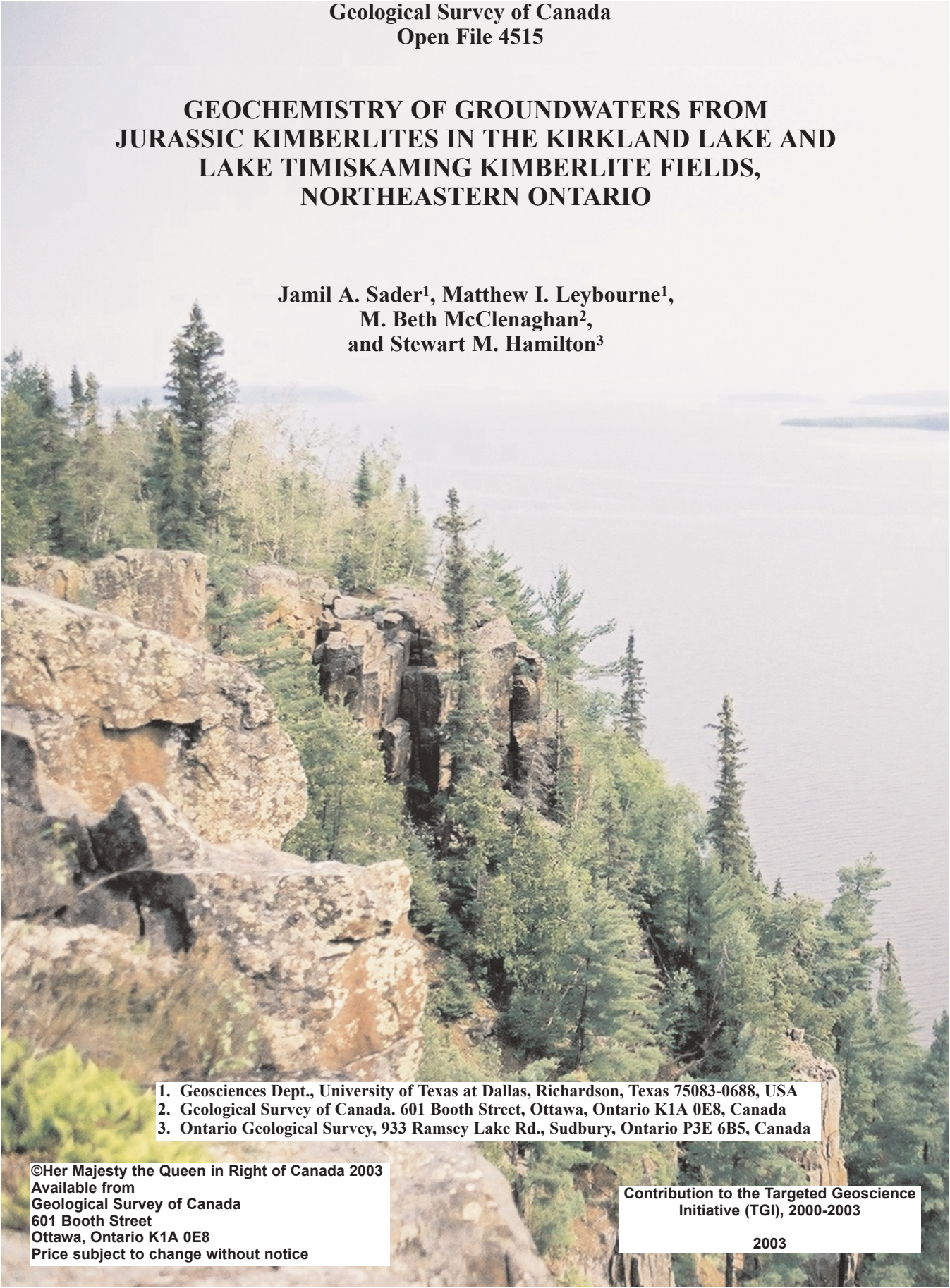


Geological Survey of Canada
Open File 4515

**GEOCHEMISTRY OF GROUNDWATERS FROM
JURASSIC KIMBERLITES IN THE KIRKLAND LAKE AND
LAKE TIMISKAMING KIMBERLITE FIELDS,
NORTHEASTERN ONTARIO**

**Jamil A. Sader¹, Matthew I. Leybourne¹,
M. Beth McClenaghan²,
and Stewart M. Hamilton³**

- 
1. Geosciences Dept., University of Texas at Dallas, Richardson, Texas 75083-0688, USA
 2. Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario K1A 0E8, Canada
 3. Ontario Geological Survey, 933 Ramsey Lake Rd., Sudbury, Ontario P3E 6B5, Canada

©Her Majesty the Queen in Right of Canada 2003
Available from
Geological Survey of Canada
601 Booth Street
Ottawa, Ontario K1A 0E8
Price subject to change without notice

Contribution to the Targeted Geoscience
Initiative (TGI), 2000-2003

2003

TABLE OF CONTENTS

ABSTRACT	1
INTRODUCTION	1
General Geology	1
Kimberlite Locations and Local Geology	1
A4 Kimberlite	1
B30 Kimberlite	3
C14 Kimberlite	5
Diamond Lake Kimberlite	6
95-2 Kimberlite	6
METHODS	7
Sample Collection	7
Sample Preparation and Analysis	9
Chemical treatment of water samples	9
Water analysis	9
Analytical quality control	9
RESULTS	10
Field Geochemistry	10
Stable Isotopes	10
Elemental Geochemistry	14
INITIAL INTERPRETATIONS AND CONCLUSIONS	16
FUTURE WORK	16
ACKNOWLEDGMENTS	17
REFERENCES	17
APPENDICES	
Appendix 1. Kimberlite groundwater sample locations, samples methods and analysis summary	20
Appendix 2. Field geochemical data	21
Appendix 3. Data for groundwater alkalinities	22
Appendix 4. $\delta^2\text{H}$ and $\delta^{18}\text{O}$ stable isotope data of selected groundwaters	22
Appendix 5. $\delta^{13}\text{C}$ stable isotope and DIC data of selected groundwaters	23
Appendix 6. ICP-OES data for sulphur and the conversion to SO_4	23
Appendix 7. $\delta^{34}\text{S}$ and $\delta^{18}\text{O}$ stable isotope data in BaSO_4 precipitate and $\delta^{34}\text{S}$ stable isotope data in ZnS from selected samples.	24
Appendix 8. ICP-OES data for major elements in groundwaters	25
Appendix 9. ICP-MS data for trace elements in groundwaters	26

GEOCHEMISTRY OF GROUNDWATERS FROM JURASSIC KIMBERLITES IN THE KIRKLAND LAKE AND LAKE TIMISKAMING KIMBERLITE FIELDS, NORTHEASTERN ONTARIO

Jamil A. Sader¹, Matthew I. Leybourne¹, M. Beth McClenaghan², and Stewart M. Hamilton³

1. Geosciences Dept., University of Texas at Dallas, Richardson, Texas 75083-0688, USA

2. Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario K1A 0E8, Canada

3. Ontario Geological Survey, 933 Ramsey Lake Rd., Sudbury, Ontario P3E 6B5, Canada

ABSTRACT

A hydrogeochemical study of the Lake Timiskaming and Kirkland Lake kimberlite fields was undertaken as part of the Geological Survey of Canada's Targeted Geoscience Initiative (TGI-1, 2000-2003). The goals are to understand the geochemistry and hydrology of groundwater in kimberlites as compared to the surrounding Archean and Proterozoic rocks and to develop a useful kimberlite exploration tool. Groundwater from exploration holes drilled in the 1980s and 1990s was sampled at five kimberlites: B30, C14, A4, Diamond Lake, and 95-2. The waters were measured in the field for pH, oxidation-reduction potential (Eh), dissolved oxygen, electrical conductivity, and temperature. Field results indicate that many pH values are unusually high for natural groundwaters, with pH values at B30, C14, and A4 in the range of 11.00 to 12.45. Laboratory analyses of the waters were completed for major and trace elements, and stable isotopes $\delta^{13}\text{C}$, $\delta^2\text{H}$, $\delta^{18}\text{O}$, and $\delta^{34}\text{S}$. Results from $\delta^2\text{H}$ and $\delta^{18}\text{O}$ analyses demonstrate that most waters plot along a local meteoric water line (defined using precipitation data from the Ottawa Meteoric Water Line (OMWL) IAEA station). The A4 kimberlite is the exception, with waters that are up to 10 ‰ more enriched in $\delta^2\text{H}$ compared to the OMWL. Reasons for this enrichment may include: 1) fractionation due to high amounts of OH^- ; 2) longer reaction times with rocks; or, 3) the water may simply be older than water collected from the other kimberlites. The $\delta^{13}\text{C}$ analyses indicate enriched ratios in some waters suggesting dissolution of Paleozoic or mantle carbonates due to the addition of organic acids. For all waters, potassium increases with increasing pH to a maximum of 39600 mg/L. As K and pH increase, Mg decreases to a minimum value of less than the detection limit (1 ppb). The relationship between K and Mg likely indicates that the Mg is consumed in the formation of brucite, serpentine, and chlorite. The same is true for calcium where there is a definite trend observed with pH versus K/Mg, pH versus K/Ca, and pH versus K/Rb. Elemental concentrations of waters from wells in country rock in the Kirkland Lake region have been compared to kimberlitic waters and demonstrate how unusual these kimberlitic waters are.

INTRODUCTION

Since the 1980s, numerous kimberlite pipes and dykes have been discovered in the Kirkland Lake and Lake Timiskaming areas (Fig. 1) through the use of indicator minerals and geophysical methods (Brummer et al., 1992a, 1992b; McClenaghan and Kjarsgaard, 2001). Groundwater analysis, however, has never been used as an exploration tool for kimberlites in this region. To our knowledge, only one other published study world-wide (Kosolapova and Kosolapov, 1962) has investigated the chemistry of groundwater associated with kimberlites.

Groundwater was collected from exploration drill holes in five kimberlites in the Kirkland Lake and Lake Timiskaming kimberlite fields of northeastern Ontario. The geochemical data for these samples contribute to the ongoing development of a geochemical model of groundwaters in and around kimberlites. On completion of this groundwater characterization study, it is hoped that the model may be used as a tool to aid in the discovery of kimberlites targets.

General Geology

Four out of the five kimberlites sampled are within the Kirkland Lake kimberlite field: A4, B30, C14, and Diamond Lake. The geology surrounding these pipes is similar and the pipes are of the same approximate age (155 – 160 Ma; Heaman and Kjarsgaard, 2000). The host rocks are Archean mafic to felsic volcanics and felsic to intermediate intrusives, intruded by Proterozoic mafic dykes (Jensen, 1975).

The fifth kimberlite, 95-2, is in the Lake Timiskaming kimberlite field, 80 km south of Kirkland Lake and, in contrast, has intruded Paleoproterozoic siltstone. At the time of kimberlite emplacement, the Kirkland Lake - Lake Timiskaming region was overlain by Paleozoic carbonate rocks (Brummer et al., 1992b), estimated to have once been up to 700 m thick (Armstrong and McCracken, 1996). Paleozoic sedimentary cover, the crater facies, and the upper part of the diatreme facies kimberlite (Fig. 2) have been removed by preglacial weathering and glacial erosion. Subsequent weathering and glacial erosion have eroded the kimberlites such that they are 20 to 50 m below the surrounding bedrock surface. Quaternary glacial sediments, consisting of sand, silt, clay, and till have been deposited in the bedrock depressions on top of the kimberlites.

Kimberlite Locations and Local Geology

A4 Kimberlite

The A4 kimberlite, also known as the Alfie Creek 1 pipe, in Arnold Township, is located at UTM coordinates (NAD 27) 0583142 E and 5341294 N close to the North Arm of Victoria Lake (Fig. 3a). The elevation of the land surface overlying the kimberlite, from a 1:20,000 scale topographic map, is 315 m asl (above sea level). The A4 kimberlite's age is approximately 156 Ma (Brummer et al., 1992b) and its subcropping surface is approximately 200 by 350 m. Monopros Ltd. discovered this pipe in 1983 and in 1987 Lac Minerals Ltd. completed additional drilling on the kimberlite

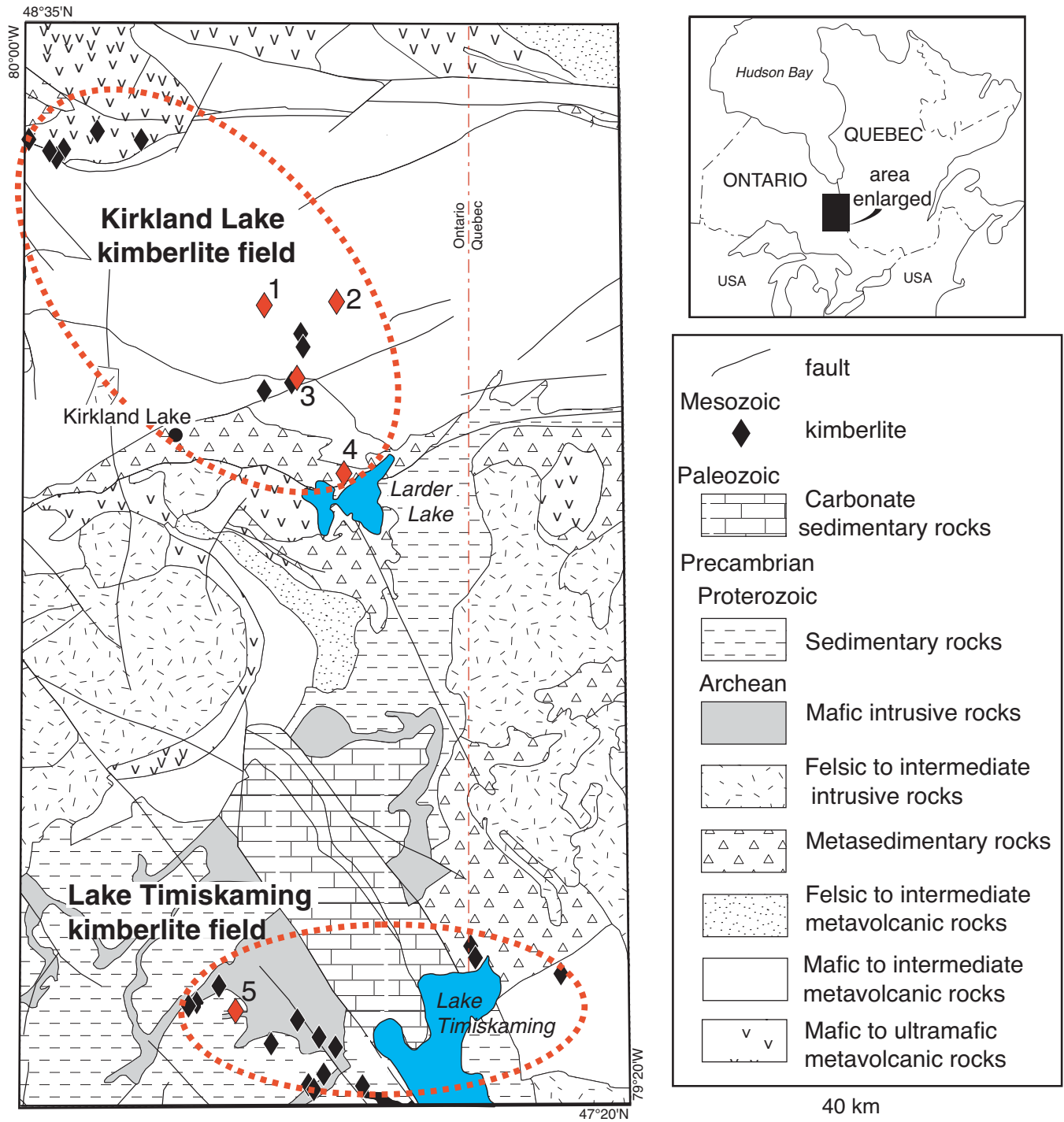


Figure 1. Location of the Kirkland Lake and Lake Timiskaming kimberlite fields in northeastern Ontario and the five kimberlites sampled in this study (red diamonds: 1: B30; 2: C14; 3: A4; 4: Diamond Lake; 5: 95-2). Bedrock geology from Ontario Geological Survey (1991).

(holes A, B, and C). Another hole, labeled JS14 in this study, was drilled by rotary percussion in a subsequent exploration program.

The kimberlite has been preferentially weathered to produce a bedrock depression below the surrounding bedrock and diatreme facies kimberlite subcrops below 45 to 55 m of glacial sediments (McClenaghan et al., 1999a). The kimberlite contains 10 to 14 % clasts, which are up to 4 mm in diameter and consist of limestone and calcareous mudstone,

minor volcanic rock and ultramafic nodules as well as abundant macrocrysts of olivine, garnet, ilmenite, and phlogopite (Brummer et al. 1992b). Xenoliths of Archean metavolcanics and Paleozoic carbonates are present and range in size from <1 to 4 cm in diameter (McClenaghan et al., 1999a). The kimberlite subcrops and is overlain by 1 to 3 m of silty sand till, which is in turn overlain by 40 to 50 m of well sorted glaciolacustrine silty sand (Fig. 3b) (McClenaghan et al., 1999a). In this study, groundwater was sampled in four

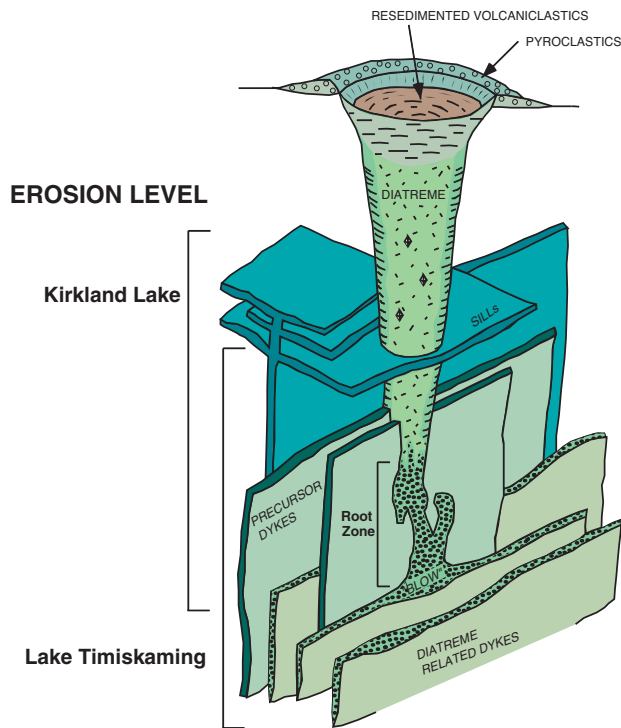


Figure 2. Idealized model of a kimberlite (from Mitchell, 1986) showing present day erosion levels for kimberlites in the Kirkland Lake and Lake Timiskaming kimberlite fields.

exploration drill holes (A, B, C, and JS14) (Fig. 3a) that had been drilled into the kimberlite body.

B30 Kimberlite

The B30 kimberlite, also known as the Nickila Lake kimberlite, is in Bisley Township at UTM coordinates (NAD27) 0580322 E and 5348175 N close to Esker Lakes Provincial Park (Fig. 4a). The surface elevation of glacial sediments overlying the kimberlite (1:20,000 scale topographic map) is 326 m asl and the approximate dimensions of the kimberlite are 200 by 400 m. Both Monopros Ltd. and Lac Minerals Ltd. have carried out drilling at the B30 kimberlite.

The pipe, which has been dated at 157 Ma, intrudes andesitic and dacitic rocks and consist of lithic-tuffisitic breccia to pelletal-tuffisitic breccia containing 10 to 20 % xenolithic material (Brummer et al., 1992b). Analysis by Sage (1996) of drill core obtained from Monopros Ltd. showed angular Paleozoic limestone clasts up to 2 to 3 cm in diameter. He also found traces of ilmenite and 4 to 5 mm in diameter serpentinized olivine megacrysts. Other nodules such as ultramafic nodules of granulites, glimmerites, peridotites, and rare eclogites as well as deformed pelletal lapilli from 1 to 10 cm in diameter are abundant (Brummer et al., 1992b). It was noted by Sage (1996) and McClenaghan et al. (1996) that the B30 kimberlite was much softer and friable (i.e. more weathered) than other kimberlites in the Kirkland Lake area. The kimberlite subcrops and is overlain by 5 to 10 m of till and 40 m of glaciofluvial sediments (Fig. 4b) (Brummer et al., 1992b).

Groundwater was sampled in one hole drilled by Lac Minerals in the 1980s. The hole is in the south-central part of

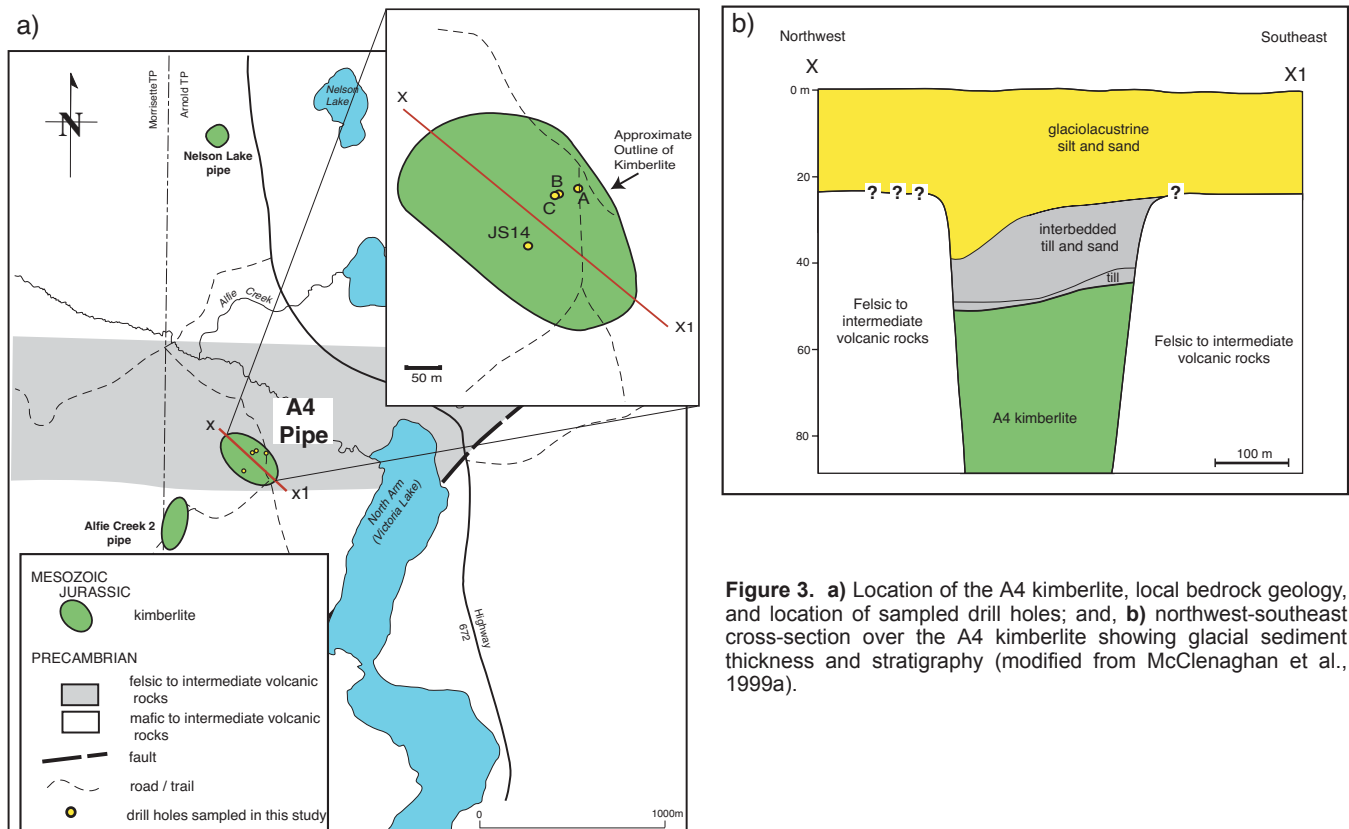


Figure 3. a) Location of the A4 kimberlite, local bedrock geology, and location of sampled drill holes; and, b) northwest-southeast cross-section over the A4 kimberlite showing glacial sediment thickness and stratigraphy (modified from McClenaghan et al., 1999a).

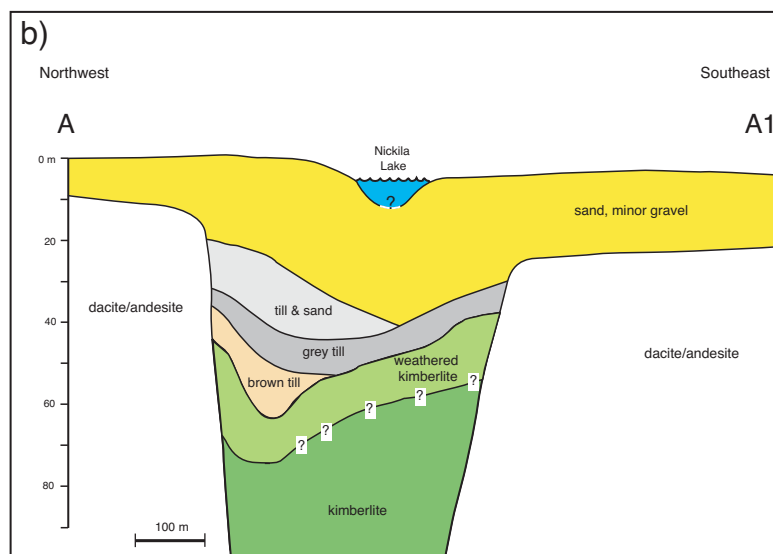
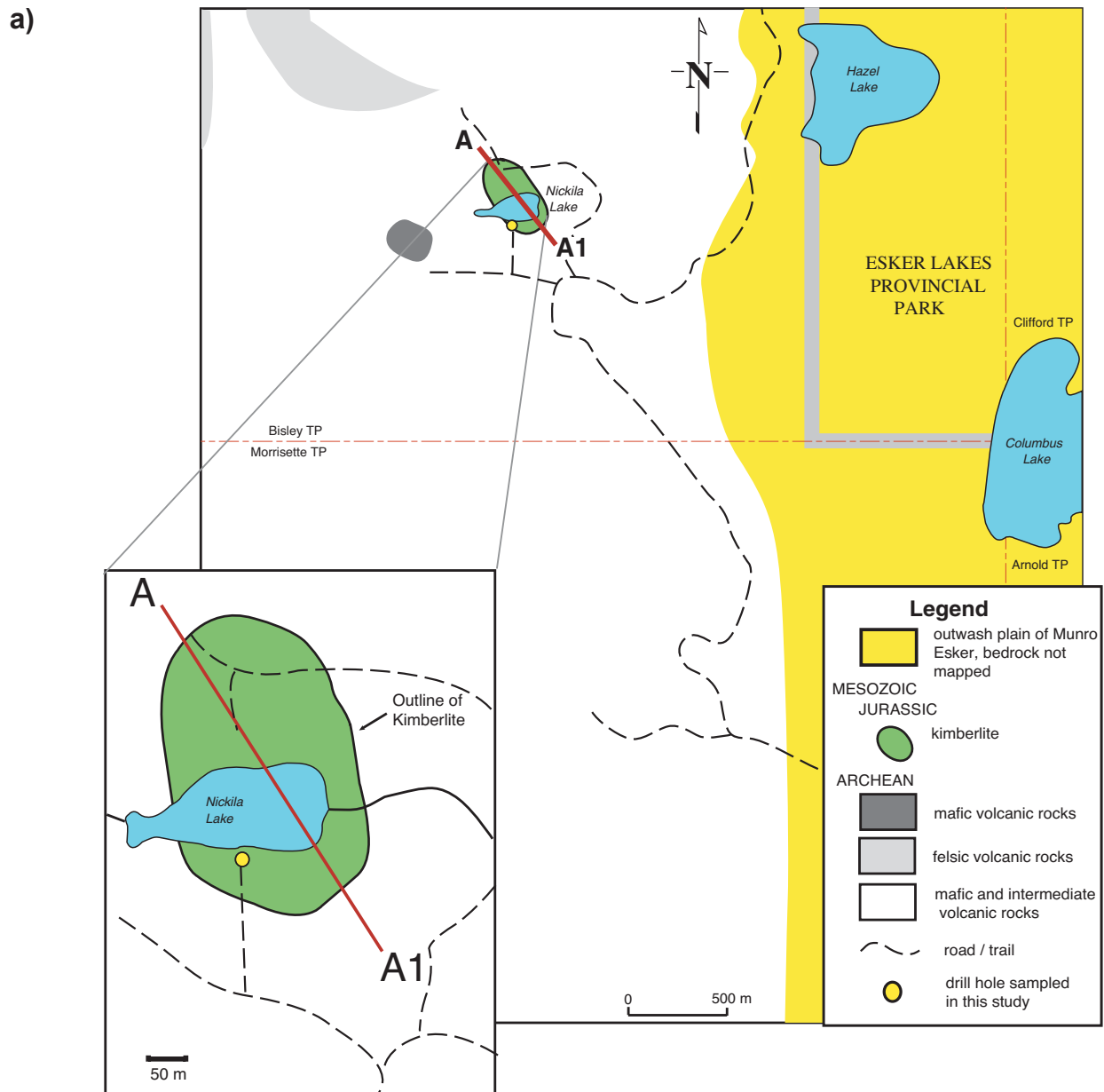


Figure 4. a) Location of the B30 kimberlite, local bedrock geology, and location of sampled drill holes; and, b) northwest-southeast cross-section over the B30 kimberlite showing glacial sediment thickness and stratigraphy (modified from McClenaghan et al., 1996).

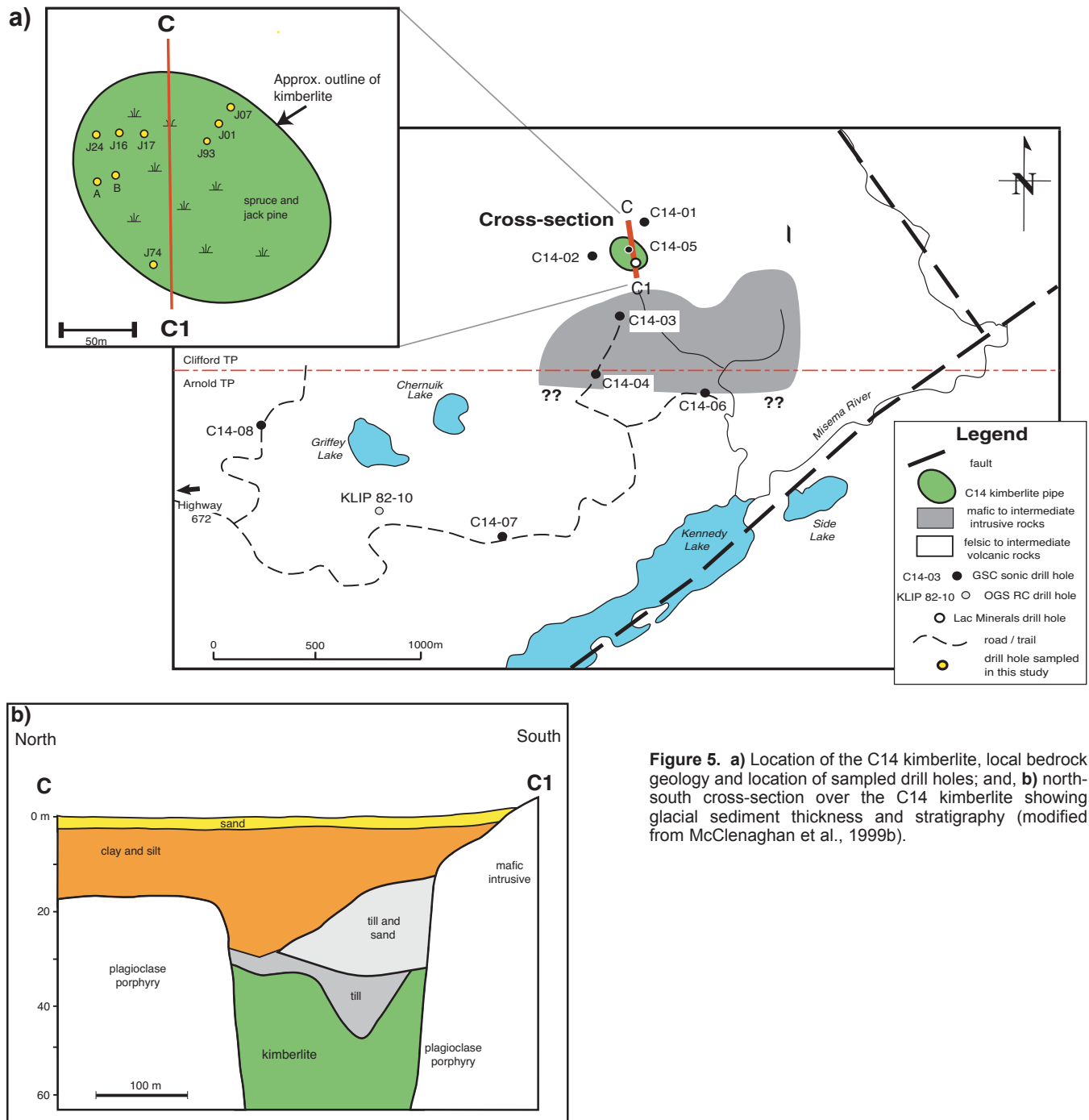


Figure 5. a) Location of the C14 kimberlite, local bedrock geology and location of sampled drill holes; and, b) north-south cross-section over the C14 kimberlite showing glacial sediment thickness and stratigraphy (modified from McClenaghan et al., 1999b).

the kimberlite, on the south shore of Nickila Lake. The drill hole was blocked at approximately 30 m, which is near the contact between the overburden and weathered kimberlite (Fig. 4b).

C14 Kimberlite

The C14 kimberlite pipe is located in Clifford Township, at UTM coordinate (NAD27) 0588751 E and 5348074 N (Fig. 5a). The surface elevation taken from a 1:20,000 scale topographic map is 315 m asl. The pipe dimensions are approximately 200 by 300 m. The kimberlite has been dated at 156 Ma and intruded dacite and feldspar porphyry (Brummer et al.,

1992b). The kimberlite was discovered by Lac Minerals Ltd., and further explored by Dia Met Minerals and Regal Goldfields, with drilling completed by all three companies.

The C14 kimberlite appears to be at a transition zone between diatreme and hypabyssal facies kimberlite (Sage, 1996) and the pipe contains several different phases: tuffaceous kimberlite breccia, coarse tuffaceous breccia, hypabyssal kimberlite, and tuffaceous kimberlite (Brummer et al., 1992b). All phases of the kimberlite contain clasts of Paleozoic rock. The groundmass contains serpentine, phlogopite, chlorite, and calcite (McClenaghan et al., 1999b). The matrix is composed of a fine-grained mixture of carbon-

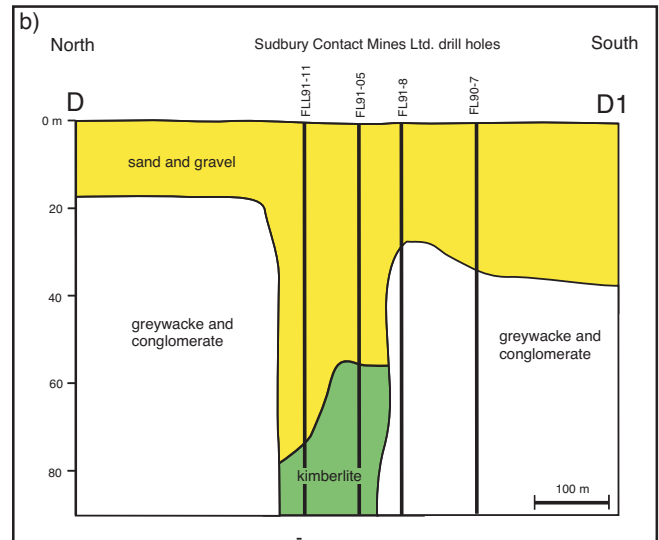
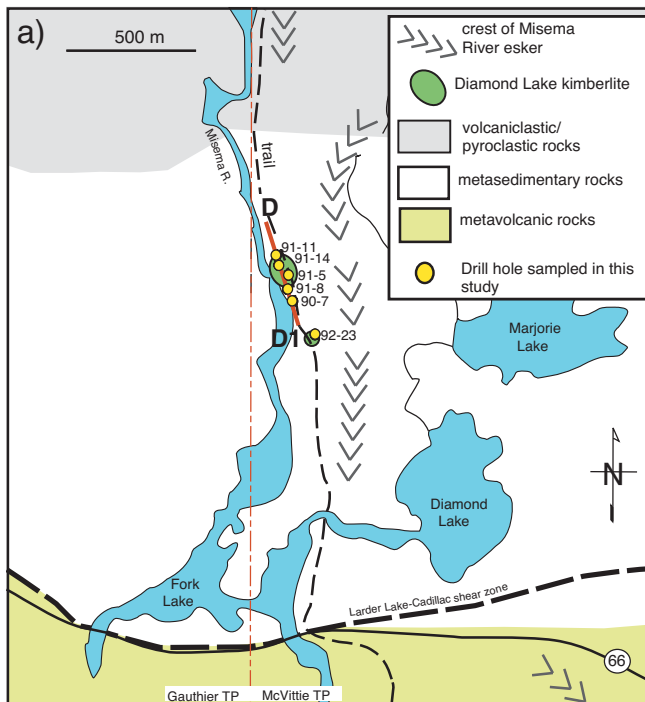


Figure 6. a) Location of the Diamond Lake kimberlite, local bedrock geology and location of sampled drill holes; and, b) north-south cross-section over the Diamond Lake kimberlite showing glacial sediment thickness and stratigraphy (modified from McClenaghan et al., 1998).

ate, chlorite, and serpentine (Sage, 1996). The kimberlite subcrops and is overlain by 7 m of silty sand till, 2 m of well-sorted sand, and 23 m of glaciolacustrine clay and silt and in places, eolian sand dunes (Fig. 5b) (McClenaghan et al., 1999b). Groundwater was sampled in nine drill holes, labeled in this study as J24, J16, J17, J93, J01, J07, J74, and Lac Minerals drill holes A and B (Fig. 5a). All drill holes were in the kimberlite body.

Diamond Lake Kimberlite

The Diamond Lake kimberlite is located on the west flank of the Misema River esker in McVittie Township. The UTM coordinates at the southern most point of the pipe are 0592450 E and 5329933 N (NAD27) (Fig. 6a). The elevation taken from a 1:20,000 scale topographic map is 280 m asl and the dimensions of the pipe are 250 by 100 m. Its age is approximately 153 Ma (Heaman and Kjarsgaard, 2000). A 15 m wide kimberlite blow, 300 m south of the main kimberlite pipe, was intersected by diamond drill hole 92-23. Both of these kimberlites were discovered by Sudbury Contact Mines Ltd. in the late 1980s.

The two kimberlites are thought to have been emplaced at approximately the same time (McClenaghan et al., 1998) and have intruded along the east flank of a north-trending diabase dyke (Sage, 1996). The main kimberlite groundmass is similar in composition to other kimberlites in the Kirkland Lake region. Serpentine, phlogopite, chlorite, and calcite are the major minerals (McClenaghan et al., 1998). The diatreme facies contain 15 to 25 % xenoliths and is a pelletal textured kimberlite matrix. Below the diatreme zone, in the hypabyssal zone, the rock is fine to medium grained and is estimated to contain 50 to 75 % olivine and smaller amounts of opaques and minor garnet and phlogopite (Sage, 1996). The surrounding country rocks consist of Archean greywacke and conglomerate metasedimentary rocks

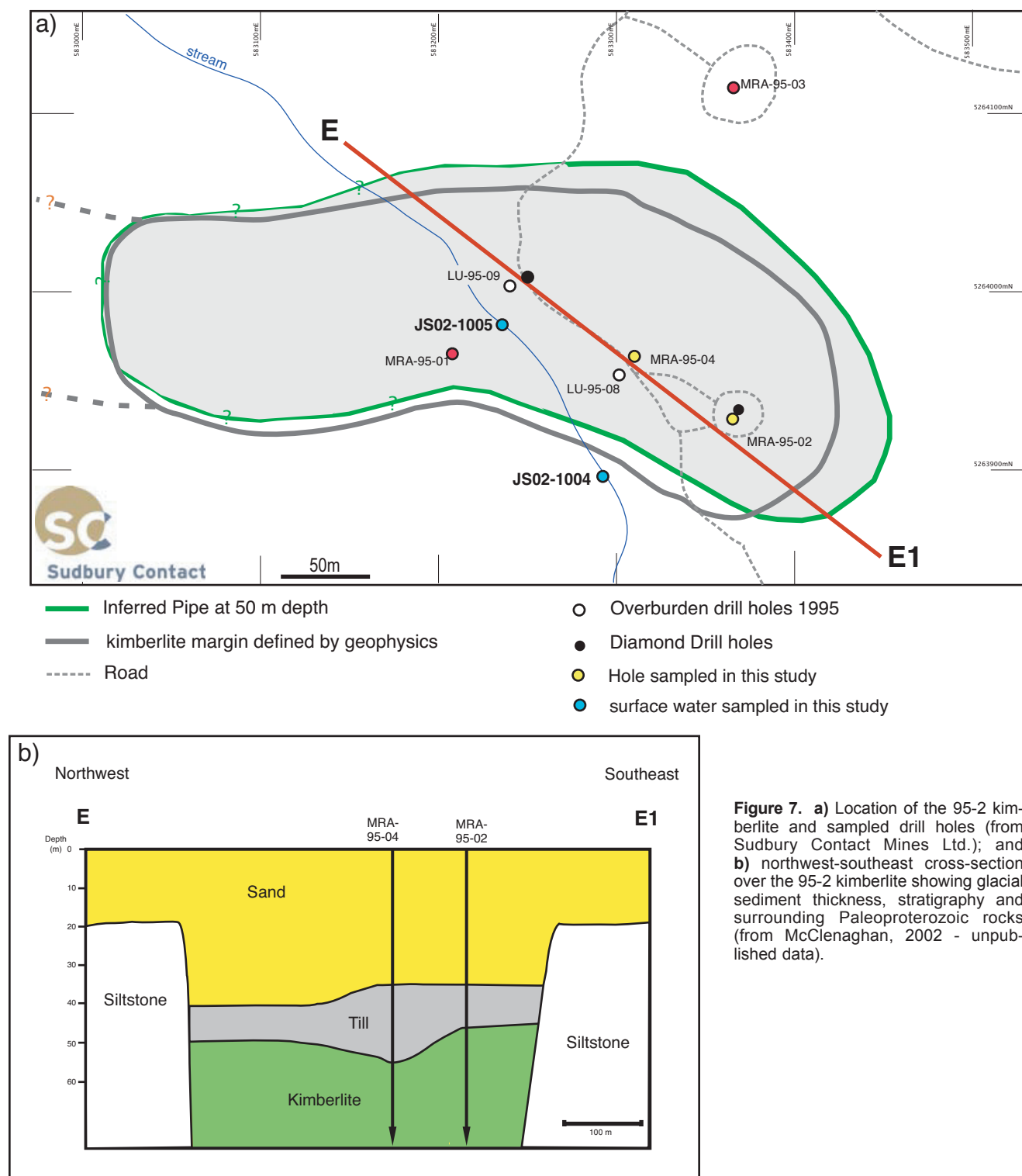
(McClenaghan et al., 1998). The main kimberlite subcrops and is overlain by glaciofluvial sand and gravel between 60 and 80 m thick (Fig. 6b) (McClenaghan et al., 1998). The kimberlite blow subcrops below 50 m of sand and gravel.

Groundwater was collected from Sudbury Contact Mines Ltd. diamond drill holes: 91-05, 90-7, 91-8, 91-11, and 92-23 (Fig. 6a). Hole 91-05 is near the centre of the main kimberlite; hole 91-11 is in the northern part of the kimberlite; hole 90-7 was drilled approximately 125 m south of the main kimberlite and intersected a 5 m wide kimberlite dyke at approximately 112 m; hole 91-8 was drilled approximately 20 m south of the main kimberlite and intersected a 5 m wide kimberlite dyke at approximately 200 m; and, 92-23 is an inclined (60°) hole drilled in the kimberlite blow that intersected kimberlite at approximately 85 m inclined depth.

95-2 Kimberlite

The 95-2 kimberlite is located at 0583334 E and 5263598 N (NAD27) in Lundy Township and is approximately 12 km west of the town of New Liskeard. The surface elevation taken from a 1:20,000 scale topographic map is 300 m asl. Dimensions of this kimberlite are approximately 220 by 120 m (Fig. 7a). Although the age of this kimberlite has not yet been determined, it is likely within the range of other known kimberlites in the Lake Timiskaming field (134 to 154 Ma) (Brummer et al., 1992b). This kimberlite was discovered in 1995 by Sudbury Contact Mines Ltd.

The 95-2 kimberlite consists of tuffisitic kimberlite breccia and tuffisitic kimberlite. Deeper holes in the kimberlite have intersected transitional hypabyssal to diatreme kimberlite (Kjarsgaard et al., 2003). The groundmass is composed of serpentine, talc, pelletal mantle fragments, and various amounts of country rock (siltstone and gneissic fragments). It intruded Proterozoic siltstone (Firstbrook Member: argillite, greywacke, siltstone, and arkose). The kimberlite



subcrops and is overlain by approximately 10 m of till, which is in turn overlain by 40 m of glaciofluvial sand and gravel (Fig. 7b). Groundwater was collected from Sudbury Contact Mines Ltd. diamond drill holes 95-04 and 95-01 (Fig. 7a), both of which were drilled into the kimberlite. Surface water samples were collected from the stream that flows northwest over the kimberlite (Fig. 7a).

METHODS

Sample Collection

A total of 60 groundwater samples were collected during June and July of 2002 from exploration holes drilled into the five kimberlites: B30, C14, A4, Diamond Lake, and 95-2. Several water sampling methods were used: 1) straddle-packer (a sliding-head packer system built by the Geological

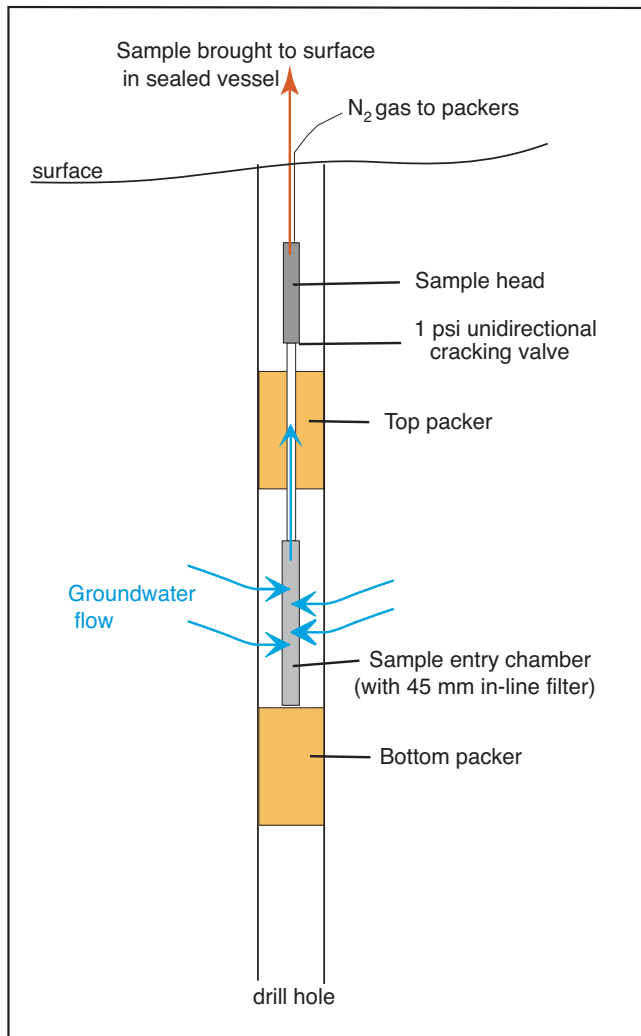


Figure 8. Schematic diagram of the operation of a straddle-packer groundwater sampling system (from Leybourne et al., 2001).

Survey of Canada, using RST packer heads, and a fixed-head packer built by Solinst); 2) a Grundfos pump; and, 3) a double-valve pump at the top part of the packer. Both types of packer system work by inflating an upper and lower section of piping that has rubber tubing around it. Between the two packers is a pipe, approximately 1.5 m in length, that has perforations in it to allow groundwater through the upper packer into a sample chamber located immediately above the upper packer (Fig. 8). The upper and lower packers are inflated using compressed N₂ gas (Fig. 9), sealing the zone with the perforated pipe in the middle. Numerous slugs of water were taken in order to flush the water column of the initial standing water. Flushing the system and taking numerous slugs of water give a better indication and more accurate sampling of groundwater at a given depths. N₂ gas was used to force the water sample to the surface. Gas pressure was regulated with a regulator on the tank and a control box. A reel that holds the tubing was held on a trolley that could be moved around on wheels and a larger, electrically operated reel was used at one hole to go down to depths below 200 m. The hand reel system is depth limited to 145 m. However, the straddle-packer system collects the most precise depth-specific samples.



Figure 9. Equipment used for down-hole groundwater sampling.



Figure 10. Grundfos electric pump used for down-hole groundwater sampling.

Another method that was implemented was the Solinst double valve pump. This system involves lowering the pump head to a given depth in the hole and using N₂ gas to drive a column of water to the surface. In many cases the drill hole diameter was either too large or too small for either packer system, so the pump head was the only method available for sampling. The drawback of using the double valve pump and not the packer system is that the water being sampled at any given depth may have mixed with water not specifically from that zone.

A third method implemented in this study was a Grundfos electric pump (Fig. 10). This method involved using a gasoline-powered generator to provide the energy for the pump. Water could be pumped up from a maximum depth of approximately 20 m. The Grundfos pump was used to pump water out of the drill holes for sampling and to carry out pump tests in holes in the 95-2, C14, and A4 kimberlites. The water pumped up the tube was then collected in a sample bottle. To ensure that the collected sample was the most reflective of a specific depth in the drill hole, water was pumped for approximately 20 minutes. At the surface, the end of the tubing was attached to a flow-through cell so the water could be constantly monitored for changes in geochemical characteristics. When the pH, Eh, conductivity, dissolved oxygen, and temperature were constant, a sample was collected. The drawback of this sampling procedure is that,

similar to the pump head, the water sampled may have been mixed from other zones and may not be a true indication of the water at that depth.

The pH, conductivity, oxidation-reduction potential (ORP), dissolved oxygen, and temperature of groundwater samples were measured in the field at the time of collection with a Quanta Multiprobe manufactured by Hydrolab Corporation. The temperature, however, is not accurate for sampling done with the packer or double-valve pump due to the time required to pump the water sample to the surface. Temperatures for samples collected with the Grundfos pump are accurate because the water is pumped out much more quickly and no additional tubing is required at the ground surface where temperatures might be affected.

For packer and double-valve pump collected samples, depths were developed until conductivity, Eh, and pH stabilized. Because many slugs of sample must be removed before a sample is taken for lab analysis, stabilization of pH, electrical conductivity, and Eh are interpreted to represent flow specifically from the depth being investigated. Once readings had stabilized, oxidation-reduction potential was typically measured after the first minute, the third minute, and finally the fifth minute. Dissolved oxygen was measured when the Quanta displayed the lowest reading of this parameter.

Groundwater samples were collected in Nalgene sample bottles of various sizes (high density polyethylene – HDPE; filtered cation (FC), filtered anion (FA), and radiogenic isotopes (RI)). Polypropylene (PP) sample bottles were used for samples for O and H isotopic analysis and filled to the top with no headspace. Amber plastic or glass bottles were used for samples for $\delta^{13}\text{C}$ analysis and also were filled completely to the top with no headspace. All sample bottles were tightened by hand and kept cool in a refrigerator to prevent any fractionation of the isotopes. The sulphate and sulphide samples were collected in 1-gallon HDPE jugs that were cleaned and reused daily.

At selected holes, geophysical borehole data were used to constrain optimal locations to sample groundwaters from fracture zones. Drill hole A at A4 kimberlite was sampled at depths corresponding to geophysical logs (J. Mwenifumbo, unpublished data, 1993). The depths were chosen to coincide with likely bedrock fractures indicated by lower rock densities and colder water temperatures. All data regarding sampling depth, sample location, method, depth, and containers used in this study are presented in Appendix 1.

Sample Preparation and Analysis

Chemical treatment of water samples

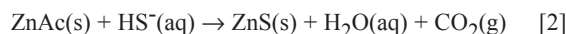
Various chemicals were added to some of the collected water samples. Each sample set that was taken included a sample for dissolved sulphide and sulphate. Barium chloride was added in excess to the sulphate sample in order to precipitate barium sulphate (Equation 1). Each sulphate sample consisted of approximately 1 to 1.5 liters. If sulphates exist, BaSO_4 (barite) will precipitate from solution (Equation 1).



After the precipitate settled to the bottom of the container, the sample was decanted and filtered through 0.45 mm filters

(typically at the end of the same day). The filtrate was air dried and kept for $\delta^{34}\text{S}$ isotopic analysis.

Zinc acetate was added to a sample of water to precipitate any dissolved sulphide that may be present. One to two grams of ZnAc ($\text{ZnC}_2\text{H}_3\text{O}_2$) was added to 1 to 2 litres of water in a 1-gallon HDPE jug. Care was taken not to shake this sample immediately after the ZnAc was added in order to prevent oxidation of aqueous sulphide. A precipitate forms where sulphides are present. The reaction produces ZnS (sphalerite) (Equation 2).



As with the sulphate sample, any sulphide precipitate was allowed to settle to the bottom after which the water was decanted and filtered, usually at the end of the same day. Small amounts of mercuric chloride (HgCl_2) were added to the samples taken for $\delta^{13}\text{C}$ analysis to kill any bacteria that may fractionate the $\delta^{13}\text{C}$ ratios. Upon arrival at the University of Texas at Dallas, all samples were refrigerated. The filtered cation (FC) samples were acidified using 2.5 ml of concentrated HNO_3 . This concentration, when added to the FC sample (250 ml), gave an overall acidified concentration for the sample of 1% (by volume).

Water analysis

Groundwater collected in June and July of 2002 was measured at the time of sampling for pH, electrical conductivity, oxidation-reduction potential (ORP), dissolved oxygen, and temperature. Carbonate alkalinity by titration was conducted at the Geological Survey of Canada, Ottawa and groundwaters have been analyzed for C, H, and O stable isotopes at the University of Ottawa, Ontario using isotope ratio mass spectrometry. Analysis of major and minor elements has been completed at the University of Texas at Dallas (UTD) using the Geoscience Department's inductively coupled plasma optical emission spectroscopy (ICP-OES) for Ca, Mg, Na, K, Si, Al, As, Ba, Cu, Fe, Li, Mn, Mo, Se, Sr, S, and Zn. Trace elements Li, Be, Al, V, Cr, Mn, Fe, Ni, Co, Cu, Zn, Ga, As, Se, Rb, Cd, Cs, Ba, Tl, Pb, and U were analyzed with UTD's inductively coupled plasma mass spectrometer (ICP-MS). Prior to ICP-MS and ICP-OES analyses, waters were diluted with 1 % HNO_3 (% vol.) so that electrical conductivity was < 1 ms/cm (<1000 mg/L salinity).

X-ray diffraction (XRD) analysis was carried out at the UTD Chemistry Department on select precipitates collected from the tests for sulphides and sulphates (described above). Interpretation of the XRD data using MacDiff 4.2.5 aided in determining which dry precipitates should be analyzed for sulphur stable isotopes ($\delta^{34}\text{S}(\text{ZnS})$ for sulphides; $\delta^{34}\text{S}(\text{BaSO}_4)$ and $\delta^{18}\text{O}(\text{BaSO}_4)$ for sulphates) at the Department of Physics and Astronomy, University of Calgary, Alberta.

Analytical quality control

One standard was inserted every fifth sample for the UTD Geoscience ICP-OES and ICP-MS analyses. The standard used for the ICP-OES was an in-house standard created from Ultra Scientific standards ICM-231, 232, 234, and 235. The ICP-MS standard was an in-house standard created from AccuTrace calibration standard 2. Data for the ICP-ES and

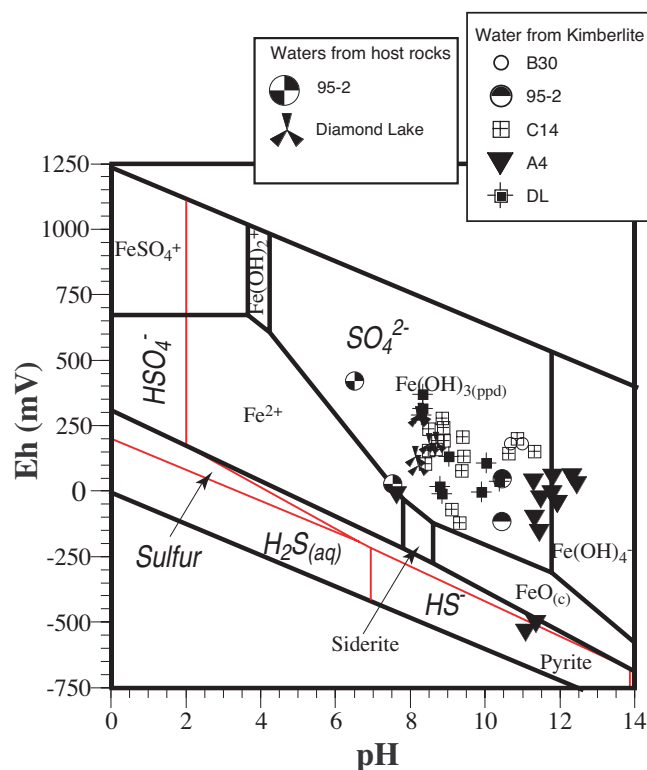


Figure 13. Plot of stability fields for Fe and S species.

Isotope Hydrology Section database (<http://isohis.iaea.org>). A large majority of the waters from the A4 kimberlite (the site with the highest pH values), however, do not fall along this line and the A4 kimberlite appears to be the only kimberlite that consistently plots farthest from the OMWL. This deviation from the OMWL suggests that some of the waters are not from meteoric recharge and are possibly paleowaters. A correlation may exist between the longer period that the waters have had to react with the rock, the elevated pH and Eh, and the gas concentrations. A4 kimberlite waters and other high alkalinity waters are the most enriched in $\delta^2\text{H}$ suggesting that there is a link between hydroxide controlled alkalinity and $\delta^2\text{H}$ fractionation.

The data obtained for $\delta^{13}\text{C}$ (Appendix 5) display a wide range of ratios (-3 to -24 ‰), which suggests multiple processes are occurring. In an ideal open system, $\delta^{13}\text{C}$ ratios are expected to be in the range of -25 to -15 ‰ (Deines and Langmuir, 1974) and in an ideal closed system they are expected to become further enriched to higher values (a maximum of approximately -10 ‰) (Deines and Langmuir, 1974). The most DIC-rich samples (Diamond Lake kimberlite) demonstrate a $\delta^{13}\text{C}$ range of between -10 to -12 ‰ (Fig. 15), suggesting there is an additional source of organic acid that is causing further carbonate dissolution. Most vegetation in northeastern Ontario produce $\delta^{13}\text{C}$ ratios for PCO_2 of approximately -27 ‰ from bacterial activity (Smith, 1971), and if an influx of organic acid (either from the top of a well that was uncapped or through groundwater flow) were to dissolve more carbonate (with $\delta^{13}\text{C}$ near 0 ‰), the groundwaters would become progressively enriched in DIC, with a $\delta^{13}\text{C}$ ratio representing a mixture between organic C (~ -27 ‰) and marine carbonate (~ 0 ‰). The possibility of

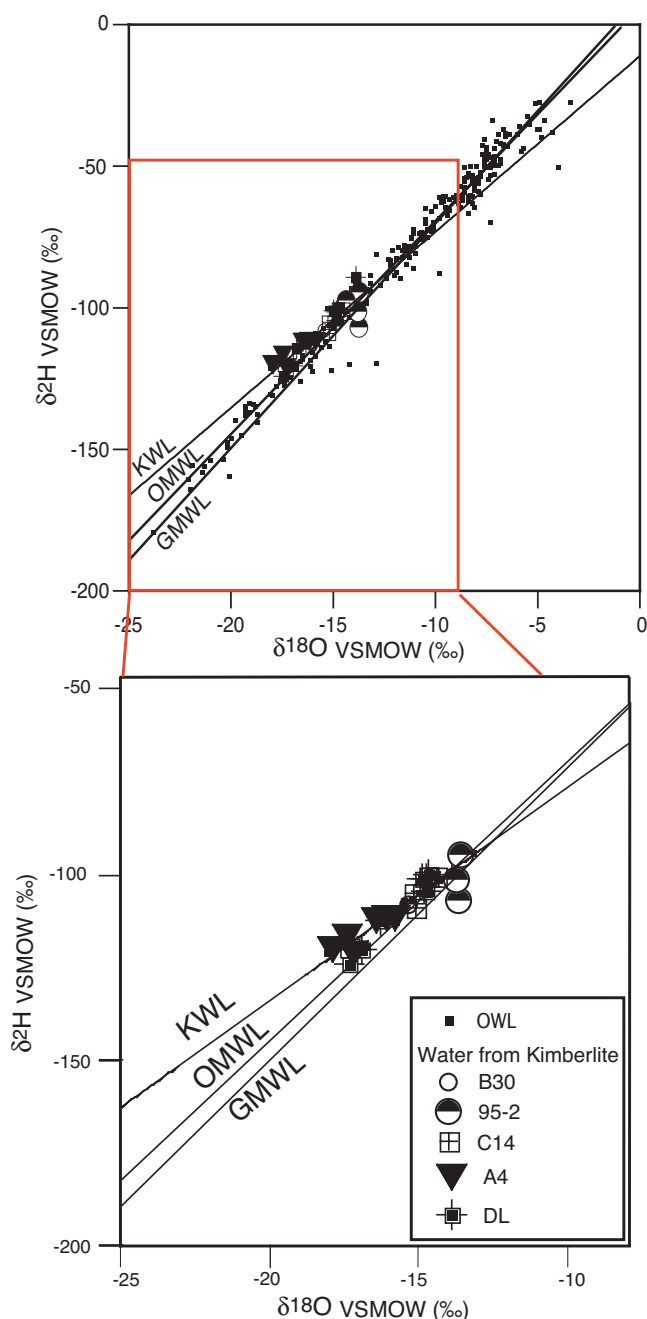


Figure 14. Comparison of kimberlite mean water line (KWL) (this study), Ottawa mean water line (OMWL), and the global mean water line (GMWL).

the PCO_2 from biotic activity mixing with C derived from marine carbonates would also explain the four-fold increase in DIC of three Diamond Lake samples compared to other groundwater samples. Not all of the anomalous three Diamond Lake samples with high DIC are from wells that were uncapped and this seems to have had little effect on the ratios. The river that flows directly over this kimberlite may have, however, affected results compared to other kimberlites sampled.

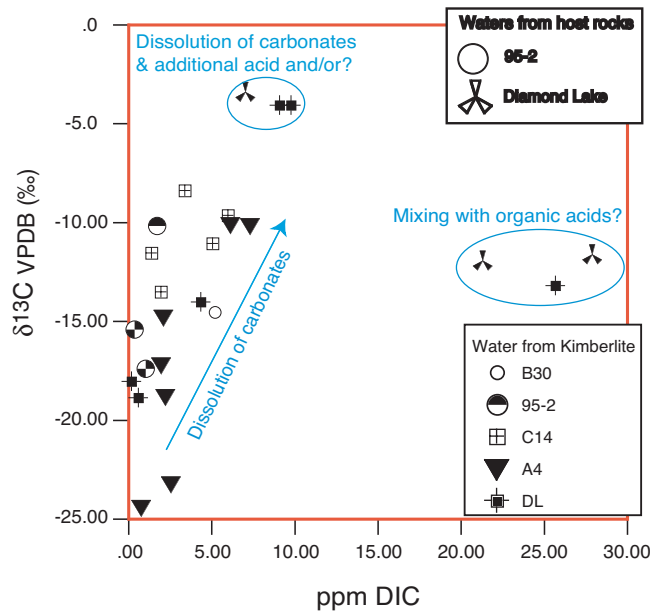


Figure 15. Comparison of the dissolved inorganic carbon and the $\delta^{13}\text{C}$ isotopic ratios for groundwater samples from the five kimberlites.

There are also three outliers from the Diamond Lake kimberlite that are as enriched as approximately -3 to -5 ‰ but have minor associated increases in DIC. These samples are from drill holes 91-8 and 92-23, which are south of the main Diamond Lake kimberlite and have intersected smaller kimberlite bodies. In a closed system alone with no other processes acting of the waters, it is difficult for groundwaters to become enriched in $\delta^{13}\text{C}$ to a ratio as high as -3 ‰, and therefore could be the result of some degree of dissolution of carbonates again due to the influx of organic acids. Another possible source of isotopically heavy carbon is mantle carbon, which has been shown to have a $\delta^{13}\text{C}$ range from -2.1 to -7.0 ‰ from kimberlites and carbonatites in the Canadian Shield (Deines and Gold, 1973). The other main source of carbon is from Paleozoic limestone that has been incorporated into the kimberlite as xenoliths. These carbonates have a ratios very near to 0 ‰ fractionation, which is an indicative of oceanic deposits (Spivak-Birndorf and Glumac, 2001). One final mechanism to produce $\delta^{13}\text{C}$ enrichment is methanogenesis (Carothers and Kharaka, 1980).

Diamond Lake kimberlite is the only kimberlite of the four sampled in Kirkland Lake that has intruded into Archean metasedimentary rocks. This difference in host rock is not seen as the cause for the low $\delta^{13}\text{C}$ values because other Archean metasedimentary rocks from the Timmins region have depleted $\delta^{13}\text{C}$ values in the range of between -17.5 and -43.8 ‰ (Strauss, 1989). The $\delta^{13}\text{C}$ in groundwater samples for this study are far too enriched for the Archean metasedimentary host rocks to have influenced the system.

A correlation between $\delta^{13}\text{C}$ fractionation and depth occurs in many of the kimberlitic waters. The plot of $\delta^{13}\text{C}$ versus depth (Fig. 16) demonstrates that the $\delta^{13}\text{C}$ does not become much more enriched than approximately -9.5 ‰ for most samples and approximately half the samples from a number of the kimberlites demonstrate a definite relationship between $\delta^{13}\text{C}$ and depth to 140 m (generally the greatest depth from which a sample was collected). The change in

ratios with depth could be the result of an open system at shallow depths that becomes progressively closed with depth, and could indicate a lowering of P_{CO_2} (Deines and Langmuir, 1974). A closed system with decreasing P_{CO_2} will therefore cause the waters to progress to a more enriched $\delta^{13}\text{C}$ ratio before calcite precipitation occurs (Deines and Langmuir, 1974) and $\delta^{13}\text{C}$ enrichment will stop. The data plotted in Figure 16 may also indicate that increasing depth represents increasing water-rock reactions. Points that do not fall along the enrichment trend may indicate the presence of other processes or mixing trends.

Sulphur in kimberlitic waters appears to be dominated by sulphate (Appendix 6) inferred from semi-quantitative XRD analysis, however, a small fraction of the sulphur has also been shown, by chemical precipitation, to be sulphide in some samples. The amounts of sulphides are small and are not known, therefore all sulphur has been calculated for sulphate (SO_4) for Appendix 6. Much of the sulphate ($\delta^{34}\text{S}_{(\text{SO}_4)}$) reduction that occurs in nature involves biological processes such as with the organism *Desulphovibrio desulphuricans* (Neal et al., 2001) and may be the cause of the sulphate reduction in lower pH waters in the five kimberlites. Reduction of sulphates to sulphides in water samples collected from the Diamond Lake kimberlite appears to have been subjected to biological reduction (also indicating a depletion of $\delta^{34}\text{S}_{(\text{ZnS})}$ ratios) (Appendix 7). However, the $\delta^{34}\text{S}_{(\text{ZnS})}$ data from the A4 kimberlite sample (JS02-1036-fc), with a pH value of 11.5, may not be a product of biogenic reduction, but abiotic reduction due to the high pH and low Eh. The existence of A4's high pH and low Eh, along with the existence of presumed CH_4 and H_2 gas in the waters suggests that the system has reached the end point of reduction (Petrucchi and Harwood, 1997) and must use carbon as a electron acceptor rather than sulphur, as the sulphur has been almost completely reduced. The high pH and low Eh conditions would make living conditions for sulphate reducing organisms difficult not only because of the inhospitable environment of the high pH,

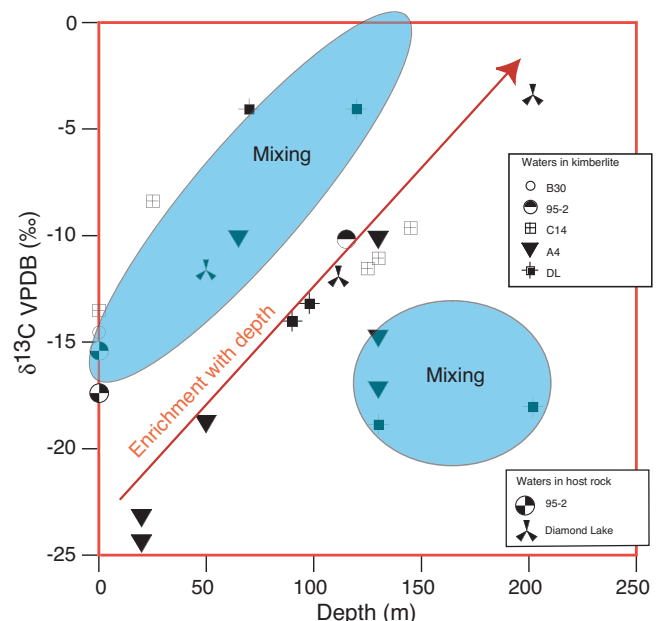


Figure 16. Trend of increasing enrichment of $\delta^{13}\text{C}$ with increasing depth.

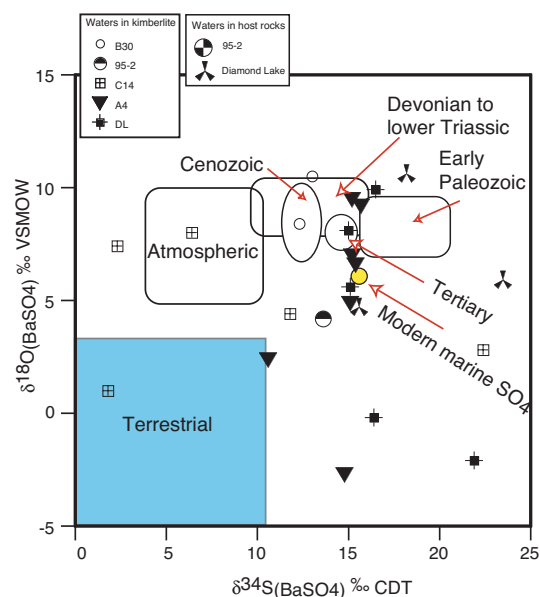


Figure 17. Plot showing the mixing of sulphates from different sources based on the sulphate isotopic composition (modified from Clark and Fritz, 1997).

but also because the water would be abiotically consuming and reduce the sulphate that these organisms survive on. Mixing could explain the more depleted B30 sample and the extremely reducing environment of A4 could be solely the result of an abiotic reducing process.

To accurately make more inferences and correlations on sulphur isotopes, it is necessary to know the source of the sulphur, as different isotopic ratios will be present from different sources (Fig. 17). The sulphate-oxygen isotopic ratios (Appendix 7) do not plot in the known fields and appear to be the result of mixing of various sources. The sulphide ratios in the kimberlite samples are enriched compared to sulphides (0.6 – 2.8 ‰) in the Archean metavolcanic rocks from northwestern Quebec (Gaboury et al., 2000). The comparatively depleted $\delta^{34}\text{S}$ of the sulphides in the kimberlitic waters suggests that sulphides in the metavolcanics and felsic host rocks did not significantly contribute to the waters except for $\delta^{34}\text{S}_{(\text{ZnS})}$ for sample JS02-1002 (0.2 ‰).

In Yakutian kimberlites, sulphur isotope data for kimberlite bedrock display a wide variation in ratios (-14 to +52 ‰; Vinogradov and Ilupin, 1972). Whole rock analysis should be performed on rocks from the five kimberlites in this study

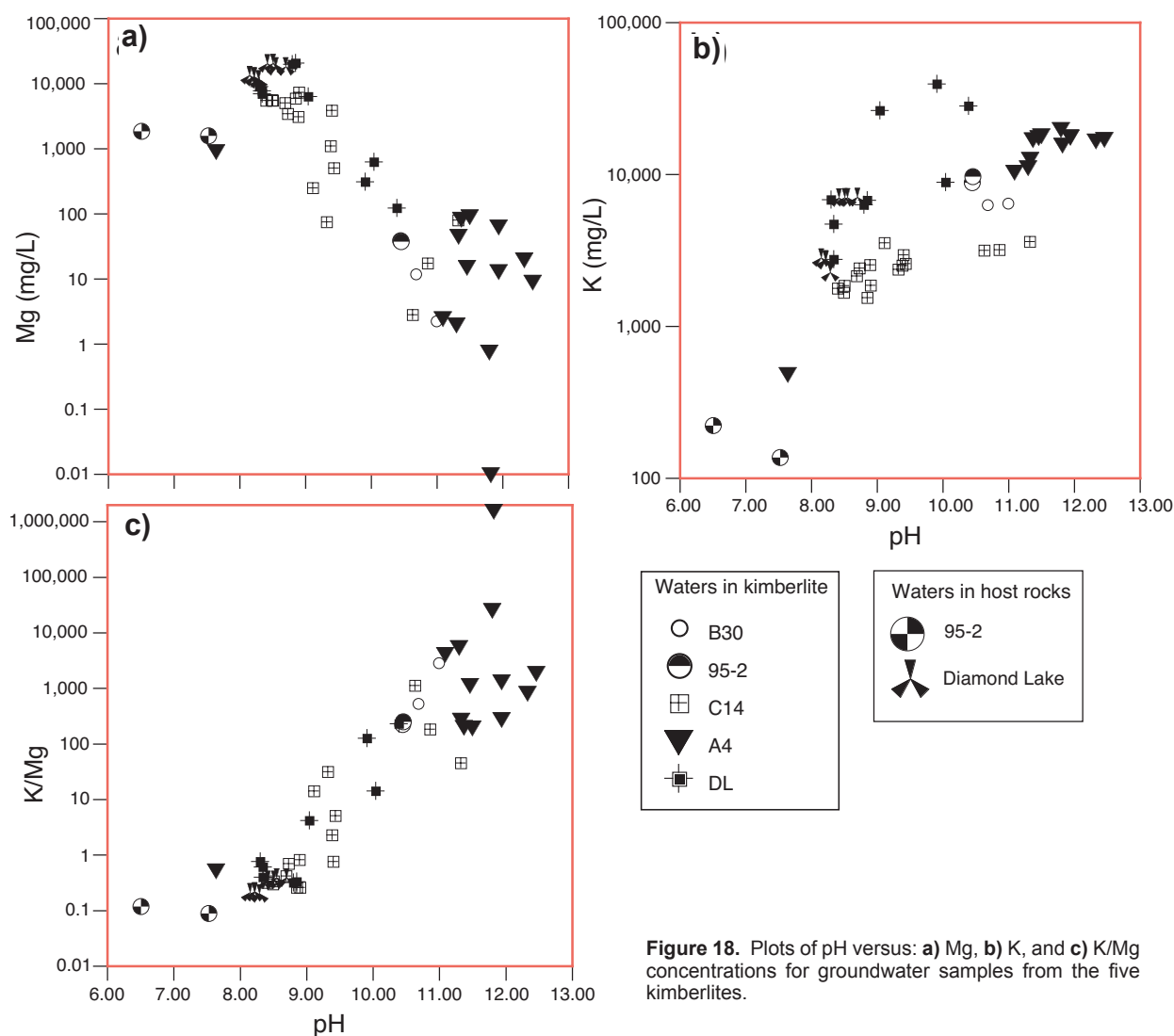


Figure 18. Plots of pH versus: a) Mg, b) K, and c) K/Mg concentrations for groundwater samples from the five kimberlites.

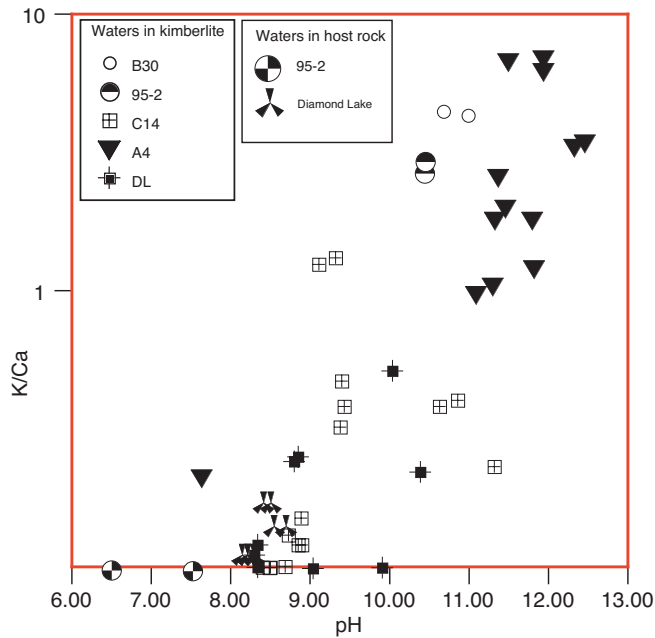


Figure 19. Plot of pH versus K/Ca concentrations for groundwater samples from the five kimberlites.

and from the surrounding country rocks that may have interacted with groundwaters. Analysis of waters in the surrounding country rock should also be completed to achieve a greater understanding of the sulphur isotope data.

Elemental Geochemistry

The kimberlitic waters are unusual in that the ratio of the major elements K to Mg is large and almost directly proportional to the pH (Fig. 18; Appendix 8). This positive correlation suggests that the Mg is being buffered whereas the K is not. In most groundwaters, K is typically controlled by cation exchange on clay mineral formation (Sawhney, 1972; Griffioen, 2001). The Mg may be held in alteration minerals such as brucite $[(Mg(OH)_2)]$, and serpentine $[Mg_3Si_2O_5(OH)_4]$, which can be supersaturated in waters from ultramafic rocks (Barns and O'Neil 1969; Barns et al., 1972). The K concentrations in the groundwaters from this study are as high as 39600 mg/L and the lowest Mg value in the groundwaters is <0.09 ppb (lower detection limit). Again, the A4 kimberlite is anomalous with respect to the other kimberlites and has the most consistently high K and low Mg contents. The A4 kimberlite has an average K concentration of 16100 mg/L and an average Mg content of 27.4 mg/L. The pH versus K/Ca (Fig. 19) trend is also similar to the pH versus K/Mg plot where, when the ratio between the two elements increase, so does the pH. These correlations suggest that the elements Ca and Mg are also preferentially precipitating out of solution to form alteration minerals. The correlation, however, of pH versus Na/K (Fig. 20) is the opposite and shows an increase in the amount of Na compared to K with the increase of pH.

Correlations between Rb and K concentrations in groundwater samples in this study (Appendix 9) mirror correlations of these elements in kimberlite bedrock from various locations around the world (Mitchell, 1986; Fig. 21a).

The elements Rb and K are both incompatible elements and come from mantle-derived basic under-saturated magmas. The range of K/Rb in kimberlite bedrock is between 100 and 250, however, kimberlitic waters from this study have an average K/Rb ratio of approximately 1000 (Fig. 21b).

Similar to K/Ca and K/Mg, there is a positive correlation between K/Rb and pH (Fig. 22), which suggests that with increased pH, there is an increase in micaceous minerals (phlogopites) that are being altered. Figure 22 indicates that with increasing pH, Rb content in waters decreases with respect to K. Also similar to K, Rb has a large ionic radius (1.48Å), which excludes it from many minerals, however it appears that an increase in pH results in a loss of Rb to a source that is not known. The K, however, is accumulates in the waters. If Rb was not being buffered out of the water, the plot of pH versus K/Rb would plot as a horizontal line.

Trace elements in the kimberlite groundwaters also have concentrations that vary significantly compared to waters from surrounding Archean host rock and waters from the kimberlite at the Snap Lake deposit, NWT. The Snap Lake waters were collected in February, 2002 for an environmental impact assessment (De Beers Canada Mining Inc., 2002). Many of the elemental concentrations in the northeastern Ontario kimberlite waters have much lower concentrations compared with the Snap Lake kimberlite waters. The Cu, Cr, Pb, Mg, and Ni concentrations are considerably depleted as compared to the Snap Lake waters (Fig. 23). However, U and Zn have very similar averages, and the concentrations for Mo and Fe are higher for northeastern Ontario kimberlite waters (Fig. 24). The Archean host rock waters have average concentrations that are all higher than the kimberlite water samples for Cu, Cr, Pb, Mg, Ni, U, Zn, Mo, and Fe (Fig. 23, 24). The differences in trace element concentrations between waters from Archean rocks and waters from the five kimberlites indicate that groundwater can be a useful sample media for kimberlite exploration. These differences also demon-

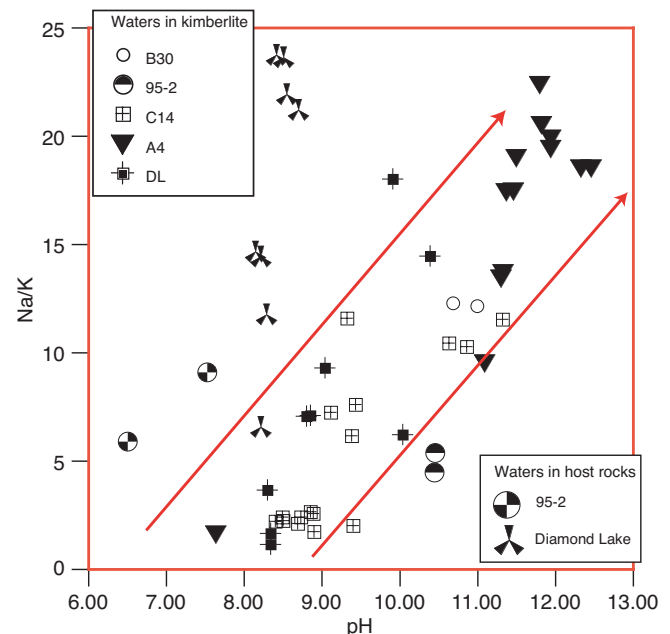


Figure 20. Plot of pH versus Na/K concentrations for groundwater samples from the five kimberlites.

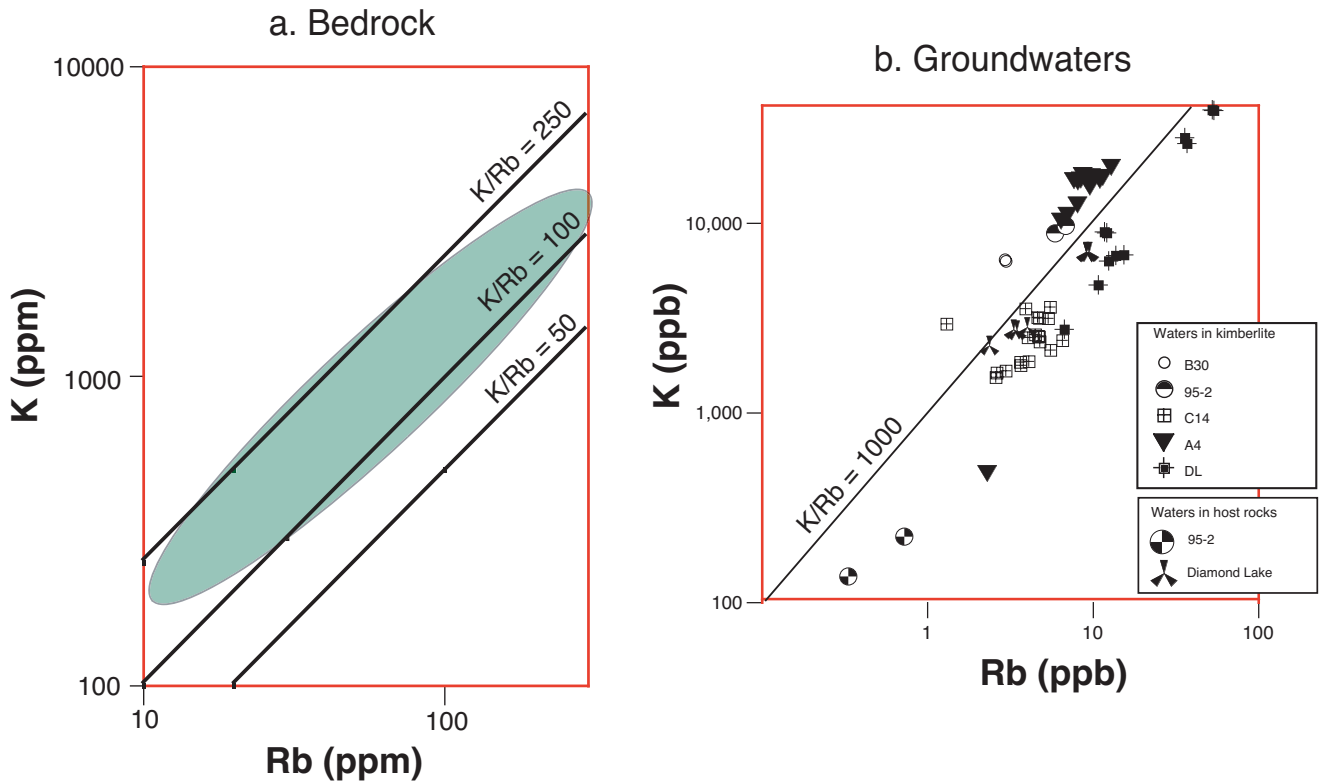


Figure 21. a) K versus Rb in kimberlite as determined by whole rock analysis (modified from Mitchell, 1986); and, b) K versus Rb from groundwater samples from the five kimberlites in this study.

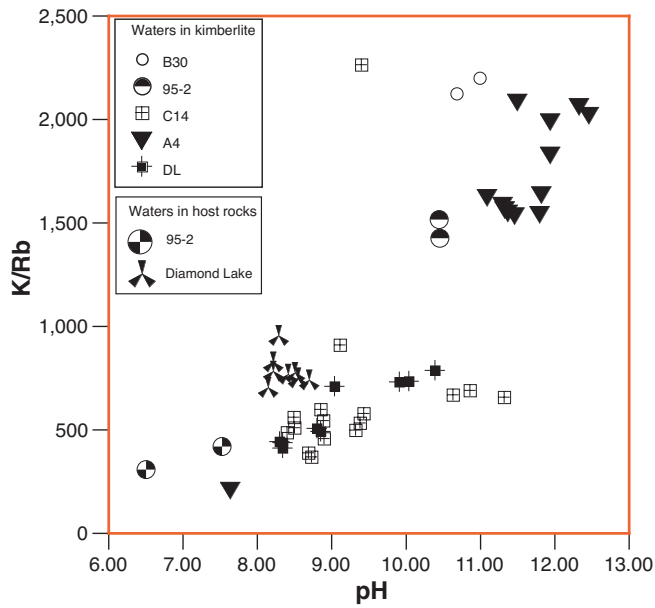


Figure 22. K/Rb versus pH for groundwater samples from the five kimberlites in this study.

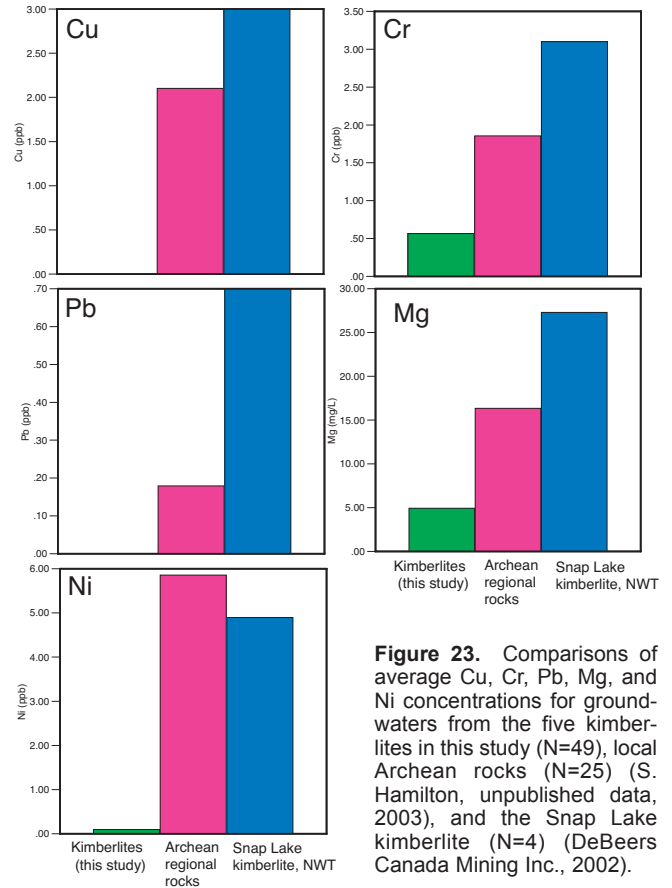


Figure 23. Comparisons of average Cu, Cr, Pb, Mg, and Ni concentrations for groundwaters from the five kimberlites in this study (N=49), local Archean rocks (N=25) (S. Hamilton, unpublished data, 2003), and the Snap Lake kimberlite (N=4) (DeBeers Canada Mining Inc., 2002).

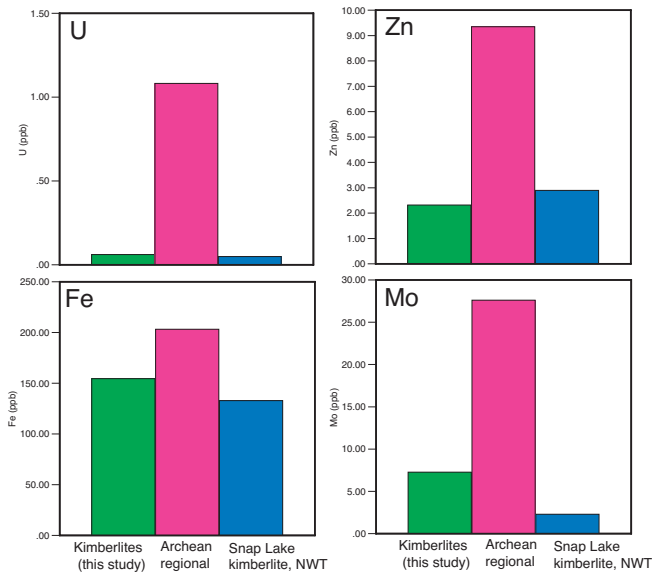


Figure 24. Comparisons of average U, Zn, Fe, and Mo concentrations for groundwaters from the five kimberlites in this study (N=49), local Archean rocks (N=25) (S. Hamilton, unpublished data, 2003), and the Snap Lake kimberlite (N=4) (DeBeers Canada Mining Inc. 2002).

strate the need for the broadening of the scope of this study to include other kimberlite fields.

INITIAL INTERPRETATIONS AND CONCLUSIONS

Comparison of kimberlitic waters to groundwaters from Archean rocks that dominate the geology in this region (S.A. Hamilton, unpublished data, 2003) suggests that kimberlitic waters have unique characteristics. The Eh versus pH plot (Fig. 25) of the waters in kimberlite and in Archean rocks shows that waters from Archean rocks are neither as reduced, nor do they fall in the same iron and sulphur stability fields. As pH and Eh determine many of other geochemical reactions in waters, the differences in Eh versus pH between kimberlitic and non-kimberlitic waters suggest that other aspects of the waters will also differ significantly.

There is also a marked difference with respect to elemental concentrations as well. When compared to groundwater from Archean rock, it is clear that the kimberlitic waters have unique elemental characteristics. The pH versus Mg plot (Fig. 26a) demonstrates that the waters from Archean rocks contain high amounts of Mg that do not vary with a change in pH. The Mg is not being removed from waters as occurs with many of the kimberlitic waters with high pH and low Eh. The pH versus K plot (Fig. 26b) also demonstrates that lower K values do not correlated with pH. These values are consistent with expected values for groundwaters in crystalline rocks. The ratio of K/Mg and its relationship to pH (Fig. 26c) shows that the ratio is consistent with the change in pH. It appears that some DL and C14 waters plot close to the Archean waters however, the 95-2, B30, and A4 kimberlites are not similar to these Archean waters. This difference may be attributed to a shorter residence time of the groundwater.

The indications from kimberlitic and local Archean country rock data support the conceptual model that groundwater can be a useful kimberlite exploration medium in northeastern Ontario. With knowledge of groundwater flow paths, waters sampled at varying distances down gradient of kimberlites may also display a kimberlitic signature, demonstrating that groundwater can act as an indicator of the existence of kimberlite up the flow gradient. This method may also be applied to spring, lake, and stream surveys on a local and regional scale as they all ultimately receive their water from groundwater recharge. The major and trace elemental analyses, stable isotopic data, and field data strengthen the argument that these waters are unusual with respect to other surrounding natural waters and act as excellent tracers in the Canadian Shield.

Generally, water movement through ultramafic rock is only along fractures and, therefore, water contact with the majority of rock does not occur and water-rock reactions are limited to places near these fractures. These findings suggest that surface water drainage from processed kimberlite rock piles at diamond mines can potentially develop into alkaline mine drainage. The process of low-temperature serpentinization may be increased due to the greater surface area of kimberlite rock. It is critical to have accurate determinations of geochemical reaction times and geochemical pathways to understand how significant alkaline mine drainage might be.

FUTURE WORK

Various analyses are underway for this aqueous geochemical study. Mentioned in the paper was the existence of water samples containing large amounts of gas. In order to obtain an accurate mass-balance calculation of the fractionation of $\delta^2\text{H}_{(\text{H}_2\text{O})}$, gas samples were collected from drill holes and analyzed for both stable isotopes and gas concentration in

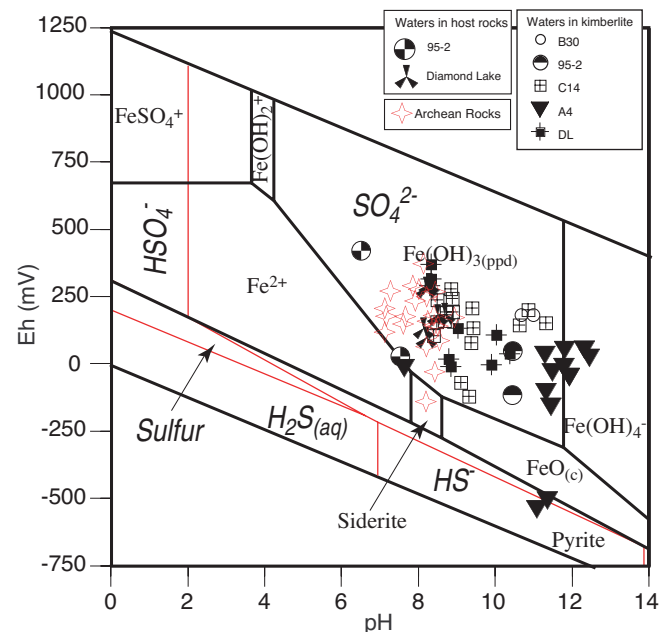


Figure 25. Plot of pH versus Eh for groundwater samples from the five kimberlites in this study and Archean rocks in the region (S. Hamilton, unpublished data, 2003).

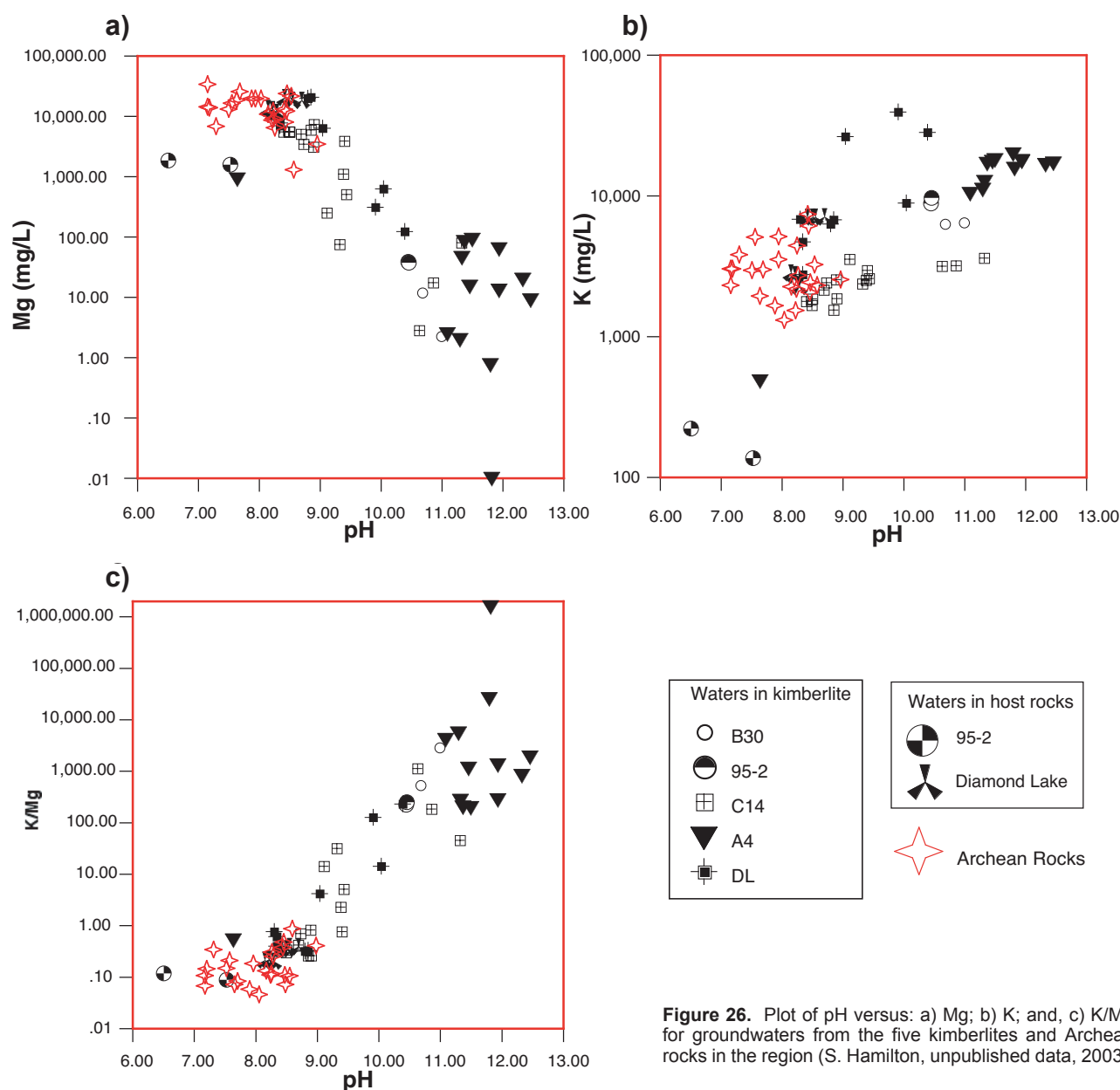


Figure 26. Plot of pH versus: a) Mg; b) K; and, c) K/Mg for groundwaters from the five kimberlites and Archean rocks in the region (S. Hamilton, unpublished data, 2003).

July, 2003. Whole rock and mineral-separate geochemical analysis of the kimberlite from drill holes will be completed to determine contents of olivine and various alteration minerals. The groundwaters will undergo analysis for Sr radiogenic isotopes in order to determine groundwater residence time in the kimberlite.

ACKNOWLEDGEMENTS

The study is being funded as an M.Sc. thesis project (J. Sader) at the University of Texas at Dallas by the Geological Survey of Canada's Targeted Geoscience Initiative (TGI-1), Project No. 000022. The Ontario Geological Survey are thanked for providing geological data, field support, and helpful advice. We would also like to thank GSC Research Scientist M. Hinton for his time and assistance with titration analysis of the samples and D. Coutinho at the University of Texas at Dallas, Chemistry Department for completing XRD

analysis. P. Sobie (MPH Consulting Ltd.) and Sudbury Contact Mines Ltd. are thanked for providing geological information and access to the 95-2 kimberlite.

REFERENCES

- Armstrong, D.K. and McCracken, A.D.**
1996: Summary of Paleontological Report on Xenoliths from Kirkland Lake and Lake Timiskaming Area Kimberlite Pipes; in Kimberlites of the Lake Timiskaming Structural Zone; Ontario Geological Survey, Open File Report 5937, p. 377-382.
- Barns, I. and O'Neil, J.R.**
1969: The Relationship between Fluids in Some Fresh Alpine-Type Ultramafics and Possible Modern Serpentinization, Western United States; Geological Society of America Bulletin, v. 80, p. 1947-1960.

Barnes, I., Rapp, J.B., O'Neil, J.R., Sheppard, R.A., and Gude, A. J. III.

1972: Metamorphic Assemblages and the Direction of Flow of Metamorphic Fluids in Four Instances of Serpentinization; *Contributions to Mineralogy and Petrology*, v. 35, p. 263-276.

Brummer, J.J., MacFadyen, D.A., and Pegg, C.C.

1992a: Discovery of Kimberlites in the Kirkland Lake Area Northern Ontario, Canada, Part I: Early Surveys and the Surficial Geology; *Exploration Mining Geology*, v. 1, no. 4, p. 339-350.

1992b: Discovery of Kimberlites in the Kirkland Lake Area Northern Ontario, Canada, Part II: Kimberlite Discoveries, Sampling, Diamond Content, Ages and Emplacement; *Exploration Mining Geology*, v. 1, no. 4, p. 351-370.

Bucher, K. and Stober, I.

2000: The Composition of Groundwater in the Continental Crystalline Crust; in *Water Science and Technology Library*, v. 34, p. 141-175.

Carothers, W.B. and Kharaka, Y.K.

1980: Stable Carbon Isotopes of HCO₃⁻ in Oil-Field Waters – Implications for the Origin of CO₂; *Geochimica et Cosmochimica Acta*, v. 44, p. 323-332.

Clark, I. and Fritz, P.

1997: Environmental Isotopes in Hydrogeology, Chapter 5; Lewis Publishers, Boca Raton, New York, 328 p.

De Beers Canada Mining Inc.

2002: Snap Lake Diamond Project Environmental Impact Assessment, Feb. 2002, Appendix III.2 – Geochemistry Report.

Deines, P. and Gold, D.P.

1973: The Isotopic Composition of Carbonatite and Kimberlite Carbonates and their Bearing on the Isotopic Composition of Deep-Seated Carbon; *Geochimica et Cosmochimica Acta*, v. 37, p.1709-1733.

Deines, P. and Langmuir, D.

1974: Stable Carbon Isotope Ratios and the Extent of a Gas Phase in the Evolution of Carbonate Groundwaters; *Geochimica et Cosmochimica Acta*, v. 38, p. 1147-1164.

Douglas, M., Clark, I.D., Raven, K., and Bottomley, D.

2000: Groundwater Mixing Dynamics at a Canadian Shield Mine; *Journal of Hydrology*, v.235, no.1-2, p.88-103.

Fetter, C.W.

2001: Applied Hydrogeology, Fourth Edition, Chapter 9; Prentice Hall, New Jersey; 598 p.

Gaboury, D., Daigneault, R., and Beaudoin, G.

2000: Volcanogenic-Related Origin of Sulphide-Rich Quartz Veins: Evidence from O and S Isotopes at the Géant Dormant Gold Mine, Abitibi Belt, Canada; *Mineralium Deposita*, v. 35, p. 21-36.

Griffioen, J.

2001: Potassium Adsorption Ratios as an Indicator for the Fate of Agricultural Potassium in Groundwater; *Journal of Hydrology*, v. 254 p. 244-254.

Heaman, L. M. and Kjarsgaard, B. A.

2000: Timing of Eastern North American Kimberlite Magmatism; Continental Extension of the Great Meteor Hotspot Track?; *Earth and Planetary Science Letters*, v.178, no.3-4, p. 253-268.

Jensen, L.S.

1975: Geology of Clifford and Ben Nevis Townships – District of Cochrane; Ontario Division of Mines, Geoscience Report 132, 55 p.

Kjarsgaard, B.A., McClenaghan, M.B., Boucher, D.R., and Kivi, K.

2003: Kimberlites and Ultrabasic Rocks of the Wawa, Chapleau, Kirkland Lake, and Lake Timiskaming Areas; in *Northern Ontario Field Trip Guide Book*, 8th International Kimberlite Conference, p. 1-37.

Leybourne, M. I., Goodfellow, W. D., and Boyle, D. R.

2001: Sulphide Oxidation and Groundwater Transport of Base Metals at the Halfmile and Restigouche Zn-Pb Massive Sulphide Deposits, Bathurst Mining Camp, New Brunswick; *Geochemistry: Exploration, Environment, Analysis*, v. 2, p. 37-44.

Kosolapova, M.I. and Kosolapov, A.I.

1962: *Primenenie gidrokhimicheskogo metoda pri poiskakh Kimberlitovykh tel*; *Geologiya I geofizika*, Akad Nauk SSSR, sibirsk, otdel, no. 2, p. 95-100.

McClenaghan, M. B. and Kjarsgaard, B. A.

2001: Indicator Mineral and Geochemical Methods for Diamond Exploration in Glaciated Terrain in Canada; in *Geological Society Special Publications*, v. 185, p. 83-123.

McClenaghan, M.B., Kjarsgaard, I.M., Schulze, D.J.,

Stirling, J.A.R., Pringle, G., and Berger, B.

1996: Mineralogy and Geochemistry of the B30 Kimberlite and Overlying Glacial Sediments, Kirkland Lake, Ontario; Geological Survey of Canada, Open File 3295, 245 p.

McClenaghan, M.B., Kjarsgaard, I.M., Schulze, D.J.,

Stirling, J.A.R., Berger, B., and Pringle, G.

1998: Mineralogy and Geochemistry of the Diamond Lake Kimberlite and Associated Esker Sediments, Kirkland Lake, Ontario; Geological Survey of Canada, Open File 3576, 200 p.

McClenaghan, M.B., Kjarsgaard, I.M., Kjarsgaard, B.A.,

Stirling, J.A.R., Pringle, G., and Berger, B.

1999a: Mineralogy and Geochemistry of the A4 Kimberlite and Associated Glacial Sediments, Kirkland Lake, Ontario; Geological Survey of Canada, Open File 3769, 162 p.

McClenaghan, M.B., Kjarsgaard, I.M., Stirling, J.A.R.,

Pringle, G., Kjarsgaard, B.A., and Berger, B.

1999b: Mineralogy and Geochemistry of the C14 Kimberlite and Associated Glacial Sediments, Kirkland Lake, Ontario; Geological Survey of Canada, Open File 3719, 147 p.

Mitchell, R.H.

1986: Kimberlites: Mineralogy, Geochemistry, and Petrology; Plenum Publishing Corporation, New York, 442 p.

Neal, A.L., Techkarnjanaruk, S., Dohnalkova, A., McCready, D., Peyton, B., and Geesey, G.G.

2001: Iron Sulphides and Sulphur Species Produced at Hematite Surfaces in the Presence of Sulphate-Reducing Bacteria; *Geochimica et Cosmochimica Acta*, v. 65, no. 2, p. 223-235.

Ontario Geological Survey

1991: Bedrock Geology of Ontario, East-Central Sheet; Ontario Geological Survey, Map 2543, scale 1:1 000 000.

Petrucchi, R.H. and Harwood, W.S.

1997: General Chemistry – Principles and Modern Applications, Prentice Hall, New Jersey.

Sage, R.P.

1996: Kimberlites of the Lake Timiskaming Structural Zone; Ontario Geological Survey Open File Report 5937, 435 p.

Sawhney, B. L.

1972: Selective Sorption and Fixation of Cations by Clay Minerals: A Review; *Clays and Clay Minerals*, v. 20, no. 2, p. 93-100.

Sheppard, M.I., Thibault, D.H., Milton, G.M., Reid, J.A.K.,

Smith, P.A., and Stevens, K.

1994: Characterization of a Suspected Terrestrial Deep Groundwater Discharge Area on the Canadian Precambrian

Shield; Journal of Contaminant Hydrology, v. 18, no. 1, p. 59-84.

Sherwood Lollar, B, Frape, S.K, Weise, S.M., Fritz, P., Macko, A., and Welhan, J.A.

1993: Abiogenic Methanogenesis in Crystalline rocks; Geochimica et Cosmochimica Acta, v. 57, p. 5087-5097.

Smith, B.M.

1971: Carbon Isotope Ratios of Respired CO₂ from Castor Bean, Corn, Peanut, Pea, Radish, Squash, Sunflower and Wheat Seedlings; Plant Cell Physiology, v. 12, p. 451-455.

Spivak-Birndorf, M. L. and Glumac, B.

2001: Carbon-Isotope Stratigraphy of the lower Gorge Formation (Upper Cambrian), northwestern Vermont; Abstracts with Programs, Geological Society of America, v. 33, no. 1, p. 28-29.

Strauss, H.

1989: Carbon and Sulphur Isotope Data for Carbonaceous Metasediments from the Kidd Creek Massive Sulphide Deposit and Vicinity, Timmins, Ontario; Economic Geology, v. 84, p. 959-962.

Vinogradov, V.I. and Ilupin, I.P.

1972: Isotopic Composition of Sulphur in Kimberlite of the Siberian Platform, Dokl. Akad. Nauk SSSR, v. 207, p. 221-223.

Appendix 1. Kimberlite groundwater sample locations, sampling methods, and analysis summary.

Sample	Kimberlite	Hole #	Sample Method	UTM Easting NAD27	UTM Northing NAD27	Depth (m)	Cations	Anion (S only)	Alkalinity	2H/18O	13C	34S (SO4)	18O (SO4)	34S (ZnS)
JS02-1001	B30	85-06-06	siphon tube	580322	5348175	0	yes	yes	yes	yes	yes	yes	yes	no
JS02-1002	B30	85-06-02	double-valve pump	580322	5348175	30	yes	yes	yes	no	no	yes	yes	yes
JS02-1004	95-2	Stream	Stream sampling	583334	5263598	N/A	yes	yes	yes	yes	yes	no	no	no
JS02-1005	95-2	Stream	Stream sampling	583279	5263928	N/A	yes	yes	yes	yes	yes	no	no	no
JS02-1006	95-2	95-04	double-valve pump	583323	5263948	70	yes	yes	yes	no	no	no	no	no
JS02-1007	95-2	95-04	double-valve pump	583323	5263948	115	yes	yes	yes	yes	yes	yes	yes	no
JS02-1008	95-2	95-01	double-valve pump	583208	5263955	50	yes	yes	yes	no	no	no	no	no
JS02-1009	95-2	95-01	double-valve pump	583208	5263955	70	yes	yes	yes	yes	yes	no	no	no
JS02-1010	C14	J74	double-valve pump	588751	5348074	25	yes	yes	yes	no	no	yes	yes	no
JS02-1011	C14	J16	double-valve pump	588761	5348116	42.5	yes	yes	yes	no	no	no	no	no
JS02-1012	C14	J16	double-valve pump	588761	5348116	72	yes	yes	yes	no	no	no	no	no
JS02-1013	C14	J16	double-valve pump	588761	5348116	94	yes	yes	yes	no	no	no	no	yes
JS02-1014	C14	J16	double-valve pump	588761	5348116	145	yes	yes	yes	yes	yes	yes	yes	no
JS02-1015	C14	J17	double-valve pump	588770	5348117	50	yes	yes	yes	no	no	no	no	no
JS02-1016	C14	J17	double-valve pump	588770	5348117	140	yes	yes	yes	no	no	no	no	no
JS02-1017	C14	J24	double-valve pump	588754	5348124	50	yes	yes	yes	no	no	no	no	no
JS02-1018	C14	J24	double-valve pump	588754	5348124	130	yes	yes	yes	yes	yes	yes	yes	no
JS02-1019	C14	J07	surface sample	588845	5348107	0	yes	yes	yes	yes	yes	yes	yes	no
JS02-1020	C14	J93	double-valve pump	588787	5348093	35	yes	yes	yes	no	no	no	no	no
JS02-1021	C14	J01	double-valve pump	588801	5348101	35	yes	yes	yes	no	no	no	no	no
JS02-1022	C14	J07	double-valve pump	588845	5348107	50	yes	yes	yes	no	no	no	no	no
JS02-1023	C14	J07	double-valve pump	588845	5348107	125	yes	yes	yes	yes	yes	yes	yes	no
JS02-1024	C14	A	Grundfos pump	588752	5348090	20	yes	yes	yes	no	no	no	no	no
JS02-1025	C14	B	Grundfos pump	588758	5348083	20	yes	yes	yes	no	no	no	no	no
JS02-1026	C14	J24	Grundfos pump	588754	5348124	20	yes	yes	yes	no	no	no	no	no
JS02-1027	C14	J27	Grundfos pump	588770	5348117	20	yes	yes	yes	no	no	no	no	no
JS02-1028	C14	J93	Grundfos pump	588801	5348101	20	yes	yes	yes	no	no	no	no	no
JS02-1029	A4	B	Grundfos pump	583142	5341294	20	yes	yes	yes	yes	yes	yes	yes	no
JS02-1030	A4	B	double-valve pump	583142	5341294	50	yes	yes	yes	no	no	no	no	no
JS02-1031	A4	B	double-valve pump	583142	5341294	130	yes	yes	yes	yes	yes	yes	yes	no
JS02-1032	A4	B	double-valve pump	583142	5341294	90	yes	yes	yes	no	no	no	no	no
JS02-1033	A4	C	Grundfos pump	583145	5341288	20	yes	yes	yes	no	no	no	no	no
JS02-1034	A4	C	double-valve pump	583145	5341288	50	yes	yes	yes	yes	yes	yes	yes	no
JS02-1035	A4	C	double-valve pump	583145	5341288	130	yes	yes	yes	yes	yes	yes	yes	no
JS02-1036	A4	A	double-valve pump	583169	5341304	130	yes	yes	yes	yes	yes	yes	yes	yes
JS02-1037	A4	A	double-valve pump	583169	5341304	130	yes	yes	yes	no	no	no	no	no
JS02-1038	A4	A	packer	583169	5341304	110	yes	yes	yes	no	no	no	no	no
JS02-1039	A4	A	packer	583169	5341304	110	yes	yes	yes	no	no	no	no	no
JS02-1040	A4	A	packer	583169	5341304	65	yes	yes	yes	yes	yes	yes	yes	no
JS02-1040-A	A4	A	packer	583169	5341304	65	yes	yes	no	no	no	no	no	no
JS02-1041	A4	JS14	Grundfos pump	583095	5341214	20	yes	yes	yes	yes	yes	yes	yes	no
JS02-1042	DL	91-05	packer	592358	5330126	70	yes	yes	yes	no	no	no	no	no
JS02-1043	DL	91-05	packer	592358	5330126	98	yes	yes	yes	yes	yes	yes	yes	no
JS02-1044	DL	91-05	packer	592358	5330126	93	yes	yes	yes	no	no	no	no	no
JS02-1045	DL	91-05	packer	592358	5330126	130	yes	yes	yes	yes	yes	yes	yes	no
JS02-1046	DL	90-7	packer	592362	5330071	50	yes	yes	yes	yes	yes	yes	yes	yes
JS02-1047	DL	90-7	packer	592362	5330071	83	yes	yes	yes	no	no	no	no	no
JS02-1048	DL	91-8	packer	592357	5330109	63	yes	yes	yes	no	no	no	no	no
JS02-1049	DL	90-7	packer	592362	5330071	111.5	yes	yes	yes	yes	yes	yes	yes	no
JS02-1050	DL	91-8	packer	592357	5330109	100	yes	yes	yes	no	no	no	no	no
JS02-1051	DL	90-7	packer	592362	5330071	116	yes	yes	yes	no	no	no	no	no
JS02-1052	DL	92-23	packer	592450	5329933	70	yes	yes	yes	yes	yes	yes	yes	yes
JS02-1053	DL	92-23	packer	592450	5329933	120	yes	yes	yes	yes	yes	yes	yes	no
JS02-1054	DL	91-11	packer	592361	5330146	202	yes	yes	yes	yes	yes	yes	yes	yes
JS02-1055	DL	91-8	packer	592357	5330109	200	yes	yes	yes	no	no	no	no	no
JS02-1056	DL	91-8	packer	592357	5330109	202	yes	yes	yes	yes	yes	yes	yes	no
JS02-1057	DL	91-11	packer	592361	5330146	202	yes	yes	yes	no	no	no	no	no
JS02-1058	DL	91-11	packer	592361	5330146	150	yes	yes	yes	no	no	no	no	no
JS02-1059	DL	91-11	packer	592361	5330146	90	yes	yes	yes	yes	yes	no	no	no
JS02-1060	DL	91-11	packer	592361	5330146	90	yes	yes	no	no	no	no	no	no
JS02-1061	sunnydale cottages	tap water	sampled from tap	N/A	N/A	N/A	yes	yes	yes	no	no	no	no	no

Appendix 2. Field geochemical data.

Sample	Kimberlite	Depth (m)	Conductivity (millisemens/cm) (stable number)	pH (stable number)	Dissolved Oxygen (lowest value)	ORP (Eh) SHE corrected (+230mV)	Temperature (°C) (lowest value)
JS02-1001	B30	0	0.549	10.99	0.38	184	11.7
JS02-1002	B30	30	0.526	10.68			
JS02-1004	95-2	surface	0.041	7.52	7.52	30	22.43
JS02-1005	95-2	surface	0.046	6.5	6.73	425	19.12
JS02-1006	95-2	70	0.254	10.44	2.94	-114	11.19
JS02-1007	95-2	115	0.323	10.45		50	10.02
JS02-1008	95-2	50	0.13	9.42	4	159	12.8
JS02-1009	95-2	70	2.37	9.45	4.6	-28	10.47
JS02-1010	C14	25	0.096	9.4	4.35	209	14.9
JS02-1011	C14	42.5	0.126	8.89	4.19	245	14.11
JS02-1012	C14	72	0.158	8.5	5.29	239	12.94
JS02-1013	C14	94	0.159	8.4	2.58	106	12.39
JS02-1014	C14	145	0.144	8.73	4.42	194	7.09
JS02-1015	C14	50	0.16	8.49	2.77	158	11.81
JS02-1016	C14	140	0.159	8.69	2.84	161	6.98
JS02-1017	C14	50	0.127	9.43	5.18	135	13.11
JS02-1018	C14	130	0.119	9.38	2.85	79	8.36
JS02-1019	C14	0	0.303	10.63	5.43	145	8.53
JS02-1020	C14	35	0.129	8.85	3.63	281	15.37
JS02-1021	C14	35	0.144	8.9	2.21	194	17.12
JS02-1022	C14	50	0.295	10.86	4.96	202	12.62
JS02-1023	C14	125	0.48	11.32	4.44	154	8.6
JS02-1024	C14	20	0.136	9.32	0.85	-120	7
JS02-1025	C14	20	0.127	9.11	0.93	-68	6.23
JS02-1026	C14	20					
JS02-1027	C14	20					
JS02-1028	C14	20					
JS02-1029	A4	20	0.839	11.09	0.81	-536	8.41
JS02-1030	A4	50	1.372	11.3	3.24	39	16.33
JS02-1031	A4	130	4.94	11.8	2.52	-6	9.24
JS02-1032	A4	90	2.9	11.82	2.97	57	13.42
JS02-1033	A4	20	2.45	11.37	0.65	-504	5.25
JS02-1034	A4	50	1.56	11.33	1.86	-100	11.33
JS02-1035	A4	130	2.76	11.46	1.82	-154	10.65
JS02-1036	A4	130	3.17	11.5	0.91	-26	10.04
JS02-1037	A4	130	3.18	11.94	1.56	-43	10.5
JS02-1038	A4	110	2.68	12.33	2.21	58	
JS02-1039	A4	110	3.18	11.94	1.56	-43	10.5
JS02-1040	A4	65	2.8	12.46	1.56	28	17
JS02-1040-A	A4	65					
JS02-1041	A4	20	0.042	7.64	0.68	-10	5.59
JS02-1042	DL	70	0.216	8.34	3.93	317	14.38
JS02-1043	DL	98	0.494	8.3	2.46	292	12.38
JS02-1044	DL	93	0.288	8.34	3.53	372	11.33
JS02-1045	DL	130	2.53	9.04	3.87	134	12.4
JS02-1046	DL	50		8.22	2.17	285	14.59
JS02-1047	DL	83	0.285	8.29	2.74	297	13.43
JS02-1048	DL	63	1.051	8.7		187	
JS02-1049	DL	111.5	0.375	8.22	2.7	98	13.71
JS02-1050	DL	100	1.069	8.55		2.6	
JS02-1051	DL	116	0.395	8.15	3.57	132	13.48
JS02-1052	DL	70	0.561	8.8	1.48	18	12.48
JS02-1053	DL	120	0.585	8.85	1.45	-9	10.71
JS02-1054	DL	202	4.62	9.91	3.1	-3	16.76
JS02-1055	DL	200	1.105	8.51	2.88	181	
JS02-1056	DL	202	1.108	8.42	2.92		
JS02-1057	DL	202	4.62			-3	
JS02-1058	DL	150	2.35	10.39	2.19	38	19.76
JS02-1059	DL	90	0.422	10.04	2.36	109	18.9
JS02-1060	DL	90					
JS02-1061	sunnydale cottages	N/A	0.669	7.08	6.34	114	9.75

Appendix 3. Data for groundwater alkalinities.

Sample	Kimberlite	Depth (m)	Bicarbonate Alk. (CaCO ₃) mg/L
JS02-1001	B30	0	129.204
JS02-1002	B30	30	124.806
JS02-1004	95-2	surface	19.5573
JS02-1005	95-2	surface	22.9606
JS02-1006	95-2	70	41.2754
JS02-1007	95-2	115	39.6595
JS02-1008	95-2	50	51.9348
JS02-1009	95-2	70	20.5525
JS02-1010	C14	25	45.7061
JS02-1011	C14	42.5	57.4575
JS02-1012	C14	72	66.8361
JS02-1013	C14	94	66.3522
JS02-1014	C14	145	59.7077
JS02-1015	C14	50	67.0507
JS02-1016	C14	140	66.5107
JS02-1017	C14	50	51.0216
JS02-1018	C14	130	46.3856
JS02-1019	C14	0	72.404
JS02-1020	C14	35	44.8111
JS02-1021	C14	35	60.8258
JS02-1022	C14	50	73.6511
JS02-1023	C14	125	85.5102
JS02-1024	C14	20	70.0389
JS02-1025	C14	20	64.5327
JS02-1026	C14	20	45.3774
JS02-1027	C14	20	40.6244
JS02-1028	C14	20	42.6939
JS02-1029	A4	20	163.144
JS02-1030	A4	50	223.042
JS02-1031	A4	130	693.113
JS02-1032	A4	90	478.318
JS02-1033	A4	20	448.318
JS02-1034	A4	50	254.436
JS02-1035	A4	130	429.527
JS02-1036	A4	130	583.31
JS02-1037	A4	130	575.136
JS02-1038	A4	110	510.565
JS02-1039	A4	110	585.161
JS02-1040	A4	65	529.406
JS02-1040-A	A4	65	
JS02-1041	A4	20	14.2971
JS02-1042	DL	70	103.006
JS02-1043	DL	98	96.6432
JS02-1044	DL	93	102.3
JS02-1045	DL	130	28.6946
JS02-1046	DL	50	132.145
JS02-1047	DL	83	128.152
JS02-1048	DL	63	57.5818
JS02-1049	DL	111.5	117.943
JS02-1050	DL	100	56.508
JS02-1051	DL	116	114.02
JS02-1052	DL	70	78.6721
JS02-1053	DL	120	71.7559
JS02-1054	DL	202	28.1387
JS02-1055	DL	200	56.4201
JS02-1056	DL	202	55.9113
JS02-1057	DL	202	28.495
JS02-1058	DL	150	37.5384
JS02-1059	DL	90	50.8355
JS02-1060	DL	90	
JS02-1061	sunnydale cottages	N/A	325.525

Appendix 4. $\delta^2\text{H}$ and $\delta^{18}\text{O}$ stable isotope data of selected groundwaters.

Sample	$\delta^2\text{H}_{(\text{VSMOW})}$	$\delta^{18}\text{O}_{(\text{VSMOW})}$
JS02-1001	-108.3	-15.45
JS02-1004	-94.8	-13.72
JS02-1005	-107.1	-13.76
JS02-1007	-101.6	-13.8
JS02-1009	-97.7	-14.38
JS02-1010	-105.5	-15.24
JS02-1014	-101.0	-14.75
JS02-1018	-101.0	-14.48
JS02-1019	-109.5	-15.18
JS02-1023	-120.3	-17.39
JS02-1029	-111.9	-15.85
JS02-1031	-116.7	-17.43
JS02-1034	-111.9	-16.16
JS02-1035	-121.2	-17.27
JS02-1036	-120.0	-17.95
JS02-1040	-119.9	-17.91
JS02-1041	-112.1	-16.46
JS02-1043	-100.4	-14.74
JS02-1045	-114.7	-16.77
JS02-1046	-101.9	-14.83
JS02-1049	-113.0	-16.31
JS02-1052	-120.9	-16.94
JS02-1053	-124.6	-17.41
JS02-1054	-89.7	-13.87
JS02-1056	-104.9	-14.82
JS02-1059	-101.5	-14.96

Appendix 5. $\delta^{13}\text{C}$ stable isotope and DIC data of selected groundwaters.

Sample	DIC (ppm)	$\delta^{13}\text{C}_{\text{(VPDB)}}(\text{DIC})$
JS02-1001	5.18	-14.53
JS02-1004	0.33	-15.39
JS02-1005	1.00	-17.37
JS02-1007	1.69	-10.15
JS02-1009	0.08	-15.83
JS02-1010	3.38	-8.39
JS02-1014	5.98	-9.64
JS02-1018	5.05	-11.06
JS02-1019	1.95	-13.51
JS02-1023	1.37	-11.54
JS02-1029	2.55	-23.20
JS02-1031	2.11	-14.78
JS02-1034	2.22	-18.80
JS02-1035	1.96	-17.19
JS02-1036	7.31	-10.16
JS02-1040	6.13	-10.11
JS02-1041	0.77	-24.40
JS02-1043	25.67	-13.19
JS02-1045	0.59	-18.86
JS02-1046	27.90	-11.63
JS02-1049	21.31	-11.93
JS02-1052	9.77	-4.08
JS02-1053	9.09	-4.08
JS02-1054	0.17	-18.03
JS02-1056	7.03	-3.41
JS02-1059	4.34	-14.02

Appendix 6. ICP-OES data for sulphur and the conversion to SO_4 .

Sample	Dilution Factor	S (ppb)	SO_4 (ppb)
1001-fc	1.000	6679.69	20009.92
1002-fc	1.000	6396.54	19161.68
1004-fc	1.000	1768.35	5297.32
1005-fc	1.000	1264.17	3787.00
1006-fc	1.000	16687.78	49990.50
1007-fc	1.000	27185.39	81437.49
1008-fc	1.000	3386.68	10145.25
1009-fc	5.033	503308.66	1507728.82
1010-fc	1.000	899.64	2694.99
1011-fc	1.000	4224.52	12655.12
1012-fc	1.000	5203.10	15586.59
1013-fc	1.000	5141.96	15403.43
1014-fc	1.000	5194.03	15559.42
1015-fc	1.000	5150.81	15429.94
1016-fc	1.000	5160.56	15459.16
1017-fc	1.000	4414.12	13223.10
1018-fc	1.000	4758.23	14253.91
1019-fc	1.000	5236.28	15685.99
1020-fc	1.000	7313.52	21908.63
1021-fc	1.000	4842.31	14505.79
1022-fc	1.000	5106.12	15296.06
1023-fc	1.000	11046.56	33091.45
1024-fc	1.000	28.49	85.35
1025-fc	1.000	30.25	90.61
1026-fc	1.000	2240.31	6711.15
1027-fc	1.000	832.50	2493.86
1028-fc	1.000	4694.77	14063.81
1029-fc	1.000	17629.02	52810.09
1030-fc	2.009	28271.20	84690.19
1031-fc	5.034	61374.85	183856.63
1032-fc	5.034	49991.10	149755.06
1033-fc	5.033	45276.94	135633.17
1034-fc	2.008	27250.04	81631.15
1035-fc	5.034	46158.52	138274.06
1036-fc	5.034	30515.24	91412.51
1037-fc	5.034	30181.21	90411.87
1038-fc	5.034	29451.21	88225.07
1039-fc	5.033	30262.53	90655.49
1040a-fc	5.034	28646.54	85814.55
1040-fc	5.034	28355.35	84942.28
1041-fc	1.000	1561.67	4678.20
1042-fc	1.000	3740.58	11205.40
1043-fc	1.000	55271.78	165574.05
1044-fc	1.000	15504.31	46445.26
1045-fc	5.034	512217.83	1534417.42
1046-fc	1.000	5605.63	16792.41
1047-fc	1.000	6859.94	20549.87
1048-fc	2.008	110741.41	331740.79
1049-fc	1.000	23294.05	69780.47
1050-fc	2.009	116913.65	350230.56
1051-fc	1.000	26693.74	79964.69
1052-fc	1.000	623.89	1868.95
1053-fc	1.000	350.86	1051.05
1054-fc	5.034	907294.74	2717923.47
1055-fc	2.009	118985.99	356438.53
1056-fc	2.008	113411.81	339740.34
1057-fc	5.034	906104.58	2714358.19
1058-fc	5.034	388866.78	1164902.77
1059-fc	1.000	40854.72	122385.80
1060-fc	5.033	39215.86	117476.39
1061-fc	1.000	6825.44	20446.52

Appendix 7. $\delta^{34}\text{S}$ and $\delta^{18}\text{O}$ stable isotope data in BaSO_4 precipitate and $\delta^{34}\text{S}$ stable isotope data in ZnS from selected samples.

Sample	$\delta^{34}\text{S}_{\text{BaSO}_4}$	$\delta^{18}\text{O}_{\text{BaSO}_4}$	$\delta^{34}\text{S}_{\text{ZnS}}$
JS02-1001	13.0	10.5	
JS02-1002	12.3	8.4	0.2
JS02-1007	13.6	4.2	
JS02-1010	22.4	2.8	
JS02-1013			11.5
JS02-1014	1.8	1.0	
JS02-1018	2.3	7.4	
JS02-1019	6.4	8.0	
JS02-1023	11.8	4.4	
JS02-1029	15.2	9.5	
JS02-1031	15.3	7.0	
JS02-1034	15.4	6.6	
JS02-1035	15.1	4.9	
JS02-1036	10.6	2.4	12.6
JS02-1040	15.7	9.2	
JS02-1041	14.8	-2.7	
JS02-1043	15.1	5.6	
JS02-1045	16.5	9.9	
JS02-1046	15.6	4.7	4.2
JS02-1049	23.5	5.9	
JS02-1052	16.4	-0.2	13.1
JS02-1053	21.9	-2.1	
JS02-1054	15.0	8.1	14.3
JS02-1056	18.2	10.6	

Geochemistry of Groundwater from Kimberlites, Kirkland Lake and Lake Timiskaming

Appendix 8. ICP-OES data for major elements in groundwaters.

Sample	Dilution Factor	Al (ppb)	As (ppb)	Ba (ppb)	Ca (ppb)	Cu (ppb)	Fe (ppb)	K (ppb)	Li (ppb)	Mg (ppb)	Mn (ppb)	Mo (ppb)	Na (ppb)	Se (ppb)	Si (ppb)	Sr (ppb)	Zn (ppb)
1001-fc	1.000	71.81	0.32	20.95	1500.67	0.00	1.67	6437.34	5.17	2.25	0.23	4.67	78366.37	0.00	18767.61	85.55	0.16
1002-fc	1.000	79.34	4.30	19.70	1421.67	0.00	16.75	6310.76	4.85	11.91	0.25	5.07	77653.44	7.30	18301.53	82.16	1.13
1004-fc	1.000	119.56	0.00	6.40	5426.05	1.41	272.64	138.08	1.28	1601.47	13.15	0.39	1257.59	7.51	1132.38	11.05	2.34
1005-fc	1.000	152.88	0.00	6.93	6130.51	1.65	346.73	223.85	0.62	1872.24	36.90	0.61	1326.44	0.48	1989.64	20.81	1.59
1006-fc	1.000	13.72	0.00	70.96	3346.81	0.61	14.97	8888.29	3.87	39.08	0.31	19.51	39941.33	4.09	168.97	270.36	0.32
1007-fc	1.000	22.80	0.00	62.59	3318.61	0.44	31.03	9721.33	4.19	38.06	0.62	37.62	52424.68	10.24	144.33	262.93	0.44
1008-fc	1.000	17.31	0.00	17.48	3257.17	0.00	2.46	3984.17	3.36	261.39	1.03	5.47	23939.75	1.23	3183.22	251.41	0.33
1009-fc	4.986	44.37	25.32	7.27	506355.60	2.36	1.04	28379.97	14.21	2526.31	6.24	16.90	96499.28	130.74	882.20	12689.24	0.00
1010-fc	1.000	4.48	0.00	13.13	6270.74	0.25	3.14	2949.21	0.57	3868.44	23.92	9.54	5958.96	1.80	45.44	127.26	0.20
1011-fc	1.000	0.00	0.00	278.57	16582.13	0.00	48.84	2535.19	0.00	3093.01	9.00	2.12	6509.29	11.29	6177.49	396.44	0.00
1012-fc	1.000	0.00	0.00	99.82	20697.11	0.00	76.30	1855.23	0.00	5468.30	4.21	1.50	4150.82	20.05	6673.52	212.49	0.00
1013-fc	1.000	0.00	0.42	89.56	20862.99	0.00	14.82	1780.87	0.00	5486.46	2.46	1.99	3960.42	14.37	6709.20	178.41	0.00
1014-fc	1.000	2.80	0.00	85.44	18816.65	0.00	7.24	2411.33	0.00	3424.34	0.93	1.46	5814.42	9.98	8681.43	324.08	0.00
1015-fc	1.000	1.76	6.51	92.21	21135.51	0.00	70.04	1667.47	0.00	5533.86	4.24	2.44	4014.48	14.36	6639.44	189.66	0.00
1016-fc	1.000	1.99	0.00	96.15	21216.00	0.00	7.08	2144.14	0.00	5067.05	0.97	1.56	4543.61	3.44	7272.15	228.55	0.00
1017-fc	1.000	13.38	0.00	107.52	6828.23	0.00	24.78	2590.71	0.82	505.80	0.93	1.72	19720.75	19.96	10700.50	227.29	0.00
1018-fc	1.000	10.71	0.00	107.85	7788.48	0.00	16.05	2514.39	1.51	1092.90	0.86	2.40	15506.53	5.36	9537.01	260.31	0.60
1019-fc	1.000	42.70	5.17	30.32	8228.43	0.00	1.46	3160.43	0.68	2.82	0.02	3.23	33021.53	8.12	11189.10	351.27	0.32
1020-fc	1.000	5.12	0.00	113.18	12699.05	0.00	17.92	1542.94	0.00	5898.48	259.67	14.77	4100.80	12.78	72.45	194.27	0.04
1021-fc	1.000	4.00	0.00	106.56	15740.36	0.00	41.64	1864.41	0.34	7301.72	127.25	6.71	3220.91	16.27	177.21	170.50	0.00
1022-fc	1.000	36.22	0.00	41.78	7883.76	0.00	4.94	3188.90	0.45	17.33	0.24	2.56	32778.69	2.52	11217.47	366.94	0.50
1023-fc	1.000	131.56	2.41	36.61	15456.77	0.00	88.96	3617.74	0.76	79.72	1.25	6.19	41747.48	9.95	5943.68	722.56	0.19
1024-fc	1.000	0.00	0.00	87.96	1815.92	0.00	95.75	2376.86	0.52	75.06	25.77	12.08	27540.46	0.75	48.29	172.16	0.40
1025-fc	1.000	0.00	0.00	65.79	2862.41	0.00	32.60	3547.45	1.15	251.09	24.53	2.27	25727.87	8.59	28.76	143.44	0.35
1026-fc	1.000	0.00	0.00	167.70	3112.96	0.00	139.94	3151.16	0.73	256.32	63.02	0.33	18690.23	3.58	1393.85	206.07	2.06
1027-fc	1.000	0.00	0.00	97.27	5830.14	0.00	105.07	2493.89	0.06	2418.73	29.60	2.50	6457.95	13.40	202.08	194.55	0.13
1028-fc	1.000	13.25	0.00	87.06	9074.56	0.00	176.29	1628.18	0.15	5783.05	212.93	9.78	4097.35	8.94	10.02	166.39	0.59
1029-fc	1.000	38.50	5.77	93.51	10760.15	0.04	3.09	10407.70	5.54	2.51	0.16	8.07	99426.42	14.02	3124.76	920.83	0.23
1030-fc	1.996	58.56	14.12	53.74	10688.83	1.16	6.10	11166.53	5.93	2.01	0.28	7.76	150444.96	31.28	3689.93	1032.13	1.20
1031-fc	4.991	52.76	0.00	27.29	11052.33	0.00	6.96	19934.24	18.38	0.77	0.95	5.24	446736.55	10.44	1864.50	2667.00	2.07
1032-fc	4.990	104.29	0.00	33.18	13062.27	0.00	6.72	15714.62	19.86	-0.09	1.13	6.03	323144.00	40.56	2008.90	2415.63	1.09
1033-fc	4.989	152.80	7.42	80.80	6638.66	0.00	51.90	17038.19	9.23	84.04	0.62	5.13	297534.70	27.03	2396.99	1498.91	3.05
1034-fc	1.997	82.99	9.95	61.26	7032.51	0.00	25.13	12656.50	6.50	46.11	0.72	8.34	173648.43	32.86	4197.01	1066.84	1.62
1035-fc	4.985	79.91	13.56	37.65	8862.77	10.40	14.54	17636.60	10.74	15.31	0.70	5.64	308593.10	55.61	2554.05	1613.90	1.84
1036-fc	4.984	48.05	21.60	22.30	2684.58	0.00	45.78	18098.25	14.23	91.88	1.40	8.15	344643.02	3.55	5287.38	434.05	2.29
1037-fc	4.988	59.76	0.00	20.50	2586.06	0.00	45.66	17816.63	12.92	63.68	0.48	6.30	346790.36	57.04	5233.84	392.48	3.41
1038-fc	4.989	228.32	0.00	31.43	5073.17	0.00	49.23	16751.77	10.88	20.05	0.77	6.20	310803.72	0.00	5149.91	851.90	8.12
1039-fc	4.985	247.60	0.00	24.30	2857.70	0.00	14.56	17717.80	13.31	13.20	0.61	7.14	353060.74	58.16	5320.67	429.98	7.06
1040-a-fc	4.988	379.65	0.00	48.84	4999.32	0.00	17.39	17107.42	10.24	9.05	0.84	4.02	317330.41	23.16	5478.06	786.10	7.77
1040-fc	4.987	582.02	0.00	49.17	5124.51	0.21	14.92	16987.85	15.42	6.97	-0.47	6.48	316441.90	18.41	5506.28	786.76	7.17
1041-fc	1.000	24.25	0.00	5.34	2316.25	0.00	7114.54	485.71	0.05	919.45	315.17	0.68	808.07	0.00	1783.82	27.38	1.36
1042-fc	1.000	6.82	0.01	421.44	31793.23	0.00	3.78	2755.41	0.42	6956.75	8.41	4.35	3158.23	16.56	4736.11	1691.35	0.20
1043-fc	1.000	5.59	3.60	207.33	64491.03	0.00	2.31	6795.97	1.02	8950.97	7.84	5.63	24826.50	28.99	4454.72	4133.90	6.93
1044-fc	1.000	0.00	0.00	169.42	37938.66	0.00	4.24	4713.41	0.00	7719.90	5.88	3.51	7790.06	22.06	4786.00	2902.02	5.79
1045-fc	4.985	0.00	33.37	132.79	376540.27	0.00	1.37	26288.68	0.00	6307.88	19.02	20.46	244594.74	112.36	1219.69	11644.62	0.00
1046-fc	1.000	0.00	32.71	138.43	24884.07	0.00	34.60	2746.21	0.27	12529.87	99.40	10.91	18026.44	13.78	4594.09	1309.06	2.10
1047-fc	1.000	5.81	24.14	124.09	20611.03	0.00	20.34	2256.81	3.21	11432.80	51.20	10.97	26531.82	14.30	5012.70	2136.81	1.25
1048-fc	1.997	63.47	4.40	53.90	50713.27	0.04	53.95	7056.93	45.44	18081.04	56.35	5.21	149504.22	46.83	2277.85	3381.11	18.87
1049-fc	1.000	20.71	34.17	62.67	24567.09	0.00	23.89	2708.56	8.59	12693.83	45.82	12.15	39094.99	20.70	4960.09	3108.39	0.90
1050-fc	1.996	55.41	2.15	25.93	50737.00	1.27	25.85	7029.76	51.57	18123.35	37.77	3.95	154083.34	28.22	2450.64	3152.06	9.44
1051-fc	1.000	24.81	27.74	68.21	25359.61	0.00	41.34	2820.96	9.87	13307.62	53.53	13.56	41313.56	21.57	4775.60	3159.23	0.75
1052-fc	1.000	11.71	0.00	457.42	26699.47	0.11	13.76	6302.22	11.22	19656.33	38.95	6.47	44521.57	21.00	1841.20	7289.20	2.33
1053-fc	1.000	18.84	0.00	343.08	26679.03	0.00	20.10	6753.93	13.50	20509.76	19.15	6.13	47959.58	14.17	1696.50	8336.98	0.87
1054-fc	4.989	103.99	34.79	22.40	501617.84	0.00	0.14	39282.98	22.54	310.02	2.44	21.03	708055.09	139.50	1869.58	13297.89	0.00
1055-fc	2.003	50.11	9.08	26.85	40950.47	0.00	26.36	7046.36	54.63	20379.57	29.47	5.28	166420.55	17.83	2513.40	3649.90	9.99
1056-fc	2.001	65.09	0.00	23.23	41249.26	1.26	46.27	6999.02	55.60	20195.29	27.09	3.89	166067.70	30.18	2481.73	3719.34	13.75
1057-fc	4.986	115.59	48.92	21.78	506373.80	0.18	0.78	39592.36	24.04	315.38	2.10	18.48	727657.98	99.95	1872.88	13295.26	1.03
1058-fc	4.985	116.91	14.54	24.69	130803.77	0.45	3.43	28143.97	9.19	122.69	0.00	19.21	407057.60	27.43	2239.61	11260.82	1.10
1059-fc	1.000	0.00	4.33	55.57	17415.10	0.00	14.79	8872.40	2.51	623.48	0.64	6.57	55125.50	13.13	7989.27	8935.49	1.65
1060-fc	4.986	12.11	0.00	55.14	17761.33	0.00	13.83	8971.38	0.00	665.26	0.35	2.89	54117.08	37.08	7782.23	8515.12	10.03
1061-fc	1.000	22.69	0.00	16.52	77637.34	4.68	0.00	2208.37	2.83	39197.75	0.75	3.09	16279.84	32.02	4456.67	339.66	2.96

Appendix 9. ICP-MS data for trace elements in groundwaters.

Sample	Dilution Factor	Li (ppb)	Be (ppb)	Al (ppb)	V (ppb)	Cr (ppb)	Mn (ppb)	Ni (ppb)	Co (ppb)	Cu (ppb)	Zn (ppb)	Ga (ppb)	As (ppb)	Se (ppb)	Rb (ppb)	Sr (ppb)	Cd (ppb)	Cs (ppb)	Ba (ppb)	Re (ppb)	Tl (ppb)	Pb (ppb)	U (ppb)
1001-fc	1.000	0.21	0.32	87.52	0.68	0.21	0.02	0.00	0.05	0.00	0.00	1.31	0.22	1.05	2.93	83.39	0.00	0.00	18.96		0.00	0.00	0.00
1002-fc	1.000	0.00	0.00	87.66	0.74	0.24	0.15	0.00	0.06	0.00	0.69	1.27	0.27	0.99	2.97	80.70	0.00	0.00	18.63		0.00	0.00	0.00
1004-fc	1.000	0.02	0.00	125.52	0.83	0.85	12.02	0.13	1.07	0.84	2.09	0.39	0.92	0.12	0.33	19.89	0.00	0.00	5.71		0.00	0.03	0.02
1005-fc	1.000	0.04	0.00	179.19	1.18	1.29	34.88	0.18	1.43	1.09	1.53	0.45	0.69	0.31	0.72	25.45	0.00	0.00	6.47		0.00	0.00	0.02
1006-fc	1.000	1.55	0.00	0.59	0.08	0.31	0.29	0.00	0.21	0.00	0.00	3.93	0.28	0.33	5.86	244.10	0.03	0.00	61.19		0.00	0.00	0.00
1007-fc	1.000	1.56	0.00	12.02	0.15	0.36	0.46	0.00	0.28	0.00	0.12	3.65	0.39	0.47	6.81	239.73	0.08	0.01	55.41		0.00	0.00	0.00
1008-fc	1.000	1.58	0.00	0.00	0.21	0.27	0.69	0.00	0.48	0.00	0.00	1.10	0.01	0.15	3.50	224.39	0.00	0.00	16.07		0.00	0.00	0.00
1009-fc	5.033	3.03	0.00	0.00	0.22	0.95	5.70	0.87	25.54	463.25		0.32	0.00	0.70	24.25	11693.90	0.06	0.01	6.27	0.00	0.00	0.00	
1010-fc	1.000	0.90	0.00	0.00	0.00	0.36	21.07	0.01	0.30	0.00	0.00	0.76	0.01	0.00	1.30	119.61	0.01	0.00	11.87		0.00	0.00	0.00
1011-fc	1.000	0.28	0.00	0.00	0.04	0.42	8.25	0.02	1.19	0.00	0.00	15.81	0.42	0.09	4.65	367.81	0.00	0.00	246.17		0.00	0.00	0.02
1012-fc	1.000	0.26	0.00	0.00	0.32	0.50	3.74	0.04	2.24	0.00	0.00	5.56	0.78	0.09	3.64	179.87	0.00	0.00	84.21		0.00	0.00	0.09
1013-fc	1.000	0.34	0.00	0.00	0.39	0.58	2.26	0.05	2.33	0.00	0.00	5.11	0.92	0.10	3.66	183.00	0.00	0.00	82.29		0.00	0.00	0.10
1014-fc	1.000	0.25	0.00	0.00	0.43	0.47	0.76	0.04	2.68	0.00	0.00	4.88	0.89	0.07	6.53	299.63	0.00	0.00	76.98		0.00	0.00	0.10
1015-fc	1.000	0.23	0.00	0.00	0.33	0.41	3.79	0.04	1.74	0.00	0.00	5.42	0.84	0.11	2.97	173.23	0.00	0.00	79.94		0.00	0.00	0.08
1016-fc	1.000	0.27	0.00	0.00	0.44	0.39	0.71	0.04	3.77	0.00	0.00	5.80	0.87	0.05	5.53	205.54	0.00	0.00	86.02		0.00	0.00	0.11
1017-fc	1.000	0.02	0.00	0.00	0.16	0.20	0.88	0.01	0.38	0.00	0.00	6.35	0.37	0.19	4.47	224.16	0.00	0.00	97.89		0.00	0.00	0.02
1018-fc	1.000	0.12	0.00	0.00	0.11	0.29	0.59	0.01	0.50	0.00	0.00	6.52	0.45	0.05	4.72	267.50	0.00	0.00	102.35		0.00	0.00	0.07
1019-fc	1.000	0.00	0.00	38.63	0.27	0.14	0.00	0.00	0.35	0.00	0.00	1.87	0.21	0.19	4.73	355.15	0.00	0.00	27.61		0.00	0.00	0.00
1020-fc	1.000	0.61	0.00	0.00	0.02	0.42	231.98	0.02	0.63	0.00	0.00	6.07	0.01	0.02	2.58	170.50	0.02	0.00	96.73		0.00	0.00	0.00
1021-fc	1.000	0.67	0.00	0.00	0.00	0.36	113.62	0.02	0.70	0.00	0.00	6.17	0.00	0.12	4.08	146.32	0.00	0.00	93.86		0.00	0.00	0.00
1022-fc	1.000	0.00	0.00	32.83	0.25	0.11	0.14	0.01	0.34	0.00	0.00	2.35	0.25	0.16	4.62	330.40	0.00	0.00	37.38		0.00	0.00	0.00
1023-fc	1.000	0.05	0.00	168.28	0.33	0.28	1.31	0.07	1.04	0.00	0.34	2.16	0.06	0.47	5.50	668.85	0.00	0.01	33.12		0.01	0.00	0.01
1024-fc	1.000	0.00	0.00	0.00	0.03	0.37	23.17	0.00	0.08	0.00	0.00	5.00	0.01	0.06	4.76	150.94	0.00	0.01	79.40		0.00	0.00	0.00
1025-fc	1.000	0.16	0.00	0.00	0.03	1.82	22.62	0.00	0.17	0.00		3.64	0.00	0.00	3.90	132.99	0.00	0.00	58.56		0.00	0.00	
1026-fc	1.000	0.22	0.00	0.00	0.01	0.36	61.64	0.00	0.12	0.00		9.62	0.00	0.02	5.35	204.07	0.00	0.00	159.06	0.00	0.00	0.00	
1027-fc	1.000	0.35	0.00	0.00	0.03	0.41	28.87	0.00	0.22	0.00	0.00	6.08	0.00	0.03	4.04	187.48	0.00	0.00	90.69		0.00	0.00	0.00
1028-fc	1.000	1.14	0.00	0.00	0.01	0.40	191.87	0.02	0.49	0.00	0.49	5.38	0.00	0.16	2.62	149.38	0.00	0.00	80.63		0.00	0.00	0.00
1029-fc	1.000	1.91	0.00	19.13	0.42	0.21	0.00	0.01	1.18	0.00	0.00	5.04	0.25	0.82	6.40	828.98	0.02	0.01	81.54		0.01	0.00	0.00
1030-fc	2.009	0.64	0.00	23.45	0.53	0.20	0.20	0.00	0.99	0.00		2.87	0.21	1.39	7.03	1031.95	0.00	0.00	49.81	0.00	0.00	0.00	
1031-fc	5.034	2.69	0.00	25.80	1.52	0.85	0.23	0.00	0.72	0.00		1.38	0.36	3.90	12.91	2608.46	0.00	0.00	24.55	0.00	0.00	0.00	
1032-fc	5.034	1.79	0.00	0.00	1.06	0.61	0.21	0.00	0.81	0.00		1.83	0.31	2.32	9.58	2304.91	0.00	0.00	29.20	0.00	0.00	0.00	
1033-fc	5.033	0.00	0.00	55.64	1.03	0.80	0.59	0.01	2.02	0.00		4.51	0.41	2.40	10.99	1407.74	0.00	0.00	72.51	0.00	0.00	0.00	
1034-fc	2.008	0.06	0.00	38.02	2.90	0.22	0.47	0.01	1.35	0.00		3.10	0.46	1.47	8.07	968.98	0.00	0.00	55.15	0.00	0.00	0.00	
1035-fc	5.034	0.50	0.00	7.91	1.24	0.80	0.16	0.00	1.34	0.00		2.02	0.31	3.09	11.47	1649.37	0.00	0.00	33.61	0.03	0.00	0.00	
1036-fc	5.034	0.00	0.00	11.11	1.22	0.69	0.49	0.00	2.23	0.00		1.08	0.45	1.19	8.68	376.13	0.00	0.01	18.24	0.02	0.00	0.00	
1037-fc	5.034	0.00	0.00	6.49	2.04	0.44	2.31	0.00	2.11	0.00		1.02	0.50	1.39	9.73	400.19	0.00	0.00	18.80	0.00	0.00	0.00	
1038-fc	5.034	0.16	0.00	124.73	1.38	0.46	0.30	0.01	2.07	0.00		1.85	0.79	1.03	8.11	888.41	0.00	0.01	29.14	0.00	0.00	0.00	
1039-fc	5.033	0.21	0.00	154.20	0.60	0.94	0.18	0.00	2.17	0.00		1.29	0.44	1.12	8.89	444.41	0.00	0.00	22.15	0.00	0.00	0.00	
1040a-fc	5.034	0.08	0.00	333.42	0.66	0.66	0.28	0.00	1.31	0.00		2.60	0.38	1.34	8.45	747.02	0.00	0.00	44.58	0.03	0.00	0.00	
1040-fc	5.034	0.00	0.00	438.61	0.64	0.61	0.15	0.00	1.70	0.00		2.49	0.33	0.90	7.68	702.80	0.00	0.00	40.19	0.00	0.00	0.00	
1041-fc	1.000	0.44	0.00	19.37	0.15	0.58	282.15	0.04	0.39	0.00	0.34	0.28	0.33	0.20	2.30	33.58	0.00	0.01	4.40		0.00	0.00	0.00
1042-fc	1.000	0.82	0.00	2.41	0.19	0.57	7.63	0.08	4.68	0.00		21.17	0.42	0.23	6.70	1475.85	0.01	0.02	351.08	0.00	0.00	0.15	
1043-fc	1.000	0.81	0.00	0.00	0.47	0.67	7.54	0.28	14.81	0.00	8.62	12.12	0.87	0.15	15.35	3894.65	0.06	0.06	190.77		0.00	0.00	0.30
1044-fc	1.000	0.65	0.00	0.00	0.42	0.71	5.17	0.16	9.06	0.00	6.77	9.34	0.79	0.09	10.78	2559.68	0.04	0.03	151.23		0.00	0.00	0.21
1045-fc	5.034	1.74	0.00	0.00	0.63	0.76	18.69	0.87	29.06	0.00		7.19	0.50	1.71	37.03	11290.51	0.17	0.13	126.01	0.00	0.00	0.07	
1046-fc	1.000	2.22	0.00	0.00	0.20	0.82	99.48	0.12	1.61	0.00	2.65	8.60	46.59	0.15	3.32	1257.11	0.02	0.07	130.55		0.00	0.00	0.03
1047-fc	1.000	4.13	0.00	0.77	0.17	0.93	47.98	0.11	1.50	0.00	1.80	7.11	32.47	0.03	2.37	1981.85	0.06	0.06	113.47		0.00	0.00	0.07
1048-fc	2.008	44.51	0.00	19.19	1.73	0.71	55.34	0.13	2.77	0.00		2.84	5.90	6.68	9.54	3271.07	0.04	0.13	50.83	0.00	0.00	0.05	
1049-fc	1.000	8.23	0.00	3.90	0.38	0.81	42.07	0.08	1.39	0.00	0.39	3.57	40.40	0.39	3.47	2835.69	0.06	0.12	55.91		0.00	0.00	0.04
1050-fc	2.009	46.61	0.00	11.30	2.18	0.52	37.50	0.15	3.83	0.00		1.47	4.65	6.54	9.38	3045.34	0.08	0.17	24.38	0.01	0.00	0.04	
1051-fc	1.000	8.75	0.00	2.95	0.31	0.75	49.36	0.12	1.63	0.00	0.35	3.96	32.28	0.29	4.01	2961.71	0.06	0.17	62.50		0.00	0.00	0.08
1052-fc	1.000	10.96	0.00	0.00	2.44	0.64	37.19	0.08	1.40	0.00	2.32	27.44	5.45	7.37	12.44	7008.57	0.14	0.55	428.50		0.00	0.00	0.00
1053-fc	1.000	11.78	0.00	0.00	2.71	0.57	17.85	0.05	1.20	0.00	0.35	20.48	3.32	7.98	13.71	7823.15	0.15	0.22	314.85		0.00	0.00	0.00
1054-fc	5.034	2.50	0.00	0.00	0.52	0.71	0.79	0.78	24.00	0.00		0.95	2.26	1.76	53.69	12802.14	0.10	0.42	19.09	0.03	0.00	0.00	
1055-fc	2.009	48.69	0.00	2.																			