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**NATURAL AND ANTHROPOGENIC EFFECTS ON THE GEOCHEMISTRY OF LAKE
SEDIMENTS AND WATERS OF LAC AYLMER, QUEBEC**

**by
Stéphanie Phaneuf**

**A thesis submitted to the Faculty of Science
in partial fulfillment of the requirements
for the degree of Master of Science**

**Department of Earth Sciences
Carleton University
Ottawa, Ontario
June, 1996**

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NATURAL AND ANTHROPOGENIC EFFECTS ON THE GEOCHEMISTRY OF
LAKE SEDIMENTS AND WATERS, LAC AYLMER, QUEBEC

Submitted by Stéphanie Phaneuf, B Sc
in partial fulfillment of the requirements for
the degree of Master of Science

Thesis Supervisor

Thesis Supervisor

Chair, Department of Earth Sciences

Carleton University
June, 1996

ABSTRACT

Lake sediment samples and water samples were collected from two major lakes, six adjacent smaller lakes and streams of the lac Aylmer drainage basin to establish geochemical variations related to mining activity on the eastern side of lac Aylmer. Natural, geological enrichments of metals are commonly obscured by anthropogenic activity especially in areas where mining activity has been present. This study uses a simple lake sediment sampling strategy combined with other sampling methods in order to establish natural background levels of base-metals for the lac Aylmer drainage basin. Natural and anthropogenic contributions of metals in lac Aylmer were evaluated.

Variations in bedrock geology and in the composition of glacial sediments dispersed from various types of bedrock clearly influenced the chemistry of individual smaller lakes and certain basin sectors of the larger lakes (Aylmer and Saint-François). Glacially-derived sediments deposited in the northern part of the study area are clearly enriched in the chemical elements associated with ophiolites, such as Fe, Ni, Mg, Cr, and Co. These metals are also enriched in lake sediments deposited in the northern part of lac Aylmer and Saint-François and are found to be enriched in streams draining these surficial sediments. Other individual smaller lakes overlying granitic rocks have waters and lake sediments enriched in U, while waters flowing over pyritiferous slates show an increase in As concentrations. However, the influence of bedrock and surficial geology on the distribution of Cu and Zn (base-metals related to mining activity) seems to be masked by concentrations much higher than background levels for the lake sediments from lac Aylmer.

Concentrations of Cu and Zn from lake sediments collected in lakes lying within rocks containing massive sulfide deposits (equivalent to estimated background concentrations) are eight times and three times lower than those found at the mouth of mine-draining effluent that flows into lac Aylmer. A core sampling study in the lac Aylmer basin suggested that mining activity and mine restoration of the Cupra site are well recorded in the sediment profiles. This would support the idea that mining activity and the disposal of wastes on the eastern side of lac Aylmer have contributed metals to the lake. It is however impossible to quantify the effects of these mining effluents to the overall metal budget based on the data available from this study.

ACKNOWLEDGEMENTS

I would like to thank my supervisors, Keith Bell and Bill Shults for their invaluable advice, support and critical review of this project. This research project was part of an environmental geochemistry program at the Geological Survey of Canada. The G.S.C. and Dr. Keith Bell provided financial support.

People at the Geological Survey of Canada gave freely their time in offering advice and help over the term of this study. They include: Dr. Rod Klassen, Dr. Alain Plouffe, Dr. Bill Coker, Gwendy Hall, Dr. Jeanne Percival, Andy Moore, André Prigent and Jules Paquette.

I would also thank Deborah Kliza for her invaluable support throughout this project and for helping in the core sampling program of the lac Aylmer. Thanks to Nicole Fu for sharing the core sampling data and for doing an excellent job in the completion of the core study at lac Aylmer. Finally, I would like to give a special thank to my friend Andrew for his love and who's been amazingly understanding and helpful, always supporting my decisions. He has freely given advise and kept me up to date on various graphic applications along with helping me with the drafting of the figures included in this manuscript. I would also like to thank him for letting me use his computer during the course of this study. Thank you.

A little note to Spotty, my canine companion, who accompanied me in the field and patiently waited for his walks every night while I was sitting in front of the computer.

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Chapter 1

General Introduction

1.0 Introduction

Lake basins are sinks for particles transported by air, water and ice. Sediment in lakes accumulates most hydrophobic organic contaminants, metal compounds and nutrients as they become associated with particulate matter (Mudrock and MacKnight, 1991). Many studies have aimed to characterize the nature and properties of lake sediments for a variety of purposes. In some instances, bottom sediments are identified as "in place toxics" which can pose a high risk and can be a serious and costly environmental issue (Mudrock and MacKnight, 1991). It is important to understand the effect that human activities have, either directly or indirectly, on the hydrological system. Anthropogenic influences on lake basins commonly result in increased sedimentation rates in the lake basin due to construction/excavation and other human activities. Such activities can accelerate the rates of weathering and erosion on surficial sediments and rocks of the lake's hydrological basin. Lake sediment sampling can be used to assess the extent of anthropogenic and natural influences on the drainage basin. The distribution of various geochemical elements in lake sediments can also be mapped for and used to evaluate the chemical effects on the biota as well as for remediation/monitoring studies.

Water is an excellent conductor of seismic energy and is an ideal medium for transmitting energy waves to the sedimentary/geological formations below. Waves are either reflected from hard surfaces or are transmitted further down through sequences of softer sediment. Returned signals can be captured at the water surface using geophysical instruments and can be recorded digitally or on a chart. These data provide information on lake sediment type and stratigraphy which is important for designing environmental surveys. Surface lake sediment samples can be obtained using a grid sampling technique with a grab sampler. When chemically analyzed, sediment samples can provide a picture of the bulk chemistry of surface lake sediment because both sediment type and sediment geochemistry can be mapped and compared; the effects of varying exchange capacities and provenance of the several sedimentary facies that occur in most lakes can be evaluated.

Lac Aylmer is located in a region well documented in terms of bedrock geology, surficial geology, including geochemistry, and thus, the area provides a strong platform from which this study could be developed. Lac Aylmer, in the Eastern Townships, Quebec, is an extensive lake into which streams are flowing from areas impacted by mining activities. Therefore, the study area was viewed as a potentially ideal site for an environmental geochemical survey. Also, some concerns were raised by the residents of lac Aylmer about the "safety" of this lake, which is intensively used for recreational purposes.

1.1 Objectives

The objectives of this study are to:

- 1 provide a geochemical data base for the lac Aylmer basin
- 2 evaluate methods, such as sonar surveys and grid sampling using a grab sampler, for environmental surveys
- 3 identify abundance of elements in lake sediments
- 4 evaluate anthropogenic and natural levels of metals within lac Aylmer

The strategic sampling used in the lac Aylmer basin was aimed at determining background levels of metals in the area. The problem associated with determining background levels in naturally enriched areas is commonly overlooked in many environmental studies. Levels of metals have been found to be naturally higher in sediments and waters from areas of known mineralization, and many metals are concentrated at the surface of lake sediments. One of the major components of this study was to determine local background concentrations.

1.2 Metals in the environment

Certain metal ions in solution are quite unstable and will reach a state of maximum stability by reacting with other chemical constituents by acid-base, precipitation, and oxidation-reduction reactions (Manahan, 1993). Metals present in water are either in ionic form or bound to inorganic or organic constituents as soluble or insoluble phases. Soluble phases include ions, complex ions, chelated ions and molecules, whereas particulate forms occur as colloidal, precipitated or adsorbed phases (Bryan, 1976). Metals eventually accumulate in the lake bottom,

interacting with overlying water and other processes in the sediment column. Diagenetic processes occurring in lake sediments commonly concentrate metals at the surface. Such enrichment is observed in the deposition of nodules near the water/sediment interface.

1.3 Metal toxicity

Metal toxicity depends largely on the availability of metals in the aquatic system. The term "metal availability" is usually based on the solubility of the metal in the environment. Certain metals may be very toxic to humans but are insoluble or very rare (e.g., Ba, Zr, Ti, Nb). Relatively mobile and potentially toxic metals include Co, Ni, Cu, Zn, Pb (Forstner and Wittman, 1983). The health hazard of these metals is controlled by their chemical state in the aqueous environment and by their concentration. As a result the toxic elements may be incorporated into the food chain or ingested directly by humans. However, the chemical form in which these metals are inserted in the food chain will determine whether the substances are metabolized by the plant or organisms and will define their chemical toxicity. Therefore, intensive studies must be undertaken on the availability of chemical elements in order to establish the hazard that these metals represent to humans.

Chapter 2

Description of the study area

2.1 Location

The study area lies in the Eastern Townships of Quebec near Thetford Mines, approximately 50km NNE of Sherbrooke (Figure 1). The area is bounded by latitudes 45°45'N and 46°00'N and longitudes 71°00'E and 71°30'E. The lakes that were studied include lac Aylmer and lac Saint-François, along with several smaller lakes within the lac Aylmer drainage basin (Figure 2).

The major inflow of water into lac Aylmer is through a short reach (3 km) of the Saint-François river. Lac Saint-François is the head water of the Saint-François river which eventually drains into the St-Lawrence River approximately 90 km east of Montréal. Therefore, lac Aylmer is a basin on the Saint-François river. Lac Aylmer is a large water reservoir that can be subdivided into three distinct basins, representing the original sites of three isolated natural lakes formerly separated by land, and flooded by damming since the late 1800's.

2.2 Bedrock Geology and Structural Geology

The bedrock lithologies of the study area consist of a series of NE-trending, steeply dipping, low-grade metasediments and volcanic strata intruded by igneous rocks of granitic and ultra-mafic compositions (Slyvitsky and St-Julien, 1985; Figure 3).

The area is located mainly within the tectonostratigraphic region of the Dunnage Zone and is made up of the following three lithotectonic units; the Saint-Daniel Mélange, the Ascot Complex and the Magog Group (Figure 1). This bedrock assemblage is bounded to the northwest by the Baie Verte-Brompton line (BVB) (William and St-Julien, 1982) and to the southeast by the La Guadeloupe fault (St-Julien and Feininger, 1983). Continental margin rocks of Cambrian age belong to the Humber Zone and are in contact with the Dunnage Zone in the northern part of the study area.

Cambrian rocks of the Daniel Mélange, mainly composed of shales and olistrostromes with ophiolite blocks, are observed in the northwestern part of the study area adjacent to rocks of the Humber Zone. In the southeastern part of the study area, the Lower Ordovician Ascot

Figure 1. Location map and principal lithotectonic units of the Appalachian region, southeast of the St-Lawrence River, modified from (Parent, 1984)

Figure 3. Bedrock geology map

LEGEND

(bedrock geology modified from St-Jean and Sévigny, 1986)

Nagog Group

- formation de St-Jean (white, sandstone, and siltstone)
- Steepbank Formation (pyritic sand)

Ascut Formation

- Sand and heavy silty shale (interbedded)
- Fine silt
- Sand (volcanic)

St. Daniel Formation

- Sand and breccia

Thetford Mines Ophiolite Complex

- Basalt
- Pyroxene and gabbro
- Serpentinized ophiolite

Caldwell Group

- Feldspathic graywacke sandstone

New Hampshire Plutonic Series

- Granite
- Coarse felsophic gneiss

Campton Group

- Pyroxene (dark) and graywacke sandstone
- Calcic gabbro
- Conglomerate and calcareous siltstone

- Sand and gravel pit
- Discovered mine

Les Ayliwer Formation

- Limestone
- Graywacke sandstone
- Conglomerate

Complex consists of basic to silicic volcanic rocks. Rhyolites are associated with economic Cu-Zn mineralization (Trottier and Gauthier, 1991). Sandstones, slates, tuffs and schists of the Upper Ordovician Magog Group are also included within the Dunnage Zone and underlie the northern parts of both lac Aylmer and lac Saint-François. The Dunnage Zone is conformably overlain by Lower Silurian strata (Boucot and Drapeau, 1968) and is overlain by thrust slices that form part of the Connecticut Vallée-Gaspé Synclinorium (Tremblay, 1992). Calcareous Siluro-Devonian rocks lie under and adjacent to the south-central basin of lac Aylmer. Granitoid intrusions of Ordovician age are also present in the southeastern part of the study area.

2.3 Glacial History

The Lac Aylmer basin was glaciated at least three times by separate continental glaciers that advanced, in succession toward the southeast (Johnville), southwest (Chaudière), and southeast (Lennoxville) (McDonald and Shilts, 1971). The glacial stratigraphic column in southeastern Quebec is shown on Figure 4. This is based on work done by McDonald (1967, 1968; 1969), Shilts (1970) and Lamothe et al. (1992).

The Johnville Till was deposited from ice that expanded from the Canadian Shield, which expanded southeast of the St-Lawrence river into the Appalachian region. This phase is represented by rare outcrops of the Johnville Till outside the study area.

Sediments of the Massawippi Formation overlie the Johnville Till and consist of fluvial and glaciolacustrine sediments that represent an interglacial stage (Lamothe et al., 1992). The Massawippi Formation has been described in the Ascot River Valley, in the southwestern part of the study area by McDonald (1967) and by Lamothe et al. (1992) in the Rivière des Plantes sections, east of the study area. Overlying the Massawippi Formation, deposits of Chaudière Till represent the onset of Wisconsinan glaciation (McDonald and Shilts, 1971). The Norbestos Till (Chauvin, 1979) is thought to be equivalent to the Chaudière Till in the Thetford Mines area. These glacial sediments are derived from southwestward-flowing ice from an ice cap located in Maine and New Brunswick. At the end of the Chaudière glaciation the ice flow shifted southeastward (McDonald, 1967b). The Gayhurst Formation (Ruisseau Perry River Formation in the Thetford Mines area) represents an interstadial event that occurred during the Wisconsin

Figure 4. Glacial stratigraphy in southeastern Quebec (modified from Shilts, 1970)

stage. During this stage, the Chaudière glacier retreated north-northwest via the Appalachians, eventually resting against the Appalachian Highlands. Glaciofluvial and glaciolacustrine sediments of the Gayhurst (Perry River) Formation were deposited during this stage, and extensive deposits have been documented in the Chaudière River Valley (Shilts, 1981). The timing of the onset of Lennoxville glaciation, the last major phase of glaciation of southeastern Quebec, has been estimated at 22 000-24 000 BP assuming that it corresponds to the onset of the last major glaciation in the Great Lakes Region (Shilts, 1981). Considerable amounts of debris were transported during this last stage as southeasterly-flowing Laurentide ice deposited the Lennoxville Till in southeastern Quebec. These sediments are overlain by glaciolacustrine, glaciofluvial or glaciomarine deposits marking late glacial and Holocene deposition.

A model for deglaciation of southeastern Quebec has been constructed based on the configuration of ice fronts inferred from the distribution of moraine complexes and on the age relationships of striations preserved on the bedrock (MacDonald and Shilts, 1971). Northward striations observed north and northeast of the Stoke Mountains suggest a late glacial movement of ice towards the St. Lawrence, post-dating the southeastward flow phase of Lennoxville glaciation. One of the main events that influenced the behavior of the Laurentide ice sheet during the last stage of deglaciation was the eustatic rise in sea level. As sea water rose against the glacier front in the lower St. Lawrence Valley, calving occurred and ice south of the estuary had to flow northward to compensate for the loss of ice. This reversal of flow has been related to the Quebec Ice Divide (Shilts, 1981) and may have involved the presence of remnant ice caps south of the St. Lawrence river during the retreat of Laurentide ice as was first proposed by Ellis (1887) and Chalmers (1898). However, there is no evidence for sea water intrusion during the reversal of flow, suggesting that Laurentide ice never left the Appalachian Front until later deglaciation. During this period, ice from the Canadian Shield retreated gradually towards the northwest as an active ice front leaving behind discontinuous moraine deposits and blocking drainage in the valleys (McDonald 1967, 1968, 1969, Shilts, 1970, 1981, Gadd et al., 1972 and Clément and Parent, 1977). McDonald (1967, 1968) was the first to recognize the existence of an extensive proglacial lake in the Saint-François river valley, which he named Glacial Lake Orford (McDonald, 1967), the Sherbrooke phase of Glacial Lake Memphrémagog (McDonald, 1968). The timing relationship between the deposition of various morainic complexes located southwest and northwest of the study area (Cherry River and Highland Front moraines respectively), the

formation of northward striae, and the possible readvance of Laurentide ice into lake water in southeastern Quebec is not well known. However, based on studies by Larocque et al. (1983), an ice lobe occupied the Saint-Francis river valley, retreating northeast, up the valley towards lac Aylmer. Water from proglacial lake Memphrémagog did not reach the valley until the ice retreated. The last water levels before lac Memphrémagog drained to its lowest phase through the Lac Nick outlet (located west of present day lac Memphrémagog) is estimated to be about 250m a.s.l (McDonald, 1968; Boissonnault et Gwyn, 1983).

2.3.1 Local Surficial Geology

The study area is covered mainly by a till veneer deposited during the Lennoxville stade and mainly occupies bedrock depressions (Min. Energ. Res., 1983 and Chauvin, 1971). Till deposits are most abundant east of lac Saint-François where bedrock exposure is less common than in the southeastern, central and western regions of the study area. Glaciolacustrine and glaciofluvial sediments are observed along the northern shores of lac Aylmer (Min. Energ. Res., 1983). Glacio-fluvial ice contact deposits, composed of sand and gravel, have been documented mainly along the eastern shores of lac Aylmer, more precisely near rivière Maskinongé and the lac Elgin effluent, near ruisseau du Troisième, south of rivière Saint-François and around Black lake, northwest of Disraeli (Figure 2). Similar deposits are found near the mouth of rivers along the northern shores of lac Saint-François. Organic flood-plain sediments occupy shallow depressions along rivers and streams in the southern region of the study area, between lac Aylmer and Saint-François and at the mouth of rivers entering shallow lake water within the southern part of lac Aylmer. Alluvial deposits are present along rivière aux Bleuets and at its mouth in lac Saint-François, and within lac Aylmer at the mouth of the upper rivière Saint-François, as well as along rivière Coulombe and Maskinongé. Other rivers and streams in the study area usually cut through till deposits with minimal flood plain development.

2.4 Human Alteration of the Natural Environment of lac Aylmer

Early settlements around lac Aylmer were established in the late 1800s and include the communities of Disraeli, Beaulac and Stratford (Figure 2). One of the first important anthropogenic effects on lac Aylmer and the surrounding lakes was the damming of the discharge channels of lac Aylmer and of lac Saint-François to facilitate floating of logs to the mills on the lower Saint-François. The dam at the mouth of lac Aylmer was built in the late 1880s and rebuilt

during the middle of the 20th century. Water levels are presently controlled by these dams at approximately 5-7 m above the natural level.

Until the mid 1980s septic tanks were rare, and municipal sewage treatment plants did not exist in the lac Aylmer region. Until 1984, waste water from Disraeli drained directly into lac Aylmer, and it was not until 1985 that the municipality of Beaulac acquired a water treatment plant (Drolet et Morais, 1985). Stratford indirectly drained waste water into lac Aylmer via rivière Bernier/Maskinongé (Drolet et Morais, 1985). In addition, cottages around lac Aylmer and Saint-François drained waste water directly into the lake. Waste water in lac Aylmer's drainage basins also results from present and past agricultural activities, such as pig, cattle, turkey and chicken farming, the exploitation of sugar bushes, and grain farming. High inputs of organic matter into ruisseau Troisième, identified by the Ministry of Natural Resources (1976), were attributed to a turkey farm, still in operation in 1985 (Drolet et Morais, 1985).

Polymetallic, volcanogenic, massive sulfide deposits hosted in chlorite schist, sericite schist and black slate were exploited from 1962 to 1977. In 1959, geologists from Solbec-Copper Mines Ltd., part of the Sullivan Mining Group, discovered mineral deposits approximately 2.5 km west of Stratford and 3 km east of lac Aylmer (Figure 2). These deposits are those mined at the Solbec mine. The mine operated as a cut-and-fill and open pit excavation, producing about 1,500,000 t of ore from 1962 to 1972 (Robert et Desmarais, 1987). The processing plant at the Solbec site treated ores from other nearby mining sites until the end of 1977 and processed a total of 4,885,000 t of ore (ib.). The waste material that accumulated within this 15 year period was pumped into a waste site on the peat-covered alluvial plain of a tributary of ruisseau Troisième, approximately 2 km northeast of the treatment plant. The tailings are mainly composed of Si, Fe, Al and Ca, along with 20% S and 2 to 5% other metals, including As, Cd, Cr, Cu, Hg, Pb and Zn (Drolet et Morais, 1985). The sulphide phases are dominantly pyrite but minor amounts of sphalerite, galena and chalcopyrite (in order of abundance) are also present in the tailings. The differential gravity settling method for separation of the ore (Cu, Pb, Zn) also used reagents such as Carbonate z-200, Xanthate z-6, Zn-sulphate, Cu-sulphate, Na-cyanide, and slaked lime (ib.). At the Cupra mine, located 2.5 km west of Stratford, the ore is similar in composition to that at Solbec, and was processed at the Solbec site. Waste water from the Cupra operation flowed into rivière Maskinongé, which eventually flowed westward into lac Aylmer.

In 1983, the Solbec and Cupra mine sites were classified by GERLED (Groupe d'étude et de restauration des lieux d'élimination des déchets dangereux) of the Ministry of the Environment of Quebec (MENVIQ) as category I sites, i.e., sites with high risk for human health and the environment (Desrochers et al., 1990). Since 1974, the government of Quebec has been monitoring pH, salinity and metal concentrations in mining effluents and has carried out some water sampling in lac Aylmer and lac Saint-François (Association des mines et des métaux du Québec, 1974; INRS-Eau, Ministère de l'Environnement du Québec, 1984, 1985; Ministère des Loisirs, de la Chasse et Pêche, 1985). Lake-sediment sampling surveys were also carried out at the mouths of rivers draining mine effluents (Réseau de surveillance de substances toxiques dans le milieu aquatique, 1979, 1980, 1981, INRS-Eau).

In 1987, Cambior Ltd. became the owner of Sullivan Mines Ltd. and inherited the Solbec-Cupra mining sites (Figure 2). An agreement was reached with the Ministry of the Environment in which Cambior stated their intention to restore the mine as well as mine tailings sites (Desrochers et al., 1990). The Solbec and Cupra mine sites have been remediated, and the Solbec tailings underwent restoration by flooding of the tailings area in the fall of 1994. The remediation strategies were developed through several studies financed under the MEND (Mine Environment Neutral Drainage) program of CANMET, Department of Natural Resources, Ottawa.

In the northern part of the lac Aylmer drainage basin, a small asbestos mine and tailings are also possible sources of Ni, Cr, Co, Mg, and other metals associated with the ultramafic rocks that host the asbestos. However, the terrain in the northern part of the study area is covered by glacial sediments rich in those components, and the geochemical influence of the erosion and weathering of this glacially transported sediment probably far exceeds that of the asbestos mining residues.

Sand and gravel deposits of glacial and fluvial origin have been exploited in the lac Aylmer area, although these are few in number. The extensive exploitation of fluvial gravel terraces and possible ice-contact deposits at the inflow of rivière Saint-François into lac Aylmer may have contributed fine-grained clastic sediment with geochemical characteristics similar to those of ultramafic rocks (Ni, Cr, Co, Mg). The geological source of much of the material that makes up the sand and gravel is the ultramafic-rich debris glacially transported southeastward from the source outcrops in the north and northwest part of the study area. Other major exploited

gravel deposits of ice-contact stratified drift lie along the southeast side of ruisseau Troisième, just north of lac Elgin on the east side of rivière Maskinongé, just south of Stratford.

Chapter 3

Logistics, Field Work, Method Description, Analyses

3.1 Logistics

The field work was carried out by the author and an assistant during June and July, 1994. Financial and logistic support was provided by the Geological Survey of Canada (GSC) through an environmental geochemistry project, and an NSERC grant to Dr.K.Bell at Carleton University. A 16 ft inflatable Zodiac boat was used for lake studies and sample collection and a vehicle was also provided by the GSC for stream sediment, water and surficial geology studies. A Geographical Positioning System, model Ensign of the Trimble Navigator company, was used to locate each sample site on a standard 1:50,000 map sheet.

3.2 Field work, method description, and analyses

3.2.1 Sonar Profiling

A sub-bottom acoustic profiler was used to produce a continuous record of vertical sedimentary sequences of the lake basin. The chart recorder transcribes the information received by the transceiver from the different sedimentary units which gives important information on: (1) glaciolacustrine and postglacial lacustrine sedimentation (Bornhold and Prior, 1990; Buckley and Grant, 1985; Carlson and Karl, 1988; Clague et al., 1989; Eyles et al., 1990, 1991; Finskh et al., 1984; Jackson et al., 1992; Larocque, 1985; Larocque and Shilts, 1986; Pickrill, 1993; Redbourn et al., 1993; Solheim, 1991; and Vail et al., 1977), (2) present day control on sedimentation and erosional processes (Carlson and Karl, 1988; Clague et al., 1991; Foster et al., 1984; and Van Andel et al., 1984) and (3) paleoseismic activity (Adams, 1982; Doig, 1991; Jackson et al., 1992; Shilts, 1984; Shilts and Clague, 1992; and Shilts et al., 1992).

Data from the lake sediment profiles can provide direction for the design of sampling surveys aimed at interpreting the effects of natural and anthropogenic sources of metals. Sedimentary units such as organic sediments (possibly gyttja), gas, proglacial laminated clays, bedrock or till can also be mapped. Knowing the precise distribution of the various sediment facies simplifies sediment sampling surveys and provides information that can help in interpreting geochemical results.

A low-frequency transducer (3.5/7 kHz) was used to achieve vertical penetration of sound into the sedimentary column for sub-bottom acoustic profiling. In the Ratheon RTT-1000 system, a high frequency (200 kHz) transducer is used to trigger the 7/3.5kHz signal and provides high resolution that precisely records the sediment surface, and therefore, lake bathymetry. The instrument is mounted on an inflatable (Zodiac, 14-16 feet) or aluminum boat. The equipment consists of a transceiver (transducer-receiver, RTT-1000), a chart recorder (DE 719 A or C), a 12 volt, fully-charged automobile battery, a DC current inverter and a 3.5/7 kHz transducer.

The boat is run at slow speed (2-6 km/hr) to permit good transmission and reception of the sound signals. The geographical position of a traverse was achieved by land markings and using a Geographical Positioning System (GPS).

3.2.2 Lake Sediment Grid Survey with a Grab Sampler

A regularly-spaced square grid was established for lake sediment sampling. This approach was used because the lateral distribution of geochemical elements in lac Aylmer is important for investigating the effects of natural and anthropogenic inputs of chemical elements into this hydrological basin. The purpose of using a regularly-spaced grid for the lac Aylmer project was to simplify and keep track of the sampling site locations and to provide uniform coverage of the surveyed area. This method was chosen to avoid extensive extrapolation between points and to avoid missing geochemical patterns of environmental significance (Howarth and Thornton, 1983).

Grab samplers basically consist of a set of jaws or bucket to scoop the sediment. A Petite Ponar Grab Sampler was used in this study. This sampler is best suited for collecting coarse and firm bottom sediments as well as soft sediments. During its descent, water passes through a screen to minimize disturbance at the sediment-water interface. A special mechanism on the Petite Ponar grab sampler prevents accidental closing during handling or transport and is released with a change in cable tension on the impact with the sediment surface. In this study, a messenger was used to ensure the release of the protection mechanism and closure of the grab sampler. The sediment sample can be easily retrieved upon opening the jaws into a sufficiently large container.

A grid sampling method consists of taking samples at equidistant intervals along a line or a grid. The grid can be square, rectangular or triangular and each sample is located at the junction of the segments. Triangular intervals on a grid seem to be most effective for covering an

area but almost match with the square-pattern strategy chosen for this sampling project (McBratney et al., 1981; cited in Gilbert, 1987). Using a "Petite Ponar" sampler, grab samples of the upper 10-15 cm of bottom sediment were collected at 128 sites distributed on an arbitrarily drawn square grid in lac Aylmer (Figure 5). Similar sampling was carried out at 13 sites in lac Saint-François and at 3 to 4 sites each in lac Elgin, lac des Isles, lac Maskinongé, lac Equerre, lac à la Barbue, and Baie Sauvage of lac Saint-François. These lakes were chosen because they occur in geological environments different to lac Aylmer and hence provide comparative background values.

All samples were homogenized in the field, which in some cases involved disrupting and "folding in" obvious horizontal, chemically-contrasting layers. A five-gram split was obtained from each sample after being stored at 5°C. Each split was digested in 30 ml of, 3-1-2 HCl-HNO₃-H₂O at 95°C for one hour and diluted to 100 ml with water. The solution was analyzed directly at Acme Laboratories of Vancouver, B.C. using an Inductively Coupled Plasma (ICP) technique for Mn, Fe, Sr, Ca, P, La, Cr, Mg, Ba, Ti, B, W, Na, and K. Aluminum, Mo, Cu, Pb, Zn, Ag, As, Au, Cd, Sb, Bi, Tl, Se, Te, and Ga, were extracted with MIBK-Aliquot and analyzed by cold-vapor atomic absorption spectroscopy (AAS). Total carbon, also done at Acme Laboratories, was determined using a Leco carbon analyzer. Ten duplicate samples of lake sediment of known composition collected from a lake in the Huntsville area, Ontario were inserted randomly among the Aylmer samples and repeat analyses of the Quebec samples were carried out once in every 30 samples for quality control. Interlaboratory standards were also analyzed after every 35th sample.

3.2.3 Water Sampling

Surface and bottom water samples were collected in lac Aylmer and in adjacent lakes and inflowing streams (Figure 6). A one-kilometre grid was used for surface water samples in Lac Aylmer, itself. Surface lake water samples were collected approximately 20 cm below the air/water interface, whereas bottom water samples were collected at 1-2 m above the sediment/water interface. The pattern of stream water sampling was chosen to evaluate compositional variations before and after confluence of tributaries carrying contaminated effluents.

At each site, three nalgene water bottles, 175 ml capacity, were rinsed and then filled. Water was then tested immediately on site for pH, conductivity, and temperature. The apparatus was rinsed

Figure 5. Location map of surficial lake sediment samples in the study area

using de-ionized water. Water samples were also kept cool (4°C) until sent to the laboratories. The three water samples at each site were filtered in the field through a 0.45 µm Millipore filter, using a hand pump. Filtered and filtered-acidified samples were kept refrigerated in 175 ml nalgene bottles. The extra 175 ml water sample was used in the filtering procedure to rinse the apparatus and the sampling bottles. Double distilled HNO₃ was used to acidify the samples in the field to a 0.4% solution of pH=2. Acidifying the samples slows down bacterial activity, reducing any post-sampling alteration of water chemistry. Filtered, unacidified samples were shipped to Barringer Laboratories for analysis of the anions F⁻, Cl⁻, NO₂⁻, Br⁻, NO₃⁻, PO₄⁻³ and SO₄⁻². Filtered acidified samples were analysed for a suite of cations in the research laboratories of the Geological Survey of Canada.

3.2.4 Scanning Electron Microscopy

Scanning electron microscopes (SEM) provide information on surface morphology, composition, crystallography and magnetic properties of solid objects. SEM analysis is a non-destructive method that can operate at low and high magnification without degrading resolution and depth of focus (Lloyd, 1985). The analyses were completed at the Geological Survey of Canada under the supervision of D. Walker. The instrument used is a LEICA-Cambridge S-360 with a Link-Tetra detector necessary to generate the back-scattered image and a Link Oxford model eXL-2 for the X-ray analyses. The analyses were performed with an acceleration beam of 20 kV with working distances to the specimen of 25 mm.

SEM analyses, using the back-scattered emission and the energy dispersive X-ray spectrometry, of concretions collected at three locations in lac Aylmer during lake sediment sampling using the "Petite Ponar" grab sampler were undertaken to evaluate the possibility that the concentric ring pattern, visible with the naked eye, records the mining history along with evaluating the scavenging capacity of metals in these nodules. Nodule samples were collected from sediments of the artificially flooded bottom (i.e. water depths of <6 m) along the shores of Baie Ward and Baie Moose of lac Aylmer. Four nodular shaped concretions were mounted in epoxy under vacuum to make them hard enough to section because of their friable and porous nature. The four mounts were polished using an oil-based polish to limit any oxidation reaction.

Filter papers, with pore diameter equal to 0.45 µm, were analyzed under a scanning electron microscope to investigate the possible mode of transport of trace-metals in suspended residues. After filtering the water samples, filter papers containing originally-suspended residue

Figure 6. Water sample localities in the study area

that would not pass through the pores, were disposed into a petry dish and stored in a refrigerator prior to analysis on the SEM. Compositional analyses of highly reflectant particles were undertaken on 9 samples collected from bottom and surface waters from the lakes, and stream samples within the lac Aylmer drainage basin.

3.2.5 Microprobe and Laser Analyses

Microprobe analyses were performed at the Geological Survey of Canada using a Cameca SX50, which has four wavelength dispersive spectrometers. The microprobe was operated at 15kV with beam current of 10 or 30 nA depending on the element. The laser instrument is a system composed of a Model 320 Laser Sampler and a Perkin Elmer mass spectrometer, Model Elan 5000. The sample is vaporized in the ablation unit (laser sampler) and the material is transported to the torch of the ICP-mass spectrometer by a flow of argon.

Microprobe and laser analyses were undertaken on one concretion sample previously analyzed under the SEM to evaluate quantitatively any geochemical variations. A silicate routine on the microprobe provided geochemical concentrations of elements listed in Appendix IV. Four transects were performed on the concretion, previously analyzed using the SEM, and compiled in Appendix IV for an evaluation of results.

3.2.6 Sequential Extractions

Selective extraction involves a series of chemical attacks with increasing reagent strength on sediments in order to release metals that occur in different forms. The procedure was developed in the geochemical laboratories of the Geological Survey of Canada, Ontario by G.E.M. Hall. Appendix I gives a complete description of the selective extraction procedure.

Lake sediments of lac Aylmer and lac Saint-François, as well as sediments collected at the mining waste site from the oxidized zone of tailings, and a stream sediment sample from a stream draining the tailing site were submitted for sequential extractions. The sites were carefully selected, based on the geochemical distribution of metals within the lake basins. Sequential extractions were performed for trace-metal elements (Ni, Cr, Cu, Pb, and Zn) and organic matter concentrations.

Chapter 4

Physical and Chemical Characteristics of the Lac Aylmer Drainage Basin

4.1 Bathymetry of lac Aylmer and lac Saint-François

Sonar profiling using a high frequency sound signal (200 kHz) of both lac Aylmer and Saint-François documented the sediment/water interface of these basins. Bathymetric maps of both lac Aylmer and lac Saint-François were compiled from previous work undertaken by the Geological Survey of Canada in 1982, 1983, 1984 and from field work related with this study in 1994. These sonar surveys provided information on the water depth which was plotted at 6m contour intervals (Figures 7, 8 and 9).

Lac Aylmer is characterized by three distinct basins, represented by Baie Moose, Baie Ward and a southern basin with water depths reaching 21m, 31m and 15m, respectively. The three basins within lac Aylmer are joined together by presently flooded channels with approximately 5m of water. The water level has been raised from its earlier level due to damming activities.

The surface of lac Aylmer lies around 245 m a.s.l. The basin's surrounding relief is low to moderate in the area south of ruisseau du Troisième, and varies from 245 m to 260-290 m within 1 km of the lake's shore. North of ruisseau du Troisième, the topographic relief along the shores of lac Aylmer is generally steeper and varies from 245 m to 270-350 m within 1 km distance from the shore. Silty limestone and calcareous siltstone striking NE-SW constitute the lower lying areas of southern lac Aylmer. The silty limestone and calcareous siltstone has a northern geological contact cutting across the southeastern part of Baie Ward through Long Pointe and a southern geological contact comprising the eastern shore of lac Aylmer. This bedrock unit is part of a southwestward plunging syncline which does not cut across lac Saint-François.

Lac Saint-François is formed by two distinct narrow basins that form an elongated outline, oriented NNW-SSE (Figure 9). Maximum water depths of 38m are found in an area south of Baie aux rats musqués. The surface of the lake lies around 285m a.s.l. Unfortunately,

Figure 7. Location of sonar traverses in the study area

Figure 8. Bathymetric map of lac Aylmer, Quebec

sonar profiles in the southern part of the basin were not available from the 1983 survey (Figure 8). The basin's surrounding topography is steepest in the southern part, varying from 280 m to 370-400 m within 1 km of the lake's shores. North of Baie Sauvage, the terrain is moderately rolling, varying from 280m to 310-350m within 1 km from lac Saint-François' shores. Ordovician slates and sandstones outcrop in the lower lying areas adjacent to lac Saint-François.

4.2 Lake sediment facies of lac Aylmer and lac Saint-François

Detailed information on the vertical and horizontal distribution of lake sediment facies can be observed from the sonar profiles. The results of the sonar profiles are shown in Figures 10, 11a and b, 12, and 13.

Organic-rich sediments (gyttja) with locally developed gas, unconsolidated sand, acoustically laminated sediments and bedrock all crop out at various places on the bottom of lac Aylmer (Figure 10). Gyttja is a modern sediment that has accumulated within depressions in lac Aylmer. Gyttja appears as an acoustically "clear" unit on the sonar profiles. Gyttja consists mainly of finely-divided plant and animal remains with an admixture of fine-grained inorganic material that can reach a thickness of up to 6m or more within the lac Aylmer basin. Commonly referred to as an "acoustic mask", gas can also be observed on the sonar profiles recorded for lac Aylmer (Figure 11). This reflection can be recognized by its masking characteristics and can appear near the sediment/water interface, but predominantly it is found at what seems to be the contact between gyttja and underlying inorganic laminated sediments of lac Aylmer's glaciolacustrine sediment facies (Figure 11). Other studies have shown that this gas is usually composed of nitrogen and methane (0.6:1 to greater than 19:1) and minor amounts of CO₂ and C₂+ hydrocarbons (Edwards and Klassen, 1984).

Unconsolidated sand is present along the shores of lac Aylmer at water depths of less than 5 m. Multiple acoustic signals on the sonar profiles are characteristic echos of signals reverberating between sandy sediments, commonly referred to as a "hard surface", and the air/water interface. The thickness of these sediments usually cannot be inferred from the profiles of hard bottoms because of the lack of penetration and the multiple signals overprinting the contact with the underlying sediments where penetration is achieved. Acoustically-laminated sediments, probably inorganic silt and clay with minor amounts of sand, drape the bedrock

Figure 9. Bathymetric map of lac Saint-Francois, Quebec

Figure 10. Lake sediment facies of lac Aylmer, Quebec

topography. These sediments reach a thickness of 9 m within lac Aylmer. The acoustic layering is generally continuous and uniform in thickness throughout the basin. However, the banding becomes thinner over rising bedrock topography and the inclined acoustic layers can be abruptly interrupted at the sediment/water interface (Figure 11a and b). Underlying this laminated sequence, in places but not outcropping at the sediment/water interface, is a convex upward massive unit probably composed of clay or diamicton. This massive unit is acoustically clear on the profiles, underlying the laminated sediments (Figure 11a and b). This unit, observed southeast of Longue Pointe, is non-uniform in thickness, reaching a maximum of 9 m. Bedrock topography can also be observed from the sonar profiles although the reader must bear in mind the large, vertical exaggeration of 15 to 20:1. This unit is recognized by its continuity throughout the basin and the acoustic multiples generated by the "hard" bedrock surface (Figure 11a and b).

Gyttja, unconsolidated sand, acoustically laminated sediments, and bedrock constitute the lake bottom of lac Saint-François (Figure 12). Gyttja within lac Saint-François has accumulated in water depths greater than 6 m and is variable in thickness, reaching up to 7 m within the deepest part of the basin. Unconsolidated sand, present at the mouth of rivers entering the northern part of lac Saint-François, occurs as deltaic deposits overlying either organic sediments or acoustically laminated, fine-grained sediments. This sandy sediment facies can also be observed at the mouth of lac Saint-François near the dam. The nearshore environments of lac Saint-François are dominantly composed of acoustically-laminated, fine-grained sediments and bedrock (Figure 13). This laminated sequence is variable in thickness and can reach 15 m (Figure 13).

4.3 Discussion

The Lac Aylmer sonar study has been used to assess the distribution of lake sediment facies and to document the bathymetry of both lac Aylmer and lac Saint-François. The lake sediment facies maps identify zones of deposition and erosion. These zones can be further classified with respect to their sediment type, such as organic, unconsolidated sand and proglacial sediments. One of the main objectives of this study is to evaluate the relationship of the lake sediment facies and bathymetry to the geochemistry of the surficial lake sediments. Because it is important to understand the depositional history of the lake in order to differentiate between natural and anthropogenic enrichments of metals in a lake basin, an attempt was made to evaluate

Legend

gas

gyttja

unconsolidated sand, post-glacial
sediments

laminated silt/clay, proglacial
sediments

bedrock

Legend. This legend applies to Figure 11a, 11b and 13

Figure 11a

Lac Aylmer 84 - 06 a

Figure 11a. Interpretation of sonar profile 84-06 a from the lac Aylmer basin, Quebec

Figure 11b

Lac Aylmer 84 - 06 b

Figure 11b. Interpretation of sonar profile 84-06 b from the lac Aylmer basin, Quebec

glacial control on the proglacially and post-glacially derived sediments in the two major lakes of the study area.

Sediment fill in lac Aylmer and lac Saint-François consists of proglacial and post-glacial sediments. The sediment fill of these two basins mainly consists of proglacial sediments. Both lakes have laminated sequences of silt/clay sediments draping over bedrock topography with thicknesses that vary from 4 m in nearshore environments to 15 m for lac Aylmer and 7 m for Lac Saint-François within the deepest part of the basin. The thickness of this sediment-fill at the bottom in both lakes is related to different factors, such as the position of the ice front at the time of sediment deposition, the length of time available to accumulate the sediments, the availability of sediment and the capacity of the ice to transport and deposit these sediments.

Each time the Laurentide ice advanced south of the Saint-Lawrence, drainage from Eastern Quebec was blocked, permitting water to pond in front of the ice. Drainage of proglacial lake water to a lower lake level was controlled by the position of the ice front and the topographic relief. Lake water levels for the area have been extensively studied by McDonald (1967, 1968; 1969), who defined a large proglacial lake in the Saint-François river valley, which he named proglacial lake Memphrémagog. McDonald inferred the position of the ice front at the time of the Sherbrooke phase by the position of the Highland Front moraine, located across the Saint-François river valley, NW of Richmond, Quebec. It is possible that proglacial laminated sediments that accumulated at the bottom of lac Aylmer and lac Saint-François are enriched in ultra-mafic debris derived from the glacial erosion of the Thetford Mines ophiolitic complex during the northwesterly retreat of Laurentide ice.

Post-glacial sediments deposited in both lac Aylmer and lac Saint-François, such as unconsolidated sand, have developed different depositional patterns. In lac Aylmer, the distribution of this sedimentary facies along the shore can also be observed on air photos. Air photos from 1966 indicate the build up of sandy deposits at the mouth of rivière Maskinongé, Troisième and Jackman. Lake water levels lower than the present day levels in lac Aylmer were observed in 1984 and enabled the distribution of these sandy deposits to be seen at the mouth of the rivers. Northwest of rivière Maskinongé, unconsolidated sand accumulated as a sand bar deposit oriented north-south. The sand bar build up may indicate a redistribution of sediments

Figure 12. Lake sediment facies of lac Saint-François, Quebec

Figure 13. Interpretation of a sonar profile from the lac Saint-François basin, Quebec

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caused by long shore currents. Unconsolidated sediments present along the shore of lac Aylmer may have been brought in from inflowing streams and redistributed along the shores or as a result of reworking by wave action of glacio-fluvial sediments. On the other hand, the sediment type map of lac Saint-François indicates the build up of sandy sediments at the mouth of the rivers and at the dam. This suggests that sediment brought in from rivers is deposited rapidly at the mouth. Some material seems to be transported near the dam at the mouth of the lake. Sand and gravel deposits occur only in restricted zones of the lac Saint-François drainage basin relative to lac Aylmer.

4.4 Temperature, pH and conductivity measurements within the Lac Aylmer drainage basin

Temperature, pH and conductivity were measured at each water sampling site throughout the lac Aylmer drainage basin. Temperatures of both surface and bottom lake water samples were recorded using a thermometer that had been inserted into the water sampler. Conductivity and pH measurements of surface and bottom lake water, stream and mining effluents were made on site with a portable pH and conductivity instrument, calibrated with standard solutions once a day. The measurements were collected once during the sampling period of June and July 1994 (Appendix I). Limnological characteristics of water samples are summarized in Table 1.

Surface water temperature measurements from 23 samples in lac Aylmer vary between 22.0°C and 26.8°C, averaging 23.9°C (Table 1). Only two temperature measurements were taken from bottom waters of lac Aylmer during the course of this study with values of 13.0°C and 16.0°C. Surface-water temperatures in lac Saint-François also varied between 23.0-23.6°C, with an average temperature of 23.1°C (N=4). In lakes adjacent to lac Aylmer and lac Saint-François, temperature values ranged from 22.0°C to 24.8°C and averaged at 23.4°C (N=6). One bottom water in Lac des Isles had a temperature of 17.0°C.

Table 1 Summary statistics of physical limnology of water samples within the lac Aylmer drainage basin

LAKE NAME & NUMBER	SURFACE WATER SAMPLES "B" (-0.2 m from the surface)											
	T (°C)				pH				Conductivity (mS/cm)			
	n	MIN.	MAX.	MEAN	n	MIN.	MAX.	MEAN	n	MIN.	MAX.	MEAN
Lac Aylmer, SCAA-W	23	22.0	28.0	24.0	41	6.5	8.0	7.0	41	58.5	73.8	64.3
Lac Saint-Francois, SCAF-W	4	22.8	23.6	23.1	5	6.6	6.9	6.8	5	58.0	62.1	60.5
Lac Elgin, SCAG-W	1		23.8		2	6.6	7.0	6.8	2	60.0	278.0	169.0
Lac Equerre, SCAE-W	1		24.0						1		32.5	
Lac des Iles, SCAI-W	1		23.6		1		7.1		1		16.6	
Lac a la Barbe, SCAB-W	1		24.8		1		6.5		1		15.3	
Lac Maskinonge, SCAK-W	1		23.0		1		7.0		1		91.0	
Baie Sauvage, SCAS-W	1		22.0		1		6.8		1		65.0	
NUMBER	STREAM WATER SAMPLES											
SCAP-W	2	24.8	27.6	26.2	18	2.0	7.7	6.6	18	35.2	2570.0	327.0
LAKE NAME & NUMBER	BOTTOM WATER SAMPLES "A" (1-2 m above the sediment surface)											
	T (°C)				pH				Conductivity (mS/cm)			
	n	MIN.	MAX.	MEAN	n	MIN.	MAX.	MEAN	n	MIN.	MAX.	MEAN
Lac Aylmer, SCAA-W	2	13.0	16.0	14.5	7	6.4	8.3	7.1	7	58.0	100.0	69.9
Lac Saint-Francois, SCAF-W												
Lac Elgin, SCAG-W												
Lac Equerre, SCAE-W												
Lac des Iles, SCAI-W	1		17.0		1		6.4		1		17.1	
Lac a la Barbe, SCAB-W												
Lac Maskinonge, SCAK-W												
Baie Sauvage, SCAS-W												

The distribution of pH values measured from surface and bottom lake water and stream water are also summarized in Table 1. The pH values of surface waters of Lac Aylmer vary from 6.5 to 8.0. Water collected at the sediment/water interface in all lakes of the study area averaged pH 6.8, varying from 6.4-8.3. Stream and mine effluent water samples range from pH values of 2.0 to 7.7, averaging around pH 6.9.

Conductivity is the measure of the total number of charged particles (anions and cations) dissolved in water. Conductivity values for surface lake water of lac Aylmer vary between 58.5 µS/cm (microSiemens/cm) and 73.8 µS/cm (Table 1). Similarly, lac Saint-François has conductivity values ranging from 58.0 to 62.1 µS/cm, with a mean value of 60.5 µS/cm. Smaller lakes in the study area show variations in conductivity from 15.3 to 278µS/cm; stream water

ranges from 17.1 to 2570.0 $\mu\text{S}/\text{cm}$. The lowest conductivity values were observed in lac des Isles, lac a la Barbut and lac Equerre (15.1 to 32.5 $\mu\text{S}/\text{cm}$). Conductivities similar to those of lac Aylmer and Saint-François were observed in lac Maskinongé, Elgin and Baie Sauvage of lac Saint-François as well as most streams draining into lac Aylmer. The highest conductivity values were recorded in lac Elgin from a sample collected near the mouth of an incoming stream (278.0 $\mu\text{S}/\text{cm}$) and in areas near the Solbec and Solbec-Cupra mining sites (2570.0 $\mu\text{S}/\text{cm}$).

4.5 Discussion

Temperature, pH and conductivity of the waters sampled during the 1994 field studies in the lac Aylmer drainage basin were fairly uniform throughout the area. Surface lake water and stream water temperatures show a variation of 6°C over a period of one month (June 25th to July 21st 1994). It is possible that diurnal temperature variation as well as a general warming during this period caused surface water temperature within the same body of water to rise. Temporal patterns developed in surface water temperature are quite complex, although solar radiation is usually the most important variable (Constantz et al., 1994). For example, samples SCAA-W021 to W029, (see Appendix I: Limnological characteristics of water samples), were collected on the same day, but during this sampling period variation in weather conditions occurred before collecting sample W027. Other natural factors that affect diurnal, monthly and seasonal temperature variation include long wave radiation, evaporation, heat conduction, snow melt, precipitation and air temperature (Constantz et al., 1994). Other external parameters that could have affected temperature measurements are related to precision of the sampling depth and change in the calibration of the instrument during the day. Bottom-lake water temperatures are lower than those of surface water, reflecting the natural decrease in temperature with increasing water depth. Unfortunately, it is not possible to define the depth of the thermocline based on measurements taken at two different depths and hence, evaluate water stratification in lac Aylmer and adjacent lakes. In conclusion, water temperatures are considered fairly uniform throughout the study area.

Water with conductivity values <50 $\mu\text{S}/\text{cm}$ does not contain many ions in comparison to sea water, which usually has values around 32 000 $\mu\text{S}/\text{cm}$ (Burgis and Morris, 1987). Large lakes such as lac Aylmer and Saint-François have an average conductivity value around 62 $\mu\text{S}/\text{cm}$

for surface water samples. This value is similar to lac Maskinongé and Baie Sauvage of lac Saint-François. Water samples with markedly lower ionic charge were collected in lac des Isles, lac à la Barbue and lac Equerre. These three lakes, along with Baie Sauvage, are located within the same geological setting, since both are underlain by rocks of granitic composition. Lac Equerre has conductivity values twice those of the two lakes observed in Frontenac Parc but still much lower than what is observed in other lakes in the area. Part of lac Equerre is underlain by granodiorites but more than half of the lake's shore is surrounded by quartzites, greywackes and some calcareous beds. The higher conductivity values observed in lac Equerre suggest that the nature of the surrounding rocks, may play an important role in affecting the conductivity of the water.

The natural weathering of the rocks generates ions in solution, but the presence of human activity may also play an important role in controlling the rates of weathering. Other adjacent lakes (Maskinongé and Baie Sauvage) are underlain by the same granodioritic intrusion as lac des Isles, lac à la Barbue and lac Equerre, but have approximately two to four times the amount of ions in solution. The highest conductivity values were measured in mine-draining effluents and at the mouth of a minor stream draining into lac Elgin, and this may reflect the importance of dissolved material in water issuing from abandoned mining sites where pH values of 2.0 to 5.5 allow fast dissolution of metals and other ionic species. In lac Elgin, a higher conductivity value of 278 $\mu\text{S}/\text{cm}$, collected at the mouth of a stream draining into lac Elgin, may be related to farming activity and cottages in the area. Local residents have complained about a pig farm located approximately 100 m from the lake's shore, citing the noxious smell of the water and its color after natural fertilizers were laid on an adjacent field. It is possible that ionic species such as nitrates, phosphates or other dissolved material derived from natural fertilizers may cause relatively higher conductivity values of at the mouth of the stream draining into lac Elgin than those collected in the other parts of the lake.

Chapter 5

Lake Sediments and Waters

5.1 Texture

Surficial sediments of nearshore and shallow water zones (<5 m) are firm, bluish-gray silty clay to well-oxidized orange-brown, coarse sand (see Appendix III: Description of Lake Sediments). Iron and manganese nodules are also found in some areas of the lac Aylmer basin. The nearshore and shallow water zones are characterized by a bimodal grain-size distribution of medium, sand-size and clay-size material. The sediments vary in texture from a firm and cohesive clayey material to a liquid and non-cohesive sediment as the silt and clay material decreases.

Sediments collected from deep water zones (>5m) consist predominantly of silt-to clay-sized material with minor amounts of fine sand. These sediments vary from cohesive, gel type to high-water content, liquid material. Color ranges from a dark brownish-gray to olive-green.

5.2 Manganese and Iron Precipitates

Oxides of manganese and iron were found in most grab samples collected from lakes of the study area. Fe-Mn oxide-rich zones appeared as rusty layers at the surface of the sediment, rarely exceeding 5cm in thickness, or as dark gray to black colored horizontal bands throughout the sediment. Most deep water samples (>15m) have FeO-MnO bands within the sediments and a dark gray to black layer at the surface. Shallow water samples from lac Aylmer and other lakes are usually uniformly oxidized to an orange-brown color or to a more rusty orange color at the surface of the sediment. In lac Aylmer, a hard precipitate of Fe and Mn oxide occurs as nodule-shaped concretions in less than 5 m water depths within Baie Ward, Baie Moose and an area located approximately 3 km south of ruisseau du Troisième. Plates 1 and 2 illustrate the different shapes and sizes of the concretions collected at the bottom of lac Aylmer. Other nodules were found in lac Elgin at a water depth of 22 m.

5.3 Iron and Mn nodules

XRD, SEM, probe and laser analyses were carried out on selected nodule samples to characterize and quantify the physical and chemical make-up of the nodules collected in lac Aylmer. It is possible that FeO and MnO, because of their high scavenging capacity, concentrate metals during nodule formation. Chemical analyses of the nodules were performed primarily to: (i) evaluate the relationship between the growth pattern observed in the nodules and the distribution of metals (ii) to evaluate the possible scavenging capacities of these nodules for heavy metals.

X-ray diffraction analyses of the nodules indicate the presence of goethite, quartz and feldspar (Appendix IV). In order to understand the nature of the concentric growth pattern evident in the nodular concretions, SEM analyses were performed on samples 94 SCAA -S004a, -S004b, -S091, and -S100. The nodules include two main components, a nucleus and concentric zones developed about the nucleus. The nucleus is formed by a single rock fragment, such as a lithic fragment (Appendix IV). In some cases, the concentric rings appear as regular growth patterns developed around a nucleus. The banding seems to be controlled by textural differences between the alternating clastic-rich zones, composed of cemented quartz and feldspar fragments with minor amounts of zircon and cemented layers made up of FeO, and to a lesser degree, MnO. Nodule #3 (94SCAA-S004) seems to show a more disorganized zonal pattern in which the layering is caused by the alternation of FeO-, and MnO-rich layers (Appendix IV).

Laser-fusion ICP-MS and microprobe analyses were carried out on different parts of a nodule to define their chemical composition. Due to time constraints, only one nodule sample (94SCAA-S100; collected in Baie Moose), was thoroughly analyzed. A series of seventeen oxides, as well as fluorine and chlorine (Appendix IV) were identified and measured along six transects (Appendix IV) that truncated the concentric zones.

One hundred analyses were made of transects AB to GH and 20 analyses were made of transect IJ and KL. The total percent oxide values are all near 80 wt% and such low totals may be attributed to volatile-rich material. However, the results are fairly homogeneous across a transect for a given oxide, which can reflect the presence of crystalline material. The most abundant chemical oxide is FeO, that averages about 60 wt% followed by Al_2O_3 and SiO_2 which are usually <10 wt%.

The abundance of Fe and Mn oxides from the nodule indicate that both elements correlate positively with one another. A similar relationship is observed between SiO_2 and K_2O but an inverse relationship exists between FeO and SiO_2 abundance. The heavy metal abundances are heterogeneously distributed along the same transect and do not follow any discernible pattern. Nickel and Co abundances are highest in the nucleus whereas Cu, Pb and Zn have their lowest concentrations in the nucleus. The base metals show no obvious pattern across the rings of the nodule and therefore, seem to vary randomly.

5.3.1 Discussion

The behavior of Fe and Mn in lake sediments and water has been studied intensively by many researchers. Concretions similar to those observed in the lac Aylmer drainage basin have been collected and documented by other scientists from other lakes in the U.S and Finland (Carlson, 1982; Carlson and Schwertmann, 1980; Carlson et al., 1977; Dean and Ghosh, 1978; Dean and Greeson, 1979; Gulson et al., 1992; Moore et al., 1980). Although many nodules have been chemically analyzed, few studies have dealt with the relationships between structure, physical nature, and chemical composition.

Scanning electron microscopy of nodules collected in lac Aylmer shows that the banding can be either texturally controlled by the presence of clastic-rich and "cement" layers or chemically-controlled where the ring pattern is a reflection of the alternation between Fe - Mn-rich layers.

Iron and Mn are ubiquitous elements that are closely affected by redox conditions, pH, pore water chemistry and water movement, among other processes. The concentrations of Fe and Mn are also affected by certain external processes such as organic matter, which might be present in the sediments or in water, and by the intensity of erosional activity on a substrate. Ferrous (Fe^{2+}) iron is readily oxidized to ferric (Fe^{3+}) iron under slightly acid to alkaline conditions, and Mn requires much higher pH levels for equivalent rates of oxidation (Forstner and Wittmann, 1983). Morgan and Stumm (1964b) have established that for each unit increase in pH, the oxidation rate of Fe and Mn increase by a factor of 100. Both elements are mobile under reducing conditions which favors the soluble divalent form of these metals and will cause them to precipitate under oxidizing conditions, depending on pH background, with a high pH favoring rapid oxidation (Manahan, 1993). Manganese is relatively more soluble than Fe, but in a phase of increasing oxygen concentration, Fe will tend to precipitate first, before the retention of Mn is increased (Mackereth, 1966). As reducing conditions

are re-established in the sediments, the rate of precipitation of Mn will first be reduced, followed by the mobilization of Fe (Mackereth, 1966).

Reducing conditions at the sediment-water interface are most commonly found in eutrophic lakes where bottom waters and sediments are depleted in oxygen. The presence of nodules at the sediment-water interface within the lac Aylmer basin in water depths less than 5m suggests that redox conditions at the sediment-water interface are not those of anoxic character. It is possible that within the sediment column, local centers of reduction were produced, which increased the solubility of Fe and Mn already available within the sediment, which then precipitated due to the presence of surrounding oxygen. Precipitation of FeO and MnO can then proceed as a result of diffusion mechanisms (Mackereth, 1966). The nodules within the lake basin are all located in the flooding zone caused by damming activity. It is possible that the flooding of the shoreline favored decomposition of organic matter and the generation of local zones of reduction due to plant and wood chip remains.

The random distribution of the clastic material in the Baie Ward nodule sample, along with the flattened shape of the nodules parallel to the sediment-water interface suggest that the nodules envelop clastic material from the surrounding sediment. Depending on rates of precipitation and diffusion, clastic material may form layers or they may be pushed apart in a more random distribution. The Baie Ward sample suggests that the nodules evolved in an environment where conditions fluctuate between reducing to oxidizing, allowing the precipitation of both Fe and Mn.

Unfortunately, as a result of time constraint, only one nodule collected in Baie Moose was thoroughly analyzed for trace metals. As a result, it is difficult to assess the possibility that these nodules may record mining activity on the eastern side of lac Aylmer.

5.4 Geochemistry of lake sediment (<80µm) and Waters

5.4.1 Distribution of chemical elements in surficial lake sediments of lac Aylmer

The distribution of certain chemical elements for lac Aylmer sediments is shown in Figures 14 to 18 and the abundance data are given in Appendices V and VI. All of these maps show the 50th, 75th, 90th, 95th and 100 percentiles to allow comparisons to be made among different elements and demonstrate their relation with lake sediment facies mapped during the sonar survey.

- Figure 14 a. Distribution of total carbon (%) in surficial lake sediment of lac Aylmer with respect to lake sediment facies*
- b. Distribution of manganese (ppm) in surficial lake sediment of lac Aylmer with respect to lake sediment facies*
- c. Distribution of iron (%) in surficial lake sediment of lac Aylmer with respect to lake sediment facies*
- d. Distribution of nickel (ppm) in surficial lake sediment of lac Aylmer with respect to lake sediment facies*

Total C

(%)

in lake sediments

MIN.	MAX.	#SAMP	%TILE
0.24	3.06	64	50.4
3.06	4.91	32	75.6
4.91	5.98	19	90.6
5.98	7.29	7	96.1
7.29	17.61	5	100

a

Fe

(%)

in lake sediments

MIN.	MAX.	#SAMP	%TILE
0.77	3.26	64	50.4
3.26	4.29	32	75.6
4.29	5.28	19	90.6
5.28	6.2	7	96.1
6.2	7.52	5	100

b

Mn

(ppm)

in lake sediments

MIN.	MAX.	#SAMP	%TILE
96	845	63	49.6
845	1206	32	74.8
1206	17.6	19	89.8
1706	2332	7	95.3
2332	8208	6	100

c

Ni

(ppm)

in lake sediments

MIN.	MAX.	#SAMP	%TILE
26	206	63	49.6
206	279	32	74.8
279	310	19	89.8
310	328	7	95.3
328	397	6	100

d

Concentrations for Mn and Fe in the sediments range from 96-8208 ppm and 0.8-7.5 %, respectively, within the lac Aylmer basin (Figure 14b, c). Iron and Mn show a similar geochemical distribution in the lake basin where high values (above the 90th percentile) are located in the deepest parts (>5m) of the lake. The highest Mn and Fe concentrations (100th percentile) are observed in Baie Ward. The distribution pattern of total C (%) does not match with the Fe and Mn patterns (Figure 14a, b and c). The highest total C (%) concentrations reach 17.6 % in the southernmost basin of lac Aylmer. Throughout the lac Aylmer basin, C concentrations lie between 0.2 to 7.3 %.

The distribution patterns of Fe and Mn developed in lac Aylmer clearly match the distribution of lake sediment facies at the bottom of the lake. The two metals have their highest concentration within mature organic sediments and within the deepest part of the basin. The distribution of total C (%) concentrations is not as clearly correlated with the distribution of gyttja in lac Aylmer, as the highest values are found in unconsolidated sandy sediments in the southernmost basin of the lake.

Metals associated with the ophiolitic complexes, such as Ni, Cr, Co and Mg, have also been mapped within the lac Aylmer basin (Figure 14d and 15a, b, c). Concentrations between 26 to 397 ppm Ni, 1 to 144 ppm Cr, 2 to 35 ppm Co and 0.35 to 2.65% Mg have been measured. The deeper parts of Baie Moose of lac Aylmer have consistently high levels of these metals (above the 90th percentile). Similar concentrations of Ni and Co (>279 ppm and >28 ppm, respectively) have been measured for sediments from Baie Ward. High concentrations of Cr (>97 ppm) and Ni (>279 ppm) have been measured for sediments of the basin south of ruisseau du Troisième and north of the mouth of the Maskinongé in lac Aylmer.

In general, the geochemical patterns developed by these metals correlate with lake sediment facies in lac Aylmer. The lowest concentrations of these elements are found along the shores of the lake where unconsolidated sandy material, clays and bedrock dominate. The highest concentrations are generally observed in the deepest parts of the lake within organic sediments. However, high concentrations of Ni and Cr were found in a few locations in the lake overlying proglacial lake sediments. Anomalously high values of Cr (115-144 ppm) are observed in sandy sediments deposited near the mouth of rivière Maskinongé.

The patterns shown by Cu, Pb, Zn and Cd concentrations related to the massive sulfide deposits are very similar to one another. The highest concentrations are observed in Baie Ward, near

- Figure 15 a. Distribution of chromium(ppm) in surficial lake sediment of lac Aylmer with respect to lake sediment facies*
- b. Distribution of cobalt (ppm) in surficial lake sediment of lac Aylmer with respect to lake sediment facies*
- c. Distribution of magnesium (ppm) in surficial lake sediment of lac Aylmer with respect to lake sediment facies*
- d. Distribution of copper (ppm) in lake sediment of lac Aylmer with respect to lake sediment facies*

Cr(ppm)
in lake sediments

MIN.	MAX.	#SAMP	%TILE
1	79	65	51.2
79	97	30	74.8
97	105	19	89.8
105	115	7	95.3
115	144	6	100

a

Co(ppm)
in lake sediments

MIN.	MAX.	#SAMP	%TILE
2	19	64	50.4
19	28	36	78.7
28	31	18	92.9
31	34	5	98.9
34	35	4	100

b

Mg(%)
in lake sediments

MIN.	MAX.	#SAMP	%TILE
0.35	1.33	63	49.6
1.33	1.61	32	74.8
1.61	2.04	19	89.8
2.04	2.24	7	95.3
2.24	2.65	6	100

c

Cu(ppm)
in lake sediments

MIN.	MAX.	#SAMP	%TILE
2.8	54.4	64	50
54.4	109.5	32	75
109.5	184.5	20	90.6
184.5	230.1	6	95.3
230.1	454.4	6	100

d

- Figure 16 a. Distribution of lead(ppm) in surficial lake sediment of lac Aylmer with respect to lake sediment facies*
- b. Distribution of zinc (ppm) in surficial lake sediment of lac Aylmer with respect to lake sediment facies*
- c. Distribution of cadmium (ppm) in surficial lake sediment of lac Aylmer with respect to lake sediment facies*
- d. Distribution of mercury (ppm) in lake sediment of lac Aylmer with respect to lake sediment facies*

Pb

(ppm)
in lake sediments

MIN	MAX	#SAMP	%TILE
2.6	27.6	64	50.4
27.6	52.2	32	75.6
52.2	84.9	18	89.8
84.9	101	7	95.3
101	112	6	100

a

Zn

(ppm)
in lake sediments

MIN.	MAX.	#SAMP	%TILE
21.7	183.4	64	50.4
183.4	303.7	31	74.8
303.7	436.2	19	89.8
436.2	551.9	7	95.3
551.9	689.2	6	100

b

Cd

(ppm)
in lake sediments

MIN.	MAX.	#SAMP	%TILE
0.04	0.91	64	50.4
0.91	1.75	31	74.8
1.75	2.59	19	89.8
2.59	2.99	7	95.3
2.99	3.75	6	100

c

Hg

(ppb)
in lake sediments

MIN.	MAX.	#SAMP	%TILE
6	96	63	49.6
96	175	32	74.8
175	231	19	89.8
231	290	7	95.3
290	367	6	100

d

- Figure 17a. Distribution of arsenic (ppm) in surficial sediment of lac Aylmer with respect to lake sediment facies**
- b. Distribution of lead (ppb) in surficial lake water of lac Aylmer**
- c. Distribution of zinc (ppb) in surficial lake water of lac Aylmer**
- d. Distribution of nickel (ppb) in surficial lake water of lac Aylmer**

As

(ppm)
in lake sediments

MIN.	MAX.	#SAMP	%TILE
1.6	12.8	65	51.2
12.8	17.9	30	74.8
17.9	22.2	19	89.8
22.2	33	7	95.3
33	89	6	100

Pb

(ppm)
in lake water

MIN.	MAX.	#SAMP	%TILE
2.5	27.6	64	50
27.6	52.2	32	75
52.2	84.9	18	92.5
84.9	101	7	95
101	166.6	6	100

Zn

(ppb)
in lake water

MIN.	MAX.	#SAMP	%TILE
1.06	3.1	20	50
3.1	4.53	10	75
4.53	5.85	6	90
5.85	8.27	2	95
8.27	10.13	2	100

Ni

(ppb)
in lake water

MIN.	MAX.	#SAMP	%TILE
6.51	7.26	20	50
7.26	7.82	10	75
7.82	8.54	6	90
8.54	9.32	2	95
9.32	9.97	2	100

Figure 18a. Distribution of iron (ppb) in surficial sediment of lac Aylmer with respect to lake sediment facies

b. Distribution of manganese (ppb) in surficial lake water of lac Aylmer

c. Distribution of sulfate (mg/l) in surficial lake water of lac Aylmer

d. Distribution of aluminum (ppb) in surficial lake water of lac Aylmer

Fe

(ppb)
in lake water

MIN.	MAX.	#SAMP	%TILE
96.53	113.76	20	50
113.76	130.67	10	75
130.67	148.45	6	90
148.45	177	2	95
177	234.21	2	100

a

Mn

(ppm)
in lake water

MIN.	MAX.	#SAMP	%TILE
1.72	2.34	21	52.5
2.34	2.84	9	75
2.84	3.96	6	90
3.96	5.34	2	95
5.34	7.57	2	100

b

SO₄(mg/l)
in lake water

MIN.	MAX.	#SAMP	%TILE
4.35	4.83	23	57.5
4.83	4.93	7	75
4.93	5	6	90
5	5.58	2	95
5.58	6.73	2	100

c

Al

(ppb)
in lake water

MIN.	MAX.	#SAMP	%TILE
47.66	54.81	20	50
54.81	57.27	10	75
57.27	61.73	7	92.5
61.73	62.07	1	95
62.07	66.64	2	100

d

the mouth of ruisseau du Troisième, in the basin south of Troisième and north of the rivière Maskinongé near its mouth. Although, Cu values are high in Baie Ward, the highest values are found near the rivière Maskinongé and ruisseau Troisième.

The geochemical patterns of Cu, Pb, Zn and Cd are noticeably different than those observed for the ophiolite-related metals in lac Aylmer. Both patterns (base-metals and ophiolitic metals) are distinguished by: 1) the differences in concentrations of metals in the northern part of the lake where Ni, Cr, Co, and Mg are clearly enriched relative to Cu, Pb, Zn and Cd, 2) enrichment of base-metals in Baie Ward and in the southern basin (intermediate to both the Maskinongé river and ruisseau Troisième 3) enrichment of Zn, Cd, and Cu at the mouth of rivière Maskinongé and ruisseau Troisième. The patterns of base-metal concentration in lac Aylmer matches the distribution of organic material such as those found in Baie Ward area and in the southern basin. Anomalous levels of metals (above the 95th percentile) at the mouth of the two main inflowing rivers (Maskinongé and Troisième) occur in sandy sediments.

Mercury concentrations in lac Aylmer reach 357 ppb in the deep zones (>5m) of Baie Ward. Concentrations range from 6-290 ppb for other areas in the basin. Arsenic concentrations are also highest (>22 ppm) within Baie Ward. These two metals exhibit similar geochemical patterns that can be correlated with sediment type. Both are clearly enriched in organic sediments that occur in the deepest part of lac Aylmer (Baie Ward) while the lowest concentrations match the distribution of sandy material at the bottom of the lake.

5.4.2 Distribution of chemical elements in waters of lac Aylmer

Elements such as Al, Fe, Mn, Ni, Pb and Zn for the <45 µm fraction in surface water samples show values above the 95th percentile at the mouth of Ruisseau du Troisième in conjunction with high sulfate values (Figures 17b, c, d and 18). The 95th percentile for these elements corresponds to concentrations above 0.5 ppb Pb, 5.9 ppb Zn, 8.5 ppb Ni, 148.5 ppb Fe, 4.0 ppb Mn and 61.2 ppb Al. The distribution of dissolved metals in surface water is similar. Concentrations of these elements are usually greatest in the nearshore environment, especially at the mouth of inflowing rivers.

SEM analyses were performed on suspended particles caught on Millipore filter papers used for filtration of the water samples. The diameters of particulate matter present in the sample in suspension were generally greater than the pore size of these filter papers (45µm) but some smaller

particles may have collected on the paper. Using the back-scattered images from the SEM it was possible to obtain semi-quantitative analyses of the particles. These findings are summarized in Table 2.

Table 2. Summary of SEM analyses of particulate matter

Sample Number	Metal-Oxides	Sulfides	Silicates
94SCAS-W001	FeO, FeMnO, FeTiO	FePbS	FeCaSiAl, FeMgSiAl
94SCAA-W003a	FeO, FeTiO		FeSi, FeCaSi, FeCaSiAl
94SCAA-W003b	FeO, FeTiO		ZrSi, CaSiP
94SCAP-W024	NiO, FeO, MnO		Si, FeSiAl, KAlSi, CaTiSi
94SCAB-W001	FeO, MnO, NiO, FeMnO	FeS	Ca(Fe,Mn)Si, FeMgKSiAl
94SCAA-W010B	FeO, NiO, TiO, FeTiO		KAlSi, FeMgSiAl, FeCaSi
94SCAA-W022	FeO, MnO, FeNiO FeTiO, FeCrO	FeSO	FeSi, FeCrMgSiAl, FeMgSi, FeTiSi, KMgSiAl, KAlSi, FeCrTiMgSiAl, CaTiSi, CeLaSiP
94SCAA-W032	FeO, FeTiO,	FeS	MgSiAl, YPSi
94SCAF-W005	NiO, FeNiO, FeO		
94SCAA-W022	NiFeO, FeTiO, FeOMnO FeSO	FeS	FeMgKAlSi, CrFeMgAl, CaTiSi, CeLaSiP, FeMgAlSi, KAlSi

Particles of different chemical composition were observed along each transect, and their general chemical compositions are shown in Table 2. Iron, Mn and Ti are ubiquitous elements, whereas some metals, such as Ni, are only found in six samples and Cr in only one sample. Sample F-W005 collected in the northern part of lac Saint-François only contains Ni and Fe-rich particles. The sample collected at the mouth of ruisseau du Troisième (A-W022) includes Ni and Cr in the suspended load. Particulate material including iron sulfides and sulfates larger than 1 µm have been observed from samples of lac à la Barbue, from the mouth of ruisseau du Troisième and from the mouth of rivière Saint-François (B-W001, A-W022, and S-W001).

5.4.3 Distribution of chemical elements in surface lake sediments of the study area in relation to till geochemistry and bedrock geology

Metals related to the base-metal mines (Cu, Zn) were mapped throughout the study area in till and lake sediments (Figures 19 and 20). Geochemical patterns in till and lake sediments for Cu and Zn are similar. However, Cu and Zn in till sediments do not follow a geochemical trend outlining the massive sulfide deposit. This may be partly attributed to the scarcity of till samples collected in the southern part of the area, where the massive sulfide deposit is found. Enrichment in both metals is restricted to lake sediments of the lac Aylmer basin south of ruisseau Troisième. Copper concentrations in other lakes of the study area are found below the 50th percentile interval, corresponding to concentrations between 3 and 42 ppm Cu. Similar observations can be made for Zn. Sediments collected in lakes adjacent to lac Aylmer show a concentration of Zn below the 50th

Figure 19 Geochemical distribution of Cu in till and lake sediment of the study area with respect to bedrock geology

Cu

(ppm)

in lake sediments

MIN.	MAX.	#SAMP	%TILE
2.8	42.4	63	50.3
42.4	90.4	41	73.2
90.4	182.8	26	88.9
182.8	224.7	7	95.2
224.7	454.7	6	100

Cu

(ppm)

in the <0.063mm fraction of till

MIN.	MAX.	#SAMP	%TILE
16	31	46	51.7
31	38	25	79.8
38	39	10	91
39	45	4	95.5
45	59	4	100

Figure 20. Geochemical distribution of Zn in till and lake sediment of the study area with respect to bedrock geology

Zn

(ppm)

in lake sediments

MIN.	MAX.	#SAMP	%TILE
21.7	188.6	63	50.3
188.6	272.7	42	75.2
272.7	411.5	24	90.0
411.5	485.5	8	95.2
485.5	656.2	3	100

Zn

(ppm)

in the <0.063mm fraction of till

MIN.	MAX.	#SAMP	%TILE
42	72	48	53.9
72	78	19	75.3
78	83	14	81
83	86	4	95.5
86	96	4	100

Figure 21 Geochemical distribution of Ni in till and lake sediment of the study area with respect to bedrock geology

Ni

(ppm)

in lake sediments

MIN.	MAX.	#SAMP	%TILE
26	186	62	50.3
186	272	42	75.8
272	310	24	80.3
310	328	8	95.2
328	410	8	100

Ni

(ppm)

in the <0.063mm fraction of till

MIN.	MAX.	#SAMP	%TILE
88	100	3	3.4
100	200	22	28.1
200	300	16	48.1
300	500	22	70.8
500	700	15	87.6
700	1600	11	100

Figure 22. Geochemical distribution of Zn in till and lake and stream water

Figure 23 Geochemical distribution of sulfate in till and lake and stream water

Figure 24 Geochemical distribution of Ni in till and lake and stream water

percentile interval (22 to 170 ppm). Lakes lying within the felsic tuffs in which massive sulfide deposits are found, may include one or two sediment samples that fall in the 75th percentile range (170 to 273 ppm Zn).

Nickel in lake sediments and surficial deposits show distinct patterns in the study area. Nickel shows an enrichment in the northern part of the region where the highest concentrations in till and lake sediments can be observed (Figure 21). The 100th percentile for Ni in lake sediments of northern lac Aylmer and Saint-François was found to be 323 to 410 ppm. Enrichment in Ni is found in the deepest parts of lac Aylmer.

5.4.4. Distribution of chemical elements in surface waters of the study area

Zinc and sulfates show high concentrations (Figures 22 and 23) mainly at the mine sites (21 to 10,500 ppb and 10 to 1920 mg/l, respectively). Values within the 95th percentile are also observed in lac Elgin for sulfate, and in lac Elgin and lac Aylmer (at the mouth of ruisseau Troisième and in Baie Ward) for Zn. Nickel concentrations (Figure 24) in the 100th percentile are observed along the Jackman river and at its mouth into lac Aylmer and at the Cupra mine site.

5.4.5 Stream Sampling

Stream water sampling was used to trace metals transported in solution to lac Aylmer. Samples were collected along rivière Maskinongé, ruisseau Troisième and rivière Jackman. The metal concentrations in stream waters appear to be independent of the bedrock or surficial material, but dependent on incoming mining effluents of the Solbec and Cupra sites.

In general, dissolved Mo and Cr concentrations gradually increase from the mouth of lac Maskinongé to P-W025 (Figure 25 and Table 3). However, water samples collected from the Maskinongé river, downstream from both mining effluents (Cupra and Solbec open pit sites) show an abrupt increase in metal concentration for elements such as Ba, Cu, Fe, Ni, Ti and Zn. These metal concentrations rapidly drop again after confluence with the lac Elgin effluent.

The uppermost portion of the Maskinongé river flows across a granitic pluton, pyritiferous slate and greywacke and calcareous siltstone. Samples K-W001 and P-W027 were collected along the upper stretches of the river. Copper and Ti concentrations are consistent downstream from the lake, whereas concentrations of Zn and Cd show some degree of scatter. Arsenic shows an enrichment which could reflect underlying drift derived from pyritiferous slate.

Figure 25. Location of water samples along rivière Maskinongé

Table 3. Metal concentration in stream water along rivière Maskinongé

Sample	Ti (ppb)	Cr (ppb)	Fe (ppb)	Mn (ppb)	Co (ppb)	Ni (ppb)	Cu (ppb)	Zn (ppb)	As (ppb)	Mo (ppb)	Cd (ppb)	Ba (ppb)	Pb (ppb)	U (ppb)
94SCAK-W001	<0.5	<0.1	26	3	<0.1	1.4	1.1	2.3	0.3	0.1	0.10	4	0.2	0.14
94SCAP-W027	<0.5	0.2	52	19	<0.1	1.5	1.1	1.1	0.8	0.2	<0.05	7	<0.1	0.23
94SCAP-W026	37.4	<0.1	28345	<1	157.5	383.3	14.4	10499.0	0.3	<0.1	27.16	29	0.2	0.10
94SCAP-W023	0.6	0.3	189	43	<0.1	2.6	2.0	2.7	0.7	0.3	<0.05	11	0.5	0.24
94SCAP-W025	0.9	0.4	192	25	0.1	3.5	4.9	12.6	0.7	0.3	0.13	12	0.6	0.29
94SCAG-W001	<0.5	0.4	35	3	<0.1	2.5	1.5	4.4	0.4	0.1	0.06	4	0.2	0.12
94SCAP-W024	<0.5	0.5	89	13	0.1	23.6	12.2	21.0	0.6	0.2	0.21	6	0.6	0.17

Downstream from sample P-W027, effluent from the Cupra restored mine site (1993) drains into the Maskinongé river. The dissolved base-metal contents are slightly higher after the confluence with the Cupra or Solbec mining effluents (Fe: 52 to 189 ppb, Mn: 19 to 43 ppb, Ni: 1.5 to 2.6 ppb, Cu: 1.1 to 2.2 ppb). Mining effluent draining out of the pipe from the restored Cupra mine site (Plate 3) has concentration levels many orders of magnitude greater than those found in the Maskinongé river. Although concentration levels in As, Cr, Co, Cd, Pb, U and Mo are relatively constant, elements such as Ba, Cu, Fe, Ni, Ti, Mn and Zn show an increase in concentration. Zinc levels show the greatest variation in concentration after confluence with the Solbec open pit effluent. Concentrations of Co, Cr, and Ni observed in the mining effluent at the Cupra site are higher than those of the Solbec tailing site. The cover and possibly the infilling material used for the restoration of the mine site (Cupra) is a till rich in ultra-mafic clasts may affect the concentrations for Co, Cr, and Ni at the Cupra site. The water results also show that there is a dilution of the metal contents after confluence of the stream with the lac Elgin stream.

In the uppermost part of the ruisseau du Troisième, Fe concentrations are much higher than those along rivière Maskinongé upstream from the mining effluents (Figure 26). Sample sites located within felsic tuffs and basic volcanics of the area are P-W020 along with the two mines and lac Elgin. Iron concentrations are much higher at P-W020 (575 ppb) than in lac Elgin (35 ppb; Figure 23). This difference in concentration might reflect the influence of other factors such as the concentration of Fe in surficial sediments where tills contain ophiolitic material. Such an explanation would account for the high concentration of Ni and Cr in the stream waters of ruisseau Troisième. Waters draining from the Solbec tailing site have been compared with the Cupra site in the Maskinongé river section. Unfortunately, because the stream was difficult to access, water samples were not collected immediately after the confluence between the ruisseau Troisième and the tributary carrying the mining effluent. However, data at the mouth of ruisseau du Troisième show that metal concentration in the dissolved phase drops considerably due to a dilution effect downstream from the mining effluent and/or precipitation and/or formation of metal complexes in suspension.

Rivière Jackman flows parallel to the ruisseau Troisième, in bedrock composed of schist, sandstone and felsic tuffs (Figure 26). However, the sample collected at the uppermost part of the river (P-W012) shows the highest concentrations of Fe (792 ppb), and Cr (3.2 ppb) found in samples from the rivière Jackman. Towards the mouth of the rivière Jackman, there is a decrease in metal

Figure 26. Location of water samples along ruisseau Troisième and rivière Jackman

Table 4. Metal concentration in stream water along ruisseau Troisième and rivière Jackman

Sample	Ti (ppb)	Cr (ppb)	Fe (ppb)	Mn (ppb)	Co (ppb)	Ni (ppb)	Cu (ppb)	Zn (ppb)	As (ppb)	Mo (ppb)	Cd (ppb)	Ba (ppb)	Pb (ppb)	U (ppb)
94SCAP-W019	1.4	0.8	449	26	0.2	5.6	1.1	1.8	1.0	0.3	<0.05	3	0.4	0.04
94SCAP-W020	1.2	1.5	575	738	1.6	20.6	2.6	3.7	1.1	0.5	0.05	3	0.6	0.04
94SCAP-W021	5.5	3.8	16619	821	9.2	12.2	393.2	1236.2	0.6	<0.1	4.99	48	97.9	0.68
94SCAA-W021	0.6	1.1	234	7	<0.1	7.5	6.5	10.1	0.5	0.1	0.07	4	0.6	0.05
94SCAA-W022	1.1	0.9	221	8	<0.1	7.7	5.8	8.3	0.4	0.1	0.06	4	0.5	0.05
94SCAA-W023	1.1	1.0	131	2	<0.1	7.5	2.4	2.6	0.5	0.1	<0.05	3	0.2	0.06
94SCAP-W012	3.4	3.2	792	108	1.4	18.1	1.8	5.2	1.3	0.2	0.11	3	0.8	0.04
94SCAP-W013	2.0	2.4	286	23	0.2	13.7	1.4	2.2	0.7	0.4	0.06	2	0.3	0.03
94SCAP-W011	2.4	2.8	509	26	0.5	24.8	2.5	4.0	1.1	0.3	0.09	2	2.7	0.08
94SCAP-W010	2.6	2.7	588	18	0.3	24.2	2.7	3.4	1.1	0.3	0.08	3	0.6	0.07

concentration that results mainly from confluence with a stream draining from the north which has slightly lower metal levels than those observed along the rivière Jackman.

5.4.6 Discussion

Variation in bedrock geology and in the composition of glacial sediments dispersed from various types of bedrock outcrops clearly influence the chemistry of individual smaller lakes and certain basins or sectors of the larger lakes (Aylmer and Saint-François). For instance, lakes lying on granite have sediments and water enriched in U, while lakes receiving streams draining glacial sediments rich in the asbestos-bearing bedrock of the Thetford Mines ophiolite complex are enriched in Co, Cr, Fe, Mg, and Ni. In both cases, these bedrock types (granite and ultramafic rock) are typically enriched in those elements that are high in the lake sediments. The anomalously high Mn and Mo in sediment of lac Elgin, although difficult to explain, may be related to Mo deposits in the region.

Metallic species that were extracted as ore from the Cupra and Solbec base-metal mines are found in patterns in lake sediments that suggest enrichment above natural levels found elsewhere in lac Aylmer. The greatest enrichments appear to be confined largely to the deepest part of Baie Ward and to areas just offshore from rivière Maskinongé and ruisseau Troisième, which have carried effluents from the mine sites for the past thirty years. It should be noted that a wide range of metals associated with the mined deposits is found offshore from inflowing streams from the base-metal mining areas.

The main findings from the mapping of lake sediment facies and geochemical distribution of metals in lac Aylmer are:

- 1 The geochemical patterns of As, Cd, Co, Cr, Cu, Fe, Hg, Mg, Mn, Ni, Pb and Zn are clearly affected by the distribution of organic sediments in lac Aylmer. Enrichments of ophiolite-related metals (Co, Cr, Mg and Ni) are restricted to Baie Moose. All other metals are enriched in Baie Ward, the deepest and isolated basin of lac Aylmer.
- 2 The total C content is most enriched in the southernmost part of lac Aylmer. Total C(%) patterns are influenced by the distribution of gyttja in the lac Aylmer basin.
- 3 The enrichment of Ni and Cr may also be observed in sediments collected over proglacial silts/clays
- 4 Anomalously high concentrations (>95th percentile) of base-metals are found in unconsolidated sand deposited along the eastern shore of lac Aylmer at the mouth of ruisseau Troisième and rivière Maskinongé and in Baie Ward.

The main findings from the mapping of lake sediment and till geochemistry along with bedrock geology are:

- 1 The enrichments in base-metals (Cu, Zn) in lake sediments are restricted to the southern part of lac Aylmer although there is no clear pattern of enrichment of Cu and Zn in till sediments. Nickel and Cr are enriched in the most northern parts of both lac Aylmer and lac Saint-François where ophiolite-rich tills are found.
- 2 Lac Elgin and a section of lac Saint-François lie in felsic tuffs, rocks that contain exploited Cu-Pb-Zn massive sulfide deposits, and have no direct inflow of mining effluent. These two lakes show Cu concentrations below the 50th percentile interval (2 to 42 ppm), and Zn concentrations within these lakes may reach the 75th percentile range (170 to 273 ppm) in lake sediments.

The main findings from the water geochemistry section are:

- 1 The highest concentrations of dissolved metals in the surface water of lac Aylmer are restricted to nearshore zones, near the mouth of inflowing rivers.
- 2 The highest concentrations of sulfates and Zn are restricted to the mine sites, whereas the highest concentrations of Ni are restricted to the rivière Jackman.
- 3 In general, rivière Maskinongé shows increases of metal content (Ti, Fe, Mn, Ni, Cu, Zn and Ba) as a result of confluence with mine-draining effluent of the Cupra site, eventually diluted further downstream after confluence with the lac Elgin effluent.
4. Water from the Cupra site of the open pit cover, composed of till rich in ultra-mafic clasts, and waters along ruisseau Troisième and rivière Jackman, are relatively enriched in Cr, Fe and Ni compared with that of the rivière Maskinongé as a result of weathering of drift derived from the ophiolitic complex.
- 5 Zinc shows the greatest increase in concentrations in water collected after confluence with mine draining effluents.
- 6 In the suspended load, particles containing Fe, Mn and Ti are ubiquitous in the study area whereas, Ni, Cr are restricted to certain areas.

The distribution maps of the different elements indicate that there is a strong correlation between lake sediment facies and the distribution of metal concentrations in the lake basin. As

sediments are deposited further from the shore line, grain size decreases and organic content of the constituents generally increases. One of the main controlling physical factors in concentrating metals is related to grain size. This is due to both physical and chemical factors. Clay-size particles have a greater surface area (m^2/g) than sand size material (10^3scm/g) (Grim, 1968; Jones and Bowser, 1978) which affects the cation exchange capacity and surface charge of a particle. Therefore, trace element accumulation is most likely to occur at the center of lake basins where material with high cation exchange capacity is the most abundant and where hydrological conditions are more stable. The effectiveness of gyttja, fine-grained, organic-rich, gel-type sediment, in scavenging trace-elements is observed in Baie Ward and Baie Moose of lac Aylmer where high concentrations of Fe, Mn, Ni, Cr, Co, Mg, Pb, Zn, Cd, Hg and As are present. Both of these basins reach water depths greater than 24m. Baie Moose receives water mainly from rivière Saint-François whereas Baie Ward is an isolated basin of lac Aylmer with water possibly inflowing from the main basin and mainly from rivers draining along its western banks. Based on the distribution of metals and lake sediment facies, the most important scavengers present in lac Aylmer are probably Fe and Mn oxides, and organic matter. Organic matter is expected to be concentrated in the deepest parts of the basin where biological activity is, in general, higher due to slower water currents, that permits fine-grained sediments to be deposited from suspension more easily. Total C in lac Aylmer does not follow the same distribution as Fe and Mn but has its highest concentrations in the southernmost basin. This enrichment in total C may be related to a higher component of organic or inorganic carbon. Most of the higher C values are observed in clayey to silty material (Appendix II) which contains wood chips and algal remains (Appendix II). However, it is also possible that some carbonate material, derived from the calcareous beds cutting across the southern part of lac Aylmer, accounts for some of the C concentrated in the southern basin.

Nearshore zones (<5 m) of lac Aylmer are largely composed of sandy material. Anomalously high values of base-metals within this sediment facies are restricted to the mouths of inflowing rivers draining mine effluents. This suggests transport and rapid deposition of trace metals at the mouths of ruisseau Troisième and rivière Maskinongé. Nickel and Cr also may be enriched in sediments collected in the nearshore environment within proglacial sediments. It is possible that during sampling of the nearshore environments, glacial clays were incorporated with modern sediment and that the high Cr, Ni, Mg and Co content simply reflect glacially-derived material admixed with modern sediments.

Figures (19 to 21) of lake sediment concentrations, bedrock geology and surficial geochemistry show the importance of erosion in concentrating metals in the lake basin. Lakes act as sediment sinks and their geochemical characteristics depend on the type of material brought in from rivers. Figure 21 shows the distribution of Ni throughout the study area in till and lake sediments. This figure shows the importance of weathering on surface sediments in providing material to a lake basin. Weathering of tills is much more effective than weathering of bedrock surfaces because minerals have already been crushed and made more vulnerable to weathering processes. The natural process of erosion and sediment loading can be accelerated by human activities such as quarrying activities, farming and the building of residential housing or cottages along the shore of the lakes and streams. It is impossible to quantify the relative proportion of these influences, but the maps, nevertheless, show that Ni and Cr are coming from naturally-enriched tills deposited in the northern part of the area in both lac Aylmer and lac Saint-François.

On the other hand, base-metals are enriched in sediments of lac Aylmer only. The main influences on the enrichment in base-metals in lac Aylmer have been identified as a reflection of the erosion of surficial deposits, and to a lesser extent of the bedrock and/or a result of mining activities and related processes. It is impossible to quantify the relative effects that these activities have played, based on concentration values and distribution patterns from the lake sediments and till. However, anomalous concentrations of Cu and Zn in till are not distributed in a specific pattern around lac Aylmer as seen for Ni and Cr in the northern part of the area.

Background concentrations were estimated at <42 ppm Cu and <272 ppm Zn in lake sediments of the study area, based on the concentrations of these metals in adjacent lakes lying in bedrock hosting the massive sulfide deposits. The Cu and Zn abundances in sediments of lac Aylmer are therefore well above estimated metal levels attributed to the natural weathering of tills in the study area. Copper is eleven times greater than estimated background levels, while Zn is 2.4 times greater.

Changes in metal concentrations within the dissolved load of stream water samples downstream from the mining sites have shown abrupt increases in metal concentrations after confluence with metal-rich mining effluents. These high concentrations become somewhat diluted after confluence with streams containing lower metal concentrations.

Water draining mining areas commonly shows enrichment in metals relative to other non-affected areas partly because of the special environmental conditions generated at these sites. At the tailings site it was observed that pyrite had been weathered to a limonitic material in the surficial oxidized zone, but was fresh and unaltered in the gray, subsurface unoxidized zone. The tailings are composed of 20% sulfur-rich material of which 2-5% includes heavy metals such as As, Cd, Cr, Cu, Hg, Pb and Zn (Drolet and Morais, 1985). At the mine site, low pH values are caused by the weathering of sulfide-rich tailings. This process studied at the mine site involves a series of chemical reactions that oxidize sulfide minerals such as pyrite, generating acidic conditions due to the nature of these chemicals (Drolet and Morais, 1985).

Weathering rates at the tailing site would be relatively fast due to the acidic conditions (pH~2.0). Low pH and high conductivity (1348 $\mu\text{S}/\text{cm}$) conditions change rapidly downstream from the tailing site due to hydrolysis, commonly resulting in the co-precipitation of Cu, Zn and As with Fe and Mn hydroxides. It is possible that higher rates of weathering on the readily available metals were generated at the tailings sites and have favored the transport of metals to lac Aylmer. The availability of base metals from these mine sites, the higher rates of weathering present at the tailings site, the restricted zones of base metal accumulation within lac Aylmer, and the lower concentrations of base metals within lakes adjacent to lac Aylmer, suggest that the enrichment of Cu, and Zn in lac Aylmer is probably the result of mining activity. An enrichment in Cr is also observed along rivière Maskinongé and at its mouth into lac Aylmer. This may be related to weathering of tills rich in ultra mafic clasts which were used for the cover of the restored Cupra site.

5.5 Sequential extraction on grab samples from lac Aylmer and lac Saint-François

Several lake sediment samples were subjected to sequential extraction in an attempt to identify the main binding sites of trace elements and to evaluate metal mobility. Specific samples were chosen for partial dissolution techniques.

Samples from lac Saint-François were chosen to use as a comparison with those from lac Aylmer, since there is no mine effluent draining directly into the former basin. Sediment deposited at the mouth of the upper rivière Saint-François that drains into lac Aylmer, along with a deep-water sample from Baie Moose, were used to evaluate the transport mechanisms from lac Saint-François into lac Aylmer. Sediment located at the tailings site in the oxidized zone, as well as iron precipitate collected from stream sediment deposited immediately downstream from the dam at the tailing site (mine effluent) as well as sediments collected at the mouth of ruisseau du Troisième, were analyzed to evaluate the main binding sites of base metals and possibly discriminate between sources (hydromorphic transport vs. clastic dispersion). Samples collected in Baie Ward, at the mouth of the Maskinongé river, in the most southern basin of lac Aylmer and in an intermediate basin between the Maskinongé and Troisième were analyzed to establish chemical bounding of metals of interest found in lac Aylmer.

5.5.1 Results

A total of 6 metals and total organic carbon (TOC) were extracted in 5 different dissolution stages for 13 samples from the lac Aylmer area (Table 3a to f and Appendix VII). These stages are: (i) adsorbed/exchangeable/carbonate (AEC), (ii) amorphous Fe oxyhydroxide (am Fe ox), (iii) crystalline Fe oxide (cry Fe ox), (iv) sulphides and organics and (v) silicates and residual oxides. Tables 3a-f show the percentage of metals that were extracted from each chemical phase along with a factor which corresponds to the ratio:

$$\frac{[\text{Sum sequential extraction}]}{[\text{Total metal concentration in bulk sediment}]}$$

This factor verifies the reliability of the analyses. Sequential extraction sums for individual metals are generally slightly higher than the bulk analysis results giving a ratio greater than 1. The ratio for sample A-S128 shows a consistently larger total concentration in the sequential leach method compared to the bulk chemistry results by a ratio of 2.5:1 to 5:1. Chemical reagents used in both

trace metal extractions are different and as a result variations in total metal concentrations for each samples may be expected. The data in table 5a-f were used as a basis for Figures 27 and 28 which permit a better visualization of the data.

The percentage of Fe associated with each "phase" is different to that of Mn (Figure 27a and b). The highest concentration of Fe (440, 600 ppm) in the samples from the study area was observed within stream sediments collected immediately downstream from the tailings, adjacent to the weir. At the tailing site, Fe (up to 83,000 ppm) within the oxidized zone is associated mainly with the sulfides, organics and cry Fe ox phases. Total Fe concentrations increase rapidly in stream sediments downstream from the tailings, and become increasingly bound to or adsorbed to crystalline iron oxides and amorphous Fe oxides. In lake sediment samples, Fe concentrations in the silicate and residual phase exceed those observed at the mine site. However, with increasing lake water depth, the percentage of Fe associated with am Fe ox increases with a proportional decrease in the most resistant phase.

The concentration of Mn, unlike Fe, is greatest in the lake sediment sample collected in the southern part of lac Saint-François. At this site, Mn is largely bound up to AEC and Am Fe ox (60% and 33% respectively). For those sediments collected at the tailing site, sequential leach series for Mn show that this element is mainly associated with residual material (81%), followed by Mn bound up to the AEC phase (8%). In stream sediments adjacent to the weir, Mn is tied up in the AEC phase (48%) followed by the residual phase (25%). The concentrations are similar to those found in the tailings site (342 ppm) and the stream sediment site (359 ppm). At the mouth of ruisseau du Troisième, two sediment samples (A-S086 and A-S088) show a high proportion of Mn that is associated with the residual phase (42% and 49% respectively), and in one sample (A-S085), 49% of the Mn is mainly bound up to the AEC phase (49%). The distribution of Mn in the sequential extraction leaches for samples A-S088 and A-S086 is similar to that observed in the oxidized zone of the tailing site. However, there is an increase in Mn as with amorphous Fe oxide for samples A-S086 and A-S088 relative to upstream samples collected at the mine site. Concentrations for both samples at ruisseau du Troisième (A-S088; 382 ppm and A-S086; 438 ppm) are also similar to those

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Table 5. Calculated percentage values from sequential extraction analyses

Sample Number	Abs. and exch. carbonate (%)	IRON				Ratio
		Amorphous Fe oxides (%)	Crystalline Fe oxides (%)	Sulphides (%)	Silicates (%)	
A-S025	10.72	36.46	26.92	5.44	20.45	1.04
A-S058	3.17	28.4	32.87	7.37	28.18	1.2
A-S065	0.71	14.43	21.49	14.51	48.86	1.31
A-S085	4.72	21.6	29.45	8.48	35.75	1.35
A-S086	0.91	12.69	23.93	17.4	45.07	1.2
A-S088	0.42	11.49	21.56	20.66	45.87	1.76
A-S102	4.48	32.55	28.55	7.83	26.6	1.11
A-S115	0.96	17.02	23.59	10.49	47.93	1.28
A-S128	1.22	21.63	33.73	10.66	32.68	2.54
F-S004	7.31	38.75	34.63	5.6	13.72	1.01
F-S012	1.6	19.36	28.79	15.76	34.49	1.88
T-002	9.69	6	25.03	49.49	9.8	0.96
P-002	0.34	21.45	74.34	2.67	1.2	

Sample Number	Abs. and exch. carbonate (%)	MANGANESE				Ratio
		Amorphous Fe oxides (%)	Crystalline Fe oxides (%)	Sulphides (%)	Silicates (%)	
A-S025	74	16	4	1	4	0.97
A-S058	36	31	12	3	17	1.09
A-S065	14	23	8	6	48	1.40
A-S085	11	34	8	5	42	1.64
A-S086	49	15	9	3	24	1.14
A-S088	60	19	9	3	10	1.55
A-S102	7	31	13	6	43	1.03
A-S115	37	37	9	3	14	1.58
A-S128	60	33	4	1	2	3.44
F-S004	28	41	9	3	19	1.05
F-S012	8	1	6	5	81	2.02
T-002	48	12	9	5	25	2.46
P-002	4	18	15	14	49	

Sample Number	Abs. and exch. carbonate (%)	NICKEL				Ratio
		Amorphous Fe oxides (%)	Crystalline Fe oxides (%)	Sulphides (%)	Silicates (%)	
A-S025	19.51	36.93	28.22	4.18	10.8	0.97
A-S058	9.76	39.39	31.65	5.05	14.81	1.01
A-S065	7.41	28.15	28.89	8.89	25.93	1.17
A-S085	7.76	33.62	28.44	6.9	22.41	1.21
A-S086	4.82	22.89	25.3	8.43	38.55	0.88
A-S088	1.44	15.11	23.75	16.55	43.17	1.62
A-S102	11.63	37.12	27.43	3.88	19.94	1.16
A-S115	5.9	39.85	31	6.27	16.24	1.03
A-S128	8.81	37.86	30.23	5.48	17.62	2.96
F-S004	9.91	28.77	34.44	4.25	22.64	1.04
F-S012	7.14	30.65	34.52	7.74	19.94	1.73
T-002					100	1
P-002	24	12			68	

Sample Number	Abs and exch carbonate (%)	COPPER				Ratio
		Amorphous Fe oxides (%)	Crystalline Fe oxides (%)	Sulphides (%)	Silicates (%)	
A-S025	5.04	59.66	24.37	8.4	1.68	0.96
A-S058	13.93	51.43	21.42	12.14	1.07	1.19
A-S065	15.92	56.69	13.38	13.38	1.27	0.9
A-S085	13.86	58.42	19.81	4.95	1.98	1.51
A-S086	15	55	10	<5	10	0.64
A-S088	16.19	53.33	23.8	4.76	1.9	1.11
A-S102	8.24	55.29	25.88	8.24	2.35	1.04
A-S115	6.25	50	25	12.5	6.25	1.19
A-S128	11.17	55.31	22.35	7.82	3.35	3.69
F-S004	<3.45	41.38	41.38	<3.45	6.9	0.82
F-S012	<6.25	43.75	31.25	12.5	12.5	1.96
T-002	28.11	6.54	17.32	47.06	0.65	1.05
P-002	6.26	30.03	45.54	16.7	0.57	

Sample Number	Abs and exch carbonate (%)	ZINC				Ratio
		Amorphous Fe oxides (%)	Crystalline Fe oxides (%)	Sulphides (%)	Silicates (%)	
A-S025	35.44	32.73	18.05	6.32	7.45	1.37
A-S058	33.1	42.28	11.96	7.09	5.42	1.16
A-S065	39.85	41.54	7.33	6.58	4.7	0.96
A-S085	31.72	45.31	11.97	2.59	8.74	1.64
A-S086	23.23	40.4	15.15	5.05	16.16	0.92
A-S088	17.53	41.56	14.29	7.14	19.48	1.21
A-S102	23.26	33.72	20.93	7.75	13.95	1.36
A-S115	7.14	39.8	19.39	8.16	25.51	1.33
A-S128	27.59	43.31	16.14	5.93	7.03	3.7
F-S004	19.05	35.24	28.57	6.19	10.95	1.18
F-S012	9.7	36.7	24.85	9.7	18.79	1.97
T-002	33.4	1.74	12.58	31.24	21.04	1.41
P-002	9.59	13.24	32.87	32.88	11.42	

Sample Number	Abs and exch carbonate (%)	LEAD				Ratio
		Amorphous Fe oxides (%)	Crystalline Fe oxides (%)	Sulphides (%)	Silicates (%)	
A-S025	34.34	50.65	5.81	1.52	7.68	1.243
A-S058	38.22	52.47	4.49	0.65	4.17	1.315
A-S065	37.58	43.77	3.67	0.94	14.05	1.333
A-S085	29	43.95	6.16	1.24	19.74	2.03
A-S086	13.74	37.43	5.58	1.46	41.78	1.45
A-S088	21.33	38.67	10.21	1.89	28.1	1.34
A-S102	30.58	48.9	4.34	0.42	15.77	1.24
A-S115	17.49	29.59	3.42	0.83	48.66	2.81
A-S128	30.52	48.16	4.49	0.48	16.35	4.94
F-S004	23.05	58.98	6.61	0.45	9.91	1.21
F-S012	23.62	46.97	7.22	2.58	20.02	2.82
T-002	0.1	12.77	77.52	2.57	7.03	1.56
P-002	4.16	27.69	29.91	0.92	37.33	

Legend

Adsorbed/Exchangeable/Carbonates
Amorphous Fe oxides
Crystalline Fe oxides
Sulfides/Organics
Residuals/Silicates

Legend. This legend applies to Figure 27a to f

- Figure 27*
- a Distribution of iron from sediment samples throughout the study area submitted for partial dissolution techniques*
 - b Distribution of manganese from sediment samples throughout the study area submitted for partial dissolution techniques*
 - c Distribution of nickel from sediment samples throughout the study area submitted for partial dissolution techniques*

- Figure 27d Distribution of copper from sediment samples throughout the study area submitted for partial dissolution techniques*
- e Distribution of zinc from sediment samples throughout the study area submitted for partial dissolution techniques*
- f Distribution of lead from sediment samples throughout the study area submitted for partial dissolution techniques*

found at the tailings (342 ppm) and in the stream sediments immediately downstream from the tailings (359 ppm). On the other hand, sample A-S085 has a similar distribution of Mn in each of the extraction stages to the stream sediment sample adjacent to the weir. Concentration found at sample A-S085 is almost twice (722 ppm) those observed in samples A-S086 and A-S088 and those collected upstream at the mine site. Deep- water samples of lac Aylmer have Mn preferentially tied up in the adsorbed or exchangeable carbonate phase (1051 ppm and 2661 ppm).

In the oxidized mine wastes, Ni is 100% bound up to the residual phase. Immediately downstream from the dam site, partial dissolution analyses show an increase in Ni association with the AEC and am Fe ox phases but a large fraction still remains in the residual phase (70%). The two samples collected in the Solbec mine area correspond to the lowest measured Ni value in the study area (3 and 25 ppm). The highest concentrations of Ni in lake sediments are recorded in the northern part of lac Aylmer and lac Saint-François (361 ppm and 336 ppm, respectively) and in the southern basin of lac Aylmer (420 ppm). At the mouth of ruisseau Troisième, more than 50% of the Ni is found in the more resistant phases, such as crystalline iron, sulfide and silicate phases and the data reveal that Ni shows an increased affinity for the am Fe ox phase. The concentration of Ni in samples collected at the mouth of ruisseau du Troisième is increased up to 4x the concentration observed at the tailings site. Lake sediment samples collected in other areas of lac Aylmer and in lac Saint-François, demonstrate an increase in the percentage of Ni associated with hydrous am Fe ox. Overall, Ni is largely found in the resistant phases of the sequential leach.

At the tailings site, the greatest percentage of Cu and Zn is associated with the sulfide and AEC phases. Sediments collected immediately downstream of the tailings site show that Cu and Zn become increasingly adsorbed onto or bound up to cry Fe ox. Concentrations for Zn in the oxidized zone at the mine site are two times greater (461 ppm) than the concentration measured in the stream sediment collected immediately downstream from the mining effluent (219 ppm). Copper concentrations, on the other hand, are higher in stream sediment samples (527 ppm) compared to the mine site (307 ppm). Samples collected at the mouth of ruisseau du Troisième reveal that Zn and Cu concentrations are lower than those observed at the tailings and that the percentage of Zn associated with the am Fe ox phase has increased. Zinc and Cu are preferentially bound up to the am Fe ox phase in other lake sediments, but a higher percentage of Zn is adsorbed onto the AEC phase relative to copper.

Lead from the tailings shows a strong affinity to the crystalline iron oxide. At the stream sediment site, adjacent to the tailings, Pb becomes increasingly adsorbed onto or bound up in am Fe ox and residuals. Concentrations of Pb at these two sites are the highest for the study area (337,400 ppb and 378,000 ppb). At the mouth of ruisseau du Troisième, concentrations of Pb are much lower than those upstream at the mine site (~20,000 ppb) and most of the Pb is bound up with the am Fe ox phase. The other lake sediment samples collected in the lac Aylmer drainage basin show that Pb is closely associated with am Fe ox and AEC phases.

5.5.2 Discussion

The most significant features from the sequential extraction study are:

- 1 The sample collected at the tailing site in the oxidized zone (T-002) contains some of the more stable phases residing in the tailings. Except for Zn, which shows a greater concentration at this site in the AEC phase, other metals are mainly bound up to crystalline iron (Pb), sulfides (Cu, Fe, Zn) or residual phases (Ni, Mn). The tailings are greatly enriched in Fe compared to other samples in the study area. These results reflect the provenance of the wastes from a Cu-Pb-Zn massive sulfide deposit. During processing of the ore, minerals are subjected to chemical processes aimed at extracting the desired constituents. High Fe concentrations at the tailings site reflect the enrichment of pyrite minerals in the residue during ore processing. Other metals, such as Zn, are associated with AEC and may reflect the use of carbonates as agents during the ore treatment process by becoming bound up to carbonates.
- 2 The "leached" metals from the oxidized tailings seem to be deposited immediately downstream from the weir. The highest concentrations of Cu, Fe, Pb in the study area are observed in the stream sediments. The stream sediments are also enriched in Ni relative to the tailings. This increase in concentration in stream sediments relative to the tailings site suggests secondary accumulation of Fe, Cu, Pb and Ni. These metals also become increasingly associated with AEC and Fe-Mn oxide phases in stream sediments adjacent to the tailings. On the other hand, Mn concentrations in the stream sediment adjacent to the tailings are equivalent to those observed at the tailings site.
- 3 Zinc appears to be relatively more mobile than Cu. Concentrations of Zn in stream sediments collected adjacent to the weir are lower than those at the tailings whereas Cu concentrations are higher in the stream sediments relative to the tailings.

4 Copper, Pb, Fe and Zn are mainly associated with sulfide minerals at the tailings. These minerals are easily oxidized in the surface environment. Copper, Pb and Fe show secondary accumulation in the stream sediments adjacent to the tailings. The concentration of these metals increases and they become increasingly bound up to AEC and am Fe ox. However, these metals seem to accumulate as clastic particles because the more resistant phases of the sequential leaches contain high concentrations. Nevertheless, stream sediments adjacent to the tailings seem to be an important sink for Cu, Pb, and Fe.

6 Nickel is mainly bound up in the residual phase of the tailings. Higher concentrations of Ni in stream sediments relative to the tailings and an increase in association of Ni with Fe-Mn oxides suggests some secondary accumulation of this metal. However, most of the Ni seems to be transported in clastic particles.

7 With increasing water depth all metals become increasingly adsorbed onto hydrous manganese and iron oxides. The relative importance of these oxides as scavengers will depend on different conditions, one of which is organic matter content (Hall et al., 1996). The latter increases with water depth as shown by the TOC data.

5.6 Comparison of lake sediment and water geochemistry with sequential extraction results

Trace element concentrations at the various sample sites reflect the effects of different dispersion mechanisms. Stream sediments collected immediately downstream from the tailings area reflect both clastic dispersion and hydromorphic transport of metals. The most resistant phases of the sequential extraction (crystalline iron, sulfide or organic, and residual), commonly observed at the tailings site, also dominate in the stream sediments adjacent to the waste site. Ubiquitous Fe and Mn at the tailings site and downstream in stream sediments are thought to play important roles in the scavenging process for most of the metals left in suspension or present as dissolved species. This correlates with the rapid increase in metal concentrations immediately downstream from the tailing site and the precipitation of iron oxides (limonitic material) in stream sediments. Most metals in lake sediments are also associated with the more labile phases of the sequential leach. The mode of transport of base-metals from the mine site to the lake basin is difficult to assess because metals such as Fe, Cu, Pb and Zn are contained within sulfide minerals at the tailings site. However, these minerals are easily oxidized in low pH and oxidizing conditions. The base-metals then may be preferentially tied up to am Fe ox phases which can be transported to the lake environment. It may be

possible that primary sulfide particles may be transported to the lake environment where they become associated with am Fe ox as a result of oxidation. However, 50-80% of Ni is associated with resistant phases of the sequential leach at the mouth of ruisseau du Troisième and the sequential extraction confirms the greater resistance to weathering processes for those phases containing Ni. The greater mobility of Zn can be inferred from the sequential extraction results. Zinc, unlike the other metals, does not concentrate in the stream sediments collected adjacent to the weir. Most of the Zn in the study area is associated with adsorbed/exchangeable/carbonates or am Fe oxides. Anomalously high Zn concentrations seem to be strongly correlated with the concentration of total organic C obtained from the sequential data more so than any of the other trace elements.

5.7 Discussion

Two cores collected in lac Aylmer during the winter field season 1995 were submitted for geochemical analysis. The findings from these cores help in interpreting some of the data collected during the course of this work. The data obtained formed the basis of a B.Sc. thesis at Carleton University (Fu, 1995). A 1 m core was collected in deep waters of Baie Ward (#1) and the second core (#2; 67cm) in Longue Pointe. Multiple laminations of light and dark sequences characterized core #1 with a top 8cm of black sulfide-rich gyttja (Fu, 1995). The core was sampled every 2cm for the top 30cm and every 5cm below. Core #2 had no visible laminations and was sampled every 2cm for the first 36cm and every 5cm below.

The main conclusions of Fu's study are:

- 1 Estimated background levels of metals in lake sediments of lac Aylmer based on the vertical variation of metals in the core are: Cu: 25ppm, Pb: 10-11ppm, Zn: 145-150ppm, Cd: 0.75-1.1ppm, Ni: 250-270ppm, As: 8-15ppm, Hg: 170ppb. Mercury levels were difficult to estimate due the relatively unstable vertical profile in both cores.
- 2 The effects of mine remediation at the Cupra site seems to be observable in core #2 as shown by a sharp decrease in concentration in the upper 5 cm of the core. This was mainly evident from Cu and Pb geochemical profiles. On the other hand, core #1, collected in Baie Ward, does not show any decrease in concentration but rather a gradual increase towards the surface of the sediments.

3 Sulfur concentrations generally increased with depth. Organic matter is a possible sink for sulfur in lake sediments. The increase in sulfur with depth was associated with submergence of logs. The decrease in organic content in more recent sediments was related to an increase in clastic sedimentation correlated with mining activity for the Longue Pointe core sample.

4 Mn and Fe in core profiles of the Baie Ward sample show much greater variation than in core #2. Thus, along with the presence of nodules in Baie Ward, were attributed to diagenetic processes occurring in lake sediments. These processes may be able to concentrate metals at the surface of the sediments as a result of remobilization.

5.7.1 Comparison and importance of core sampling

Detailed core analyses give an insight into the changes in metal concentration with time, whereas the grab sampling analyses provide a good indication on the provenance of the metals. Baie Ward is an isolated part of lac Aylmer where diagenetic processes in the sediment column seem to play an important role in the distribution of metals with depth and in concentrating them at the sediment/water interface. The hypothesis that diagenetic processes are more important in Baie Ward than in Baie Moose and Longue Pointe is shown by the core study and the SEM analysis on the nodules. The former indicates a high surface enrichment of metals that can be mainly attributed to the occurrence of higher levels of organic sediments which may affect the stability of Fe and Mn oxides under anaerobic conditions, while the latter indicates that nodules in Baie Ward are probably formed under fluctuating redox conditions within the sediment column.

The deep waters of Baie Ward favor the accumulation of organic material relative to the Longue Pointe core. This is observed in the Baie Ward core where sediments are distributed in thin laminated sequences requiring a tranquil depositional environment. Low sedimentation rates and isolation to currents in Baie Ward, favor the deposition of organic and Fe-Mn oxides that concentrate metals as a result of their high exchange capacities. On the other hand, higher clastic deposition in the Longue Pointe core is shown by the decrease in S and organic material that was correlated with the beginning of mining activities. Evidence of remediation of the Cupra site was observed in the Longue Pointe core as opposed to the Baie Ward core.

The estimation of background concentrations of metals in lac Aylmer from the core-sampling study reveals that base-metals and other metals deposited in Baie Ward are largely enriched in surface

sediments of the lac Aylmer basin. The background levels for Zn are generally higher than those for Cu confirming those patterns obtained from the grab samples of adjacent lakes lying in bedrock hosting the massive sulfide deposits. Background levels estimated from grab samples collected in areas of massive sulfide deposits for Cu and Zn are similar to those of the core sampling program in lake sediments of lac Aylmer (Cu: 42 ppm, Zn: 170-275 ppm for grab samples and 25 ppm Cu, 145-150 ppm Zn for core samples). Concentrations of metals in nearshore environments near the mouth of rivières Maskinongé and Troisième reached 300 ppm Cu, 550 ppm Zn and 225 ppm Cu, 472 ppm Zn respectively, well above natural background levels in the study area. On the other hand, naturally enriched tills in the northern part of the area acted as a source for Ni, Cr, Mg, and Co that are now contained in lake sediments. Estimated background levels of Ni in lake sediments of the southern part of lac Aylmer range between 250-270 ppm from the core study. Concentrations of Ni in the southern part of lac Aylmer are mainly below 300 ppm. However, samples in Baie Ward and in the basin intermediate to ruisseau Troisième and rivière Maskinongé have concentrations reaching 400 ppm Ni for sediments collected in mature organic sediments and over proglacially laminated clays. This enrichment is mainly attributed to the presence of organic material which tends naturally to concentrate metals. Proglacial laminated sediments of lac Aylmer, deposited during northwesterly retreating ice, are probably enriched in ophiolite derived debris and may have contributed to some of the Ni enrichment observed in those samples collected over this sediment facies.

CHAPTER 6.0

6.0 Conclusions

The combined results of the distribution patterns of chemical elements in surface lake sediments and waters, sequential extraction analyses, and core studies of the lac Aylmer basin helped to identify sources and pathways of naturally and possibly anthropogenically-derived metals in the study area. The main conclusions of this study are:

1 Background levels of base metals have been determined from sampling adjacent lakes to provide information on the chemical variation within lakes lying in similar and/or different geological settings, and core sampling in lac Aylmer. Background concentrations in lakes lying within rocks containing massive sulfide deposits and within lac Aylmer are up to 8x and 3x (Cu and Zn, respectively) lower than those observed in sediments collected at the mouth of creeks draining mine-effluent into lac Aylmer. Estimated background levels from a core sampling study match those of the grab sampling study.

2 The effects of mine remediation at the Cupra mine site have been observed in the core sampling study supporting the hypothesis that metals concentrated in the lac Aylmer basin are partly derived from mining activity.

3 The availability of base metals from these mine sites, the higher rates of weathering present at the tailings site, the restricted zones in which base metals tend to accumulate within lac Aylmer, and the lower concentrations of base metals within lakes adjacent to lac Aylmer suggest that the enrichment of Cu, and Zn in lac Aylmer is mainly the result of mining activity

4 Variation in bedrock geology and in the composition of glacial sediments dispersed from various types of bedrock clearly influenced the chemistry of individual smaller lakes and certain basins or sectors of the larger lakes (Aylmer and Saint-François). Glacially-derived sediments deposited in the northern part of the study area are clearly enriched in elements such as Fe, Ni, Mg, Cr, and Co associated with ophiolite complexes. These metals are also enriched in lake sediments deposited in the northern part of lac Aylmer and Saint-François and are found to be enriched in streams draining the glacial sediments.

5 The influence of bedrock and surficial geology in the distribution of metals is also observed in lakes lying on granite which have sediments and water enriched in U.

6 The influence of bedrock and surficial geology in the distribution of Cu and Zn seems to have little effect on the concentrations of these metals in lac Aylmer.

7 Mine-related metals are mainly associated with am Fe ox which is consistent with the easily oxidized nature of the sulfide-rich minerals. Although, there is some evidence for clastic deposition of metals at the mouth of ruisseau Troisième, most clastic particles are accumulating immediately downstream from the tailing site.

8 Nickel and Cr are dispersed in lake sediments, mainly in the northern part of lac Aylmer and this is attributed to the weathering of tills rich in ophiolite debris (associated with silicate minerals). Analyses of suspended material ($>45\mu\text{m}$) have demonstrated the ubiquity of Fe, Ni and Cr in the study area, especially in regions of drift material.

9 Manganese and Fe oxides commonly form a coating on the surface of minerals or fine-grained particles, a process particularly important in acid mine drainage. The formation of these oxides is quite complex and is beyond the scope of this study. However, the significance of these substances in collecting heavy metals is well observable from the sequential analysis. Iron and manganese oxides are clearly the phases in which metals are scavenged within the lake basin, especially for deep water samples.

10 Enrichment of metals in surface sediments of Baie Ward is closely related to diagenetic processes occurring in the sediment column. The presence of Fe and Mn nodules and the way in which the nodules are formed suggest a very unstable environment where fluid migration plays an important role in maintaining high concentrations of trace and minor elements at the sediment surface.

11 Transport mechanisms of metals to lac Aylmer are difficult to assess. This is attributed to the complex sediment/water interactions from the time the parent material is altered or weathered to the state in which the metals are bound up at sampling time.

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Appendix I: Description of methods and analytical techniques used in the lac Aylmer study

<i>INSTRUMENT</i>	<i>METHOD DESCRIPTION</i>
Sonar	<p>There are two criteria that need to be satisfied during a sonar survey: resolution and depth penetration. One is achieved at the expense of the other such that it is often necessary to run the two systems simultaneously. Resolution is strongly dependent on the frequency and pulse length of the transmitted signals. High resolution profiles require high frequencies that are quickly attenuated at the contact of an obstacle due to a rapid loss of energy. Deep penetration, up to 100 m, requires low frequency signals (3.5/12 kHz transducer), achieved at the expense of a reduction in resolution (e.g. Rathyeon 1000 system) (Sylwester, 1983).</p> <p>The horizontal axis on the chart recorder depends on the boat speed over the distance covered which is the cause of the extent of the vertical exaggeration on the chart paper (5:1 to 20:1) (Sylwester, 1983). The low-frequency profiling system does not allow water depth measurements, which requires higher resolution, but is essential for the identification of sedimentary units and their vertical distribution as it records the sediment surface.</p>
SEM	<p>A target specimen is inserted in a vacuum chamber where it is irradiated with a finely focused electron beam. The electrons interact with the specimen and emit a signal that is captured by a detector which transmits an image (Lloyd, 1985). The emission signals are dependent on morphology, composition, crystallography and even more so on the amount of current in the electron beam which determines the signal strength (Lloyd, 1985). Therefore, the image formed is dependent on the emission signals transmitted from the target specimen (Lloyd, 1985).</p> <p>The most commonly used images for geological analyses are produced by Backscattering Electron (BSE) and energy dispersive X-ray spectrometry. BSE produces an image with contrasts dependent on the atomic number and also due to the orientation contrasts and electron</p>

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	<p>channeling properties (Lloyd, 1985). On the other hand, the X-Ray analyses provide a quantitative representation of various mineral phases. These methods when used together, yield information on morphology, chemistry and crystallography.</p>
Sequential Extractions	<p><u><i>Adsorbed and Exchangeable carbonates (AEC)</i></u></p> <p>The first extractable mineral phase, absorbed and exchangeable carbonate, is achieved by submitting the sediments to a weak reagent such as a 1M sodium acetate solution (1M NaOAc) with pH 5. The first fraction to be brought into solution is water-soluble material which is usually negligible (Hall et al., 1996). The reaction extracts trace metals that may be held through electrostatic attraction on the surface or interface of soils (Hall et al., 1996). Some metals can substitute for Ca^{2+} or Mg^{2+} at the surface of the carbonate minerals or those present in an Fe or Mn oxide phase can be adsorbed onto the carbonates (Chao, 1984; cited in McDonald, 1993). Exchangeable and adsorbed metals have been grouped with those coprecipitated with carbonates (Hall et al., 1996).</p> <p><u><i>Hydrous iron oxides (Am Fe oxide)</i></u></p> <p>Oxides are effective scavengers of trace-metals. Manganese and iron oxides are often observed as coatings precipitated on the surface detrital grains, as cement between particles, and as pure concretions (Batley, 1989; cited on McDonald, 1993). Metals bound to this phase may occur by coprecipitation, adsorption, surface complex formation, ion exchange, and penetration of the lattice (Hall et al., 1996). External factors influencing the formation of iron and manganese oxides include those of pH-Eh values, degree of oxide crystallinity, their abundance and presence of organic matter (Hall et al., 1996). This mineral phase is extracted using a 0.25M Hydroxy-hydrochloride solution ($\text{NH}_2\text{OH}\cdot\text{HCl}$) in 0.25M HCl.</p>

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Crystalline iron oxides (Cry Fe oxide)

Crystalline iron oxides are those that form hematite, goethite, and magnetite. These have a mineral structure and are abundantly found in sediments. These minerals were extracted using a 0.25M Hydroxy-hydrochloride solution (0.25M $\text{NH}_2\text{OH}\cdot\text{HCl}$) in 25% HOAc at 90°C.

Sulfides and organic matter

This phase extract metals that are less reactive because of the stronger bounding developed with sulfides and organic matter. Stronger reagents such as KClO_3/HCl followed by 4M HNO_3 are used to isolate these trace metals from this phase assuming that these forms have not been previously dissolved to any significant degree (Hall et al., 1996).

Silicate and residual crystalline fraction

Finally, the last phase includes the remnant metals usually present in a more stable form such as in silicates and in crystalline forms. This phase is significant in the procedure to obtain the total concentration of a metal in a sample. The reagent used is a mixture of 50% hydrofluoric (HF), 70% perchloric (HClO_4) and concentrated nitric acid (HNO_3). Sometimes, total decomposition of the residue fails, leaving behind refractory primary minerals such as tourmaline, beryl, chromite, and sphene (Hall et al., 1996).

SAMPLE NUMBER	ZONE	EASTING	NORTHING	TEMPERATURE		CONDUCTIVITY	
				°C	pH	µS/cm	
94SCAA-W001	19	316356	5077469		7.4	59.0	
94SCAA-W002	19	315043	5077333		7.5	58.5	
94SCAA-W003A	19	315973	5076564		7.7	58.0	
94SCAA-W003B	19	315973	5076564		7.3	59.0	
94SCAA-W003C	19	315973	5076564		7.3	59.0	
94SCAA-W004	19	315041	5077292		7.6	64.2	
94SCAA-W005A	19	315072	5076490		6.8	63.5	
94SCAA-W005B	19	315072	5076490		7.1	64.9	
94SCAA-W006	19	314040	5076513		7.0	61.2	
94SCAA-W007	19	316020	5075526		7.1	65.9	
94SCAA-W008A	19	315057	5075542		7.0	66.9	
94SCAA-W008B	19	315057	5075542		7.1	62.6	
94SCAA-W009	19	314030	5075630		7.0	64.0	
94SCAA-W010A	19	315918	5074509		8.3	100.6	
94SCAA-W010B	19	315918	5074509		6.8	60.9	
94SCAA-W011	19	315004	5074506		6.9	60.1	
94SCAA-W012	19	314615	5074328		6.9	58.5	
94SCAA-W013	19	318037	5073500		7.2	59.0	
94SCAP-W010	19	318700	5079550		7.7	64.8	
94SCAP-W011	19	320600	5081325		7.6	65.4	
94SCAP-W012	19	325350	5085300		7.4	46.2	
94SCAP-W013	19	323925	5085800		7.7	72.1	
94SCAA-W014	19	316982	5073560		6.5	68.2	
94SCAA-W015	19	316963	5074473		6.6	66.8	
94SCAA-W016A	19	318009	5074503		6.4	68.6	
94SCAA-W016B	19	318009	5074503		6.7	68.0	
94SCAA-W017A	19	318035	5075510	16	6.6	71.4	
94SCAA-W017B	19	318035	5075510	23.6	6.8	73.8	
94SCAA-W018	19	319009	5075497	24.8	6.8	70.2	
94SCAA-W019	19	318946	5074528	25.2	6.8	68.5	
94SCAA-W020	19	315986	5072505	24	6.9	69.2	
94SCAA-W021	19	318852	5078944	23.6	6.5	67.8	
94SCAA-W022	19	318957	5078737	23.4	7.3	67.3	
94SCAA-W023	19	318909	5078667	24	7.4	65.6	
94SCAA-W024	19	318969	5077482	24.6	7.3	65.7	
94SCAA-W025	19	318091	5077389	23.2	7.3	65.1	
94SCAA-W026	19	318070	5076524	24	7.3	61.8	
94SCAA-W027	19	318024	5078520	28	7.2	66.5	
94SCAA-W028	19	318514	5079000		8.0	65.6	
94SCAA-W029	19	318585	5079407	26.8	7.3	66.8	
94SCAA-W030	19	317079	5080492	22	6.9	61.1	

SAMPLE NUMBER	ZONE	EASTING	NORTHING	TEMPERATURE		CONDUCTIVITY	
				°C	pH	µS/cm	
94SCAA-W031	19	316977	5081537	23	7.1	65.5	
94SCAA-W032	19	317490	5085080	23.4	6.9	61.2	
94SCAA-W033A	19	318000	5084000	13	6.6	60.1	
94SCAA-W033B	19	318000	5084000	23.8	6.7	62.7	
94SCAA-W034	19	318027	5082466	24.6	6.9	62.9	
94SCAA-W035	19	317967	5080579	23	6.8	63.1	
94SCAA-W036	19	315054	5072516	23	7.0	67.1	
94SCAA-W037	19	314332	5071550	23.2	6.7	67.2	
94SCAA-W038	19	313193	5070155	23.4	6.6	61.4	
94SCAA-W039	19	313193	5070155	22.8	6.6	67.0	
94SCAA-W040	19	316024	5071527	24.2	6.5	61.5	
94SCAE-W001	19	325943	5076256	24		32.5	
94SCAK-W001	19	325447	5071607	23	7.0	91.0	
94SCAG-W001	19	317842	5069917	23.8	7.0	60.0	
94SCAG-W002	19	318975	5068700		6.6	278.0	
94SCAS-W001	19	333529	5072840	22	6.8	65.0	
94SCAI-W001A	19	329688	5073020	17	6.4	17.1	
94SCAI-W001B	19	329688	5073020	23.6	7.1	16.6	
94SCAB-W001	19	329897	5075214	24.8	6.5	15.3	
94SCAP-W014	19	313950	5073750	24.8	6.7	61.8	
94SCAP-W015	19	313550	5075325		7.4	71.2	
94SCAP-W016	19	312800	5076150		6.7	59.9	
94SCAP-W017	19	309600	5079050		6.9	35.2	
94SCAP-W018	19	314950	5080800		6.9	88.6	
94SCAP-W019	19	322200	5079950		6.9	58.5	
94SCAP-W020	19	323050	5079250		6.7	87.1	
94SCAF-W001	19	334064	5078917	23	6.9	61.4	
94SCAF-W002	19	336101	336101		6.9	60.3	
94SCAF-W003	19	333081	333081	23	6.8	62.1	
94SCAF-W004	19	330490	330490	23.6	6.6	60.6	
94SCAF-W005	19	324525	324525	22.8	6.7	58.0	
94SCAP-W021	19	323300	5076675		2.0	705.0	
94SCAP-W022	19	321975	5074150		5.4	1348.0	
94SCAP-W023	19	320275	5071575		5.9	151.0	
94SCAP-W024	19	318100	5071700	27.6	6.2	92.7	
94SCAP-W025	19	318800	5071800		7.2	168.8	
94SCAP-W026	19	320100	5070825		6.0	2570.0	
94SCAP-W027	19	321800	5070825		7.0	140.0	
94SCAP-W028		BLANK					

Appendix III: Description of surficial lake sediment

SAMPLE NUMBER	DEPTH CM	SEDIMENT TYPE	GRAIN SIZE	TEXTURE	SEDIMENT COMPOSITION	NON-SEDIMENT CONTENTS	PERCENT WATER	PERCENT SOLIDS
94SCAA-S001	4.1	Ultramafic, quartz	variable	clastic				
94SCAA-S002	3.2		clay	cohesive	rusty red	grass		
94SCAA-S003			f. sand+clay	cohesive				
94SCAA-S004b	2.5Y 3.2		clay	cohesive, fe. nodules				
94SCAA-S005	5Y 3.2		clay	low water content				
94SCAA-S006			sandy	cohesive	grey	weeds		
94SCAA-S007	5Y 3.2		f.-med. sand	cohesive	uniform			
94SCAA-S008	5Y 2.5.2		sandy	cohesive	uniform			
94SCAA-S009	5Y 2.5.2		clay	cohesive				
94SCAA-S010	5Y 2.5.1		clay	cohesive				
94SCAA-S011	5Y 3.1		clay	cohesive, dark stripes, clumps				
94SCAA-S012	5Y 3.2		sandy	cohesive, dark stripes	crangy			
94SCAA-S013	5Y 2.5.2		clay	fairly cohesive				
94SCAA-S014	2.5Y 2.0		clay	cohesive, cold				
94SCAA-S015	5Y 2.5.1		clay	less cohesive	orange brown	twigs		27
94SCAA-S016	5Y 3.2		f.-med. sand	fairly cohesive, black grains	orange brown			28.5
94SCAA-S017	5Y 3.2		f. sand	cohesive, black particles	not pronounced	snails		4
94SCAA-S018	5Y 2.5.2		f.-v.f. sand			shells		2.5
94SCAA-S019a	5Y 3.1		clay	cohesive, dark stripes	crangy brown			3.5
94SCAA-S019b								14
94SCAA-S020	5Y 5.1		clay	cohesive	crangy brown			28.5
94SCAA-S021	2.5Y 2.0		clay	cohesive	crangy brown			31
94SCAA-S022	5Y 4.4	variable	clay matrix	ill?				0.5
94SCAA-S023	5Y 3.2		clay	cohesive	crangy brown			7.5
94SCAA-S024								
94SCAA-S025	5Y 2.5.1		clay		crangy brown			19
94SCAA-S026			f. sand+clay	firm, cohesive, clumps	pale brown orange			8.75
94SCAA-S027	5Y 3.2		f. sand	firm, cohesive	uniform			
94SCAA-S028	5Y 3.2		silt+coarse sand	patchy colours, light grey+olive, f.e. nodules	non-uniform			1
94SCAA-S029	5Y 2.5.2		clay	firm, clumps, v. cohesive	brownish			8.5
94SCAA-S030	5Y 2.5.2		clay	liquid, cold				20
94SCAA-S031	5Y 3.2		clay	cohesive, rel. firm, clumps				18
94SCAA-S032	5Y 2.5.2		clay	firm	brownish orange			10
94SCAA-S033	5Y 2.5.2		clay+silt-v.f. sand	water rich surface, firm, cohesive	uniform			5.5
94SCAA-S034	5Y 2.5.2		sandy	silt, f. sand pockets, clumps, mod. firm	uniform			
94SCAA-S035	5Y 2.5.2		f.-med. sand	water rich	uniform			
94SCAA-S036	10YR 3.3		med. sand	water rich		weeds		1.25
94SCAA-S037			clay	firm, dark layer				0.5

Appendix III: Description of surficial lake sediment

Sample ID	Depth (cm)	Grain Size	Color	Texture	Notes	Depth (cm)
94SCAA-3038	5Y 3.1	clay		firm	brownish red uniform	7
94SCAA-3039	5Y 2.5,2	clay		liquid		8
94SCAA-3040	2.5Y 3.2	med.sand-pebble		liquid		0.5
94SCAA-3041	5Y 2.5,2	med-coarse sand		liquid		2
94SCAA-3042	5Y 2.5,2	sand-clay		liquid		3
94SCAA-3043	5Y 2.5,2	v.f. sand		high water, cohesive	twigs	2.5
94SCAA-3044	5Y 2.5,2	med-coarse sand		high water, not v. cohesive		1
94SCAA-3045	5Y 2.5,2	f.-med.sand		firm		2.75
94SCAA-3046	5Y 3.1	clay		fe-nodules	brownish orange well oxidized surf.	11
94SCAA-3047	5Y 3.2	silt-f. sand		firm, clumps	brownish red uniform	4
94SCAA-3048	5Y 3.2	clay		cohesive, mod. water	uniform	6
94SCAA-3049	5Y 3.2	f.-med. sand		firm	9.5.5.3	3
94SCAA-3050	2.5Y 3.2	clay, silt		firm, cohesive	grass	3
94SCAA-3051	5Y 2.5,2	f.-med.sand, pebble	Slime, Quartzite, Marble	high water, swampy	uniform	1
94SCAA-3052	5Y 3.2	f.-med.sand	Quartz	firm, low water	well oxidized surf.	1
94SCAA-3053	2.5Y 3.2	clay, silt-f. sand	Quartzite, Marble	v. firm,	orange-brown	3
94SCAA-3054	5Y 2.5,2	clay		high water	orange	7.5
94SCAA-3055	5Y 3.2	med.sand		low-mod. water, clumps	uniform	4.5
94SCAA-3056	5Y 3.1	clay		firm, cohesive, mod. water, cold	brownish orange	2.5
94SCAA-3057	5Y 2.5,2	clay		firm, cohesive, mod. water	dark brown-orange	6
94SCAA-3058	5Y 3.1	clay		high water	orange	12
94SCAA-3059	5Y 3.1	clay		firm, cohesive, mod. water	dark brown	12.5
94SCAA-3060	5Y 3.1	clay		high water	twigs	9
94SCAA-3061	2.5Y 3.2	clay+ff. sand		firm, cohesive, clumps, low water	wood chips	2.75
94SCAA-3062	2.5Y 3.2	med.sand		firm, cohesive, clumps, low water		4
94SCAA-3063	5Y 3.1	clay		firm, cohesive, clumps, low water	dark brown (firm, bit) rusty	7.5
94SCAA-3064	5Y 3.2	clay		med-high water, cohesive	dark below surface	6
94SCAA-3065	5Y 2.5,2	clay		low water	leaves, twigs	2
94SCAA-3066	5Y 3.2	clay		mod.-high water		2.5
94SCAA-3067	5Y 3.1	clay		mod. water	orange-brown	9
94SCAA-3068	5Y 3.2	clay		mod. water, firm, dark stripes	brownish-orange	11
94SCAA-3069	5Y 3.1	clay		firm, mod. water	brownish-orange	9.75
94SCAA-3070	5Y 3.2	clay		mod. firm, mod.-high water, black stripes	orange-brown	15
94SCAA-3071	5Y 3.1	clay		mod. water, clumps	crusty orange-brown stripes not preserved	10
94SCAA-3072	5Y 3.2	clay		high water	7.5, 4, 1.8	13
94SCAA-3073	5Y 3.1	med.sand	Quartz	high water	broken shells, snails	5
94SCAA-3074	5Y 3.1	med.sand		high water		3.5
94SCAA-3075	5Y 3.2	med.sand		high water		3.5

Appendix III: Description of surficial lake sediment

Sample ID	Depth (cm)	Grain Size	Moisture	Consistency	Color	Notes	Depth (cm)
94SCAA-3076	5Y 3.1	clay+silt	liquid	firm, low water, clumps	dark orange-black stripes	worms	3
94SCAA-3077	5Y 2.5.2	clay+silt	mod.firm, mod. water, clumps	rusty orange	wood chips		4.5
94SCAA-3078	5Y 3.1	clay, v.f. silt	v.firm, cohesive, low water	orange	leaves		4
94SCAA-3079		clay-silt	glaciolacustrine sds. firm	uniform			4.5
94SCAA-3080		med.sand	liquid	uniform			2.75
94SCAA-3081	5Y 3.1	clay	firm, cohesive, low water	orange-brown, brown stripes			3.5
94SCAA-3082	5Y 3.2	f.-med.sand	liquid, w. sorted	uniform			4.5
94SCAA-3083	dark grey	med.-coarse sand	high water, poorly sorted	uniform			3
94SCAA-3084	5Y 3.2	f.-v.f. sand	high water	uniform			1
94SCAA-3085	5Y 2.5.2	med.sand	high water, well sorted	gold, grey, yellow, orange			1
94SCAA-3086		sand	liquid, well sorted	yellow-grey			5
94SCAA-3087		med.-coarse sand	non-cohesive, poorly sorted	uniform			1.25
94SCAA-3088	5Y 3.2	f.-med.sand	liquid, well sorted	bright orange			1.5
94SCAA-3089	5Y 2.5.2	silt-clay	cohesive, low-mod. water	orange			4.5
94SCAA-3090	5Y 3.2	clay+silt-v.f. sand	cohesive, mod. water, Fe-scales	mixed colours			4
94SCAA-3091		f.-med. sand	mod. water	brownish orange			3
94SCAA-3092	5Y 3.2	clay	low water, cohesive	uniform			8.5, 4.5, 2. clams
94SCAA-3093	5Y 3.2	f. sand	high water, Fe-scales	brownish orange			4.5
94SCAA-3094	5Y 3.2	clay+silt-v.f. sand	low water, cohesive, firm	uniform			2.5
94SCAA-3095		clay	mod. water, cohesive	uniform			1.5
94SCAA-3096		med.-coarse sand	liquid, mod. sorting	uniform			5.25
94SCAA-3097	5Y 3.2	clay	low water, cohesive, firm	uniform			1
94SCAA-3098	5Y 3.2	med.sand	high water, cohesive	uniform			2
94SCAA-3099	5Y 3.1	clay	cohesive, Fe-scales, local grey clay	uniform			1
94SCAA-3100	5Y 3.1	clay	low water, black stripes, cold	uniform			4
94SCAA-3101	5Y 2.5.2	clay	low water, cohesive, firm, black stripes	thick (2cm)			19
94SCAA-3102	5Y 2.5.2	clay	low water, cohesive, firm, cold, black stripes	orange-brown, black streams			25
94SCAA-3103	5Y 4.1	clay	low water, cohesive, black stripes	brownish			26
94SCAA-3104	5Y 4.1	clay	low water, cohesive, black stripes	silvery-yellow			10.5
94SCAA-3105	5Y 4.1	clay	low water, cohesive, black stripes	silvery-yellow			6.5
94SCAA-3106	5Y 4.1	clay	low water, cohesive, black stripes	silvery-yellow			13
94SCAA-3107	5Y 4.1	clay	low water, cohesive, black stripes	brownish			9
94SCAA-3108	5Y 3.1	clay	low water, cohesive, black stripes	silvery-yellow			9
94SCAA-3109	5Y 2.5.2	silty	liquid	uniform			
94SCAA-3110	5Y 3.2	v.f. sand	high water, mod. cohesive, well sorted, Fe-scales	uniform			0.5
94SCAA-3111	5Y 3.2	silty-clay	mod. water, firm	brown-orange			3
94SCAA-3112		f. sand	high water, well sorted	uniform, rusty colour			7
94SCAA-3113				uniform			lots of broken shells

EXPERIMENTAL DESIGN	STIMULI COND.	MEASUREMENT TYPE	CHARACTERISTICS OF STIMULI	MEASUREMENT CHARACTERISTICS	ANALYSIS METHOD	RESULTS
1	1	1	1	1	1	1
2	2	2	2	2	2	2
3	3	3	3	3	3	3
4	4	4	4	4	4	4
5	5	5	5	5	5	5
6	6	6	6	6	6	6
7	7	7	7	7	7	7
8	8	8	8	8	8	8
9	9	9	9	9	9	9
10	10	10	10	10	10	10
11	11	11	11	11	11	11
12	12	12	12	12	12	12
13	13	13	13	13	13	13
14	14	14	14	14	14	14
15	15	15	15	15	15	15
16	16	16	16	16	16	16
17	17	17	17	17	17	17
18	18	18	18	18	18	18
19	19	19	19	19	19	19
20	20	20	20	20	20	20
21	21	21	21	21	21	21
22	22	22	22	22	22	22
23	23	23	23	23	23	23
24	24	24	24	24	24	24
25	25	25	25	25	25	25
26	26	26	26	26	26	26
27	27	27	27	27	27	27
28	28	28	28	28	28	28
29	29	29	29	29	29	29
30	30	30	30	30	30	30
31	31	31	31	31	31	31
32	32	32	32	32	32	32
33	33	33	33	33	33	33
34	34	34	34	34	34	34
35	35	35	35	35	35	35
36	36	36	36	36	36	36
37	37	37	37	37	37	37
38	38	38	38	38	38	38
39	39	39	39	39	39	39
40	40	40	40	40	40	40
41	41	41	41	41	41	41
42	42	42	42	42	42	42
43	43	43	43	43	43	43
44	44	44	44	44	44	44
45	45	45	45	45	45	45
46	46	46	46	46	46	46
47	47	47	47	47	47	47
48	48	48	48	48	48	48
49	49	49	49	49	49	49
50	50	50	50	50	50	50
51	51	51	51	51	51	51
52	52	52	52	52	52	52
53	53	53	53	53	53	53
54	54	54	54	54	54	54
55	55	55	55	55	55	55
56	56	56	56	56	56	56
57	57	57	57	57	57	57
58	58	58	58	58	58	58
59	59	59	59	59	59	59
60	60	60	60	60	60	60
61	61	61	61	61	61	61
62	62	62	62	62	62	62
63	63	63	63	63	63	63
64	64	64	64	64	64	64
65	6					

95

Appendix III: Description of surficial lake sediment

Sample ID	Depth (cm)	Grain Size	Moisture	Color	Texture	Notes	Length	Width	Thickness
94SCAL-S002	5Y 2.5,1	clay-f.sand	v. well sorted, liquid	dark brown					9.5
94SCAL-S003	5Y 2.5,1	clay	high-mod. water						
94SCAL-S004									
94SCAK-S001	2.5Y 3,2	clay	liquid						
94SCAK-S002		clay	mod. water	brownish					1
94SCAK-S003		clay	liquid						6.5
94SCAK-S004		clay	mod. water, black stripes				7-8, 3.5-4.5, 2-2.5		2.5
94SCAS-S001	5Y 3,2	f. sand	high water						3
94SCAS-S002	5Y 2.5,2	clay	low water, firm	uniform					5
94SCAS-S003	5Y 2.5,2	clay	liquid	uniform					5
94SCAS-S004	5Y 3,2	clay	low water, cohesive, firm	weak rusty orange					6

* Length, Width, Thickness of shells

X-Ray **SEM**

#1

2mm

#2

5mm

#3

5mm

Appendix IV: Analytical data from nodule samples collected in lac Aylmer

Microprobe Analyses on nodule sample 94SCAA-S100

* for all elements greater than 2 wt% the analytical uncertainty is $\pm 2\%$, for elements between 1-2 wt% the analytical uncertainty is $\pm 10\%$, and for elements less than 1 wt% the analytical uncertainty is the detection limit

	Na2O (%)	K2O (%)	MgO (%)	FeO (%)	F (%)	SiO2 (%)	MnO (%)	Cl (%)	BaO (%)	CaO (%)	Al2O3 (%)	Cr2O3 (%)	NiO (%)	ZnO (%)	TiO2 (%)	SrO (%)	V2O3 (%)	SO3 (%)	P2O5 (%)	TOTAL (%)
Transect AB																				
	0.2	1.0	0.1	55.8	0.0	7.7	0.5	0.1	0.1	0.2	8.6	0.1	0.1	0.0	0.0	0.1	0.1	0.2	0.4	75.2
	0.0	0.1	0.1	66.6	0.0	3.4	0.5	0.0	0.0	0.2	8.5	0.0	0.0	0.2	0.0	0.0	0.0	0.1	0.5	80.3
	0.0	0.0	0.0	64.7	0.0	2.6	0.5	0.0	0.0	0.3	7.4	0.0	0.0	0.1	0.1	0.1	0.0	0.1	0.6	76.5
	0.2	4.2	0.5	35.2	0.0	25.2	0.3	0.0	0.0	0.1	11.2	0.0	0.0	0.1	0.0	0.0	0.0	0.2	0.3	77.7
	0.1	0.0	0.1	69.5	0.0	3.5	0.6	0.0	0.0	0.1	4.4	0.0	0.0	0.0	0.0	0.2	0.0	0.1	0.4	79.1
	0.0	0.1	0.1	68.0	0.0	3.4	0.7	0.0	0.0	0.2	7.7	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.3	80.7
	0.0	0.1	0.0	66.5	0.0	2.8	0.7	0.0	0.1	0.1	7.8	0.0	0.2	0.1	0.0	0.1	0.0	0.8	0.4	79.8
	0.0	0.1	0.0	64.0	0.0	3.2	0.5	0.0	0.0	0.1	8.3	0.0	0.1	0.1	0.0	0.1	0.0	0.5	0.6	77.6
	0.1	0.1	0.0	64.1	0.0	2.5	0.7	0.0	0.0	0.2	9.9	0.0	0.0	0.0	0.0	0.0	0.1	0.9	0.7	79.5
	0.1	0.1	0.1	69.3	0.0	2.4	0.6	0.0	0.0	0.3	4.9	0.0	0.1	0.1	0.0	0.0	0.0	1.2	0.5	79.7
	0.0	0.2	0.2	66.9	0.0	4.6	0.6	0.0	0.1	0.1	6.2	0.0	0.0	0.0	0.1	0.1	0.0	0.3	0.3	79.7
	0.0	0.0	0.0	68.6	0.0	2.8	0.7	0.0	0.1	0.1	4.0	0.0	0.0	0.0	0.0	0.1	0.0	0.3	0.3	77.1
	0.2	0.3	0.0	68.6	0.0	3.6	0.5	0.0	0.1	0.1	4.9	0.0	0.0	0.1	0.1	0.0	0.0	1.4	0.5	80.2
	0.0	0.1	0.0	69.0	0.0	3.3	0.5	0.0	0.0	0.1	3.9	0.0	0.0	0.0	0.0	0.0	0.1	0.8	0.4	78.4
	0.0	0.0	0.0	68.0	0.0	3.4	0.5	0.0	0.1	0.1	3.3	0.0	0.1	0.1	0.0	0.1	0.0	0.7	0.3	76.7
	0.0	0.0	0.0	66.6	0.0	3.4	0.4	0.0	0.0	0.1	5.0	0.0	0.1	0.0	0.0	0.0	0.0	0.5	0.3	76.4
	0.0	0.0	0.0	65.2	0.0	3.0	0.6	0.0	0.1	0.1	5.0	0.1	0.1	0.1	0.0	0.2	0.1	0.7	0.2	75.5
	0.0	0.0	0.1	65.2	0.0	3.2	0.5	0.0	0.1	0.1	6.3	0.1	0.1	0.0	0.0	0.1	0.0	0.9	0.5	77.0
	0.2	0.1	0.0	67.7	0.0	4.2	0.8	0.0	0.0	0.1	6.7	0.0	0.1	0.0	0.1	0.0	0.0	0.7	0.4	81.2
	0.0	0.1	0.0	65.6	0.0	3.6	0.6	0.0	0.0	0.1	6.6	0.0	0.1	0.0	0.0	0.0	0.0	0.6	0.4	77.7
	0.1	0.2	0.1	66.9	0.0	4.5	0.6	0.0	0.1	0.1	4.5	0.0	0.1	0.0	0.0	0.0	0.0	0.2	0.3	77.7
	0.0	0.0	0.1	65.3	0.0	3.1	0.5	0.0	0.1	0.1	7.2	0.0	0.0	0.1	0.1	0.0	0.1	0.4	0.4	77.6
	0.1	0.1	0.1	65.8	0.0	3.8	0.6	0.0	0.0	0.1	8.7	0.0	0.1	0.2	0.0	0.0	0.0	1.0	0.4	81.2
	0.1	0.1	0.1	66.2	0.0	3.6	0.7	0.0	0.0	0.1	7.3	0.0	0.2	0.0	0.0	0.0	0.1	1.2	0.7	80.5
	0.0	0.1	0.0	65.0	0.0	3.1	0.5	0.0	0.1	0.1	7.1	0.0	0.1	0.0	0.0	0.0	0.0	0.8	0.7	77.4
	0.0	0.0	0.1	67.1	0.0	3.4	0.6	0.0	0.0	0.1	5.3	0.1	0.0	0.2	0.1	0.1	0.0	1.0	0.7	78.8
	0.0	0.0	0.0	65.9	0.0	3.0	0.4	0.0	0.0	0.1	5.6	0.1	0.0	0.0	0.0	0.1	0.1	0.2	0.6	76.1
	0.0	0.2	0.1	65.6	0.0	3.7	0.4	0.0	0.0	0.1	9.6	0.0	0.0	0.1	0.0	0.0	0.0	0.4	0.5	80.7

Appendix IV: Analytical data from nodule samples collected in lac Aymer

Na2O (%)	K2O (%)	MgO (%)	FeO (%)	F (%)	SiO2 (%)	MnO (%)	Cl (%)	BaO (%)	CaO (%)	Al2O3 (%)	Cr2O3 (%)	NiO (%)	ZnO (%)	TiO2 (%)	SrO (%)	V2O3 (%)	SO3 (%)	P2O5 (%)	TOTAL (%)
0.1	0.1	0.0	68.4	0.0	3.0	0.5	0.0	0.0	0.1	5.8	0.0	0.1	0.0	0.0	0.1	0.0	0.6	0.7	79.6
0.0	0.0	0.1	69.2	0.0	3.0	0.5	0.1	0.0	0.1	5.7	0.0	0.1	0.0	0.0	0.0	0.0	0.3	0.6	79.6
0.0	0.2	0.1	68.0	0.0	3.3	0.5	0.0	0.1	0.1	3.9	0.0	0.1	0.1	0.1	0.0	0.1	0.0	0.4	77.1
0.0	1.3	0.2	61.0	0.0	10.0	0.4	0.0	0.1	0.1	5.7	0.0	0.1	0.1	0.1	0.0	0.0	0.2	0.5	79.7
0.0	0.1	0.1	69.8	0.0	3.1	0.5	0.0	0.1	0.1	4.7	0.0	0.2	0.0	0.1	0.0	0.0	0.0	0.4	79.3
0.0	0.1	0.0	69.0	0.0	2.6	0.5	0.0	0.1	0.1	4.5	0.0	0.1	0.1	0.0	0.0	0.0	0.2	0.6	77.8
0.0	0.0	0.0	67.8	0.0	2.4	0.4	0.0	0.1	0.1	4.4	0.0	0.0	0.0	0.0	0.0	0.1	0.4	0.8	76.5
0.1	0.1	0.1	67.8	0.0	2.9	0.5	0.0	0.1	0.1	4.8	0.1	0.1	0.0	0.0	0.0	0.1	1.1	0.8	78.7
0.0	0.1	0.0	70.0	0.0	3.2	0.4	0.0	0.0	0.1	3.5	0.0	0.0	0.0	0.1	0.0	0.3	0.5	0.5	78.9
0.0	0.0	0.0	69.6	0.0	3.4	0.6	0.0	0.0	0.1	3.5	0.0	0.2	0.0	0.1	0.0	0.0	0.0	0.5	78.0
0.0	0.1	0.1	67.7	0.0	3.4	0.5	0.0	0.1	0.1	4.0	0.0	0.1	0.0	0.0	0.0	0.1	0.2	0.3	76.7
0.0	0.0	0.0	23.2	0.0	1.0	0.7	0.3	0.0	0.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	26.2
0.0	0.2	0.1	67.3	0.0	6.1	1.3	0.0	0.0	0.2	5.2	0.0	0.1	0.1	0.1	0.0	0.1	0.0	0.6	81.5
0.0	0.0	0.1	57.2	0.0	17.2	0.9	0.1	0.1	0.1	1.6	0.0	0.0	0.0	0.2	0.0	0.0	0.2	0.2	77.8
0.0	0.1	0.1	69.9	0.0	3.4	1.3	0.0	0.1	0.2	1.2	0.0	0.1	0.0	0.1	0.1	0.1	0.0	0.5	77.0
0.0	0.0	0.1	29.8	0.0	2.9	0.6	0.3	0.0	0.2	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.2	35.4
0.0	0.0	0.0	19.6	0.0	0.5	0.4	0.7	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.1	21.8
0.0	0.0	0.0	66.7	0.0	3.1	1.4	0.0	0.0	0.1	1.7	0.0	0.1	0.0	0.1	0.1	0.1	0.0	0.3	73.8
0.0	0.1	0.1	67.9	0.0	4.5	1.7	0.0	0.1	0.1	2.1	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.2	77.1
0.0	0.1	0.1	71.1	0.0	4.6	1.0	0.0	0.0	0.1	2.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.2	79.5
0.0	0.1	0.1	49.2	0.0	15.1	1.1	0.1	0.0	0.0	2.3	0.0	0.0	0.1	0.6	0.0	0.0	0.0	0.2	68.3
0.0	0.2	0.0	43.6	0.0	5.0	1.2	0.2	0.0	0.1	4.6	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.2	55.4
0.0	0.1	0.0	33.0	0.0	2.7	0.6	0.2	0.0	0.0	2.1	0.0	0.1	0.0	0.1	0.1	0.0	0.2	0.1	39.4
0.0	0.1	0.1	40.9	0.0	3.0	0.8	0.3	0.0	0.1	2.6	0.0	0.1	0.0	0.1	0.0	0.0	0.1	0.2	48.4
0.0	0.0	0.0	0.8	0.0	95.4	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	96.5
0.0	0.0	0.1	67.7	0.0	1.4	2.1	0.1	0.0	0.2	0.9	0.0	0.1	0.2	0.2	0.1	0.0	0.3	0.3	73.7
0.0	0.1	0.0	68.5	0.0	12.0	1.2	0.0	0.9	0.1	2.0	0.0	0.1	0.1	0.0	0.0	0.1	0.1	0.2	84.4
0.0	0.1	0.0	30.8	0.0	0.0	0.5	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.3	0.2	32.3
0.0	0.2	0.1	66.1	0.0	7.7	1.4	0.0	0.0	0.1	3.1	0.0	0.2	0.0	0.1	0.0	0.0	0.5	0.4	79.9
0.0	0.0	0.1	69.2	0.0	4.0	2.2	0.0	0.1	0.1	3.9	0.0	0.1	0.2	0.0	0.1	0.0	0.1	0.4	80.4
12.6	0.0	0.1	3.6	0.0	63.6	0.1	0.0	0.1	0.0	17.6	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1	98.1
0.0	0.1	0.0	69.2	0.0	3.6	1.9	0.0	0.1	0.0	2.9	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.4	78.7

Appendix IV: Analytical data from nodule samples collected in lac Aylmer

Na2O (%)	K2O (%)	MgO (%)	FeO (%)	F (%)	SiO2 (%)	MnO (%)	Cl (%)	BaO (%)	CaO (%)	Al2O3 (%)	Cr2O3 (%)	NiO (%)	ZnO (%)	TiO2 (%)	SnO (%)	V2O3 (%)	SO3 (%)	P2O5 (%)	TOTAL (%)
0.0	0.0	0.0	70.2	0.0	3.7	1.9	0.0	0.0	0.0	2.3	0.0	0.1	0.2	0.0	0.0	0.0	0.2	0.4	79.2
0.0	0.0	0.0	69.7	0.0	3.4	1.0	0.0	0.1	0.0	3.7	0.1	0.1	0.0	0.1	0.0	0.0	0.3	0.4	78.9
0.0	0.3	0.1	66.9	0.0	4.7	1.7	0.0	0.1	0.1	4.7	0.0	0.2	0.0	0.1	0.0	0.0	0.1	0.4	79.1
0.2	4.5	1.2	41.2	0.0	21.9	0.4	0.0	0.1	0.0	13.8	0.1	0.1	0.1	0.1	0.0	0.0	0.2	0.2	84.1
0.1	0.1	0.0	68.9	0.0	4.3	0.5	0.1	0.0	0.1	4.2	0.0	0.1	0.1	0.1	0.0	0.1	0.6	0.5	79.8
0.0	0.1	0.0	70.9	0.0	1.4	1.0	0.1	0.0	0.0	1.3	0.1	0.1	0.1	0.0	0.0	0.1	0.6	0.4	76.2
0.0	0.1	0.0	71.3	0.0	3.6	0.6	0.0	0.1	0.1	1.9	0.0	0.2	0.0	0.0	0.0	0.0	0.5	0.5	78.9
0.0	0.0	0.0	70.0	0.0	3.1	0.5	0.0	0.1	0.0	2.8	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.5	77.5
0.0	0.1	0.1	70.6	0.0	3.3	0.4	0.0	0.0	0.1	2.7	0.0	0.1	0.1	0.0	0.0	0.1	0.3	0.4	78.3
0.0	0.0	0.0	69.7	0.0	3.1	0.6	0.0	0.1	0.1	2.7	0.0	0.1	0.2	0.3	0.0	0.0	0.1	0.4	77.5
0.2	1.6	0.2	59.8	0.0	8.5	0.5	0.0	0.1	0.0	5.6	0.1	0.1	0.0	0.0	0.0	0.0	0.5	0.4	77.6
0.0	0.2	0.0	38.5	0.0	58.1	0.4	0.0	0.0	0.1	2.4	0.0	0.1	0.0	0.0	0.1	0.1	0.2	0.3	100.6
0.0	0.1	0.0	69.1	0.0	3.5	0.6	0.1	0.0	0.1	3.5	0.0	0.1	0.2	0.1	0.1	0.0	0.2	0.3	77.2
0.0	0.2	0.0	68.0	0.0	4.2	0.6	0.0	0.1	0.1	5.1	0.1	0.1	0.2	0.1	0.0	0.1	0.0	0.4	79.2
0.0	0.0	0.0	63.8	0.0	3.0	0.9	0.1	0.0	0.0	2.3	0.0	0.0	0.2	0.0	0.0	0.1	0.0	0.4	70.8
0.0	0.2	0.0	36.3	0.0	66.4	0.3	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	103.8
0.0	0.1	0.0	62.6	0.0	14.1	0.5	0.0	0.0	0.0	1.6	0.0	0.0	0.2	0.1	0.1	0.1	0.3	0.3	80.1
0.2	3.4	0.9	48.5	0.0	17.3	0.5	0.1	0.1	0.0	12.6	0.0	0.1	0.2	0.1	0.1	0.0	0.3	0.2	84.5
0.0	0.2	0.1	65.9	0.0	4.3	0.5	0.0	0.0	0.0	5.5	0.0	0.1	0.0	0.0	0.1	0.0	0.4	0.4	77.8
0.3	3.5	0.4	42.7	0.0	21.2	0.4	0.0	0.1	0.1	9.9	0.0	0.1	0.1	0.1	0.0	0.0	0.2	0.3	79.5
0.0	0.1	0.0	70.2	0.0	3.5	0.5	0.0	0.0	0.1	2.4	0.0	0.1	0.2	0.1	0.0	0.0	0.4	0.3	78.0
0.1	0.5	0.1	68.3	0.0	5.4	0.5	0.0	0.0	0.0	3.7	0.1	0.1	0.0	0.2	0.0	0.1	0.4	0.5	80.0
0.1	0.2	0.1	68.2	0.0	8.4	0.5	0.0	0.0	0.0	4.3	0.0	0.1	0.0	0.0	0.0	0.0	0.5	0.3	82.9
0.1	0.4	0.1	67.0	0.0	4.7	0.7	0.0	0.0	0.0	6.0	0.0	0.2	0.1	0.0	0.0	0.0	0.4	0.4	80.1
0.0	0.2	0.0	70.1	0.0	3.8	0.5	0.0	0.1	0.1	2.4	0.0	0.2	0.0	0.1	0.1	0.0	0.1	0.3	77.9
0.0	0.1	0.0	70.6	0.0	3.3	0.6	0.0	0.0	0.1	2.5	0.0	0.1	0.1	0.1	0.0	0.0	0.4	0.3	78.2
0.0	0.1	0.4	70.4	0.0	4.2	0.6	0.1	0.0	0.1	2.8	0.1	0.1	0.2	0.1	0.0	0.0	0.3	0.3	79.8
0.2	0.5	0.1	66.6	0.0	7.3	0.5	0.0	0.1	0.0	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.2	80.2
0.0	0.1	0.0	69.3	0.0	3.4	0.4	0.0	0.1	0.0	2.4	0.1	0.1	0.1	0.0	0.1	0.1	0.3	0.3	76.7
0.0	0.2	0.1	69.9	0.0	3.9	0.6	0.0	0.0	0.0	2.5	0.0	0.1	0.0	0.2	0.1	0.0	0.2	0.2	77.8
0.3	0.5	0.1	64.9	0.0	8.6	0.5	0.0	0.0	0.0	5.2	0.0	0.1	0.0	0.0	0.0	0.0	0.8	0.3	81.3
0.0	0.2	0.1	52.1	0.0	10.8	0.4	0.0	0.0	0.0	6.5	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.2	75.5

Appendix IV: Analytical data from nodule samples collected in lac Aylmer

Na2O (%)	K2O (%)	MgO (%)	FeO (%)	F (%)	SiO2 (%)	MnO (%)	Cl (%)	BaO (%)	CaO (%)	Al2O3 (%)	Cr2O3 (%)	NiO (%)	ZnO (%)	TiO2 (%)	SiO (%)	V2O3 (%)	SO3 (%)	P2O5 (%)	TOTAL (%)
0.0	0.1	0.1	68.3	0.0	3.1	0.5	0.0	0.0	0.1	3.9	0.0	0.2	0.1	0.2	0.1	0.0	0.3	0.3	77.3
0.0	0.2	0.1	68.0	0.0	6.7	0.5	0.0	0.0	0.0	5.3	0.0	0.1	0.1	0.1	0.0	0.0	0.3	0.5	82.0
0.0	1.0	0.5	54.4	0.0	17.8	0.5	0.0	0.0	0.0	7.4	0.0	0.2	0.0	0.1	0.0	0.0	0.1	0.4	82.5
0.0	0.0	0.0	5.5	0.0	0.4	0.1	1.0	0.0	0.0	0.3	0.0	0.0	0.1	0.0	0.1	0.0	0.4	0.2	8.2
0.0	0.0	0.0	66.5	0.0	2.9	0.7	0.0	0.1	0.1	0.1	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.1	70.7
0.0	0.1	0.1	69.5	0.0	2.4	0.6	0.0	0.0	0.1	3.3	0.1	0.2	0.1	0.0	0.0	0.0	0.1	0.3	76.7
0.1	0.3	0.1	65.4	0.0	4.6	0.4	0.0	0.0	0.0	7.8	0.1	0.2	0.1	0.1	0.0	0.0	0.1	0.5	80.1
0.0	0.0	0.0	71.2	0.0	3.0	0.7	0.0	0.0	0.0	0.2	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.3	75.8
Transect CD																			
0.0	0.1	0.5	57.1	0.5	4.5	0.6	0.0	0.0	0.3	16.1	0.1	0.1	0.1	0.0	0.1	0.1	0.5	2.2	82.9
0.2	0.3	0.1	61.6	0.0	4.7	0.5	0.0	0.0	0.2	12.2	0.0	0.1	0.1	0.1	0.1	0.1	1.2	1.8	83.3
0.2	0.1	0.1	62.6	0.0	4.0	0.6	0.0	0.0	0.2	11.9	0.0	0.1	0.0	0.1	0.0	0.0	0.9	1.4	82.4
0.1	0.1	0.1	68.9	0.0	3.2	0.5	0.0	0.0	0.2	5.7	0.0	0.0	0.1	0.1	0.0	0.1	0.5	0.9	80.6
0.1	0.0	0.0	67.3	0.0	2.9	0.5	0.0	0.1	0.1	5.9	0.1	0.1	0.1	0.0	0.0	0.0	0.2	0.6	78.0
0.2	0.0	0.1	67.9	0.0	3.8	0.5	0.1	0.0	0.1	4.8	0.0	0.1	0.2	0.0	0.0	0.0	0.8	0.6	79.3
0.0	0.0	0.0	65.3	0.0	4.0	0.4	0.0	0.0	0.1	7.3	0.1	0.0	0.0	0.0	0.0	0.1	0.7	0.6	78.7
0.0	0.1	0.0	62.2	0.0	3.5	0.7	0.0	0.1	0.1	4.4	0.0	0.1	0.1	0.0	0.1	0.0	0.4	0.5	72.3
0.1	0.0	0.0	69.3	0.0	3.2	0.5	0.0	0.0	0.2	3.6	0.0	0.2	0.2	0.0	0.0	0.0	0.6	0.3	78.2
0.1	0.2	0.1	65.7	0.0	5.0	0.5	0.0	0.0	0.1	6.0	0.0	0.0	0.0	0.1	0.0	0.0	0.4	0.6	78.9
0.0	0.0	0.1	67.5	0.0	3.7	0.5	0.0	0.1	0.1	4.8	0.0	0.0	0.0	0.2	0.1	0.0	0.4	0.4	77.9
0.1	0.1	0.1	69.6	0.0	3.8	0.4	0.0	0.0	0.1	4.3	0.0	0.1	0.0	0.0	0.1	0.1	0.4	0.4	79.6
0.0	0.0	0.0	68.3	0.1	3.6	0.5	0.0	0.0	0.1	6.3	0.0	0.1	0.0	0.1	0.1	0.1	0.6	0.6	80.5
0.2	0.0	0.1	66.7	0.0	4.5	0.5	0.0	0.0	0.2	8.2	0.1	0.1	0.0	0.0	0.0	0.1	0.6	0.3	81.7
0.0	0.1	0.0	68.7	0.0	4.1	0.5	0.0	0.1	0.1	5.0	0.0	0.1	0.0	0.1	0.0	0.0	0.3	0.6	79.8
0.0	0.4	0.2	63.3	0.0	6.2	0.4	0.0	0.1	0.1	6.5	0.0	0.0	0.1	0.0	0.1	0.0	0.3	0.5	78.3
0.1	2.2	0.8	55.0	0.1	13.8	0.4	0.0	0.0	0.0	15.2	0.0	0.1	0.0	0.0	0.0	0.0	0.4	0.3	88.4
0.0	0.0	0.1	66.0	0.0	2.7	0.7	0.0	0.1	0.1	1.4	0.0	0.1	0.0	0.1	0.1	0.0	0.1	0.3	71.8
0.0	0.0	0.1	68.6	0.0	2.8	0.4	0.0	0.0	0.1	4.2	0.0	0.1	0.0	0.1	0.0	0.0	0.1	0.5	76.8
0.0	0.0	0.0	70.3	0.0	2.8	0.5	0.0	0.0	0.1	3.8	0.0	0.1	0.0	0.1	0.0	0.0	0.2	0.7	78.8
0.0	0.1	0.0	69.4	0.0	2.7	0.5	0.0	0.0	0.1	2.9	0.0	0.1	0.1	0.0	0.0	0.0	0.2	0.6	76.7
0.0	0.1	0.1	70.9	0.0	2.9	0.4	0.0	0.0	0.1	3.7	0.0	0.1	0.0	0.1	0.1	0.0	0.5	0.5	79.4
0.0	0.0	0.0	71.4	0.0	2.8	0.4	0.1	0.1	0.1	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	79.4

Appendix IV: Analytical data from nodule samples collected in lac Aylmer

Na2O (%)	K2O (%)	MgO (%)	FeO (%)	F (%)	SiO2 (%)	MnO (%)	Cl (%)	BaO (%)	CaO (%)	Al2O3 (%)	Cr2O3 (%)	NiO (%)	ZnO (%)	TiO2 (%)	SrO (%)	V2O3 (%)	SO3 (%)	P2O5 (%)	TOTAL (%)
00	00	00	70.0	00	3.0	0.3	00	00	01	4.4	0.1	01	01	00	00	01	02	06	79.1
00	01	00	69.8	00	2.9	0.4	00	01	00	3.5	0.1	01	00	01	00	00	00	05	77.7
00	00	00	70.3	00	2.8	0.4	00	00	01	3.1	6.0	01	00	00	00	01	04	04	77.7
00	00	6.0	45.0	00	15.4	0.7	00	00	00	15.3	0.1	01	00	00	00	00	01	02	83.0
00	01	00	68.1	00	3.7	0.5	00	01	01	5.7	0.1	01	03	01	00	01	01	06	79.5
00	02	01	68.1	00	5.2	0.5	00	00	01	6.6	00	01	01	01	00	00	00	05	81.6
00	01	00	71.1	00	2.7	0.4	00	00	00	1.3	00	00	01	00	01	01	00	03	76.4
00	02	01	72.8	00	3.9	0.5	00	00	01	2.2	0.1	00	00	01	00	00	01	03	80.5
00	00	00	72.8	00	3.1	0.7	00	00	01	1.5	00	01	01	02	00	00	00	02	79.0
00	00	00	72.4	00	3.0	0.5	00	00	01	1.5	00	01	00	01	01	01	01	06	78.6
00	00	00	09	00	01	0.1	03	00	00	00	00	00	00	00	00	00	00	00	1.5
00	00	00	73.3	00	3.1	0.7	00	00	01	1.0	00	01	02	00	00	00	00	02	78.8
00	00	01	72.4	00	3.0	0.8	00	00	01	1.5	00	00	01	00	02	00	06	02	79.0
00	00	01	1.7	00	62.3	0.1	00	00	00	00	01	00	01	00	00	00	00	00	64.5
00	01	01	72.0	00	3.3	0.9	00	00	01	2.2	00	02	01	00	00	01	01	01	79.3
00	01	01	71.9	00	3.1	0.7	00	01	01	1.4	00	00	00	00	00	00	00	02	77.5
00	00	00	56.6	00	2.7	2.8	00	00	01	0.4	00	00	01	00	01	00	02	02	63.2
00	01	00	70.9	00	3.8	0.6	00	01	01	1.6	00	00	00	00	00	00	00	02	77.4
00	00	00	71.3	00	3.7	0.9	00	00	01	1.5	00	01	00	00	00	00	04	02	78.4
00	01	01	70.7	00	4.3	0.7	00	01	02	2.8	00	01	00	00	00	00	04	02	79.8
00	00	12.7	28.1	00	21.8	0.7	00	01	01	15.4	01	01	01	01	00	00	04	00	79.8
01	02	01	59.6	00	17.1	0.7	01	00	01	3.8	00	00	02	01	00	00	04	01	82.7
02	01	01	69.5	00	4.1	0.8	00	00	02	5.2	01	01	00	00	00	00	10	03	81.6
00	00	00	68.1	00	4.2	1.6	00	00	01	3.6	00	01	00	00	01	00	01	03	78.4
00	00	00	71.5	00	3.8	0.6	00	01	01	2.2	01	01	01	00	01	00	03	03	79.5
00	02	03	71.0	00	5.2	0.9	00	01	01	4.5	00	00	01	00	00	00	02	02	82.8
01	01	00	65.8	00	11.7	1.5	00	01	01	2.1	00	00	01	01	00	01	04	03	82.5
00	13	03	48.8	00	16.7	1.1	00	02	01	13.7	00	00	00	01	00	01	05	02	83.2
00	04	01	55.3	00	6.5	1.2	00	01	01	4.3	01	01	00	01	01	00	06	03	69.4
01	01	01	66.4	00	5.8	0.9	00	00	01	2.8	01	01	03	01	00	01	03	05	77.8
00	02	01	67.2	00	4.2	2.0	00	00	01	3.9	00	01	00	00	00	00	02	04	78.5
00	00	01	69.6	00	3.4	2.4	00	01	01	2.3	01	00	02	01	00	00	01	04	78.9

Appendix IV: Analytical data from nodule samples collected in lac Aylmer

Na2O (%)	K2O (%)	MgO (%)	FeO (%)	F (%)	SiO2 (%)	MnO (%)	Cl (%)	BaO (%)	CaO (%)	Al2O3 (%)	Cr2O3 (%)	NiO (%)	ZnO (%)	TiO2 (%)	SiO (%)	V2O3 (%)	SO3 (%)	P2O5 (%)	TOTAL (%)
0.1	0.0	0.1	69.6	0.0	3.1	1.6	0.0	0.0	0.1	2.8	0.1	0.2	0.0	0.0	0.0	0.0	0.1	0.5	78.2
9.0	0.3	0.1	68.3	0.0	5.8	0.7	0.0	0.1	0.1	3.9	0.1	0.2	0.2	0.1	0.0	0.0	0.3	0.4	80.7
0.0	0.0	0.0	69.2	0.0	3.5	1.9	0.0	0.0	0.0	2.5	0.1	0.1	0.0	0.1	0.0	0.0	0.2	0.4	78.0
0.0	0.0	0.0	69.7	0.0	4.5	1.2	0.0	0.1	0.1	3.5	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.4	79.8
0.1	0.8	0.2	64.6	0.0	8.7	0.9	0.0	0.2	0.0	11.5	0.0	0.1	0.1	0.1	0.0	0.0	0.2	0.5	88.1
0.1	0.1	0.1	69.0	0.0	3.0	0.5	0.0	0.1	0.0	3.4	0.0	0.0	0.0	0.1	0.0	0.0	0.4	0.4	77.4
0.0	0.0	0.1	71.3	0.0	3.2	0.6	0.0	0.1	0.1	3.2	0.0	0.1	0.1	0.0	0.0	0.0	0.7	0.5	80.0
0.1	0.1	0.0	65.9	0.0	10.3	0.6	0.0	0.0	0.1	4.6	0.1	0.0	0.0	0.1	0.0	0.0	0.7	0.4	83.1
0.3	1.2	0.1	61.8	0.0	8.2	0.6	0.0	0.0	0.0	5.2	0.0	0.1	0.0	0.2	0.0	0.0	0.2	0.2	78.2
0.0	0.1	0.1	70.5	0.0	3.0	0.6	0.0	0.1	0.0	1.5	0.1	0.1	0.1	0.0	0.0	0.0	0.3	0.2	76.6
0.0	0.0	0.0	68.6	0.0	4.1	0.4	0.0	0.0	0.1	2.3	0.1	0.0	0.0	0.1	0.0	0.0	0.5	0.2	76.5
0.3	3.0	0.2	50.2	0.0	17.9	0.4	0.0	0.1	0.0	11.0	0.1	0.1	0.2	0.3	0.0	0.0	0.3	0.2	84.2
0.0	0.2	0.0	68.7	0.0	3.7	0.5	0.0	0.0	0.1	2.9	0.0	0.1	0.0	0.1	0.0	0.1	0.9	0.2	77.7
0.0	0.0	0.0	1.2	0.0	99.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	100.6
0.0	0.4	0.2	70.6	0.0	6.7	0.4	0.0	0.1	0.1	3.3	0.0	0.1	0.0	0.0	0.0	0.0	0.6	0.3	82.8
0.6	0.1	0.1	68.8	0.0	4.6	0.5	0.0	0.1	0.1	2.4	0.0	0.1	0.1	0.0	0.1	0.0	0.2	0.2	78.0
0.0	0.2	0.0	43.3	0.0	47.6	0.3	0.0	0.0	0.0	1.5	0.1	0.1	0.0	0.1	0.0	0.0	0.3	0.1	93.8
0.2	0.1	0.0	71.3	0.0	4.4	0.7	0.0	0.0	0.1	4.2	0.0	0.2	0.1	0.1	0.0	0.1	0.2	0.4	81.9
0.1	0.1	0.1	61.9	0.0	14.2	0.6	0.0	0.0	0.1	3.4	0.0	0.1	0.0	0.1	0.1	0.0	0.4	0.2	81.3
0.1	0.1	0.0	70.1	0.0	4.8	0.6	0.0	0.0	0.0	3.8	0.0	0.0	0.0	0.1	0.0	0.0	0.6	0.3	80.7
0.1	0.4	0.1	68.1	0.0	6.0	0.5	0.0	0.0	0.1	5.4	0.1	0.1	0.2	0.1	0.1	0.0	0.7	0.4	82.3
0.0	0.4	0.1	67.7	0.0	5.9	0.6	0.0	0.1	0.1	4.8	0.1	0.0	0.0	0.1	0.1	0.0	0.3	0.4	80.7
0.5	0.2	0.1	66.5	0.0	6.2	0.6	0.0	0.1	0.1	4.4	0.1	0.1	0.1	0.2	0.1	0.1	0.9	0.4	80.5
0.0	0.1	0.0	68.1	0.0	3.9	0.5	0.0	0.1	0.1	4.1	0.1	0.0	0.3	0.0	0.0	0.0	0.4	0.4	78.0
0.0	0.2	0.1	69.6	0.0	4.2	0.6	0.1	0.0	0.1	5.1	0.0	0.1	0.1	0.0	0.0	0.0	0.4	0.4	81.1
0.0	0.3	0.1	68.2	0.0	4.6	0.6	0.0	0.0	0.0	4.9	0.1	0.1	0.0	0.2	0.0	0.0	0.4	0.4	80.0
0.0	0.4	0.1	67.4	0.0	5.3	0.5	0.0	0.0	0.1	5.2	0.1	0.1	0.1	0.0	0.0	0.0	0.5	0.3	80.1
0.0	0.1	0.1	68.8	0.0	3.9	0.7	0.0	0.0	0.1	5.5	0.0	0.2	0.1	0.2	0.1	0.0	0.6	0.4	80.8
0.0	0.0	0.1	24.5	0.0	1.0	0.4	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	26.7
0.0	0.0	0.0	1.2	0.0	97.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	99.2
0.0	0.2	0.1	63.1	0.0	4.7	0.6	0.1	0.1	0.1	5.9	0.1	0.1	0.1	0.1	0.0	0.0	0.6	0.3	76.3
0.0	0.0	0.1	55.2	0.0	2.9	0.5	0.0	0.0	0.1	4.9	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.1	64.2

Appendix IV: Analytical data from nodule samples collected in lac Aylmer

	Na2O (%)	K2O (%)	MgO (%)	FeO (%)	F (%)	SiO2 (%)	MnO (%)	Cl (%)	BaO (%)	CaO (%)	Al2O3 (%)	Cr2O3 (%)	NiO (%)	ZnO (%)	TiO2 (%)	SiO (%)	V2O3 (%)	SO3 (%)	P2O5 (%)	TOTAL (%)
	0.0	0.0	0.0	63.9	0.0	2.4	0.6	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.1	0.0	0.0	0.2	0.3	68.7
	0.0	6.6	0.9	28.3	0.0	28.3	0.4	0.0	0.1	0.0	11.8	0.0	0.1	0.2	0.5	0.0	0.1	0.1	0.2	77.4
	0.0	0.4	0.0	4.6	0.0	2.7	0.0	0.1	0.1	0.0	0.4	0.0	0.0	0.1	0.4	0.0	0.1	0.2	0.0	9.1
	0.0	1.1	0.2	30.2	0.0	7.5	1.3	0.1	0.1	0.0	9.7	0.0	0.0	0.0	0.2	0.0	0.1	0.1	0.2	50.7
	0.0	0.0	0.1	16.8	0.0	31.1	0.5	0.1	0.0	0.0	1.3	0.0	0.1	0.1	0.1	0.0	0.0	0.1	0.0	50.3
	0.0	0.0	0.1	49.4	0.0	6.5	0.3	0.1	0.0	0.0	0.6	0.1	0.0	0.0	0.1	0.0	0.0	0.1	0.1	57.3
	0.0	0.2	0.1	70.3	0.0	5.9	0.6	0.0	0.1	0.0	1.4	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.3	79.1
	0.2	0.2	0.1	71.1	0.0	4.1	0.6	0.0	0.0	0.1	5.5	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.1	82.4
	0.0	0.2	0.1	66.2	0.0	3.4	0.6	0.0	0.0	0.0	6.7	0.1	0.2	0.1	0.0	0.0	0.1	0.1	0.6	78.5
	0.0	0.0	0.1	67.3	0.0	3.0	0.5	0.0	0.0	0.1	6.2	0.0	0.2	0.0	0.0	0.1	0.0	0.1	0.7	78.4
	0.0	0.1	0.1	71.2	0.0	2.4	0.6	0.0	0.0	0.1	5.0	0.0	0.2	0.0	0.0	0.0	0.1	0.1	0.6	80.8
	0.0	0.1	0.1	65.3	0.0	6.7	0.4	0.0	0.0	0.1	6.7	0.1	0.2	0.2	0.1	0.0	0.1	0.2	0.5	81.0
	0.0	14.3	0.1	12.6	0.0	52.5	0.1	0.0	0.1	0.0	10.6	0.1	0.1	0.0	0.2	0.0	0.1	0.0	0.2	90.9
Transect E*																				
	0.0	0.1	0.0	71.1	0.0	4.4	1.2	0.0	0.0	0.1	2.8	0.0	0.0	0.2	0.0	0.0	0.0	0.1	0.2	80.3
	0.1	0.2	0.1	63.7	0.0	15.6	0.8	0.0	0.1	0.1	5.9	0.0	0.2	0.0	0.3	0.0	0.0	0.3	0.2	87.6
	0.0	0.1	0.1	51.3	0.0	3.9	0.8	0.2	0.1	0.1	3.0	0.0	0.1	0.0	0.1	0.0	0.0	0.2	0.2	59.9
	0.0	0.1	0.0	70.3	0.0	4.2	1.0	0.0	0.0	0.1	3.3	0.0	0.0	0.2	0.0	0.0	0.0	0.1	0.2	79.7
	0.0	0.1	0.1	72.0	0.0	3.7	0.8	0.0	0.1	0.1	2.8	0.0	0.1	0.1	0.0	0.0	0.0	0.2	0.2	80.1
	0.5	4.5	0.4	38.3	0.0	22.3	0.5	0.0	0.1	0.1	18.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	85.3
	0.1	0.1	0.0	70.4	0.0	3.4	0.8	0.0	0.0	0.2	3.6	0.0	0.2	0.0	0.0	0.1	0.1	0.2	0.1	79.3
	0.1	0.1	0.1	70.7	0.0	4.3	0.7	0.0	0.0	0.1	5.1	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.2	82.2
	0.1	0.1	0.1	69.2	0.0	3.4	0.6	0.0	0.0	0.1	5.0	0.1	0.0	0.0	0.0	0.1	0.0	0.3	0.4	79.4
	0.0	0.0	0.0	68.9	0.0	2.7	0.6	0.0	0.0	0.1	3.9	0.0	0.1	0.0	0.1	0.2	0.1	0.2	0.4	77.5
	0.0	0.0	0.0	69.9	0.0	2.8	0.6	0.0	0.0	0.1	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	77.6
	0.0	0.1	0.5	65.2	0.0	4.0	0.5	0.0	0.1	0.1	6.6	0.0	0.0	0.2	0.0	0.0	0.0	0.1	0.5	78.0
	0.0	0.0	0.1	64.4	0.0	3.4	0.5	0.0	0.0	0.1	9.5	0.1	0.1	0.1	0.1	0.1	0.0	0.3	0.8	79.6
	0.0	0.0	0.0	64.6	0.0	3.2	0.5	0.0	0.0	0.1	8.9	0.0	0.2	0.0	0.1	0.0	0.0	0.3	0.9	78.8
	0.0	0.0	0.0	65.5	0.0	3.1	0.5	0.0	0.0	0.1	7.1	0.1	0.2	0.1	0.0	0.0	0.0	0.6	0.9	78.3
	0.0	0.0	0.0	1.0	0.0	97.9	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	99.1
	0.1	1.1	0.5	60.7	0.0	9.2	0.5	0.0	0.1	0.1	8.9	0.0	0.1	0.0	0.0	0.0	0.1	0.5	0.8	82.7
	0.0	0.0	0.0	32.7	0.0	1.4	0.9	0.1	0.0	0.1	0.3	0.0	0.0	0.1	0.1	0.0	0.0	1.0	0.2	36.8

Appendix IV: Analytical data from nodule samples collected in lac Aylmer

Na2O (%)	K2O (%)	MgO (%)	FeO (%)	F (%)	SiO2 (%)	MnO (%)	Cl (%)	BaO (%)	CaO (%)	Al2O3 (%)	Cr2O3 (%)	NiO (%)	ZnO (%)	TiO2 (%)	SiO (%)	V2O3 (%)	SO3 (%)	P2O5 (%)	TOTAL (%)
0.0	0.0	0.0	66.0	0.0	2.5	0.6	0.0	0.0	0.1	3.7	0.0	0.1	0.0	0.0	0.1	0.1	0.1	0.6	73.9
0.0	0.0	0.0	64.9	0.0	2.5	0.5	0.0	0.0	0.1	4.9	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.5	73.9
0.0	0.0	0.0	69.0	0.0	3.2	2.3	0.0	0.1	0.0	0.5	0.0	0.0	0.0	0.1	0.0	0.0	0.2	0.4	76.0
0.0	0.0	0.0	8.7	0.0	0.3	0.2	0.2	0.0	0.1	0.1	0.0	0.1	0.0	0.1	0.0	0.0	1.0	0.2	11.0
0.0	0.0	0.0	65.2	0.0	2.8	2.0	0.0	0.0	0.1	0.6	0.0	0.1	0.0	0.1	0.0	0.0	0.1	0.3	71.4
0.0	0.0	0.0	65.8	0.0	2.9	0.5	0.0	0.0	0.0	5.3	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.7	75.7
0.0	0.0	0.0	63.3	0.0	2.4	0.7	0.0	0.0	0.1	2.3	0.0	0.0	0.0	0.1	0.0	0.0	0.2	0.4	69.6
0.0	0.0	0.1	65.0	0.0	3.0	1.5	0.1	0.0	0.1	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.5	71.0
0.0	0.7	0.1	63.6	0.0	3.8	0.4	0.0	0.1	0.1	8.1	0.1	0.1	0.0	0.0	0.1	0.0	0.3	0.8	78.3
0.0	0.0	0.0	1.0	0.0	96.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	97.9
0.0	0.4	0.1	66.3	0.0	5.1	0.7	0.0	0.1	0.1	4.5	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.6	78.2
0.0	0.0	0.0	69.9	0.0	2.4	0.7	0.0	0.0	0.2	3.6	0.0	0.1	0.0	0.0	0.1	0.0	0.1	0.5	77.6
0.0	0.1	0.1	70.2	0.0	3.5	0.6	0.1	0.0	0.1	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.6	78.2
0.0	0.0	0.0	42.1	0.0	55.9	0.2	0.0	0.1	0.1	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	100.1
0.6	6.2	0.6	26.3	0.0	28.4	0.2	0.0	0.2	0.0	14.4	0.0	0.1	0.2	0.1	0.0	0.1	0.1	0.2	77.6
0.0	0.0	0.0	0.8	0.0	100.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.1	101.4
0.0	0.0	0.0	0.6	0.0	100.7	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	101.6
0.0	0.0	0.0	0.8	0.0	102.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	103.1
0.0	0.1	0.1	27.5	0.0	1.2	0.8	0.3	0.0	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.5	0.2	31.0
0.0	0.1	0.0	69.3	0.0	4.8	0.7	0.0	0.0	0.1	2.2	0.0	0.0	0.1	0.1	0.6	0.0	0.1	0.1	77.7
0.0	0.0	0.1	69.3	0.0	4.3	0.6	0.0	0.0	0.1	2.4	0.0	0.0	0.0	0.3	0.0	0.0	0.2	0.3	77.5
0.0	0.2	0.0	68.0	0.0	4.5	0.8	0.0	0.0	0.1	2.4	0.0	0.1	0.1	0.0	0.0	0.0	0.4	0.3	77.0
0.1	0.9	0.2	58.8	0.0	9.0	0.7	0.0	0.1	0.2	5.7	0.1	0.0	0.1	2.1	0.1	0.1	0.5	0.2	79.1
0.1	0.1	0.1	69.0	0.0	4.3	0.8	0.0	0.0	0.1	3.0	0.0	0.1	0.2	0.0	0.1	0.0	0.4	0.3	78.5
0.1	1.1	0.5	60.5	0.0	9.0	0.5	0.0	0.1	0.1	6.6	0.0	0.0	0.1	0.1	0.1	0.0	0.5	0.3	79.6
0.0	0.0	0.1	70.5	0.0	3.9	0.9	0.0	0.0	0.1	2.5	0.0	0.1	0.0	0.1	0.0	0.1	0.4	0.2	78.9
0.0	0.1	0.0	58.2	0.0	16.0	0.6	0.0	0.1	0.1	2.6	0.0	0.1	0.1	0.2	0.0	0.0	0.2	0.2	78.7
0.0	0.2	0.1	69.5	0.0	4.7	0.6	0.0	0.0	0.1	4.1	0.0	0.1	0.1	0.2	0.0	0.1	0.2	0.1	80.0
0.0	0.1	0.1	69.8	0.0	3.5	0.9	0.0	0.0	0.1	2.3	0.0	0.1	0.0	0.1	0.0	0.1	0.7	0.2	77.9
0.0	0.0	0.1	68.4	0.0	4.4	0.8	0.0	0.1	0.1	3.6	0.0	0.0	0.0	0.1	0.0	0.1	0.5	0.2	78.4
0.1	0.2	0.1	67.6	0.0	5.2	0.8	0.0	0.0	0.1	5.6	0.0	0.2	0.2	0.1	0.1	0.1	0.2	0.1	80.5
0.0	0.0	0.0	4.0	0.0	91.5	0.1	0.0	0.0	0.0	0.3	0.0	0.1	0.1	0.0	0.0	0.1	0.1	0.1	96.4

Appendix IV: Analytical data from nodule samples collected in lac Aylmer

Na2O K2O MgO FeO F SiO2 MnO Cl BaO CaO Al2O3 Cr2O3 NiO ZnO TiO2 SiO V2O3 SO3 P2O5 TOTAL																				
(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	
01	02	01	702	00	42	07	01	00	01	23	00	01	00	01	00	00	00	05	03	789
02	16	00	626	00	99	05	00	01	00	73	01	00	00	02	00	00	00	00	02	827
00	01	00	662	00	31	07	00	00	01	32	01	01	00	07	00	00	00	00	04	747
00	00	00	671	00	30	05	00	00	00	49	00	01	00	00	00	01	00	00	04	763
00	00	01	656	00	27	07	00	00	01	54	00	02	01	00	01	00	00	00	06	755
00	01	00	679	00	29	06	00	01	01	45	01	02	00	00	00	00	00	00	05	769
00	00	01	689	00	28	05	00	00	01	24	00	01	01	00	00	00	00	01	05	756
00	00	01	732	00	22	05	00	00	01	21	01	01	01	00	00	00	00	01	04	801
00	02	00	693	00	71	06	01	00	00	36	00	01	01	01	00	01	01	01	05	819
01	04	01	692	00	39	05	00	00	00	28	01	02	03	00	01	00	01	00	05	781
00	02	01	673	00	32	05	00	00	01	28	01	01	00	00	00	01	02	05	05	751
00	00	00	716	00	33	06	00	00	01	28	00	00	01	01	00	00	01	00	03	790
00	03	01	709	00	37	04	00	00	01	23	00	01	02	00	00	01	02	05	05	789
00	00	00	723	00	29	06	00	00	00	26	00	01	00	00	00	00	00	02	04	793
00	01	01	703	00	70	04	00	00	00	25	00	01	00	01	02	01	00	00	04	815
00	00	00	13	00	968	00	00	00	00	00	00	01	01	00	00	00	00	00	01	984
00	01	00	726	00	29	06	00	01	00	12	00	01	00	00	00	01	01	00	02	780
00	00	00	695	00	26	05	00	00	00	27	00	02	01	01	01	01	01	00	05	764
00	09	03	620	00	67	05	00	01	00	60	00	01	00	01	02	01	00	00	03	771
00	01	00	696	00	32	06	00	00	00	30	01	02	01	00	00	01	00	00	03	775
00	12	03	639	00	89	06	00	00	00	62	00	01	00	01	00	00	00	00	02	815
00	01	01	546	00	254	05	00	01	00	22	01	01	00	01	00	00	00	01	03	839
00	02	01	708	00	46	05	00	01	00	31	01	02	01	00	00	00	00	00	04	801
00	00	00	592	00	21	03	00	00	00	09	00	01	02	00	00	00	00	00	01	631
00	01	01	693	00	37	06	00	00	00	37	01	01	01	01	00	00	00	00	05	788
00	01	00	695	00	78	05	00	00	01	41	00	02	00	01	00	00	01	00	02	828
01	03	01	697	00	49	05	00	00	01	38	00	02	00	00	00	00	00	00	04	802
00	05	00	686	00	52	05	00	00	00	49	00	01	00	01	00	00	00	01	04	805
01	00	01	654	00	29	06	00	01	00	12	01	00	00	00	02	00	00	00	03	709
00	03	01	701	00	42	06	00	00	00	52	01	00	00	00	01	00	01	00	02	809
00	01	01	723	00	33	07	00	00	01	14	00	02	00	00	00	00	00	01	02	786
01	02	00	721	00	40	06	00	00	01	44	01	01	00	02	01	00	00	06	02	827

Appendix IV Analytical data from nodule samples collected in lac Aylmer

	Na2O (%)	K2O (%)	MgO (%)	FeO (%)	F (%)	SiO2 (%)	MnO (%)	Cl (%)	BaO (%)	CaO (%)	Al2O3 (%)	Cr2O3 (%)	NiO (%)	ZnO (%)	TiO2 (%)	SiO (%)	V2O3 (%)	SO3 (%)	P2O5 (%)	TOTAL (%)
	0.0	0.1	0.1	71.7	0.0	3.9	0.7	0.0	0.0	0.0	4.9	0.1	0.2	0.1	0.1	0.0	0.1	0.1	0.3	82.3
	0.0	0.0	0.0	72.6	0.0	3.1	0.7	0.0	0.0	0.1	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	79.6
	0.0	0.1	0.0	73.3	0.0	3.2	0.6	0.0	0.1	0.1	2.3	0.0	0.1	0.0	0.2	0.0	0.0	0.4	0.2	80.6
	0.0	0.2	0.1	68.8	0.0	4.8	1.3	0.0	0.0	0.0	2.3	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.3	77.9
	0.4	7.6	0.7	25.2	0.0	34.3	0.2	0.0	0.3	0.0	27.4	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	96.4
	0.0	0.1	3.4	63.4	0.0	6.2	0.6	0.0	0.0	0.0	3.6	0.0	0.1	0.0	0.0	0.0	0.0	0.2	0.3	78.0
	0.0	0.0	0.0	70.6	0.0	2.6	0.4	0.0	0.0	0.1	3.6	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.6	78.2
	0.0	0.1	0.0	72.0	0.0	2.5	0.6	0.1	0.0	0.0	2.5	0.0	0.1	0.2	0.0	0.0	0.1	0.1	0.4	78.8
	0.0	0.1	0.0	66.9	0.0	3.1	0.5	0.0	0.1	0.0	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	74.2
	0.0	0.1	0.0	70.3	0.0	3.7	0.5	0.0	0.0	0.2	2.6	0.0	0.2	0.2	0.2	0.0	0.1	0.0	0.3	78.6
	0.0	0.0	0.0	67.2	0.0	2.6	0.4	0.0	0.0	0.0	3.7	0.0	0.2	0.1	0.0	0.0	0.1	0.2	0.3	75.0
	0.0	0.1	0.1	70.7	0.0	3.6	0.5	0.0	0.0	0.1	3.5	0.0	0.1	0.0	0.0	0.1	0.1	0.4	0.3	79.8
	0.0	0.0	0.0	64.3	0.0	2.7	1.1	0.0	0.1	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.3	68.8
	0.0	0.1	0.0	25.9	0.0	1.1	0.4	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.3	0.1	28.5
	0.1	0.1	0.1	49.5	0.0	1.9	0.5	0.2	0.0	0.1	0.1	0.1	0.1	0.0	0.1	0.2	0.1	0.4	0.3	53.8
	0.0	0.0	0.1	68.6	0.0	3.8	1.0	0.0	0.1	0.0	1.7	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.4	75.9
	0.0	0.0	0.0	68.6	0.0	2.4	0.6	0.0	0.0	0.1	3.7	0.2	0.2	0.0	0.0	0.1	0.1	0.1	0.4	76.5
	0.0	0.0	0.1	69.0	0.0	2.3	0.5	0.0	0.0	0.1	3.3	0.1	0.3	0.0	0.1	0.0	0.0	0.1	0.4	76.2
Transtect GH																				
	0.0	0.0	0.0	71.9	0.0	2.9	0.6	0.0	0.0	0.1	2.9	0.0	0.1	0.0	0.0	0.1	0.2	0.0	0.2	79.1
	0.0	0.0	0.0	70.4	0.0	3.5	0.7	0.1	0.0	0.1	3.7	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.1	79.0
	0.0	0.2	0.1	69.1	0.0	4.0	0.7	0.0	0.0	0.1	3.9	0.1	0.0	0.0	0.1	0.0	0.0	0.2	0.3	78.8
	0.1	0.2	0.1	68.8	0.0	4.6	0.6	0.0	0.0	0.1	5.9	0.1	0.2	0.0	0.1	0.0	0.0	0.7	0.5	82.2
	0.0	0.1	0.0	69.3	0.0	3.5	0.9	0.0	0.0	0.1	4.8	0.1	0.1	0.1	0.1	0.0	0.0	0.5	0.6	80.0
	0.0	0.1	0.0	65.5	0.0	3.7	0.5	0.0	0.1	0.0	6.8	0.0	0.0	0.0	0.1	0.0	0.0	0.3	0.7	77.9
	0.0	0.0	0.0	65.6	0.0	3.1	0.5	0.0	0.0	0.1	5.3	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.5	75.2
	0.0	0.0	0.0	66.1	0.0	13.2	0.6	0.0	0.0	0.1	5.9	0.0	0.1	0.0	0.1	0.0	0.1	0.4	0.7	87.5
	0.1	0.3	0.1	66.4	0.0	4.7	0.6	0.0	0.1	0.1	5.8	0.1	0.0	0.0	0.1	0.0	0.0	0.5	0.6	79.4
	0.0	0.1	0.1	65.6	0.0	2.2	0.5	0.0	0.0	0.1	6.1	0.1	0.1	0.0	0.0	0.1	0.0	0.3	0.9	76.0
	0.0	0.1	0.0	68.6	0.0	2.8	0.4	0.0	0.0	0.1	3.8	0.0	0.0	0.2	0.1	0.0	0.0	0.3	0.7	77.0
	0.0	0.0	0.0	70.8	0.0	2.8	0.4	0.0	0.0	0.0	2.9	0.0	0.1	0.1	0.1	0.0	0.1	0.4	0.6	78.4
	0.0	0.0	0.0	72.1	0.0	2.4	0.4	0.0	0.0	0.1	2.6	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.7	78.7

Appendix IV: Analytical data from nodule samples collected in lac Aylmer

Na2O (%)	K2O (%)	MgO (%)	FeO (%)	F (%)	SiO2 (%)	MnO (%)	Cl (%)	BrO (%)	CaO (%)	Al2O3 (%)	Cr2O3 (%)	NiO (%)	ZnO (%)	TiO2 (%)	SiO (%)	V2O3 (%)	SO3 (%)	P2O5 (%)	TOTAL (%)
0.0	0.0	0.0	71.1	0.0	2.5	0.5	0.0	0.1	0.1	3.1	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.5	78.2
0.0	0.0	0.1	71.4	0.0	2.7	0.5	0.1	0.0	0.1	3.3	0.0	0.1	0.0	0.1	0.0	0.1	0.1	0.5	79.1
0.0	0.0	0.0	72.0	0.0	2.6	0.5	0.0	0.1	0.1	2.1	0.0	0.1	0.0	0.2	0.0	0.1	0.2	0.6	78.6
0.0	0.0	0.1	71.0	0.0	3.1	0.5	0.0	0.0	0.1	2.7	0.0	0.0	0.1	0.0	0.1	0.0	0.2	0.5	78.5
0.1	0.4	0.1	69.6	0.0	4.5	0.6	0.1	0.0	0.1	2.7	0.0	0.1	0.1	0.0	0.1	0.1	0.5	0.6	79.5
0.0	0.1	0.0	71.0	0.0	3.1	0.4	0.0	0.1	0.1	2.1	0.1	0.1	0.0	0.1	0.0	0.0	0.4	0.5	78.1
0.0	0.1	0.0	69.3	0.0	3.0	0.4	0.0	0.0	0.0	1.9	0.1	0.1	0.2	0.0	0.0	0.0	0.1	0.4	75.8
0.0	0.0	0.0	68.3	0.0	2.7	0.4	0.0	0.0	0.1	3.1	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.6	75.5
0.0	0.1	0.1	69.1	0.0	3.5	0.5	0.0	0.0	0.1	4.7	0.0	0.1	0.2	0.0	0.0	0.1	0.1	0.6	79.2
7.4	0.4	0.0	5.1	0.0	56.9	0.0	0.0	0.0	0.4	13.6	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.1	84.3
0.0	0.1	0.0	71.7	0.0	3.1	0.6	0.0	0.0	0.1	3.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	80.0
0.0	0.4	0.1	70.1	0.0	5.3	0.8	0.0	0.1	0.1	3.0	0.0	0.2	0.0	0.1	0.1	0.0	0.1	0.3	80.5
0.1	0.1	0.1	72.3	0.0	2.8	0.6	0.0	0.1	0.1	0.7	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	77.5
0.1	0.1	0.0	68.5	0.0	4.9	0.6	0.0	0.0	0.1	1.9	0.0	0.1	0.1	0.0	0.0	0.0	0.2	0.1	76.5
1.0	0.0	0.0	66.9	0.0	7.1	0.6	0.0	0.1	0.1	3.6	0.0	0.1	0.2	0.1	0.0	0.0	0.3	0.3	80.5
0.0	0.5	0.5	9.3	0.0	86.9	0.1	0.0	0.1	0.0	8.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	107.9
0.0	0.0	0.1	67.6	0.0	4.0	0.7	0.0	0.0	0.1	2.9	0.1	0.1	0.2	0.0	0.1	0.0	0.3	0.3	76.6
0.0	0.2	0.1	60.8	0.0	6.8	0.8	0.1	0.0	0.1	3.9	0.0	0.1	0.0	0.0	0.1	0.0	0.2	0.2	73.4
0.0	0.1	0.0	71.4	0.0	2.8	0.8	0.0	0.0	0.1	2.0	0.0	0.1	0.0	0.1	0.0	0.0	0.2	0.4	78.1
0.0	0.0	0.1	65.4	0.0	3.6	0.9	0.0	0.0	0.2	3.7	0.0	0.1	0.2	0.1	0.0	0.0	0.2	0.3	74.7
0.0	0.6	0.1	60.3	0.0	4.0	0.7	0.1	0.0	0.1	4.3	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.3	70.6
0.0	0.0	0.0	73.1	0.0	2.4	0.5	0.0	0.0	0.1	1.4	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.3	78.2
0.0	0.0	0.0	19.2	0.0	1.2	0.4	0.2	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	22.0
0.1	0.2	0.1	70.2	0.0	5.3	0.7	0.0	0.0	0.1	3.3	0.0	0.1	0.1	0.1	0.1	0.1	0.3	0.2	81.0
0.0	0.1	0.0	70.9	0.0	3.4	0.6	0.1	0.0	0.1	2.8	0.1	0.1	0.1	0.6	0.1	0.1	0.6	0.3	79.8
0.0	0.1	0.1	70.9	0.0	3.1	0.8	0.0	0.0	0.2	2.1	0.0	0.1	0.0	0.1	0.0	0.0	0.8	0.3	78.6
0.0	0.5	0.2	68.4	0.0	6.2	0.6	0.0	0.1	0.1	4.8	0.0	0.1	0.0	0.1	0.0	0.0	0.3	0.2	81.5
9.5	0.3	0.0	1.3	0.0	61.7	0.0	0.0	0.1	4.2	22.8	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	100.0
0.0	0.0	0.0	30.4	0.0	2.2	0.4	0.2	0.0	0.1	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	34.5
0.0	0.1	0.0	70.3	0.0	3.0	0.8	0.0	0.0	0.2	1.1	0.0	0.1	0.0	0.0	0.0	0.1	0.2	0.2	76.2
0.0	0.1	0.0	34.8	0.0	54.2	0.8	0.0	0.0	0.1	1.4	0.0	0.1	0.0	0.0	0.1	0.0	0.3	0.2	92.2
0.1	0.1	0.0	70.7	0.0	3.3	0.5	0.0	0.0	0.1	3.8	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.4	79.5

Appendix IV: Analytical data from nodule samples collected in lac Aymer

Na2O (%)	K2O (%)	MgO (%)	FeO (%)	F (%)	SiO2 (%)	MnO (%)	Cl (%)	BaO (%)	CaO (%)	Al2O3 (%)	Cr2O3 (%)	NiO (%)	ZnO (%)	TiO2 (%)	SrO (%)	V2O3 (%)	SO3 (%)	P2O5 (%)	TOTAL (%)
0.1	0.1	0.1	67.8	0.0	4.2	0.5	0.0	0.1	0.1	4.7	0.0	0.1	0.0	0.0	0.1	0.0	0.6	0.4	78.9
0.2	0.5	0.2	66.1	0.0	6.0	0.5	0.0	0.1	0.1	5.1	0.0	0.0	0.1	0.1	0.0	0.0	0.5	0.4	79.9
0.0	0.3	0.1	70.9	0.0	3.2	0.6	0.0	0.1	0.1	2.5	0.0	0.1	0.1	0.1	0.0	0.1	0.5	0.4	78.9
0.0	0.0	0.0	71.8	0.0	3.0	0.6	0.1	0.0	0.1	3.9	0.1	0.2	0.1	0.1	0.0	0.0	0.2	0.3	80.4
0.1	0.1	0.1	69.9	0.0	3.3	0.5	0.0	0.0	0.1	3.1	0.0	0.1	0.2	0.0	0.0	0.1	0.3	0.4	78.0
0.1	0.1	0.0	69.6	0.0	3.3	0.7	0.0	0.0	0.1	5.5	0.1	0.1	0.0	0.1	0.1	0.0	0.2	0.5	78.5
0.0	0.0	0.0	1.0	0.0	98.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	99.9
0.0	0.0	0.0	0.5	0.0	97.3	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	98.3
0.0	0.0	0.0	0.7	0.0	98.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	98.9
2.1	0.1	0.1	54.9	0.0	16.4	0.6	0.0	0.0	0.1	2.5	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.2	77.2
0.0	0.0	0.0	69.7	0.0	2.5	0.8	0.0	0.0	0.1	1.6	0.0	0.2	0.0	0.0	0.0	0.1	0.1	0.4	75.7
0.0	0.1	0.0	69.0	0.0	2.8	0.8	0.0	0.0	0.0	1.7	0.0	0.1	0.0	0.1	0.1	0.0	0.0	0.5	75.4
0.0	0.0	0.0	73.0	0.0	2.3	0.8	0.0	0.0	0.0	1.0	0.0	0.2	0.1	0.0	0.0	0.0	0.1	0.5	78.0
0.0	0.0	0.1	71.3	0.0	2.4	0.7	0.0	0.0	0.1	0.9	0.0	0.2	0.0	0.0	0.1	0.0	0.0	0.5	76.4
0.0	0.3	0.1	69.1	0.0	3.7	0.9	0.0	0.0	0.1	5.2	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.4	80.0
0.2	1.6	0.2	57.0	0.0	10.4	0.4	0.0	0.0	0.1	6.1	0.1	0.1	0.2	0.0	0.1	0.0	0.5	0.3	77.3
0.0	0.0	0.0	70.0	0.0	3.2	0.7	0.1	0.0	0.1	2.5	0.0	0.1	0.1	0.0	0.0	0.0	0.2	0.4	77.4
0.0	0.2	0.1	68.8	0.0	4.5	0.5	0.0	0.1	0.0	3.2	0.0	0.2	0.1	0.0	0.1	0.0	0.1	0.3	78.3
0.0	0.0	0.0	71.0	0.0	2.7	0.5	0.0	0.0	0.1	2.2	0.1	0.1	0.2	0.1	0.0	0.1	0.1	0.5	77.6
0.0	0.0	0.0	67.1	0.0	2.9	0.7	0.0	0.1	0.1	3.3	0.1	0.0	0.1	0.0	0.1	0.0	0.6	0.4	75.8
0.0	0.1	0.1	65.7	0.0	3.9	0.5	0.0	0.0	0.1	4.3	0.0	0.1	0.1	0.0	0.0	0.1	0.3	0.4	75.7
0.0	0.1	0.1	70.0	0.0	3.3	0.5	0.1	0.0	0.1	3.2	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.4	77.9
0.0	0.1	0.0	70.0	0.0	3.2	0.6	0.0	0.1	0.1	2.9	0.0	0.2	0.1	0.2	0.1	0.0	0.0	0.3	77.9
0.1	0.1	0.1	66.6	0.0	3.1	0.4	0.0	0.0	0.0	3.4	0.0	0.1	0.2	0.0	0.1	0.0	0.6	0.4	75.2
0.0	0.1	0.0	68.0	0.0	3.9	0.8	0.0	0.1	0.0	3.3	0.1	0.1	0.2	0.1	0.0	0.0	0.1	0.4	77.1
0.0	0.0	0.0	72.4	0.0	3.1	0.4	0.0	0.0	0.1	2.4	0.1	0.1	0.0	0.1	0.0	0.0	0.1	0.3	79.1
0.0	0.0	0.1	69.2	0.0	3.5	0.5	0.0	0.0	0.0	2.8	0.0	0.1	0.2	0.0	0.1	0.1	0.1	0.4	77.0
0.0	0.1	0.0	72.0	0.0	3.3	0.4	0.0	0.0	0.0	2.5	0.1	0.0	0.0	0.0	0.1	0.1	0.0	0.3	79.0
0.0	0.1	0.0	71.0	0.0	3.3	0.5	0.1	0.1	0.0	2.8	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.3	78.4
0.0	0.1	0.1	71.2	0.0	2.8	0.4	0.0	0.0	0.1	2.3	0.0	0.1	0.2	0.0	0.1	0.0	0.0	0.5	78.1
0.0	0.2	0.0	68.7	0.0	1.2	0.5	0.0	0.0	0.1	0.8	0.0	0.1	0.1	0.5	0.0	0.0	0.1	0.3	72.6
0.0	0.1	0.0	71.5	0.0	4.6	0.6	0.0	0.0	0.0	1.8	0.1	0.1	0.1	0.0	0.1	0.0	0.0	0.4	79.4

Appendix IV: Analytical data from nodule samples collected in lac Aylmer

	Na2O (%)	K2O (%)	MgO (%)	FeO (%)	F (%)	SiO2 (%)	MnO (%)	Cl (%)	BaO (%)	CaO (%)	Al2O3 (%)	Cr2O3 (%)	NiO (%)	ZnO (%)	TiO2 (%)	SiO (%)	V2O3 (%)	SO3 (%)	P2O5 (%)	TOTAL (%)
	0.1	1.1	0.1	65.9	0.0	8.0	0.5	0.0	0.1	0.1	3.6	0.0	0.0	0.1	0.3	0.0	0.0	0.2	0.4	80.4
	0.0	0.0	0.0	68.6	0.0	2.6	0.5	0.0	0.0	0.0	1.7	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.3	74.4
	0.0	0.2	0.0	69.2	0.0	2.4	0.4	0.0	0.1	0.1	2.1	0.0	0.2	0.1	0.0	0.1	0.0	0.0	0.3	75.3
	0.0	0.0	0.0	1.0	0.0	98.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	99.3
	0.0	0.5	0.2	68.7	0.0	5.2	0.5	0.0	0.0	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	77.8
	0.0	0.1	0.0	69.9	0.0	3.8	0.5	0.0	0.1	0.0	2.0	0.0	0.2	0.1	0.0	0.0	0.1	0.0	0.2	77.0
	0.0	0.1	0.1	63.9	0.0	11.6	0.4	0.0	0.0	0.0	5.5	0.1	0.2	0.0	0.1	0.0	0.0	0.2	0.5	82.9
	0.0	1.7	0.8	53.9	0.0	13.1	0.5	0.0	0.0	0.1	8.1	0.1	0.0	0.0	1.1	0.0	0.0	0.1	0.3	79.9
	0.1	0.2	0.0	69.2	0.0	3.6	0.5	0.0	0.0	0.1	4.7	0.1	0.2	0.1	0.1	0.0	0.0	0.2	0.6	79.6
	0.0	1.3	0.2	61.2	0.0	8.7	0.6	0.1	0.0	0.0	8.3	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.4	81.5
	0.3	0.1	0.1	65.7	0.0	6.5	0.6	0.0	0.0	0.1	4.7	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.7	79.0
	0.4	2.8	0.3	50.7	0.0	20.5	0.4	0.0	0.1	0.0	11.6	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.4	87.5
	0.1	1.8	0.2	52.6	0.0	18.6	0.5	0.0	0.2	0.1	8.0	0.0	0.0	0.1	0.0	0.1	0.1	0.0	0.4	82.8
	0.2	0.1	0.0	68.2	0.0	5.2	0.7	0.0	0.1	0.1	5.7	0.0	0.2	0.1	0.0	0.0	0.0	0.0	0.5	81.1
	0.0	0.2	0.1	66.5	0.0	3.1	0.6	0.1	0.1	0.1	6.1	0.1	0.2	0.0	0.1	0.0	0.0	0.1	0.5	77.8
	0.0	0.1	0.1	66.6	0.0	2.6	0.5	0.0	0.0	0.1	4.1	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.4	74.9
	0.0	0.1	0.1	68.2	0.0	3.4	0.6	0.0	0.0	0.1	6.5	0.0	0.2	0.0	0.1	0.0	0.0	0.0	0.5	79.9
	0.0	0.0	0.1	67.2	0.0	3.6	0.5	0.0	0.0	0.1	7.8	0.1	0.2	0.0	0.1	0.0	0.1	0.0	0.7	80.8
	0.0	0.0	0.1	45.5	0.0	2.0	0.8	0.3	0.0	0.1	5.5	0.0	0.2	0.0	0.2	0.1	0.1	0.1	0.4	55.2
	0.0	0.1	0.1	68.2	0.0	2.5	0.5	0.0	0.0	0.1	6.1	0.1	0.2	0.0	0.0	0.0	0.1	0.1	0.6	78.7
	0.0	0.1	0.1	67.2	0.0	2.5	0.6	0.1	0.0	0.1	5.1	0.1	0.2	0.0	0.0	0.0	0.0	0.3	0.5	76.9
	0.0	0.1	10.7	37.1	0.0	19.1	0.3	0.0	0.1	0.1	15.0	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.1	82.9
	0.0	0.3	1.1	64.2	0.0	8.5	0.4	0.0	0.1	0.0	5.3	0.0	0.2	0.0	0.3	0.1	0.0	0.1	0.3	80.9
Transect LJ																				
	0.0	0.1	0.1	57.3	0.0	3.9	0.6	0.0	0.0	0.2	17.0	0.2	0.0	0.1	0.1	0.0	0.1	0.5	2.7	82.9
	0.4	0.3	0.1	61.5	0.0	5.1	0.6	0.0	0.1	0.2	11.6	0.1	0.1	0.1	0.1	0.1	0.1	0.3	2.2	83.0
	0.2	0.6	0.1	63.6	0.0	5.1	0.4	0.0	0.0	0.2	9.3	0.1	0.1	0.2	0.0	0.0	0.1	0.6	2.1	82.7
	0.0	0.0	0.1	68.3	0.0	2.4	0.5	0.0	0.1	0.1	6.2	0.0	0.2	0.1	0.1	0.0	0.1	0.1	1.6	79.9
	0.0	0.1	0.1	68.5	0.0	2.8	0.4	0.0	0.0	0.1	5.7	0.0	0.1	0.0	0.0	0.0	0.1	0.5	1.5	80.0
	0.1	0.1	0.1	70.0	0.0	2.7	0.4	0.0	0.0	0.1	5.3	0.0	0.1	0.1	0.1	0.0	0.0	0.5	1.3	81.1
	0.0	0.0	0.1	70.6	0.0	2.5	0.5	0.0	0.0	0.1	4.3	0.0	0.2	0.1	0.1	0.1	0.0	0.4	1.0	80.0
	0.0	0.1	0.1	71.4	0.0	3.2	0.3	0.0	0.1	0.1	4.9	0.1	0.1	0.1	0.0	0.1	0.1	0.2	0.8	81.8

Appendix IV: Analytical data from nodule samples collected in lac Aylmer

Na2O (%)	K2O (%)	MgO (%)	FeO (%)	F (%)	SiO2 (%)	MnO (%)	Cl (%)	BaO (%)	CaO (%)	Al2O3 (%)	Cr2O3 (%)	NiO (%)	ZnO (%)	TiO2 (%)	SrO (%)	V2O3 (%)	SO3 (%)	P2O5 (%)	TOTAL (%)
0.0	0.4	0.1	67.0	0.0	5.5	0.4	0.0	0.0	0.1	6.7	0.0	0.0	0.1	0.1	0.0	0.1	0.0	0.9	81.5
0.0	0.2	0.0	68.4	0.0	4.5	0.6	0.0	0.0	0.1	6.2	0.1	0.0	0.2	0.0	0.0	0.0	0.0	0.9	81.2
2.5	0.1	0.0	25.5	0.0	23.2	0.2	0.1	0.0	0.5	7.7	0.0	0.2	0.2	2.0	0.0	0.0	0.1	0.8	63.3
0.1	0.1	0.1	63.3	0.0	4.4	0.5	0.0	0.0	0.1	10.7	0.0	0.1	0.2	1.5	0.2	0.0	0.4	1.1	82.9
0.0	0.1	0.1	65.0	0.0	3.7	0.5	0.0	0.1	0.1	10.0	0.2	0.2	0.1	0.1	0.0	0.1	0.2	1.2	81.5
0.0	0.1	0.1	67.1	0.0	3.1	0.5	0.0	0.0	0.1	8.2	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.9	80.6
0.0	0.0	0.1	59.4	0.0	2.2	0.5	0.0	0.0	0.0	0.8	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.4	63.5
0.0	0.2	0.1	65.9	0.0	4.2	0.6	0.0	0.0	0.1	8.2	0.0	0.2	0.0	0.0	0.2	0.1	0.0	0.8	80.6
0.0	0.1	0.1	66.0	0.0	3.3	0.6	0.0	0.0	0.0	8.0	0.1	0.3	0.1	0.1	0.0	0.1	0.0	0.7	79.5
0.0	0.1	0.0	5.1	0.0	92.7	0.1	0.0	0.0	0.1	1.8	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.1	100.1
0.0	0.3	0.1	69.0	0.0	4.4	0.5	0.0	0.0	0.0	6.2	0.1	0.1	0.0	0.6	0.1	0.0	0.0	0.3	81.8
0.0	3.7	0.6	50.7	0.0	17.7	0.4	0.0	0.0	0.0	11.1	0.1	0.0	0.2	0.2	0.0	0.0	0.0	0.2	85.1
Transect KL																			
0.1	0.3	0.0	64.0	0.0	10.2	0.4	0.0	0.1	0.1	5.5	0.0	0.1	0.0	0.0	0.1	0.0	0.2	1.0	82.0
5.3	9.7	0.0	1.8	0.0	65.1	0.1	0.0	0.2	0.4	17.4	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	100.5
0.0	0.0	0.0	70.5	0.0	3.0	0.5	0.0	0.0	0.1	5.5	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.9	80.9
0.0	0.1	0.0	69.1	0.0	3.9	0.5	0.0	0.0	0.1	6.6	0.0	0.1	0.0	0.0	0.2	0.0	0.1	0.8	81.6
0.0	0.0	0.1	70.3	0.0	3.3	0.5	0.0	0.0	0.1	5.3	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.7	80.8
0.1	0.1	0.0	67.7	0.0	3.5	0.6	0.0	0.0	0.1	6.1	0.1	0.2	0.1	0.1	0.1	0.0	0.4	0.9	80.1
0.1	0.3	0.1	64.8	0.0	4.4	0.5	0.0	0.0	0.1	8.3	0.1	0.2	0.2	0.1	0.0	0.0	0.4	1.0	80.6
0.0	1.3	0.0	61.4	0.0	7.0	0.4	0.1	0.0	0.1	12.3	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.7	84.2
0.0	0.1	0.1	64.5	0.0	4.0	0.5	0.1	0.1	0.2	9.2	0.1	0.2	0.0	0.0	0.0	0.0	0.5	1.0	80.4
0.0	0.1	0.1	66.7	0.0	3.5	0.5	0.0	0.0	0.1	11.0	0.1	0.2	0.1	0.0	0.0	0.0	0.1	0.9	83.3
0.0	0.2	0.1	64.6	0.0	11.1	0.4	0.0	0.0	0.1	7.3	0.1	0.0	0.1	0.0	0.0	0.0	0.1	0.6	84.7
0.0	0.0	0.0	65.4	0.0	3.0	0.4	0.0	0.0	0.1	7.4	0.1	0.1	0.2	0.1	0.0	0.0	0.3	0.9	78.2
0.0	0.1	0.1	70.4	0.0	3.0	0.5	0.0	0.0	0.0	5.2	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.6	80.0
0.0	0.1	0.1	67.6	0.0	3.5	0.5	0.0	0.0	0.1	9.4	0.1	0.2	0.0	0.0	0.0	0.0	0.2	0.6	82.4
0.0	0.0	0.1	66.0	0.0	4.0	0.6	0.0	0.1	0.1	8.2	0.1	0.1	0.0	0.1	0.1	0.1	0.2	0.8	80.5
0.0	0.5	0.2	63.9	0.1	6.1	0.6	0.0	0.0	0.1	9.6	0.1	0.2	0.2	0.2	0.1	0.0	0.2	0.8	82.7
0.0	0.2	0.1	64.6	0.0	4.2	0.6	0.0	0.1	0.1	8.6	0.1	0.3	0.1	0.2	0.0	0.0	0.2	0.8	80.2
0.1	1.6	0.3	56.6	0.0	11.2	0.6	0.0	0.0	0.1	9.9	0.1	0.2	0.0	0.1	0.0	0.0	0.1	0.5	81.3
10.3	0.2	0.0	20.0	0.0	53.0	0.1	0.0	0.0	0.1	12.5	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.3	96.9

Appendix IV: Analytical data from nodule samples collected in lac Aylmer

Na2O (%)	K2O (%)	MgO (%)	FeO (%)	F (%)	SiO2 (%)	MnO (%)	Cl (%)	BaO (%)	CaO (%)	Al2O3 (%)	Cr2O3 (%)	NiO (%)	ZnO (%)	TiO2 (%)	SrO (%)	V2O3 (%)	SO3 (%)	P2O5 (%)	TOTAL (%)
0.0	0.3	0.1	67.5	0.0	10.4	0.5	0.0	0.0	0.1	5.7	0.0	0.1	0.1	0.1	0.0	0.0	0.3	0.4	85.6

Appendix IV: Analytical data from nodule samples collected in lac Aylmer

	Na2O (%)	K2O (%)	MgO (%)	FeO (%)	F (%)	SiO2 (%)	MnO (%)	Cl (%)	BaO (%)	CaO (%)	Al2O3 (%)	Cr2O3 (%)	NiO (%)	ZnO (%)	TiO2 (%)	SnO (%)	V2O3 (%)	SO3 (%)	P2O5 (%)	TOTAL (%)
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Laser analyses on nodule sample 94SCAA-S100

sample	CaO (%)	Co (ppm)	Ni (ppm)	Cu (ppm)	Zn (ppm)	Pb (ppm)
1.0	0.1	71.0	372.0	24.0	290.0	42.0
2.0	0.1	57.0	384.0	21.0	285.0	39.0
3.0	0.1	59.0	402.0	24.0	265.0	32.0
4.0	0.1	69.0	598.0	35.0	308.0	35.0
5.0	0.1	74.0	651.0	43.0	347.0	52.0
6.0	0.1	78.0	770.0	70.0	261.0	56.0
7.0	0.1	97.0	1161.0	70.0	311.0	64.0
8.0	0.1	91.0	984.0	39.0	237.0	30.0
9.0	0.1	79.0	805.0	36.0	185.0	22.0
10.0	0.1	94.0	1010.0	41.0	225.0	31.0
11.0	0.1	84.0	846.0	53.0	275.0	45.0
12.0	0.1	84.0	781.0	51.0	264.0	50.0
13.0	0.1	68.0	554.0	42.0	221.0	46.0
14.0	0.1	77.0	501.0	31.0	216.0	34.0
15.0	0.1	74.0	321.0	15.0	166.0	17.0
16.0	0.1	60.0	395.0	26.0	299.0	61.0
17.0	0.3	64.0	363.0	27.0	320.0	53.0

Sample site location for laser analyses on nodule sample 94SCAA-S100

Appendix V: Surficial lake sediment geochemistry of the study area from the <80µm fraction

SAMPLE NUMBER	ZONE	EASTING	NORTHING	TOT/C (%)	Mn (ppm)	Fe (%)	Zn (ppm)	Cu (ppm)	Pb (ppm)	Cr (ppm)	Ni (ppm)	Co (ppm)	Mg (%)	Cd (ppm)	Ag (ppb)	As (ppm)	U (ppm)	Au (ppm)	Cu (%)
93SCAP-S003	19	323225	5076723	4.38	439	13.11	573	961	646	52	45	10	1.11	3.0	1073	22	6	0.67	0.2
93SCAP-S004	19	323000	5076900	5.33	354	4.72	812	8868	646	42	85	10	0.91	0.4	514	33	5	0.05	0.26
93SCAP-S005	19	322960	5077000	2.44	447	4.21	79	222	48	50	101	12	0.92	0.1	268	11	5	0.09	0.13
93SCAP-S006	19	319150	5078800	0.74	551	2.11	40	42	12	76	139	19	1.1	0.1	36	12	5	0.05	0.25
93SCAP-S007	19	319050	5079050	2.25	356	3.29	235	295	50	65	155	18	1.52	0.8	28	13	5	0.05	0.28
93SCAP-S008	19	320700	5081400	0.99	280	2.46	66	38	15	110	266	18	2.21	0.1	60	4	5	0.05	0.15
93SCAP-S009	19	322200	5079950	0.94	1070	3.31	82	20	13	54	127	20	1.38	0.3	34	16	5	0.05	0.32
93SCAP-S014	19	319075	5079075	1.22	330	3.22	164	184	39	58	100	14	1.03	0.6	58	12	5	0.05	0.22
93SCAT-001	19	323350	5076550	0.03	787	9.88	2242	2528	1057	46	16	12	2.07	4.9	6285	45	10	0.05	0.21
93SCAT-002	19	323350	5076550	0.06	146	8.63	326	293	216	7	3	9	0.55	1.1	2544	25	5	0.05	0.09
93SCAT-003	19	323350	5076550	43.78	11	6.02	23	575	40	10	3	1	0.02	0.1	329	5	5	0.27	0.02
93SCAT-004	19	322200	5077650	9.38	593	5.28	273	454	58	66	150	18	0.77	1.2	197	18	5	0.06	0.26
94SCAA-S001	19	316356	5077469	0.24	1531	3.21	42	26	6	41	14	15	1.3	0.1	40	89	5	0.05	0.27
94SCAA-S002	19	315641	5077549	4.59	1108	3.95	239	64	49	83	253	24	1.59	1.3	289	13	5	0.05	0.29
94SCAA-S003	19	315043	5077333	1.43	378	2.23	104	24	12	41	114	11	1.08	0.4	48	7	5	0.05	0.22
94SCAA-S004b	19	315356	5077333	1.96	2964	3.82	157	41	26	55	216	21	1.09	0.9	139	22	5	0.05	0.23
94SCAA-S005	19	314493	5077454	1.49	710	2.96	116	26	12	48	131	15	1.11	0.5	89	8	5	0.07	0.2
94SCAA-S006	19	314131	5076803	1.08	257	1.56	75	14	7	36	95	9	0.88	0.2	72	3	5	0.06	0.14
94SCAA-S007	19	314234	5077437	2.52	529	2.91	106	27	11	68	208	19	1.66	0.5	55	7	5	0.05	0.22
94SCAA-S008	19	314566	5076997	0.51	426	2.66	81	11	6	49	114	10	0.89	0.3	37	15	5	0.05	0.14
94SCAA-S009	19	314987	5077028	4.91	1614	4.6	304	82	56	93	280	27	1.62	1.7	322	16	5	0.05	0.31
94SCAA-S010	19	315563	5076994	4.86	2258	5.43	386	133	83	93	288	30	1.58	2.2	509	26	5	0.05	0.27
94SCAA-S011	19	316088	5076996	2.27	823	2.9	170	53	25	59	160	16	1.33	0.9	110	8	5	0.05	0.26
94SCAA-S012	19	316513	5076419	0.97	330	2.25	65	16	8	50	103	9	0.81	0.4	61	11	5	0.05	0.18
94SCAA-S013	19	314973	5076564	3.42	1267	4.83	178	58	44	115	319	33	2.24	0.7	303	16	5	0.05	0.23
94SCAA-S014	19	315537	5076596	5.42	2105	6.2	435	188	108	94	289	29	1.51	3.0	745	38	5	0.18	0.27
94SCAA-S015	19	314072	5076490	4.74	1271	5.49	376	130	93	105	290	30	1.69	1.9	622	23	5	0.18	0.28
94SCAA-S016	19	314040	5076471	0.7	481	2.47	114	17	10	45	125	11	0.88	0.4	17	11	5	0.05	0.2
94SCAA-S017	19	314026	5076577	2.26	646	3.3	129	27	18	60	177	16	1.19	0.6	19	24	5	0.05	0.18
94SCAA-S018	19	314026	5076577	4.84	2215	4.85	405	161	96	91	299	29	1.58	2.5	597	26	5	0.08	0.26
94SCAA-S019a	19	314499	5075989	4.9	2332	6.69	399	177	167	94	310	31	1.55	2.6	562	34	5	0.07	0.27
94SCAA-S019b	19	315504	5075994	5.98	3674	6.37	324	111	80	89	287	31	1.49	2.1	538	33	5	0.05	0.25
94SCAA-S020	19	315504	5075994	6.35	2826	6.61	565	195	108	104	313	34	1.55	3.0	782	40	5	0.16	0.3
94SCAA-S021	19	316041	5076019	1.1	663	3.26	64	11	12	57	191	16	0.98	0.2	159	6	5	0.05	0.26
94SCAA-S022	19	316020	5075526	4.7	1263	4.01	259	62	40	85	282	25	1.41	1.3	231	16	5	0.05	0.27
94SCAA-S023	19	314464	5075553	5.9	4039	6.92	412	157	103	96	297	31	1.57	2.2	569	33	5	0.07	0.27
94SCAA-S024	19	314657	5075442	5.69	3709	6.43	324	124	89	96	297	31	1.59	1.5	277	16	5	0.05	0.19
94SCAA-S025	19	314657	5075442	5.01	1316	4.29	217	61	45	92	290	30	1.59	1.5	277	16	5	0.05	0.19
94SCAA-S026	19	314488	5075441	5.01	1316	4.29	217	61	45	92	290	30	1.59	1.5	277	16	5	0.05	0.19
94SCAA-S027	19	314030	5075441	1.06	561	2.95	86	18	11	45	106	10	0.83	0.5	41	11	5	0.05	0.19
94SCAA-S028	19	314480	5074968	1	967	2.47	107	27	15	51	158	17	0.83	0.7	90	11	5	0.05	0.19
94SCAA-S029	19	314503	5075044	5.35	1300	4.22	326	67	51	91	309	29	1.61	1.8	288	18	5	0.05	0.31
94SCAA-S030	19	314574	5075041	4.68	8208	7.52	597	183	101	92	338	35	1.48	3.8	614	47	5	0.05	0.35
94SCAA-S031	19	316104	5075056	6.57	1470	4.53	377	139	82	104	309	30	1.61	2.0	492	18	5	0.05	0.35

Appendix V: Surficial lake sediment geochemistry of the study area from the < 80µm fraction

SAMPLE NUMBER	ZONE	EASTING	NORTHING	TOT/C (%)	Mn (ppm)	Fe (%)	Zn (ppm)	Cu (ppm)	Pb (ppm)	Cr (ppm)	Ni (ppm)	Cu (ppm)	Mg (%)	Cd (ppm)	Ag (ppb)	As (ppm)	U (ppm)	Vu (ppm)	Co (%)
94SC/AA-S032	19	315918	5074509	5.45	1295	1.71	274	76	4.7	88	299	26	1.52	1.6	314	15	5	0.05	0.33
94SC/AA-S033	19	315527	5074524	2.87	504	2.14	124	31	18	51	142	13	0.99	0.7	158	10	5	0.05	0.26
94SC/AA-S034	19	315004	5074506	1.92	560	2.23	141	31	18	49	141	13	1	0.7	167	12	5	0.05	0.21
94SC/AA-S035	19	318536	5074504	0.72	322	1.8	82	14	8	40	92	8	0.78	0.4	45	16	5	0.05	0.13
94SC/AA-S036	19	314615	5074328	0.58	96	0.77	22	3	3	20	26	2	0.35	0.0	10	2	5	0.08	0.06
94SC/AA-S037	19	316004	5073990	3.97	882	3.22	220	50	28	81	245	22	1.21	1.3	254	13	5	0.05	0.28
94SC/AA-S038	19	316526	5074052	5.46	1015	3.6	284	71	43	90	277	24	1.4	1.4	321	12	5	0.1	0.32
94SC/AA-S039	19	317004	5074024	5.55	961	3.76	246	54	31	102	279	26	1.5	1.3	212	14	5	0.05	0.34
94SC/AA-S040	19	317526	5072736	1.48	572	4.22	185	48	10	144	193	20	1.7	0.9	85	11	5	0.05	0.22
94SC/AA-S041	19	317686	5073093	3.34	763	3.23	486	185	42	68	147	16	1.22	2.6	275	13	5	0.05	0.29
94SC/AA-S042	19	318037	5073500	4.48	1868	4.35	597	241	63	80	201	23	1.27	3.5	495	25	5	0.05	0.46
94SC/AA-S043	19	316521	5072519	4	391	2.22	266	76	25	62	137	11	1.09	1.3	214	12	5	0.05	0.34
94SC/AA-S044	19	316521	5073006	0.51	203	1.79	127	26	10	60	53	5	0.54	0.6	70	7	5	0.05	0.18
94SC/AA-S045	19	316494	5073407	2.38	417	2.52	159	49	20	61	147	12	1.24	0.9	164	10	5	0.06	0.29
94SC/AA-S046	19	316513	5074526	5.8	1444	4.62	331	120	66	98	307	29	1.67	2.1	425	18	5	0.1	0.32
94SC/AA-S047	19	317035	5075020	0.98	549	2.46	90	20	12	55	157	14	1.18	0.4	99	10	5	0.05	0.18
94SC/AA-S048	19	317520	5074993	4.18	1279	4.11	214	55	28	88	307	26	1.67	1.5	209	12	5	0.05	0.31
94SC/AA-S049	19	317491	5075409	1.19	515	2.61	140	28	16	53	154	12	1.01	0.7	57	14	5	0.05	0.18
94SC/AA-S050	19	317640	5076012	4.28	740	2.88	151	51	22	65	186	15	1.06	0.9	125	17	5	0.05	0.34
94SC/AA-S051	19	317657	5076505	1.96	291	1.01	43	15	6	25	51	5	0.42	0.2	10	3	5	0.05	0.21
94SC/AA-S052	19	317548	5077063	1.8	297	1.08	83	21	11	29	61	6	0.47	0.3	93	3	5	0.1	0.18
94SC/AA-S053	19	317580	5077554	4.17	926	2.88	132	50	23	66	198	18	1.31	0.7	170	9	5	0.05	0.31
94SC/AA-S054	19	318502	5078011	5.82	949	4.35	221	263	42	98	295	28	1.87	1.1	398	16	5	0.26	0.35
94SC/AA-S055	19	318493	5077549	4.53	1175	3.93	174	84	31	87	265	25	1.61	0.9	219	13	5	0.05	0.32
94SC/AA-S056	19	318514	5076510	0.76	392	2.33	93	20	8	65	123	9	0.98	0.3	10	15	5	0.05	0.19
94SC/AA-S057	19	318499	5075980	4.79	874	2.86	276	65	33	78	222	20	1.36	1.2	228	10	5	0.05	0.34
94SC/AA-S058	19	318532	5075556	5.58	968	4.29	619	236	105	102	295	28	1.72	2.9	762	19	5	0.05	0.39
94SC/AA-S059	19	318504	5075002	5.94	921	4.58	427	185	89	104	296	28	1.7	2.5	603	20	5	0.22	0.35
94SC/AA-S060	19	318476	5074589	6.08	1122	4.26	319	110	60	99	286	28	1.58	1.9	386	17	5	0.09	0.31
94SC/AA-S061	19	318378	5073967	3.11	1553	3.64	356	88	25	72	202	20	1.41	1.8	65	17	5	0.05	0.33
94SC/AA-S062	19	318046	5074020	1.31	829	3.55	200	59	26	73	153	12	0.86	0.9	195	19	5	0.05	0.21
94SC/AA-S063	19	317492	5073944	4.08	1191	4.11	282	92	46	90	341	31	1.5	1.7	347	18	5	0.13	0.29
94SC/AA-S064	19	317504	5071499	4.04	1131	4.01	509	220	98	132	266	25	2.17	1.0	762	21	5	0.2	0.26
94SC/AA-S065	19	317504	5072951	2.72	332	2.11	552	174	33	50	115	12	0.99	2.1	237	8	5	0.05	0.22
94SC/AA-S066	19	317007	5073018	3.71	487	2.68	659	239	47	55	142	15	1.12	2.8	373	12	5	0.05	0.32
94SC/AA-S067	19	316982	5073560	5.39	938	4.55	553	297	112	97	250	26	1.49	3.3	932	21	5	0.17	0.31
94SC/AA-S068	19	316963	5074473	6.24	1224	4.09	381	125	80	102	296	29	1.59	2.0	562	19	5	0.06	0.33
94SC/AA-S069	19	317502	5074495	6.18	1225	4.71	409	132	82	117	337	32	1.87	2.0	524	19	5	0.08	0.38
94SC/AA-S070	19	318009	5074503	5.79	1104	5.06	476	215	100	105	278	29	1.57	3.0	707	22	5	0.11	0.31
94SC/AA-S071	19	318046	5075006	5.65	1048	4.3	380	152	72	101	269	27	1.58	2.2	507	18	5	0.06	0.32
94SC/AA-S072	19	318035	5075610	5.77	918	4.81	496	230	99	103	271	28	1.58	2.9	774	20	5	0.15	0.29
94SC/AA-S073	19	318029	5076011	3.82	1269	3.32	253	78	40	83	235	22	1.4	1.4	273	14	6	0.05	0.29
94SC/AA-S074	19	319009	5075497	1.68	416	2.78	194	55	22	67	168	14	1.37	0.9	146	11	5	0.05	0.22
94SC/AA-S075	19	319003	5075029	1.37	468	2.3	188	47	24	54	121	11	0.86	0.8	118	10	5	0.06	0.2

Appendix V: Surficial lake sediment geochemistry of the study area from the <80µm fraction

SAMPLE NUMBER	ZONE	EASTING	NORTHING	TOT/C (%)	Mn (ppm)	Fe (%)	Zn (ppm)	Cu (ppm)	Pb (ppm)	Cr (ppm)	Ni (ppm)	Co (ppm)	Mg (%)	Cd (ppm)	Ag (ppb)	As (ppm)	U (ppm)	Am (ppm)	Cu (%)
94SC-AA-S077A	19	315986	5072503	8.74	1206	3.14	469	166	80	84	224	20	1.2	2.7	518	13	5	0.11	0.11
94SC-AA-S077B	19	315986	5072505	8.57	1055	2.91	416	163	76	79	209	19	1.13	2.6	481	13	5	0.05	0.1
94SC-AA-S078	19	315505	5072500	3.94	826	2.91	272	90	40	68	175	15	0.98	1.6	291	12	5	0.1	0.25
94SC-AA-S079	19	315504	5072016	7.82	1201	3.86	383	151	70	95	253	22	1.33	2.5	500	16	5	0.06	0.4
94SC-AA-S080	19	314998	5072001	1.85	557	2.55	187	52	21	58	158	15	1.35	1.0	114	8	5	0.11	0.21
94SC-AA-S081	19	315520	5071522	3.14	915	4.34	348	89	34	91	232	19	1.51	1.7	257	24	5	0.05	0.25
94SC-AA-S082	19	316037	5072051	7.09	842	3.18	278	100	47	81	238	19	1.21	1.8	347	13	5	0.07	0.37
94SC-AA-S083	19	316544	5072045	2.39	457	3.33	176	45	19	68	172	14	1.09	0.9	104	22	5	0.09	0.21
94SC-AA-S084	19	318552	5078944	4.82	1206	4.13	472	225	85	83	259	24	1.46	2.9	673	19	5	0.13	0.31
94SC-AA-S085	19	318957	5078737	1.51	441	2.19	188	67	15	47	96	12	0.92	0.8	49	8	5	0.14	0.2
94SC-AA-S086	19	318909	5078667	1.2	384	1.68	107	30	7	65	94	9	0.99	0.5	10	9	5	0.05	0.21
94SC-AA-S087	19	318783	5078670	1.09	251	1.91	146	91	17	43	86	10	1.02	0.6	35	5	5	0.15	0.16
94SC-AA-S088	19	318754	5078759	1.4	247	1.96	128	95	16	49	86	10	1.02	0.5	26	5	5	0.05	0.16
94SC-AA-S089	19	318969	5077482	0.69	362	1.32	96	15	8	44	67	6	0.72	0.3	10	4	5	0.05	0.3
94SC-AA-S090	19	318091	5077389	3.32	1875	4.79	222	125	8	86	281	30	1.72	1.2	328	19	5	0.11	0.28
94SC-AA-S091	19	318006	5076992	1.51	794	2.86	110	30	18	67	179	19	1.32	0.6	123	14	5	0.05	0.22
94SC-AA-S092	19	318070	5076524	0.79	463	2.11	95	18	11	51	101	10	0.56	0.5	70	15	5	0.05	0.16
94SC-AA-S093	19	318008	5078001	4.2	1125	4.11	166	58	32	90	246	26	1.46	1.0	233	14	5	0.05	0.3
94SC-AA-S094	19	318024	5078520	2.69	989	3.49	145	57	29	70	169	18	1.15	0.8	172	15	5	0.05	0.29
94SC-AA-S095	19	318069	5079024	2.12	376	1.97	92	28	13	42	87	10	0.77	0.4	77	3	5	0.05	0.23
94SC-AA-S096	19	318514	5079007	3.35	1066	4.18	207	166	48	98	250	25	1.69	1.1	301	14	5	0.05	0.28
94SC-AA-S097	19	318585	5079407	1.11	474	3.55	120	27	11	14	163	14	1.73	0.5	72	13	5	0.05	0.17
94SC-AA-S098	19	317929	5079482	2.48	529	3.23	144	43	19	59	149	16	1.32	0.4	46	4	5	0.05	0.26
94SC-AA-S099	19	317486	5080054	0.77	221	1.3	45	11	5	29	59	7	0.63	0.1	10	2	5	0.05	0.19
94SC-AA-S100	19	317513	5080473	2.43	903	3.85	118	28	24	76	172	20	1.3	0.6	129	10	5	0.05	0.27
94SC-AA-S101	19	317506	5081003	3.66	2119	5.44	204	66	57	112	337	35	2.18	0.9	293	21	5	0.05	0.25
94SC-AA-S102	19	317506	5081519	3.57	1708	5.42	190	82	68	126	312	34	2.09	1.2	390	19	5	0.06	0.26
94SC-AA-S103	19	317505	5082019	3.3	1378	5.59	183	68	63	133	328	35	2.24	1.9	389	19	5	0.05	0.25
94SC-AA-S104	19	317511	5082529	2.6	1020	4.73	153	35	36	117	279	30	2.13	0.8	194	19	5	0.1	0.25
94SC-AA-S105	19	317403	5083030	2.4	1007	3.94	148	32	31	92	255	27	2.04	0.6	190	8	5	0.05	0.25
94SC-AA-S106	19	318005	5082992	3.06	1091	4.22	165	42	38	114	317	29	2.48	0.6	131	11	5	0.05	0.26
94SC-AA-S107	19	318023	5082020	2.62	1124	4.61	150	30	31	105	244	29	1.9	0.8	168	8	5	0.05	0.26
94SC-AA-S108	19	318058	5080999	3.05	1323	4.84	164	37	34	106	271	31	1.9	0.9	215	12	5	0.05	0.27
94SC-AA-S109	19	317070	5080492	3.99	845	3.19	118	31	23	65	158	17	1.2	0.6	142	6	5	0.09	0.28
94SC-AA-S110	19	316478	5080684	1.73	308	1.46	61	10	8	33	64	8	0.65	0.2	10	3	5	0.15	0.2
94SC-AA-S111	19	316935	5081008	0.55	621	2.26	66	9	9	62	102	11	0.57	0.3	47	11	5	0.05	0.16
94SC-AA-S112	19	316977	5081453	2.67	1063	3.99	149	26	27	87	256	27	1.89	0.7	98	8	5	0.05	0.27
94SC-AA-S113	19	317682	5082014	1.26	567	2.23	76	14	11	43	95	11	0.91	0.3	73	3	5	0.05	0.22
94SC-AA-S114	19	317424	5083451	2.18	454	3.08	102	22	18	85	186	18	1.72	0.4	91	4	5	0.05	0.26
94SC-AA-S115	19	317424	5084516	1.75	318	2.25	74	13	10	100	264	20	2.56	0.3	59	4	5	0.05	0.23
94SC-AA-S116	19	317038	5084022	2.03	469	3.01	95	23	22	106	269	21	2.53	0.4	162	6	5	0.08	0.26
94SC-AA-S117	19	317495	5084088	1.35	404	2.73	66	17	11	105	272	21	2.56	0.2	96	5	5	0.05	0.23
94SC-AA-S118	19	318060	5084989	2.54	530	3.13	113	21	18	102	260	22	2.21	0.4	104	6	5	0.07	0.25
94SC-AA-S119	19	318060	5084989	2.71	948	4.17	138	33	30	123	327	28	2.65	0.6	154	8	5	0.05	0.29

Appendix V: Surficial lake sediment geochemistry of the study area from the ~80µm fraction

SAMPLE NUMBER	ZONE	EASTING	NORTHING	TOT/C (%)	Mn (ppm)	Fe (%)	Zn (ppm)	Cu (ppm)	Pb (ppm)	Cr (ppm)	Ni (ppm)	Co (ppm)	Mg (%)	Cd (ppm)	Ag (ppb)	As (ppm)	V (ppm)	Au (ppm)	Cu (%)
94SC-AA-S120	19	318027	5082466	1.04	1449	4.53	122	31	21	79	237	24	2.02	0.5	125	11	5	0.05	0.25
94SC-AA-S121	19	317967	5080579	3.77	2313	5.49	204	105	63	115	354	35	2.27	1.1	412	20	5	0.08	0.28
94SC-AA-S122	19	314483	5072453	11.94	712	2.25	246	73	33	71	202	15	0.92	1.8	242	11	5	0.14	0.6
94SC-AA-S123	19	315054	5072516	2.48	638	2.42	203	50	25	52	146	12	0.72	1.3	182	13	5	0.05	0.22
94SC-AA-S124	19	314503	5072085	4.88	483	2	144	33	14	69	126	9	0.81	0.8	119	6	5	0.04	0.3
94SC-AA-S125	19	316338	5071550	17.61	585	2.22	246	88	33	79	208	14	0.98	2.2	216	8	5	0.06	0.82
94SC-AA-S126	19	313960	5071006	9.44	591	2.6	418	183	59	91	206	18	1.06	2.9	418	13	5	0.12	0.43
94SC-AA-S127	19	313765	5070142	7.29	450	1.87	183	54	22	74	123	10	0.68	1.2	170	5	5	0.05	0.36
94SC-AA-S128	19	314972	5071513	2.06	612	2.56	196	49	23	64	142	14	0.8	1.1	170	12	5	0.06	0.21
94SC-AB-S001	19	329897	5075214	22.95	263	1.18	127	23	41	22	46	8	0.23	1.9	195	6	8	0.08	0.49
94SC-AB-S002	19	330642	5076464	17.12	328	1.36	152	29	33	29	74	8	0.36	1.8	179	4	5	0.12	0.46
94SC-AB-S003	19	329977	5075755	19.03	201	1.02	100	22	48	26	44	6	0.27	1.3	219	4	6	0.05	0.38
94SC-AL-S001	19	324902	5075940	24.47	98	0.81	69	15	6	24	69	5	0.2	0.8	82	2	5	0.08	1.08
94SC-AL-S002	19	325943	5076256	26.69	112	0.69	90	16	10	21	62	6	0.19	0.9	70	2	5	0.05	0.86
94SC-AL-S001	19	334064	5078917	4.33	899	3.1	134	20	31	60	117	16	0.96	0.8	144	9	5	0.05	0.31
94SC-AL-S002	19	335734	5078617	2.41	418	3.36	105	26	20	59	139	16	1.23	0.3	151	10	5	0.05	0.46
94SC-AL-S003	19	336101	5076208	4.42	1003	4.02	137	28	33	72	160	19	1.21	0.7	185	13	5	0.17	0.81
94SC-AL-S004	19	334006	5080854	5.57	5227	6.6	177	33	57	82	204	28	1.18	1.3	237	38	5	0.05	0.46
94SC-AL-S005	19	312878	5081289	8.44	1134	3.29	177	25	21	85	191	24	1.18	1.2	263	13	5	0.14	0.57
94SC-AL-S006	19	332895	5085419	5.15	3775	6.11	175	30	61	111	272	40	1.61	1.5	255	27	5	0.05	0.5
94SC-AL-S007	19	333081	5087594	2.06	469	2.51	74	14	11	74	163	19	1.69	0.3	76	7	5	0.1	0.21
94SC-AL-S008	19	331403	5089358	5.53	3632	6.57	178	29	67	128	322	43	1.96	1.4	264	32	5	0.15	0.29
94SC-AL-S009	19	330490	5091302	2.61	907	2.64	94	14	19	95	187	20	1.62	0.5	40	9	5	0.05	0.24
94SC-AL-S010	19	328369	5092655	5.76	1264	3.72	144	23	33	156	355	38	2.63	1.0	175	13	5	0.1	0.32
94SC-AL-S011	19	327961	5093736	7.52	1356	3.11	105	21	32	155	410	35	2.79	0.7	114	9	5	0.16	0.4
94SC-AL-S012	19	325687	5093090	4.01	527	2.28	84	10	16	94	194	22	1.65	0.5	64	8	5	0.05	0.26
94SC-AL-S013	19	324525	5091096																
94SC-AG-S001	19	317842	5069917	1.14	286	2.14	115	17	12	58	118	10	1.45	0.4	59	5	5	0.05	0.22
94SC-AG-S002	19	318096	5068946	6.92	15038	7.4	234	30	56	54	245	20	0.69	2.1	290	45	6	0.08	0.43
94SC-AG-S003	19	319601	5067537	8.29	2285	4.29	200	27	51	60	180	21	0.89	1.7	238	19	5	0.05	0.48
94SC-AG-S004	19	318376	5068043	7.53	1377	3.27	200	29	54	65	159	17	0.81	1.8	212	22	5	0.08	0.48
94SC-AL-S001	19	329351	5072877	17.77	646	1.37	152	28	139	30	45	10	0.28	2.3	374	7	7	0.08	0.41
94SC-AL-S002	19	329649	5072562	7.08	288	1.25	92	13	47	31	53	9	0.75	0.9	156	4	5	0.05	0.22
94SC-AL-S003	19	329984	5073354	13.92	905	1.69	139	20	32	34	58	11	0.32	1.1	204	5	10	0.05	0.33
94SC-AL-S001	19	325447	5071607		2991	2.18	110	17	33	39	88	10	0.86	0.7	86	7	5	0.05	0.35
94SC-AL-S002	19	326300	5071844	9.6	815	2.51	183	27	30	48	117	12	0.58	1.4	203	9	14	0.07	0.62
94SC-AL-S003	19	326823	5072470	8.98	2917	3.91	275	30	91	44	120	15	0.68	2.1	242	10	5	0.05	0.76
94SC-AL-S004	19	326380	5070941	5.69	2894	3.35	166	26	36	52	129	16	0.96	1.1	125	13	5	0.05	0.47
94SC-AP-S001	19	325350	5085300	1.68	952	2.86	60	23	12	84	254	23	2.36	0.2	14	12	5	0.05	0.3
94SC-AR-S001	19	317580	5077554	4.28	865	2.98	142	54	28	68	178	18	1.16	0.7	194	7	5	0.05	0.29
94SC-AR-S002	19	316513	5074526	6	1294	4.6	359	144	84	97	297	28	1.55	2.2	547	17	5	0.05	0.31
94SC-AR-S003	19	315505	5072500	4.98	837	2.85	301	103	46	66	178	15	0.97	1.7	343	9	5	0.06	0.27
94SC-AS-S001	19	333547	5073112	2.17	367	1.92	62	15	10	30	49	8	0.62	0.2	10	6	5	0.05	0.25
94SC-AS-S002	19	332645	5074608	6.29	859	3.4	128	21	22	46	87	13	0.92	0.5	68	9	5	0.05	0.42

Appendix V: Surficial lake sediment geochemistry of the study area from the <80µm fraction

SAMPLE NUMBER	ZONE	EASTING	NORTHING	TOT/C (%)	Mn (ppm)	Fe (%)	Zn (ppm)	Cu (ppm)	Pb (ppm)	Cr (ppm)	Ni (ppm)	Co (ppm)	Mg (%)	Cd (ppm)	Ag (ppb)	As (ppm)	U (ppm)	Au (ppm)	Cs (%)
94SL/AS-S003	19	331582	5076774	4.16	610	2.56	116	14	24	33	70	15	0.76	0.6	48	7	5	0.05	0.39
94SL/AS-S004	19	332405	5077945	4.94	763	3.39	135	23	39	49	100	14	0.94	0.6	151	8	5	0.05	0.37

Appendix V: Surficial lake sediment geochemistry of the study area from the <80µm fraction

SAMPLE NUMBER	ZONE	EASTING	NORTHING	P (%)	Al (%)	Na (%)	K (%)	Hg (ppb)	B (ppm)	Ba (ppm)	Bi (ppm)	Ga (ppm)	La (ppm)	Sb (ppm)	Se (ppm)	Sr (ppm)	Tc (ppm)	Tb (ppm)	Ti (%)	Ti (ppm)	V (ppm)	W (ppm)
93SC/AP-S003	19	323225	5076725	0.042	1.48	0.01	0.08	9	2	309	1.5	6	8	2	11	18	9	2	0	0.1	51	2
93SC/AP-S004	19	323000	5076900	0.063	1.26	0.01	0.07	5	2	60	0.3	0	11	0	4	20	5	2	0.03	0.1	27	2
93SC/AP-S005	19	322900	5077000	0.046	1.11	0.01	0.09	12	2	127	0.2	4	16	1	3	9	3	2	0.03	0.1	23	2
93SC/AP-S006	19	319150	5078800	0.055	0.64	0.01	0.03	12	2	31	0.1	2	16	0	1	17	0	3	0.04	0.1	17	2
93SC/AP-S007	19	319050	5079050	0.054	1.08	0.02	0.06	20	3	45	0.2	3	16	0	1	16	1	3	0.03	0.3	23	2
93SC/AP-S008	19	320700	5081400	0.013	1.28	0.01	0.05	28	2	45	0.2	4	20	1	1	12	0	5	0.03	0.1	20	2
93SC/AP-S009	19	322200	5079950	0.05	1.04	0.01	0.08	27	3	43	0.1	3	16	0	0	19	0	3	0.04	0.1	22	2
93SC/AP-S014	19	319075	5079075	0.051	0.93	0.01	0.05	18	4	42	0.7	3	17	0	1	12	1	3	0.04	0.2	22	2
93SC/A1-001	19	323350	5076550	0.021	1.63	0.01	0.21	8	2	10	6.0	7	4	3	5	15	9	3	0.03	1.2	22	2
93SC/A1-002	19	323350	5076550	0.013	0.44	0.03	0.11	16	2	5	2.1	3	2	1	6	10	4	1	0.03	1.3	14	2
93SC/A1-003	19	323350	5076550	0.046	0.04	0.01	0.01	64	17	163	0.8	0	1	0	4	4	1	1	0.01	0.1	2	2
93SC/A1-004	19	322200	5077650	0.064	1.57	0.01	0.07	59	4	99	0.4	5	14	0	5	15	2	1	0.03	0.2	33	2
94SC/AA-S001	19	316356	5077469	0.06	1.04	0.01	0.08	14	2	48	0.1	3	24	0	0	17	0	5	0.04	0.1	22	2
94SC/AA-S002	19	315641	5077549	0.082	2.08	0.01	0.15	231	3	101	0.2	5	24	1	1	22	0	3	0.03	0.0	30	2
94SC/AA-S003	19	315356	5078082	0.059	0.96	0.01	0.06	44	2	36	0.1	2	21	0	0	13	0	3	0.03	0.0	16	2
94SC/AA-S004b	19	315043	5077333	0.074	1.12	0.01	0.07	105	2	73	0.1	3	19	0	1	16	0	2	0.02	0.0	20	2
94SC/AA-S005	19	314493	5077454	0.052	1.27	0.01	0.08	55	2	49	0.2	3	24	0	0	14	0	5	0.03	0.0	20	2
94SC/AA-S006	19	314110	5076803	0.04	0.69	0.01	0.04	21	2	23	0.1	2	16	0	0	8	0	3	0.02	0.0	13	2
94SC/AA-S007	19	314234	5077437	0.065	1.31	0.01	0.08	61	3	54	0.1	3	20	0	1	13	0	2	0.03	0.0	22	2
94SC/AA-S008	19	314366	5076997	0.04	0.63	0.01	0.03	16	2	16	0.1	1	14	0	0	7	0	2	0.02	0.0	13	2
94SC/AA-S009	19	314987	5077028	0.093	2.23	0.01	0.14	254	3	109	0.3	5	24	1	1	24	0	2	0.03	0.0	33	2
94SC/AA-S010	19	315563	5076994	0.104	2.12	0.01	0.15	295	2	135	0.4	5	22	1	2	23	1	2	0.03	0.0	35	2
94SC/AA-S011	19	316088	5076996	0.073	1.28	0.01	0.09	88	2	59	0.2	3	23	0	1	17	0	2	0.03	0.0	21	2
94SC/AA-S012	19	316513	5076419	0.044	0.69	0.01	0.04	27	2	22	0.1	2	16	0	1	10	0	3	0.03	0.0	16	2
94SC/AA-S013	19	315973	5076564	0.083	1.98	0.01	0.15	122	2	108	0.3	5	23	1	1	21	1	4	0.03	0.0	30	2
94SC/AA-S014	19	315537	5076596	0.122	2.08	0.01	0.17	327	3	151	0.7	5	21	1	2	24	1	3	0.03	0.0	37	2
94SC/AA-S015	19	315072	5076490	0.107	2.17	0.01	0.15	196	4	138	1.0	6	24	1	1	25	1	4	0.03	0.0	38	2
94SC/AA-S016	19	314461	5076471	0.062	0.67	0.01	0.04	26	2	22	0.1	1	19	0	0	10	0	3	0.03	0.0	17	2
94SC/AA-S017	19	314040	5076513	0.056	0.85	0.01	0.05	61	2	30	0.1	2	16	0	0	10	0	3	0.03	0.0	18	2
94SC/AA-S018	19	314026	5076037	0.059	1.21	0.01	0.07	77	2	49	0.1	3	21	0	0	16	0	3	0.03	0.0	21	2
94SC/AA-S019a	19	314499	5075989	0.1	2.22	0.01	0.16	308	3	127	0.6	6	23	1	2	24	0	2	0.03	0.0	35	2
94SC/AA-S019b	19	314499	5075989	0.101	2.12	0.01	0.13	288	3	123	0.7	5	22	1	2	23	1	2	0.03	0.0	34	2
94SC/AA-S020	19	315005	5075995	0.108	2.18	0.01	0.17	305	3	171	0.5	6	23	1	2	23	0	3	0.03	0.0	36	2
94SC/AA-S021	19	315505	5075946	0.136	2.04	0.01	0.15	202	3	191	0.8	5	23	1	2	29	1	4	0.02	0.0	39	2

Appendix V: Surficial lake sediment geochemistry of the study area from the <80µm fraction

SAMPLE NUMBER	ZONE	EASTING	NORTING	P (%)	Al (%)	Na (%)	K (%)	Hg (ppb)	B (ppm)	Ba (ppm)	Bi (ppm)	Ga (ppm)	La (ppm)	Sb (ppm)	Se (ppm)	Sr (ppm)	Te (ppm)	Th (ppm)	Ti (%)	Ti (ppm)	V (ppm)	W (ppm)
94SC/AA-S022	19	316041	5075519	0.026	1.85	0.01	0.05	64	2	118	0.1	5	21	0	0	28	0	4	0.01	0.0	29	2
94SC/AA-S023	19	316020	5075526	0.098	2.03	0.01	0.12	154	3	96	0.3	4	25	0	1	25	0	3	0.03	0.0	29	2
94SC/AA-S024	19	315465	5075551	0.123	2.21	0.01	0.17	366	3	195	0.7	6	23	1	3	26	1	2	0.03	0.0	38	2
94SC/AA-S025	19	315057	5075542	0.107	2.24	0.01	0.18	306	2	173	0.6	6	22	1	2	25	1	2	0.03	0.0	36	2
94SC/AA-S026	19	314488	5075541	0.098	2.28	0.01	0.14	260	3	100	0.5	6	23	1	1	24	0	2	0.03	0.0	32	2
94SC/AA-S027	19	314030	5075630	0.048	0.72	0.01	0.05	28	3	24	0.1	2	18	0	0	10	0	2	0.03	0.0	18	2
94SC/AA-S028	19	314480	5074968	0.054	0.82	0.01	0.05	46	2	49	0.1	2	18	1	1	11	0	2	0.03	0.0	19	2
94SC/AA-S029	19	315034	5075044	0.099	2.41	0.01	0.17	290	3	110	0.4	6	24	1	2	25	0	2	0.03	0.0	33	2
94SC/AA-S030	19	315579	5075091	0.145	1.98	0.01	0.14	367	2	195	0.8	5	23	1	2	33	1	2	0.02	0.0	38	2
94SC/AA-S031	19	316104	5075056	0.098	2.3	0.01	0.15	204	4	123	0.5	6	25	1	1	31	1	3	0.03	0.0	35	2
94SC/AA-S032	19	315918	5074509	0.104	2.22	0.01	0.15	269	3	95	0.3	5	22	1	2	26	0	2	0.03	0.0	30	2
94SC/AA-S033	19	315527	5074524	0.069	1	0.01	0.06	105	2	39	0.1	3	16	1	1	16	0	2	0.03	0.0	18	2
94SC/AA-S034	19	315004	5074506	0.066	0.9	0.01	0.05	100	2	34	0.3	3	16	1	1	13	0	2	0.03	0.0	17	2
94SC/AA-S035	19	314556	5074504	0.03	0.6	0.01	0.02	25	2	16	0.2	2	11	0	0	7	0	1	0.03	0.0	16	2
94SC/AA-S036	19	314615	5074328	0.007	0.49	0.01	0.01	14	2	9	0.1	2	14	0	0	4	0	2	0.03	0.0	12	2
94SC/AA-S037	19	316004	5073990	0.101	1.92	0.01	0.11	202	3	70	0.5	4	20	1	1	20	0	2	0.03	0.0	24	2
94SC/AA-S038	19	316526	5074052	0.094	2.09	0.01	0.12	186	3	92	0.3	5	22	1	1	26	0	3	0.02	0.0	28	2
94SC/AA-S039	19	317004	5074024	0.105	2.3	0.01	0.13	251	3	94	0.2	5	22	1	1	24	0	2	0.03	0.0	29	2
94SC/AA-S040	19	317526	5072736	0.044	1.33	0.01	0.04	28	2	43	0.2	3	18	1	0	12	0	2	0.06	0.1	46	2
94SC/AA-S041	19	317686	5073093	0.059	1.22	0.01	0.08	67	2	59	0.4	3	18	1	1	18	0	2	0.04	0.0	27	2
94SC/AA-S042	19	318037	5073500	0.077	1.52	0.01	0.1	124	2	84	0.6	4	18	1	1	25	0	1	0.03	0.0	30	2
94SC/AA-S043	19	316521	5072519	0.046	1.03	0.01	0.05	93	2	43	0.5	3	13	0	1	15	0	1	0.02	0.0	21	2
94SC/AA-S044	19	316521	5073006	0.03	0.56	0.01	0.02	6	2	15	0.1	2	19	0	0	9	0	3	0.07	0.1	23	2
94SC/AA-S045	19	316494	5073497	0.051	0.9	0.01	0.05	79	3	36	0.1	4	16	1	1	16	0	3	0.03	0.0	21	2
94SC/AA-S046	19	316513	5074526	0.102	2.31	0.01	0.16	259	4	115	0.4	7	24	1	1	27	1	2	0.03	0.2	34	2
94SC/AA-S047	19	317035	5075020	0.061	0.82	0.01	0.04	79	3	25	0.1	3	14	0	0	12	0	2	0.02	0.0	15	2
94SC/AA-S048	19	317520	5074993	0.112	2.46	0.01	0.16	182	4	98	0.2	6	22	0	1	25	0	2	0.03	0.3	30	2
94SC/AA-S049	19	317401	5075509	0.51	0.8	0.07	0.05	74	3	27	0.1	2	15	0	0	11	0	2	0.03	0.1	16	2
94SC/AA-S050	19	317640	5076012	0.064	1.12	0.01	0.07	118	3	52	0.1	3	18	0	1	23	0	2	0.03	0.2	19	2
94SC/AA-S051	19	317657	5076405	0.058	0.53	0.01	0.03	27	2	29	0.1	3	16	0	0	13	0	2	0.02	0.1	16	2
94SC/AA-S052	19	317548	5077063	0.036	0.59	0.01	0.03	46	2	29	0.2	2	17	0	0	15	0	2	0.02	0.0	9	2
94SC/AA-S053	19	317580	5077554	0.069	1.41	0.01	0.1	114	3	67	0.1	5	21	0	1	23	0	1	0.03	0.2	21	2
94SC/AA-S054	19	318402	5078011	0.08	2.12	0.01	0.13	136	4	103	0.5	4	23	0	2	28	1	2	0.03	0.3	35	2
94SC/AA-S055	19	318493	5077540	0.006	2.01	0.01	0.13	163	3	86	0.2	6	25	0	1	25	1	2	0.03	0.3	27	2

Appendix V: Surficial lake sediment geochemistry of the study area from the <80µm fraction

SAMPLE NUMBER	ZONE	EASTING	NORTHING	P	Al	Na	K	Hg	B	Ba	Bi	Ga	La	Sb	Se	Sr	Te	Th	Ti	Ti	V	W
				(%)	(%)	(%)	(%)	(ppb)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(%)	(%)	(ppm)	(ppm)
94SCAA-S056	19	318514	5076510	0.047	0.67	0.01	0.03	32	4	18	0.1	1	20	0	0	10	0	2	0.05	0.1	19	2
94SCAA-S057	19	318499	5075980	0.076	1.46	0.01	0.09	120	3	66	0.1	4	20	1	1	21	0	2	0.02	0.0	23	2
94SCAA-S058	19	318532	5075556	0.093	1.89	0.01	0.13	140	3	104	0.8	5	23	1	1	26	1	3	0.03	0.0	33	2
94SCAA-S059	19	318504	5075002	0.094	2.22	0.01	0.15	222	3	118	0.6	6	23	1	2	27	1	2	0.03	0.3	35	2
94SCAA-S060	19	318476	5074589	0.095	2.27	0.01	0.16	218	4	114	0.5	6	23	1	1	27	0	1	0.03	0.2	33	2
94SCAA-S061	19	318378	5073967	0.069	1.17	0.01	0.08	79	3	59	0.2	2	18	0	0	23	0	2	0.03	0.2	24	2
94SCAA-S062	19	318046	5074020	0.062	0.96	0.01	0.06	60	2	34	0.2	3	18	0	0	12	0	2	0.04	0.2	22	2
94SCAA-S063	19	317492	5073944	0.094	2.22	0.01	0.14	183	3	114	0.3	5	25	0	1	22	0	2	0.03	0.3	30	2
94SCAA-S064	19	317504	5073499	0.099	2.05	0.01	0.15	180	4	130	0.7	6	25	1	1	26	1	4	0.03	0.3	35	2
94SCAA-S065	19	317504	5072951	0.048	0.91	0.01	0.06	36	2	43	0.1	3	16	1	1	14	1	2	0.03	0.0	22	2
94SCAA-S066	19	317007	5073018	0.064	1.25	0.01	0.09	59	2	91	0.3	3	19	1	1	22	1	3	0.03	0.0	25	2
94SCAA-S067	19	316982	5073360	0.09	2.27	0.01	0.15	193	3	195	0.6	6	22	1	2	24	1	1	0.03	0.2	35	2
94SCAA-S068	19	316963	5074473	0.092	2.21	0.01	0.14	180	2	116	2.1	6	24	1	1	28	1	3	0.03	0.0	33	2
94SCAA-S069	19	317502	5074495	0.102	2.48	0.01	0.15	179	4	124	0.3	6	27	1	1	32	1	3	0.03	0.0	36	2
94SCAA-S070	19	318009	5074503	0.099	2.26	0.01	0.16	214	3	127	0.7	6	22	1	2	26	1	2	0.03	0.2	35	2
94SCAA-S071	19	318046	5075006	0.09	2.2	0.01	0.15	183	3	111	0.5	6	22	1	2	25	1	1	0.03	0.7	33	2
94SCAA-S072	19	318035	5075610	0.097	2.24	0.01	0.16	182	3	124	0.7	6	22	1	2	24	1	2	0.03	0.2	34	2
94SCAA-S073	19	318029	5076011	0.09	1.66	0.01	0.11	132	2	76	0.3	5	23	1	1	22	0	4	0.02	0.0	24	2
94SCAA-S074	19	319009	5075497	0.067	1	0.01	0.08	48	2	39	0.2	3	17	0	1	15	0	2	0.03	0.1	20	2
94SCAA-S075	19	319003	5075029	0.054	0.76	0.01	0.05	39	2	28	0.4	3	19	0	0	12	0	3	0.03	0.0	18	2
94SCAA-S077A	19	315986	5072505	0.076	1.76	0.01	0.1	154	3	103	0.4	5	21	1	1	31	1	2	0.02	0.1	28	2
94SCAA-S077B	19	315986	5072505	0.072	1.67	0.01	0.09	136	2	101	0.1	4	20	1	1	31	1	2	0.02	0.1	26	2
94SCAA-S078	19	315505	5072500	0.066	1.38	0.01	0.08	131	3	66	0.2	4	16	0	1	19	0	1	0.02	0.1	23	2
94SCAA-S079	19	315504	5072016	0.089	2.24	0.01	0.14	204	4	120	0.4	6	21	1	2	31	1	1	0.03	0.4	33	2
94SCAA-S080	19	314998	5072001	0.06	1.08	0.01	0.08	58	3	49	0.2	3	19	0	1	14	0	2	0.03	0.1	21	2
94SCAA-S081	19	315520	5071522	0.053	1.54	0.01	0.08	130	4	61	0.3	5	18	1	1	18	0	2	0.03	0.3	31	2
94SCAA-S082	19	316037	5072051	0.086	1.99	0.01	0.12	207	4	90	0.3	5	19	0	2	27	0	1	0.02	0.3	27	2
94SCAA-S083	19	316544	5072045	0.046	1.01	0.01	0.05	96	4	34	0.2	2	13	0	0	13	0	2	0.03	0.2	21	2
94SCAA-S084	19	318852	5078944	0.094	2.14	0.01	0.14	171	4	132	0.6	5	22	1	2	24	1	2	0.03	0.1	32	2
94SCAA-S085	19	318957	5078737	0.045	1.02	0.01	0.05	23	3	46	0.1	3	18	0	0	13	0	2	0.03	0.1	16	2
94SCAA-S086	19	318909	5078667	0.045	0.8	0.01	0.04	9	2	38	0.1	2	16	0	0	14	0	2	0.03	0.2	0.17	2
94SCAA-S087	19	318783	5078670	0.42	0.83	0.01	0.05	19	2	28	0.2	2	14	0	1	10	0	1	0.03	0.2	14	2
94SCAA-S088	19	318754	5078759	0.045	0.93	0.01	0.04	23	2	31	1.2	2	15	0	0	10	0	2	0.03	0.0	16	2
94SCAA-S089	19	318969	5077482	0.062	0.55	0.01	0.03	11	3	24	0.2	1	19	0	0	12	0	3	0.04	0.0	12	2

Appendix V: Surficial lake sediment geochemistry of the study area from the <80µm fraction

SAMPLE NUMBER	ZONE	EASTING	NORTHING	P (%)	Al (%)	Na (%)	K (%)	Hg (ppb)	B (ppm)	Ba (ppm)	Bi (ppm)	Ga (ppm)	La (ppm)	Sb (ppm)	Se (ppm)	Sr (ppm)	Te (ppm)	Th (ppm)	Ti (%)	Ti (ppm)	V (ppm)	W (ppm)
94SC/AA-S090	19	318091	5077389	0.076	2	0.01	0.13	85	3	103	0.5	5	23	0	1	22	1	3	0.03	0.2	30	2
94SC/AA-S091	19	318006	5076992	0.068	1.05	0.01	0.07	86	3	42	0.2	2	18	1	0	16	0	3	0.03	0.0	18	2
94SC/AA-S092	19	318070	5076524	0.052	0.61	0.01	0.04	24	2	20	0.1	1	12	0	0	9	0	2	0.03	0.0	13	2
94SC/AA-S093	19	318008	5078001	0.077	1.95	0.01	0.12	134	2	81	0.1	4	23	1	1	23	0	2	0.03	0.0	29	2
94SC/AA-S094	19	318024	5078520	0.059	1.48	0.01	0.1	88	2	66	0.2	4	24	1	0	20	0	2	0.03	0.0	25	2
94SC/AA-S095	19	318069	5079024	0.051	0.95	0.01	0.07	34	2	44	0.2	3	20	0	0	15	0	2	0.03	0.0	15	2
94SC/AA-S096	19	318514	5079007	0.074	2.1	0.01	0.13	96	2	81	0.3	5	23	1	1	22	1	1	0.03	0.0	29	2
94SC/AA-S097	19	318585	5079407	0.036	1.2	0.01	0.05	29	2	25	0.2	3	15	1	0	10	0	2	0.04	0.0	23	2
94SC/AA-S098	19	317929	5079482	0.059	1.63	0.01	0.1	5	2	69	0.1	5	27	0	0	20	0	4	0.03	0.0	22	2
94SC/AA-S099	19	318009	5080254	0.051	0.57	0.01	0.04	11	2	19	0.6	2	17	0	0	10	0	3	0.03	0.0	11	2
94SC/AA-S100	19	317486	5080473	0.066	1.65	0.01	0.13	60	2	64	0.2	4	24	0	0	18	0	2	0.04	0.0	25	2
94SC/AA-S101	19	317513	5081003	0.093	2.03	0.01	0.14	135	2	124	2.4	6	24	1	0	23	0	5	0.03	0.0	32	2
94SC/AA-S102	19	317406	5081519	0.089	2.24	0.01	0.16	159	2	114	0.6	6	22	1	1	21	0	3	0.03	0.0	34	2
94SC/AA-S103	19	317505	5082019	0.09	2.32	0.01	0.17	152	2	111	0.5	6	23	1	1	20	0	3	0.04	0.3	35	2
94SC/AA-S104	19	317511	5082529	0.072	2.23	0.01	0.14	120	2	82	0.4	6	26	1	1	19	0	3	0.04	0.0	32	2
94SC/AA-S105	19	317503	5083030	0.067	1.88	0.01	0.11	86	2	73	0.6	6	25	0	0	19	0	4	0.03	0.0	26	2
94SC/AA-S106	19	318005	5082992	0.079	1.81	0.01	0.12	105	3	76	0.1	5	23	0	0	21	0	4	0.03	0.0	27	2
94SC/AA-S107	19	318023	5082020	0.076	2.36	0.01	0.15	117	2	88	0.3	6	27	1	1	20	0	3	0.04	0.0	32	2
94SC/AA-S108	19	318058	5080949	0.08	2.41	0.01	0.17	148	2	95	0.3	7	26	1	1	21	0	2	0.04	0.0	33	2
94SC/AA-S109	19	317079	5080492	0.063	1.56	0.01	0.11	88	2	65	0.3	5	24	1	1	21	0	2	0.03	0.0	22	2
94SC/AA-S110	19	316478	5080684	0.048	0.85	0.01	0.06	31	2	46	0.1	3	17	0	0	14	0	3	0.02	0.0	12	2
94SC/AA-S111	19	316935	5081008	0.062	0.65	0.01	0.04	20	2	21	0.2	2	12	0	0	8	0	2	0.02	0.0	11	2
94SC/AA-S112	19	316977	5081537	0.074	2.01	0.01	0.12	103	3	77	0.1	6	27	0	0	21	0	4	0.03	0.0	28	2
94SC/AA-S113	19	316883	5082014	0.053	0.96	0.01	0.06	21	2	33	0.1	3	18	0	0	12	0	2	0.03	0.0	15	2
94SC/AA-S114	19	317582	5082453	0.062	1.39	0.01	0.08	41	2	45	0.2	4	21	0	0	16	0	2	0.03	0.0	21	2
94SC/AA-S115	19	317424	5084516	0.06	0.99	0.01	0.07	34	4	32	0.2	3	17	0	0	15	0	3	0.03	0.0	17	2
94SC/AA-S116	19	317038	5085022	0.067	1.24	0.01	0.08	128	3	40	0.5	4	19	1	1	16	0	2	0.03	0.0	21	2
94SC/AA-S117	19	317495	5085088	0.056	0.95	0.01	0.07	41	3	30	0.3	3	15	1	0	13	0	2	0.03	0.0	18	2
94SC/AA-S118	19	318060	5083989	0.07	1.46	0.01	0.1	57	4	53	0.4	4	23	1	0	19	0	3	0.03	0.0	22	2
94SC/AA-S119	19	318060	5083989	0.078	1.22	0.01	0.1	87	3	61	0.2	5	23	0	0	19	0	3	0.04	0.0	27	2
94SC/AA-S120	19	318027	5082466	0.073	1.7	0.01	0.11	45	2	63	0.3	5	26	1	0	17	0	4	0.05	0.1	28	2
94SC/AA-S121	19	317967	5080579	0.097	2.24	0.01	0.16	162	4	121	0.2	6	24	1	1	24	1	3	0.04	0.2	36	2
94SC/AA-S122	19	314483	5072453	0.068	1.54	0.01	0.09	160	21	82	0.8	4	19	1	1	44	0	2	0.02	0.0	21	2
94SC/AA-S123	19	315054	5072516	0.047	1.01	0.01	0.06	69	2	47	0.2	3	16	1	0	15	0	1	0.03	0.0	19	2

Appendix V: Surficial lake sediment geochemistry of the study area from the <80 μ m fraction

SAMPLE NUMBER	ZONE	EASTING	NORTHING	P (%)	Al (%)	Na (%)	K (%)	Hg (ppb)	B (ppm)	Ba (ppm)	Bi (ppm)	Ga (ppm)	La (ppm)	Sb (ppm)	Se (ppm)	Sr (ppm)	Te (ppm)	Th (ppm)	Ti (%)	Ti (ppm)	V (ppm)	W (ppm)
94SCAA-S124	19	314503	5072085	0.052	1.79	0.01	0.08	95	3	79	0.1	5	21	0	1	26	0	1	0.02	0.0	21	2
94SCAA-S125	19	316338	5071550	0.064	1.57	0.01	0.07	175	3	86	0.1	4	19	1	2	53	0	1	0.02	0.0	24	2
94SCAA-S126	19	313960	5071006	0.063	1.86	0.01	0.1	144	7	99	1.7	5	21	1	1	35	1	2	0.02	0.0	28	2
94SCAA-S127	19	313765	5070142	0.056	1.82	0.01	0.12	128	3	101	0.1	6	19	0	1	27	0	1	0.02	0.0	21	2
94SCAA-S128	19	314972	5071513	0.049	1.01	0.01	0.05	70	2	42	0.2	2	15	0	0	13	0	1	0.03	0.0	21	2
94SCAB-S001	19	329897	5074214	0.08	0.97	0.01	0.04	234	3	64	0.4	3	17	1	2	28	0	1	0.03	0.0	17	2
94SCAB-S002	19	330642	5076464	0.08	1.3	0.01	0.07	293	2	64	0.4	4	23	1	2	22	0	1	0.05	0.1	19	2
94SCAB-S003	19	329977	5075755	0.107	1.22	0.01	0.07	236	3	62	0.6	4	18	1	2	24	0	1	0.03	0.0	17	2
94SCAF-S001	19	324902	5075940	0.035	0.74	0.01	0.04	70	3	59	0.2	2	18	0	1	58	0	1	0.02	0.0	8	2
94SCAF-S002	19	325943	5076256	0.039	0.83	0.01	0.04	83	5	65	0.1	1	19	0	1	48	0	1	0.14	0.0	14	2
94SCAF-S001	19	334064	5078917	0.074	1.99	0.04	0.15	136	190	83	0.2	6	23	1	0	30	0	1	0.07	0.1	35	2
94SCAF-S002	19	335734	5078617	0.084	1.44	0.01	0.14	60	5	52	0.4	5	27	1	0	28	0	4	0.03	0.0	22	2
94SCAF-S003	19	336101	5076208	0.079	2.11	0.02	0.2	110	6	88	0.4	7	29	1	0	37	0	4	0.07	0.1	39	2
94SCAF-S004	19	334006	5080854	0.115	2.31	0.01	0.22	220	4	191	0.5	7	28	1	0	40	0	3	0.05	0.1	46	2
94SCAF-S005	19	332878	5083289	0.142	2.85	0.01	0.14	237	4	95	0.6	7	26	1	1	48	0	1	0.04	0.0	35	2
94SCAF-S006	19	332895	5085419	0.1	2.32	0.01	0.18	190	13	165	0.6	8	26	1	1	33	1	4	0.04	0.0	41	2
94SCAF-S007	19	333081	5087594	0.051	1.24	0.01	0.08	51	4	42	0.4	4	22	1	0	18	0	3	0.03	0	18	2
94SCAF-S008	19	331403	5089358	0.105	2.29	0.01	0.18	199	6	170	0.5	7	26	1	1	33	1	4	0.03	0.0	41	2
94SCAF-S009	19	330490	5091302	0.049	1.2	0.01	0.08	64	29	50	0.1	3	18	0	0	19	0	2	0.03	0.0	20	2
94SCAF-S010	19	328369	5092655	0.076	1.91	0.01	0.12	174	7	83	0.3	6	21	1	1	28	0	2	0.03	0.0	29	2
94SCAF-S011	19	327961	5093736	0.054	1.35	0.01	0.09	103	10	59	0.3	5	17	1	1	31	0	2	0.02	0.0	23	2
94SCAF-S012	19	325687	5093090	0.054	1.08	0.01	0.07	82	13	44	0.1	3	14	0	0	19	0	2	0.02	0.0	16	2
94SCAF-S013	19	324525	5091096																			
94SCAG-S001	19	317842	5069917	0.042	0.8	0.01	0.04	25	3	21	0.1	2	13	0	0	11	0	1	0.04	0.0	21	2
94SCAG-S002	19	318096	5068946	0.115	1.97	0.01	0.1	277	3	352	0.7	4	20	1	2	33	0	4	0.03	0.0	29	2
94SCAG-S003	19	319601	5067537	0.108	2	0.01	0.09	205	4	97	0.3	4	19	1	2	29	0	1	0.03	0.0	31	2
94SCAG-S004	19	318376	5068043	0.143	2.29	0.01	0.09	185	4	68	0.5	4	22	1	1	31	0	1	0.03	0.0	33	2
94SCAI-S001	19	329351	5072877	0.144	1.37	0.01	0.06	417	4	72	1.1	5	19	1	3	22	0	1	0.03	0.0	36	2
94SCAI-S002	19	329649	5072562	0.097	0.86	0.01	0.05	179	2	35	0.1	3	14	1	1	13	0	1	0.03	0.0	20	2
94SCAI-S003	19	329984	5073354	0.136	1.51	0.01	0.07	473	4	55	0.3	5	23	0	2	17	0	1	0.04	0.0	26	2
94SCAK-S001	19	325447	5071607	0.049	0.92	0.01	0.07	43	3	68	0.3	3	18	0	0	22	0	1	0.04	0.0	27	2
94SCAK-S002	19	326300	5071844	0.128	2.33	0.02	0.09	197	28	75	0.3	3	35	0	2	36	0	1	0.04	0.0	36	2
94SCAK-S003	19	326823	5072470	0.118	1.59	0.02	0.12	177	3	106	0.3	4	29	1	1	34	0	3	0.07	0.1	41	2
94SCAK-S004	19	326380	5070941	0.069	1.77	0.01	0.13	153	4	118	0.3	5	26	0	1	31	0	1	0.05	0.1	36	2

Appendix V: Surficial lake sediment geochemistry of the study area from the <80µm fraction

SAMPLE NUMBER	ZONE	EASTING	NORTHING	P (%)	Al (%)	Na (%)	K (%)	Hg (ppb)	B (ppm)	Ba (ppm)	Bi (ppm)	Ga (ppm)	La (ppm)	Sb (ppm)	Se (ppm)	Sr (ppm)	Te (ppm)	Th (ppm)	Ti (%)	Ti (%)	V (ppm)	W (ppm)
94SCAP-S001	19	325350	5083300	0.048	1.09	0.01	0.09	19	3	42	0.2	4	18	1	0	21	0	3	0.04	0.0	22	2
94SCAR-S001	19	317580	5077554	0.066	1.41	0.01	0.1	113	3	66	1.5	4	22	0	1	22	0	3	0.02	0.0	21	2
94SCAR-S002	19	316513	5074526	0.091	2.17	0.01	0.14	242	4	110	0.3	6	24	1	1	27	0	3	0.02	0.0	32	2
94SCAR-S003	19	315505	5072500	0.065	1.41	0.01	0.08	132	5	71	0.2	4	18	1	1	21	0	3	0.02	0.0	23	2
94SCAS-S001	19	333547	5073112	0.045	1	0.01	0.08	32	2	37	0.1	3	18	0	0	18	0	3	0.06	0.1	20	2
94SCAS-S002	19	332645	5074608	0.061	1.91	0.01	0.16	96	3	76	0.2	6	24	0	0	37	0	2	0.07	0.1	33	2
94SCAS-S003	19	331582	5076774	0.08	1.34	0.01	0.16	92	2	64	0.2	6	16	0	0	23	0	3	0.12	0.1	36	2
94SCAS-S004	19	332405	5077945	0.059	1.9	0.01	0.15	153	2	73	0.2	8	22	0	1	31	0	3	0.06	0.1	33	2

SAMPLE NUMBER	ZONE	EASTING	NORTHING	TOT/C (%)	Mn (ppm)	Fe (%)	Zn (ppm)	Cu (ppm)	Pb (ppm)	Cr (ppm)	Ni (ppm)	Co (ppm)	Mg (%)	Cd (ppm)	As (ppm)	U (ppm)	P (%)	Al (%)	Na (%)	K (%)	Hg (ppb)	Sb (ppm)	Ti (%)
94SCAA-S001	19	317580	5077554	4.17	926	2.88	132.4	49.8	22.6	66	198.0	18	131	1	9	5	0	1.41	0.01	0.1	119	0.43	0.03
94SCAR-S001	19	317580	5077554	4.28	865	2.98	142.1	53.6	27.9	68	178.0	18	116	1	7	5	0	1.41	0.01	0.1	113	0.3	0.02
Analytical uncertainty (°o)																							
94SCAA-S008	19	315505	5072500	2.6	6.8	3.4	7.3	0.7	20.0	3.0	10.6	0	12.0	0	25	0.0	0	0.0	0.0	0.0	5.2	35.6	40.0
94SCAR-S001	19	315505	5072500	3.94	826	2.91	271.9	90.4	40.2	68	175.0	15	0.98	2	12	5	0	1.38	0.01	0.1	131	0.38	0.02
Analytical uncertainty (°o)																							
94SCAA-S006	19	316513	5074526	5.8	1444	4.62	331	119.8	66	98	307.0	29	1.67	2	18	5	0	2.31	0.01	0.2	259	0.72	0.03
94SCAR-S002	19	316513	5074526	6	1294	4.6	359.4	144	84.3	97	297.0	28	1.55	2	17	5	0	2.17	0.01	0.1	242	0.8	0.02
Analytical uncertainty (°o)																							
				3.4	11.0	0.4	8.2	18.3	24.4	1.0	3.3	4	7.5	0	9	0.0	0	6.3	0.0	13.3	6.8	10.5	40.0

Appendix VI: Lake and stream water geochemistry of the study area of filtered water samples (~45mm)

Sample Number	Zone	Northing	Lasting	Li (ppb)	Be (ppb)	Al (ppb)	Ti (ppb)	V (ppb)	Cr (ppb)	Fe (ppb)	Mn (ppb)	Co (ppb)	Ni (ppb)	Cu (ppb)	Zn (ppb)	As (ppb)	Se (ppb)	Rb (ppb)	Sr (ppb)	Y (ppb)	Mg (ppb)	Ag (ppb)	Cd (ppb)	In (ppb)	Sb (ppb)	Ba (ppb)
19	94SC-AA-W001	316156	5077469	0.3	<0.05	55	0.5	0.2	1.0	119	3	<0.1	7.1	3.8	5.2	0.5	<1	0.6	41	0.13	0.1	<0.1	0.41	<0.02	0.07	3
19	94SC-AA-W002	315943	5077333	0.3	<0.05	46	0.9	0.3	1.1	108	2	<0.1	7.3	3.3	4.6	0.3	<1	0.5	38	0.14	<0.1	<0.1	0.18	<0.02	0.05	3
19	94SC-AA-W003A	315973	5076464	0.3	<0.05	60	0.7	0.3	1.1	187	79	0.2	15.8	5.3	15.6	0.5	<1	0.5	34	0.14	<0.1	<0.1	0.10	<0.02	0.07	4
19	94SC-AA-W003B	315973	5076464	0.3	<0.05	55	0.6	0.2	1.0	103	2	<0.1	7.2	3.5	5.6	0.4	<1	0.5	38	0.13	<0.1	<0.1	0.52	<0.02	0.07	3
19	94SC-AA-W003C	315973	5076464	<0.1	<0.05	<2	<0.5	<0.1	<0.1	<5	<1	<0.1	<0.5	<0.3	1.2	<0.2	<1	<0.2	<1	<0.02	<0.1	<0.1	<0.05	<0.02	0.03	3
19	94SC-AA-W004	315011	5077292	0.3	<0.05	59	0.6	0.2	1.1	121	3	<0.1	10.0	5.2	9.4	0.3	<1	0.6	39	0.14	<0.1	<0.1	0.16	<0.02	0.08	3
19	94SC-AA-W005A	315072	5076490	0.3	<0.05	61	0.6	0.2	1.1	106	2	<0.1	8.2	4.0	7.0	0.3	<1	0.5	36	0.13	0.1	<0.1	0.16	<0.02	0.07	3
19	94SC-AA-W005B	315072	5076490	0.3	<0.05	55	0.8	0.2	1.1	106	2	<0.1	6.9	3.5	4.6	0.4	<1	0.5	38	0.14	0.1	<0.1	0.18	<0.02	0.07	3
19	94SC-AA-W006	314040	5076513	0.3	<0.05	62	0.8	0.1	1.1	137	4	<0.1	7.6	2.9	4.1	0.4	<1	0.5	34	0.16	0.1	<0.1	0.17	<0.02	0.10	3
19	94SC-AA-W007	316020	5075526	0.3	<0.05	55	0.6	0.2	1.1	108	2	<0.1	6.8	3.0	3.6	0.4	<1	0.6	39	0.14	0.1	<0.1	0.13	<0.02	0.06	3
19	94SC-AA-W008A	315057	5075342	0.3	<0.05	63	0.6	0.1	1.1	101	2	<0.1	7.9	3.5	9.1	0.3	<1	0.5	35	0.13	0.1	<0.1	0.08	<0.02	0.08	3
19	94SC-AA-W008B	315057	5075342	0.3	<0.05	59	0.7	0.2	1.1	115	2	<0.1	8.0	3.3	5.8	0.5	<1	0.6	41	0.14	0.1	<0.1	0.21	<0.02	0.08	3
19	94SC-AA-W009	314030	5075630	0.3	<0.05	67	0.9	0.2	0.9	131	4	<0.1	7.4	3.1	3.6	0.4	<1	0.6	39	0.13	<0.1	<0.1	0.07	<0.02	0.07	3
19	94SC-AA-W010A	315918	5074509	0.3	<0.05	66	0.7	<0.1	0.8	137	4	<0.1	14.6	6.2	15.3	0.3	<1	0.5	38	0.15	0.1	<0.1	0.07	<0.02	0.05	3
19	94SC-AA-W010B	315918	5074509	0.3	<0.05	56	0.8	0.1	1.0	112	2	<0.1	7.3	3.5	4.9	0.4	<1	0.6	39	0.13	0.1	<0.1	0.23	<0.02	0.08	3
19	94SC-AA-W011	315004	5074506	0.3	<0.05	56	0.8	0.1	1.0	114	2	<0.1	7.2	3.1	3.8	0.3	<1	0.6	40	0.13	0.1	<0.1	0.06	<0.02	0.07	3
19	94SC-AA-W012	314615	5074328	0.3	<0.05	55	0.6	0.2	1.0	113	2	<0.1	7.1	3.1	3.9	0.3	<1	0.6	38	0.13	<0.1	<0.1	0.05	<0.02	0.07	3
19	94SC-AA-W013	318037	5073400	0.3	<0.05	49	0.6	<0.1	0.9	103	2	<0.1	6.5	2.7	3.4	0.4	<1	0.5	41	0.13	<0.1	<0.1	0.06	<0.02	0.06	3
19	94SC-AA-W014	316982	5073560	0.3	<0.05	53	0.9	0.2	1.3	108	2	<0.1	7.1	2.8	2.8	0.6	<1	0.6	42	0.13	0.2	<0.1	<0.05	<0.02	0.08	3
19	94SC-AA-W015	316963	5074373	0.3	<0.05	51	0.6	0.2	0.9	110	2	<0.1	6.9	2.7	2.7	0.5	<1	0.6	43	0.13	0.1	<0.1	<0.05	<0.02	0.06	3
19	94SC-AA-W016A	318009	5074503	0.3	<0.05	61	0.7	0.2	1.0	144	11	<0.1	13.3	4.6	8.9	0.4	<1	0.6	37	0.14	<0.1	<0.1	<0.05	<0.02	0.06	4
19	94SC-AA-W016B	318009	5074503	0.3	<0.05	53	0.6	0.2	0.9	112	2	<0.1	6.8	2.7	2.6	0.4	<1	0.6	42	0.13	0.1	<0.1	<0.05	<0.02	0.05	3
19	94SC-AA-W017A	318035	5075510	0.3	<0.05	56	0.6	0.1	1.1	113	4	<0.1	8.5	4.0	6.2	0.3	<1	0.5	39	0.14	0.1	<0.1	<0.05	<0.02	0.07	3
19	94SC-AA-W017B	318035	5075510	0.3	<0.05	51	0.7	0.2	1.0	113	2	<0.1	7.0	2.7	2.3	0.5	<1	0.6	42	0.13	0.1	<0.1	<0.05	<0.02	0.08	3
19	94SC-AA-W018	319009	5075497	0.3	<0.05	52	0.6	0.2	1.0	109	2	<0.1	6.8	4.3	2.5	0.4	<1	0.6	42	0.13	0.1	<0.1	<0.05	<0.02	0.08	3
19	94SC-AA-W019	318946	5074528	0.3	<0.05	52	0.6	0.2	1.4	111	3	<0.1	6.9	2.7	2.7	0.3	<1	0.6	41	0.13	0.1	<0.1	<0.05	<0.02	0.07	3
19	94SC-AA-W020	315986	5072505	0.3	<0.05	51	0.6	0.2	1.0	111	2	<0.1	7.0	2.8	3.1	0.3	<1	0.6	42	0.13	0.1	<0.1	<0.05	<0.02	0.06	3
19	94SC-AA-W021	318852	5078044	0.4	<0.05	60	0.6	0.2	1.1	214	7	<0.1	7.5	6.5	10.1	0.5	<1	0.7	46	0.17	0.1	<0.1	0.07	<0.02	0.08	4
19	94SC-AA-W022	318957	5078737	0.4	<0.05	64	1.1	0.2	0.9	221	8	<0.1	7.7	5.8	8.3	0.4	<1	0.7	44	0.17	0.1	<0.1	0.06	<0.02	0.07	4
19	94SC-AA-W023	318909	5078667	0.3	<0.05	54	1.1	0.2	1.0	131	2	<0.1	7.5	2.4	2.6	0.5	<1	0.6	43	0.14	0.1	<0.1	<0.05	<0.02	0.07	3
19	94SC-AA-W024	318969	5077482	0.3	<0.05	52	0.6	0.1	1.0	125	2	<0.1	7.5	2.6	2.2	0.5	<1	0.6	44	0.14	0.1	<0.1	<0.05	<0.02	0.09	3
19	94SC-AA-W025	318093	5077189	0.3	<0.05	55	0.7	0.2	1.1	130	3	<0.1	7.8	2.4	2.5	0.5	<1	0.6	44	0.15	0.1	<0.1	<0.05	<0.02	0.07	3
19	94SC-AA-W026	318070	5076524	0.3	<0.05	52	0.7	0.2	1.0	110	2	<0.1	7.1	2.7	2.1	0.5	<1	0.6	43	0.13	0.1	<0.1	<0.05	<0.02	0.06	3
19	94SC-AA-W027	318024	5078520	0.4	<0.05	61	1.1	0.2	1.3	160	3	<0.1	9.7	2.5	1.9	0.6	<1	0.7	53	0.15	0.2	<0.1	<0.05	<0.02	0.07	3

Appendix VI: Lake and stream water geochemistry of the study area of filtered water samples (<45mm)

Sample Number	Zone	Northing	Easting	Li (ppb)	Be (ppb)	Al (ppb)	Ti (ppb)	V (ppb)	Cr (ppb)	Fe (ppb)	Mn (ppb)	Co (ppb)	Ni (ppb)	Cu (ppb)	Zn (ppb)	As (ppb)	Se (ppb)	Rb (ppb)	Sr (ppb)	Y (ppb)	Mo (ppb)	Ag (ppb)	Cd (ppb)	In (ppb)	Sb (ppb)	Sn (ppb)
94SC-AA-W028	19	318514	5079000	0.3	<0.05	57	0.6	0.2	1.1	138	3	<0.1	8.0	3.2	3.0	0.5	<1	0.7	46	0.15	0.1	<0.1	<0.05	<0.02	0.07	1
94SC-AA-W029	19	318585	5079307	0.4	<0.05	62	0.7	0.2	1.1	177	3	<0.1	7.9	4.4	4.5	0.5	<1	0.7	47	0.15	0.1	<0.1	<0.05	<0.02	0.07	3
94SC-AA-W030	19	317079	5080492	0.4	<0.05	57	1.1	0.2	1.4	148	5	<0.1	9.3	3.1	4.5	0.5	<1	0.7	48	0.16	0.2	<0.1	0.10	<0.02	0.07	1
94SC-AA-W031	19	316977	5081537	0.3	<0.05	58	0.9	0.3	1.3	146	3	<0.1	8.6	2.1	1.8	0.6	<1	0.6	45	0.15	0.1	<0.1	<0.05	<0.02	0.06	1
94SC-AA-W032	19	317490	5085080	0.3	<0.05	62	0.8	0.2	1.2	97	2	<0.1	7.3	1.0	1.1	0.5	<1	0.6	49	0.13	0.1	<0.1	<0.05	<0.02	0.07	1
94SC-AA-W033A	19	318000	5081000	0.3	<0.05	60	1.0	0.2	1.1	158	6	<0.1	8.7	3.8	4.1	0.5	<1	0.6	43	0.15	0.1	<0.1	<0.05	<0.02	0.07	1
94SC-AA-W033B	19	318000	5084000	0.3	<0.05	53	0.8	0.2	1.1	107	4	<0.1	8.2	2.0	1.3	0.5	<1	0.6	44	0.14	0.1	<0.1	<0.05	<0.02	0.07	1
94SC-AA-W034	19	318027	5082406	0.3	<0.05	54	0.8	0.2	1.1	125	2	<0.1	8.5	1.9	1.5	0.7	<1	0.6	43	0.14	0.1	<0.1	<0.05	<0.02	0.06	1
94SC-AA-W035	19	317967	5080479	0.3	<0.05	57	0.9	0.2	1.2	147	2	<0.1	8.5	2.1	2.0	0.5	<1	0.6	44	0.15	0.1	<0.1	<0.05	<0.02	0.08	1
94SC-AA-W036	19	315054	5072516	0.3	<0.05	48	0.6	<0.1	1.0	110	2	<0.1	6.8	3.2	4.2	0.5	<1	0.6	40	0.13	0.1	<0.1	<0.05	<0.02	0.06	3
94SC-AA-W037	19	314332	5071550	0.3	<0.05	49	0.6	0.2	0.9	115	2	<0.1	7.0	3.1	3.1	0.5	<1	0.6	42	0.14	0.1	<0.1	<0.05	<0.02	0.08	3
94SC-AA-W038	19	313193	5070155	0.3	<0.05	51	1.0	0.2	1.0	122	3	<0.1	7.2	3.9	4.5	0.6	<1	0.6	42	0.13	0.1	<0.1	<0.05	<0.02	0.07	4
94SC-AA-W039	19	313193	5070155	0.3	<0.05	53	0.8	0.2	1.0	123	3	<0.1	7.7	4.2	6.1	0.4	<1	0.6	42	0.14	0.1	<0.1	<0.05	<0.02	0.07	4
94SC-AA-W040	19	316024	5071827	0.3	<0.05	48	0.8	0.1	1.0	107	2	<0.1	6.7	3.4	2.5	0.5	<1	0.6	42	0.13	0.1	<0.1	<0.05	<0.02	0.07	3
94SC-AP-W001	19	329897	5075214	0.6	<0.05	76	1.1	0.2	0.5	171	20	<0.1	1.7	1.9	6.2	0.5	<1	0.9	9	0.07	0.1	<0.1	<0.07	<0.02	0.05	1
94SC-AP-W001	19	324943	5076256	0.5	<0.05	31	<0.5	0.2	<0.1	34	4	<0.1	1.5	5.2	5.4	0.4	<1	0.8	24	0.06	<0.1	<0.1	<0.06	<0.02	0.03	5
94SC-AP-W001	19	314064	5078917	0.4	<0.05	55	0.7	0.2	0.6	73	1	<0.1	3.8	1.4	1.3	0.4	<1	0.8	62	0.13	0.2	<0.1	0.11	<0.02	0.06	4
94SC-AP-W002	19	336101	5076208	0.4	<0.05	54	0.7	0.1	0.6	64	1	<0.1	4.0	2.4	3.8	0.4	<1	0.8	58	0.15	0.1	<0.1	<0.05	<0.02	0.05	1
94SC-AP-W003	19	334081	5073494	0.3	<0.05	54	0.7	0.1	0.6	74	1	<0.1	5.1	1.6	1.2	0.5	<1	0.7	55	0.14	0.1	<0.1	<0.05	<0.02	0.05	1
94SC-AP-W004	19	330490	5091302	0.3	<0.05	54	0.7	0.1	0.8	76	2	<0.1	5.8	1.8	2.2	0.6	<1	0.7	53	0.13	0.1	<0.1	<0.05	<0.02	0.05	1
94SC-AP-W005	19	331525	5091096	0.3	<0.05	56	0.7	0.1	1.0	81	1	<0.1	6.5	1.6	1.0	0.5	<1	0.7	54	0.14	0.1	<0.1	2.36	<0.02	<0.7	1
94SC-AP-W001	19	317842	5069017	0.3	<0.05	49	<0.5	0.2	0.4	35	3	0.1	2.5	1.5	4.4	0.4	<1	0.8	41	0.09	0.1	<0.1	<0.05	<0.02	0.05	1
94SC-AP-W002	19	318975	5068700	0.4	<0.05	14	0.5	0.1	0.3	38	6	0.1	3.7	1.7	2.8	1.1	<1	2.9	222	0.04	0.6	0.1	0.06	<0.02	0.07	1
94SC-AP-W001A	19	329688	5073029	0.6	<0.05	105	1.0	0.2	0.4	191	79	<0.1	3.2	5.8	9.6	5.3	<1	1.0	8	0.09	0.1	<0.1	0.22	<0.02	0.08	1
94SC-AP-W001B	19	329688	5073029	0.7	<0.05	85	0.9	0.2	0.4	115	5	0.1	1.7	2.1	5.1	0.3	<1	1.0	8	0.09	0.1	<0.1	0.22	<0.02	0.08	1
94SC-AP-W001	19	324417	5071607	0.5	<0.05	22	<0.5	<0.1	<0.1	26	3	<0.1	1.4	1.1	2.3	0.3	<1	1.2	59	0.02	0.1	<0.1	<0.05	<0.02	0.05	1
94SC-AP-W001	19	318700	5079450	0.4	<0.05	127	2.5	0.3	2.7	488	18	0.3	24.2	2.7	3.4	1.1	<1	0.4	27	0.35	0.3	0.1	0.08	<0.02	0.13	3
94SC-AP-W001	19	320800	5081325	0.5	<0.05	132	2.4	0.4	2.8	509	26	0.5	24.8	2.5	1.0	1.1	<1	0.4	27	0.32	0.3	<0.1	0.09	<0.02	0.14	2
94SC-AP-W002	19	325330	5085300	0.3	<0.05	207	3.4	0.4	3.2	792	198	1.4	18.7	1.8	5.2	1.3	<1	0.3	18	0.32	0.2	<0.1	0.11	<0.02	0.12	3
94SC-AP-W003	19	323255	5084560	0.4	<0.05	75	2.0	0.4	2.4	286	23	0.2	13.7	1.4	2.2	0.7	<1	0.5	23	0.18	0.4	<0.1	0.06	<0.02	0.11	2
94SC-AP-W004	19	313950	5073550	0.4	<0.05	107	2.1	0.4	2.1	224	--	0.4	15.4	1.5	2.9	1.6	<1	0.4	32	0.22	0.3	<0.1	<0.05	<0.02	0.08	1
94SC-AP-W005	19	313550	5075325	0.5	<0.05	98	2.6	0.6	2.7	959	63	0.6	22.6	3.5	5.5	2.5	<1	1.6	27	0.19	0.5	<0.1	<0.05	<0.02	0.13	1
94SC-AP-W006	19	312800	5076150	0.8	<0.05	54	1.3	0.3	1.1	548	33	0.2	7.9	2.2	3.3	2.1	<1	0.6	34	0.14	0.4	<0.1	<0.05	<0.02	0.09	3
94SC-AP-W007	19	309800	5079450	0.4	<0.05	83	1.0	0.2	0.9	154	11	<0.1	5.4	2.0	2.5	1.0	<1	0.5	15	0.06	0.1	<0.1	<0.05	<0.02	0.18	1
94SC-AP-W008	19	314950	5080800	0.7	<0.05	87	2.3	0.4	1.6	544	27	0.3	22.7	2.8	2.7	1.2	<1	1.4	65	0.29	0.8	<0.1	<0.05	<0.02	0.10	4

Appendix VI: Lake and stream water geochemistry of the study area of filtered water samples (~45mm)

Sample Number	Zone	North	East	Li (ppb)	Be (ppb)	Al (ppb)	Ti (ppb)	V (ppb)	Cr (ppb)	Fe (ppb)	Mn (ppb)	Co (ppb)	Ni (ppb)	Cu (ppb)	Zn (ppb)	As (ppb)	Se (ppb)	Rb (ppb)	Sr (ppb)	Y (ppb)	Mo (ppb)	Ag (ppb)	Cd (ppb)	In (ppb)	Sb (ppb)	Ba (ppb)	
94SC/AP-W019	19	322200	5070950	0.5	-0.05	61	1.4	0.3	0.8	449	26	0.2	5.6	1.1	1.8	1.0	-1	0.5	50	0.17	0.3	-0.1	-0.05	0.02	0.07	1	
94SC/AP-W020	19	323050	5070250	0.4	-0.05	61	1.2	0.3	1.5	575	718	1.6	20.6	2.6	3.7	1.1	1	0.6	44	0.21	0.5	-0.1	0.05	-0.02	0.13	3	
94SC/AP-W021	19	323300	5076675	5.2	0.1	1923	5.5	-0.1	3.8	16619	821	9.2	12.2	303.2	1236.2	0.6	-1	12.9	108	4.80	-0.1	-0.1	4.99	0.03	-0.03	48	
94SC/AP-W022	19	321975	5074150	13.7	-0.05	28	17.1	-0.1	-0.1	30	170	0.7	23.0	67.9	1160.0	0.4	1	9.7	999	0.13	0.7	-0.1	6.23	0.32	0.18	14	
94SC/AP-W023	19	320275	5071575	0.6	-0.05	19	0.6	0.2	0.3	189	43	-0.1	2.6	2.0	2.7	0.7	1	1.9	131	0.05	0.3	-0.1	-0.05	0.02	0.06	11	
94SC/AP-W024	19	318100	5071700	0.5	-0.05	44	-0.5	0.2	0.5	89	13	0.1	23.6	12.2	21.0	0.6	1	1.4	77	0.06	0.2	-0.1	0.21	-0.02	0.08	6	
94SC/AP-W025	19	318800	5071800	0.7	-0.05	25	0.9	0.3	0.4	192	25	0.1	3.5	3.9	12.6	0.7	-1	2.1	141	0.05	0.3	-0.1	0.13	-0.02	0.07	12	
94SC/AP-W026	19	320100	5070825	33.8	-0.05	39	37.4	-0.1	-0.1	28335	-1	157.5	183.3	14.4	10499.0	0.3	-1	19.1	1480	0.55	-0.1	-0.1	27.16	-0.02	0.03	29	
94SC/AP-W027	19	321800	5070825	0.6	-0.05	38	-0.5	0.2	0.2	52	19	-0.1	1.5	1.1	1.1	0.8	-1	1.9	117	0.02	0.2	-0.1	-0.05	0.02	0.06	7	
94SC/AP-W028	Blank			-0.1	-0.05	-2	-0.5	-0.1	-0.1	-5	-1	-0.1	-0.5	0.7	1.0	-0.2	-1	-0.2	-1	0.02	-0.1	-0.1	0.05	0.02	0.03	1	
94SC/AS-W001	19	333529	5072840	0.6	-0.05	92	1.7	0.3	0.7	182	16	0.1	3.7	3.1	6.7	0.8	-1	1.1	79	0.19	0.2	-0.1	0.23	0.02	0.06	5	
REPEATS																											
94SC/AA-W006				0.3	-0.05	62	0.8	0.1	1.1	147	4	-0.1	7.6	2.9	4.1	0.4	-1	0.5	34	0.16	-0.1	-0.1	0.17	0.02	0.10	3	
94SC/AA-W006				0.3	-0.05	75	0.9	0.2	1.2	168	4	-0.1	8.5	3.1	4.1	0.4	-1	0.6	39	0.16	-0.1	-0.1	0.13	0.02	0.09	3	
94SC/AA-W020				0.3	-0.05	51	0.6	0.2	1.0	111	2	-0.1	7.0	2.8	3.1	0.3	-1	0.6	42	0.13	-0.1	-0.1	0.05	0.02	0.06	3	
94SC/AA-W020				0.3	-0.05	56	0.5	0.2	1.0	122	3	-0.1	7.4	3.1	3.3	0.6	-1	0.6	35	0.15	-0.1	-0.1	-0.05	-0.02	0.07	3	
94SC/AA-W026				0.3	-0.05	52	0.7	0.2	1.0	110	2	-0.1	7.1	2.7	2.1	0.5	-1	0.6	33	0.13	-0.1	-0.1	-0.05	0.02	0.06	3	
94SC/AA-W026				0.3	-0.05	55	0.6	0.2	1.0	118	2	-0.1	7.6	2.8	2.5	0.5	-1	0.6	46	0.14	-0.1	-0.1	-0.05	-0.02	0.08	3	
94SC/AA-W034				0.3	-0.05	54	0.8	0.2	1.1	125	2	-0.1	8.5	1.9	1.5	0.7	-1	0.6	44	0.14	-0.1	-0.1	-0.05	0.02	0.06	3	
94SC/AA-W034				0.3	-0.05	57	0.7	0.2	1.2	128	2	-0.1	8.5	2.0	1.7	0.7	-1	0.7	47	0.17	-0.1	-0.1	-0.05	0.02	0.08	3	
94SC/AT-W001H				0.7	-0.05	85	0.9	0.2	0.4	115	5	-0.1	1.7	2.0	5.1	0.3	-1	1.0	8	0.08	-0.1	-0.1	0.05	0.02	0.05	4	
94SC/AT-W001H				0.6	-0.05	84	0.9	0.2	0.4	118	6	-0.1	1.5	2.0	4.8	0.3	-1	1.0	8	0.08	-0.1	-0.1	0.05	0.02	0.06	4	
94SC/AP-W015				0.5	-0.05	98	2.6	0.6	2.7	738	63	0.6	22.6	3.5	5.5	2.0	-1	1.6	27	0.19	0.5	-0.1	-0.05	-0.02	0.13	3	
94SC/AP-W015				0.4	-0.05	97	2.1	0.5	2.5	775	66	0.6	20.6	3.1	4.6	1.7	-1	1.5	29	0.18	0.5	-0.1	-0.05	-0.02	0.12	3	
94SC/AP-W020				0.4	-0.05	61	1.2	0.3	1.5	575	915	1.6	20.6	2.6	3.7	1.1	-1	0.6	44	0.21	0.5	-0.1	-0.05	-0.02	0.13	3	
94SC/AP-W020				0.3	-0.05	58	1.0	0.3	1.4	598	944	1.5	17.3	2.3	2.9	0.8	-1	0.5	43	0.17	0.4	-0.1	-0.05	0.02	0.11	3	
94SC/AF-W001				0.3	-0.05	54	0.7	0.1	0.8	76	2	-0.1	5.8	1.8	2.2	0.6	-1	0.7	53	0.13	0.1	-0.1	-0.05	-0.02	0.06	3	
94SC/AF-W004				0.3	-0.05	51	-0.5	-0.1	0.8	86	2	-0.1	5.0	1.7	2.0	0.4	-1	0.6	50	0.13	0.1	-0.1	-0.05	-0.02	0.05	3	
CONTROLS																											
TAP				0.6	-0.05	84	2.3	0.2	0.2	46	12	-0.1	0.6	3.8	5.0	0.7	-1	1.6	66	0.11	0.2	-0.1	-0.05	-0.02	0.07	18	
TAP				0.6	-0.05	89	2.4	-0.1	0.2	44	12	-0.1	0.9	3.7	4.8	0.7	-1	1.6	69	0.12	0.2	-0.1	-0.05	-0.02	0.07	18	
TAP				0.6	-0.05	91	2.3	0.2	0.3	42	11	-0.1	1.0	3.5	4.8	0.6	-1	1.5	70	0.11	0.3	-0.1	-0.05	-0.02	0.08	18	
TAP				0.6	-0.05	94	2.3	0.2	0.4	46	12	-0.1	1.3	3.9	4.8	0.7	-1	1.5	69	0.11	0.3	-0.1	-0.05	-0.02	0.08	18	
TAP				0.6	-0.05	95	2.6	0.2	0.4	45	12	-0.1	1.3	3.8	5.3	0.8	-1	1.7	71	0.12	0.2	-0.1	-0.05	-0.02	0.07	18	

Appendix VI: Lake and stream water geochemistry of the study area of filtered water samples (<45µm)

Sample Number	Zone	Northing	Easting	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Tl	Pb	U
94SCAA-W027	19	318024	5078520	0.15	0.21	0.04	0.18	0.04	0.01	0.03	<0.01	0.02	<0.01	0.01	<0.01	0.02	<0.01	<0.01	0.2	0.07
94SCAA-W028	19	318514	5079000	0.13	0.17	0.03	0.13	0.03	<0.01	0.03	<0.01	0.03	<0.01	0.02	<0.01	0.01	<0.01	<0.01	0.4	0.06
94SCAA-W029	19	318585	5079407	0.13	0.20	0.03	0.16	0.03	<0.01	0.03	<0.01	0.03	<0.01	0.02	<0.01	0.01	<0.01	<0.01	0.3	0.06
94SCAA-W030	19	317079	5080492	0.15	0.19	0.03	0.15	0.03	<0.01	0.03	<0.01	0.03	<0.01	0.01	<0.01	0.02	<0.01	<0.01	0.5	0.06
94SCAA-W031	19	316977	5081537	0.13	0.18	0.04	0.15	0.02	<0.01	0.02	<0.01	0.02	<0.01	0.01	<0.01	0.01	<0.01	<0.01	0.2	0.07
94SCAA-W032	19	317490	5085080	0.13	0.17	0.03	0.14	0.02	<0.01	0.03	<0.01	0.02	<0.01	0.01	<0.01	0.01	<0.01	<0.01	0.1	0.07
94SCAA-W033A	19	318000	5084000	0.14	0.20	0.04	0.16	0.04	<0.01	0.04	<0.01	0.03	<0.01	0.02	<0.01	0.02	<0.01	<0.01	0.4	0.06
94SCAA-W033B	19	318000	5084000	0.13	0.17	0.03	0.16	0.03	<0.01	0.03	<0.01	0.03	<0.01	0.01	<0.01	0.01	<0.01	<0.01	0.3	0.05
94SCAA-W034	19	318027	5082466	0.13	0.16	0.03	0.14	0.03	<0.01	0.03	<0.01	0.03	<0.01	0.02	<0.01	0.02	<0.01	<0.01	0.3	0.06
94SCAA-W035	19	317967	5080579	0.14	0.20	0.04	0.17	0.04	0.01	0.03	<0.01	0.02	<0.01	0.02	<0.01	0.01	0.01	0.01	0.2	0.07
94SCAA-W036	19	315054	5072516	0.11	0.13	0.03	0.13	0.02	<0.01	0.02	<0.01	0.02	<0.01	0.01	<0.01	0.01	<0.01	<0.01	0.2	0.06
94SCAA-W037	19	314332	5071550	0.11	0.14	0.03	0.12	0.02	<0.01	0.02	<0.01	0.02	<0.01	0.01	<0.01	0.01	<0.01	<0.01	0.3	0.06
94SCAA-W038	19	313193	5070155	0.11	0.15	0.03	0.14	0.03	<0.01	0.02	<0.01	0.02	<0.01	0.01	<0.01	0.01	<0.01	<0.01	0.5	0.06
94SCAA-W039	19	313193	5070155	0.12	0.16	0.03	0.17	0.04	<0.01	0.02	<0.01	0.02	<0.01	0.02	<0.01	0.01	<0.01	<0.01	0.3	0.06
94SCAA-W040	19	316024	5071827	0.10	0.13	0.02	0.13	0.02	<0.01	0.02	<0.01	0.03	<0.01	0.02	<0.01	0.01	<0.01	<0.01	0.3	0.06
94SCAB-W001	19	329897	5075214	0.09	0.13	0.02	0.09	0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	0.4	0.10
94SCAI-W001	19	325043	5076256	<0.05	0.06	0.01	0.05	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.2	0.02
94SCAI-W001	19	314004	5078017	0.13	0.17	0.03	0.14	0.02	<0.01	0.03	<0.01	0.03	<0.01	0.01	<0.01	0.01	<0.01	<0.01	0.3	0.09
94SCAI-W002	19	336101	5076208	0.14	0.15	0.03	0.13	0.01	<0.01	0.03	<0.01	0.03	<0.01	0.01	<0.01	0.01	<0.01	<0.01	0.4	0.07
94SCAI-W003	19	333681	5073504	0.13	0.16	0.03	0.13	0.03	<0.01	0.03	<0.01	0.03	<0.01	0.01	<0.01	0.01	<0.01	<0.01	0.3	0.07
94SCAI-W004	19	330490	5091302	0.13	0.16	0.03	0.14	0.02	<0.01	0.04	<0.01	0.03	<0.01	0.01	<0.01	0.01	<0.01	<0.01	0.4	0.07
94SCAI-W005	19	324525	5091006	0.13	0.16	0.04	0.15	0.03	<0.01	0.03	<0.01	0.03	<0.01	0.02	<0.01	0.01	<0.01	<0.01	0.2	0.06
94SCAG-W001	19	317842	5069917	0.08	0.11	0.02	0.08	0.01	0.01	0.02	<0.01	0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	0.1	0.048
94SCAG-W002	19	318275	5068700	<0.05	<0.05	<0.01	0.03	<0.01	<0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.1	0.048
94SCAI-W003A	19	324085	5073026	0.14	0.20	0.03	0.13	0.02	<0.01	0.02	<0.01	0.02	<0.01	0.01	<0.01	0.01	<0.01	<0.01	0.8	0.17
94SCAI-W003B	19	326088	5073023	0.11	0.14	0.03	0.10	0.03	0.01	0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.01	<0.01	<0.01	0.6	0.14
94SCAN-W001	19	325442	5071007	<0.05	0.05	<0.01	0.03	<0.01	<0.01	0.03	<0.01	0.03	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	0.2	0.06
94SCAP-W001	19	318701	5072450	0.33	0.53	0.08	0.37	0.08	0.02	0.09	0.03	0.07	0.01	0.01	<0.01	0.01	<0.01	<0.01	0.6	0.17
94SCAP-W001	19	326088	5073023	0.29	0.47	0.07	0.32	0.08	0.02	0.08	0.01	0.05	0.01	0.01	<0.01	0.01	<0.01	<0.01	0.2	0.14
94SCAP-W001	19	326088	5073023	0.32	0.54	0.09	0.36	0.09	0.02	0.08	0.01	0.07	0.01	0.01	<0.01	0.01	<0.01	<0.01	0.6	0.17
94SCAP-W012	19	325835	5085300	0.32	0.54	0.09	0.36	0.09	0.02	0.08	0.01	0.07	0.01	0.01	<0.01	0.01	<0.01	<0.01	0.8	0.17
94SCAP-W013	19	325835	5085300	0.32	0.54	0.09	0.36	0.09	0.02	0.08	0.01	0.07	0.01	0.01	<0.01	0.01	<0.01	<0.01	0.8	0.17
94SCAP-W014	19	313046	5072450	0.14	0.22	0.04	0.18	0.04	<0.01	0.05	<0.01	0.04	<0.01	0.02	<0.01	0.01	<0.01	<0.01	0.5	0.13
94SCAP-W014	19	313046	5072450	0.16	0.22	0.04	0.19	0.04	<0.01	0.05	<0.01	0.04	<0.01	0.02	<0.01	0.01	<0.01	<0.01	0.5	0.13
94SCAP-W014	19	313046	5072450	0.16	0.22	0.04	0.19	0.04	<0.01	0.05	<0.01	0.04	<0.01	0.02	<0.01	0.01	<0.01	<0.01	0.5	0.13
94SCAP-W014	19	313046	5072450	0.16	0.22	0.04	0.19	0.04	<0.01	0.05	<0.01	0.04	<0.01	0.02	<0.01	0.01	<0.01	<0.01	0.5	0.13
94SCAP-W014	19	313046	5072450	0.16	0.22	0.04	0.19	0.04	<0.01	0.05	<0.01	0.04	<0.01	0.02	<0.01	0.01	<0.01	<0.01	0.5	0.13
94SCAP-W014	19	313046	5072450	0.16	0.22	0.04	0.19	0.04	<0.01	0.05	<0.01	0.04	<0.01	0.02	<0.01	0.01	<0.01	<0.01	0.5	0.13
94SCAP-W014	19	313046	5072450	0.16	0.22	0.04	0.19	0.04	<0.01	0.05	<0.01	0.04	<0.01	0.02	<0.01	0.01	<0.01	<0.01	0.5	0.13
94SCAP-W014	19	313046	5072450	0.16	0.22	0.04	0.19	0.04	<0.01	0.05	<0.01	0.04	<0.01	0.02	<0.01	0.01	<0.01	<0.01	0.5	0.13
94SCAP-W014	19	313046	5072450	0.16	0.22	0.04	0.19	0.04	<0.01	0.05	<0.01	0.04	<0.01	0.02	<0.01	0.01	<0.01	<0.01	0.5	0.13
94SCAP-W014	19	313046	5072450	0.16	0.22	0.04	0.19	0.04	<0.01	0.05	<0.01	0.04	<0.01	0.02	<0.01	0.01	<0.01	<0.01	0.5	0.13
94SCAP-W014	19	313046	5072450	0.16	0.22	0.04	0.19	0.04	<0.01	0.05	<0.01	0.04	<0.01	0.02	<0.01	0.01	<0.01	<0.01	0.5	0.13
94SCAP-W014	19	313046	5072450	0.16	0.22	0.04	0.19	0.04	<0.01	0.05	<0.01	0.04	<0.01	0.02	<0.01	0.01	<0.01	<0.01	0.5	0.13
94SCAP-W014	19	313046	5072450	0.16	0.22	0.04	0.19	0.04	<0.01	0.05	<0.01	0.04	<0.01	0.02	<0.01	0.01	<0.01	<0.01	0.5	0.13
94SCAP-W014	19	313046	5072450	0.16	0.22	0.04	0.19	0.04	<0.01	0.05	<0.01	0.04	<0.01	0.02	<0.01	0.01	<0.01	<0.01	0.5	0.13
94SCAP-W014	19	313046	5072450	0.16	0.22	0.04	0.19	0.04	<0.01	0.05	<0.01	0.04	<0.01	0.02	<0.01	0.01	<0.01	<0.01	0.5	0.13
94SCAP-W014	19	313046	5072450	0.16	0.22	0.04	0.19	0.04	<0.01	0.05	<0.01	0.04	<0.01	0.02	<0.01	0.01	<0.01	<0.01	0.5	0.13
94SCAP-W014	19	313046	5072450	0.16	0.22	0.04	0.19	0.04	<0.01	0.05	<0.01	0.04	<0.01	0.02	<0.01	0.01	<0.01	<0.01	0.5	0.13
94SCAP-W014	19	313046	5072450	0.16	0.22	0.04	0.19	0.04	<0.01	0.05	<0.01	0.04	<0.01	0.02	<0.01	0.01	<0.01	<0.01	0.5	0.13
94SCAP-W014	19	313046	5072450	0.16	0.22	0.04	0.19	0.04	<0.01	0.05	<0.01	0.04	<0.01	0.02	<0.01	0.01	<0.01	<0.01	0.5	0.13
94SCAP-W014	19	313046	5072450	0.16	0.22	0.04	0.19	0.04	<0.01	0.05	<0.01	0.04	<0.01	0.02	<0.01	0.01	<0.01	<0.01	0.5	0.13
94SCAP-W014	19	313046	5072450	0.16	0.22	0.04	0.19	0.04	<0.01	0.05	<0.01	0.04	<0.01	0.02	<0.01	0.01	<0.01	<0.01	0.5	0.13
94SCAP-W014	19	313046	5072450	0.16	0.22	0.04	0.19	0.04	<0.01	0.05	<0.01	0.04	<0.01	0.02	<0.01	0.01	<0.01	<0.01	0.5	0.13
94SCAP-W014	19	313046	5072450	0.16	0.22	0.04	0.19	0.04	<0.01	0.05	<0.01	0.04	<0.01	0.02	<0.01	0.01	<0.01	<0.01	0.5	0.13
94SCAP-W014	19	313046	5072450	0.16	0.22	0.04	0.19	0.04	<0.01	0.05	<0.01	0.04	<0.01	0.02	<0.01	0.01	<0.01	<0.01	0.5	0.13
94SCAP-W014	19	313046	5072450	0.16	0.22	0.04	0.19	0.04	<0.01	0.05	<0.01	0.04	<0.01	0.02	<0.01	0.01	<0.01	<0.01	0.5	

Appendix VI: Lake and stream water geochemistry of the study area of filtered water samples (<45µm)

Sample Number	Zone	Northing	Easting	La (ppb)	Ce (ppb)	Pr (ppb)	Nd (ppb)	Sm (ppb)	Eu (ppb)	Gd (ppb)	Tb (ppb)	Dy (ppb)	Ho (ppb)	Er (ppb)	Tm (ppb)	Yb (ppb)	Lu (ppb)	Ti (ppb)	Pb (ppb)	U (ppb)
94SCAP-W017	19	309600	5079050	0.10	0.17	0.03	0.14	0.02	<0.01	0.03	<0.01	0.03	<0.01	0.02	<0.01	0.01	<0.01	<0.01	0.4	0.03
94SCAP-W018	19	314950	5080800	0.16	0.30	0.04	0.19	0.04	<0.01	0.04	<0.01	0.04	<0.01	0.03	<0.01	0.02	<0.01	<0.01	0.7	0.05
94SCAP-W019	19	322200	5079950	0.11	0.19	0.03	0.13	0.03	<0.01	0.03	<0.01	0.03	<0.01	0.02	<0.01	0.01	<0.01	<0.01	0.4	0.03
94SCAP-W020	19	323050	5079250	0.14	0.30	0.04	0.16	0.04	<0.01	0.03	<0.01	0.04	0.01	0.02	<0.01	0.02	<0.01	<0.01	0.6	0.03
94SCAP-W021	19	323300	5076675	3.88	10.18	1.27	5.72	1.39	0.38	1.43	0.20	1.17	0.21	0.49	0.07	0.39	0.05	0.67	97.9	0.68
94SCAP-W022	19	321975	5074150	0.09	0.09	0.01	0.07	0.01	<0.01	0.02	<0.01	0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.03	0.4	0.60
94SCAP-W023	19	320275	5071575	<0.05	0.05	<0.01	0.04	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.5	0.24
94SCAP-W024	19	318100	5071700	0.06	0.08	0.01	0.05	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.6	0.17
94SCAP-W025	19	318900	5071800	<0.05	0.06	<0.01	0.04	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.6	0.29
94SCAP-W026	19	320100	5070825	0.43	0.29	0.02	0.05	<0.01	<0.01	0.03	<0.01	0.02	<0.01	0.01	<0.01	<0.01	<0.01	0.10	0.2	0.10
94SCAP-W027	19	321800	5070825	<0.05	<0.05	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.1	0.23
94SCAP-W028		blank		<0.05	<0.05	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.1	0.02
94SCAS-W001	19	333529	5072840	0.23	0.30	0.05	0.21	0.03	<0.01	0.04	<0.01	0.03	<0.01	0.02	<0.01	0.01	<0.01	<0.01	0.8	0.12
REPEATS																				
94SCAA-W006				0.13	0.19	0.04	0.15	0.04	<0.01	0.02	<0.01	0.03	<0.01	0.02	<0.01	0.02	<0.01	<0.01	0.4	0.05
94SCAA-W006				0.13	0.20	0.04	0.15	0.03	0.01	0.04	<0.01	0.03	<0.01	0.02	<0.01	0.01	<0.01	<0.01	0.4	0.05
94SCAA-W020				0.11	0.15	0.03	0.14	0.02	<0.01	0.03	<0.01	0.02	<0.01	0.02	<0.01	0.02	<0.01	<0.01	0.2	0.06
94SCAA-W020				0.12	0.16	0.03	0.12	0.03	<0.01	0.03	<0.01	0.02	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.2	0.05
94SCAA-W026				0.11	0.15	0.03	0.12	0.03	<0.01	0.04	<0.01	0.02	<0.01	0.01	<0.01	0.01	<0.01	<0.01	0.2	0.05
94SCAA-W026				0.12	0.15	0.03	0.14	0.03	0.01	0.02	<0.01	0.03	<0.01	0.02	<0.01	0.01	<0.01	<0.01	0.2	0.06
94SCAA-W034				0.13	0.16	0.03	0.14	0.03	<0.01	0.03	<0.01	0.03	<0.01	0.02	<0.01	0.02	<0.01	<0.01	0.2	0.06
94SCAA-W034				0.14	0.17	0.03	0.15	0.04	<0.01	0.02	<0.01	0.03	<0.01	0.02	<0.01	0.01	<0.01	<0.01	0.2	0.07
94SCAI-W001B				0.11	0.14	0.03	0.10	0.03	<0.01	0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.6	0.17
94SCAI-W001B				0.10	0.14	0.03	0.11	0.02	<0.01	0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.6	0.18
94SCAP-W015				0.12	0.22	0.04	0.16	0.04	<0.01	0.04	<0.01	0.04	<0.01	0.02	<0.01	0.02	<0.01	<0.01	1.0	0.05
94SCAP-W015				0.11	0.21	0.04	0.14	0.04	<0.01	0.04	<0.01	0.04	<0.01	0.02	<0.01	0.02	<0.01	<0.01	1.0	0.05
94SCAP-W020				0.14	0.30	0.04	0.16	0.04	<0.01	0.03	<0.01	0.04	<0.01	0.02	<0.01	0.02	<0.01	<0.01	0.6	0.04
94SCAP-W020				0.13	0.29	0.04	0.16	0.03	<0.01	0.04	<0.01	0.03	<0.01	0.02	<0.01	0.02	<0.01	<0.01	0.6	0.05
94SCAF-W004				0.13	0.16	0.03	0.14	0.02	<0.01	0.04	<0.01	0.03	<0.01	0.01	<0.01	0.01	<0.01	<0.01	0.4	0.07
94SCAF-W004				0.13	0.16	0.03	0.12	0.03	<0.01	0.03	<0.01	0.02	<0.01	0.01	<0.01	0.01	<0.01	<0.01	0.4	0.08
CONTROLS																				
TAP				0.19	0.18	0.03	0.14	0.02	<0.01	0.02	<0.01	0.01	<0.01	0.01	<0.01	0.01	<0.01	<0.01	0.4	0.03

Appendix VI: Lake and stream water geochemistry of the study area of filtered water samples (<45µm)

Sample Number	Zone	Northing	Easting	La (ppb)	Ce (ppb)	Pr (ppb)	Nd (ppb)	Sm (ppb)	Eu (ppb)	Gd (ppb)	Tb (ppb)	Dy (ppb)	Ho (ppb)	Er (ppb)	Tm (ppb)	Yb (ppb)	Lu (ppb)	Ti (ppb)	Pb (ppb)	U (ppb)
TAP				0.18	0.19	0.04	0.14	0.01	<0.01	0.02	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.4	0.03
TAP				0.17	0.19	0.03	0.13	0.02	<0.01	0.02	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.4	0.02
TAP				0.19	0.18	0.03	0.13	0.02	<0.01	0.02	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.4	0.03
TAP				0.18	0.17	0.01	0.12	0.01	<0.01	0.02	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.4	0.02
MEAN				0.18	0.18	0.04	0.13	0.02	<0.01	0.02	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.4	0.03
±SD				±0.05	±0.05	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	0.1	±0.02
LAB MEAN				0.17	0.17	0.03	0.12	0.02	<0.01	0.02	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.3	0.02
BLANK				±0.05	±0.05	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	0.1	0.02
BLANK				±0.05	±0.05	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	0.1	0.02
BLANK				±0.05	±0.05	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	0.1	0.02
BLANK				±0.05	±0.05	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	0.1	0.02
MEAN				±0.05	±0.05	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	0.1	0.02
±SD				±0.05	±0.05	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	0.1	0.02
OTT 94				0.27	0.30	0.06	0.26	0.05	<0.01	0.04	<0.01	0.02	<0.01	0.02	<0.01	0.01	<0.01	<0.01	0.2	0.08
OTT 94				0.24	0.31	0.06	0.22	0.04	<0.01	0.03	<0.01	0.03	<0.01	0.02	<0.01	0.01	<0.01	<0.01	0.2	0.07
OTT 94				0.25	0.29	0.06	0.23	0.05	<0.01	0.04	<0.01	0.02	<0.01	0.01	<0.01	0.01	<0.01	<0.01	0.2	0.07
OTT 94				0.26	0.30	0.06	0.25	0.05	<0.01	0.03	<0.01	0.03	<0.01	0.01	<0.01	0.01	<0.01	<0.01	0.2	0.07
MEAN				0.25	0.30	0.06	0.24	0.05	<0.01	0.03	<0.01	0.02	<0.01	0.01	<0.01	0.01	<0.01	<0.01	0.2	0.07
±SD				±0.05	±0.05	±0.01	±0.02	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	0.1	±0.02
LAB MEAN				0.24	0.28	0.06	0.23	0.04	<0.01	0.03	<0.01	0.02	<0.01	0.01	<0.01	0.01	<0.01	<0.01	0.2	0.07

Appendix VI: Lake and stream water geochemistry of the study area of filtered water samples (<45µm)

SAMPLE NUMBER	ZONE	EASTING	NORTHING	F ⁻ (mg/L)	Cl ⁻ (mg/L)	NO ₂ ^{-N} (mg/L)	Br ⁻ (mg/L)	NO ₃ ^{-N} (mg/L)	PO ₄ ⁻³ (mg/L)	SO ₄ ⁻² (mg/L)
94SCAA-W001	19	316336	5077469	<0.1	2.97	<0.02	<0.05	0.15	<0.1	4.72
94SCAA-W002	19	315043	5077333	<0.1	2.97	<0.02	<0.05	0.14	<0.1	4.72
94SCAA-W003A	19	315973	5076564	<0.1	3.14	<0.02	<0.05	0.20	<0.1	4.76
94SCAA-W003B-1	19	315973	5076564	<0.1	3.05	<0.02	<0.05	0.16	<0.1	4.76
94SCAA-W003B-2	19	315973	5076564	<0.1	2.99	<0.02	<0.05	0.12	<0.1	4.76
94SCAA-W003C	19	315973	5076564	<0.1	0.02	<0.02	<0.05	<0.02	<0.1	<0.05
94SCAA-W004	19	315041	5077292	<0.1	3.01	<0.02	<0.05	0.13	<0.1	4.56
94SCAA-W005A-1	19	315072	5076490	<0.1	3.16	<0.02	<0.05	0.18	<0.1	4.76
94SCAA-W005A-2	19	315072	5076490	<0.1	3.22	<0.02	<0.05	0.19	<0.1	4.72
94SCAA-W005B	19	315072	5076490	<0.1	3.11	<0.02	<0.05	0.16	<0.1	4.66
94SCAA-W006	19	314040	5076513	<0.1	2.97	<0.02	<0.05	0.15	<0.1	4.35
94SCAA-W007	19	316020	5075526	<0.1	3.16	<0.02	<0.05	0.15	<0.1	4.87
94SCAA-W008A	19	315057	5075542	<0.1	3.29	<0.02	<0.05	0.19	<0.1	4.66
94SCAA-W008B	19	315057	5075542	<0.1	3.14	0.02	<0.05	0.15	<0.1	4.76
94SCAA-W009	19	314030	5075630	<0.1	3.06	<0.02	<0.05	0.15	<0.1	4.52
94SCAA-W010A	19	315918	5074509	<0.1	3.12	<0.02	<0.05	0.11	<0.1	4.52
94SCAA-W010B	19	315918	5074509	<0.1	3.12	<0.02	<0.05	0.15	<0.1	4.72
94SCAA-W011	19	315004	5074506	<0.1	3.16	<0.02	<0.05	0.15	<0.1	4.72
94SCAA-W012	19	314615	5074328	<0.1	3.22	<0.02	<0.05	0.16	<0.1	4.83
94SCAA-W013	19	318037	5073500	<0.1	3.26	<0.02	<0.05	0.15	<0.1	4.93
94SCAA-W014	19	316982	5073560	<0.1	3.33	<0.02	<0.05	0.15	<0.1	4.83
94SCAA-W015	19	316963	5074473	<0.1	3.37	<0.02	<0.05	0.16	<0.1	4.78
94SCAA-W016A	19	318009	5074503	<0.1	3.53	<0.02	<0.05	0.22	<0.1	4.83
94SCAA-W016B	19	318009	5074503	<0.1	3.37	<0.02	<0.05	0.16	<0.1	4.78
94SCAA-W017A	19	318035	5075510	<0.1	3.46	<0.02	<0.05	0.19	<0.1	4.87
94SCAA-W017B	19	318035	5075510	<0.1	3.41	<0.02	<0.05	0.13	<0.1	4.93
94SCAA-W018	19	319009	5075497	<0.1	3.44	<0.02	<0.05	0.15	<0.1	4.97
94SCAA-W019	19	318946	5074528	<0.1	3.42	<0.02	<0.05	0.18	<0.1	4.87
94SCAA-W020	19	315986	5072505	<0.1	3.44	<0.02	<0.05	0.16	<0.1	5.03
94SCAA-W021	19	318852	5078944	<0.1	3.07	<0.02	<0.05	0.11	<0.1	6.73

Appendix VI: Lake and stream water geochemistry of the study area of filtered water samples (<45µm)

SAMPLE NUMBER	ZONE	EASTING	NORTHING	F ⁻ (mg/L)	Cl ⁻ (mg/L)	NO ₂ ^{-N} (mg/L)	Br ⁻ (mg/L)	NO ₃ ^{-N} (mg/L)	PO ₄ ⁻³ (mg/L)	SO ₄ ⁻² (mg/L)
94SCAA-W022	19	318957	5078737	<0.1	3.14	<0.02	<0.05	0.14	<0.1	6.48
94SCAA-W023	19	318909	5078667	<0.1	3.46	<0.02	<0.05	0.13	<0.1	4.78
94SCAA-W024-1	19	318969	5077482	<0.1	3.55	<0.02	<0.05	0.07	<0.1	4.93
94SCAA-W024-2	19	318539	5077482	<0.1	3.52	<0.02	<0.05	0.13	<0.1	4.93
94SCAA-W025	19	318091	5077389	<0.1	3.27	<0.02	<0.05	0.14	<0.1	4.83
94SCAA-W026	19	318070	5076524	<0.1	3.31	<0.02	<0.05	0.17	<0.1	4.97
94SCAA-W027	19	318024	5078520	<0.1	3.57	<0.02	<0.05	0.12	<0.1	4.83
94SCAA-W028	19	318514	5079000	<0.1	3.31	<0.02	<0.05	0.12	<0.1	4.93
94SCAA-W029	19	318585	5079407	<0.1	2.94	<0.02	<0.05	0.14	<0.1	5.58
94SCAA-W030	19	317079	5080492	<0.1	3.04	<0.02	<0.05	0.13	<0.1	4.62
94SCAA-W031	19	316977	5081537	<0.1	3.07	<0.02	<0.05	0.13	<0.1	4.67
94SCAA-W032	19	317490	5085080	<0.1	2.65	<0.02	<0.05	0.17	<0.1	4.47
94SCAA-W033A	19	318000	5084000	<0.1	2.94	<0.02	<0.05	0.23	<0.1	4.57
94SCAA-W033B	19	318000	5084000	<0.1	2.86	<0.02	<0.05	0.14	<0.1	4.48
94SCAA-W034	19	318027	5082466	<0.1	2.95	<0.02	<0.05	0.13	<0.1	4.53
94SCAA-W035	19	317967	5080579	<0.1	3.12	<0.02	<0.05	0.15	<0.1	4.72
94SCAA-W036	19	315054	5072516	<0.1	3.16	<0.02	<0.05	0.18	<0.1	4.98
94SCAA-W037	19	314332	5071550	<0.1	3.12	<0.02	<0.05	0.17	<0.1	5.00
94SCAA-W038	19	313193	5070155	<0.1	3.12	<0.02	<0.05	0.17	<0.1	4.98
94SCAA-W039	19	313193	5070155	<0.1	3.14	<0.02	<0.05	0.17	<0.1	4.90
94SCAA-W040	19	316024	5071527	<0.1	3.16	<0.02	<0.05	0.17	<0.1	4.99
94SCAB-W001	19	329897	5075214	0.2	0.21	<0.02	<0.05	<0.02	6.1	2.80
94SCAE-W001-1	19	325943	5076256	<0.1	0.29	<0.02	<0.05	<0.02	<0.1	4.71
94SCAE-W001-2	19			<0.1	0.26	<0.02	<0.05	0.02	<0.1	4.37
94SCAE-W001-3	19			<0.1	0.31	<0.02	<0.05	<0.02	<0.1	4.52
94SCAF-W001	19	334064	5078917	<0.1	2.75	<0.02	<0.05	0.14	<0.1	4.38
94SCAF-W002	19	336101	336101	<0.1	2.83	<0.02	<0.05	0.15	<0.1	4.66
94SCAF-W003	19	333081	333081	<0.1	2.74	<0.02	<0.05	0.16	<0.1	4.57
94SCAF-W004	19	330490	330490	<0.1	2.69	<0.02	<0.05	0.16	<0.1	4.56
94SCAF-W005	19	324525	324525	<0.1	2.64	<0.02	<0.05	0.16	<0.1	4.55

Appendix VI: Lateral and stream water geochemistry of the study area of filtered water samples (<45µm)

SAMPLE NUMBER	ZONE	EASTING	NORTHING	F (mg/L)	Cl ⁻ (mg/L)	NO ₃ ^{-N} (mg/L)	Br ⁻ (mg/L)	NO ₃ ^{-N} (mg/L)	PO ₄ ^{-P} (mg/L)	SO ₄ ^{-S} (mg/L)
94SCAG-W001	19	317842	5069917	<0.1	0.72	<0.02	<0.05	0.06	<0.1	5.20
94SCAG-W002	19	318975	5068700	<0.1	9.86	<0.02	<0.05	0.21	<0.1	8.54
94SCAI-W001A	19	329688	5073020	<0.1	0.30	<0.02	<0.05	0.05	<0.1	3.14
94SCAI-W001B	19	329688	5073020	<0.1	0.26	<0.02	<0.05	<0.02	<0.1	3.04
94SCAK-W001	19	325447	5071607	<0.1	7.23	<0.02	<0.05	<0.02	<0.1	4.86
94SCAP-W010	19	318700	5079550	<0.1	2.74	<0.02	<0.05	0.03	<0.1	2.69
94SCAP-W011	19	320600	5081325	<0.1	2.90	<0.02	<0.05	0.03	<0.1	2.69
94SCAP-W012	19	325350	5085300	<0.1	2.28	<0.02	<0.05	0.03	<0.1	1.46
94SCAP-W013	19	323925	5085800	<0.1	1.33	<0.02	<0.05	0.13	<0.1	2.03
94SCAP-W014	19	313950	5073750	<0.1	3.51	<0.02	<0.05	0.06	<0.1	2.03
94SCAP-W015	19	313550	5075325	<0.1	4.64	<0.02	<0.05	0.36	<0.1	2.27
94SCAP-W016	19	312800	5076150	<0.1	0.23	<0.02	<0.05	0.12	<0.1	2.00
94SCAP-W017	19	309600	5079050	<0.1	2.70	<0.02	<0.05	0.02	<0.1	2.87
94SCAP-W018	19	314950	5080800	<0.1	1.56	<0.02	<0.05	0.31	<0.1	4.69
94SCAP-W019	19	322200	5079950	<0.1	0.17	<0.02	<0.05	0.06	<0.1	2.27
94SCAP-W020	19	323050	5079250	<0.1	0.21	<0.02	<0.05	0.05	<0.1	1.14
94SCAP-W021	19	323300	5076675	0.1	0.31	<0.02	<0.05	<0.02	<0.1	268.
94SCAP-W022	19	321975	5074150	<0.1	0.46	<0.02	<0.05	<0.02	<0.1	925.
94SCAP-W023	19	320275	5071575	<0.1	9.93	<0.02	<0.05	0.15	<0.1	7.13
94SCAP-W024	19	318100	5071700	<0.1	4.47	<0.02	<0.05	0.14	<0.1	6.90
94SCAP-W025	19	318800	5071800	<0.1	9.99	<0.02	<0.05	0.20	<0.1	10.2
94SCAP-W026	19	320100	5070825	0.2	1.29	<0.02	<0.05	<0.02	<0.1	1520.
94SCAP-W027	19	321800	5070825	<0.1	9.89	<0.02	<0.05	0.07	<0.1	6.74
94SCAP-W028	19	333529	5072840	<0.1	0.06	<0.02	<0.05	<0.02	<0.1	<0.05
94SCAS-W001	19			<0.1	2.94	<0.02	<0.05	0.22	<0.1	3.82
Blank				<0.1	<0.01	<0.02	<0.05	<0.02	<0.1	<0.05
Blank				<0.1	<0.01	<0.02	<0.05	<0.02	<0.1	<0.05
Blank				<0.1	<0.01	<0.02	<0.05	<0.02	<0.1	<0.05
Blank				<0.1	<0.01	<0.02	<0.05	<0.02	<0.1	<0.05
QC Standard (actual)	19			0.6	1.99	1.02	1.91	0.46	1.8	1.97

Appendix VI: Lake and stream water geochemistry of the study area of filtered water samples (<45µm)

SAMPLE NUMBER	ZONE	EASTING	NORTHING	F ⁻ (mg/L)	Cl ⁻ (mg/L)	NO ₂ ^{-N} (mg/L)	Br ⁻ (mg/L)	NO ₃ ^{-N} (mg/L)	PO ₄ ³⁻ (mg/L)	SO ₄ ²⁻ (mg/L)
QC Standard (actual)				0.6	2.03	0.99	<0.05	0.46	1.9	2.05
QC Standard (actual)				0.6	2.00	1.01	1.94	0.47	1.8	2.02
QC Standard (expected)	19			0.1	2.00	1.00	2.00	0.44	2.0	2.00
QC Standard (expected)				0.6	2.00	1.00	1.95	0.44	2.0	2.00
QC Standard (expected)				0.6	2.00	1.00	2.00	0.44	2.0	2.00
QC Standard (expected)				0.6	2.00	1.00	2.00	0.44	2.0	60.9
QC Standard (found)				0.6	2.00	0.99	1.90	0.46	1.9	60.0
Repeat 94SCAA-W001	19			<0.1	3.28	<0.02	<0.05	0.14	<0.1	4.83
Repeat 94SCAA-W029	19			<0.1	2.98	<0.02	<0.05	0.14	<0.1	5.61
Repeat 94SCA1-W01B	19			<0.1	0.24	<0.02	<0.05	0.02	<0.1	3.04
Repeat 94SCAP-W011	19			<0.1	3.00	<0.02	2.00	0.03	<0.1	2.71

Appendix VII: Concentration of metals in sequential extraction analyses

SAMPLE NUMBER	ZINC						FAAS SUM (ppm)
	FAAS NaOAc	FAAS NH ₂ OH HCl	FAAS NH ₂ OH HOAc	FAAS NH ₂ OH HOAc	FAAS KClO ₃	FAAS RESIDUE HF- PRESSURE	
	6 HR (ppm)	2 HR (ppm)	3 HR (ppm)	1.5 HR (ppm)	30 MIN (ppm)	(ppm)	
DL	1	1	1	1	1	1	1
94SCAA-5025	157	145	67	13	28	33	443
94SCAA-5058	238	304	78	8	51	39	719
94SCAA-5065	212	221	35	4	35	25	532
94SCAA-5086	23	40	13	2	5	16	99
94SCAA-5085	98	140	31	6	8	27	309
94SCAA-5102	60	87	42	12	20	36	258
94SCAA-5115	7	39	14	5	8	25	98
94SCAA-5128	200	314	93	24	43	51	725
94SCAF-5004	40	74	48	12	13	23	210
94SCAF-5012	16	61	31	10	16	31	165
93SCAT-002	154	8	54	4	144	97	461
93SCAP-5002	21	29	52	20	72	25	219
94SCAA-5088	27	64	18	4	11	30	154
BLK	< 1	< 1	2	< 1	< 1	< 1	2
TILL-2	1	27	44	14	24	27	137
LKSD-4	46	94	22	3	9	16	190
94SCAA-5025R	164	137	47	9	29	32	419
93SCAT-002R	154	8	52	2	144	94	456

SAMPLE NUMBER	COPPER						FAAS SUM (ppm)
	FAAS NaOAc	FAAS NH ₂ OH HCl	FAAS NH ₂ OH HOAc	FAAS NH ₂ OH HOAc	FAAS KClO ₃	FAAS RESIDUE HF- PRESSURE	
	6 HR (ppm)	2 HR (ppm)	3 HR (ppm)	1.5 HR (ppm)	30 MIN (ppm)	(ppm)	
DL	1	1	1	1	1	1	1
94SCAA-5025	6	71	29	< 1	10	2	119
94SCAA-5058	39	144	58	2	34	3	280
94SCAA-5065	25	89	21	< 1	21	2	157
94SCAA-5086	3	11	2	< 1	< 1	2	19
94SCAA-5085	14	59	19	1	5	2	101
94SCAA-5102	7	47	22	< 1	7	2	85
94SCAA-5115	1	8	4	< 1	2	1	16
94SCAA-5128	20	99	40	< 1	14	6	179
94SCAF-5004	< 1	12	12	< 1	< 1	2	27
94SCAF-5012	< 1	7	5	< 1	2	2	16
93SCAT-002	86	20	53	< 1	144	2	307
93SCAP-5002	33	163	210	30	88	3	527
94SCAA-5088	17	56	23	2	5	2	105
BLK	< 1	< 1	< 1	< 1	< 1	< 1	< 1
TILL-2	7	48	52	11	10	27	155
LKSD-4	1	6	9	3	11	2	32
94SCAA-5025R	9	69	32	2	11	2	126
93SCAT-002R	87	20	54	3	155	2	322

Appendix VII: Concentration of metals in sequential extraction analyses

SAMPLE NUMBER	NICKEL						FAAS SUM (ppm)
	FAAS NaOAc	FAAS NH ₂ OH HCl	FAAS NH ₂ OH .HOAc	FAAS NH ₂ OH HOAc	FAAS KClO ₃	FAAS RESIDUE HF- PRESSURE	
	6 HR (ppm)	2 HR (ppm)	3 HR (ppm)	1.5 HR (ppm)	30 MIN (ppm)	(ppm)	
D.L.	/	/	/	/	/	/	/
94SCAA-5025	56	106	71	10	12	31	286
94SCAA-5058	29	117	76	15	15	44	297
94SCAA-5065	10	38	31	8	12	35	135
94SCAA-5086	4	19	15	6	7	32	83
94SCAA-5085	9	39	26	7	8	26	116
94SCAA-5102	42	134	88	11	14	72	361
94SCAA-5115	16	108	70	14	17	44	271
94SCAA-5128	37	159	113	14	23	74	420
94SCAF-5004	21	61	64	9	9	48	212
94SCAF-5012	24	103	97	19	26	67	336
93SCAT-002	< 1	< 1	< 1	< 1	< 1	3	3
93SCAP-5002	6	3	< 1	< 1	< 1	17	25
94SCAA-5088	2	21	26	7	23	60	139
BLK	< 1	< 1	< 1	< 1	< 1	< 1	< 1
TILL-2	1	3	10	3	8	12	37
LKSD-4	3	12	3	< 1	5	6	29
94SCAA-5025R	57	103	80	11	11	34	298
93SCAT-002R	< 1	< 1	< 1	< 1	< 1	3	3

SAMPLE NUMBER	MANGANESE						FAAS SUM (ppm)
	FAAS NaOAc	FAAS NH ₂ OH HCl	FAAS NH ₂ OH .HOAc	FAAS NH ₂ OH HOAc	FAAS KClO ₃	FAAS RESIDUE HF- PRESSURE	
	6 HR (ppm)	2 HR (ppm)	3 HR (ppm)	1.5 HR (ppm)	30 MIN (ppm)	(ppm)	
D.L.	/	/	/	/	/	/	/
94SCAA-5025	2661	581	131	27	35	152	3587
94SCAA-5058	385	329	107	24	34	175	1054
94SCAA-5065	66	105	30	9	29	225	464
94SCAA-5086	50	148	27	8	20	184	438
94SCAA-5085	355	109	50	14	22	172	722
94SCAA-5102	1051	332	125	31	47	177	1762
94SCAA-5115	35	156	48	16	29	218	502
94SCAA-5128	775	783	156	37	60	292	2102
94SCAF-5004	3318	1814	218	25	34	102	5510
94SCAF-5012	300	440	76	16	33	200	1064
93SCAT-002	27	2	17	4	17	276	342
93SCAP-5002	174	41	25	8	19	91	359
94SCAA-5088	16	68	44	13	53	189	382
BLK	< 1	< 1	< 1	< 1	< 1	< 1	< 1
TILL-2	39	317	96	31	56	167	706
LKSD-4	187	104	44	9	14	91	449
94SCAA-5025R	2711	595	140	32	37	165	3681
93SCAT-002R	28	3	16	6	15	273	340

Appendix VII: Concentration of metals in sequential extraction analyses

SAMPLE NUMBER	IRON						FAAS SUM (ppm)
	FAAS NaOAc	FAAS NH ₂ OH HCl	FAAS NH ₂ OH HOAc	FAAS NH ₂ OH HOAc	FAAS KClO ₃	FAAS RESIDUE HF- PRESSURE	
	6 HR (ppm)	2 HR (ppm)	3 HR (ppm)	1.5 HR (ppm)	30 MIN (ppm)	(ppm)	
<i>D.L.</i>	<i>1</i>	<i>1</i>	<i>1</i>	<i>1</i>	<i>1</i>	<i>1</i>	<i>1</i>
94SCAA-5025	7182	24420	15405	2623	3643	13698	66972
94SCAA-5058	1634	14633	14379	2562	3800	14523	51531
94SCAA-5065	196	3994	4624	1327	4017	13527	27685
94SCAA-5086	184	2567	3609	1233	3520	9117	20230
94SCAA-5085	1395	6384	6993	1711	2505	10565	29553
94SCAA-5102	2687	19529	14130	2997	4695	15962	60000
94SCAA-5115	278	4904	5185	1614	3024	13812	28816
94SCAA-5128	840	14044	17874	4029	6923	21222	64932
94SCAF-5004	4864	25792	20245	2800	3728	9133	66562
94SCAF-5012	688	8303	9915	2431	6759	14794	42890
93SCA1-002	7991	4942	20145	505	40824	8088	82495
93SCAP-5002	1499	94495	290553	36992	11760	5300	440600
94SCAA-5088	146	3967	5561	1882	7132	15836	34525
BLK	< 1	< 1	1	1	1	5	6
TILL-2	115	7725	12825	3390	5670	7600	37325
LKSD-4	244	5805	8675	1680	5160	5640	27204
94SCAA-5025R	6563	23472	16429	2803	3791	14292	67351
93SCAT-002R	8257	5240	19906	685	41189	8010	83286

SAMPLE NUMBER	LEAD						ICP-MS SUM (ppb)
	ICP-MS NaOAc	ICP-MS NH ₂ OH HCl	ICP-MS NH ₂ OH HOAc	ICP-MS NH ₂ OH HOAc	ICP-MS KClO ₃	ICP-MS RESIDUE HF- PRESSURE	
	6 HR (ppb)	2 HR (ppb)	3 HR (ppb)	1.5 HR (ppb)	30 MIN (ppb)	(ppb)	
<i>D.L.</i>	<i>30</i>	<i>30</i>	<i>30</i>	<i>30</i>	<i>30</i>	<i>20</i>	<i>230</i>
94SCAA-5025	37762	55702	5289	1100	1676	8441	109971
94SCAA-5058	52659	72300	5778	408	890	5744	137780
94SCAA-5065	16355	19049	1443	151	410	6114	43522
94SCAA-5086	1473	4012	516	83	156	4479	10720
94SCAA-5085	8799	13379	1681	195	379	6009	30443
94SCAA-5102	25702	41104	3342	302	352	13256	84057
94SCAA-5115	4766	8062	813	121	225	13259	27246
94SCAA-5128	34110	53818	4624	387	540	18273	111752
94SCAF-5004	15876	41305	4214	336	310	6826	68867
94SCAF-5012	10437	20578	2808	386	1139	8847	44196
93SCAT-002	337	43097	251415	10154	8681	23715	337399
93SCAP-5002	15715	104656	109890	3159	3467	141127	378015
94SCAA-5088	4533	8219	1975	196	360	5972	21256
BLK	<30	<30	<50	<50	<50	<20	<230
TILL-2	2739	11994	4706	751	1870	13097	35157
LKSD-4	31712	49843	6237	533	270	11209	99805
94SCAA-5025R	36537	58761	4400	286	156	11252	111392
93SCAT-002R	383	55746	259384	13243	9832	17873	356462

Appendix VII: Concentration of metals in sequential extraction analyses

SAMPLE NUMBER	TOC
	SHIMADZU
	NH ₂ OH
	HCl
	2 HR
	(ppm)
DL	150
94SCAA-5025	29053
94SCAA-5058	21084
94SCAA-5065	2793
94SCAA-5086	938
94SCAA-5085	5144
94SCAA-5102	24678
94SCAA-5115	4280
94SCAA-5128	36762
94SCAF-5004	20679
94SCAF-5012	18990
93SCAT-002	861
93SCAP-5002	48656
94SCAA-5088	3338
BLK	< 150
TILL-2	8175
LKSD-4	19680
94SCAA-5025R	35777
93SCAT-002R	821
94SCAA-5128REP	36639

Appendix VIII: Till geochemistry in the study area for the <63µm fraction

SAMPLE NUMBER	ZONE	EASTING	NORTHING	OXIDATE	Ag ppb	Cd ppm	Co ppm	Cr ppm	Cu ppm	Fe %	Mn ppm	Mo ppm	Ni ppm	Pb ppm	Zn ppm	U ppm	Sn ppm	As ppm	W ppm
72UF0024	19	318180	5094850	oxidized	1.10	0.1	40	195	18	3.00	530	2	960	15	57	0.40		7	2
72UF0025	19	318120	5095550	oxidized	0.90	0.1	25	83	20	3.00	530	2	348	14	62	0.60	5	8	1
72UF0026	19	318120	5095560		0.80		30	83	22				410	13	60	0.60			
72UF0026A	19	318120	5095560													1.00			
72UF0026B	19	306610	5096220	unoxidized	0.90	0.1	22	28	46	3.00	635	2	42	20	85	0.60		12	1
72UF0027	19	306960	5095730	unoxidized	0.80		18	22	32				35	15	75				
72UF0028	19	306960	5095730	unoxidized	0.90		18	24	34				35	18	80	1.00			
72UF0028A	19	306960	5095730	unoxidized	0.90		20	26	36				38	16	82	0.20			
72UF0028B	19	306960	5095730	oxidized	0.70		22	24	45				36	20	90	0.40			
72UF0028C	19	306960	5095730	oxidized												1.50			
72UF0028D	19	310930	5093860	oxidized	0.80	0.1	30	40	34	3.10	695	2	215	22	70	0.40	7	21	1
72UF0029	19	311930	5093990	oxidized	0.90	0.1	28	36	38	2.90	680	2	100	25	80	0.40		17	1
72UF0030	19	313720	5092600	oxidized	0.80	0.1	26	53	36	2.60	900	2	190	19	70	0.60	2	6	1
72UF0031	19	313720	5092600	oxidized	0.80		30	59	34				205	18	70	0.40			
72UF0031A	19	311670	5090850	oxidized	0.70	0.1	36	57	45	3.40	500	2	275	18	63	0.60	2	30	1
72UF0032	19	314540	5092990	oxidized	0.70	0.1	28	59	30	3.40	660	2	260	19	75	1.00	5	15	2
72UF0033	19	314540	5092990	oxidized	0.80		30	70	45				340	23	73				
72UF0033A	19	317960	5092520	oxidized	1.10	0.1	36	100	36	3.70	1722	2	300	18	73	0.60	5	8	1
72UF0034	19	320640	5095400	oxidized	0.60	0.1	30	189	24	2.40	578	2	550	17	60	0.20	6	16	1
72UF0036	19	322200	5096840	oxidized	0.80	0.1	26	68	41	2.90	760	2	100	24	92	0.60	4	22	1
72UF0037	19	322540	5096410	unoxidized	0.70	0.1	33	92	16	2.10	505	2	520	11	42	0.20		7	1
72UF0067	19	329330	5094660	unoxidized	1.00	0.1	38	149	28	3.20	680	1	425	15	63	1.00	4	10	1
72UF0068	19	327370	5095280	oxidized	1.10	0.1	47	190	29	3.10	638	2	740	15	57	0.60	4	16	1
72UF0069	19	327230	5094520	oxidized	1.10	0.1	58	210	22	2.30	650	2	950	13	50	0.40		8	1
72UF0070	19	326710	5093640	oxidized	1.20	0.1	38	188	26	2.80	698	2	570	14	65	1.50	5	7	1
72UF0071	19	324350	5091750	oxidized	1.10		30	149	30				350	15	73				
72UF0072	19	323260	5090520	oxidized	0.90		29	96	22				330	10	70			11	1
72UF0073	19	322800	5089890	oxidized	1.00	0.1	32	118	30	3.50	590	2	345	14	73	0.90	6	11	1
72UF0074	19	321390	5089350	unoxidized	1.10	0.1	30	133	28	3.10	705	2	352	13	70	0.60	6	12	1
72UF0075	19	320150	5088640	oxidized	0.90	0.1	28	118	28	2.80	600	2	355	14	70	2.50	2	15	1
72UF0076	19	318250	5086300	oxidized	0.90	0.1	45	118	45	3.70	890	2	570	19	70	0.80	2	27	1
72UF0076A	19	318250	5086300	oxidized												1.00			
72UF0097	19	319830	5091240	oxidized	1.10	0.1	38	131	26	3.10	895	2	600	12	63	1.00	4	10	1
72UF0098	19	314980	5088730	unoxidized	1.00	0.1	24	46	28	2.80	940	3	132	14	73	0.60	6	9	1
72UF0099	19	314170	5087760	oxidized	1.00	0.1	28	55	38	2.90	555	2	194	15	75	0.40	6	15	1
72UF0100	19	310620	5087420	oxidized	1.00	0.1	26	42	36	3.20	770	2	128	17	80	0.40	1	19	1
72UF0101	19	307650	5088920	oxidized	0.90	0.1	22	24	32	2.90	1000	2	36	16	85	0.60	2	11	1
72UF0107	19	322660	5085900	oxidized	1.00	0.1	34	129	31	3.50	1666	2	340	15	72	0.60	4	16	1
72UF0108	19	323860	5085530	oxidized	1.00	0.1	29	87	38	3.30	698	2	245	16	75	0.40	1	29	1

Appendix VIII: Till geochemistry in the study area for the <63µm fraction

SAMPLE NUMBER	ZONE	EASTING	NORTHING	OXIDATE	Ag ppb (aa)	Cd ppm (aa)	Co ppm (aa)	Cr ppm (aa)	Cu ppm (aa)	Fe % (aa)	Mn ppm (aa)	Mo ppm (aa)	Ni ppm (aa)	Pb ppm (aa)	Zn ppm (aa)	U ppm (Fl)	Sn ppm (arf)	As ppm (cel)	W ppm (cel)
721F0109	19	325400	5085300	oxidized	1.10	0.1	30	89	32	3.10	658	2	230	20	75	0.20	6	22	1
721F0110	19	327030	5084890	oxidized	1.00	0.1	32	85	36	3.20	658	2	220	23	80	0.60	3	17	1
721F0111	19	330800	5082920	oxidized	0.90	0.1	29	72	38	3.50	630	2	195	17	75	1.00	3	20	1
721F0112	19	331770	5081360	oxidized	1.10	0.1	20	89	24	3.00	500	1	86	13	60		5	14	1
721F0113	19	333340	5079810	oxidized	1.30	0.1	28	74	34	4.50	790	2	167	17	80	1.00	3	11	1
721F0114	19	334620	5077680	oxidized	1.10	0.1	26	70	33	3.50	680	2	195	16	70	2.00	2	16	1
721F0115	19	335520	5076300	oxidized	1.50	0.1	24	68	30	3.70	745	2	163	16	67	0.60		11	1
721F0116	19	336100	5075120	oxidized	0.80	0.1	21	44	22	2.80	625	1	110	11	55	1.00		10	1
721F0117	19	336900	5076170	oxidized	1.00	0.1	24	57	28	3.40	630	2	114	17	80	1.50	5	8	1
721F0118	19	335200	5082160	oxidized	1.10	0.1	30	87	35	4.10	745	2	260	22	80	1.50		21	1
721F0118A	19	335170	5082220	oxidized	1.00		28	79	30				200	15	75	0.40			
721F0119	19	333750	5086800	oxidized	1.00	0.1	30	96	32	4.50	680	2	245	19	77	0.80	4	18	1
721F0120	19	334520	5083190	oxidized	1.00	0.1	32	74	38	3.70	590	2	242	22	83	1.00	4	19	1
721F0121	19	337650	5083830	oxidized	1.10	0.1	32	96	36	3.40	545	2	260	20	77	1.50	1	14	1
721F0122	19	338690	5082870	oxidized	1.10	0.1	32	94	36	3.50	1111	2	250	20	75	1.00	6	20	1
721F0123	19	343460	5070450	oxidized	0.90	0.1	20	27	20	2.70	462	2	54	14	53	0.60	7	13	1
721F0207	19	344850	5093340	oxidized	0.70	0.1	32	110	43	4.00	1444	2	270	24	88	0.50	2	16	1
721F0208	19	344320	5093310	oxidized	0.60	0.1	16	75	35	3.40	420	3	82	18	82	1.40	3	14	1
721F0209	19	343750	5093820	oxidized	0.70	0.1	24	79	63	3.90	530	2	160	26	94	1.60	5	20	1
721F0218	19	344610	5095780	oxidized	0.70	0.1	29	82	53	3.20	385	1	150	24	86	1.10		17	1
721F0219	19	342060	5085980	oxidized	0.80	0.1	28	146	37	3.60	505	2	375	20	82	1.70		19	1
721F0220	19	340910	5086860	oxidized	0.70		24	187	37				485	18	84				
721F0221	19	340230	5087410	oxidized	0.50	0.1	20	102	12	2.30	378	2	135	14	73	1.40	1	6	1
721F0222	19	339890	5087620	oxidized	0.60	0.3	18	115	5	2.00	165		118	14	61	1.40	1	3	1
721F0223	19	339260	5088120	oxidized	0.70	0.1	31	154	31	3.60	558	2	430	19	70	1.20		12	1
721F0224	19	338000	5089060	oxidized	0.70	0.1	26	116	33	3.10	425	2	239	20	75	1.60	1	4	1
721F0224A	19	338000	5089060	oxidized	0.60		25	112	33				239	20	70				
721F0225	19	337750	5089240	oxidized	0.70	0.1	23	105	36	3.90	548	2	225	21	82	0.70	3	19	1
721F0226	19	337610	5089120	oxidized	0.80	0.1	25	122	44	3.60	472	1	290	22	81	0.70	5	19	1
721F0229	19	337240	5095700	oxidized	0.80	0.1	34	206	33	3.50	662	2	530	18	68	0.70	1	20	1
721F0230	19	337250	5095380	oxidized	0.70	0.1	22	121	31	3.20	630	2	215	14	68	1.00		18	1
721F0231	19	337300	5094080	oxidized	0.80	0.1	40	215	33	3.50	850	1	580	17	69	0.70		14	1
721F0232	19	334620	5094380	oxidized	0.80	0.1	38	218	31	3.90	910	2	585	16	68	1.00	1	16	1
721F0233	19	335320	5093250	oxidized	0.70	0.1	28	232	32	3.60	490	2	580	12	69	1.50	4	9	1
721F0233A	19	335330	5093250	oxidized	0.50	0.1	16	133	12	3.40	320	2	195	16	54	1.60	5	3	1
721F0234	19	333370	5092240	oxidized	0.70	0.1	40	222	27	2.90	528	2	600	14	65	1.60	1	15	1
721F0234A	19	332880	5093370	oxidized	0.80		40	238	31				880	15	65				
721F0236	19	331320	5092380	oxidized	0.90	0.1	30	189	24	3.00	560	1	550	17	60	0.70		8	1
721F0243	19	339850	5093370	oxidized	0.60	0.2	20	40	39	3.80	450	2	125	18	78	0.70	2	20	1

Appendix VIII: Till geochemistry in the study area for the <63µm fraction

SAMPLE NUMBER	ZONE	EASTING	NORTHING	OXIDATE	Ag ppb (aa)	Cd ppm (aa)	Co ppm (aa)	Cr ppm (aa)	Cu ppm (aa)	Fe % (aa)	Mn ppm (aa)	Mo ppm (aa)	Ni ppm (aa)	Pb ppm (aa)	Zn ppm (aa)	U ppm (Fl) (xrf)	Sn ppm (xrf)	As ppm (col)	W ppm (col)
72UF0254	19	340350	5086010	oxidized	0.60	0.2	18	60	33	3.40	665	2	160	18	70	1.00	5	22	1
72UF0255	19	341170	5079400	oxidized	0.80	0.1	25	70	33	3.60	688	2	210	20	80	0.70	3	12	1
72UF0271	19	338140	5071400	oxidized	0.60	0.1	20	62	31	3.20	512	2	136	18	78	1.00		16	1
72UF0272	19	339240	5070490	oxidized	0.50	0.1	21	47	28	3.10	270	1	127	17	70	1.00		27	1
72UF0273	19	341770	5068260	oxidized	0.50	0.1	16	51	20	3.20	592	2	90	14	58	1.70		16	1
72UF0276	19	343630	5068110	oxidized	0.60	0.1	19	57	29	3.40	575	2	120	17	80	0.80		12	1
72UF0282	19	341070	5075890	oxidized	0.90	0.1	22	62	30	3.60	960	2	150	18	72	0.80		23	1
72UF0283	19	338320	5077890	oxidized	0.70	0.1	21	54	30	3.20	530	1	190	17	70	1.00	4	19	1
72UF0284	19	342070	5078680	oxidized	0.80	0.1	20	80	31				160	19	70				
72UF0285	19	343970	5077230	oxidized	0.80	0.1	25	62	34	3.60	760	2	190	22	80	1.00		18	1
72UF0400	19	326080	5069120	oxidized	0.50	0.2	17	39	31	2.70	840	2	115	16	73	0.70	2	12	1
72UF0401	19	324300	5070510	oxidized	0.40	0.1	15	32	22	2.20	480	2	90	12	54	0.70		9	1
72UF0402	19	323340	5071330	oxidized	0.80	0.3	28	60	51	3.50	1030	2	185	19	95	1.00		19	1
72UF0403	19	321420	5073080	oxidized	0.60	0.2	19	58	53	3.40	455	2	180	17	83	1.10		25	1
72UF0404	19	320470	5073740	oxidized	1.00	0.1	23	50	32	4.50	1837	2	165	16	82	1.00		17	1
72UF0405	19	319580	5074620	oxidized	0.60	0.1	22	51	37	3.50	700	2	195	17	81	1.00		17	1
72UF0406	19	319420	5075160	oxidized	0.80	0.1	24	59	33	3.50	800	2	178	16	78	0.50	2	12	1
72UF0407	19	319120	5077850	oxidized	0.50	0.2	22	57	32	3.00	452	2	165	17	70	2.60		11	1
72UF0408	19	318570	5079940	oxidized	0.80	0.2	28	70	33	4.10	555	2	218	18	96	1.40		11	1
72UF0409	19	318200	5081450	oxidized	0.50	0.1	29	56	32	3.50	392	1	188	17	86	1.10	2	16	1
72UF0410	19	306060	5081080	oxidized	0.70	0.1	26	50	39	3.50	682	2	240	19	92	0.70	3	17	1
72UF0411	19	307120	5080590	oxidized	0.70	0.2	20	24	45	3.40	800	2	50	18	97	0.50	2	18	1
72UF0412	19	309740	5079080	oxidized	0.80	0.2	29	106	67	3.50	610	1	275	21	110	1.40	1	22	1
72UF0413	19	312220	5078060	oxidized	0.70	0.1	22	55	44	3.40	800	2	188	18	93	1.20		20	2
72UF0414	19	319150	5082850	oxidized	0.60	0.1	24	61	31	3.30	620	2	228	16	76	1.00		21	1
72UF0415	19	319270	5082740	oxidized	0.50	0.1	27	67	32	3.00	352	2	240	17	76	0.80	2	5	1
72UF0416	19	320570	5081250	oxidized	0.50	0.3	22	138	59	2.50	235	2	325	22	72	2.20	5	6	1
72UF0417	19	323060	5079240	oxidized	0.80	0.1	20	63	27	3.10	740	2	175	14	70	0.70		15	1
72UF0418	19	323880	5078610	oxidized	0.60	0.1	20	65	37	3.40	725	2	200	16	76	1.20	1	23	1
72UF0419	19	325790	5079220	oxidized	0.60	0.2	24	70	23	2.90	590	1	154	14	66	0.60		9	1
72UF0429	19	317900	5096000	oxidized	0.70	0.1	40	98	20	3.50	550	1	800	16	55	0.70	1	11	1
72UF0430	19	309740	5094880	oxidized	0.60	0.1	31	78	32	3.40	440	2	370	19	67	0.80		15	1
72UF0430A	19	309830	5094870	oxidized	0.90		31		38				216	20	86				
72UF0431	19	321540	5095890	oxidized	1.00	0.1	42		24	3.60	970	2	880	15	67	0.80	3	5	1
72UF0432	19	322560	5095750	oxidized	1.20	0.1	74	178	28	3.70	780	1	1600	18	56	0.30		11	1
72UF0433	19	323410	5094630	oxidized	0.70	0.1	25	180	38	4.10	332	1	520	17	72	1.20	3	9	1
72UF0434	19	324480	5094280	oxidized	0.60	0.2	31		30	3.70	318	2	342	17	67	0.80	2	10	1
72UF0435	19	324890	5094550	oxidized	0.60	0.1	40		29	4.10	422	1	800	20	54	1.20		20	1
72UF0436	19	324500	5095180	unoxidized	1.00	0.1	55		30	3.60	742	2	860	16	66	0.70		6	1

Appendix VIII: Till geochemistry in the study area for the <63µm fraction

SAMPLE NUMBER	ZONE	EASTING	NORTHING	OXIDATE	Ag ppb (aa)	Cd ppm (aa)	Co ppm (aa)	Cr ppm (aa)	Cu ppm (aa)	Fe % (aa)	Mn ppm (aa)	Mo ppm (aa)	Ni ppm (aa)	Pb ppm (aa)	Zn ppm (aa)	U ppm (fl)	Sn ppm (surf)	As ppm (col)	W ppm (col)
72UF0437	19	324170	509420	oxidized	1.00	0.2	34		28	3.60	700	2	400	16	80	0.60	1	11	1
72UF0438	19	322120	5096070	oxidized	0.60	0.1	47		26	3.60	790	2	900	17	61	0.60		9	1
72UF0441	19	318340	5092220	oxidized	1.00	0.1	34	86	24	4.00	725	1	580	15	87	0.80	1	7	1
72UF0442	19	319010	5091760	oxidized	0.60	0.1	32	123	34	3.90	700	2	570	19	67	0.60		17	1
72UF0443	19	320280	5090700	oxidized	0.60	0.1	28	78	39	3.60	710	1	300	20	75	0.80	3	21	1
72UF0444	19	321190	5090830	oxidized	0.60	0.1	28	91	20	3.40	620	2	400	15	60	0.70		8	1
72UF0444	19	321330	5091110	oxidized	1.10		39		36				500	20	85				
72UF0445	19	321670	5091480	oxidized	1.00	0.1	25	143	31	3.90	560	2	430	15	67	1.00	6	9	1
72UF0446	19	323840	5091160	oxidized	1.00	0.1	33		30	3.40	795	1	330	16	80	0.90	2	9	1
72UF0447	19	325300	5093200	oxidized	1.00	0.1	35	165	24	3.90	560	2	700	16	59	1.00		14	1
72UF0448	19	324760	5092220	unoxidized	1.10	0.1	60		34	3.30	740	2	1100	15	59	0.80	3	7	1
72UF0449	19	322490	5086740	oxidized	0.80	0.1	36	132	35	3.70	1000	2	420	20	68	0.80		17	2
72UF0450	19	322820	5087040	oxidized	0.80	0.1	36		36	3.80	930	1	370	20	79	0.80	6	16	1
72UF0451	19	323500	5087860	oxidized	1.10	0.2	36	98	49	4.10	870	1	350	26	89	0.80	3	24	1
72UF0452	19	324040	5088520	oxidized	1.00	0.2	28		39	3.70	612	2	370	16	80	0.80	3	15	1
72UF0453																			
72UF0455	19	328910	5090930	oxidized	0.60	0.1	32		36	3.70	800	2	460	20	72	0.90		16	1
72UF0456	19	328290	5090300	oxidized	0.70	0.1	36		39	3.90	810	2	330	20	76	0.60	8	15	1

Plate 1 Nodular shaped concretions collected at sample site 94SCAA-S004

Plate 2 Nodular shaped concretion collected at sample site 94SCAA-S100

Plate 3 Water sample collected from the pipe draining the Cupra restored mine site

END

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