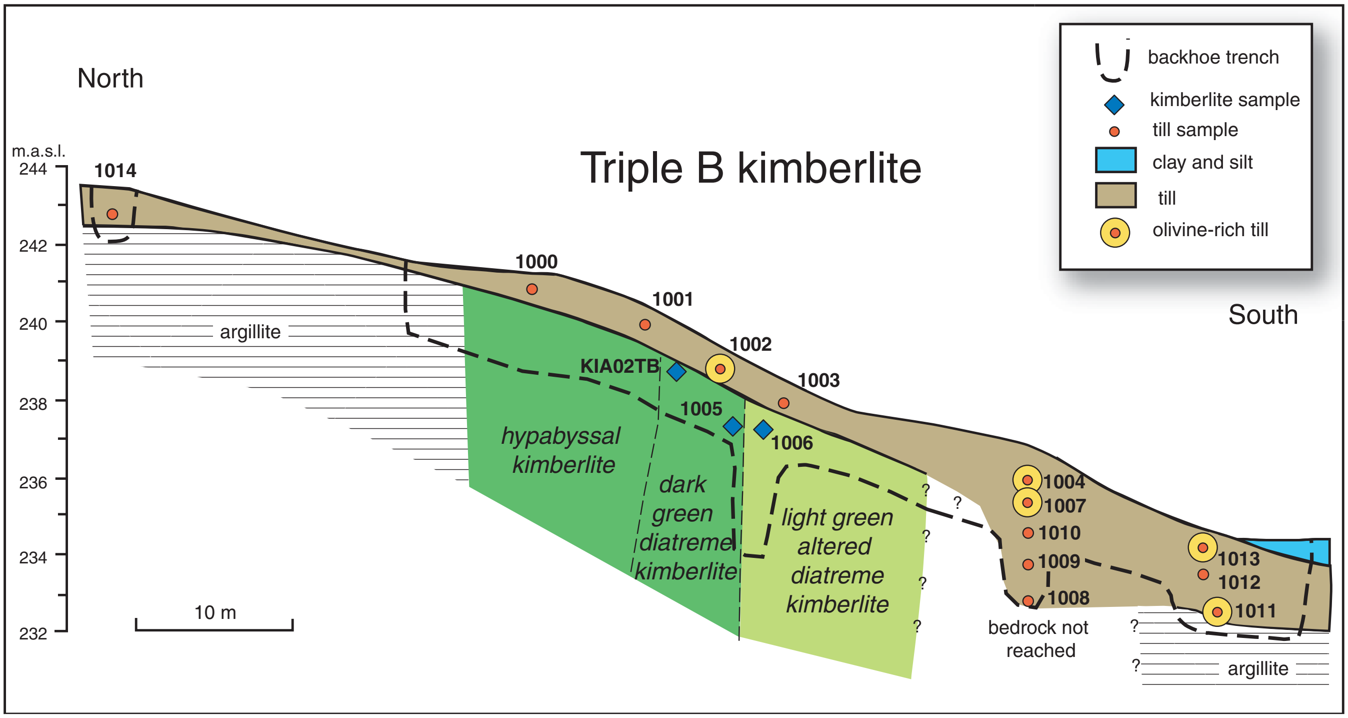


Figure 47. Schematic north-south section over the Triple B kimberlite showing glacial sediment thickness and sample locations.

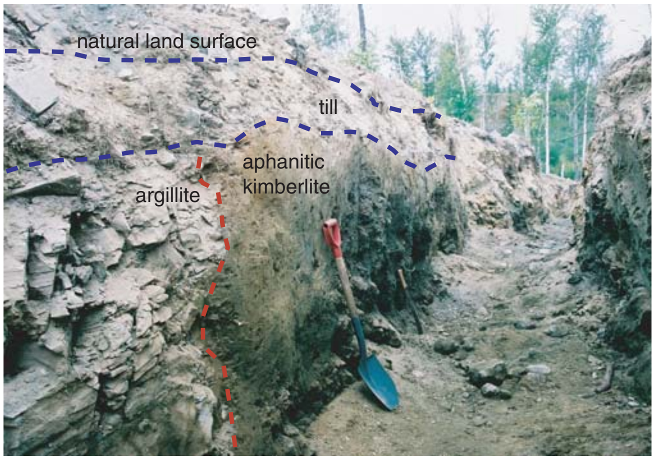


Figure 48. Northern edge of Triple B kimberlite in contact with Paleoproterozoic argillite. Photo looking south.

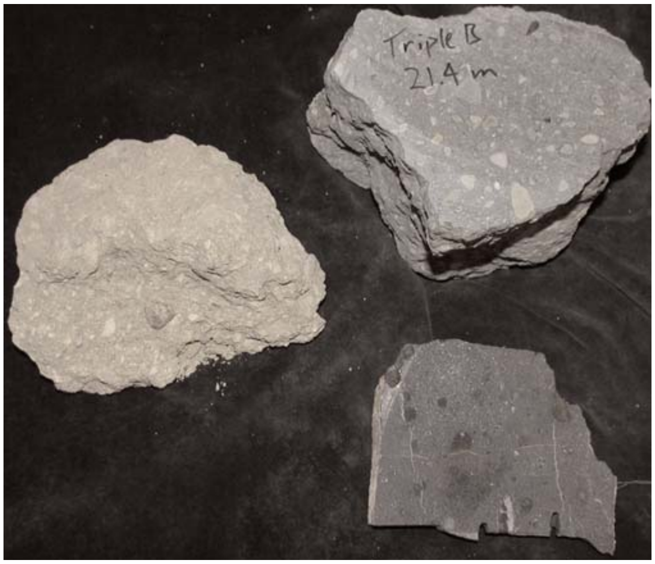


Figure 49. Photographs of Triple B kimberlite: aphanitic to sparsely macrocrystic hypabyssal kimberlite (at bottom); 'fresh' diatreme kimberlite microbreccia (at top); 'altered' diatreme kimberlite microbreccia(on left).

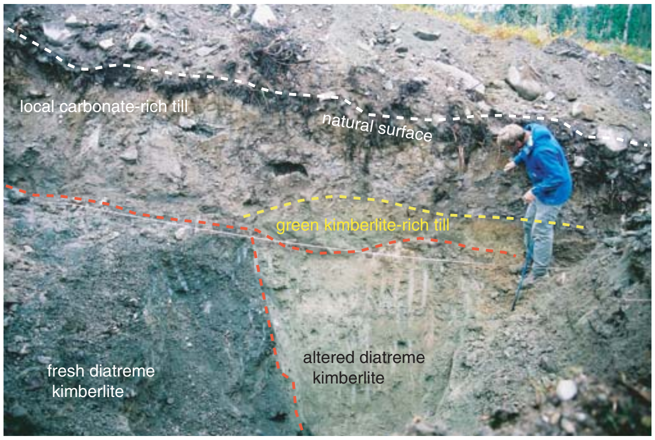


Figure 50. Southern part of Triple B kimberlite showing contact between dark green kimberlite and light green altered kimberlite microbreccia. Photo looking east.

47. At its north edge, the kimberlite is covered by a thin veneer of soil. Moving towards the south, a brown argillite-rich silty sand till of variable thickness (0.05–1.5 m) overlies the kimberlite (Fig. 48). The southern part of the kimberlite is overlain by thick green-brown kimberlite-rich silty sand till (Fig. 50). The upper 0.5 to 1.5 m of the kimberlite is variably weathered. More highly weathered kimberlite is yellow in colour, less weathered kimberlite yellow-green to light green in colour. The weathered kimberlite could be easily excavated with a backhoe. Kimberlite fragments as well as bands of green kimberlite-rich debris are common in till overlying and just down-ice (south). The kimberlite is in a lee-side (south-side) hollow of an argillite bedrock ridge and thus was likely protected from extensive glacial erosion.

PEDDIE KIMBERLITE

The Peddie kimberlite is located at latitude 47°26’30”N, longitude 79°41”W (UTM Zone 17, Easting 599450, Northing 5254900; NAD 27) in Bucke Township, 8 km south of the town of New Liskeard and 5 km north of the town of Cobalt (Fig. 33, 34). Part of it underlies a wooded area and part underlies a swampy area associated with a beaver pond on the Peddie Farm south of Highway 558 (Fig. 51). The host rocks to the Peddie kimberlite are Paleoproterozoic Nipissing diabase sills. The Peddie kimberlite was discovered by Consolidated Pine Channel from a drill program, on the basis of a circular magnetic anomaly on an airborne survey (Fig. 52).

The Peddie kimberlite is classified as a hypabyssal phlogopite macrocrystic monticellite kimberlite. A high precision U-Pb perovskite radiometric age determination of 153.6 Ma (Heaman and Kjarsgaard, 2000) indicates the kimberlite is of Late Jurassic age. The kimberlite contains quite unusual ‘eggs’ (10–20 cm in size) consisting of >90 modal% olivine. These ‘eggs’ are not mantle dunite xenoliths, but are autoliths of crystallinoclastic kimberlite. The kimberlite has been eroded by preglacial and glacial processes. The upper surface of the kimberlite has undergone varying degrees of post-glacial weathering, leaving most of the upper surface friable and soft. A portion of the upper surface, however, is unweathered, hard kimberlite and displays what may be the first reported striated kimberlite surface.

Eleven trenches 2 to 3 m deep were excavated by the Geological Survey of Canada (McClenaghan et al., 1999) using a backhoe to collect bulk (10 kg) samples of weathered and fresh kimberlite as well as glacial sediments overlying, up-ice, and down-ice of the kimberlite. Pits were dug along an east-west line across the kimberlite and along a north-south line down-ice of the kimberlite (Fig. 51, 52, 53). The Peddie kimberlite is covered by 1 to 3 m of grey, silty sand till (Fig. 53), which is overlain by fine-grained discontinuous glaciolacustrine sediments. Striations on the kimberlite and other bedrock in the area indicate that ice flowed toward 200° and 180°. Highly weathered kimberlite containing tree roots, weakly weathered kimberlite, and fresh kimberlite were collected from backhoe pits #2 and #3 to compare mineralogy and geochemistry of weathered and unweathered kimberlite. Additional samples of fresh kimberlite were taken from backhoe pit #4 and from large boulders in till from pits #7 and #8.

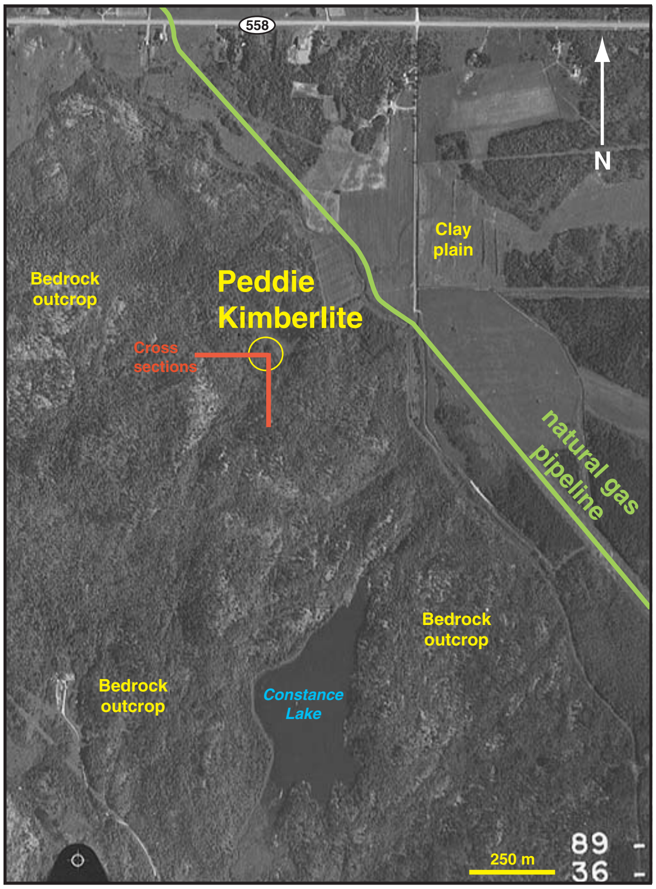


Figure 51. Aerial photograph showing the location of the Peddie kimberlite. Red lines indicate position of cross-sections shown in Figure 53.

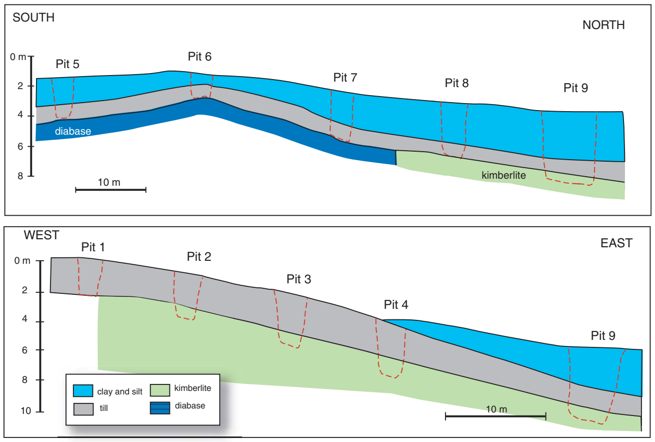
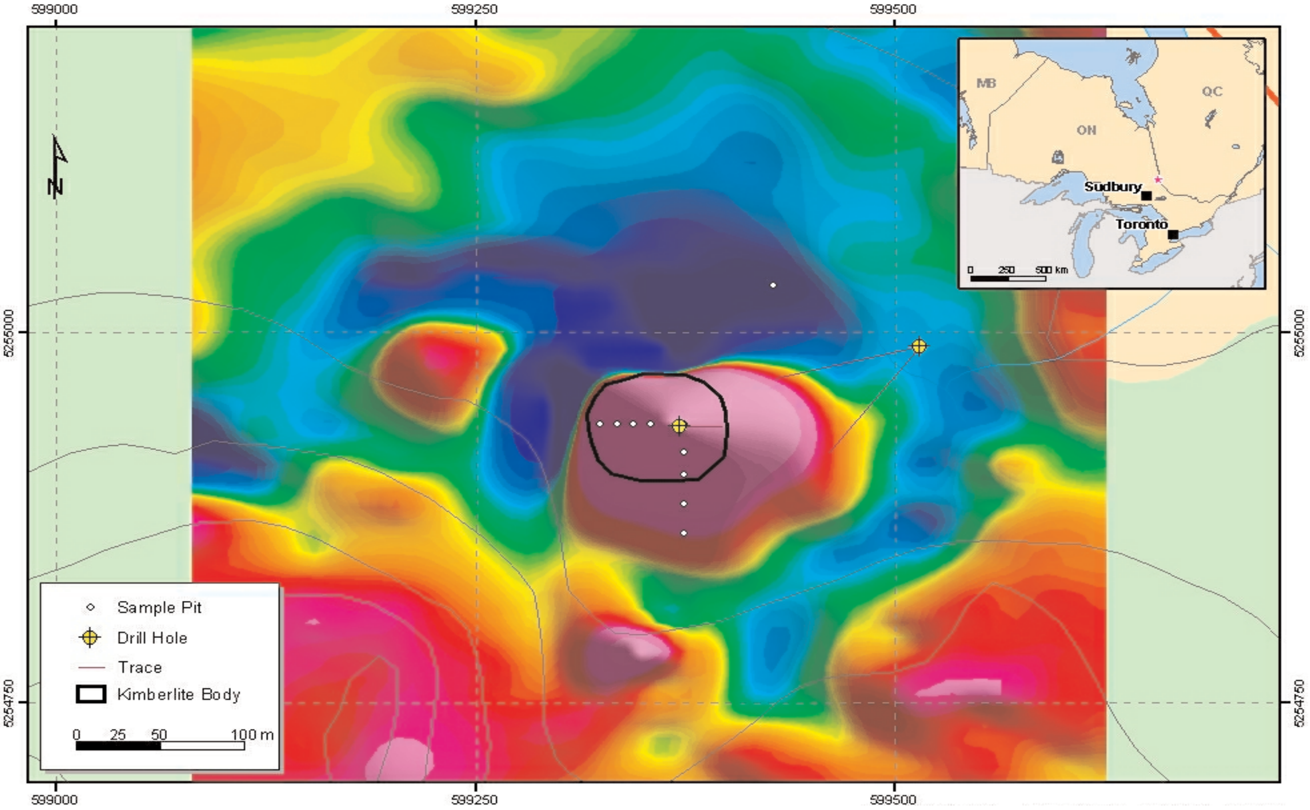
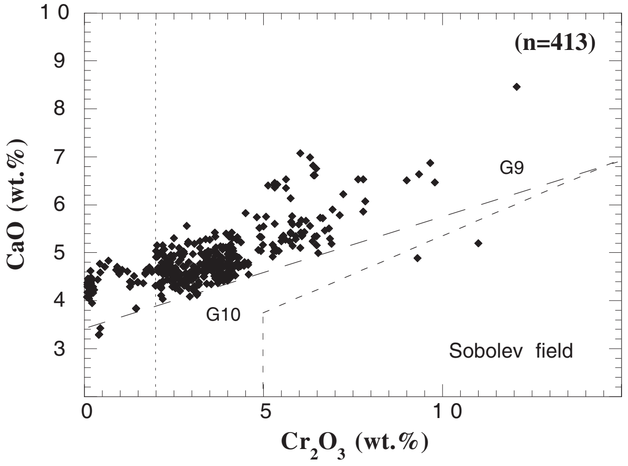


Figure 53. Schematic north-south and west-east cross-sections over the Peddie kimberlite showing glacial sediment thickness and-sample locations.

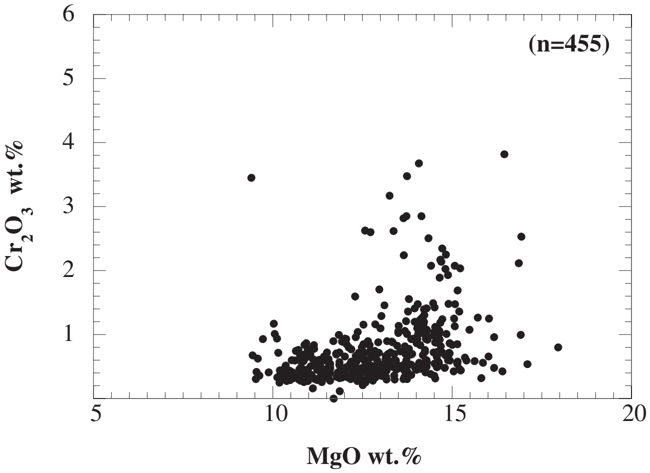
Figure 52 Airborne magnetic survey showing the magnetic anomaly associated with the Peddie kimberlite, Location of GSC trenches indicted in white circles, and drill holes by yellow circles with black lines.



a) garnet



b) Mg-ilmenite



c) chromite

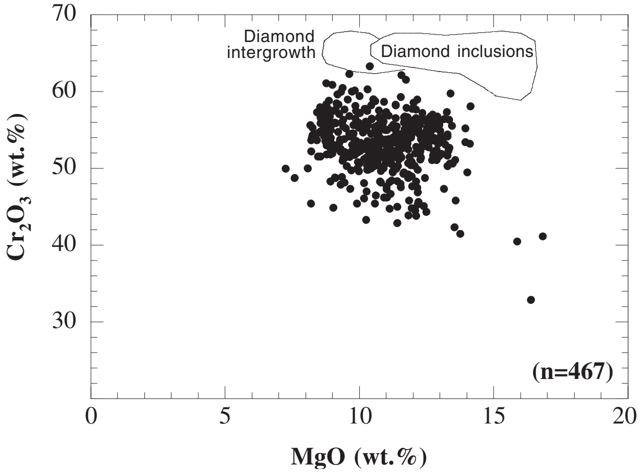


Figure 54. a) Bivariate plot of Cr_2O_3 versus CaO for garnet from the Peddie kimberlite. Sobolev field is from Sobolev et al. (1973, 1993), dashed diagonal line separating G9 and G10 garnets is from Gurney (1984), dashed vertical line at 2 wt.% Cr_2O_3 is from Fipke et al. (1995); **b)** Bivariate plot of MgO versus Cr_2O_3 for Mg-ilmenite from the Peddie kimberlite; **c)** Bivariate plot of MgO versus Cr_2O_3 for chromite from the Peddie kimberlite. Diamond inclusion and intergrowth fields are from Fipke et al. (1995).

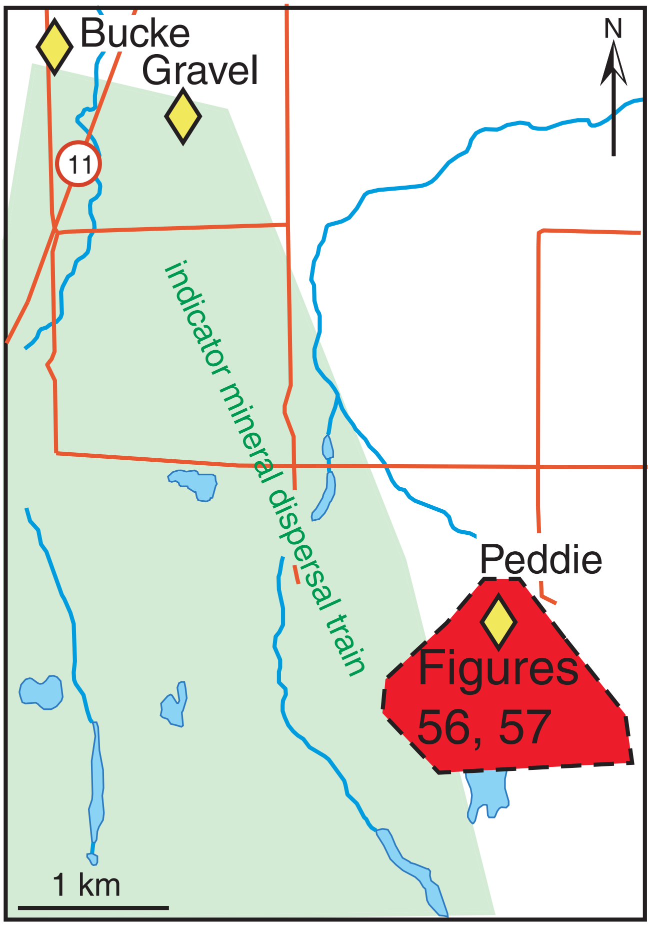


Figure 55. Location of detailed till sampling area (in red) down-ice of the Peddie kimberlite, in relation to part of the fan-shaped dispersal train (shaded green) of visually identified kimberlite indicator minerals in the 0.3 to 2.0 mm fraction of surface till and glaciofluvial sediment samples down-ice of the Bucke and Gravel kimberlites, Lake Timiskaming kimberlite field (unpublished data from De Beers Canada Exploration Inc., 2003).

The relative abundance of kimberlite indicator minerals in the Peddie kimberlite is: olivine >> Mg-ilmenite >> pyrope > Cr-spinel > Cr-diopside. A selection of the picked olivine grains from kimberlite and till samples (N=1231 grains) was analyzed by electron microprobe. These grains exhibit a very limited chemical variation: Mg# varies from 85.4 to 94.7 and NiO from 0.00 to 0.50 wt.%. The high Mg-numbers (>91.5) are typical for mantle olivine derived from peridotite xenoliths. The lower Mg-numbers (<91) are likely phenocrysts from the kimberlite (Mitchell, 1986), which is also evident from their lower Ni levels. A similar range in Mg-numbers is seen both in weathered kimberlite and in till. Most pyrope garnets from the Peddie kimberlite (Fig. 54a) are of lherzolitic paragenesis. Only two (out of 422) Cr-pyrope garnets from the Peddie kimberlite plot within the subcalcic field (Fig. 54a). This chemistry indicates that there is a low proportion of depleted harzburgite/dunite in the mantle xenolith suite sampled by the Peddie kimberlite. Mg-ilmenite in the Peddie kimberlite (Fig. 54b) is characterized by extremely high MgO (9–18 wt.%). Chromite grains from the Peddie kimberlite are shown on bivariate plots of MgO versus Cr_2O_3 in Figure 54c. A single chromite grains falls

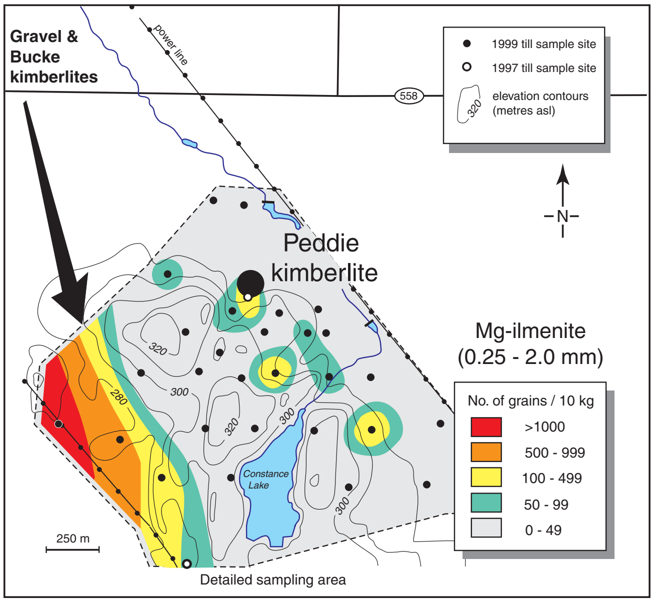


Figure 56. Distribution of Mg-ilmenite in the 0.25 to 2.0 mm fraction of till around the Peddie kimberlite.

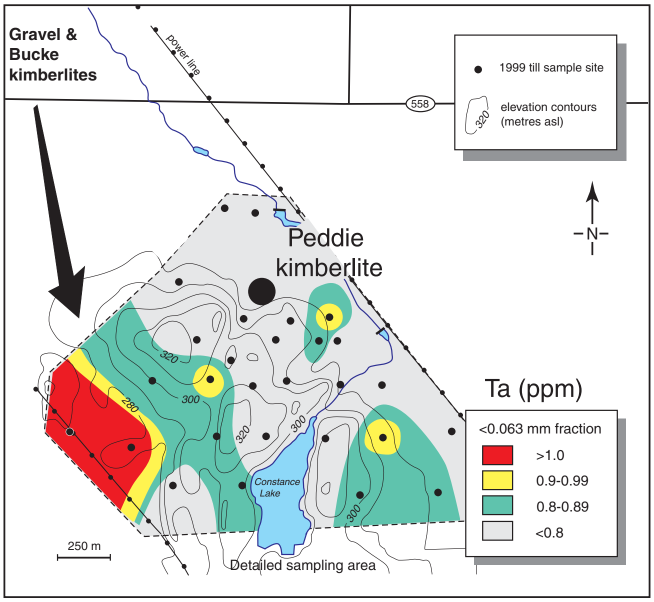


Figure 57. Distribution of Ta in the <0.063 mm fraction of till around the Peddie kimberlite.

into the diamond intergrowth field as defined by Fipke et al. (1995).

On the basis of a limited number of till samples taken up-ice, and samples 2 to 7 km down-ice having similar indicator mineral chemistry, and different to that from the Peddie kimberlite (McClenaghan et al. 1999), additional sampling was undertaken in 1999. The results of this work are reported in McClenaghan et al. (2002b), and summarized here. Thirty till samples were collected (mainly south) of the Peddie kimberlite (Fig. 55) to document the nature of glacial dispersal from the kimberlite, using both indicator minerals and till geochemistry. Most of the kimberlite indicator minerals in till were found in the finest of the three size fractions (0.25–0.5, 0.5–1.0 and 1.0–2.0 mm) of heavy mineral concentrates examined. Till in the vicinity of the Peddie kimberlite contains a distinctive kimberlitic geochemical signature defined by Ni, Cr, Nb, and Ta, which is most apparent in the coarse to very coarse sand (0.5 to 2.0 mm) and the silt+clay (<0.063 mm) fractions. Two dispersal trains in till were detected near the Peddie kimberlite. One short train immediately down-ice of, and derived from, the Peddie kimberlite is defined by the minerals olivine and Mg-ilmenite (Fig. 56), with elevated concentrations of Ni, Cr, and Nb. A second dispersal train 800 m southwest of the Peddie kimberlite and trending southeast, is defined by abundant Mg-ilmenite (Fig 56) and Cr-pyrope, and elevated concentrations of Nb and Ta (Fig. 57). This second dispersal train is likely derived from the Gravel and or Bucke kimberlites 4 to 5 km up-ice (Fig. 55, 25) and/or an unknown kimberlite.

SUDBURY CONTACT KIMBERLITE 95-2

The following was contributed by P. Sobie of MPH Consulting. Drill core will be will be displayed as part of the field trip in New Liskeard, from kimberlites 95-2, 96-1, and MR6.

Results of logging of thirteen delineation boreholes, as well as four historical core holes indicate the internal geology of kimberlite 95-2 is at lower diatreme levels, and consists of: (a) a weathered cap designated “WTKB” in the upper 20 to 25 metres of the pipe; (b) a dilute tuffisitic kimberlite breccia primarily located in the extreme eastern portion of the pipe designated as “K1”; and (c) the dominant facies designated as “K3”, which grades from a tuffisitic kimberlite breccia in the east into a tuffisitic kimberlite in the western portion of the pipe (Fig. 58). Deeper holes in all parts of kimberlite pipe 95-2 have intersected transitional hypabyssal to diatreme kimberlite, and pure “K4” globular-segregationary hypabyssal kimberlite. However further drilling and petrographic study is required to refine these internal contacts, and therefore K4 is not portrayed in the current 3-D geological model as shown in Figure 58.

Petrographic and indicator mineral studies previously completed on kimberlite 95-2 establish it as an ilmenite-poor, Group 1 monticellite-phlogopite kimberlite. Presently K1, K3, and K4 are considered to be genetically related intrusions, all of which engulfed an earlier precursor hypabyssal kimberlite (“K2”), which is evident as autoliths in all of these facies. K2 is only known presently as thin “smears” of remnant material found in embayments around the margins of the pipe and as autoliths in all other facies.

Results thus far indicate that kimberlite 95-2 has an inferred surface area of approximately five hectares under 30 to 50 metres of overburden. Overburden varies from 30 metres in the north to 50 metres in the centre of the pipe. In addition, geophysical and drilling data suggest that the western limit of kimberlite 95-2 extends farther than previously estimated and has not yet been concisely ascertained. Based on the results thus far from the delineation drilling program, kimberlite 95-2 has a drill indicated strike length of 400 metres at the -200 m level, and a width that varies from 75 to 150 metres at the same depth. Drill holes shallower than 200 metres suggest that kimberlite 95-2’s expanse flares out significantly on its northern, western, and southern borders. However, further drilling is required to confirm its subcropping surface expression. At present, the delineation pro-

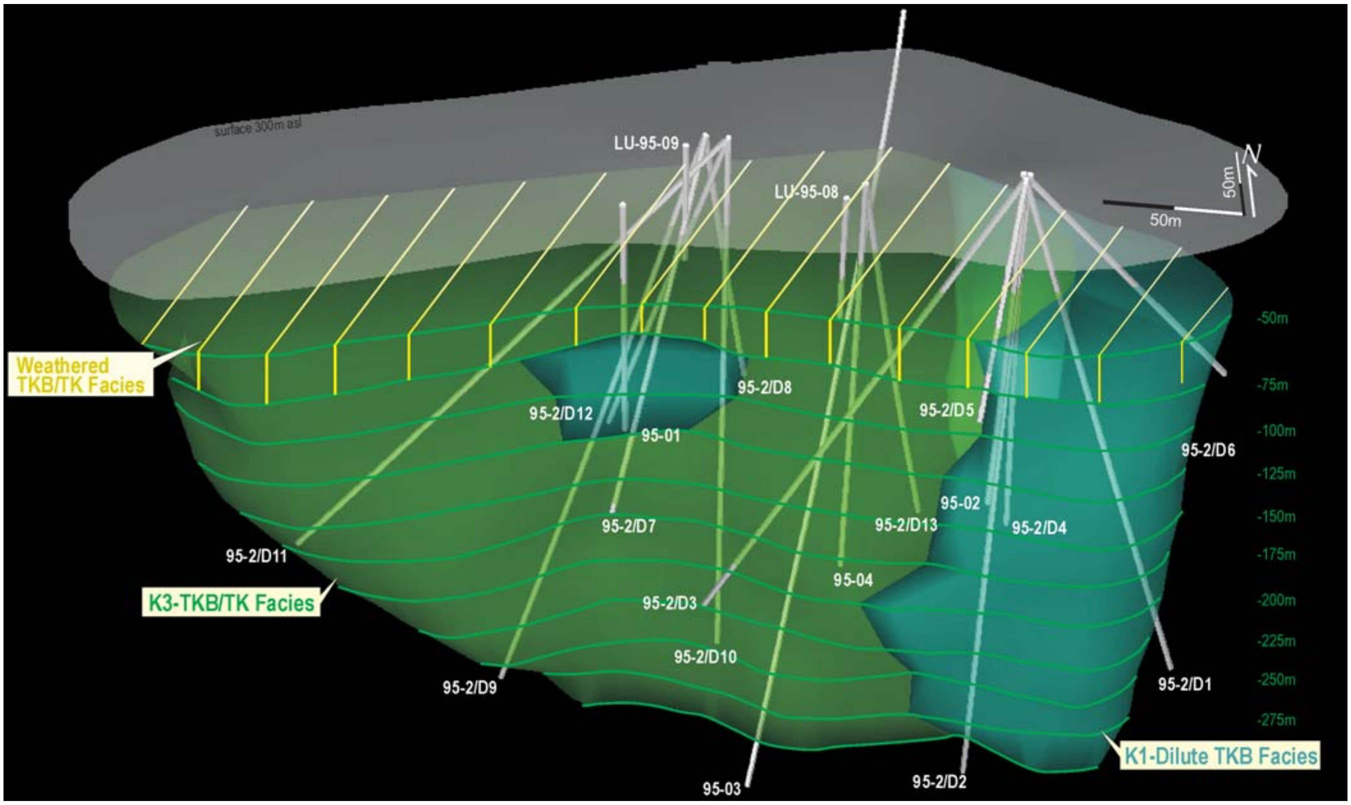


Figure 58. Three-dimensional model of the 95-2 kimberlite, based on currently available drilling information (courtesy MPH Consulting and Sudbury Contact Mines Ltd.).

Figure 59. Photo of fresh kimberlite drill core from the Troika pipe.

Figure 60. Kimberlite boulder exposed in a massive, poorly sorted pebble to boulder gravel facies of the Sharp Lake esker.

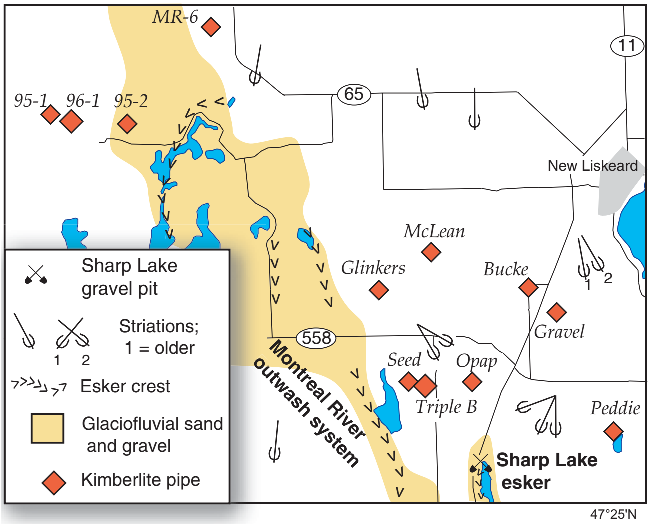


Figure 61. Areas covered by glaciofluvial sand and gravel deposits of the Sharp Lake esker and Montreal river outwash system and the location of gravel pit containing kimberlite boulders (modified from McClenaghan et al., 2002).

Figure 62. Section in east wall of gravel pit at north end of Sharp Lake esker.

gram indicates that 23 to 25 million tonnes of kimberlite are located in 95-2 to a depth of less than 300 metres. More drilling is required to ascertain the position of the margins, the ultimate tonnage estimate, and the internal geology of kimberlite 95-2, particularly in respect of the western portion of the pipe.

Diamond content can generally be described as modest in terms of the gross numbers of microdiamonds, however, the microdiamond distribution present includes a high proportion of larger stones, providing encouragement for a potentially viable commercial stone population. A 300 to 500 tonne mini-bulk sample is planned in order to test for the recovery of commercial sized diamonds from 95-2.

DRILL CORE FROM THE TROIKA, NDN#2, AND GUIGES KIMBERLITES, QUEBEC

The following was contributed by H. Cookenboo of Tres-Or Resources, and N. McBride and P. Brown. Drill core from three kimberlites, Troika (Fig. 59), NDN#2, and Guiges will be displayed as part of the field trip in Notre Dame du Nord. These three kimberlites are all on the east side of the Lake Timiskaming graben, in contrast to the rest of the known kimberlites in the Lake Timiskaming field, which either lie within the graben, or to the west of the graben. Indicator mineral chemistry for these kimberlites has been described by Sage (1996). Cr-pyrope garnets are dominated by lherzolite, with less than 1% being subcalcic. Chromites are Cr-rich, with a few grains having >60 wt% Cr_2O_3. Mineral chemistry is reported to be similar in all three kimberlites. The Troika kimberlite, and its satellite NDN#2, was discovered in 1994 by KWG. On the basis of ground magnetic data, the Troika pipe is considered to have three lobes. Diamonds have been recovered from the Troika, NDN #2, and Guiges kimberlites.

SHARP LAKE PIT

Over the past 30 years, numerous kimberlite boulders (Fig. 60) and cobbles have been found in gravel pits in the Sharp Lake and Lac Baby eskers, two eskers that cross the Lake Timiskaming kimberlite field. The Sharp Lake esker (Fig. 61, 62) trends southward for 5 km to where it joins the larger Montreal River outwash system (Fig. 61; Veillette, 1986b). Six kimberlite boulders from gravel pits along the esker have been examined by the Geological Survey of Canada to determine their kimberlite indicator mineralogy and to attempt to identify their kimberlite sources up-stream/up-ice (McClenaghan et al., 2002a). Both glacial (striation orientations) and glaciofluvial (esker trends) transport directions must be considered when attempting to determine the source of kimberlite boulders in eskers in the Lake Timiskaming region. They may have been glacially transported by the last phase of ice flow to the southeast prior to being incorporated into the meltwater drainage system of the glacier.

The six boulders from the esker display very similar mineral chemistry and mineral abundances and are likely derived from one kimberlite source. They have almost identical Mg-ilmenite and similar garnet and perovskite compositions. They are further characterized by Ti-poor (0.5 wt.% TiO_2) megacryst garnets, an abundance of very coarse perovskite, low concentrations of chromite and clinopyroxene, and a lack of fresh olivine. Mg-ilmenite compositions are characterized by a wide spread of MgO from about 6 to 14 wt.% at comparatively low Cr_2O_3 (<0.8 wt.%), with a distinct break in the pattern at about 8.5 wt.% MgO. Radiometric age dating (U-Pb perovskite technique) of two of the boulders produced ages of 145.0±1.5 Ma and 144.7±1.0 Ma, respectively, which are within the range of age determinations for kimberlites from the Lake Timiskaming field (134–155 Ma; Heaman and Kjarsgaard, 2000). These boulders do not, however, display similarities in mineral chemistry, abundance or age to any of the known kimberlites in the Lake Timiskaming field, which suggests they are derived from a yet to be discovered kimberlite.

KIMBERLITE CORE AND ROCK SAMPLES AT THE DE BEERS WAREHOUSE, SUDBURY

On the last day of the field trip, the morning and early afternoon will be spent at the De Beers warehouse in Sudbury. There will be a display of drill core form the Victor kimberlite, Attawapiskat field, James Bay Lowland. Further details on the geology of the Victor kimberlite are described by Webb (2003, this guidebook). In addition, there will be samples from the Wemindji kimberlites from the Quebec side of the James Bay Lowland. The Wemindji kimberlites are further described by Letendre et al. (2003) and Mitchell and Letendre (2003).

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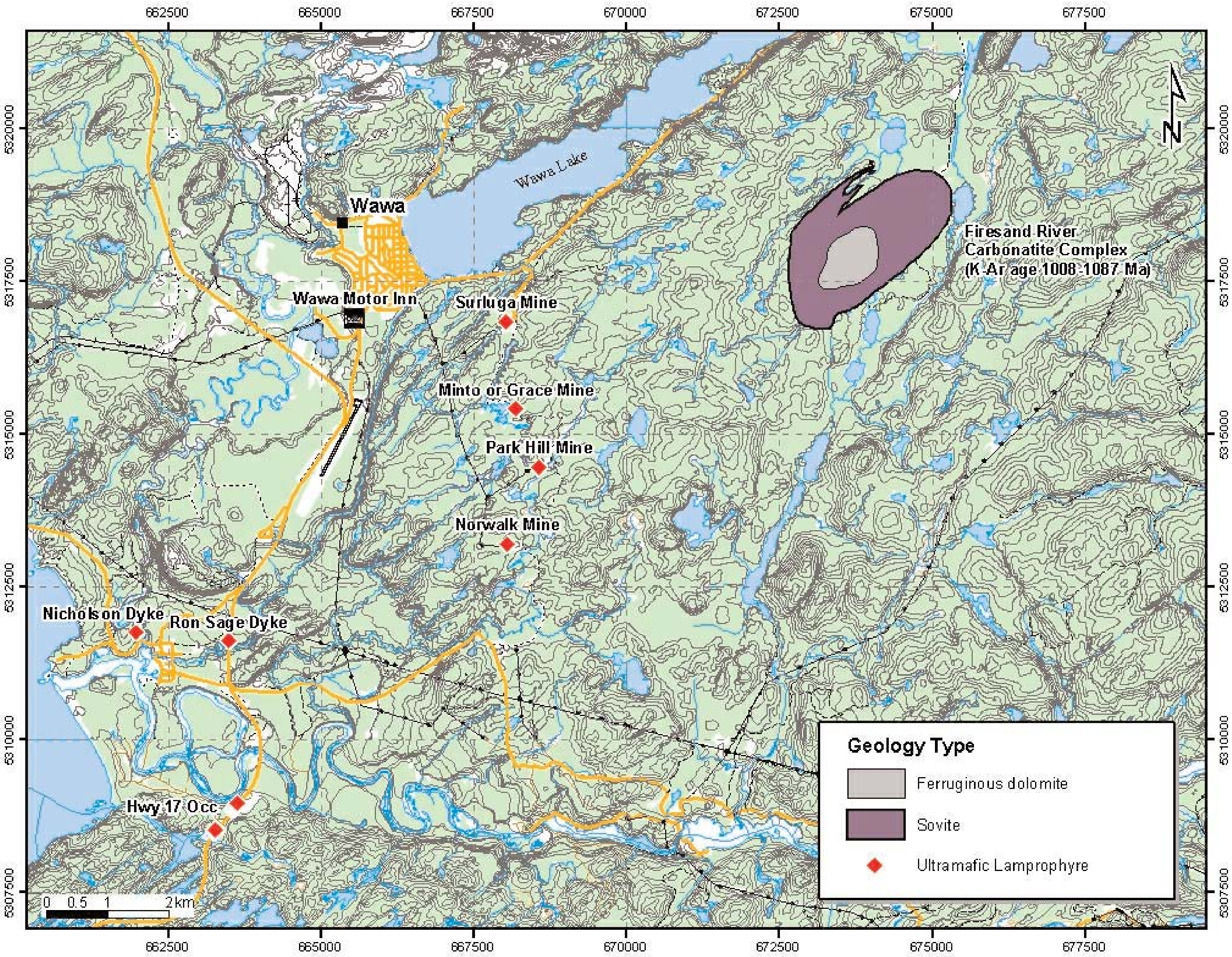
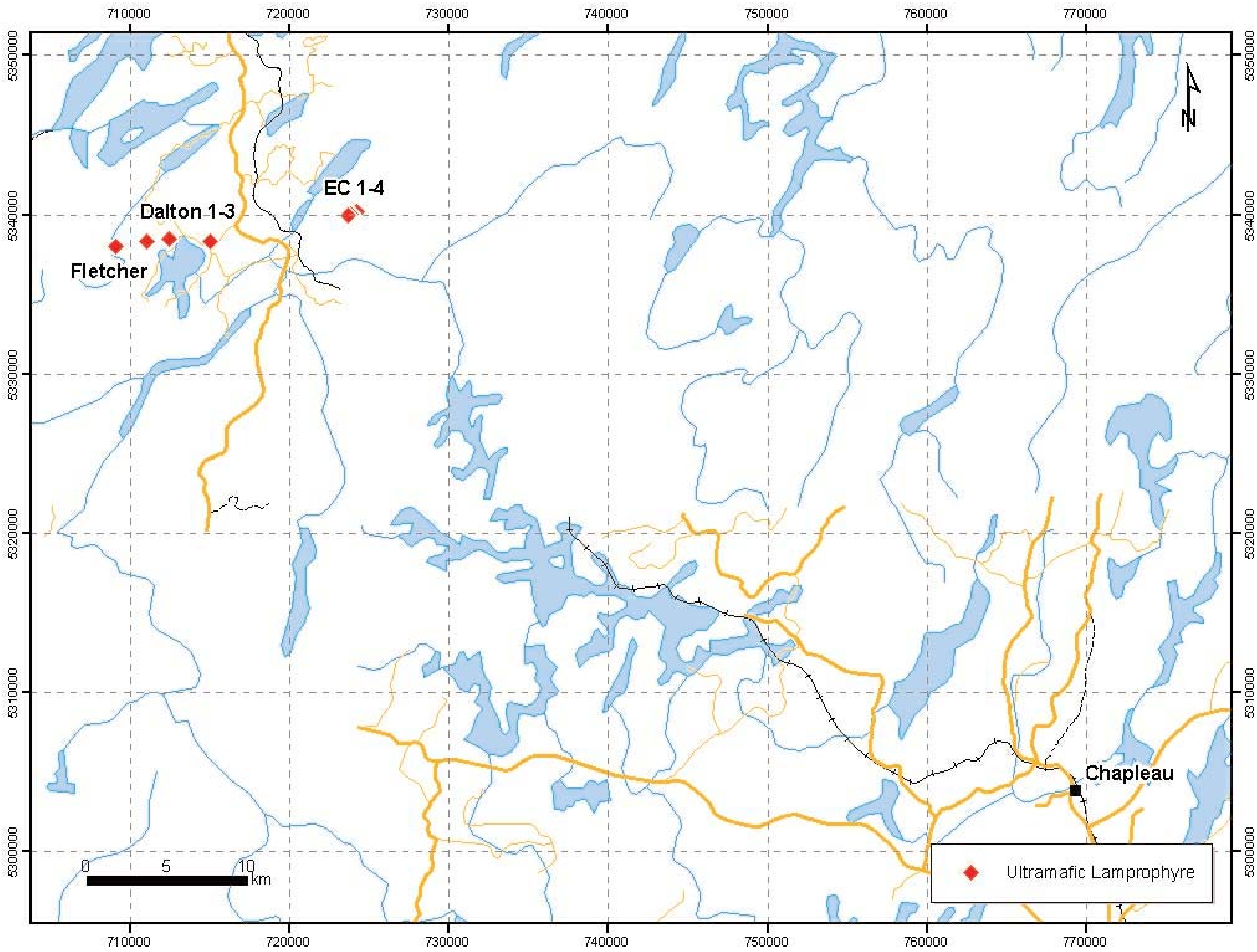


Appenidix 1a. Field trip stops, Day 2, morning.



Appendix 1b. Field trip stops, Day 2, afternoon.

OVERVIEW OF THE DISCOVERY, EVALUATION AND GEOLOGY OF THE VICTOR KIMBERLITE, ATTAWAPISKAT, NORTHERN ONTARIO

K. J. Webb

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INTRODUCTION

Access to the Victor Project Camp is not possible in June, the time of the VIIIth International Kimberlite Conference field trips (*see* Access *below*). At the Sudbury warehouse site there will be a selection of drillcores representative of the main geological features in the two Victor pipes, Victor North and Victor South (*see* Kimberlite Geology *below*). Additional information pertaining to the specific drillcores on display will be available on site.

In 1984, De Beers Canada Exploration Inc. (a subsidiary of De Beers Consolidated Mines Ltd. and previously known as Monopros Ltd.) started a regional sediment sampling program to the north-northwest of the Selco alnoites. The combination of sediment sampling, indicator mineral chemistry and geophysics proved effective in locating diamondiferous kimberlites in the Attawapiskat area, approximately 100 km west of the coast of James Bay in the James Bay Lowland (Fig. 1; Kong et al., 1999).

The Victor kimberlite is the largest of a cluster of 19 kimberlites discovered (Fig. 2). Of these, 16 were staked by De Beers and 16 have been proven diamondiferous. The Victor kimberlite, which consists of two adjacent but separate pipes with a total area of 15 ha, is currently undergoing a feasibility study.

GEOLOGICAL SETTING

The Attawapiskat area is part of the Hudson Platform that consists of flat-lying Paleozoic sedimentary rocks unconformably overlying the Precambrian Superior Province, the largest Archean craton in the world. Isotopic ages range from 3.1 Ga in the north to 2.6 Ga. in the south (Card, 1990). The kimberlites are located on the southern flank of the Cape Henrietta Maria (or Transcontinental) Arch, which separates the erosional remnants of two adjacent cratonic sedimentary basins, the Hudson Bay Basin and the Moose River Basin (Fig. 1; Norris, 1986). The Paleozoic sediments can attain thicknesses of up to 800 m in the Moose River Basin and up to 1800 m in the Hudson Bay Basin, but they thin towards the arch (Norris and Sanford, 1968) and are approximately 250 m thick in the vicinity of the kimberlites (*see* General Geology *below*). The Attawapiskat area is transected by a set of minor faults striking northwest-southeast and northeast-southwest, as well as the Winisk River Fault system and the Mackenzie and Matchewan/Hearst dyke sets.

ACCESS

The Victor kimberlite lies 350 km from the nearest road in a remote swampy wetlands (muskeg) region. Access to the site in summer is only possible by helicopter. In the winter, fixed wing aircraft can land on a temporary airstrip that is constructed on the frozen muskeg. Winter access is also possible by a 110 km temporary road constructed from the Victor site to the Attawapiskat community in the east. This road connects with the winter ice road from Attawapiskat to Moosonee, 240 km to the south. These winter roads provide access for heavy earth moving equipment, fuel, truck-mounted drill-rigs, camp construction material and a modular treatment plant.

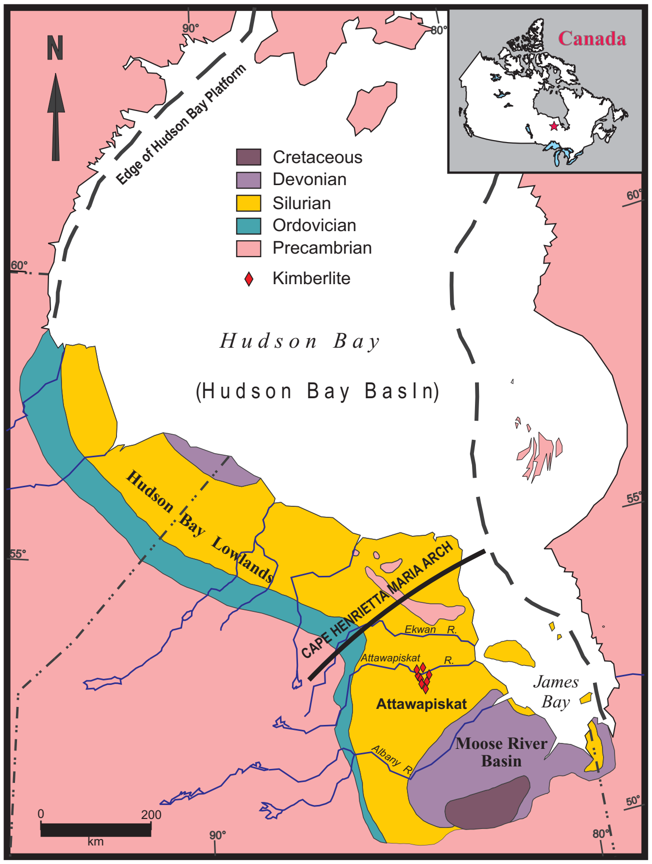

Figure 1. Regional geological setting and location of the Attawapiskat kimberlites (from Kong et al., 1999; after Norris, 1986).

DISCOVERY AND EVALUATION HISTORY

1984 – 1987: Stream Sampling and Kimberlite Boulders Discovered

Systematic regional stream sediment sampling during this period between the Kenogami River and Ekwan River to the north revealed a "kimberlitic" indicator mineral train (Fig. 3).

Webb, K. J.
2003: Overview of the Discovery, Evaluation and Geology of the Victor Kimberlite, Attawapiskat, Northern Ontario; in VIIIth International Kimberlite Conference, Northern Ontario Field Trip Guidebook, B. A. Kjarsgaard (ed.); p. 39-46.

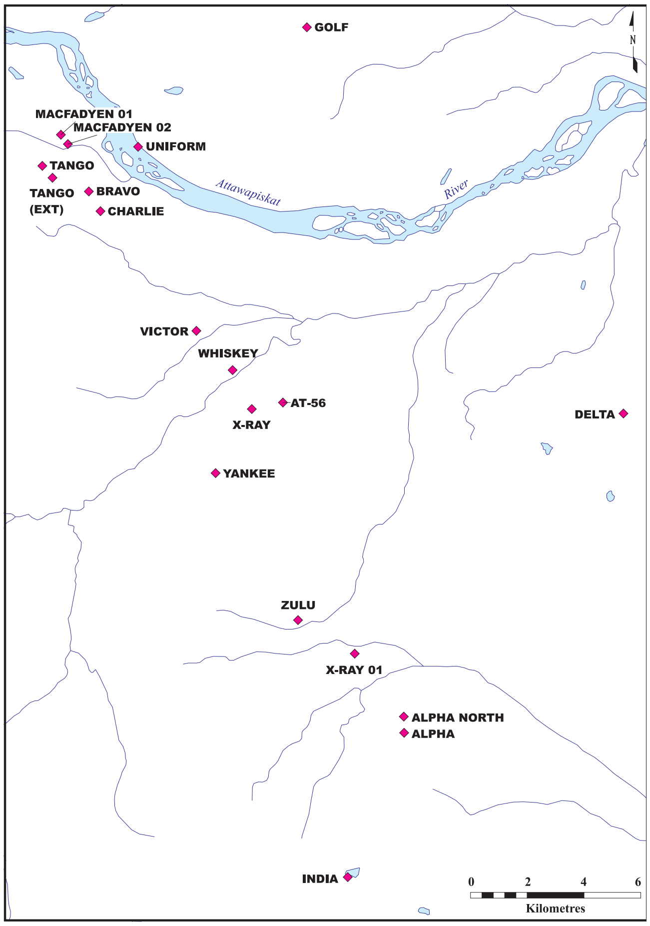

Figure 2. Map showing all the kimberlites in the Attawapiskat cluster (from Fowler et al., 2001).

The Ekwan River was devoid of indicator minerals and proved a good "up ice cut off" to the mineral train. The compositions of the mantle-derived ilmenites, garnets, spinels and clinopyroxenes were not only distinct from those that occur in the vicinity of the Selco alnoites, situated 250 km to the south, but also implied derivation from diamondiferous kimberlites (Kong et al., 1999). In 1987, kimberlite boulders were discovered along a 10 km stretch of the Attawapiskat River, where stream samples were also found to contain super abundant concentrations of kimberlitic indicator mineral grains.

1987 - 1988: Geophysical Survey Identified 31 Targets

The discovery of the kimberlite boulders prompted an aeromagnetic survey covering 2,900 km^2. The survey used both total magnetic field and vertical magnetic gradient measurements to identify 31 targets (Fig. 4). Detailed ground magnetics further defined these anomalies. The original aeromagnetic signature over Victor was resolved into two discrete anomalies (Victor South and North pipes) by the detailed ground magnetic survey (Kong et al., 1999).

1988 - 1989: Drilling Confirms 16 Kimberlites

Drilling of the geophysical anomalies in 1988 and 1989 confirmed 16 kimberlites. Subsequently two additional small bodies (MacFadyen 1 and 2) were discovered by KWG-Spider Resources and recently an additional one (AT-56) by Navigator-Canabrava (Kat project). Eight holes were drilled into Victor to ensure that representative samples from the different phases suggested by the geophysics would be obtained.

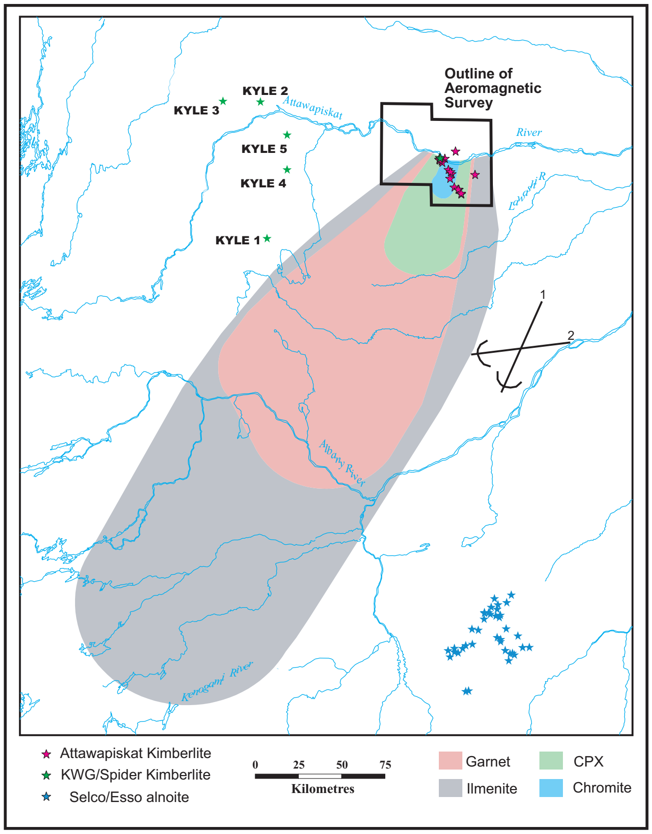

Figure 3. Indicator mineral dispersion train from the Attawapiskat kimberlites (from Kong et al., 1999).

1997 - 1998: Mini-bulk Sampling Program

Twenty-five reverse circulation drillholes were completed, totaling 1301.2 m, from which a bulk sample weighing 28,201.4 kg was recovered. A total of 96 macrodiamonds (>1.0 mm) was recovered from this sample (Sage, 2000).

1999 - 2000: Delineation Core Drilling Program

Drilling provided information on the wall rock contacts at both the 100 m and 200 m levels below surface and verified the kimberlite pipe geology before commencing a large diameter drilling program.

2000 - 2001: Bulk Sampling Program

The evaluation program consisted of the collection of 9,649 t (wet) of kimberlite: 5,349 t from two near-surface trenches and 4,300 t from 38 drillholes, each 610 mm in diameter and drilled to a maximum depth of 252 m (Fig 5). Results for these samples showed a very variable grade distribution within the Victor North kimberlite and a slightly more consistent grade within Victor South (Fowler et al., 2001).

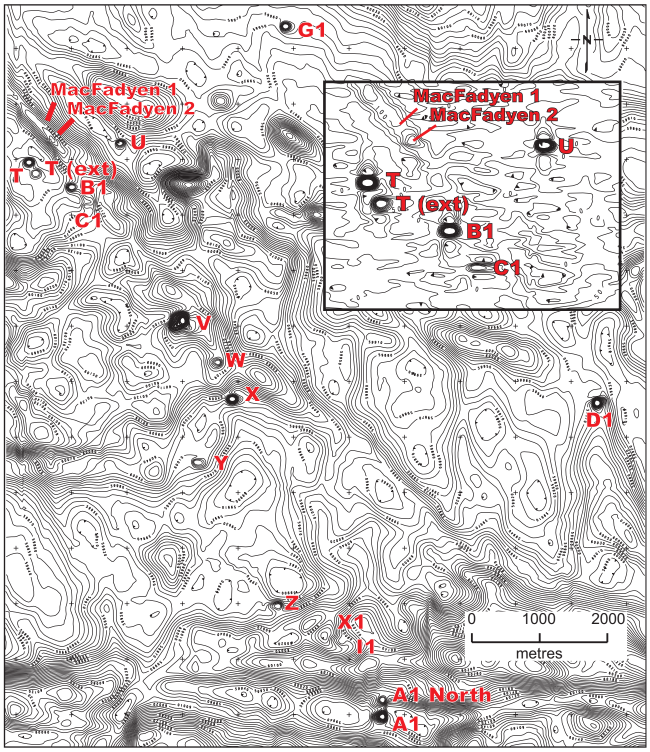

Figure 4. Aeromagnetic survey over the Attawapiskat kimberlites. The measured vertical gradient (inset) enhances the contacts of the kimberlites (from Kong et al., 1999).

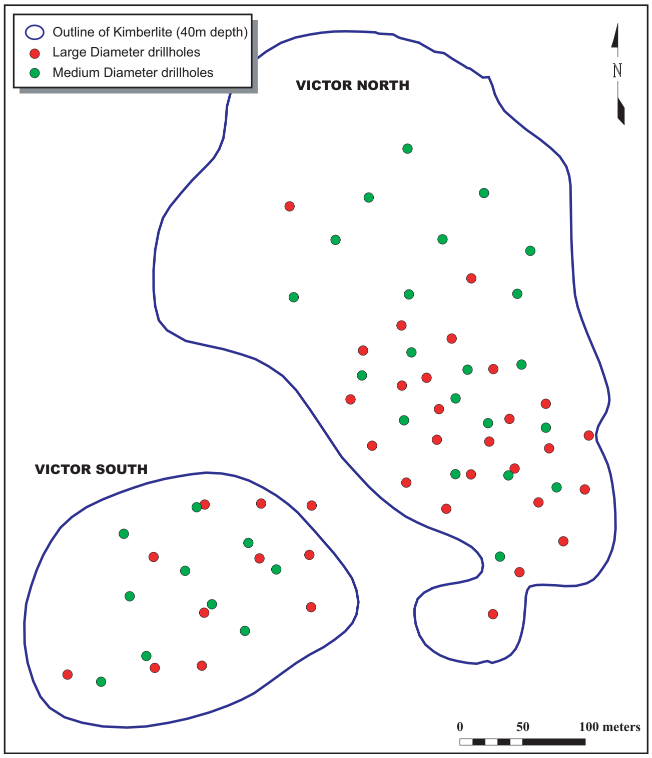

Figure 5. Map showing outline of Victor North and South as well as large- and medium-diameter reverse circulation drillholes (from Fowler et al., 2001).

2002: Pre-feasibility Study

Resource modeling based on the bulk sample results was included in this study, as well as geotechnical and geohydrological assessments. Further geological investigations, including kimberlite phase characterization, were also carried out during the pre-feasibility study.

2003: Feasibility study

The feasibility study will involve additional drilling, to further delineate Victor South and the contrasting grade zones in Victor North, as well as additional geotechnical and geohydrological investigations.

GENERAL GEOLOGY

Age

Rb/Sr dating of phlogopite from five of the Attawapiskat kimberlites yielded model ages of 155 - 170 Ma and an emplacement age of 156 + 2 Ma for two bodies (Kong et al., 1999, and references therein). U/Pb isotope dating on perovskite separates from three kimberlites gave ages of 177 - 180 Ma (Heaman and Kjarsgaard, 2000). Thus, kimberlite magmatism appears to have occurred over 25 Ma during the Jurassic.

Country Rock Geology

The 270 - 275 m thick flat-lying Paleozoic sediments that host the Victor kimberlites consist mainly of Ordovician massive microcrystalline limestone and dolostone with a basal sandstone-siltstone unit, which unconformably overlies the basement rocks (Fig. 6). Unconformably overlying the Ordovician sediments are: Silurian fossiliferous limestone of the Attawapiskat Formation; limestone and dolostone of the Ekwan Formation; limestone of the Severn River Formation; and a basal mudstone and shale unit. Upper Silurian and Devonian sediments once overlay the now exposed

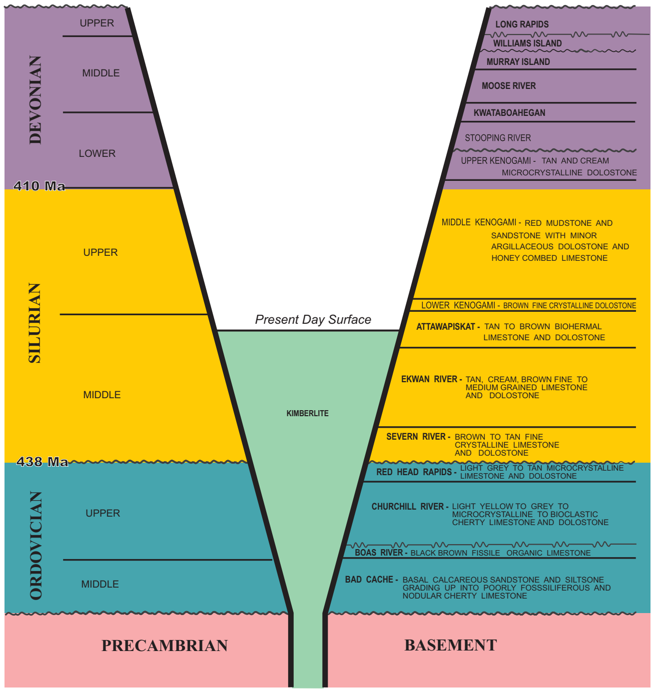

Figure 6. Country rock stratigraphy in the vicinity of the Attawapiskat kimberlites (from Kong et al., 1999).

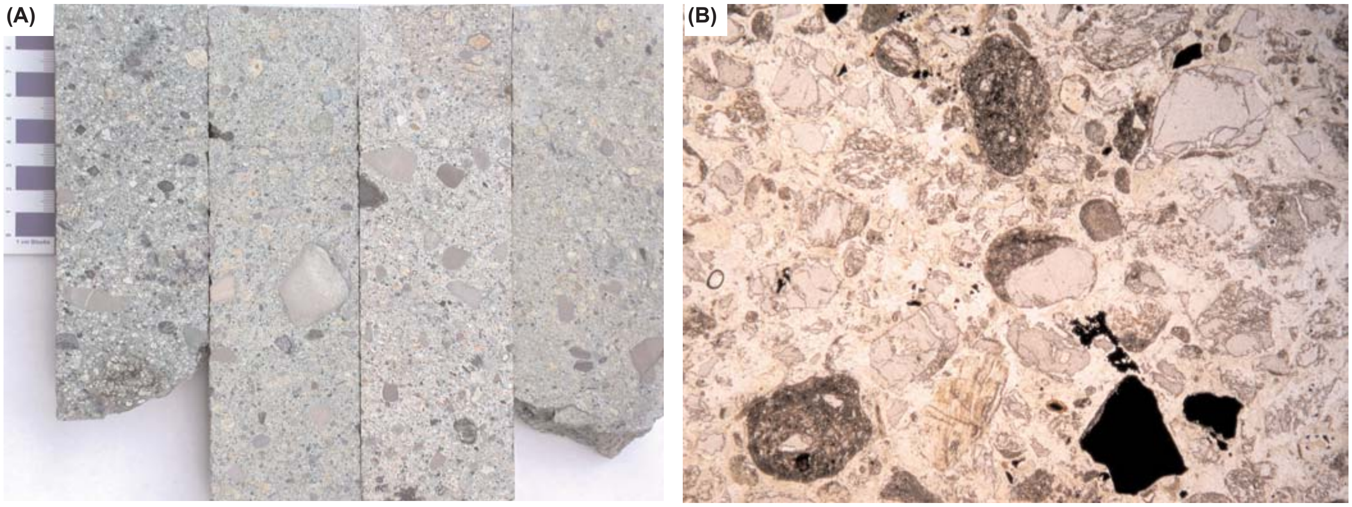

Figure 7. Typical Victor pyroclastic kimberlite shown in: **(A)** cut and polished drillcore and, **(B)** thin section. The photomicrograph shows abundant, clast-supported discrete grains of fresh and altered olivine, lesser subround juvenile lapilli and an ilmenite xenocryst set in a serpentine matrix. PPL. FOV = 9 mm (from Webb et al., 2003).

Attawapiskat Formation, but have been eroded due to the continued uplift of the Transcontinental Arch (Norris, 1986). The late Paleozoic to Mesozoic era was a time of extensive erosion in the area. The original thickness of the sediments at the time of kimberlite emplacement in the Jurassic is estimated at about 600 m, suggesting that the kimberlite pipes have been significantly eroded, with only approximately half the original pipes now preserved. Pleistocene glacial till sheets and coastal Holocene deposits overlie the Attawapiskat kimberlites and vary in thickness from 0 to 30m.

KIMBERLITE GEOLOGY

The following section is adapted from Kong et al. (1999) and Webb et al. (2003).

Mineralogical and Textural Classification

Two mineralogical varieties of kimberlite occur at Victor; spinel carbonate kimberlite is the dominant rock type while monticellite kimberlite is less common. The kimberlites are composed of olivine macrocrysts and phenocrysts, mantle-derived xenocrysts and xenoliths (*see* Mantle Indicator Mineral Chemistry *below*) and occasional megacrysts, set in fine-grained carbonate and spinel ± serpentine groundmasses. Minor monticellite, mica, apatite and perovskite may be present.

Two textural types of kimberlite are present at Victor: pyroclastic (Fig. 7) and so-called hypabyssal (Fig. 8). Textural terminology is after Field and Scott Smith (1998). The pyroclastic rocks are medium to dark green, competent and unweathered. They are composed of poorly sorted, clast-supported, fine to coarse, discrete grains of olivine and subround to curvilinear juvenile lapilli, which are usually modally less abundant than the single grains of olivine and mainly <1 cm in size. The juvenile lapilli consist of olivine macrocrysts and phenocrysts set in a groundmass of carbonate laths, spinel and interstitial cryptocrystalline carbonate. Serpentine-filled vesicles are present in some lapilli. The pyroclastic kimberlites also contain variable, but overall low, proportions of angular country rock xenoliths dominated by

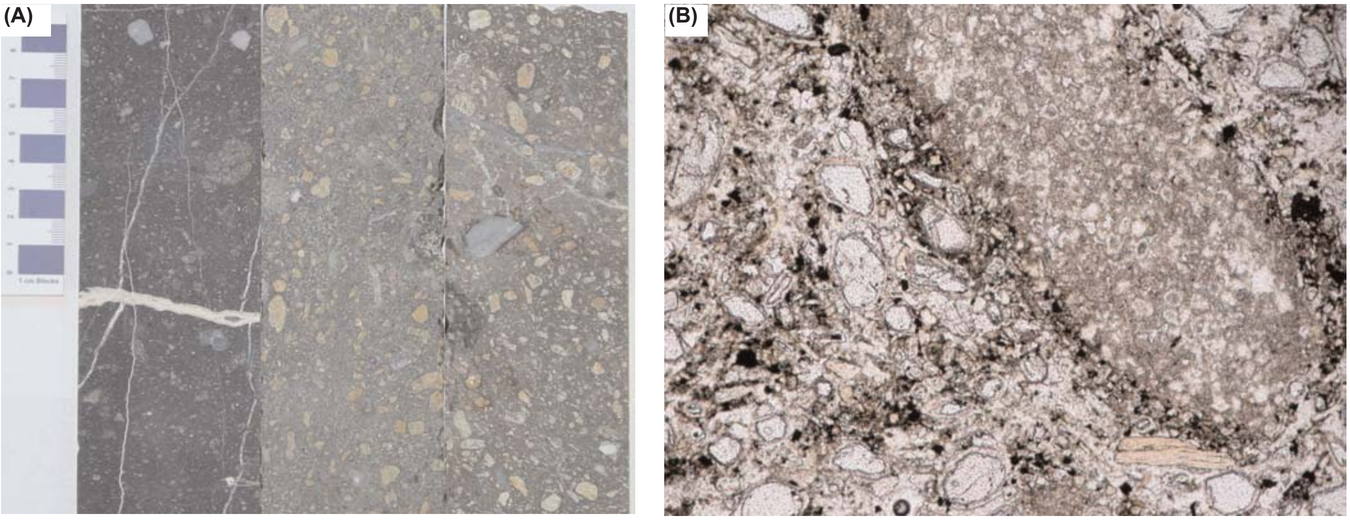

Figure 8. Typical Victor so-called hypabyssal kimberlite, shown in: **(A)** cut and polished drillcore and, **(B)** thin section. The photomicrograph shows the unusual uniform to magmaclastic texture of these rocks. PPL. FOV = 6 mm (from Webb et al., 2003).

limestone. The limestone xenoliths occur in a variety of colours and textures, suggesting that they derive from different stratigraphic horizons in the country rock (Fig. 6). Mudstone, siltstone, basement and diabase xenoliths are less common. Subtle variations in the nature, proportion and sizes of the clasts through the pyroclastic kimberlite intersections are typical. Bedding is limited and includes normal grading (< 1 - 3m thick). The pyroclastic rocks at Victor may be classified in standard volcanological terminology as juvenile lapilli-bearing olivine tuffs.

The so-called hypabyssal rocks at Victor are dark, competent and superficially resemble fresh hypabyssal kimberlite. The rocks consist of mostly medium- to coarse-grained olivine macrocrysts and phenocrysts set in fine-grained groundmasses composed of the minerals described above. The groundmasses do not display typical hypabyssal kimberlite textures and in places magmaclastic textures can be discerned. As with the pyroclastic kimberlite, the so-called hypabyssal kimberlite contains overall low proportions of country rock xenoliths, dominated by limestone, although it is closely associated in parts with sedimentary country rock breccias.

Mantle Indicator Mineral Chemistry

The Victor pyroclastic kimberlites contain abundant ilmenites and moderate proportions of garnets and chrome diopsides. Chromite is uncommon. Peridotite and eclogite xenoliths occur, but are not abundant. The mantle xenocryst content of the so-called hypabyssal kimberlite is variable and different to that of the pyroclastic kimberlite. The composition of garnet, ilmenite, chrome diopside and chromite from a number of Attawapiskat kimberlites is shown in Figure 9. The indicator mineral chemistry of Victor is overall similar to the other Attawapiskat kimberlites (Sage, 2000).

The garnets in the Attawapiskat kimberlites are predominantly mantle xenocrysts, but a significant number of garnet megacrysts is also present. As noted by Kong et al. (1999), the kimberlites contain peridotitic garnets that fall along the lherzolite trend and are classified as G9 and G10 (Gurney, 1984). The ilmenites contain very high MgO and Cr_2O_3 concentrations, and low Fe^{3+}/Fe^{2+} ratios. The kimberlites contain high Cr-Ti chromites as well as moderate to high Cr and low Ti chromites that are usually associated with kimberlites (Fipke et al., 1995). Rare chromites with compositions similar to diamond inclusions were found. Application of the garnet-nickel thermometer of Griffin et al. (1989) suggests derivation of the garnet xenocrysts from areas within the mantle and a poorly defined geotherm of 37 mW/m^2.

Pipe Geology

The Victor kimberlite comprises two adjacent but separate pipes, one large and one smaller pipe, called Victor North and Victor South, respectively. Victor South and two-thirds of Victor North comprise typical pyroclastic kimberlite, as described above and shown in Figure 10. The pipe shape and internal geology of Victor North are more complex compared to Victor South. Indistinct variations in the primary features of the pyroclastic kimberlite in Victor North, includ-

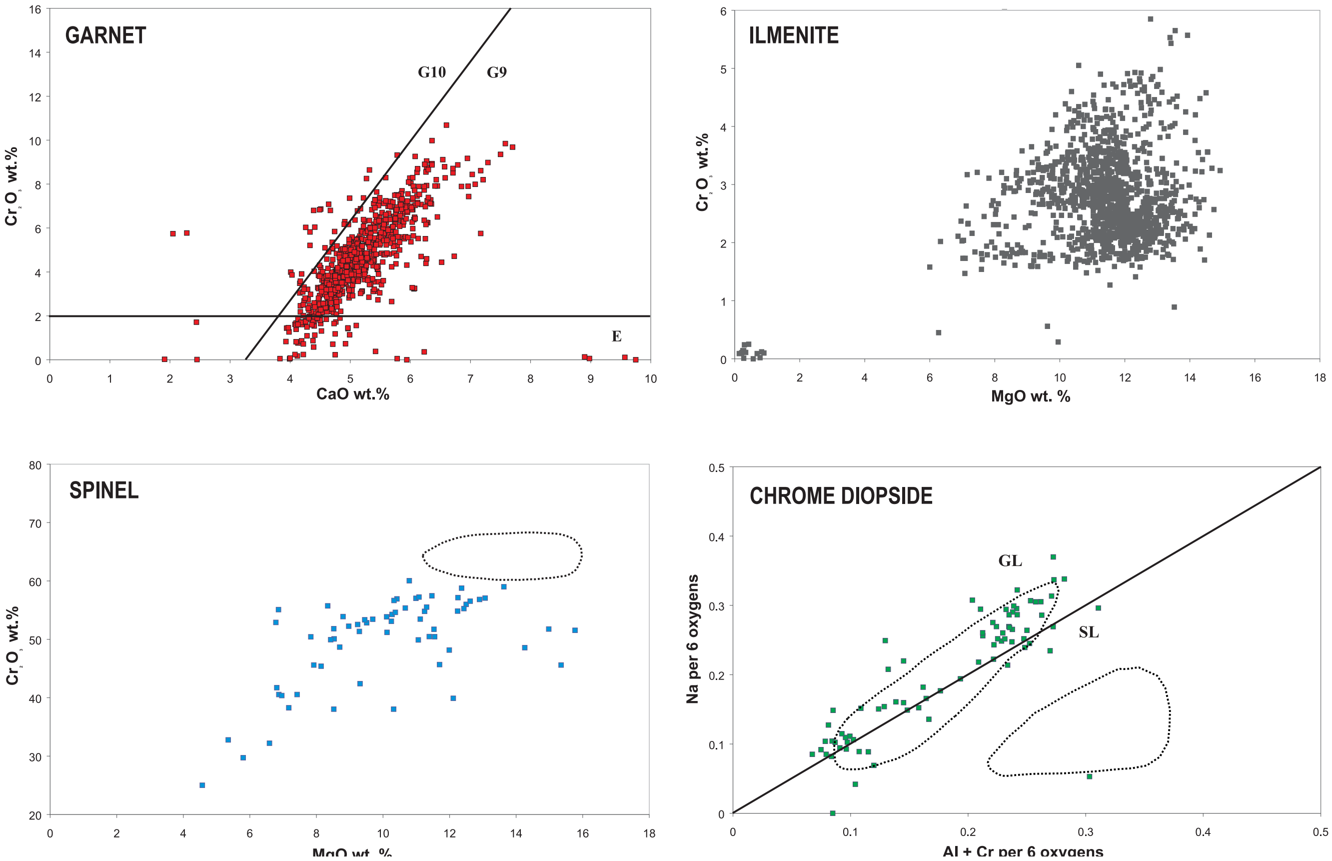

Figure 9. Composition of garnet, ilmenite, spinel and chrome diopside recovered from the Attawapiskat kimberlites (from Kong et al., 1999).

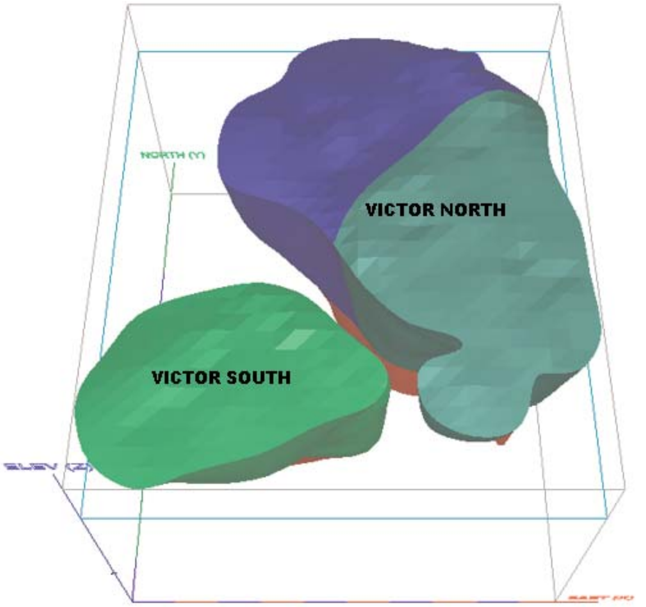

Figure 10. Victor South and Victor North pipes. Green=pyroclastic kimberlite; Blue=so-called hypabyssal kimberlite. Intervals on the east axis are 50 m (from Webb et al., 2003).

ing the diamond content, suggest that the pipe was formed and infilled by multiple phases of eruption (*see* Emplacement Model *below*). The pyroclastic kimberlite within Victor North is subdivided into two major phases of pyroclastic kimberlite. These two main pyroclastic phases are superficially similar, but are petrographically distinct and have contrasting macrodiamond grades. A third pyroclastic kimberlite forms an intermediate zone between the two main phases (Fig. 11). Grades vary from zero to in excess of 70 carats per hundred tonnes for the different phases (Fowler et al., 2001).

The northwestern area of Victor North differs from the rest of Victor in that it contains significant volumes of so-called hypabyssal kimberlite that is closely associated with minor juvenile lapilli tuff horizons and sedimentary country rock breccias ± volcaniclastic kimberlite.

Emplacement Model

Victor South and most of Victor North formed in subaerial conditions by an overall two-stage process of: (1) pipe excavation without the development of a diatreme (sensu: Clement and Reid, 1989; Field and Scott Smith, 1999) and (2) subsequent pipe infilling dominated by primary pyroclastic air-fall processes. Victor South, which appears to have a relatively simple pipe shape and infill, is used to illustrate this emplacement model in Figure. 12. Victor South has a bowl-like shape that flares from just below the basal sandstone of the sediments that overlie the basement. The sandstone is a known aquifer, suggesting that the crater excavation process was possibly phreatomagmatic. In the case of Victor North, the emplacement model described above has been advanced to account for the internal geological and grade variations observed in the pyroclastic rocks.

The northwestern part of Victor North is thought to represent a separate, earlier phase of emplacement within Victor North. The so-called hypabyssal kimberlite, which dominates this part of Victor North, was originally interpreted as a subsurface intrusion below sedimentary rocks that were considered to be in situ. However, further drilling and more detailed investigations indicate a very different type of emplacement for this area of Victor North. Available evidence suggests that the northwestern part of Victor North was an open crater subsequently infilled by a number of contrasting rock types (so-called hypabyssal kimberlite, juvenile lapilli tuffs, sedimentary country rock breccias±volcaniclastic kimberlite), and that the so-called hypabyssal kimberlite is not intrusive. This original crater was apparently later cross-cut by a second crater that was excavated and infilled with pyroclastic kimberlites during several eruptive events.

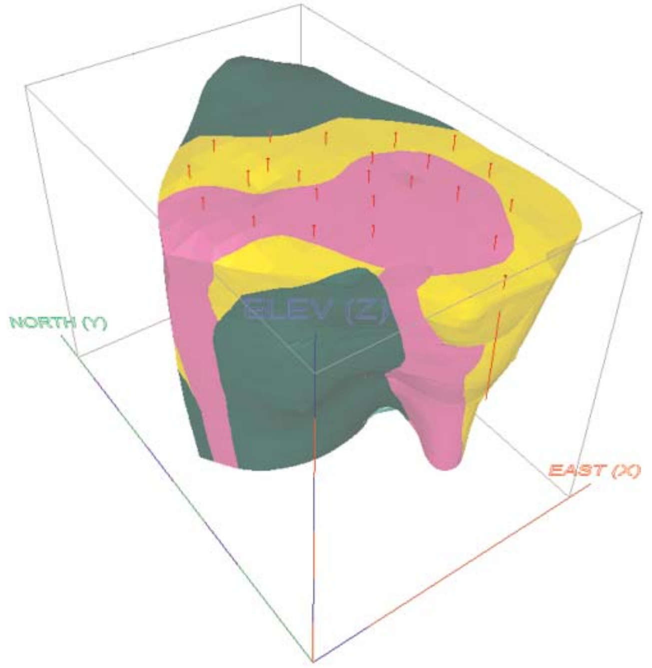

Figure 11. The macrodiamond sample grade distribution in Victor North pyroclastic kimberlite (2001/2002 bulk sampling program), courtesy of the Victor Project. Green=low grade; magenta=high grade; yellow=moderate grade. Intervals on the vertical axis are 50 m (from Webb et al., 2003).

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Many people within De Beers Canada and at other De Beers operations have contributed to the team effort at Victor and the other Attawapiskat kimberlites, and to the results presented here. The Attawapiskat First Nation is acknowledged for its cooperation and support of the project.

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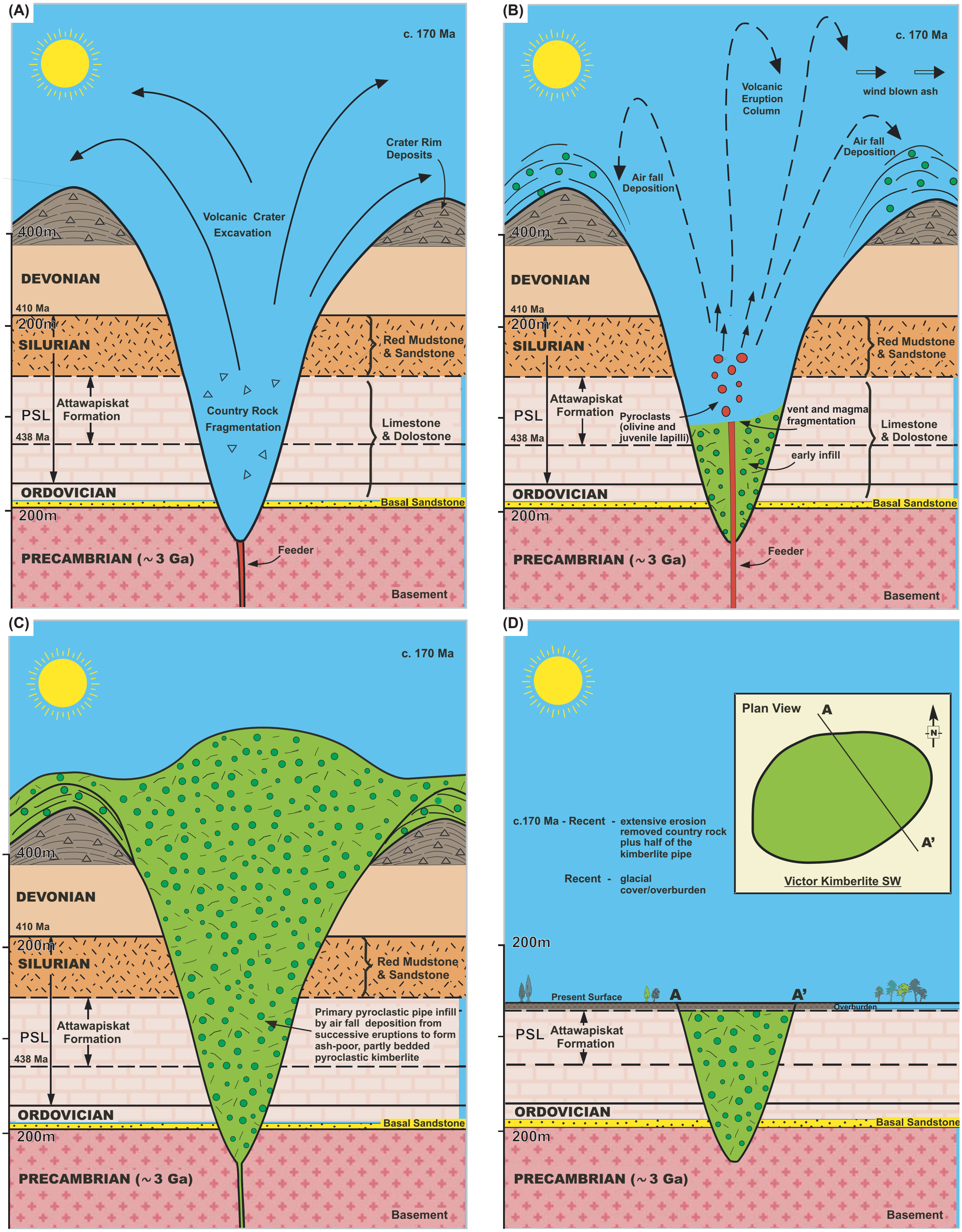

Figure 12. Emplacement model for Victor: **(A)** initial crater excavation by probable phreatomagmatic eruption processes (crater flares from basal sandstone unit, a known aquifer), **(B)** subsequent crater infilling by subaerial pyroclastic fire-fountaining processes, **(C)** the crater infill and, **(D)** the present surface with glacial overburden; pipe shape based on modeled cross-section through Victor South pipe (from Webb et al., 2003).

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