MOBILIZATION OF GOLD INTO LAKE SEDIMENTS

by

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B.Sc.(Honours), The University of British Columbia, 1977
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We accept this thesis as conforming

to the required standard

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Dr. W.W. Shilts

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Dr. André Desrochers, President of the Jury

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AUGUST 1993

To properly prospect for gold deposits one must have a knowledge of the geochemistry of the primary and secondary processes of concentration of the precious metal.

- A.E. Fersman, 1939

ABSTRACT

Geochemical exploration methods are able to contribute significantly to the detection of concealed Au mineralization in glaciated terrains. Gold analyses of lake sediments from the glaciated Canadian Shield have been used since the mid-1980s to explore for Au mineralization. For lake sediments to be an effective indicator of Au mineralization, the element must migrate in solution or adsorbed on suspensates in the boreal forest zone where low relief and disorganized drainage restricts dispersal and concentration in clastic form. Organic-rich profundal lake sediments often contain anomalous Au contents near Au mineralization, suggesting that Au is entering the lake environment in mobile form. Confirmation of the processes by which Au is mobilized into lake sediments could thus contribute to improved exploration methodologies. This study investigated the nature of Au mobility and dispersion into lake sediments under alkaline and acid hydrological conditions in the southern Canadian Shield. The study makes recommendations for exploration strategies to be employed under these conditions.

Three field areas were selected for detailed study from National Geochemical Reconnaissance lake sediment geochemical data and related orientation studies. Areas were selected based on: similarities in bedrock and surficial geology; gold concentration in lake sediment; and contrasting hydrogeochemical environments. Mineralization, till, humus, vegetation, stream sediments, lake sediments, surface waters and groundwaters were collected from Napier Lake, Ontario; PAP Lake, Saskatchewan; and Foster Lake, Manitoba. All areas contain shear zone-hosted Au mineralization. The areas were glaciated during the Wisconsinan and now support vigorous forests. Unconsolidated glacigenic deposits and post-glacial wetlands are common features. All surficial media

analyzed contain anomalous Au contents dispersed from nearby Au in bedrock. Gold mineralization up to 40 ppm is accompanied by local enrichment in As, B, Ag, Cu, Sb, Pb, W, Zn, and S, which are useful as pathfinder elements in exploration. Gold mineralization is accompanied by increased silicification and consistent patterns of enrichment and depletion in some major elements.

The study confirms that Au is being mobilized from bedrock to lake sediments in both acidic and alkaline hydrologic environments. Gold is principally dispersed from bedrock by supergene oxidation and dissolution of Au and Au-bearing sulphides; by glacial erosion and dispersal; and by biological means. Gold thus released is transported to the lake environment by glacial and post-glacial mechanical dispersal; by surface and groundwaters; and by physical dispersal of vegetation. Gold is transported as dissolved Au-complexes; as Au adsorbed on suspensates; as Au complexed in plant material; and as clastic (free or occluded) Au. The complexity of Au dispersal phenomena thus provides significant opportunity for the application of geochemical methods to Au exploration.

Significant dissolution and transport of Au was confirmed for oxidizing conditions ranging from acid to alkaline. Surface waters, including bogs, seeps, ponds and streams proximal to mineralization, contain from 1.5 to 13.3 ng Au L^{-1}. This includes a wide range of pH (5.1 to 8.3) and dissolved inorganic constituents. Groundwaters sampled from 70 m depth in drill holes penetrating mineralization at PAP Lake, contain up to 400 ng L^{-1} Au with pH of 7.8 and 23 ppm SO_4. Lake water Au contents are a maximum of 1.1 ng L^{-1}. There is a detectable quantity of Au present in suspensates > 1 m filtered from lake waters. Lake water suspensates from Reservoir and PAP Lakes contained Au contents equivalent to 0.17 and 0.039 ng L^{-1}. While the quantity of Au in solution or as suspensates is small, it is sufficient to generate anomalies in lake sediments. At Reservoir Lake, the principal inflowing stream contains 0.3 ng L^{-1} Au. The annual flux, calculated at 4.7 g Au in solution

significantly exceeds that required to generate the mean 7.3 ppb Au present in Reservoir Lake's profundal sediments compared to a regional median Au content in lake sediments of < 1 ppb. Anomalous concentrations of Au occur in lake sediments because the ambient conditions favour stable Au-complexes and are in equilibrium with native Au, and/or because the rate of Au influx exceeds downstream dispersal.

In very low energy, organic-rich environments of the Shield, clastic input is negligible and the accumulation of Au depends largely on the migration of dissolved gold and its precipitation. Under acidic conditions near mineralized environments with abundant S and humic substances, organic substances are important for the migration of Au. In comparison, under alkaline conditions with lower concentrations of aqueous transported organic species, the importance of Au-organic species diminishes, and Au-OH or other Au-inorganic species may predominate. Gold accumulation in lake sediments is therefore likely to be less pronounced.

To successfully detect bedrock Au mineralization based on follow-up of Au anomalies in lake sediments requires an integrated geochemical approach. The exploration strategy should be cognizant of catchment basin geology, hydrology, limnology, vegetation, glaciation history and deposits, superimposed post-glacial supergene weathering processes, and Au solution chemistry. A two-stage strategy is recommended. The objective of the first stage would be a review of regional survey (1 site per 5 to 13 km^2) data to select specific Au anomalies for verification by geochemical field orientation studies. Once verified, the second objective would be to trace the anomaly to its source by employing an integrated geochemical sampling and analytical strategy. In the Shield, hydrogeochemical sampling for Au can be an effective and cost-efficient sampling method which is easily complemented by detailed hydrological and water chemistry data. Gold can be accurately determined

in untreated field waters to 0.5 ng L^{-1} which is sufficiently sensitive to detect sub-economic bedrock Au at considerable distances upstream.

The National Geochemical Reconnaissance database presently contains over 40,000 lake sediment analyses for Au representing over 500,000 km^2 of the Canadian Shield. The database contains information on the regional distribution of Au, and lists many Au anomalies that possibly indicate undiscovered Au mineralization.

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International Geochemical Exploration Symposium (1991) in Reno. Various individuals are thanked for their constructive reviews of the individual manuscripts as acknowledged herein.

Finally, it is with considerable pleasure that I wish to dedicate this thesis to my family; Ruth, Annemarie, Erich, Pamela and Kaelyn, whose sacrifice of time has allowed me to pursue a greater understanding of our noblest metal.

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1.0 CHAPTER ONE: INTRODUCTION

The geochemical analyses of centre lake-bottom sediments for base metal, Au, U, and REE exploration in the Canadian Precambrian Shield provides a cost-effective mineral resource evaluation technique for large areas of glaciated terrain of characteristic low relief and limited bedrock exposure. Centre lake-bottom sediments represent a consistent sample medium with a largely predictable geochemical response for base metals and U to geological and environmental conditions (Coker et al., 1979; Timperley and Allan, 1974; Coker and Nichol, 1975; and Cameron, 1977). To date the most effective application of lake sediment geochemistry has been for elements such as U, which are readily mobilized by hydromorphic or adsorption processes (Cameron, 1980; Coker and Dunn, 1983; Maurice, 1985).

Lake sediment geochemistry has been applied to Au exploration in the Canadian Shield and Appalachian Fold Belt since the mid-1980s. Preliminary studies by Coker et al.(1982) described dispersal of Au from bedrock into nearby lake sediments in the LaRonge belt of Saskatchewan and recommended appropriate exploration strategies. With the subsequent development of commercially available, low-cost, sensitive analytical methods, Au analyses were incorporated routinely into National Geochemical Reconnaissance (NGR) surveys. In 1984, Au analyses of over 3500 lake sediments from 51,000 km^2 of Saskatchewan (Geological Survey of Canada, 1985) confirmed regional belts of Au mineralization, and identified many new exploration targets (Schmitt and Friske, 1987). To date nearly 40,000 lake sediment samples representing over 500,000 km^2 of shield terrain have been analyzed during the NGR program, and thousands of analyses have been performed by provincial and industry surveys in Canada (Friske and Hornbrook, 1991).

The interpretation and follow-up of Au in lake sediments has resulted in new mineral discoveries (V. Sopuck of CAMECO, pers. comm., 1988) and broadened

prospective areas (Davenport and Nolan, 1989; Rogers et al., 1987; Rogers, 1988; Schmitt and Friske, 1987; and Wright et al.,1988). Situations have also been identified where no mineralization has been found that can be related to Au anomalies in lake sediments (Schmitt and Friske, 1987); where significant Au mineralization is not appreciably reflected in nearby lake sediments (Friske, pers comm. 1986); and where detailed re-sampling of an anomalous area has been unable to repeat initial survey results (Thomas, 1986). Collectively, these experiences indicated the need for detailed study of Au dispersion phenomena into lake sediments in a variety of geological and surficial environments.

Geochemical studies of syngenetic and epigenetic Au dispersion patterns, with direct application to Au exploration, have been carried out for many years. The studies have employed different media, such as: till (DiLabio, 1988; Sopuck et al., 1986); humus (Curtin and King, 1986); vegetation (Baker, 1986; Brooks,1982; and Dunn, 1986a and 1986b); lake sediments (Coker et al., 1982; Davenport and Nolan, 1989; and Dunn et al, 1991); and water (Boyle, 1975; Brooks et al., 1981; Gosling et al., 1971; Hamilton et al., 1983; Hall et al., 1986; McHugh, 1988; Benedetti and Boulege, 1991; and Cook et al., 1992). The studies provide practical evidence for Au mobilization under common supergene environmental conditions.

Recently, the prediction of stable Au-inorganic and Au-organic complexes in natural surface and groundwaters at ambient conditions has benefitted from advanced thermodynamic modelling (Webster, 1986; Renders and Seward, 1989; Vlassopoulos and Wood, 1990; Vlassoupoulos et al., 1990; Benedetti and Boulegue, 1991). Together with related field studies of Pitul'ko (1976), Taisaev and Plyusnin, 1984, Webster and Mann (1984), Stoffregen (1986), Plyusnin (1987), Clough and Craw, (1989), Groen et al.,(1990), Benedetti and Boulegue (1991), and Cook et al., (1992), natural Au complexation phenomena are now better understood. Gold forms complexes in natural waters with the following ligands: HS^- in sulphur-bearing acid or alkaline reducing

environments; $S_2O_3^{2-}$ in sulphur-bearing alkaline oxidizing environments; OH^- in acid to alkaline oxidizing environments; Cl^- in acidic, oxidizing saline waters, and; S,O, and N-donor fulvic and humic acids in acid to weakly alkaline, organic-rich environments. The significance of other ligands, such as CN^- (Lakin et al.,1974; Vlassopoulos et al., 1990), and NH_3^- (Groen et al., 1990) awaits further experimental data.

For most freshwater compositions, Vlassopolous and Wood (1990) and Vlassopolous et al., (1990) suggest that the solubility of Au as $AuOH(H_2O)^0$ and Au-organic species is well above that detected in natural waters. This indicates that the Au content of natural waters reflects a balance between Au availability, the processes that cause its precipitation, and competition for binding sites with other cations. $AuOH(H_2O)^0$ may be the dominant species in waters where the S activity is low, however $Au(HS)^{2-}$, $Au(HS)^0$, $Au_2S_2^{2-}$, and Au-organic species may dominate in S-bearing, and organic-rich waters.

There is a well recognized need for enhanced integration of Au thermodynamic results with field-oriented documentation of syngenetic and epigenetic Au dispersion to improve Au exploration technology.

This study was undertaken to improve the understanding of mobilization of Au from bedrock into lake sediments. This study has focussed mainly on the documentation of dispersion pathways of Au, rather than on experiments to determine optimum sampling fractions such as an orientation survey would entail.

1.1 OBJECTIVES:

The objectives of the study were:

a.) to determine Au concentrations in bedrock, surficial materials, vegetation and water adjacent to Au mineralization and lakes with elevated Au in lake sediments,

b.) to sample areas with predominantly acid and predominantly alkaline surface and groundwaters, and

c.) to recommend strategies to improve gold exploration success during follow-up of

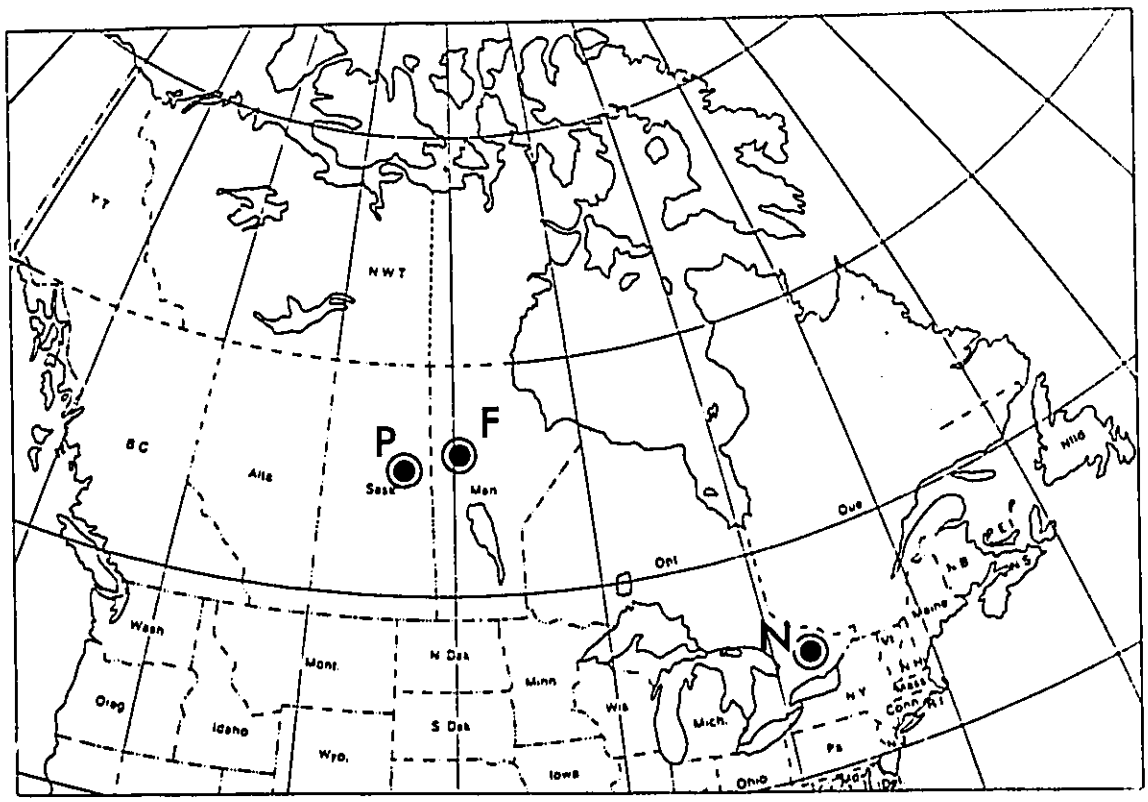
Au anomalies in lake sediments.

Field studies were conducted in three areas: Foster Lake, Manitoba; PAP Lake, Saskatchewan; and Napier Lake, Ontario during summer and early autumn in 1986 - 1988. All areas lie within the boreal forest zone of the glaciated Canadian Precambrian Shield (Figure 1) and contain similar styles of Au-quartz vein mineralization in metamorphosed Proterozoic supracrustal sequences. The areas are mantled by mixed glacial and post-glacial surficial deposits which are drained by contrasting hydrogeochemical environments. The Foster and Pap Lake areas have predominantly neutral to acidic surface waters, with alkaline groundwaters, and black spruce forests developed on immature brown podzols, grey luvisols and peat. The Napier Lake area has predominantly alkaline surface waters, and mixed deciduous forests of elm, maple and basswood developed on brown podzols. Previous geochemical studies in all areas delineated anomalous Au in lake-bottom sediments, suggesting secondary dispersion from nearby Au mineralization (Coker, 1982; Fox et al., 1985; Kharouba, 1987; Geological Survey of Canada, 1986,1989; Schmitt, 1989; and Schmitt et al., in press). Mineral exploration disturbance was negligible to slight prior to field studies, making geochemical contamination unlikely. Table 1 summarizes the main environmental characteristics of each study area.

Similar media types were collected from each study area where possible. These were analysed for a large number of elements as summarized in the Appendices.

1.2 PRESENTATION FORMAT:

The results of this study are reported in three inter-related papers combined in this thesis. For presentation purposes in this thesis, common aspects of the three published papers have been consolidated to minimize repetition. Thus, Chapter 2 describes the three study areas in detail, Chapter 6 contains a summary of key conclusions as well as recommendations for further research and exploration strategies, and Chapter 7 consolidates the references for the study. To preserve the identity of



. Location of study areas; N= Napier Lake, Ontario; P = PAP Lake, Saskatchewan; F= Foster Lake, Manitoba.

individual papers, some iteration of material occurs, for example parts of the orientation work reported in Chapter 3 is reiterated in the completion of this work in Chapter 4. The Chapters also contain additional graphics as appropriate, which are edited from the published papers for brevity.

Paper 1 was published in Geological Survey of Canada, Current Research Paper 1989-1. It summarizes the preliminary results of field investigations in the Foster Lake area of northern Manitoba. The purpose of the study was to confirm anomalous Au concentrations in lake sediments and to determine whether adjacent Au dispersion in surficial media were suitable for more detailed study. The results of these investigations laid the groundwork for more detailed studies at Foster Lake and the other sites reported in the following papers.

Paper 2, being submitted to the Journal of Geochemical Exploration as Part A of the study, outlines the scope of the research problem as well as describes the three study areas in detail (amalgamated with description from Paper 3 in Chapter 3), and presents data on dispersal of Au from mineralization into surficial materials. Bedrock and surficial sources of Au for subsequent dispersion into lake environments are confirmed.

Paper 3, submitted for review to the Journal of Geochemical Exploration in January 1993, and as Part B of the study the concluding paper, reports on the concentration of Au in lake and stream sediments and on hydrogeochemical data, which comprise a major component of the overall study. Documentation and interpretation of Au concentrations in surface and groundwaters contributes important insights into the mechanisms for Au mobilization into centre lake-bottom sediments. It concludes with interpretations on the mechanisms controlling Au mobilization into lake sediments.

The final chapter of the thesis summarizes key conclusions from the 3 papers in the form of a model for Au dispersion into lake sediments, recommends important

areas of further research, and recommends exploration strategies which could be used by the mineral industry to follow-up Au lake sediment data to find Au mineralization.

Appendices contain complete sample listings, chemical data, photographic plates of field areas, and sample location maps.

2.0 CHAPTER TWO: DESCRIPTION OF STUDY AREAS

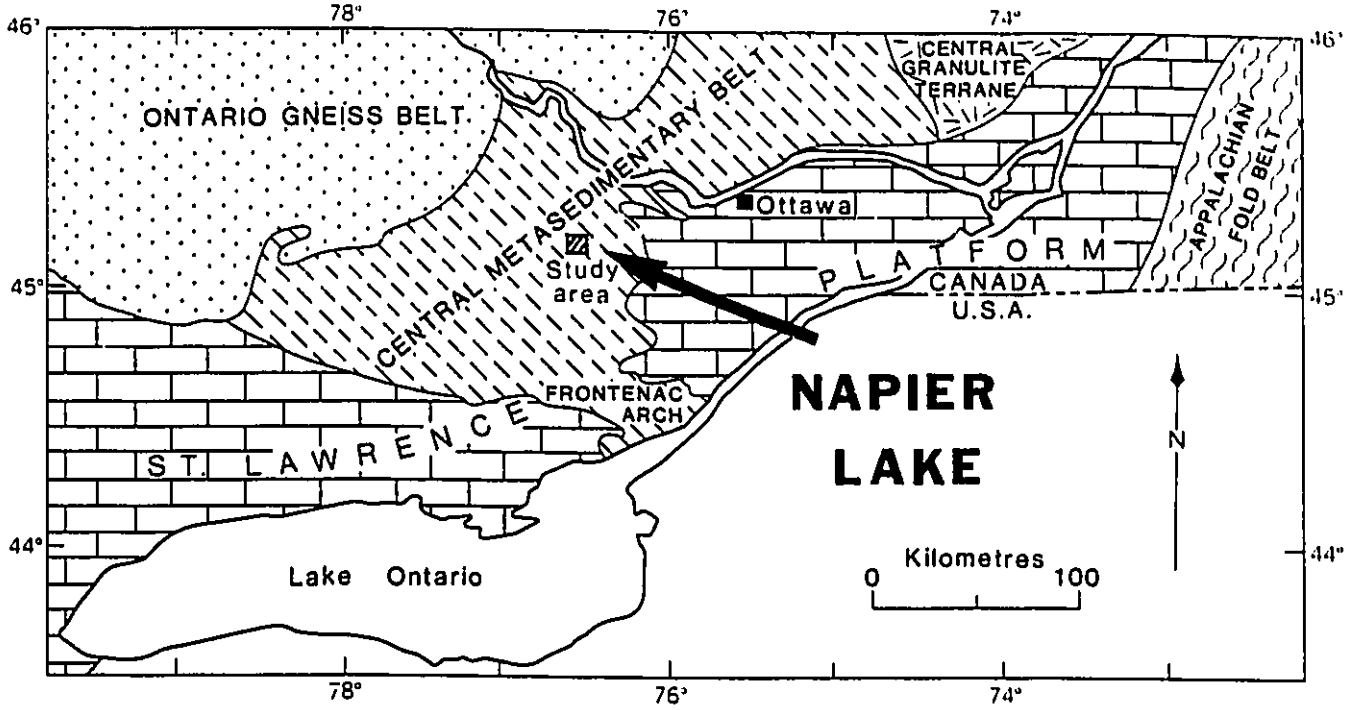
The purpose of this chapter is to describe the geological and biophysical aspects of the three field areas studied in detail. The material presented in this chapter has been consolidated from papers 2 and 3 described in Chapter 4 and 5.

Field studies were conducted in three areas: Napier Lake, Ontario; PAP Lake, Saskatchewan; and Foster Lake, Manitoba. All areas lie within the boreal forest zone of the glaciated Canadian Precambrian Shield (Figs. 1 and 2) and contain similar styles of Au-quartz vein mineralization in metamorphosed Proterozoic supracrustal sequences. The areas are mantled by mixed glacial and post-glacial surficial deposits which are drained by contrasting hydrogeochemical environments. The Foster and Pap Lake areas have predominantly neutral to acidic surface waters, with alkaline groundwaters. Black spruce forests have developed on immature brown podzols, grey luvisols and peat. The Napier Lake area has predominantly alkaline surface waters, and mixed deciduous forests of elm, maple and basswood developed on brown podzols. Previous geochemical studies in all areas delineated anomalous Au in lake-bottom sediments, suggesting secondary dispersion from nearby Au mineralization (Coker, 1982; Fox et al., 1985; Kharouba, 1987; Geological Survey of Canada, 1986,1989; Schmitt, 1989; and Schmitt et al., in press). Prior to field studies, mineral exploration disturbance was negligible to slight, making contamination of the environment unlikely.

2.1 NAPIER LAKE AREA

2.1.1 Location and Access: Napier Lake study area is located about 80 km southwest of Ottawa in NTS Map Sheet 31F/2 (Fig.1). Access is by paved highway and good secondary and private unpaved logging roads.

2.1.2 Geology and Mineralization: Napier Lake is located at the northwest end of the



PALEOZOIC

ST. LAWRENCE PLATFORM; sedimentary rocks, carbonates

LOWER PALEOZOIC - PROTEROZOIC

APPALACHIAN FOLD BELT; complex terrane containing volcanics and derived sediments, deformed crystallines, carbonates, quartzite, ophiolite complexes

PROTEROZOIC

CENTRAL METASEDIMENTARY BELT; marble, quartzite, aluminous gneiss and metavolcanics

CENTRAL GRANULITE TERRANE; leucocratic to melanocratic para- and ortho-gneisses, anorthosite

ARCHEAN

ONTARIO GNEISS BELT; predominantly quartzo-feldspathic, pink or grey, layered, amphibolite grade gneiss

GSC

Figure 1

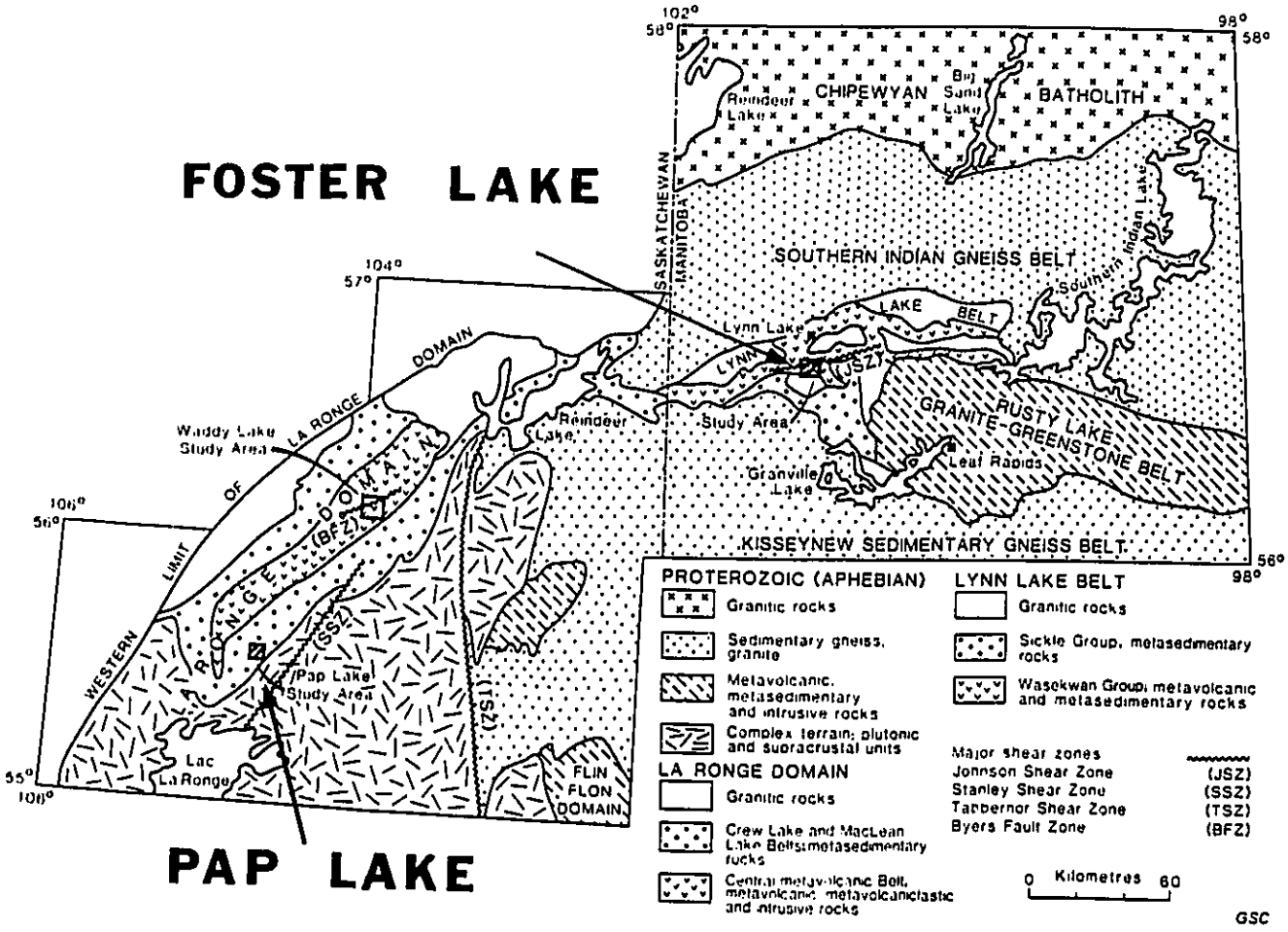

FOSTER LAKE
PAP LAKE
102°
98°
58°
104°
57°
106°
56°
55°
108°
CHIPEWYAN BATHOLITH
Reindeer Lake
Sand Lake
SASKATCHEWAN
MANITOBA
SOUTHERN INDIAN GNEISS BELT
Southern Indian Lake
LAKE BELT
Lynn Lake
LYNN
(JSZ)
Waddy Lake Study Area
LA RONGE DOMAIN
Reindeer Lake
Study Area
RUSTY LAKE GRANITE-GREENSTONE BELT
Leaf Rapids
Granville Lake
KISSEYNEW SEDIMENTARY GNEISS BELT
LIMIT OF WESTERN LA RONGE DOMAIN
(BFZ)
(SSZ)
(TSZ)
Pap Lake Study Area
Lac La Ronge
FLIN FLON DOMAIN
PROTEROZOIC (APHEBIAN)
Granitic rocks
Sedimentary gneiss, granite
Metavolcanic, metasedimentary and intrusive rocks
Complex terrain; plutonic and supracrustal units
LA RONGE DOMAIN
Granitic rocks
Crew Lake and MacLean Lake Belts; metasedimentary rocks
Central metavolcanic Belt, metavolcanic, metavolcaniclastic and intrusive rocks
LYNN LAKE BELT
Granitic rocks
Sickle Group, metasedimentary rocks
Wasekwan Group; metavolcanic and metasedimentary rocks
Major shear zones
Johnson Shear Zone (JSZ)
Stanley Shear Zone (SSZ)
Tabernor Shear Zone (TSZ)
Byers Fault Zone (BFZ)
0 Kilometres 60
GSC

Figure 2

Frontenac Arch in the Central Metasedimentary Belt of the Proterozoic Grenville Group. Bedrock comprises mafic metavolcanics, gabbro intrusions, and a variety of calcareous or quartzose metasedimentary rocks intruded by minor leucogranites (Fig. 3; Gleeson et al., 1984). The supracrustals are flanked to the west by the Addington gneiss complex, and to the east by a basic intrusive complex. Rocks are complexly deformed and metamorphosed to lower amphibolite facies and exhibit a prominent northeast fabric.

The Robertson shear zone (RSZ, Smith and Peach, 1958) parallels the northeast striking gabbro-supracrustal contact zone and is a major control on regional physiography and mineralization. Exploration has occurred in hydrothermally altered segments of the RSZ for Cu and Zn, and Au associated with carbonatized mafic metavolcanics intercalated with siliceous and dolomitic metasediments (Gleeson et al., 1984). Mineralization occurs as blebs, disseminations and fracture-fillings of pyrite, pyrrhotite, chalcopyrite, tetrahedrite, and less commonly arsenopyrite, sphalerite, and native gold. Mineralization forms stratabound layers or lenses or occurs in discordant quartz-ankerite veins in dolomitic marble, sheared metavolcanic and rusty-weathering siliceous metasediments. Au mineralization is accompanied by quartz and carbonate veining, sericite and tourmaline. Carter and Colvine (1979) have described similar deposits for the Grenville Province of southeastern Ontario.

2.1.3 Physiography, Glacial History and Soils: The area is characterized by steep to hilly terrain on the south margin of the Ottawa-Bonnechere graben with local relief up to 95 m. During the Wisconsinan, southerly ice-flow and ensuing deglaciation deposited subglacial kames, eskers, and terraces and stratified ice-contact deposits along Napier Lake and Green Lake valley slopes and bottoms. Ridges are mantled by a veneer of sandy to stoney calcareous ablation till recording southeasterly ice flow (Gleeson et al., 1984).

Brown podzols have developed on calcareous tills. They are characterized by

poor to well-developed humic, A_1 horizons 2 to 10 cm thick developed on thin A_2 horizons; B horizons from 2 to 50 cm depth, and C horizons down to at least 140 cm. C horizons represent weathered or degraded tills, and are pervasively oxidized throughout their profile. B and C horizons of podzolic soils that have developed on nearby glaciofluvial deposits and non-calcareous tills are comparable, however A_1 and A_2 horizons developed on these glacial deposits are less mature. Soils are mostly juvenile and closely reflect local variations in glacial deposit substrate, terrain and drainage environments.

2.1.4 Hydrology and Vegetation: The study area contains six small lakes, ranging from 1.5 hectares to 14 hectares, in two northeast trending basins that drain north into the Ottawa River via Craigs Creek. Napier and Little Green lake are 13 and 9 m deep respectively, and are dimictic (freely circulating twice a year). Nichols Lake and the southwestern two basins of Napier Lake are less than 3 m deep and are mostly thermally unstratified year-round. Streams are mostly seasonal, with re-emergent segments emanating from the base of glaciofluvial deposits west of Napier Lake and upstream of Little Green Lake. Bedrock depressions covered by ablation till are poorly drained and overlain by seasonal immature bogs.

Vegetation cover consists of mixed, young (10-25 year) and mature (>75 year) deciduous trees comprised predominantly of maple, elm and basswood, with lesser beech, oak, poplar and birch. Cedar is concentrated on cool, moist north-facing slopes along streams (Banville, 1987). Isolated white pine occurs on well-drained south-facing slopes. Shrubs, mosses and grasses comprise the understory vegetation.

2.2 PAP LAKE AREA

2.2.1 Location and Access: PAP Lake is 45 km northeast of La Ronge, Saskatchewan in NTS Map Sheet 73P/7 (Fig. 2). It is accessed by float plane from Missinippe 20 km to the north, or by all-terrain vehicle over an eight km exploration trail from Highway

102. The property is jointly owned by CAMECO (50%), Uranerz Exploration and Mining (30%), and Windarra Minerals (20%).

2.2.2 Geology and Mineralization: PAP Lake is underlain by a complex sequence of early Proterozoic pre- to syn-kinematic plutons and subordinate supracrustal rocks of the trans-Hudson orogen known as the Nut Bay Belt. The Nut Bay Belt represents the more intensely deformed southwestern end of the La Ronge Domain (Lewry, 1984a; and Coombe,1986). Watters (1986), and Armstrong and Parslow (1988) have concluded from lithogeochemical data which displays distinct low K-tholeiitic to calc-alkaline trends, that the supracrustal sequence resembles subduction-related primitive volcanic-plutonic arcs developed on oceanic crust. The La Ronge Domain is considered to be correlative with the Aphebian Lynn Lake Domain in northwestern Manitoba (Lewry, 1984b).

The study area is underlain primarily by mafic to felsic metavolcanic and meta-greywacke rocks intruded by gabbroic to granitic plutons and a large diorite sill (Fig. 4 and Plate 1) (Coombe, 1986; Sibbald, 1986; and Armstrong and Parslow, 1987). Stratified rocks exhibit a northeast-striking, steep northwest-dipping fabric with local isoclinal folding (Sibbald, 1986), post-kinematic brittle fracturing and dextral shear. Northeast-striking vertical shear zones in the main diorite sill comprise the main Au exploration target (Plates 2 and3). The most intensely deformed and altered zones contain quartz and carbonate veining accompanied by replacement of hornblende by chlorite and biotite, minor sericite, kaolinite, and variable amounts of sulphide mineralization.

Mineralization consists of pyrite, pyrrhotite, arsenopyrite, local minor chalcopyrite, and rare galena, sphalerite and native gold. Scanning electron microscope examination of oxidized sulphides identified trace amounts of Cu-Bi and Bi-Te minerals. Several Au-bearing arsenopyrite-pyrite-quartz veins up to 20 cm wide and several metres strike length are exposed in trenches (Plate 4). Disseminated pyrite and

arsenopyrite are also present in felsic metavolcanic and felsic- to intermediate porphyritic dykes and silicified diorites.

Drilling by CAMECO has outlined 494,000 tonnes grading 12.3 g/t Au in several subparallel zones southwest of PAP Lake. The adjacent Bakos zone has estimated reserves of 1.79 million tonnes grading 11.3 g/t Au in two main zones (Mining Journal, 1990) and is being studied for mining feasibility.

2.2.3 Physiography, Glacial History and Soils: The undulating PAP Lake area terrain has local relief to 20 m and drains northeast towards the Churchill River. Wisconsinan ice flowed southeast, parallel to bedrock lithological and structural trends, and accentuated bedrock contrasts (Schreiner and Alley, 1984). Ridges are mantled by up to a 1.5 m thick veneer of clayey to cobble-bearing till. Lowlying areas contain glaciofluvial deposits mantled by poorly drained fens and peat bogs with a possible accumulated thickness exceeding 1 m.

Immature brown podzols and grey-brown luvisols are developed on till. Podzols are characterized by 2 to 8 cm thick decomposing leaf litter or moss overlying about 2 cm dark brown-black A_1; minimal B horizon development; and C horizon material generally within 20 cm of the surface. Soils overlie partly degraded parent till which is visibly oxidized down to about 1 m, although slope and hydrology conditions cause local variations such as oxidation to the bedrock surface, or preserve a relatively un-oxidized clayey- waterlogged till at depth.

2.2.4 Hydrology and Vegetation: PAP Lake covers about 30 ha and attains a maximum 13 m depth in one central basin. It is dimictic with the surface frozen for up to six months of the year. Intermittent streams flow into it from adjacent lowlying organic depressions and several exposed shear zones. Shear zones and lithological contacts trending beneath the lake are possible aquifers for groundwater.

Vegetation consists of mixed black and white spruce, lesser birch and alder, and an understory of creeping alder, shrubs and mosses. Labrador tea and moss

predominate in lowlying areas such as peat bogs. Swampy outflows of creeks into PAP Lake are thickly overgrown by alder, birch, grasses and herbaceous plants.

2.3 FOSTER LAKE AREA:

2.3.1 Location and Access: Foster Lake is located 15 km south of Lynn Lake, Manitoba in NTS Map Sheets 64C10 and 64C11 (Fig. 2). Access is by float-equipped aircraft out of Lynn Lake. Plate 5 provides an aerial view of the study area.

2.3.2 Geology and Mineralization: The area lies in the southern Lynn Lake greenstone belt comprised of the Aphebian Wasekwan Group which includes metamorphosed tholeiites and basalts, overlain by turbidites, and mafic to felsic volcanic rocks intruded by mafic to felsic plutons and dykes (Gilbert et al. 1980; Fedikow et al., 1986).

The north side of Foster Lake is underlain by nearly 275 m of intercalated mafic to felsic metasedimentary rocks, flanked to the south by a foliated alkali granite sill, and to the north by >200 m thick plagioclase-bearing mafic metavolcanic flows, tuffs and minor gabbro (Fig. 5; Ferreira, 1986). The study area is transected by the Johnson shear zone (JSZ), a 40 km long, by 0.5 km wide zone of shearing, high strain and chemical alteration oriented subparallel to Wasekwan Group rocks. The shear zone is manifest as a low ridge of positive relief, well developed foliation oriented $240^0/60^0$N; shear and fracture cleavage, variable chloritization, silicification, carbonate-clay alteration, localized brecciation, and widespread, but as yet uneconomic Au mineralization (Fedikow et al., 1986; Ferriera, 1986; Baldwin, 1987; Baldwin et al, 1985; Sherman et al., 1989). Mineralization consists mostly of disseminated pyrrhotite and pyrite, with subordinate magnetite, chalcopyrite, arsenopyrite, and traces of galena, sphalerite, scheelite, molybdenite and native gold along cleavage fractures and in quartz veins. Quartz veins up to 20 cm wide may persist for several metres length (Plate 6 and 7).

2.3.3 Physiography, Glacial History and Soils: Southerly flow and deglaciation of Keewatin lobe ice (Kaszycki and DiLabio, 1986) at Foster Lake deposited lodgement and ablation till, eskers and kames, and minor alluvial sediments. These are now partly mantled by organic deposits. Ice-contact deposits and bedrock striae record ice-movement directions of 170^0 to 210^0 which is almost normal to bedrock strike. Bedrock structure is clearly visible through the thin veneer of till. Till is mostly <1.5 m thick to discontinuous, although accumulations >2 m thick occur in local depressions and on the lee of prominent bedrock forms. Tills are poorly stratified, have a predominant sandy matrix which is oxidized to 0.3 to 1.5 m depth, and contain abundant locally-derived bedrock fragments and ubiquitous granite boulders and cobbles derived from the north (Plate 8 and 9). Peat deposits mantle well-indurated clayey till in most depressions, permitting permafrost to exist at 30 cm depth along bog fringes. The permafrost depresses summer surface bog water temperatures to as low as 4^0 C, compared to other surface waters of 8 - 12^0 C.

Soils in the Foster Lake area are developed on till and esker parent material. They are mostly thin, immature grey to brown-black podzols with poorly distinguishable profiles. Where soils are absent, humus directly overlies oxidized weathered till.

2.3.4 Hydrology and Vegetation: The study area contains the interconnected basins of Foster Lake (70 ha by 9 m deep), Reservoir Lake (4 ha by 3 m deep), Expansion Lake (6 ha by 2 m deep), and Bay Lake (4 ha by 2 m deep) which drain south towards the Churchill River. The local drainage pattern is complex. Several small streams and bogs drain into each basin from the surrounding upland, with the entire drainage network overlying, and draining across and parallel to the JSZ. Because of the resistant nature of the JSZ, it acts as a recharge zone for much of the local drainage into the lakes. The perimeter of bogs and fens partly represent groundwater discharge zones of adjacent higher relief which is mantled by till or esker complexes. Two parallel bog systems

sampled in detail north of Foster Lake over the main JSZ are underlain by permafrost.

Black spruce, and subordinate alder and dwarf birch comprise the predominant vegetation, although pine dominates on well-drained sandy eskers. Alder, willow, labrador tea, and various grasses and mosses predominate in lowlying, wet environments.

Area	Geology	Mineralization/ Alteration	Physiography	Hydrology
Napier Lake	Mafic metavolcanics, calcareous to quartzose clastics, gabbro.	Stratabound lenses and disseminations and discordant sulphide-bearing quartz-ankerite veins along Robertson shear zone. Pyrite, pyrrhotite >>chalcopyrite, tetrahedrite, arsenopyrite, sphalerite, galena >>gold	South margin of Ottawa-Bonnechere Graben. Southerly Wisconsian ice-flow deposited a veneer of stony ablation till on ridges and mixed ice-contact deposits in valleys. Relief <95 m.	Lakes and ponds <14 ha interconnected by seasonal re-emergent streams, and minor wet bogs. Precip. 100 mm p.a. Surface water pH 6.7-8.3
PAP Lake	Mafic to felsic metavolcanic and metasedimentary rocks intruded by gabbro and quartz diorite	Sheared diorite with quartz-carbonate-sericite veins containing arsenopyrite, pyrite >pyrrhotite >>chalcopyrite, galena, sphalerite, >tourmaline >>gold	Undulating terrain in middle Churchill River basin. Southeasterly Wisconsian ice flow deposited a veneer of stony till, depressions contain post-glacial organic deposits. Relief <20 m.	Seasonal streams and seeps drain organic-rich bogs into thermally dimictic PAP Lake. Surface pH 5.1-6.9. Groundwater pH 7.6-7.8
Foster Lake	Metavolcanic rocks and turbidites intruded by mafic to felsic plutons and dykes.	Quartz-carbonate-hosted sulphides associated with brecciation, silicification and carbonate alteration along Johnson shear zone. Pyrrhotite, pyrite >magnetite >>arsenopyrite, chalcopyrite, galena, sphalerite >>scheelite, molybdenite >>gold	Undulating Kazan upland. Southerly Wisconsian ice flow, Keewatin lobe ice, and deglaciation deposited veneer of clayey to sandy till, and minor glaciofluvial sediments. Relief <30 m.	Permanent bogs drain lowlying areas into shallow lake chain, across and parallel to Johnson shear zone. Surface water pH 5.4-7.6. Groundwater pH 7.5-7.9.

Table 1. Summary of the main geological and environmental characteristics of each study area.

3.0 CHAPTER THREE: PAPER 1

A PRELIMINARY REPORT ON THE DISTRIBUTION OF GOLD IN LAKE SEDIMENTS AND SURFICIAL MATERIALS AT FOSTER LAKE, MANITOBA

by H.R. SCHMITT in

CURRENT RESEARCH, PART C, GEOLOGICAL SURVEY OF CANADA, Paper 89-1C, p. 255-262, 1989.

3.1 ABSTRACT

Lake sediment investigations along the Johnson Shear Zone in the Lynn Lake greenstone belt identified concentrations of up to 30 ppb Au in lake-bottom sediments from Foster Lake. Sampling of till, peat, humus, black spruce (*Picea mariana*) and surface waters overlying a mineralized shear zone north of Foster Lake encountered elevated concentrations of Au, As, Sb, Mo and W adjacent to exposed mineralization and dispersed down-ice toward Foster Lake. Gold concentrations up to 4.9 ng L^{-1} in surface waters suggest mobilization of Au by organic or anionic complexes in weakly acid surface waters. The aim of this study is to document some of the complex natural processes that lead to accumulation of Au in lake sediments. While lake sediments are now widely used in exploration for Au, there is relatively little information on the controls on transportation and precipitation of Au.

3.2 RÉSUMÉ

L'exploration des sédiments lacustres bordant la zone de cisaillement de Johnson dans la zone des roches vertes de Lynn Lake a permis a d'indentifier des concentrations d'or (Au) atteignant parfois 30 ppb dans les sédiments lacustres profonds prélèves dans le lac Foster. Dans des échantillons de till, de tourbe, d'humus, d'épinette noire (*Picea mariana*) et des eaux des surface recouvrement une zone de cisaillement minéralisée située au nord du lac Foster. Des concentrations de Au pouvant atteindre 4,9 ng L^{-1} dans les eaux de surface semblant indiquer une mobilisation de Au par des complexes organiques ou anioniques dans le eaux de surface faiblement acides. La présente études a pour but de décrire quelques-uns des processus naturels complexes responsables de l'accumulation de Au dans les sédiments lacustres. On utilise maintenant très communément des sédiments lacustres pour la prospection de Au, mais on dispose de relativement peu d'information sur les facteurs qui régissent le transport et la précipitation de Au.

3.3 INTRODUCTION

The geochemistry of Au in supergene environments has received much attention over the last decade. Webster and Mann (1984), Mann (1984), Webster (1986), Hall *et al.* (1986), and Stoffregen (1986) have demonstrated that Au occurring in bedrock, once exposed to supergene weathering processes, may become complexed, transported and reprecipitated under low-temperature oxidizing acid to alkaline conditions. The mobility of Au is influenced by the interaction of host rock, groundwater and surficial deposit chemistry, geomorphology, and climate.

This paper reports preliminary results for a study of Au mobilization into lake-bottom sediments at Foster Lake located 15 km south of Lynn Lake, Manitoba. Foster Lake is adjacent to the Johnson Shear Zone, a 40 km long and up to 0.5 km wide zone of variable shearing and deformation in Wasekwan Group metavolcanic and metasedimentary rocks of Aphebian age. Significant, but as yet uneconomic, gold-bearing veins occur along the shear zone (Fedikow *et al*, 1986).

Regional lake sediment and water geochemical surveys carried out in Granville Lake map area (64C) during 1983 (Geological Survey of Canada, 1984, 1986) and follow-up detailed lake sediment and water geochemical survey carried out in 1987 measured elevated concentrations of gold in centre-lake bottom sediments adjacent to the Johnson Shear Zone. Consequently, Foster Lake was chosen for detailed multi-media geochemical sampling in order to characterize surficial and chemical dispersion phenomena that mobilize Au into lakes. This work is primarily intended to aid the interpretation of regional geochemical data for mineral exploration, and to aid the design of future lake sediment geochemical surveys.

Sampling of Foster Lake in 1985, 1987, and 1988 entailed the collection of: lake bottom and stream sediments; surface waters from lakes, streams, bogs, trenches and seeps; peat; humus; black spruce (*Picea mariana*) twigs and needles; till; and mineralized and unmineralized bedrock. Apart from drainage sediments, sampling was

carried out on two 150-m-wide by 300-m-long grids encompassing mineralized segments of the shear zone.

Although a wide variety of elements have been analyzed, this report will focus on the distribution of Au.

3.4 BEDROCK GEOLOGY

The study area lies within the southern part of the Lynn Lake greentstone belt (Fig. 1), and contains a complex sequence of metamorphosed tholeiitic, aphyric and porphyritic basalts overlain by turbidite units and mafic to felsic volcanic rocks belonging to the Wasekwan Group, which are intruded by mafic to felsic plutons and dykes (Gilbert *et al*, 1980; Fedikow, 1986).

Recent mapping by geologists of Sherritt Gordon Mines (1983) (now Lynn Gold Resources) and by Ferreira (1986), describes the north side of Foster Lake as underlain by up to 275 m of intercalated mafic to felsic fine-grained metasedimentary rocks, flanked to the south by a foliated alkali granite sill, and to the north by at least 200 m thick massive plagioclase-bearing mafic metavolcanic flows, tuffs and minor gabbro. Undivided intermediate to mafic volcanic rocks occur east and southeast of Foster Lake, with tonalite and diorite of the Pool Lake intrusive suite present to the south and west (Fig. 2).

The Johnson Shear Zone trends subparallel to the strike of Wasekwan Group rocks and is represented by a low ridge of positive relief characterized by a well developed foliation oriented $240^0/60^0$N; shear and fracture cleavage, variable to intense chloritization, silicification, carbonate-clay alteration, localized brecciation, and sulphide mineralization occur (Ferrerira, 1986).

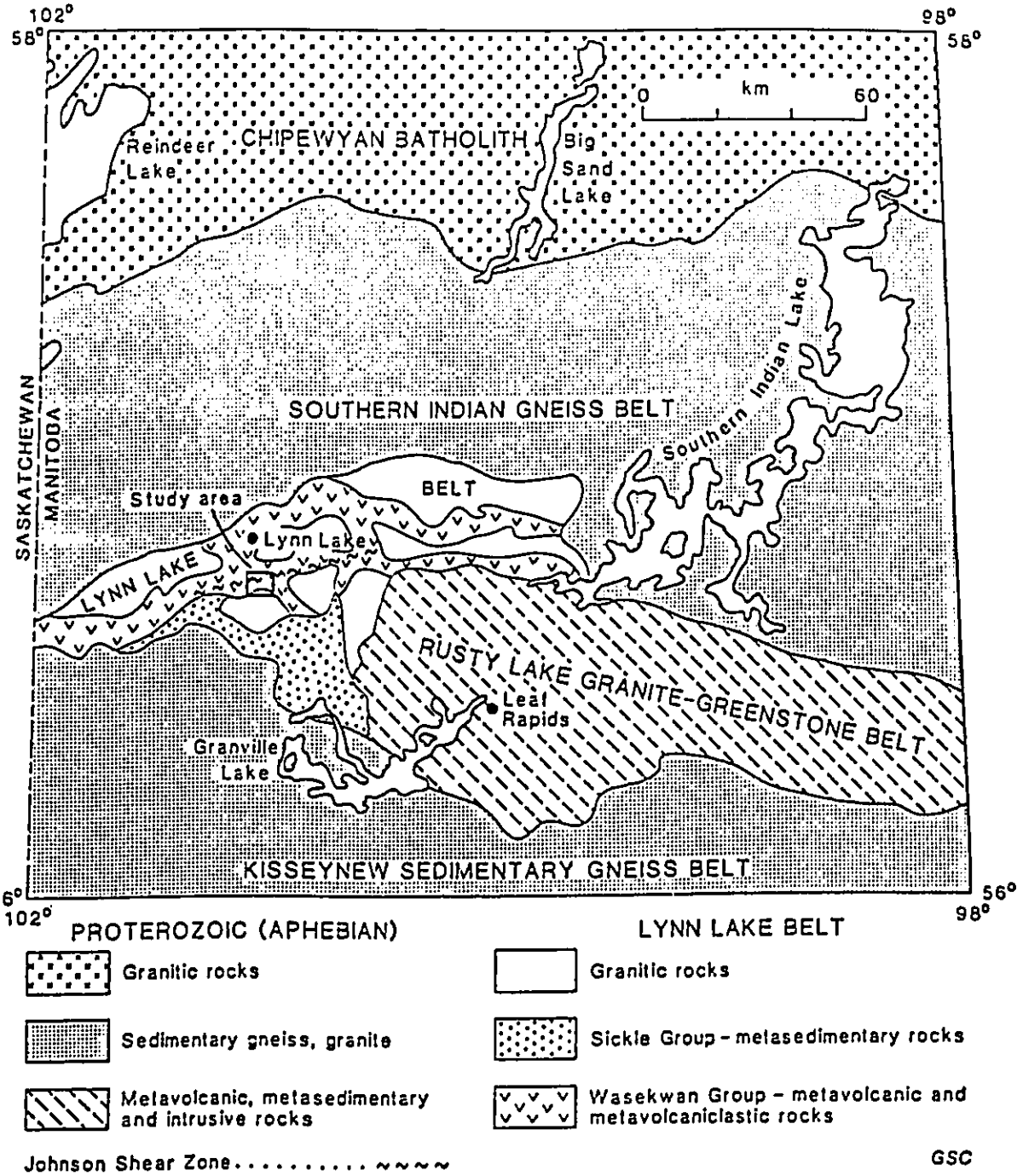


Figure 1. Location and regional geology of the study area (after Zwanzig *et al.*, 1985)

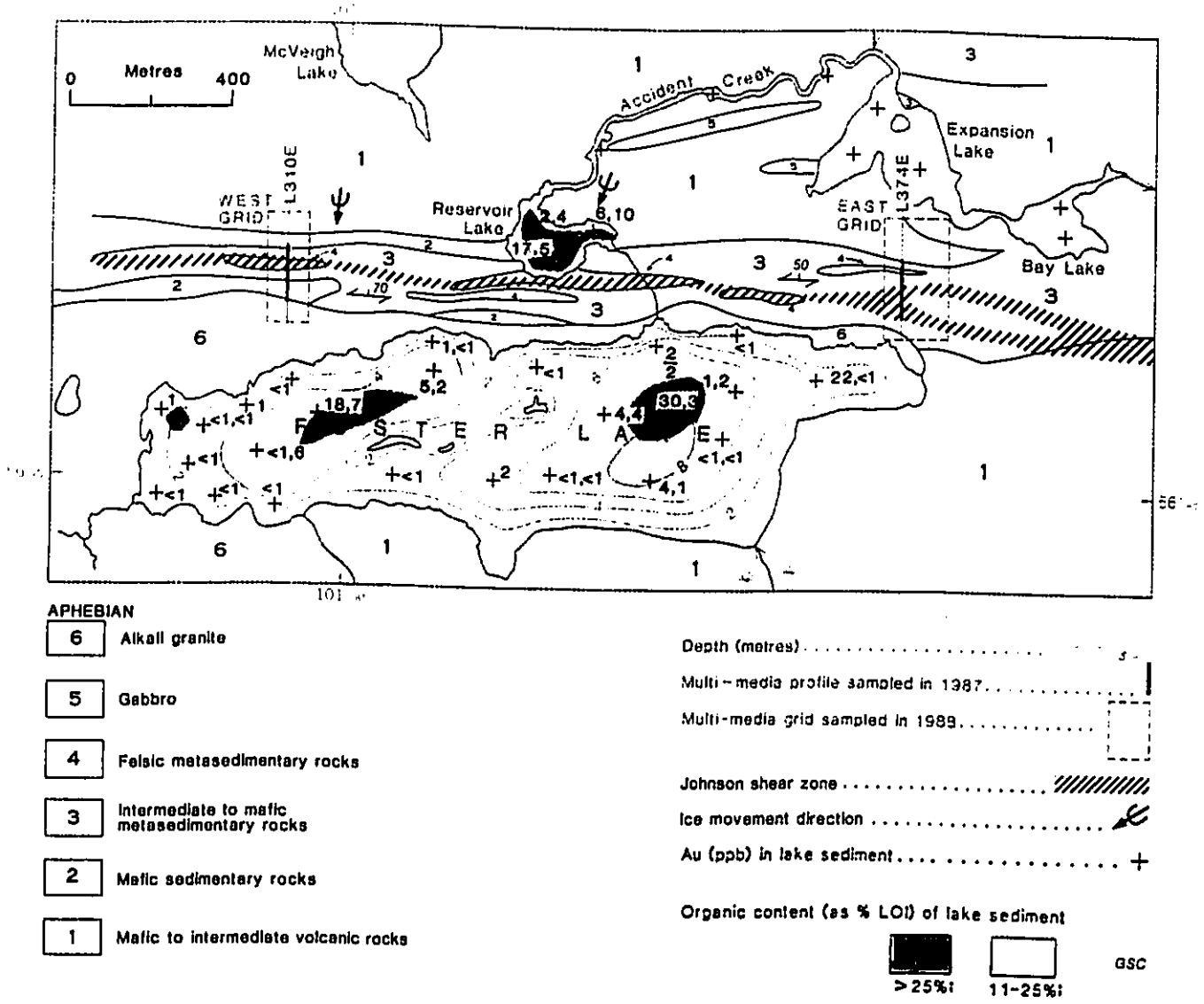


Figure 2. Geology, distribution of Au (ppb) in lake sediments, and location of multi-media geochemical sampling grids at Foster Lake.

3.5 SURFICIAL GEOLOGY

For a description of the glaciation history, surficial sediments and post-glacial deposits see Chapter 2.3.3.

3.6 MINERALIZATION

North of Foster Lake a zone up to 20 m wide and traceable over 1.5 km along strike contains locally abundant sulphide-bearing quartz veins associated with well-developed fracture cleavage, localized carbonate and sericite alteration, and fibrous amphibole.

Sulphides in quartz veins consist of 1-20% pyrrhotite, < 1-10% pyrite, arsenopyrite, and trace galena, chalcopyrite, and sphalerite as disseminated grains, streaks, and aggregates along cleavage planes, and less commonly as massive clots and blebs in 5-20 cm wide veins (Ferreira, 1986; Baldwin *et al*, 1985). Disseminated magnetite occurs in felsic metasedimentary and tuffaceous rocks within and adjacent to the zone.

Gold values locally exceed 20 000 ppb in pyritic quartz veins, compared to values typically < 100 ppb for volcanic and sedimentary rocks within and adjacent to the shear zone, and values up to 30 ppb for the alkali granite near its contact with metasedimentary rocks (Sherritt Gordon Mines, 1983).

3.7 FIELD AND ANALYTICAL METHODS

Lake sediments were collected from an inflatable boat using a modified model of the GSC 1976 lake sediment sampler (Coker *et al* , 1979). Where field duplicates were collected, or more than one sampling attempt was necessary for adequate material, drift from the site was minimized to less than 5 m or sampling was repeated. During sample retrieval, care was taken to wash out and discard the top several cm of

sediment material to avoid incorporation into the sample, of the most recent organic-rich layer with complex metal-organic compounds.

Dried samples were ball-milled using ceramic equipment and sieved to -177 microns by Golder Associates Ltd., and analyzed by Bondar-Clegg and Company Ltd., for some or all of Zn, Cu, Pb, Ni, Co, Ag, Mn, As, Mo, Fe, Hg, loss-on-ignition, U, V, Cd, Sb, S, Cl, Ba, Sr, and Au. Gold analyses were performed on a 10 g sample by Chemex Laboratories Ltd. by fire assay preconcentration followed by instrumental neutron activation to achieve a detection level of 1 ppb. Analytical methods for other elements are summarized in Geological Survey of Canada regional geochemical Open File 1641 (1988).

Lake waters were collected at most sediment sites in 250 mL Nalgene bottles from at least 30 cm below the water surface; other waters (*i.e.*, bogs, streams) were collected as deep as possible taking care not to agitate bottom sediments. Chemex Laboratories Ltd. analyzed waters for some or all of pH, F, U, Ca, Mg, and alkalinity; in addition a direct current plasma (DCP) multielement analysis provided useful information for Ca, Mg, Na and Sr. In addition to laboratory analyses of waters, *in-situ* determinations of temperature, pH, conductivity and salinity were carried out using a Corning pH Tempmeter 4 and YSI Model 33 Salinity-Conductivity-Temperature meter.

Several 1 L water samples were collected and analyzed for Au at the Geological Survey of Canada. Br_2-HCl/MIBK extraction was followed by graphite furnace-atomic absorption spectrophotometric analysis (GFAAS) as described by Hall *et al* (1986) to attain a detection level of 0.001 ppb (1 ng L^{-1}).

Till samples weighing 5 to 10 kg were collected from pits hand-dug by shovel to depths of 1.5 m or until bedrock was encountered, whichever was the shallower. Several size fraction splits have been generated. To date a -63 micron (-250 mesh) and heavy mineral concentrate (s.g. >3.32) have been analyzed at Bondar-Clegg and Company by instrumental neutron activation for Au, Na, Sc, Cr, Fe, Co, Ni, Zn, As,

Se, Br, Rb, Zr, Mo, Ag, Cd, Sn, Sb, Te, Cs, Ba, La, Ce, Sm, Eu, Tb, Yb, Lu, Hf, Ta, W, Ir, Th and U.

Peat samples weighing from 1 to 4 kg were collected from pits hand-dug to depths of 0.3 to 1.0 m over the eastern grid (Fig. 2). Air dried samples were cleaned of woody parts, and a 50-100 g subsample ashed overnight at 470^0 C. Approximately 1 g of encapsulated ash was analyzed at Activation Laboratories Ltd. by instrumental neutron activation analysis for Au plus a suite of elements similar to till samples above, but excluding Cd, Sn, Te, and Zr, and including Ca, K, Hg, Nd, and Sr.

Picea mariana (black spruce) twigs and needles representing 5-8 years growth were collected within 3 m of each till, peat and humus site. A 30-50 g sample of twigs only was ashed, encapsulated and analyzed using procedures similar to that for peat, and those described by Dunn (1988).

Bedrock and humus samples are presently being processed.

3.8 RESULTS

Table 1 is a preliminary summary of Au concentration in surficial materials. The table illustrates pronounced secondary dispersion of Au in the Foster Lake area at concentrations well above detection levels for all media types. The wide range of Au concentrations, especially between media types, stresses the importance of identifying controls on Au accumulation so that geochemical analyses of these media can be applied to mineral exploration. The following discussion provides a more detailed decription of Au distribution.

Figure 2 shows the distribution of Au in lake-bottom sediments from Foster and Reservoir Lakes.

Foster Lake, sampled from 24 sites, contains two basins up to 9 m deep separated by a partially eroded northeast trending esker (Fig. 2). Lake sediment material was olive-grey to green with a silty to thixotropic gel consistency. Gold

Table 1. Preliminary summary of gold concentrations in surficial materials at Foster Lake.

[1]Media	N	$\bar{X}$ (ppb)	Range (ppb)	Detection Level (ppb)	[2]Analytical Method
Lake-bottom sediment			< 1 to 30		FANA
- Foster	37	3.4		1	
- Reservoir	6	7.3	2 - 17	1	
- Regional	1293	1.0	1 - 30	1	
Till			5 to 160		INA
- (<63 µ)	15	54	30 to 6660	2	
- HMC (>3.3)	13	1054		2	
Peat	7	29	14 to 47	5	ASH/INA
Picea mariana (Black spruce twigs)	19	9	< 5 to 39	5	ASH/INA
Surface water	8	.0013	<.001 to .005	.001	GFAAS

[1] Media sampled but for which results are not yet available include; humus, bedrock, groundwater, filtered lake waters, stream sediments and water.
[2] FANA - fire assay preconcentration - neutron activation
ASH/INA - instrumental neutron activation of ashed sample
GFAAS - Br2 - HCl - MIBK extraction followed by graphite furnace - atomic absorption

concentrations range up to 18 ppb in the western basin and 30 ppb in the eastern basin. Highest Au concentrations occur in the organic-rich (26% LOI) profundal sediments compared to silty (5% LOI) near shore sediments.

Reservoir Lake sediments are considerably more organic-rich (30-50% LOI) and returned values up to 17 ppb Au.

Preliminary results are available from two 200 m profiles sampled along L310E and L374E over and down-ice of mineralized zones (Fig. 2,3, and 4). Samples were collected at stations 10 to 30 m apart.

The western grid (Fig. 2 and 3) represents an area of positive relief mantled by a thin veneer of locally-derived till and patcy melt-out (?) sand deposits. The area is heavily vegetated by black spruce. On L310E, the -63 micron-size fraction of tills contained up to 140 ppb Au, 28 ppm As, and 262 ppm Cr up to 75 m down-ice of oxidized gold-bearing pyritic quartz veins exposed in shallow trenches. Analyses of the non-magnetic fraction of heavy mineral concentrates from these till samples revealed similar trends with up to 6660 ppb Au, 14 ppm As, 1000 ppm Cr as well as 1.4 ppm Sb, and 224 ppm W.

Gold concentrations in ashed black spruce twigs from corresponding sites reveal a gradual increase in values from 5 - 7 ppb overlying mineralization, to 14 ppb 75 m down-ice. The highest values for As (6.6 ppm) and Co (17 ppm) occur near mineralization, the opposite is true for Sb which ranges from 0.4 ppm over mineralization to 1.0 ppm 50 m down-ice. Since vegetation will tend to integrate the geochemical signature of bedrock and surficial material (Dunn, 1988), lithogeochemical data will be required to fully assess the biogeochemical response.

The eastern grid (Fig. 2 and 4) encompasses an area of subdued relief with numerous peat bogs and fens interspersed with higher areas of till-mantled bedrock. The northwestern and southeastern parts of the grid contain prominent ice contact deposits. The 200-m profile sampled on L374E (Fig. 4) crossed two boggy areas which resulted in the collection of peat samples instead of till. At the north and south ends of the profile a thin veneer of till mantles deformed silicified metasedimentary rocks containing disseminated pyrite, magnetite and trace galena.

Till samples contained up to 160 ppb Au, 160 ppm Cr, 15 ppm As, and 30 ppm W in the -63 micron size fraction. Element concentrations in the corresponding non-magnetic heavy mineral separates range up to 904 ppb Au, 1000 ppm Cr, 37 ppm As, 1350 ppm W, 19 ppm Mo, and 4 ppm Sb. All tills show some degree of oxidation.

Peat samples were collected at sites overlying till at either end of the profile, and from below groundwater level in bogs. Peat with a noticeable silty composition (69.4% ash) overlying till at the south end of the profile, yielded 114 ppb Au, 1200 ppm As, and 3.8 ppm Sb. The Au value for this peat sample was not used in calculating the mean Au content of peat in Table 1 owing to the chemical and physical differences to other peat samples. Bog peat values range up to 35 ppb Au, 14 ppm As, 26 ppm Mo, 2.3 ppm Sb, and 5 ppm W.

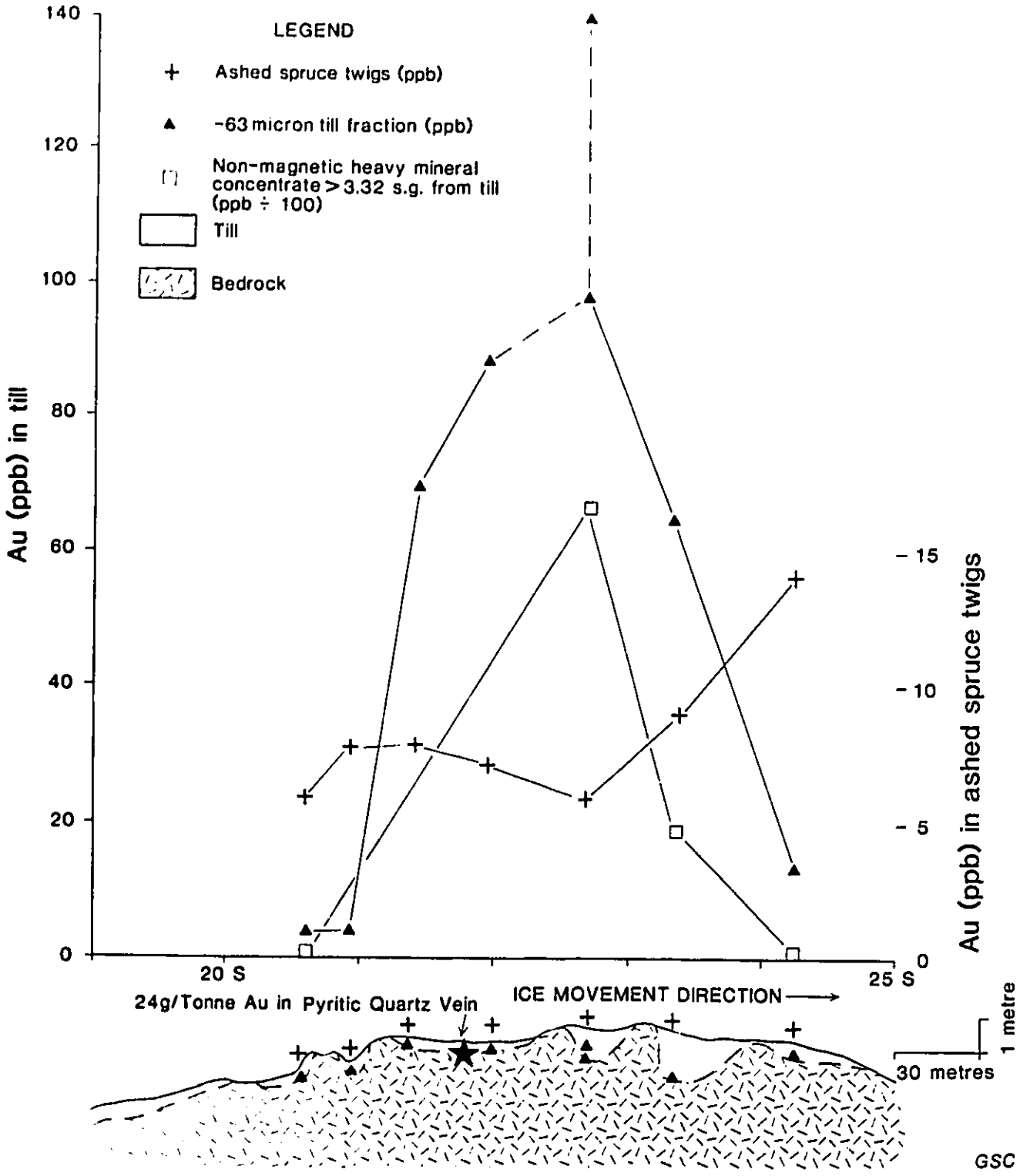


Figure 3. Distribution of Au (ppb) in till and black spruce on L310E. Note that Au concentrations in heavy mineral concentrates are divided by 100.

Gold concentration in ashed spruce twigs range from 5 to 9 ppb over bogs, and <5 to 39 ppb over and adjacent to till-mantled bedrock. Arsenic and Sb concentrations fluctuate over a narrow range of values; As 3.1 to 7.8 ppm, Sb 0.5 to 1.0 ppm.

Four 1 L water samples collected from surface bog waters (pH 5.4 - 6.2) on L374E contained up to 0.0049 ppb Au. Water (pH 6.4) collected from trenches adjacent to an arsenopyrite-bearing quartz vein approximately 200 m west of L310E contained up to 0.0023 ppb Au. The analytical results combine the analyses of Au desorbed from sample container walls with bromine-hydrochloric acid and analyses of 1 l of water filtered through 0.45 micron millipore filter; the values are thus thought to represent total Au occurring as dissolved organic or anionic complexes (Hall *et al.*, 1986; Hamilton *et al.*, 1983).

3.9 DISCUSSION

Preliminary review of geochemical data for surficial materials collected at Foster Lake indicate significant secondary dispersion of Au. Mean Au concentrations of lake sediments from Foster and Reservoir Lakes of 3.4 ppb and 7.3 ppb noticeably exceed mean Au concentrations of 1.0 ppb from an earlier regional lake sediment survey (Geological Survey of Canada, 1986). The auriferous nature of the Johnson Shear Zone is thus reflected in the chemical composition of some of the adjacent lake bottom sediments.

In addition to Au, As, W, and Cr, and to a lesser extent, Sb and Mo exhibited geochemical contrast in some or all of till, peat, and black spruce twigs collected over and down-ice of the Johnson Shear Zone. Metallic sulphides or oxides of Sb, Mo, and W have not been reported from Au occurrences along the Johnson Shear Zone by recent workers (Baldwin *et al.*, 1985) although the association of these elements with Au mineralization is well documented for many Precambrian deposits (Boyle, 1979). Future geochemical exploration along the Johnson Shear Zone should

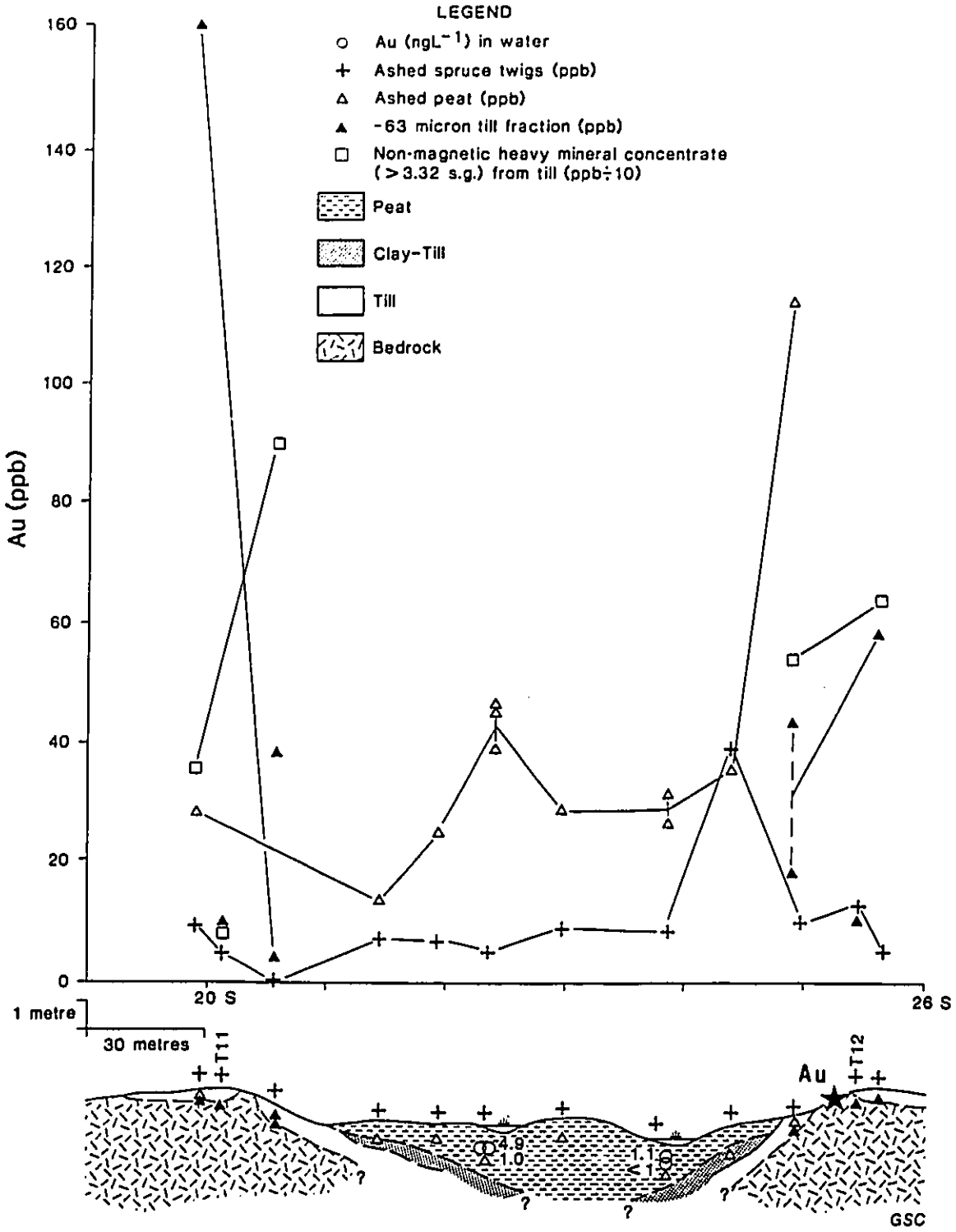


Figure 4. Au (ppb) in till, peat, ashed black spruce twigs, and waters on L374E. Au concentrations in heavy mineral concentrates are divided by 10. Samples T11 and T12 were collected 30 m east of L374E, some peat samples (open triangles) also collected adjacent to profile, but are plotted at their sampled depths, hence may be shown as plotted in other media. Ice direction from left to right (southerly).

therefore include analyses of these elements on a routine basis.

Although much analytical and interpretive work is required to complete this study, some preliminary observations can be made on the environment of Au dispersion:

(1) The principal source of Au at Foster Lake is in pyritic quartz veins contained in intensely foliated, fractured and altered intermediate to felsic metasedimentary rocks belonging to the Wasekwan Group. Pyrrhotite and accessory arsenopyrite, galena and chalcopyrite may accompany Au mineralization; the presence of molybdenum, tetrahedrite, or other antimony-sulphides, and scheelite is suggested by surficial geochemistry. Contribution of Au to the surficial environment by unmineralized rock with high background Au contents must also be considered.

(2) The Shear Zone's positive relief has exposed mineralization to glacial erosion and transport south toward Foster Lake. The Shear Zone is presently covered by a discontinous veneer of till in a moist, vegetated environment, thus permitting mineralized bedrock and till to be exposed to oxidizing conditions. Oxidation of mineralized bedrock, till, and decaying vegetation contributes to formation of acid solutions containing humic, polysaccharide, sulphate and hydroxide constituents which are able to complex positively charged metal ions (Baker, 1973; Boyle *et al.*, 1975; Cameron, 1977; and Rose *et al.*, 1979). The movement of these solutions through surficial sediments and in surface waters, their reduction and precipitation in bogs, and uptake by vegetation may result in the observed secondary dispersion patterns.

(3) The accumulation of Au in lake bottom sediments is the natural consequence of the above dynamic process involving many chemical and physical pathways.

3.10 ACKNOWLEDGEMENTS

(Consolidated with main Acknowledgements)

3.11 REFERENCES

(Consolidated with main References in Chapter Seven)

4.0 CHAPTER FOUR:

MOBILIZATION OF GOLD INTO LAKE SEDIMENTS FROM ACID AND ALKALINE MINERALIZED ENVIRONMENTS IN THE SOUTHERN CANADIAN SHIELD:

PART A. MINERALIZATION PROCESSES AND THE DISPERSAL OF GOLD FROM MINERALIZATION INTO SURFICIAL MATERIALS

4.1 ABSTRACT

Analyses for gold in lake sediments from the glaciated Canadian Shield have been used since the mid-1980's in exploration for gold mineralization. For gold in lake sediments to be an effective indicator of Au mineralization in the boreal forest zone, that is characterized by low relief and disorganized drainage, the element must be liberated from primary mineralization and migrate in solution or adsorbed on suspensates. Organic-rich profundal lake sediments often contain anomalous Au contents near Au mineralization, suggesting that Au is entering the lake environment in mobile form. This chapter focuses on the first part of a study to investigate the nature of Au mobility and dispersion into lake sediments under alkaline and acid hydrological conditions in the southern Canadian Shield.

Mineralized veins and rock, till, humus, peat and vegetation were collected from Napier Lake, Ontario; PAP Lake, Saskatchewan; and Foster Lake, Manitoba. All areas contain shear zone-hosted Au mineralization, were glaciated during the Wisconsinan, and now support vigorous boreal forests. Mineralization containing up to 40 ppm Au is commonly accompanied by enrichments in one or more of As, B, Ag,

Cu, Sb, Pb, W, Zn, and S, which are useful as pathfinder elements. All surficial media analyzed contain anomalous contents of Au reflecting Au dispersed from veins in nearby bedrock.

Gold is dispersed from bedrock by: clastic dispersal, as a result of glacial erosion; supergene oxidation and dissolution of Au and Au-bearing sulphides; and biological dissolution and uptake into vegetation. Gold may enter the lake environment as grains of rock, vein or mineral; in solution; sorbed on to suspended material; or as a constituent of decayed vegetation. Significant amounts of Au are more likely to enter the lake if other processes, such as glacial action, have dispersed the primary gold-bearing material over a large area of ground.

4.2 INTRODUCTION

Gold mineralization in the Canadian Shield commonly occurs within "greenstone" belts, along narrow linear zones of intensely silicified and carbonatized mafic to intermediate volcanic rock and lesser sedimentary rock. The processes that produced mineralization involved hydrothermal alteration of primary minerals and resulted in the mobilization of major and trace elements. The relative enrichment and depletion of elements can be useful as indicators to additional mineralization.

Geochemical analyses of surficial materials are widely used in the glaciated Canadian Shield to detect mineralization that may be of limited areal extent and is often concealed. Surficial materials derived from glaciation or post-glacial processes may include disaggregated bedrock mineralization or elements that have been derived by dissolution of vein material. This presents broad indicators for the exploration geochemist to detect and trace to source. Surficial materials commonly used because of their widespread occurrence and relative homogeneity over large regions include glacial till, soil, including its humic layer, peat, vegetation and recent lake-bottom sediments. Numerous geochemical studies have focussed on the appropriate sampling and analytical methods and the behaviour of Au, chalcophile, and major elements in various fractions of these media. Sample media such as till, soil and vegetation are effective as sample media when proximal to bedrock mineralization; drainage sediments and waters are effective both proximal to mineralization and at greater distances, but mainly when an element is easily dissolved and carried in solution such as Zn and Cu in acidic environments and U in alkaline environments.

The principal aim of the study was to improve the understanding of mobilization of Au from bedrock into lake sediments. The work discussed in this chapter includes: a) determining Au concentrations in bedrock, surficial materials, vegetation and water adjacent to Au mineralization or to lakes with elevated Au in lake sediments; and b) describing the processes which are important to making Au and associated pathfinder

elements available to the lake environment. The next chapter presents data on the distribution of Au and other elements in stream and lake sediments and waters.

4.3 DESCRIPTION OF STUDY AREAS

The physical, geological and biological characteristics of the three study areas are described in Chapter 2.

4.4 SAMPLING AND ANALYTICAL METHODS

The three study areas were chosen because of their general similarities in geology, glacial history and post-glacial geomorphological processes, and dissimilarities in pH of hydrological environments, as described in Chapter 2. Some of the lake sediments within all three areas contained anomalous amounts of gold. Field work involved an initial examination and verification of the geology and mineralization, followed by examination and mapping of the surficial material and vegetation. To permit meaningful interpretation of the geochemical data required that different types of sample be collected from the same site area whenever possible.

Field sampling was performed in all three areas during summer and early autumn in 1986, 1987 and 1988. The sampling and analytical methods for rock, till, peat, humus and vegetation samples are described below. Stream and lake sediments and waters are reviewed in Chapter 5.

4.4.1 Host Rocks and Mineralization: Mineralized and adjacent unmineralized host rocks were collected from the main auriferous shear zones. Selected thin and polished sections were prepared for visual characterization of mineralization. Twenty five samples were analyzed for whole rock oxide and minor elements. The list of elements and major oxides, analytical methods and detection levels are presented in Appendix 1. The analyses provided information on alteration as well as trace element associations with Au that may be useful as geochemical pathfinders for Au mineralization.

4.4.2 Till: Eighty-six till samples, each weighing 5 to 10 kg, were collected from pits hand-dug by shovel to 1.5 m depth, or until bedrock was encountered. The same, locally-derived till profile was sampled in each sample study area to ensure that till chemistry reflected the local bedrock. The vertical distribution of Au in till was examined by collecting samples at two levels from five sites. The first level was from till immediately above bedrock, and the second from 0.3 to 1.0 m above bedrock in the upper-most oxidized parent till ("C"-horizon). All till samples were placed in 20 L polyethelene bags for shipment. Observations recorded at each site included profile and oxidation characteristics, till texture, clast lithologies, and special features.

Two till fractions were analyzed, a <0.063mm fraction for Au plus thirty-three trace elements, and a <2mm heavy mineral concentrate fraction for a similar suite of elements. Sample preparation, analytical methods and detection levels are summarized in Appendix 2. The decision to analyze the total heavy mineral concentrate versus a heavy mineral concentrate minus the magnetic portion, considered the disadvantage of potential shielding of the neutron activation flux on Au by the magnetic or exotic heavy mineral portion, causing suppressed analytical values (Sopuck et al., 1986; Bernier and Webber, 1989) versus the advantage of unsuppressed Au analyses possible by excluding the magnetic fraction (Brereton et al., 1988). The total HMC was analyzed initially because of the small size of some samples, and the apparent localized origin of till constituents. The geochemical contrast obtained sufficiently displayed Au distribution patterns to make subsequent analyses of the non-magnetic HMC unnecessary for this study. Once the irradiated samples were safe for handling, selected samples with high Au contents were examined under a stereoscopic microscope. Sulphide, native Au and resistate grains such as scheelite were hand-picked from samples with corresponding high chemical analyses and abundant material, mounted and examined under the scanning electron microscope for mineralogical and textural information.

4.4.3 Peat: Six peat samples weighing from 1 to 4 kg (wet) were collected from pits

hand-dug to depths of 0.3 to 1.0 m over the eastern grid at Foster Lake. Several of the samples collected from the periphery of bogs were frozen and possibly represent localized areas of permafrost. Sample preparation methods, analytical methods and detection levels for Au plus thirty-four trace elements are listed in Appendix 3. The localized distribution of peat deposits made this medium unsuitable for comparative studies at all three study areas, but nevertheless provided data on Au uptake in peat.

4.4.4 Humus: Humus samples were routinely collected at Napier and Foster Lake from the same field sites where till samples were taken. Humus sample preparation methods, analytical methods and detection levels for Au plus thirty-four elements are listed in Appendix 3.

4.4.5 Vegetation: Black spruce (*Picea mariana*) needles and twigs representing five to eight years growth, were collected where possible from an area $10m^2$ centred on each till, peat and humus site. Analytical methods and detection levels for Au and thirty-four trace elements are sumarized in Appendix 3. For the Napier Lake area, Banville's (1987) study on Au in sugar maple (*Acer saccharum*) leaves was reviewed in relation to this study. Banville's sample processing and analytical procedures were similar to those employed in this study.

4.5 RESULTS - NATURE OF DISPERSION OF AU FROM MINERALIZATION

4.5.1 MINERALIZATION PROCESSES:

A summary of Au concentrations in surficial materials is presented in Table 1. Table 2 lists detection levels for trace elements of economic importance for each of the surficial media. Complete analytical results are listed in Appendix 1 to 4.

4.5.1a Lithogeochemistry: In each study area the prominent geological feature is a linear zone of deformed, altered and sheared rocks containing pervasive but variable concentrations of economic minerals. For each area mineralization is shown as a

TABLE 1.

Summary of Au (ppb) contents in surficial materials[1]

Medium		Area		
		PAP Lake	Napier Lake	Foster Lake
Till	<.063 mm	n = 21 R = 6 - 474 x = 72	n = 8 R = 6 - 47 x = 20	n = 63 R = <2 - 180 x = 7.7
	total HMC	n = 8 R = 554 - 18,000 x = 2331	n = 8 R = 49 - 1570 x = 124	n = 59 R = <5 - 12,600 x = 276
Humus			n = 7 R = <5 - 72 x = 5.5	n = 61 R = <5 - 372 x = 10.9
Spruce twigs		n = 14 R = <5 - 30 x = 7.1		n = 69 R = <5 - 125 x = 17
Maple leaves[2]			n = 60 R = 3 - 24.5 x = 11.7	

n = number of samples, R = range of values (ppb), x = mean.
[1] results for lake and stream sediments and waters reported in Schmitt *et al* (Part 2).
[2] results from Banville, 1987.
see text for description of analytical methods.

TABLE 2.

Analytical detection levels for Au (ppb) and minor elements (ppm) discussed in paper[1]

	Rocks	Till	HMC	Humus/Peat/Vegetation
Au	1	2	2	5
Ag	0.1	2	2	2
As	0.5	0.5	0.5	0.5
B	10			
Br	1	0.5	2	1
Co	10	5	5	1
Cr	50	20	20	1
Cu	1			
Fe	1	0.2%	0.2%	0.5%
Mo	1	2	2	2
Ni	20	10	20	50
Pb	2			
S	20			
Sb	0.2	0.1	0.2	0.1
W	2	2	2	1
Zn	1	100	100	20

[1]See APPENDIX text for description of analytical methods.

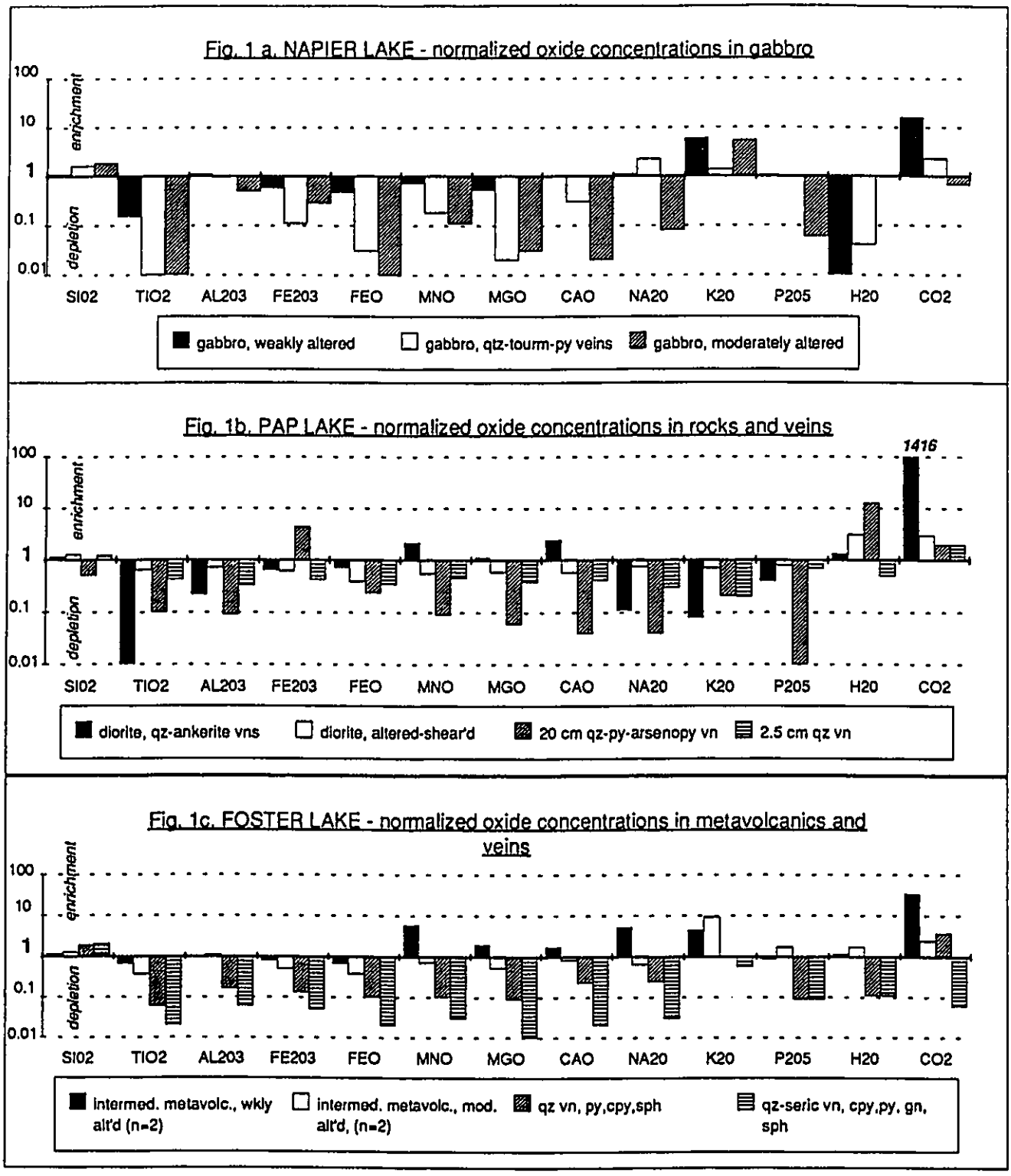


Figure 1. Normalized oxide concentrations in progressively altered rocks. The most unaltered rock is set at 1, normalized values > 1 = enrichment, < 1 = depletion.

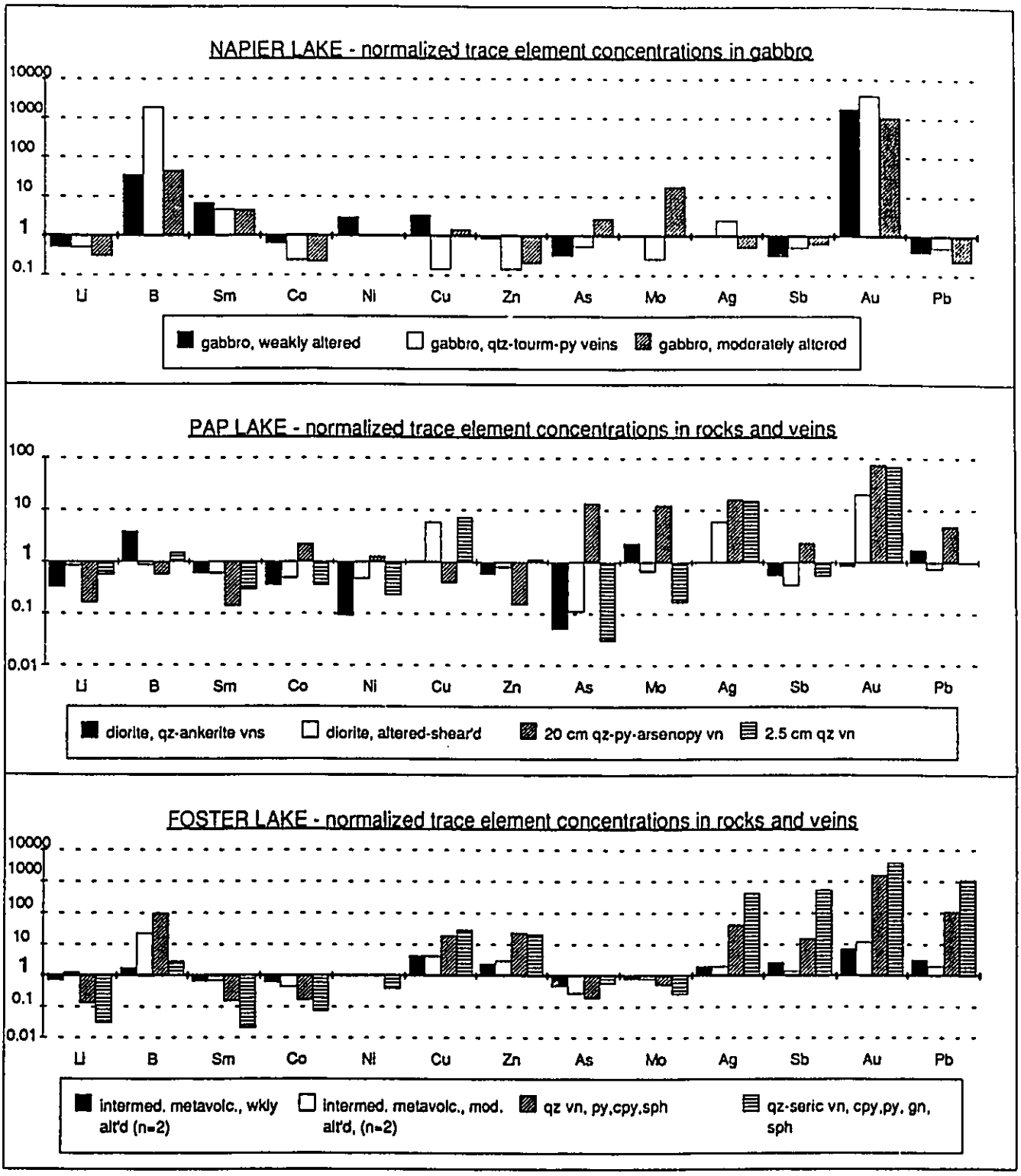


Figure 2. Normalized trace element concentrations in progressively altered rocks. The most unaltered rock is set at 1, normalized values > 1 = enrichment, < 1=depletion.

progressive change from unaltered rock, through altered rock to vein material. The change from unaltered rock through highly veined rock may be expressed as a depletion or an enrichment of individual major and trace elements as shown in Figures 1 and 2. Some elements show consistency in their depletion or enrichment from area to area, whereas other do not. As a general rule there is some enrichment in the volatiles CO2 and H2O, variable enrichment or depletion in K2O and Na2O, and general depletion or dilution of all other major oxides. Introduction of Au accompanies silicification in all cases (Fig. 3a). Progressive silicification may cause depletion by dilution of major element concentrations, as demonstrated in Figure 3b and 3c for TiO2 and MnO. Fluids passing through rocks during deformation and shearing may also chemically extract elements thereby contributing to these patterns. There is also introduction of carbonate with progressive silicification and mineralization which may have an important effect on the pH of the surficial environment and modify the behaviour of elements during supergene dispersion processes.

Trace elements such as As, Cu, Ag, Zn, and Pb are commonly considered as indicators of Au because of their tendency to be associated with Au mineralization. Figure 2 plots normalized trace element concentrations for progressively altered and mineralized rocks for all areas. It is evident that for all areas Au is the most consistent indicator of Au mineralization. Each area also has a characteristic suite of trace elements which is either consistently depleted or enriched. These element suites reflect the primary concentrations in the original rock and subsequent modifications resulting from the mineralizing processes. For Napier Lake, B and Sm show consistent enrichment with Au mineralization, whereas Cu, Mo, As and Ag show some enrichment in the most intensely altered rocks. At PAP Lake, Ag is the only trace element consistently enriched with Au mineralization although signficant enrichment also occurs for B, Cu, As, Mo and Pb. At Foster Lake, alteration and Au mineralization is reflected in consistently enriched B, Cu, Zn, Ag, Sb, Pb and W (not

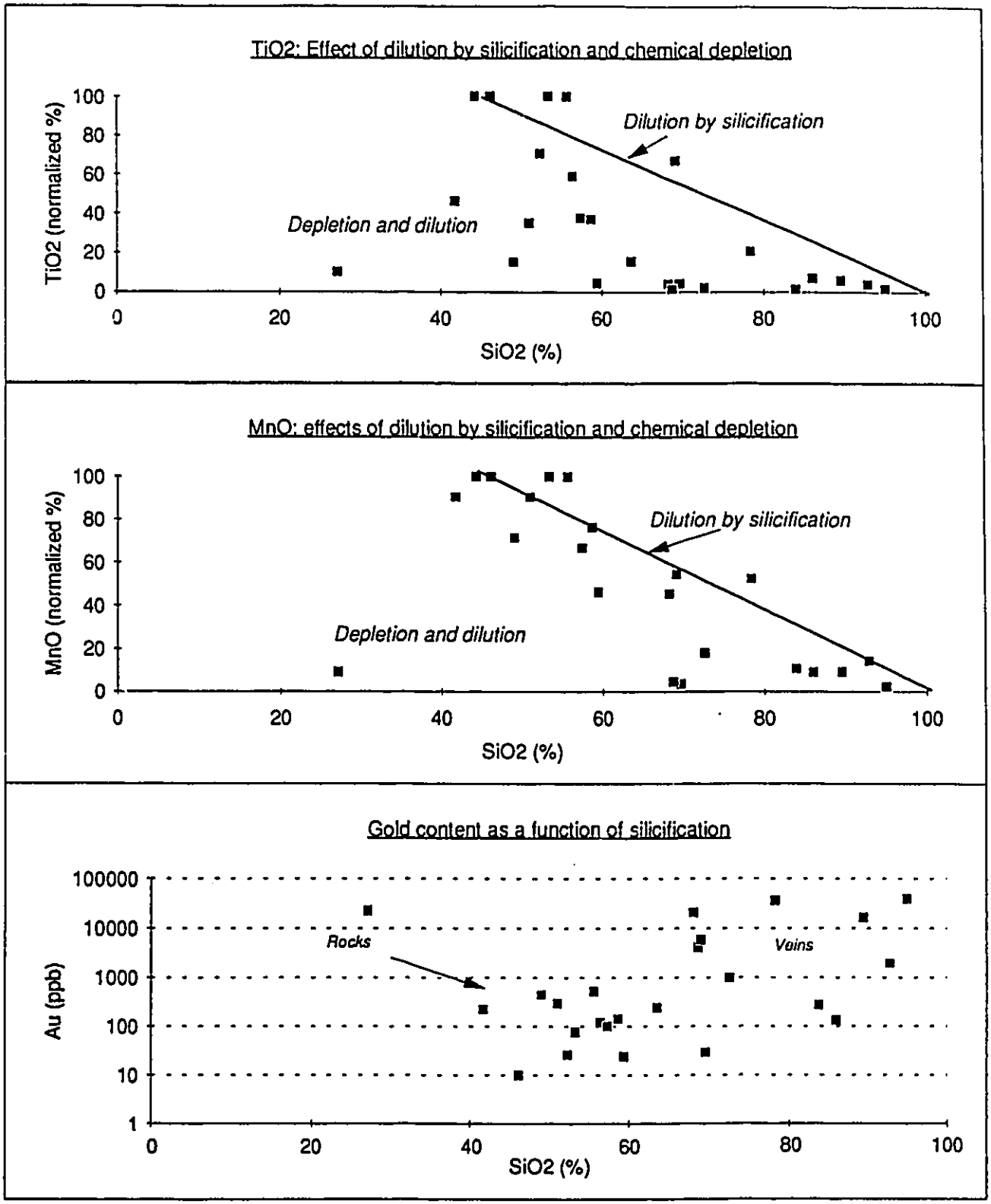


Figure 3. 3a) Gold content as a function of silicification in all rocks and veins; 3b) Depletion and dilution of MnO as a function of SiO2; 3c) Depletion and dilution of TiO2 as a function of SiO2. The dilution by silicification line connects the most SiO2 poor rock (unaltered gabbro) with theoretical 100% SiO2 rock (fully SiO2 diluted). Symbols below the line represent dilution by SiO2 or depletion during alteration and mineralization processes.

shown). Trace element suites such as these have been used in till geochemical exploration in the Foster Lake (Brereton et al.,1988; Nielsen and Fedikow, 1987; S. Amor, personal comm., 1989) and PAP Lake regions (R. Chapman, personal comm., 1988). Arsenic is commonly considered to be an indicator element in all areas because it occurs with Au mineralization, however as Figure 2 shows, this behaviour is inconsistent, which decreases the element's value as an indicator element. In all three areas, the pervasive along-strike enrichment of Au and a characteristic suite of trace elements in shear zones provides the main source of metals for secondary dispersion processes.

4.5.2 SURFICIAL MATERIALS:

Bedrock in the Canadian Shield is commonly overlain by surficial materials so that mineralized zones cannot be sampled directly. Thus geochemical methods of exploration and documentation of supergene element dispersion must rely on the sampling of surficial materials. In the Canadian Shield these are: tills; soils, including the humic layer; vegetation; drainage sediments, including stream and lake sediments; and waters. Tills and derived soils are used as proximal sampling materials, since anomalous concentrations of elements will occur over or near the mineralization. Waters and drainage sediments may give remote indications of mineralization. The distribution of Au and a corresponding suite of indicator trace elements is anticipated to show some degree of statistical or geographic correlation in proximal materials and variable relationships for more distally dispersed materials. Figures 4, 5 and 6, and Plates 1 and 5 display the general geography, bedrock geology and location where detailed surficial sampling was performed in each study area to test the dispersal of Au.

4.5.2a Till: Glacial till consists of disaggregated bedrock particles generally dispersed and lodged on bedrock in the down-ice direction. Dispersal may occur in ribbon, plumose, fan and other forms and various techniques are employed to trace dispersed mineralization to source (DiLabio and Coker, 1989). Systematic physical and chemical

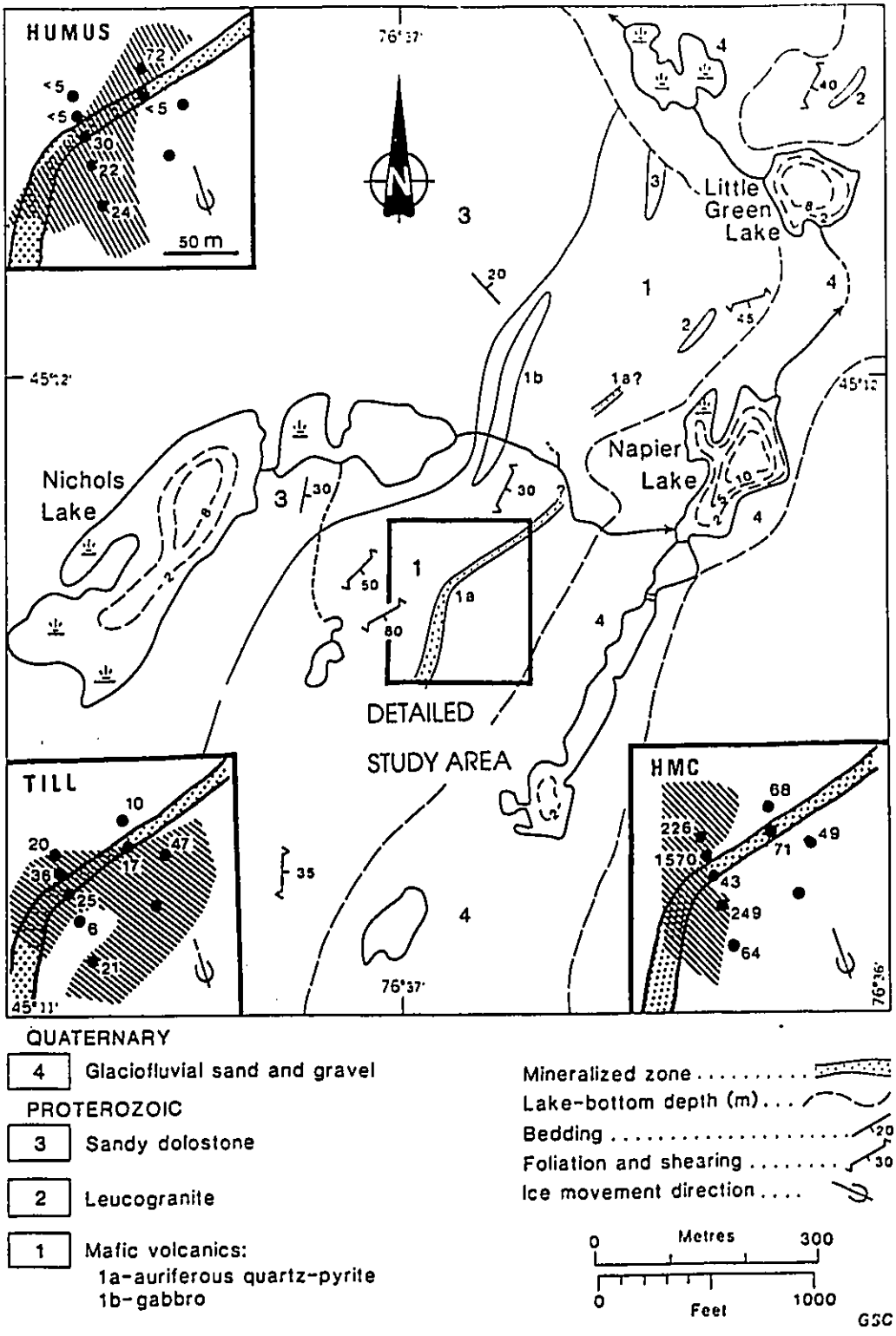


Figure 4. Napier Lake; Geology and location of detailed surficial sampling area; Distribution of Au (ppb) in Humus, Till and HMC. Shaded pattern represents Au >20 ppb (humus), >20 ppb (till), and >100 ppb (HMC).

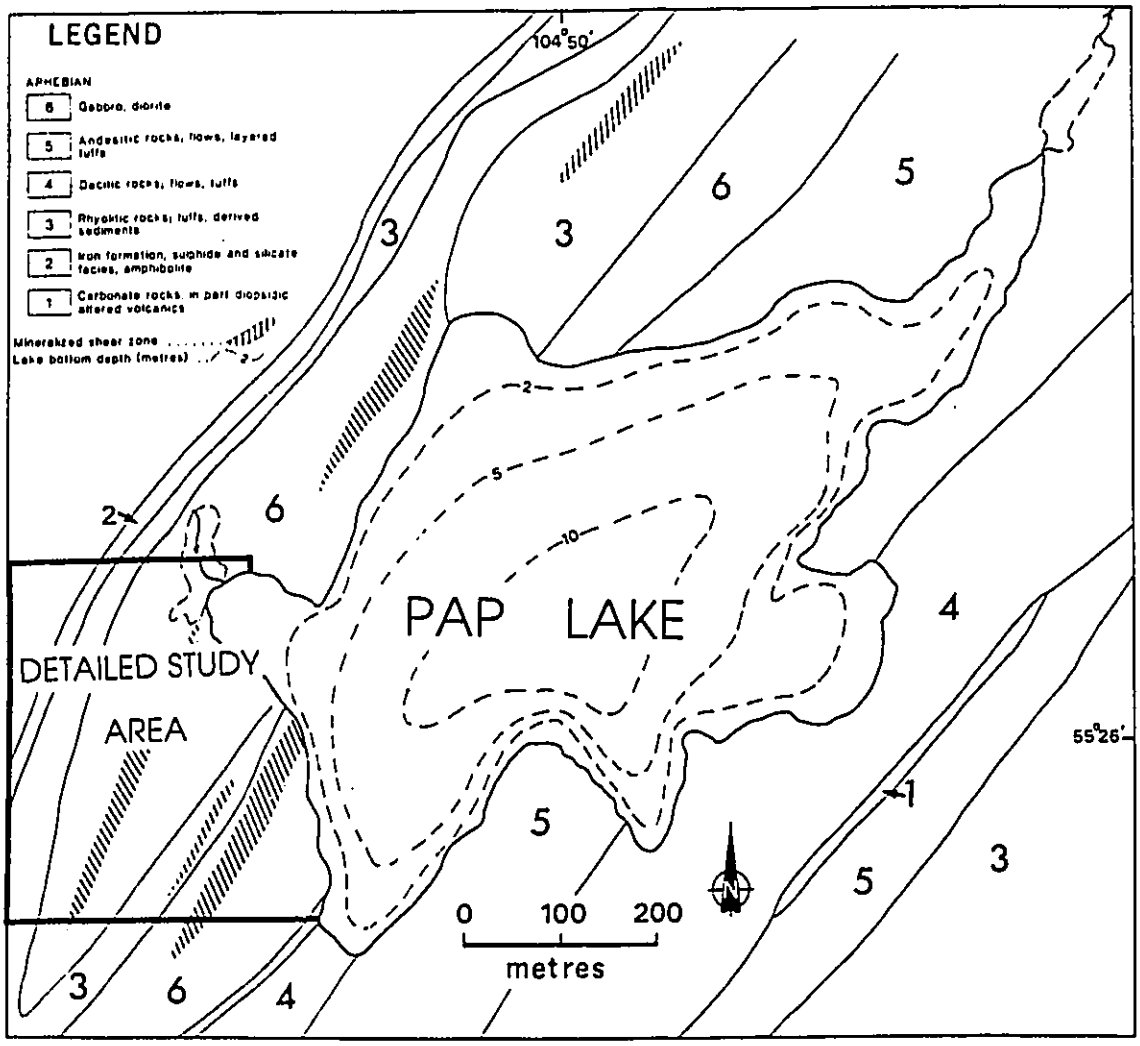


Figure 5. PAP Lake; Geology and location of detailed study area.

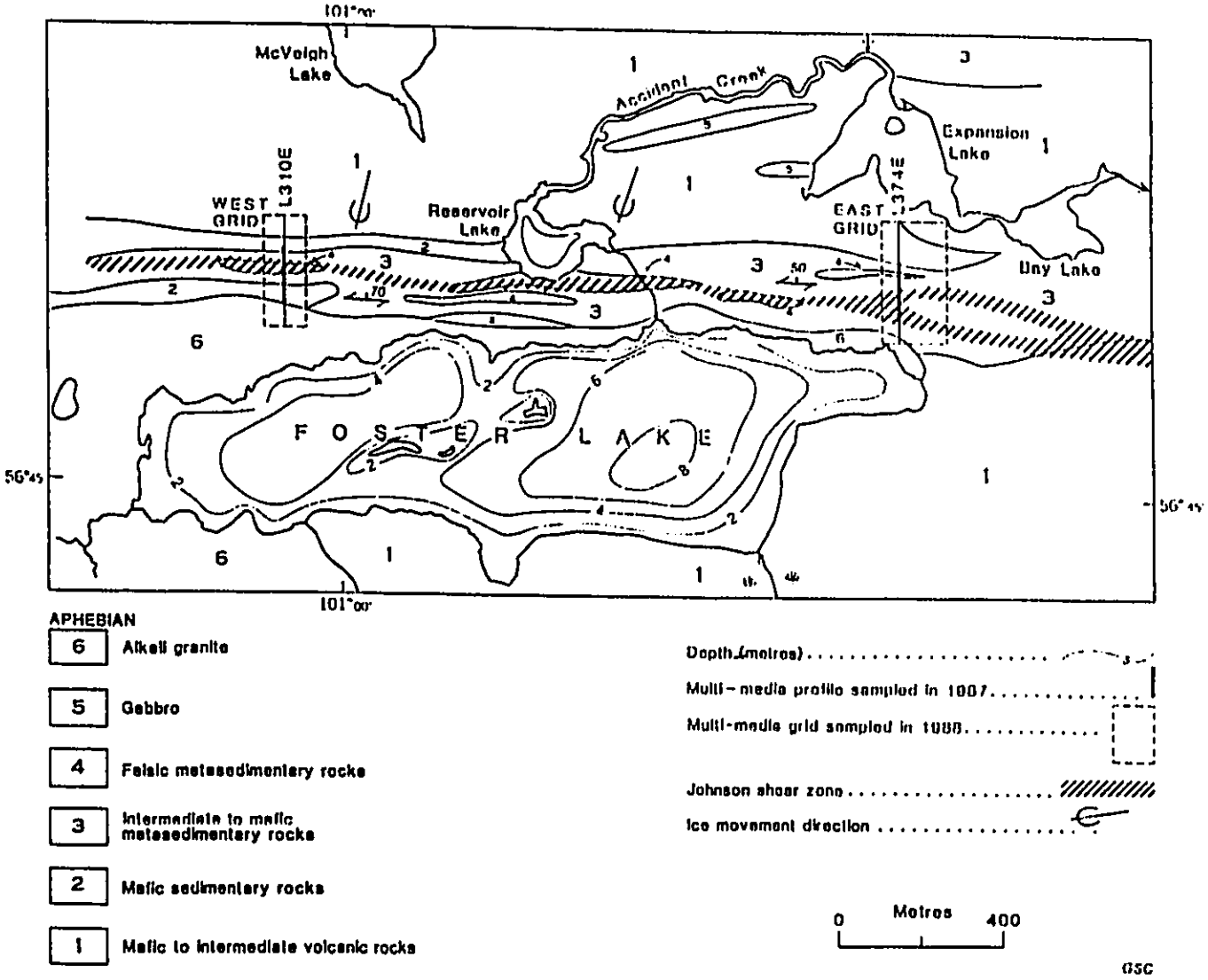


Figure 6. Foster Lake; Geology and location of west and east grid detailed sampling areas

characterization of till, and elucidation of ice-flow history and supergene chemical processes will aid interpretation of dispersal patterns.

Table 1 summarizes Au content in till for all areas in the <.063 mm (- 250 mesh) and heavy mineral (s.g. >3.32 g cm^{-3}) fractions. There is a consistent geographic correspondence between the distribution of Au in both till fractions which reflects the primary influence of glacial dispersal. The Au content of these two till fractions is compared in Figure 7. For a total sample population, n= 90, there is a strong positive correlation, r= 0.87 between the two analyses on different fractions of the bulk till sample, with significant proportions of both fractions containing Au contents well above detection level. Since Au in both sample types has a common origin, the degree of scatter on the charts may indicate different dispersal processes, particulate influence, or different mineralogical habits of Au in the two fractions. For example a greater amount of particles with occluded Au in the <0.063 mm fraction may not be represented in the heavy mineral fraction. For the explorationist, it may be more cost-effective to sample and analyze the <0.063 mm fraction, following up results with selective heavy mineral analyses if further source definition or mineralogical data are required. To facilitate some choice in analytical strategy the collection of a bulk sample of minimum 5 kg is recommended.

At Napier Lake, tills sampled were dark brown, pervasively oxidized, calcareous lodgement tills up to 140 cm thick. They contain a high proportion of clay and sand size particles with <10% subangular stones and cobbles of local origin. A total of eight till sites were sampled at intervals of 15 - 30 m along two lines 100 m apart straddling the main area of exposed mineralization (Fig. 8). The highest Au values in both analyzed fractions occur immediately overlying and adjacent to the mineralized zone. The range and mean Au content in both till fractions are listed in Table 1. Gleeson et al. (1984) had previously determined similar Au values in till at the local scale (<.063 mm fraction, mean 22 ppb; HMC fraction, mean 106 ppb) in the

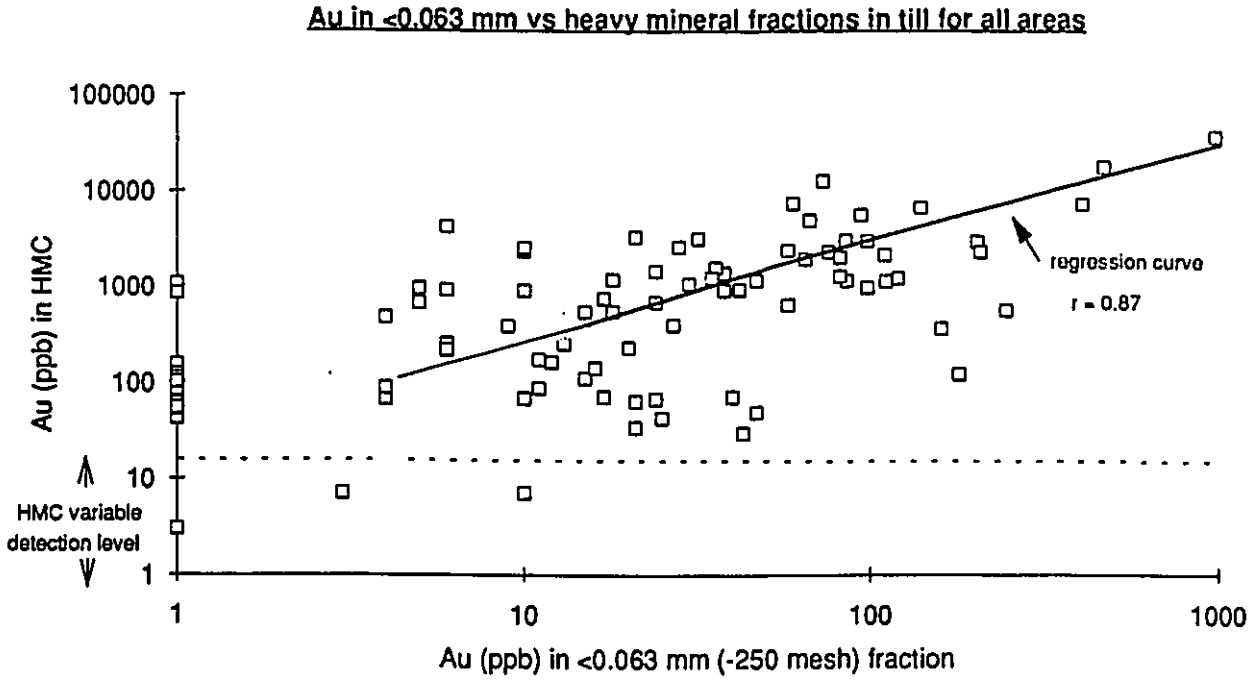


Figure 7. Comparison of Au (ppb) concentration in two till fractions.

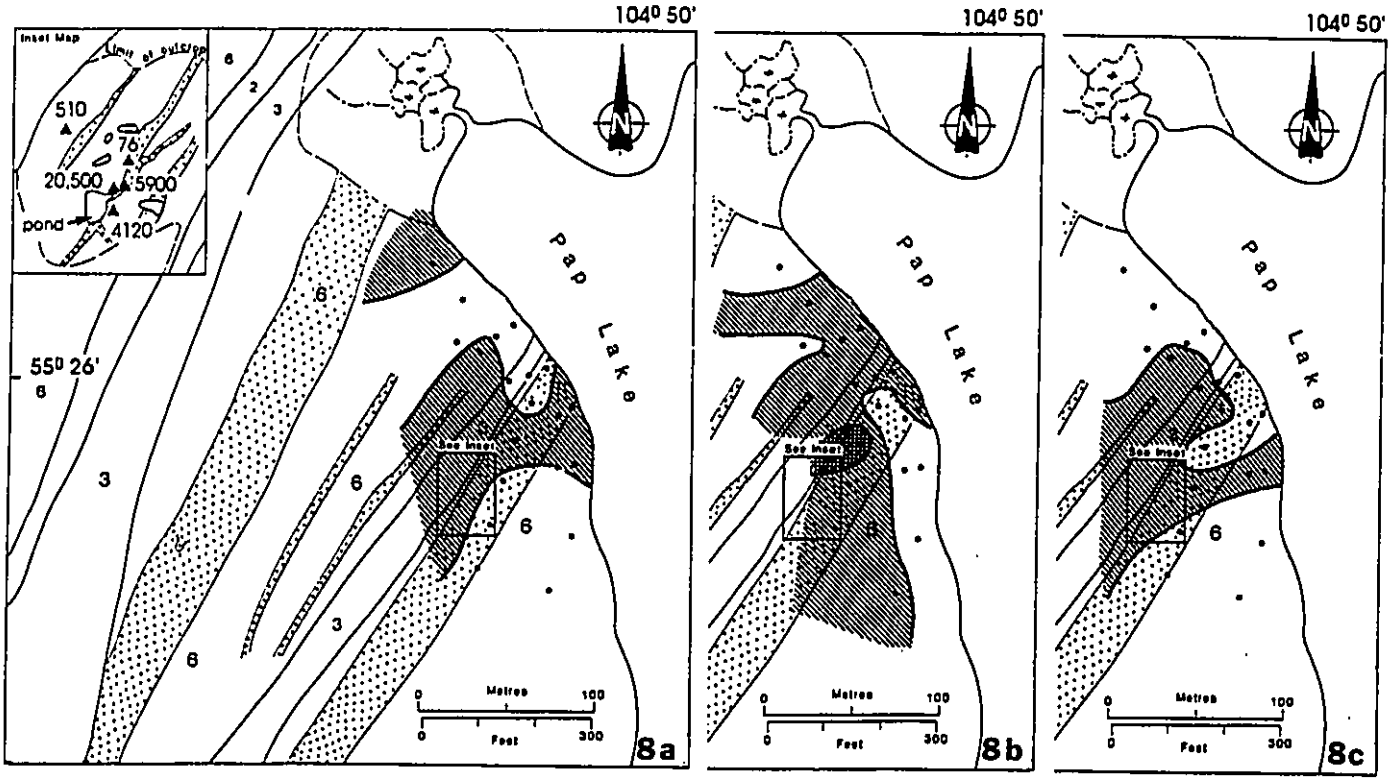


Figure 8. PAP Lake distribution of Au in till, contour interval for shaded pattern; 8a) Au (>200 ppb) in <0.063mm till fraction; 8b) Au (>2000, >5000 ppb) in HMC till fraction; 8c) Au (>20 ppb) in ashed spruce twigs. Inset box outlines- Au (ppb) in rocks, veins (solid triangles) from main exposed shear zone, stipple pattern indicates auriferous-quartz-carbonate shear zones (see Plates 1 - 3).

Little Green Lake area 2 km north, based on sample spacing of 100 m. They concluded that down-ice dispersal was mostly in the range of 60 to 100 m, which is consistent with this study's observations. Arsenic, Sb and W display similar low contrast dispersal in both fractions of till analyzed from the Napier Lake area although their behaviour as indicator elements is shown to be inconsistent (Fig. 2a).

At PAP Lake the tops and flanks of ridges are mantled by up to 150 cm thick veneer of orange-brown to medium brown-coloured clayey to subangular cobble-bearing till of local origin, overlain by immature brown podzols and grey-brown luvisols. Till is oxidized to varying depths, although completely un-oxidized tills are rare. Till samples were collected from twenty-two sites adjacent to the moderately steep, west shore of PAP Lake at 20 to 50 m intervals over 1.6 ha straddling the main auriferous shear zone (Fig. 8). Ice movement directions in this area are south-southwest, almost parallel to the shear zone strike, but appear to be deflected southeast by the abrupt shoreline relief.

Gold concentrations are highest in both till fractions from samples overlying and immediately down-ice of the shear zone, with a correlation of $r = 0.93$ between Au contents in both fractions. The range and mean Au content of the two till fractions is listed in Table 1. The highest HMC Au value, 20,500 ppb, occurs 50 m northeast and downslope of exposed mineralization. Coker et al. (1982) in an earlier regional till survey had determined an arithmetic mean Au content of 3.8 ppb in the <0.1 mm fraction ($n=550$ from sampling area of 4000 ha). The total suite of till analyses for this study can therefore be considered highly anomalous compared to regional values, and the lowest values not representative of regional background.

In an attempt to improve on the display and interpretation of Au dispersion, HMC Au contents were normalized to a mean concentration factor (weight of table feed divided by weight of HMC) of 1000 (range 625 - 1627, mean 1087) after the technique described by Sopuck et al. (1986) for non-magnetic HMC from till. Examination of

plotted adjusted Au values reveals essentially no change in the Au dispersion pattern, although less geochemical contrast is apparent because of the smoothing effect.

PAP Lake till samples exhibit a strong positive spatial and statistical correlation between As and Au concentrations, with a correlation coefficient of 0.8 in the <0.063 mm fraction and correlation coefficient of 0.85 in the HMC fraction (Fig. 9). Outliers have not been trimmed for these regression curve calculations. Despite an ambiguous enrichment/depletion relationship displayed in Figure 2, there is good reason to consider As as a reliable indicator of Au mineralization at PAP Lake based on mineralogical examination. This is shown in Figure 10 where electrum grains ranging from <2 μm to 20 x 5 μm in size are shown occluded on the surface of an intensely oxidized arsenopyrite grain separated from till overlying quartz-arsenopyrite veins. With further oxidation and physical movement, the electrum particles could become separated from the arsenopyrite grain, further attenuated, and smaller individual particles dispersed through surficial materials and made available to other epigenetic dispersion processes. The local origin of auriferous arsenopyrite, and short transport distances reinforces the strong statistical and geographic correlations despite inconsistent enrichment trends displayed for progressively altered host rocks in Figure 2b.

At Foster Lake lodgement till up to 2 m thick occurs as a discontinuous veneer. Till coloration and relative clast size composition are variable, ranging from predominantly medium orange-brown clayey to sandy cobble-bearing tills to localized tan, coarse matrix-supported sandy ablation tills. Boulder lag overlies till along the southern grid margin. Oxidation depth is variable but commonly extends to bedrock. A total of fifty-seven till sites were sampled for sixty-three samples, at 20 - 30 m intervals along N-S lines spaced about 65 m apart, from two grids located north of Foster Lake (Fig 6). The west grid (twenty-seven sites) straddles a forested topographic high representing the Johnson Shear Zone (JSZ) which slopes gently to the north and south.

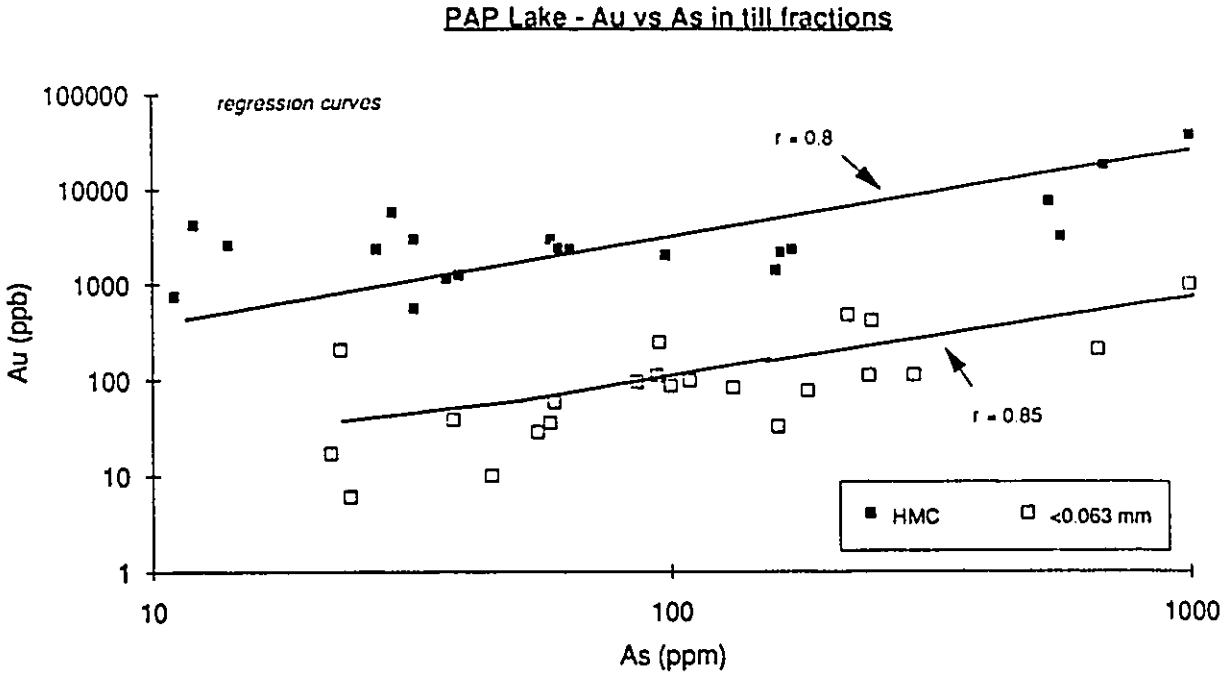


Figure 9. PAP Lake Au (ppb) vs As (ppm) in both till fractions.

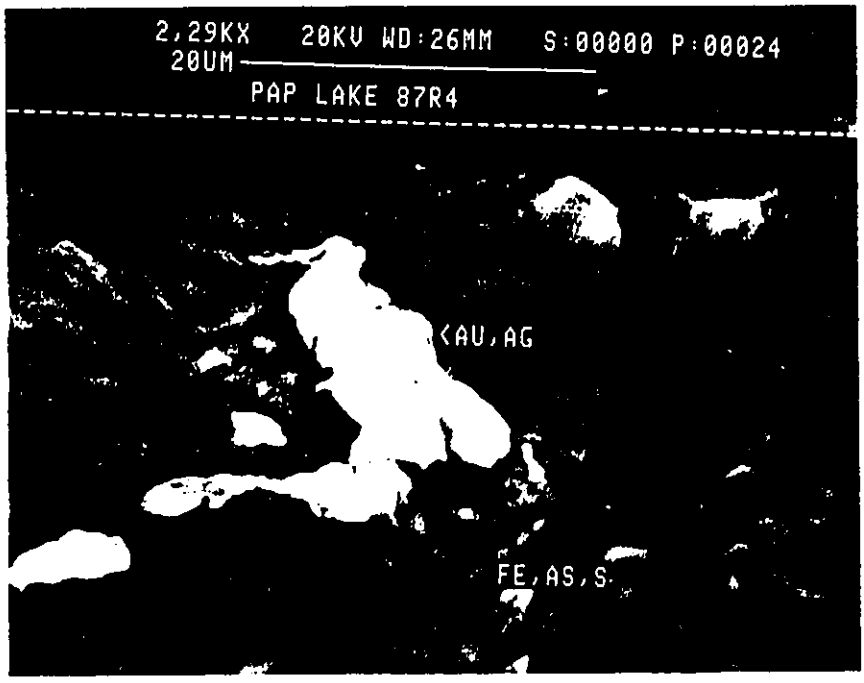


Figure 10. Scanning electron microscope image of primary electrum on oxidized arsenopyrite, separated from till overlying the main PAP shear zone.

The east grid encompasses a lowlying forested area interspersed with bogs, bordered by Foster and Expansion Lake on the south and northeast, and two northeast-trending eskers at the northwest and southeast margins. The interconnected bogs drain northeast towards Expansion Lake, obliquely across one strand of the JSZ. Till is discontinuous and overlain by boulder lag deposits near the lake margins and peat deposits in bog areas.

Included in the fifty-seven sites sampled are five sites with stratified samples comprised of a lower till sample at the bedrock surface and an upper till sample 0.3 to 1.0 m higher. The position of the upper sample was determined by a visible change in oxidation intensity in the profile. Analyses confirmed the lower sample position to be more effective. The range and mean Au concentration of the sixty-three analyses on the two till fractions are summarized in Table 1. Values are comparable to the range (1 - 15,000 ppb) and mean (299 ppb) contents of Au determined for two hundred and sixty-five non-magnetic HMC (s.g. >2.96 g cm^{-3}) by Nielsen and Fedikow (1987) down-ice of the MacLellan Au deposit situated 22 km north, and Au contents determined from two hundred and eleven total HMC samples (max 20,300 ppb; mean ca. 200 ppb) by Brereton et al. (1988) at the Farley Lake Au deposit 36 km northeast. All three Au deposit areas are hosted by Wasekwan Group rocks in the Lynn Lake greenstone belt and there would appear to be some similarity in Au concentrations dispersed into surficial deposits.

Figures 11a and 11b show that Au at Foster Lake is noticeably dispersed down-ice particularly over the west grid where terrain and till conditions are more uniform and a prominent ribbon-like dispersal pattern extends for over 150 m down-ice in the $<.063$ mm fraction. The east grid displays less prominent dispersal patterns because of the varied geomorphology and masking by organic deposits. Gold dispersal in both fractions is truncated on the up-ice side of Au-bearing shear zones. Gold in the HMC fraction shows similar, but less prominent down-ice dispersal patterns and additionally

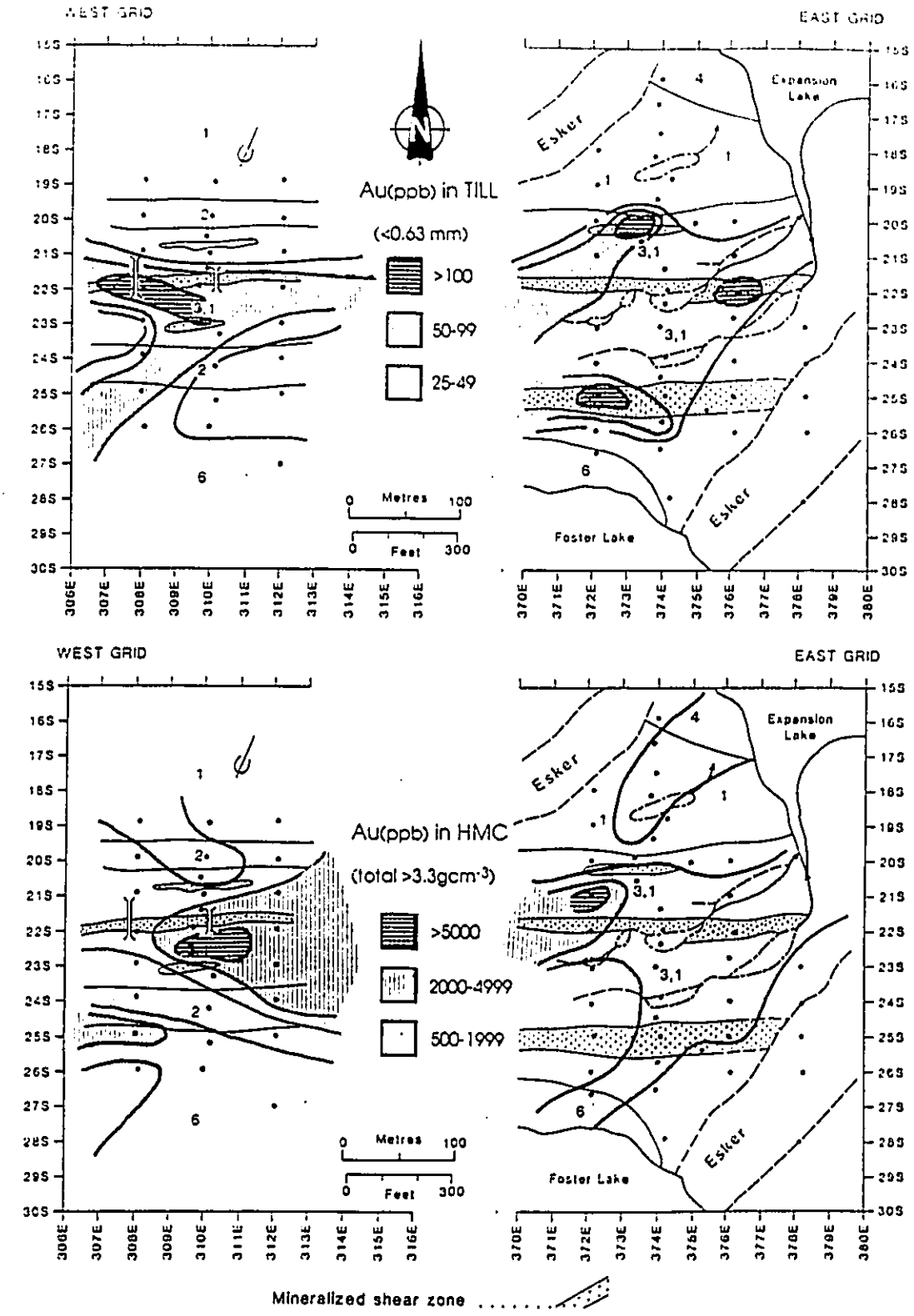


Figure 11. Foster Lake; Au (ppb) in <0.063mm and HMC till, east and west grids.

suggests that further mineralization may occur in the up-ice direction. In the east grid HMC Au content from eskers range from < 14 to 423 ppb (mean 100 ppb) suggesting that esker formation could have eroded and entrained pre-existing Au-bearing till in the manner of processes described by Drake (1983). A comparison of gold values in both till fractions from the Foster Lake area show a weak statistical correlation (r= 0.36), in part reflecting the high proportion of analyses less than detection level in the <0.063mm fraction (Fig. 12a). Figure 12a also shows the regional mean Au concentration in similar till fractions relative to the Foster Lake area illustrating that most of the Foster Lake tills are highly anomalous in Au on a regional basis.

Copper, Zn, Ag, Sb, Pb and W have been identified as indicator trace elements of auriferous mineralization at Foster Lake (Fig. 2c). Arsenic, while not showing consistent enrichment with progressive mineralization, has been used by explorationists as a possible indicator of gold mineralization. Upon examination, the concentrations and dispersal patterns of all indicator elements in till are variable however. This may reflect selective redistribution of trace elements by groundwater, capillary action, volatile diffusion or biogenic processes (Clark, 1992). Examples of the variability between Au and its indicator trace elements is shown in Figures 12b and 12c for Au-As and Au-W in HMC. Data suggest that the reliability of As as an indicator of gold mineralization be used cautiously, with reference to the As and Au geographic distribution for interpretation. However as a general rule, till samples highly anomalous in Au also contain elevated concentrations of associated chalcophile and resistate trace elements detected in bedrock mineralization.

Information on the source region of Au in HMC till fractions can be obtained by microscopic examination of discrete Au grains. Figure 13 displays a 105 μm long Au grain separated from the HMC fraction of a basal till sample at 373E/20.5S. The Au grain underwent limited transport from its bedrock source as suggested by the overall delicate shape modified by rounding of small protuberances, pockmarking and faint

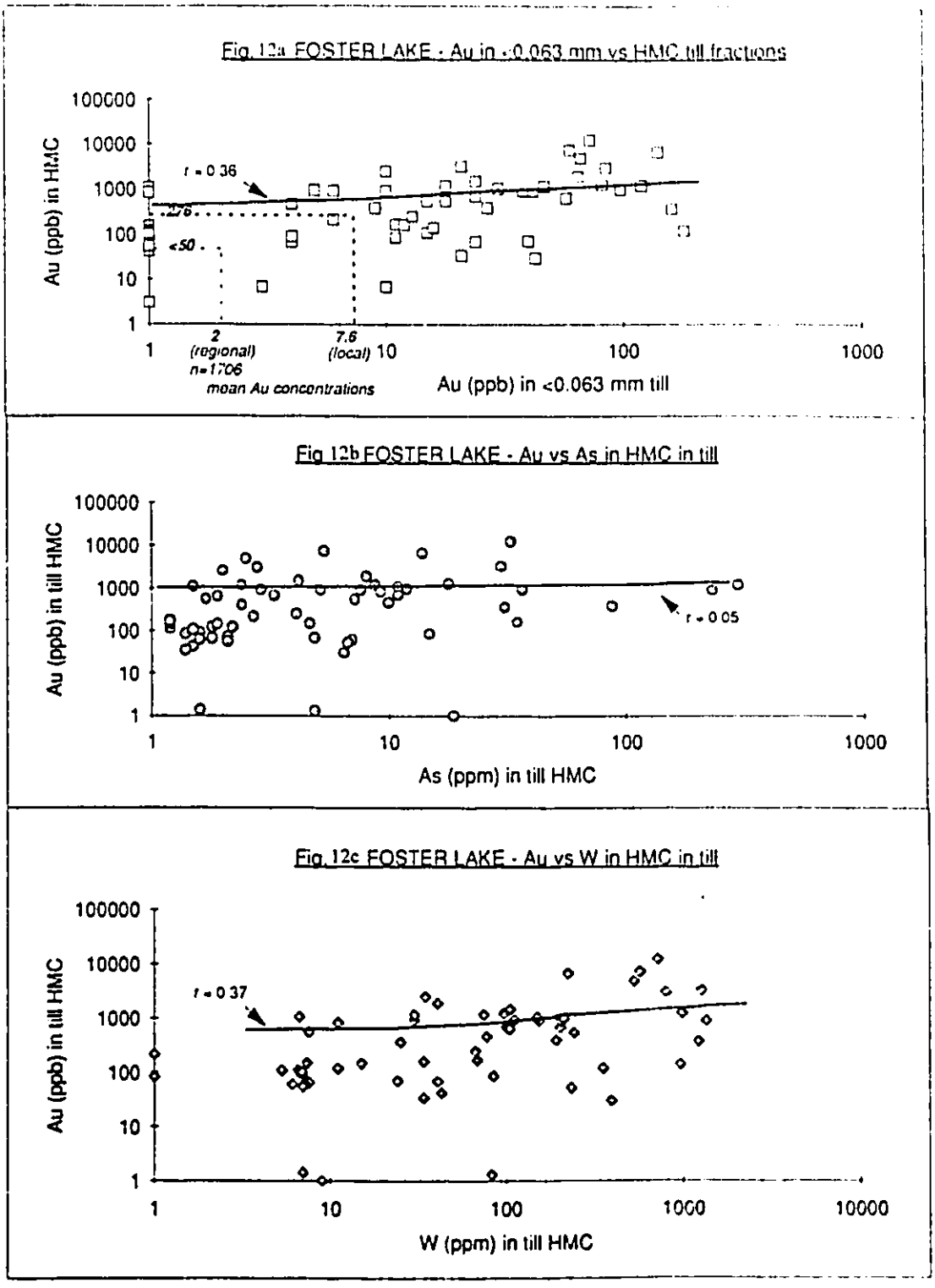


Figure 12. Foster Lake; 12a) Comparison of Au concentrations in both till fractions; 12b) Au vs As in HMC in till; 12c) Au vs W in HMC in till.

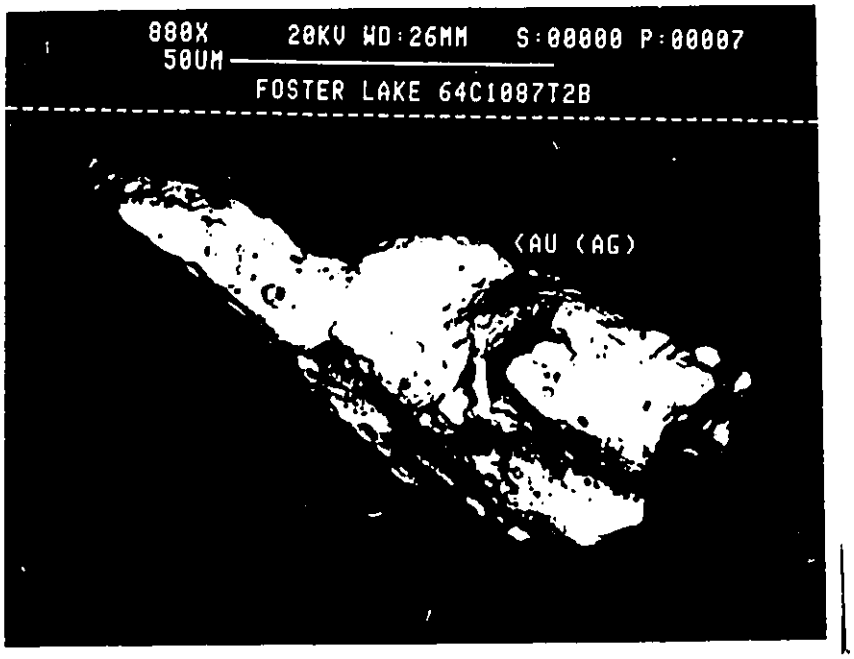


Figure 13. Foster Lake; Scanning electron microscope image of a Au grain separated from till sample 87T2B at L374E, 20.5S. The grain exhibits slight modification of surface morphology indicating < 100 m transport.

striations. Compared to the more delicate morphology of the electrum grain in Figure 10, which has undergone no transport from its source, the features in Figure 13 are consistent with a transport distance of < 100 m based on Averill's (1988) observation of Au grain morphology from over 50,000 till samples. The Au grain size also provides important information for selecting a non-HMC till fraction for exploration; finer size fractions may miss locally derived coarse Au, whereas coarser size fractions may result in lower geochemical contrast in order to capture coarse Au grains.

4.5.2b Humus and Vegetation: Humic soils, also called humus, and perennial vegetation can provide cost-effective and productive methods for gold exploration. Vegetation draws its nourishment from the underlying substrate, and depending on species type, rooting structure and local conditions may act to integrate the chemical composition of many cubic meters of rock, till, soil and humus. Some plants establish barriers to metal uptake and so there is often not a direct proportional expression of high metal contents in soil and till in the vegetation (Dunn, 1992). Humic soils represent oxidized, decaying vegetation and minor amounts of mineral sub-soil. Complex metal-organic interactions occur in vegetation root zones and humic soils which may act to enhance or inhibit trace element mobility.

Humus samples were collected over till pits at Napier and Foster Lake (Fig. 4 and 14a). Spruce twigs were collected at Foster and PAP Lake while Au biogeochemical studies utilizing maple leaves were recently reported by Banville (1987) for the Napier Lake area. All the reported values are normalized with respect to loss-on-ignition (LOI). Table 1 summarizes Au data for these sample media.

At Napier Lake the highest values occur within 20 m of the mineralized zone declining gradually in the down-ice direction. Gleeson et al's (1984) humus survey in this area measured Au contents up to 69 ppb, with similar dispersion patterns down-ice of both the main auriferous zone and the gabbro - sandy dolostone contact. Banville's results for Au in maple leaves over the same area indicate concentrations ranging from

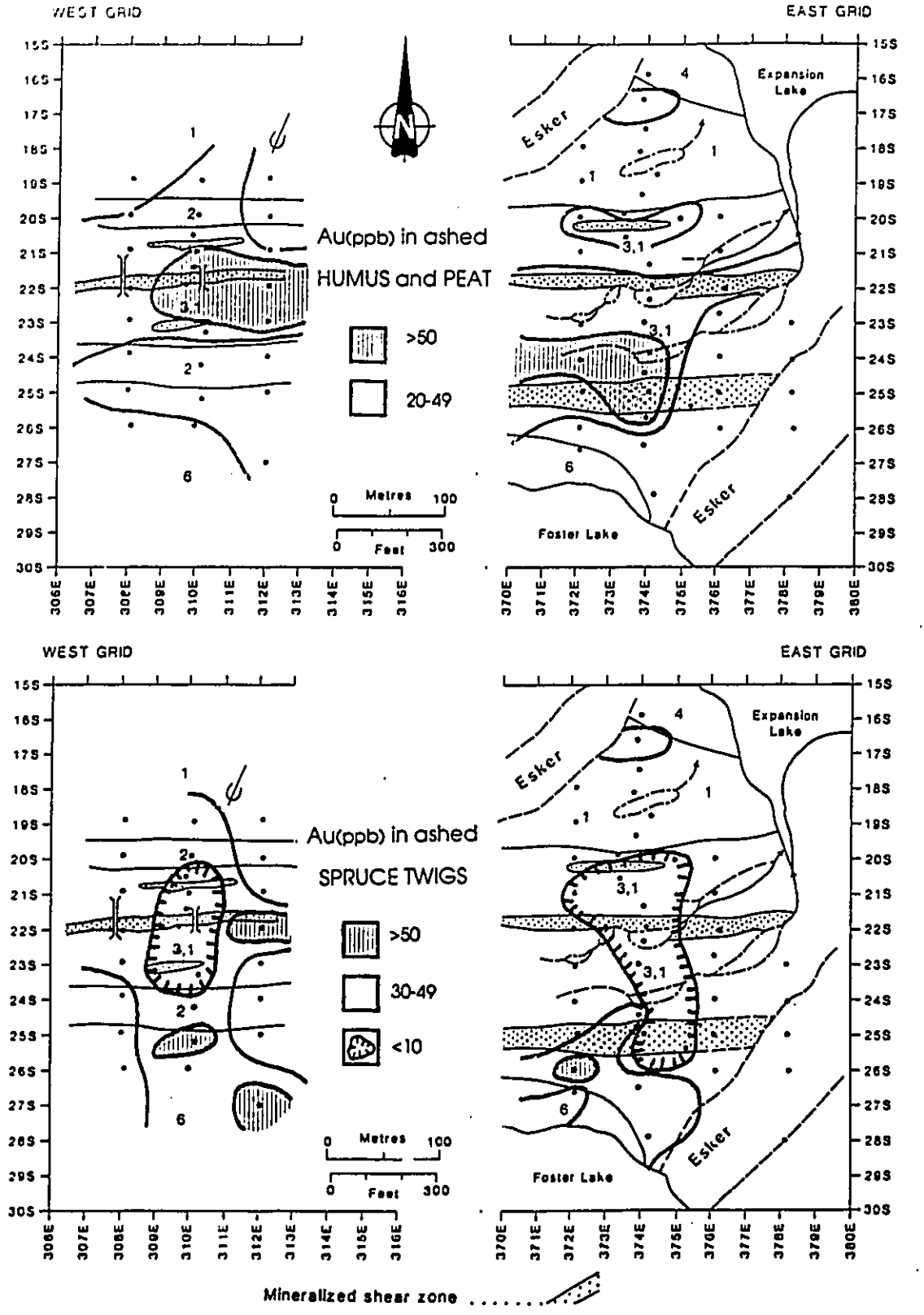


Figure 14. Foster Lake; Au (ppb) in humus, peat and ashed spruce twig over east and west grids.

3 to 24.5 ppb with a mean of 11.7 ppb. Gold is thus being concentrated in the vegetation over auriferous mineralization and till from which Au-bearing humus is subsequently derived. Anomalous Au in these media are displaced up to 100 m down-ice and downslope from mineralization, suggesting biogenic uptake of Au from till or groundwater.

At PAP Lake the fourteen spruce twig samples (Table 1) contained a mean value of 7.1 ppb Au.. These values are comparable to results reported by Dunn (1986) and Chapman (personal communication, 1991) for Au mineralized areas elsewhere in the LaRonge Domain of Saskatchewan. Fig. 8c shows that the highest values occur immediately over the main shear zone, although samples within 30 m of the lake shore are comparatively lower in Au. The suppressed Au response close to the lake may reflect lower availability of Au in underlying till as determined in the $<.063$ mm till fraction (Fig. 8a), or dilution of metal-uptake because of the perennial wetness of the site. Abundant decaying vegetation along the shoreline of PAP Lake provide low concentrations of organically-bound Au for incorporation into lake sediments. At PAP Lake, As and Sb are enriched in spruce twigs along with Au, reflecting their close relationship in bedrock mineralization and dispersion in till.

The distribution of Au in sixty-one humus and peat, and sixty-seven spruce twig sample sites at Foster Lake are shown in Figs. 14a and 14b and concentrations summarized in Table 2. Highest concentrations occur over auriferous shear zones with intervening zones of lower values. The distribution of Au in till at Foster Lake, is weakly reflected in the uptake and concentration of Au in humus on a site by site basis (Fig. 15).

Gold contents in ashed spruce twigs at Foster Lake range from <5 to 125 ppb with a mean of 17 ppb. Anomalous values over and down-ice of mineralized shear zones are displaced somewhat from elevated Au in till (Fig. 14b). Over the central part of both grids Au analyses from spruce twigs collected in 1987 define a relative zone of

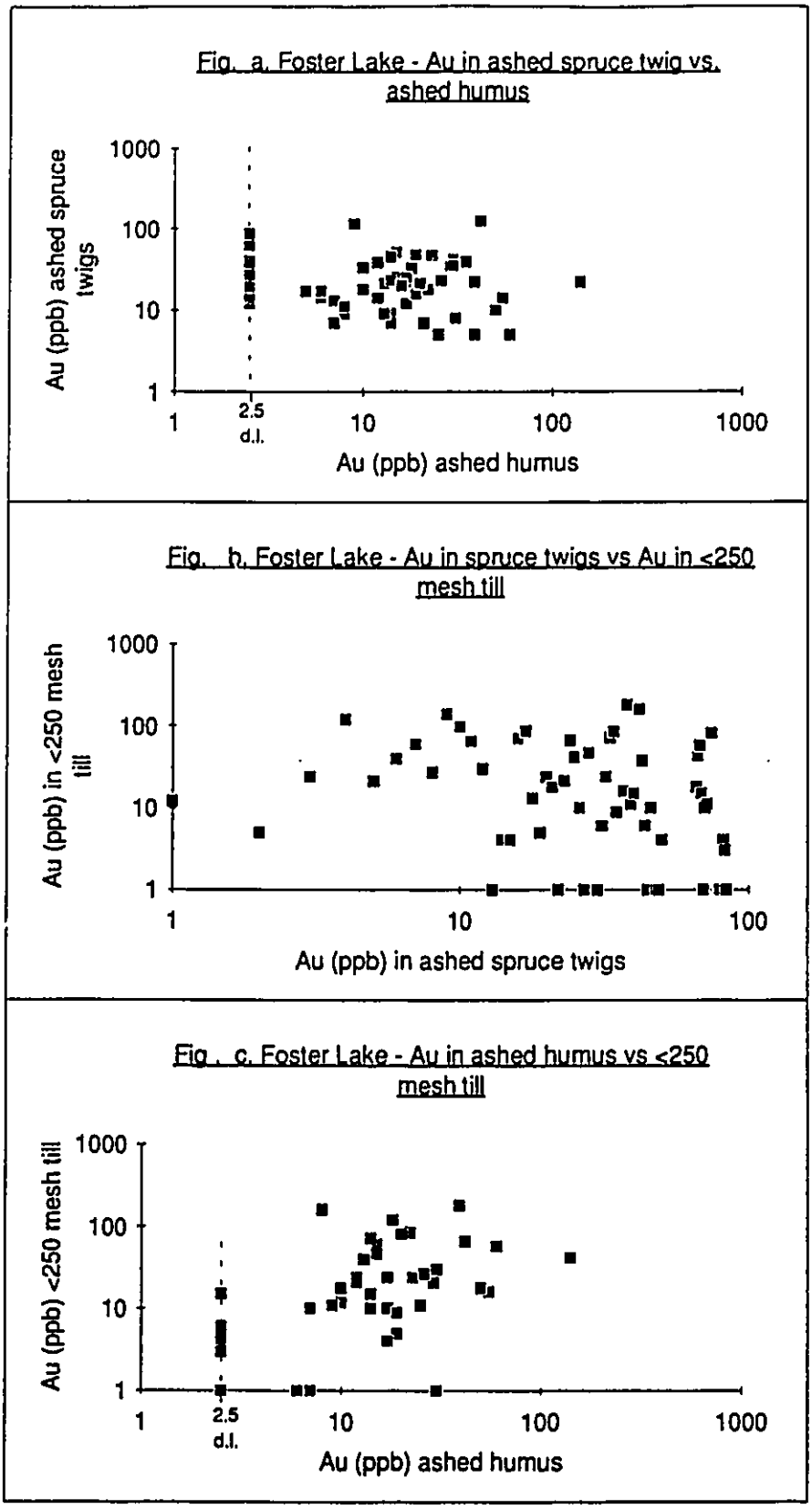


Figure 15. Foster Lake; Comparison of Au concentrations in ashed spruce twig vs ashed humus (15a), ashed spruce twig and <0.063mm till fraction (15b), and ashed humus vs <0.063 mm till fraction (15c).

depletion with Au < 10 ppb, compared to analyses performed on samples collected during the same time of year in 1988. Au contents are about 20 - 30 ppb lower for 1987 samples over the west grid, and about 5 - 10 ppb lower for 1987 samples over the east grid. The differences, confirmed by using similar quality control samples, are attributed to the substantially wetter conditions experienced in 1988 which acted to flush higher concentrations of Au into tree extremities. Dunn (1986) has documented similar seasonal variations for Au in ashed alder twigs and leaves from surveys near Au mineralization in the LaRonge Domain in Saskatchewan.

Figure 15 examines the relationship between Au content of humus, spruce twigs and the <0.063 mm till fraction at Foster Lake. The figure shows a wide scatter for the Au in spruce twigs and humus, as well as spruce twigs and till relationship. The humus - till relationship shows a weak positive relationship. The plots suggest that Au dispersion is a complex process with considerable re-distribution of Au at the local scale, although there is little apparent statistical relationship, and variable geographic coincidence between the different media. On a regional basis, however, Au content of all sample materials is anomalous.

4.6 DISCUSSION AND CONCLUSIONS

The effective application of lake sediment geochemistry to mineral exploration requires that an element be liberated from bedrock, transported and fixed in lake sediments (Timperley and Allan, 1974; Cameron, 1978, 1980; Coker et al., 1979; and Bogle and Nichol, 1981). In recent years, considerable attention has focussed on the application of lake sediment geochemistry to Au exploration. Organic-rich profundal lake sediments often contain anomalous contents of Au in the vicinity of Au-bearing mineralization (Coker et al., 1982; Fox et al., 1985; Rogers, 1988; Davenport and Nowlan, 1989; Schmitt, 1989), suggesting that Au has entered the lake environment and become fixed in these sediments.

The first part of this study has confirmed that Au is being mobilized from bedrock by mechanisms that include: supergene oxidation and dissolution of Au-bearing sulphides; glacial erosion and dispersal including physical comminution; and, biological uptake. Gold released from bedrock is transported through a combination of glacial and post-glacial mechanical dispersal, physical dispersal of vegetation, or uptake and remobilization from humic and organic accumulations.

In the three study areas, Au concentrations up to 40 ppm were measured in quartz-carbonate-iron-sulphur rich shear zones with variable amounts of the chalcophile and other lithophile trace elements. The progressive alteration and mineralization of rock can be documented by consistent depletion and enrichment trends for major oxide and trace elements. Increased silica content and Au are the most consistent indicators of Au mineralization. The silicic nature of shear zones resulted in prominent bedrock forms with mineralized zones being exposed to Wisconsinan glaciation. Lodgement till deposited immediately down-ice contains fragments of shear zone lithologies including Au-bearing sulphides and native Au plucked from primary mineralization and weathered from sulphides under supergene oxidizing conditions. Gold was dispersed down-ice in fan and ribbon-like patterns to attain concentrations of up to 474 ppb in the $<.063$ mm fraction of till, and 18,000 ppb in total heavy mineral concentrates (s.g. >3.32 g cm^{-3}). The range and mean value of Au contents in till are comparable to the results of other regional studies. The distribution of Au in bedrock and in locally-derived till adequately explain the principal sources of Au subsequently dispersed into lake sediments. At PAP and Napier Lake, sulphide grains separated from oxidized till immediately overlying mineralization, and from down-ice, display morphological features that suggest exposure to active oxidation and chemical dissolution processes. Au liberated under these circumstances is available for mechanical or hydromorphic transport, and uptake by plants. Several Au grains separated from till and examined with the scanning electron microscope, exhibit delicate to slightly modified

morphologies, suggesting limited transport from source.

The uptake of Au into vegetation is a well-documented phenomenon in boreal forests (Dunn, 1986a; 1986b). Detectable Au contents in ashed black spruce twigs range up to 30 and 125 ppb from PAP Lake and Foster Lake areas respectively, from directly over auriferous mineralization and Au-bearing till. The values are significant in comparison to other biogeochemical results reported for these regions. Decomposing vegetation contributes to production of humus and associated humic and fulvic acids which can be important local factors in mobilizing and precipitating Au. Gold concentrations up to 372 ppb in ashed humus from the Foster Lake east grid exhibit broader dispersion patterns than the canopy vegetation. This suggests that Au accumulation in humus and peat results from combined biogenic accumulation and remobilization perhaps by Au-bearing surface and groundwaters. Gleeson et al.(1988), for example, have documented similar Au patterns in peat (humus) from the Kirkland Lake area of Ontario, and Clough and Craw (1989) have suggested a link between peaty soils and authigenic Au formation in contemporary placers in New Zealand. In both of these areas, saturated conditions prevail for most of the year. Vlassopolous et al., (1990) indicate that humic acid - Au complexes are insoluble under these conditions serving to fix Au in humus and peat. The choice of humus or vegetation for Au exploration should be supported by a careful appraisal of seasonal hydrological conditions.

Figure 16 displays two down-ice profiles of the distribution of Au in surficial materials at Foster Lake. Both profiles represent a topographic high at 21.5S, with twenty percent exposed bedrock, discontinuous till to 1.5 m thick, poorly developed humus, and immature spruce stands. Although inter-site variability is apparent in Au concentrations, both profiles demonstrate significant erosion and entrainment of Au in the till for a distance detectable for over 150 metres down-ice, and subsequent uptake and dispersion in humus and spruce twigs. The content of Au in these surficial

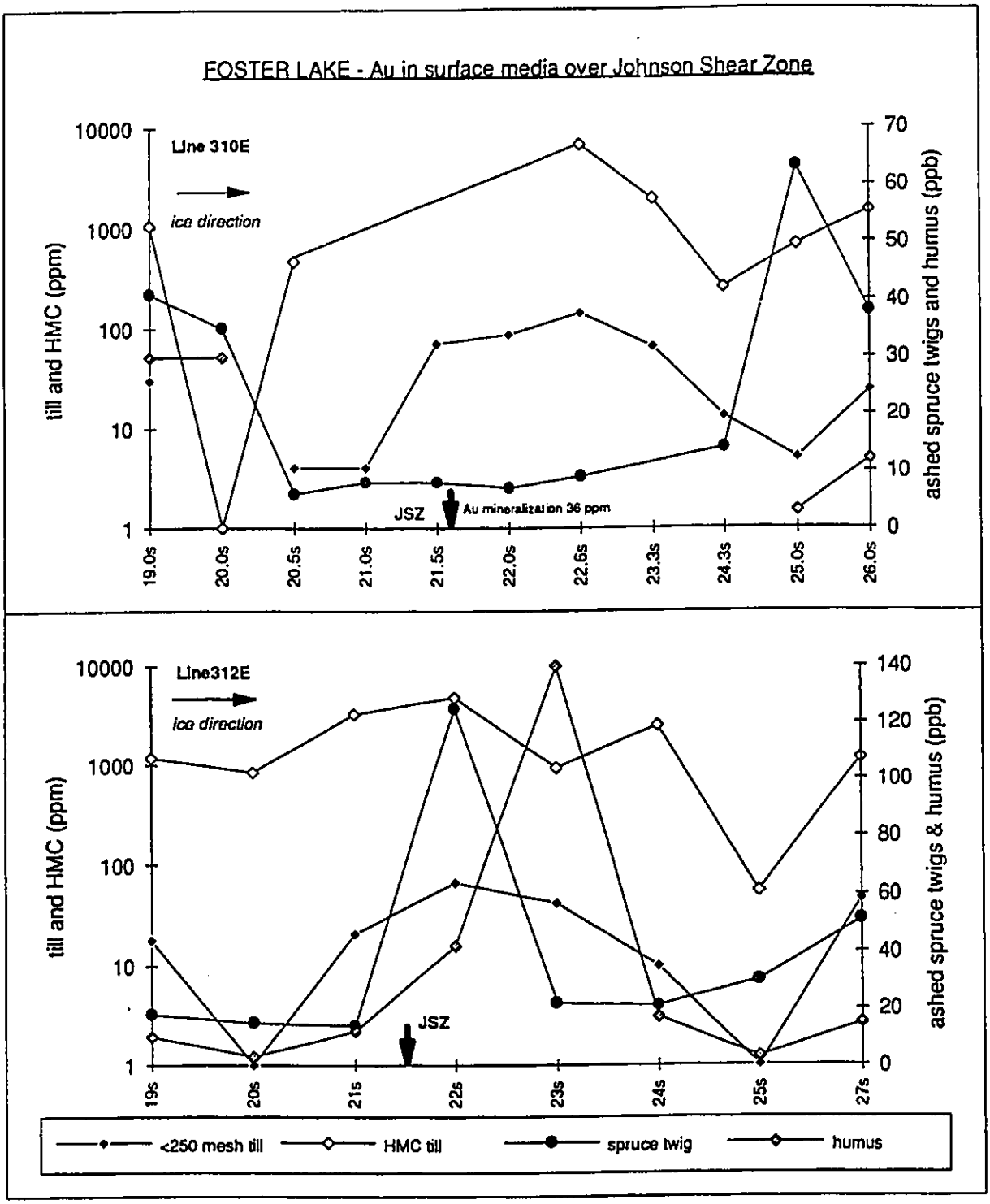


Figure 16. Foster Lake; Down-ice distribution of Au in surficial materials over the Johnson Shear Zone (JSZ).

materials provide a significantly broader exploration target than the bedrock mineralization. Additionally, there is enhanced potential for further distribution of Au by hydrogeochemical and physical methods.

From the initial part of this study it is possible to conclude that:

1) The three study areas contain similar styles of Au mineralization with identifiable major element enrichment and depletion trends associated with the mineralization process and increased silicification. Distinctive trace element associations accompany Au mineralization in each area;

At Napier Lake, Au mineralization is accompanied by consistent enrichment of B (tourmaline alteration) and Sm, and significant but variable enrichment in Cu, Mo,As and Ag.

At PAP Lake, Au mineralization is accompanied by consistent enrichment of Ag, with variable but significantly enriched Cu, Mo, Pb, B and As.

Foster Lake Au mineralization sampled at various locations along the Johnson Shear zone exhibits consistent enrichment in B, Cu, Zn, Ag, Sb, Pb and W.

2) Similar glacial and post-glacial weathering processes at all areas have liberated and dispersed Au from bedrock and concentrated it to anomalous levels in till, peat, humus and spruce twigs. There is a strong statistical correlation for Au in the <0.063mm and heavy mineral fractions of till analyzed. This relationship reflects the common local source of the Au as well as an indication that at least some of the HMC fraction may be <0.063mm. Trace elements exhibiting positive enrichment in bedrock are likewise positively correlated in till, although the relationships are variable, suggesting gradual, and perhaps selective, redistribution by physico-chemical processes. Both the geographic and statistical relationship between Au itself in different surficial media, and between Au and its indicator trace elements need to be examined to fully characterize the dispersal patterns and to identify exploration guides to sub-cropping mineralization. Au distribution in vegetation and humus suggests further redistribution

by biogenic and hydromorphic processes, but spatial relations are still strongly detectable.

3) Microscopic examination of auriferous sulphides and particulate Au in the heavy mineral fraction of tills provides evidence for the nature of dispersion processes and effects of chemical weathering; and

4) The dispersion processes and patterns provide adequate sources of Au for further mobilization into hydrologic environments and drainage sediments.

5.0 CHAPTER FIVE :

MOBILIZATION OF GOLD INTO LAKE SEDIMENTS FROM ACID AND ALKALINE MINERALIZED ENVIRONMENTS IN THE SOUTHERN CANADIAN SHIELD:

PART B. GOLD IN LAKE SEDIMENTS AND NATURAL WATERS

5.1 ABSTRACT

To be an effective indicator of mineralization in lake sediment surveys within the Canadian Shield it is necessary that an element migrate in solution or adsorbed on suspensates. Given the low relief and disorganized drainage patterns of this region, dispersal in clastic form in drainage systems is limited and gives rise to erratic distributions. The purpose of this part of the study was to discover whether Au shows significant hydromorphic mobility, which would justify the increasing use that is being made of this element and geochemical detection methods in gold mineralization in the Canadian Shield.

Waters and lake sediments were collected from Napier Lake, Ontario; PAP Lake, Saskatchewan; and Foster Lake, Manitoba, all of which contain Au-quartz vein mineralization and lie within the glaciated boreal forest zone of the Canadian Shield. In all three areas, lake-bottom sediments down-drainage of mineralization contain Au concentrations substantially higher that regional mean concentrations. Significant dissolution and transport of Au was found under oxidizing conditions associated with waters with pH that varied from acid to alkaline. Waters from drill holes penetrating mineralization contain up to 401 ng L^{-1} Au (note 1 ng L^{-1} is equivalent to 1 part per trillion, 10^{-12}). Surface waters overlying or near mineralization collected from bogs, seeps, ponds and streams contain up to 13 ng L^{-1}. The content of Au in lake waters is

lower, with a maximum of 1.1 ng L^{-1}. There is also a detectable quantity of Au present in suspensates. Two samples of particulates(> 1 μm) filtered from lake water have Au equivalent to 0.17 ng L^{-1} and 0.039 ng L^{-1}. While the contents of Au present in solution or as suspensates in lake and stream water are relatively small, they are sufficient, if precipitated, to generate anomalies in lake sediments. Thus for Reservoir Lake, in the Foster Lake area, water from the principal stream entering Reservoir Lake carries 0.3 ng L^{-1} Au. This provides an annual flux which far exceeds that required to generate the 7.3 ppb Au contained in centre lake-bottom sediments of this lake; a content that is anomalous relative to the regional median content of < 1 ppb Au for lake sediments.

Hydrogeochemical prospecting involving analysis for Au is one method for tracing the source of anomalous Au in lake sediments. Collection of 1 L samples without field treatment, followed by extraction of Au into MIBK, then analysis by graphite-furnace atomic absorption spectrophotometry, permits detection levels for Au of 0.5 ng L^{-1}. This is below the contents of Au found in some waters from mineralized areas. A detection level of 0.3 ngL^{-1} was obtained using larger water samples.

5.2 INTRODUCTION

Lake sediment geochemistry has been applied to exploration for Au in the Canadian Shield and the Appalachian Fold Belt. Au dispersal has been documented from mineralization into nearby lake bottom sediments (Coker et al., 1982), and with subsequent improvements in analytical methods, low-cost analyses for Au are now routinely incorporated into National Geochemical Reconnaissance (NGR) (Friske and Hornbrook, 1991) and mineral exploration lake sediment surveys in Canada.

Hydrogeochemical exploration for gold has received attention for many decades (Boyle, 1975). Since the early 1960s improved methods of thermodynamic modelling (Cloke and Kelly, 1964; Lakin et al., 1974; Webster, 1986; Renders and Seward, 1989; and Vlassopoulos and Wood, 1990) and improved analytical techniques (Brooks et al., 1981; Hamilton et al., 1983; McHugh, 1984; and Hall et al., 1986) have combined to allow reliable prediction of stable inorganic Au-complexes in natural waters, and advanced our understanding of Au-organic complexation phenomena (Baker, 1978, 1986; Schnitzer, 1986; and Vlassopoulos et al., 1990). Research into the contribution of Au transported in natural waters to the depositional sites of lake sediments is critical to improve the methodology and interpretation of lake sediment surveys for Au. This chapter focuses on hydrogeochemical and lake sediment data from a more extensive multi-media geochemical study concerned with pathways contributing to Au accumulation in lake-bottom sediments. Detailed descriptions of the study areas and results for surficial media are reported in Chapters 2,3, and 4. The objectives of this part of the study were to determine Au concentrations in surface and groundwater adjacent to mineralization and lakes with elevated concentrations of Au in lake bottom sediments. This was done in areas where surface waters were acid and for areas where surface and groundwaters were alkaline. The study also provided an opportunity to test analytical methods for Au in natural waters developed by Hall et al. (1986).

5.3 STUDY AREAS

The three areas selected for field studies were: Foster Lake, Manitoba; PAP Lake, Saskatchewan; and Napier Lake, Ontario, all within the boreal forest zone of the southern glaciated Canadian Precambrian Shield (Chapter 2, Fig. 1, 2). All areas contain Au-quartz vein mineralization in metamorphosed Proterozoic supracrustal sequences, mantled by a veneer of mixed glacial and post-glacial surficial deposits. The areas have contrasting hydrogeochemical environments. Foster Lake and PAP Lake areas have neutral to acidic surface waters, with alkaline subsurface waters. Napier Lake area has neutral to alkaline surface waters. Lake bottom sediments from all three areas are elevated in Au, suggesting Au transport from nearby mineralization (Coker, 1981; Coker et al., 1982; Kharouba, 1987; Geological Survey of Canada, 1986, 1989). Mineral exploration disturbance was negligible to slight, making contamination of the environment unlikely. The study areas are described in detail in Chapter 2.

5.4 SAMPLING AND ANALYTICAL METHODS

5.4.1 Lake Sediments:

Lake sediments were collected from multiple sites in larger lakes, and from one to three sites in smaller lakes and ponds (Plate 10). The samples provide information from nearshore (< 1m depth) and profundal (central basin) sediments. Samples were analyzed in groups of twenty that contain several field duplicates, a random control reference position, and a blind duplicate sample position (one sample is split and analyzed twice). The sample design was similar to that used by the Geological Survey of Canada in reconnaissance surveys (Friske and Hornbrook, 1991), except that a higher proportion of field duplicates were collected.

A total of seventy-seven lake sediment sites were sampled from an inflatable boat or canoe using the Geological Survey of Canada's 1976 model lake sediment sampler (Coker et al., 1979), the same as used on National Geochemical

Reconnaissance surveys (Plate 11). The torpedo shaped sampler was allowed to drop freely from the surface into the substrate to penetrate a variable depth, generally 0.5 to 1.5 m, depending on the proportion of clastic to organic material of the sediment. Organic-rich sediments generally permitted greater sampler penetration. Where field duplicates were collected, or more than one sampling attempt was necessary for adequate material, drift from the site was minimized to less than 5 m or sampling was repeated. During sample retrieval, care was taken to discard the top several cm of sediment to avoid sampling of recent sediment which may contain metastable metal-organic complexes. The 1 to 1.5 kg samples were placed in pre-numbered kraft paper bags and allowed to air-dry prior to the entire bag being placed in 2 mil plastic bags for shipment to the sample preparation laboratory. Samples generally required a further 2 weeks at 35^{o}C to completely dry.

Dried samples were ball-milled using ceramic equipment and then sieved to minus 80 mesh (180 μm) and analyzed for some or all of Zn, Cu, Pb, Ni, Co, Ag, Mn, As, Mo, Fe, Hg, LOI (loss-on-ignition), U, V, Cd, Sb, S, Cl, Ba, Sr, and Au. Gold analyses by a commercial laboratory, were performed on a 10 g sample by fire assay preconcentration followed by instrumental neutron activation (INAA) to provide a detection level of 1 ppb. One to three Au analyses were performed on each lake sediment sample, with most samples analyzed in duplicate. Analytical methods for other elements following the methods of the Geological Survey of Canada (1988, 1989) are described in Appendix 5.

5.4.2 Stream sediments:

Seventeen stream sediments weighing about 1.5 kg each were collected from the active channels of flowing and seasonal streams from the Napier Lake study area. The other areas lacked suitable stream sediment material. The sediments were placed in kraft sample bags and allowed to air dry prior to shipment to a commercial sample preparation facility. Upon completion of drying at 35^{0}C samples were seived to minus

80 mesh (180 μm) and reference samples inserted into sample batches prior to shipment to a commercial laboratory. Samples were analyzed for Au and 33 minor elements by INAA, and for Cu, Zn, Pb, Fe, Ni, Co, As, Mn, and Sb by a combination of various digestion/atomic absorption spectrophotometric techniques used for stream sediment analyses by the National Geochemical Reconnaissance (NGR) program (Geological Survey of Canada, 1986, 1989: see Appendix 4). For both lake and stream sediments, field site and sample characteristics were recorded on standard NGR data cards.

5.4.3 Hydrogeochemical Sampling:

Water samples were collected close to exposed or thinly-covered auriferous mineralization, and then serially away from mineralization to adjacent lakes. Samples were taken from lakes, streams, bogs, trenches and bedrock depressions, groundwater seeps, and drill holes. Sampling was during July and August of 1987 and 1988. Nalgene bottles of 1 L capacity were used to store water for Au determination. No attempt was made to stabilize Au in solution; Au adsorbed onto the walls of the container was later dissolved in the laboratory using Br^{2-}HCl. An additional 250 mL water sample was collected at each site and from additional sites for determination of all or some of Ca, Mg, F, pH, alkalinity, conductivity, SO_4 and Cl. Where possible, water was collected 30 cm below the surface, but this was not possible at all sites. Water collection from some bogs involved enlargement of depressions to 0.5 m depth, followed by collection at a later time, usually 1-3 hours, to allow organic particles to settle. In-situ determination of pH and temperature were made using a Corning pH meter and thermometer while conductivity and salinity measurements were made using a YSI Model 33 Salinity-Conductivity-Temperature meter (Plates 11 and 12). These measurements were useful in guiding field sampling into contrasting micro-environments close to mineralization, but the reported data for pH and conductivity are laboratory measurements, which showed superior precision and accuracy.

At Reservoir Lake in the Foster Lake area and at PAP Lake, large volumes of

lake water were filtered in-situ to collect suspended particulates for Au determination. From a boat, using vacuum filtration apparatus, 83.5 L (Reservoir Lake) and 128.8 L (PAP Lake) were filtered through 1.2 μm Millipore HAWP filters. The volume of water processed through successive filters declined from an initial 5 L to 1.5 L as the pump battery charge diminished. Filters were carefully air-dried to avoid particulate contamination prior to analysis.

Groundwaters were collected from BQ-size (36.5 mm inside diameter) abandoned drill holes at Foster and PAP Lakes at depths of 10 to 75 m. In all cases, the drill holes had intersected mineralized zones exposed at surface. A 1.5 m by 2.5 cm water sampling barrel was lowered to depth from a portable wireline winch. The sampling tube was tripped at the desired depth to allow for collection of approximately 300 mL per insertion. Three insertions were necessary to collect a 1 L sample for Au determination, an additional insertion was made for the 250 mL sample.

5.4.4 Analysis for Gold in Waters:

Analyses for Au in natural waters were carried out at the Geological Survey of Canada by G.E.M. Hall and J. Vaive. A Perkin-Elmer Model 5000 atomic-absorption spectrophotometer equipped with an HGA-500 graphite furnace (GFAAS), AS-1 autosampler, deuterium background corrector, and a Model 056 strip-chart recorder were used. Pyrolytically-coated graphite tubes were employed throughout. Instrument parameters are summarized in Table 1.

The procedure for Au determination in waters is as given by Hall et al. (1986) after refining McHugh's (1984) method:

1) Filter 1 L water sample through 0.45 μm pore size, Millipore HAWP.

2) Add 10 ml 5% v/v Br^{2-}-HCl to the sample and evaporate 1 L sample to dryness in sterile glass beaker (approximately 16 hours).

3) Add 7 mL 0.5% Br^{2-}-HBr solutions and warm.

4) Add 7 mL H2O and extract into MIBK.

5) Remove Fe by backwashing MIBK extract with 0.1 M HBr.

6) Analyze MIBK portion for Au by GFAAS.

7) Refill empty 1 L Nalgene field bottle with de-ionized water containing 10 mL of 5% v/v Br^{2-}-HCl solution, allow to stand for 2 days with occasional shaking, and follow steps 2 through 6.

The initial addition of Br^{2-}-HCl (step 2) aids in the decomposition of dissolved organic matter and causes the formation of the $AuBr^{4-}$ complex, which is extracted by MIBK. Step 7 is done to dissolve any Au adsorbed onto the container walls during storage.

P-E Model 5000 atomic absorption spectrometer	
Wavelength	242.8 nm
Spectral slit width	0.7 nm
Calibration mode	Absorbance, peak height
Background correction	Deuterium arc
P-E Model HGA graphite furnce atomizer	
Dry	100 oC/10 sec
Char	450 oC/10 sec
Atomize	2400 oC/5 sec
Purge gas	Argon, interrupt on atomization
Sample volume	40 µL

Table 1. Analytical instrument carameters.

The detection limit for Au using a 1L sample is 0.5 ng L^{-1}. This represents that concentration equivalent to 3 times the standard deviation of a synthetic solution spiked at 0.1 ng L^{-1} carried through the entire procedure 5 times. The detection limit is directly related to the volume of water extracted. For some samples additional water was available and a detection limit of 0.3 ng L^{-1} is reported. For other samples, a smaller volume was supplied and higher detection limits are given (e.g., < 1.0 ng L^{-1} is reported for PAP Lake). The precision at the 5.0 ng L^{-1} level of Au is indicated by a relative standard deviation of ~10% (n=5).

The filter papers used to collect particulate Au (> 1.2 µm) in Reservoir Lake (42 papers analyzed as 9 composite samples, 83.5 L filtered) and PAP Lake (116 papers analyzed as 13 composite samples, 129 L filtered) were each digested in 2.5 mL

of aqua regia on a hot plate. The 22 solutions were allowed to evaporate to incipient dryness, and Au re-dissolved by warming in 20 mL of 4M HCl. Gold was then extracted as $AuCl^{4-}$ into MIBK and the solutions analyzed by GFAAS as described above. Results are summarized in Appendix 6.

Chemical analyses on 250 mL water samples were performed by commercial laboratories under contract to the Geological Survey of Canada. Quality control procedures utilized for NGR surveys (Hornbrook and Garrett, 1976; and Coker et al., 1979) were employed.

Ca and Mg were determined by direct aspiration ICP-ES; SO_4^{2-} and Cl^- by ion chromatography; F^- by ion-specific electrode; pH by pH meter with glass calomel electrode, alkalinity by titration, and conductivity by instrumentation.

5.5 GEOCHEMICAL RESULTS

5.5.1 Lake and Stream Sediments:

Figures 1, 4, 5, and 7 display the distribution of Au in lake and stream sediments. Gold concentrations less than detection levels of 1 or 2 ppb were set to 0.5 ppb for calculations, consistent with the method employed by NGR surveys for treating sub-detection level Au concentrations in lake and stream sediments (Geological Survey of Canada, 1989).

5.5.1a Napier Lake Area: The fifteen lake sediment sites sampled in the Napier Lake area contain <2 to 4 ppb Au with a mean of 1.1 ppb, including seven sites <2ppb. Thirteen stream sediment sites were sampled with Au concentrations ranging from <2 to 150 ppb, with a mean of 9.6 ppb. The data show weak geochemical contrast for Au concentrations in organic-rich (loss-on-ignition (LOI) to 39%) profundal sediments from Napier Lake, immediately downstream and down-ice of the main auriferous zone (Fig. 1 and 2).

Figure 2 displays the distribution of Au in stream and lake sediments and

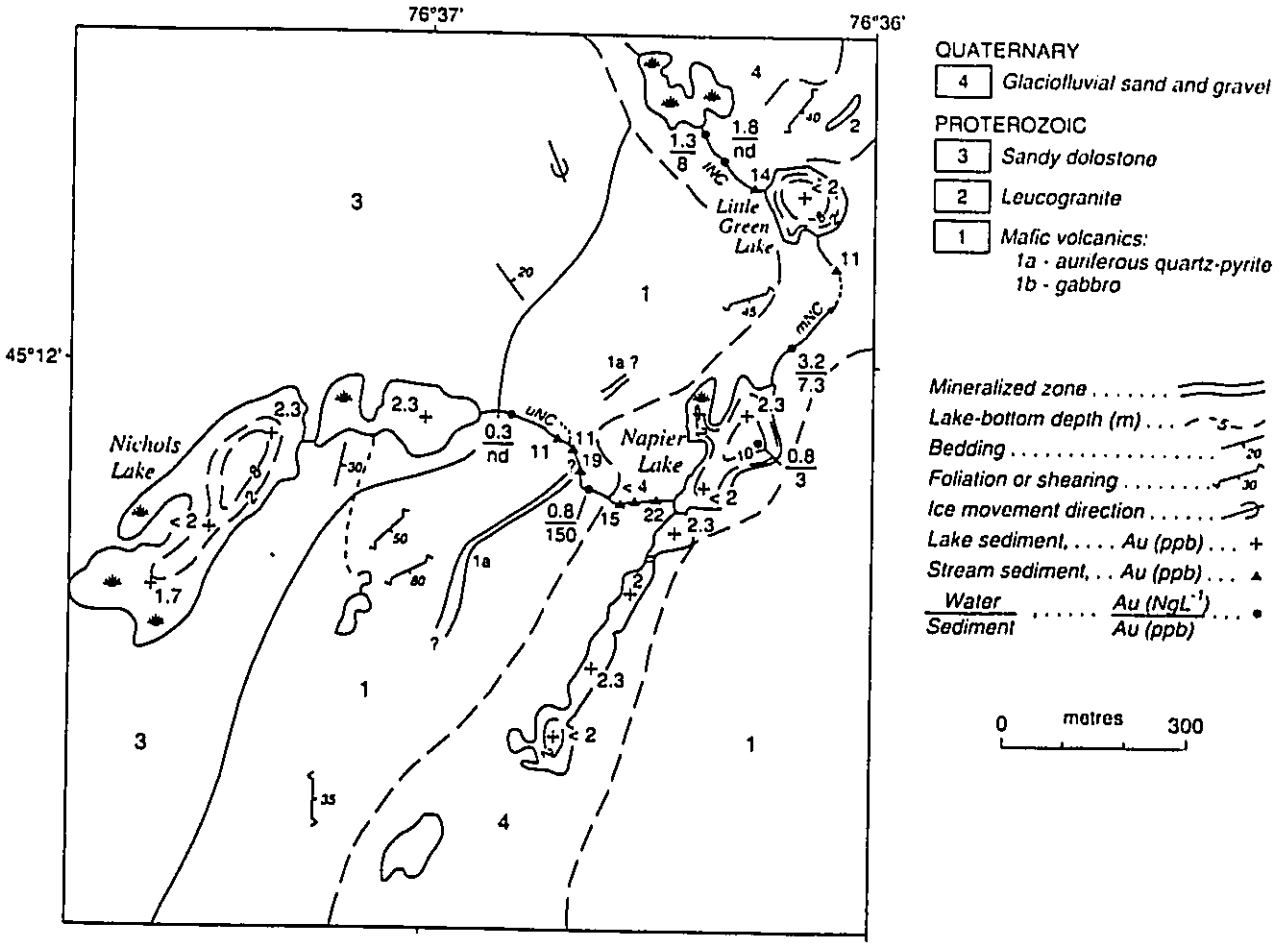


Fig. 1. Geology, water sample locations and Au (ng/L) in waters, and Au (ppb) in lake and stream sediments at Napier Lake, Ontario. Crosses indicate lake sediment and water sample sites. Solid triangles indicate stream sediment and water sample sites. Some numbers may represent mean values of more than one analysis or duplicate samples. Open circles represent water samples analysed by Kharouba (1987). UNC - upper Napier Creek; MNC - middle Napier Creek; LNC - lower Napier Creek.

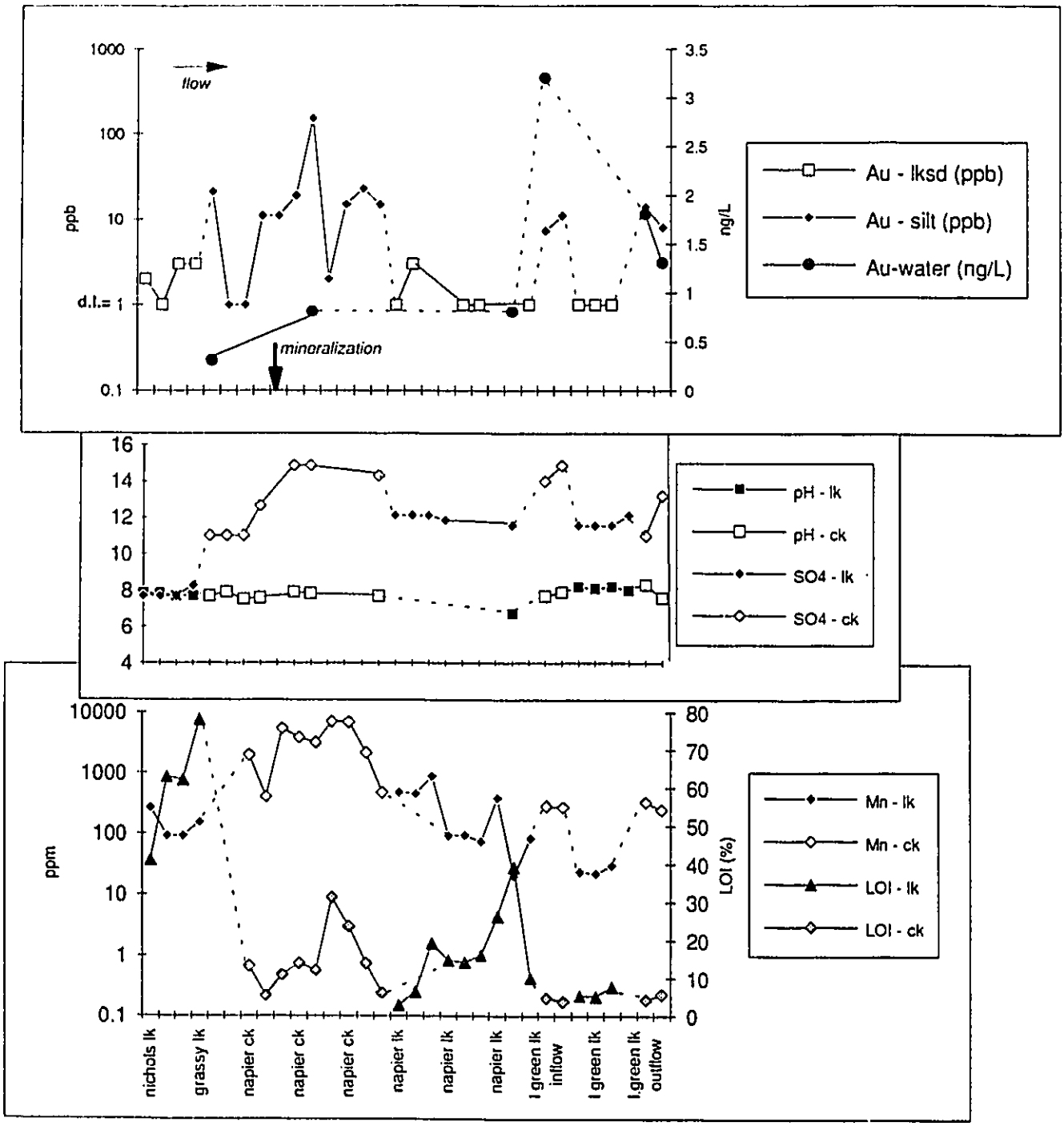


Fig. 2. Downstream dispersion of Au, pH, Mn, LOI, SO4 at Napier Lake. Solid tie lines between same medium; dashed tie lines between similar medium (eg silt-lksed).

surface waters, LOI, pH, SO_4 and Mn dispersed downstream, across the Robertson Shear zone, from Nicholls Lake to Little Green Lake. Gold concentrations in water increase progressively downstream, with a prominent localized increase in Au, SO_4 and Mn immediately downstream of the point where upper Napier Creek drains across the Robertson Shear zone, and below Napier Lake where a mineralized till may be eroding into the creek. Sulphate in stream waters remains high for considerable distance downstream of the mineralized shear zone, whereas Mn in sediments gradually decline to background levels as it is diluted by additional allocthonous material.

Gold concentrations in stream sediments increase from 11 ppb upstream of the main Au-mineralized zone to 150 ppb immediately downstream, declining to about 20 ppb 150 m further downstream where the stream enters Napier Lake. Below Napier Lake stream sediments range from <2 to 15 ppb Au; however Au concentrations in organic-deficient Little Green Lake are consistently <2 ppb. Gold concentrations in stream sediments below Little Green Lake range from 6 to 21 ppb. The difference in Au concentrations between lake and stream sediments indicate that Au is either transported through the lake basins, or is diluted to near detection levels by contemporaneous accumulation of Au-deficient lake-bottom sediment material. Zinc, Cu, Ni, Co, As, Sb, Fe and Mn occur at higher concentrations in Napier Lake compared to Nichols and Little Green lakes. These elements are also elevated in stream sediments entering Napier Lake compared to those downstream. Iron and Mn-hydroxide precipitates in upper Napier Creek may be coprecipitating chalcophile elements (Coker, 1979) thus influencing their dispersion and concentration in the lakes. This is illustrated for As and Mn in Figure 3, but does not appear an important influence on Au in these stream sediments.

5.5.1b Pap Lake Area: Lake bottom sediment was sampled in PAP Lake at thirty one profundal and six nearshore sites (Fig. 4 and 5). Organic lake-bottom sediments (up to 53% LOI; mean = 34%) contain Au concentrations ranging from <1

to 35 ppb (mean 4.6 ppb). Organic content of lake bottom sediments increase with depth, although the area of highest LOI values occur in the northeast end of the lake between 3 and 6m depth. Lake-shore sediments from the western end of the lake are mostly organic-deficient and contain 1 to 499 ppb Au, with high intra-site variability in Au analyses, likely reflecting the input of clastic Au eroded from till along the shore. Highest Au concentrations in PAP Lake sediments occur in two areas: at the west end of the lake overlying and adjacent to the projected trace of the auriferous shear zones, and at the northeast end of the lake where it

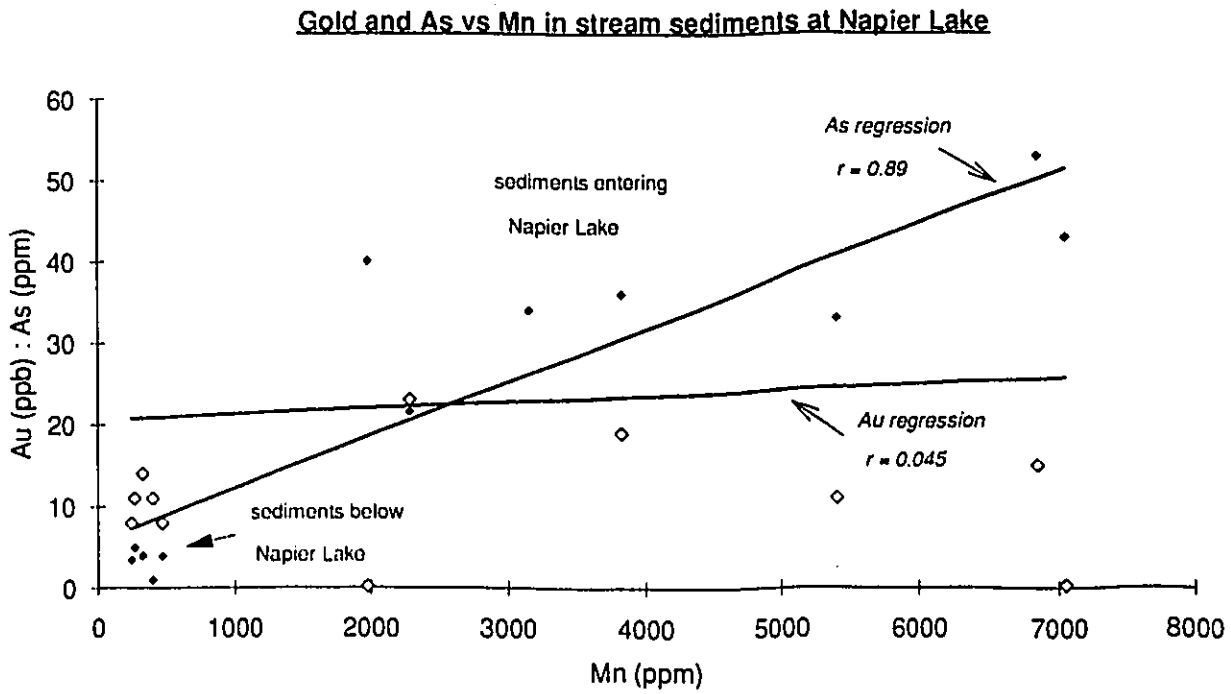


Fig. 3. Gold and As vs Mn in stream sediments at Napier Lake.

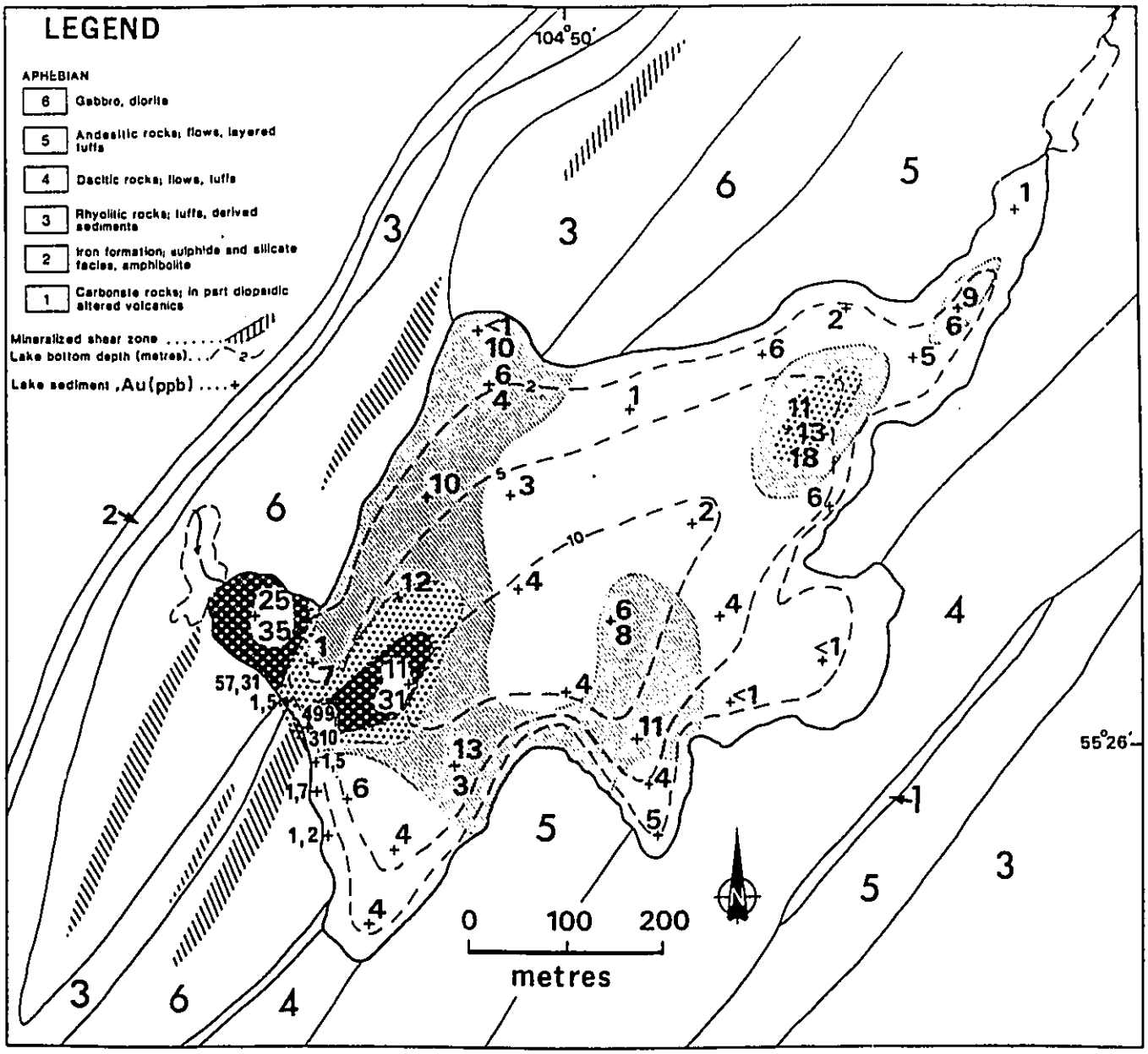


Fig. 4. Geology, and Au content (ppb) of lake sediments at PAP Lake, Saskatchewan. Contours = 7, 12 and 20 ppb Au.

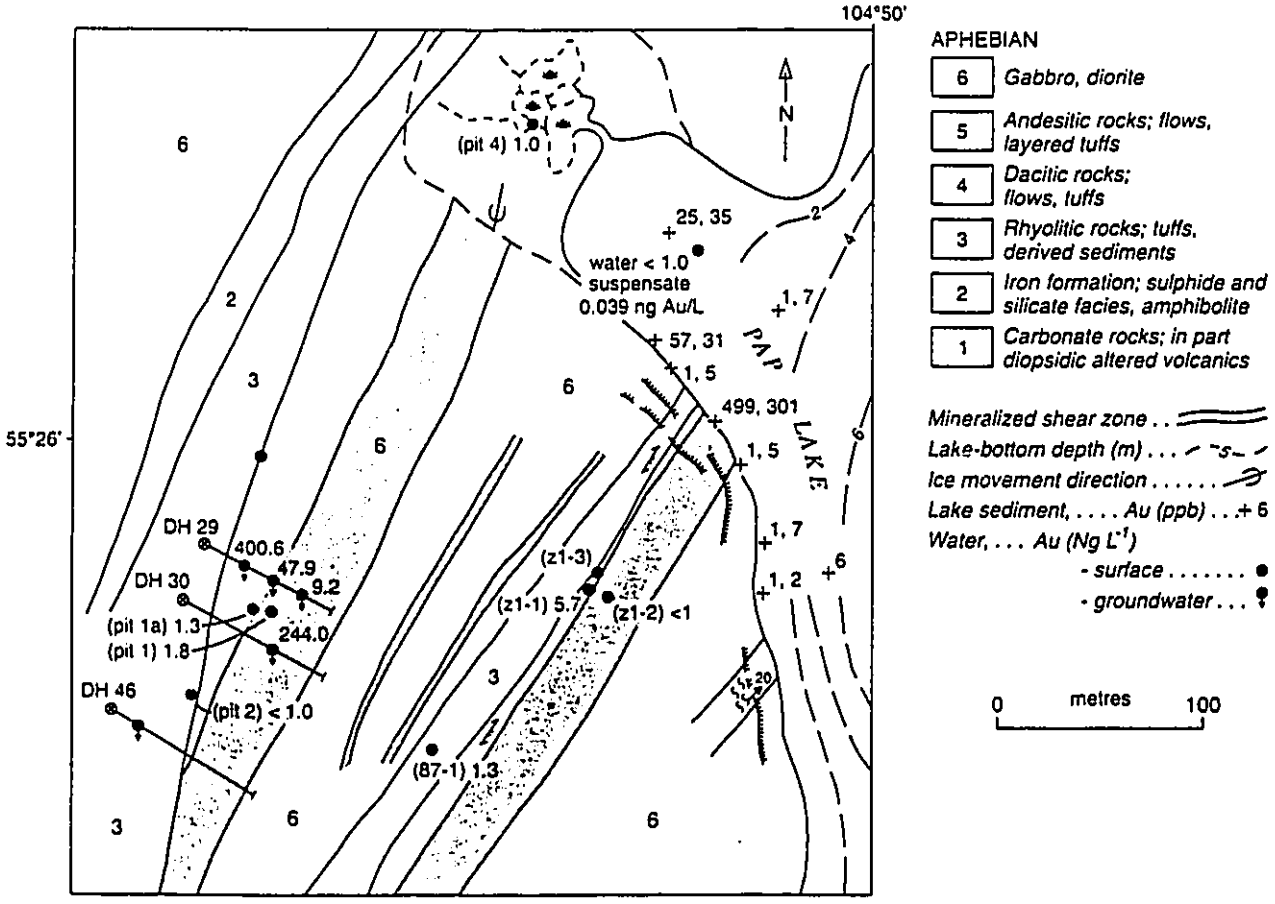


Fig. 5. Geology and Au content (ppb) of lake sediments (crosses), waters (solid dots), and nearshore lake sediments (crosses - ppb) at PAP Lake, Saskatchewan.

constricts near its outflow. The strong sympathetic behaviour of Au and As in mineralization, till and vegetation is also reflected in the profundal lake sediments in their spatial distribution and relationship to organic content of lake sediments. When three high Au values suspected of representing particulate Au are omitted from the data set, Au exhibits a correlation of 0.52 with LOI. Arsenic, with concentrations ranging from 11 to 68 ppm (mean 33 ppm) in lake-bottom sediments and 11 to 164 ppm (mean 45 ppm) in lake-shore sediments shows a correlation coefficient of r= 0.69 with LOI (Fig. 6).

5.5.1c Foster Lake Area: Foster, Reservoir, Expansion and Bay lakes were sampled at thirty-two lake sediment sites (Fig. 7). Au concentrations range from <1 to 30 ppb, with a mean value of 2.9 ppb, at least three times as high as the regional mean content of <1 ppb Au (Geological Survey of Canada, 1989). Highest Au contents occur in profundal sediments in the two basins in Foster Lake, and in Reservoir Lake. In Foster Lake at depths of <4 m, sediments have a silty composition and contain <1 ppb Au, although at greater depths concentrations range up to 30 ppb. The overall mean content of Au in this lake is 1.3 ppb, however for samples taken from >4m, the mean is 2.3 ppb. All samples from Reservoir Lake, which partially overlies the JSZ, are anomalous in Au (mean 7.3 ppb); however 1.2 km downstream in Expansion and Bay lakes the mean Au content in lake bottom sediments is 1.5 ppb, slightly greater than the regional mean. Figure 8 depicts the downstream variation in Au content in lake water and sediments, pH, SO_4^{2-}, and LOI. The oxidation of sulphides and the introduction of Au downstream of the mineralized Johnson Shear zone is clearly shown by the increase of Au content in waters and lake sediments, and SO_4. Dissolved Au contributed by surface waters in the shear zone, as depicted by short arrows in Fig. 8, are an important factor increasing the Au content in the lakes. Progressive increase in organic content in the lake basins reflects these very low energy environments where clastic sedimentation is suppressed. Arsenic, Co, Cu, Ni, Pb and Zn are weakly to

moderately elevated in lake sediments from Foster Lake only, corresponding in general with increased Fe and Mn concentrations. Reservoir, Expansion and Bay lakes have mostly background concentrations of these elements, although Hg is anomalous in organic, Fe-rich lake bottom sediments from Expansion Lake.

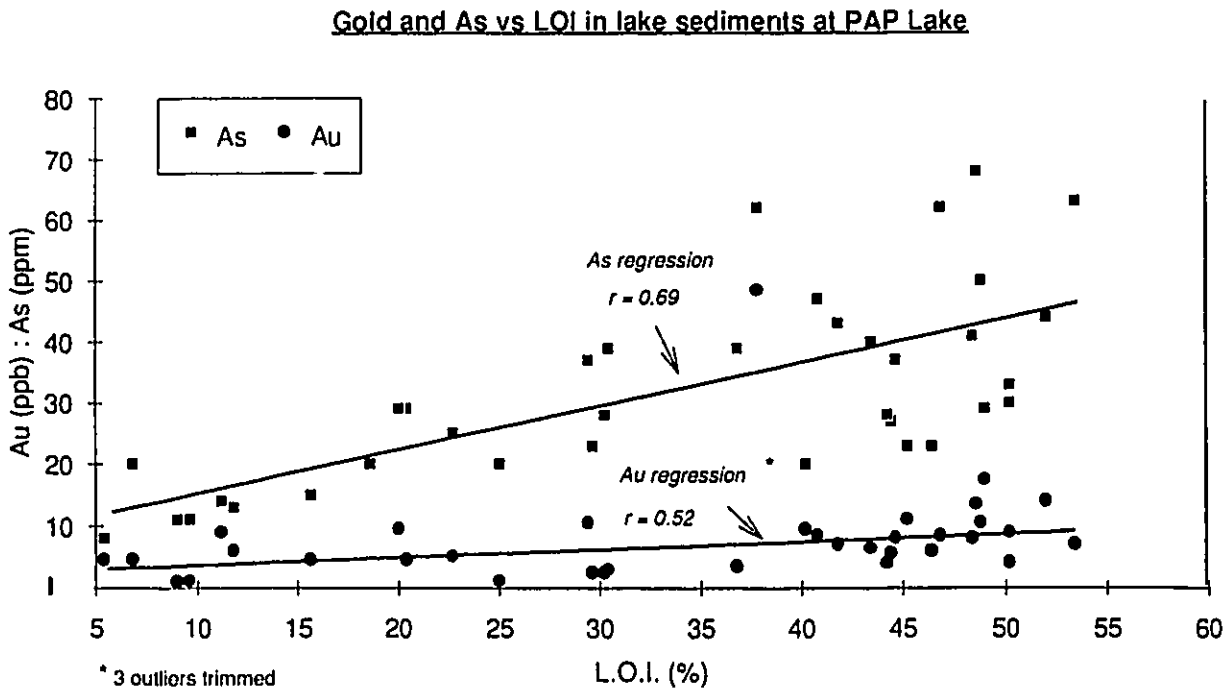


Fig. 6. Gold and As vs LOI in lake sediments at PAP Lake.

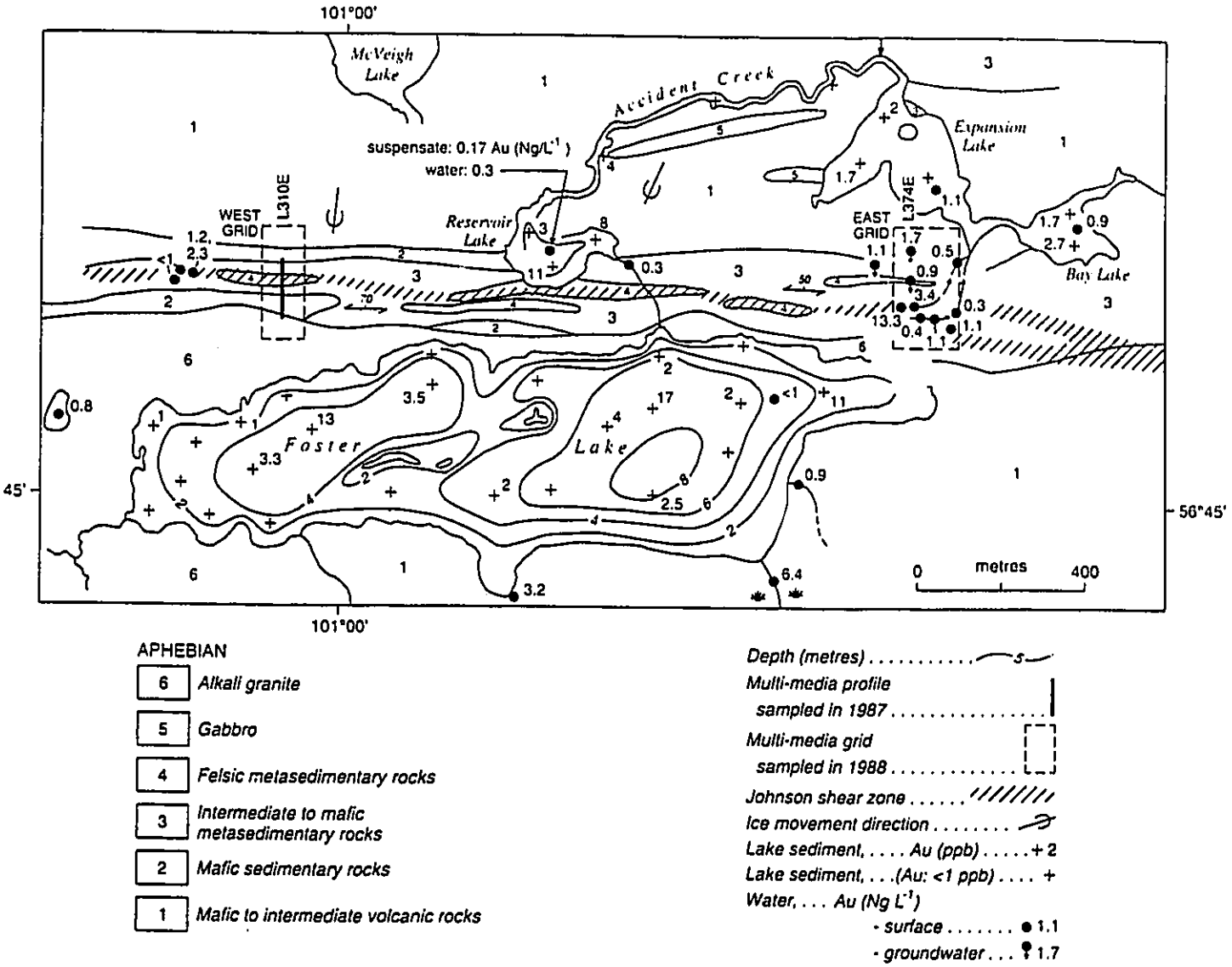


Fig. 7. Geology and Au content (ppb) of lake sediments (crosses), waters (solid dots; ng/L) and suspensates (ng/L) from Foster Lake area, Manitoba.

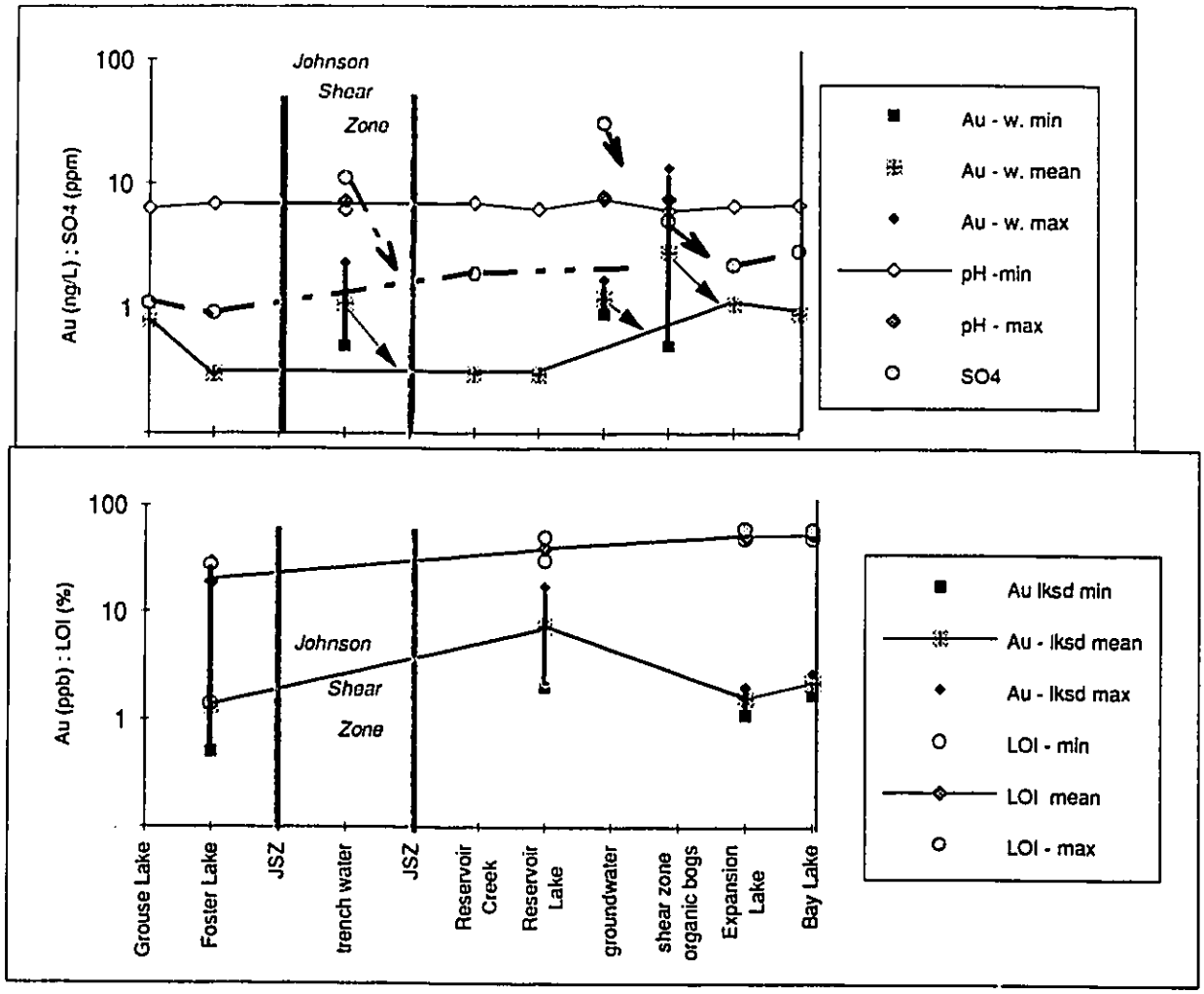


Fig. 8. Downstream dispersion of Au, pH, SO4 and LOI at Foster Lake area, Manitoba. Short arrows indicate input from surface water at various points along the main Foster Lake to Bay Lake drainage system.

5.5.2 Hydrogeochemical Results:

Surface and groundwaters were sampled to ascertain whether Au was sufficiently mobilized by waters to contribute to the formation of anomalous concentrations in lake bottom sediments. Total hydrogeochemical results are summarized in Table 2; for Napier Lake in Table 3, PAP Lake in Table 4 and Foster Lake in Table 5.

5.5.2a pH: Figure 9 shows histograms of pH values for each area categorized into surface (bog, stream, trench), lake, and groundwater (seep, drill hole). Surface and lake waters from the Napier Lake area are neutral to alkaline; groundwaters sampled from the base of carbonate-bearing glaciofluvial sand and gravel complexes are in a narrow range of 7.6 to 7.9. This is similar to that for Foster and PAP drill hole waters (pH range 7.5 - 7.9), in contact with carbonate-bearing alteration. PAP Lake area surface waters are acidic in the pH range 5.1 to 6.3, including ephemeral ponds overlying the main shear zone. Near-surface lake waters from the PAP Lake area have a narrower range, pH 6.8 - 7.0, than those from the Foster Lake area at pH 6.0 to 7.8. Lake waters from PAP Lake exhibit a pH profile with depth inverse to that normally encountered in Shield lakes (Coker, 1979); surface waters are acidic, whereas Fox et al. (1985) reported lake-bottom waters with a pH range of 8.1 to 8.7. The alkaline nature of lake bottom waters in PAP and Napier Lake is also indicated by the presence of carbonate-bearing marly lake sediments.

5.5.2b Anions and Cations: The Cl^- and F^- content of surface water is low for all areas (Table 2), with Cl^- typically < 1 ppm, and $F^- < 100$ ppb. Contents of up to 1 ppm F^- in PAP and Foster Lake drill hole waters reflect increased solubility of cation-F^- complexes in carbonate- and sulphate-bearing groundwaters and is consistent with similar relationships observed elsewhere (White et al., 1963).

Alkalinity, Ca and Mg concentrations were selectively determined for PAP and Foster Lake surface waters. Calcium concentrations range from 5 to 32 ppm for acidic, organic-rich bogs, and are comparable to background surface waters reported in Rose

	Groundwater	Trench, Pond	Bog	Stream	Lake
pH	7.6-7.9 (13)	5.1-7.2(7)	5.4-7.6(20)	6.0-8.3 (19)	6.2-8.2 (37)
Au, ng L^{-1}	0.9-401 (7)	<1-5.7 (6)	<1-13.3 (14)	0.3-10.4 (9)	0.3-1.1 (5)
Conductivity, mmhos	253-370 (14)	25-168 (5)	63-333 (11)	30-331 (16)	30-337 (31)
Alkalinity	n.d.	2-84 (6)	6-182 (10)	17-145 (7)	13-101 (24)
SO_4, ppm	6.1-38.5 (14)	1.9-16 (5)	2.2-25 (11)	0.1-14.9 (17)	0.9-12.1 (31)
Ca, ppm	n.d.	<0.5-35 (5)	5-63 (10)	5-48 (4)	4.4-34 (19)
Mg, ppm	n.d.	0.3-1.4 (6)	0.8-11 (10)	0.9-6.6 (4)	0.7-4.5 (19)
F, ppb	50-830 (13)	20-60 (7)	20-60 (17)	30-80 (19)	30-100 (40)
Cl, ppm	0.23-3.45 (14)	0.3-1.05 (5)	0.23-0.9 (11)	0.23-0.90 (16)	0.20-3.3 (31)

Table 2. Summary of hydrogeochemical data. (Ranges shown, with number of samples in brackets. n.d. = not determined).

Location	Number Samples	Au, ng L^{-1}	pH	Cond., mmho	SO_4, ppm	Cl, ppm	F, ppb
Nichols Lake	3	-	7.8	214	7.7	0.30	80
U. Napier Creek, A	4	0.3	7.7	244	11.4	0.68	50
U. Napier Creek, B	2	0.8	7.8	224	14.9	0.72	55
Napier Lake	6	0.8	6.7	300	11.9	0.68	50
L. Napier Creek	2	1.8	7.9	324	12.1	0.64	60

Table 3. Napier Lake area. hydrogeochemical data. (Results are averages for number of samples indicated).

Sample Location	Au, ng L^{-1}	pH	Cond. mmho	SO_4, ppm	Cl, ppm	F, ppb	Alk, ppm	Ca, ppm	Mg, ppm
DH 87-29 (30m)	401	7.8	370	23.1	0.30	210	-	-	-
DH 87-29 (50m)	48	7.6	287	33.6	0.30	430	-	-	-
DH 87-29 (75m)	9.2	7.6	372	24.2	0.23	450	-	-	-
DH 87-30 (70m)	244	7.8	356	22.6	0.23	270	-	-	-
DH 87-46 (20m)	-	7.7	253	6.1	0.75	280	-	-	-
Pit 1 (Bog)	1.8	5.7	63	8.8	0.90	30	16	10	2.3
Pit 1a (Bog)	1.3	5.9	-	-	-	40	22	11	2.5
Pit 2 (Bog)	<1.0	6.1	-	-	-	50	30	15	2.0
Pit 4 (Stream)	1.0	6.3	96	0.8	0.23	70	47	16	3.0
Pond Z1-1	5.7	5.1	25	2.8	0.90	30	7	0.5	0.6
Pond Z1-2	<1.0	5.1	-	-	-	20	2	<0.5	0.3
Pond Z1-3	-	5.5	32	1.9	0.38	20	7	0.5	0.6
Bog 87-1	1.3	5.4	-	-	-	40	6	5.0	1.2
PAP Lake (N=8)	<1.0	6.9	208	5.0	0.83	56	100	34	4.5

Table 4. PAP Lake area hydrogeochemical data. (For locations see Figure 4).

Sample Type, Number	Au ng L^{-1}	pH	Cond. mmho	SO_4, ppm	Cl, ppm	F, ppb	Alk, ppm	Ca, ppm	Mg, ppm
EAST GRID									
DH F87-1 (10m)	1.1	7.5	300	36	0.30	220	-	-	-
DH W86.6 (10m)	0.9	7.8	282	19	3.45	50	-	-	-
DH W86-23 (10m)	1.7	7.5	369	35	0.53	830	-	-	-
BOG 88-24	0.4	6.9	106	9.4	0.38	50	-	-	-
BOG 88-12	1.1	6.8	64	4.4	0.45	30	-	-	-
BOG 88-13	0.3	7.6	133	12.7	0.38	50	-	-	-
BOG 87-4 (N=2)	3.4	6.0	66	3.9	0.30	25	35	14	1.5
BOG 87-7 (N=2)	1.1	6.4	171	5.2	0.45	35	80	32	2.2
BOG 88-10	0.5	7.5	133	8.8	0.30	60	-	-	-
BOG 88-25	13.3	6.4	70	2.2	0.45	60	-	-	-
WEST ZONE									
TRENCH 87-J2	2.3	6.4	112	16	0.53	50	44	22	1.3
TRENCH 87-J3	<1.0	6.7	168	7.2	1.05	40	84	35	2.4
TRENCH 87-J4	<1.0	6.1	-	-	-	30	32	18	1.4
TRENCH 88-J2	1.2	7.2	101	9.4	0.30	60	-	-	-
SOUTH FOSTER LAKE									
STREAM 1	0.9	5.6	36	0.1	0.45	80	-	-	-
STREAM 2	6.4	6.5	31	0.1	0.30	50	-	-	-
STREAM 3	3.2	6.7	42	1.4	0.45	50	-	-	-
FOSTER LAKE TO BAY LAKE									
FOSTER LK (N=8)	<1.0	6.8	34	0.9	0.34	40	14	4.7	0.7
RESERVOIR CK	0.3	6.9	40	1.9	0.53	50	20	6.2	1.0
RESERVOIR LK (N=4)	0.3	6.2	-	-	-	30	22	7.1	1.1
EXPANSION LK (N=4)	1.1	6.5	44	2.2	1.05	30	--	-	-
BAY LAKE (N=3)	0.9	6.7	45	2.8	0.35	30	--	-	-

Table 5. Foster Lake area hydrogeochemical data. (See Figure 5 for sample locations).

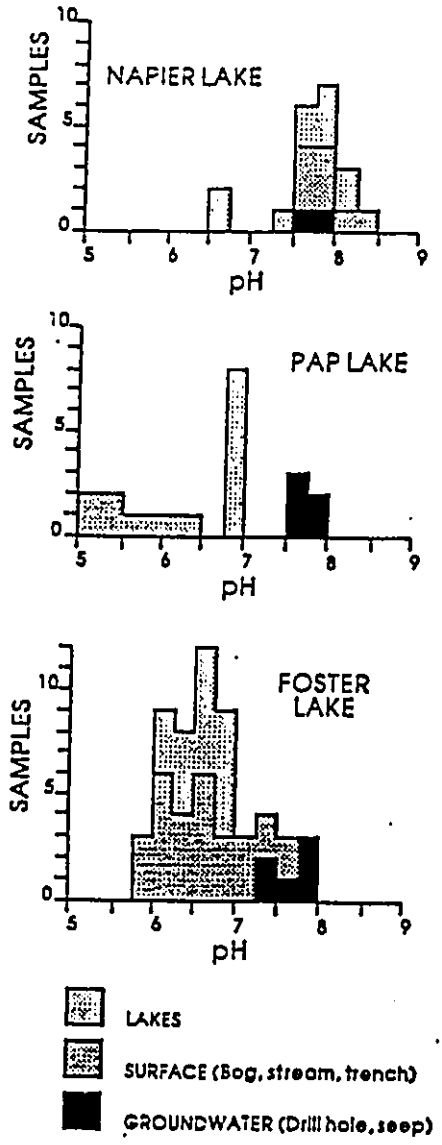


Fig. 9. Histogram of water pH for combined study areas classified by water type.

et al. (1979, Table 14.1). Surface waters with Ca values ranging from about 30 to 63 ppm occur adjacent to carbonate alteration zones reflecting the dissolution of carbonate minerals by weakly-acid, oxidizing surface waters. Magnesium contents are generally below 5 ppm and show similar patterns to Ca. Conductivity ranges from 25 to 50 μmhos/cm for acidic lake waters, streams, water ponded on bedrock and water in trenches. Conductivity of acidic bog waters and alkaline lakes or streams have a wide range of values from about 60 to 337 μmhos/cm. Alkaline surface waters of Napier Lake range from 198 to 343 μmhos/cm and are comparable to PAP and Foster Lake groundwaters with values ranging from 253 to 372 μmhos/cm. Field measurements of conductivity were useful to identify localized high conductivity micro-environments which could potentially relate to subcropping, oxidizing mineralization.

Sulphate concentrations range from 0.1 ppm for streams entering Foster Lake from the south and distant from known mineralized zones, to 38.5 ppm for groundwaters at 33 m depth in contact with sulphide-bearing shear zones. Alkaline waters from Napier Lake show lower geochemical contrast than other areas with a range of 7.7 to 14.8 ppm SO_4^{2-}. For all areas, groundwaters adjacent to sulphide-bearing zones have the highest SO_4^{2-} values. Sulphide mineralization also appears to enhance SO_4^{2-} concentrations of alkaline stream waters flowing between Nichols and Napier, and Little Green Lake, and bog waters north of Foster Lake along the main trace of the Johnson shear zone. During the collection of drill holes waters at PAP Lake, a strong sulphide odor was noticed and SO_4^{2-} measured in these waters may partially represent oxidation of sulphide prior to analysis. Chloride concentrations for these waters and SO_4^{2-}-rich drill hole waters from Foster Lake do not exceed 1 ppm, also suggesting that SO_4^{2-} may be derived from oxidized sulphides (Cameron, 1978).

Sulphide oxidation is a complex process influenced by oxygen concentration, surface area, pH, concentration of dissolved ferric ion and dissolved oxygen, temperature and bacteria (Nicholson et al., 1988; Moses and Herman, 1991). The

effects of oxidation and exposure to acidic surface waters on Au-bearing sulphides were examined by S.E.M. analyses of several sulphide mineral separates prepared from oxidized sulphides in bedrock, till and low-LOI humus. On sulphide and rare scheelite grain surfaces, ubiquitous ovoid pits, typically ranging from 0.1 to 4 μm diameter, are developed as a result of in-situ oxidation and exposure to low pH solutions (Fig. 10). Progressive pitting increases net surface area and enhances the rate at which the entire grain is oxidized (Nicholson et al., 1988). Oxidized arsenopyrite with intense pitting from the main PAP shear zone revealed electrum, Cu-Bi, and Bi-Te grains of <20 μm size protruding from the arsenopyrite surfaces, thus exposing these inclusions to oxidation, dissolution, and physical separation. Oxidized pyrite grains examined from surface Au mineralization protruding through carbonate-bearing till at Napier Lake (Fig. 11) revealed dissolution features which included raggedy, scalloped edges and crevices. Pyrite oxidation in this circum-neutral environment may partly explain the source of secondary ferric hydroxide in nearby stream sediments, and elevated SO_4^{2-} contents of stream waters.

5.5.3 Gold in Waters:

Surface waters from each of the three mineralized environments contain background and anomalous Au concentrations comparable to other areas (Gosling et al., 1971; Hamilton et al., 1983; Hall et al., 1986; Plyusnin, 1987; and McHugh, 1988). Gold contents exceeding 2 ng L^{-1} in surface waters may suggest the presence of nearby mineralization. Contents of Au in groundwater reported in the literature vary considerably, but the higher values encountered in the present study are considered to represent Au dissolved from nearby mineralization.

5.5.3a Napier Lake: In the Napier Lake area (Fig. 1), waters were collected above (U. Napier Creek A, Table 3) and downstream (U. Napier Creek B, Table 3) of sub-cropping auriferous quartz-pyrite mineralization that contains up to 1 ppm Au.

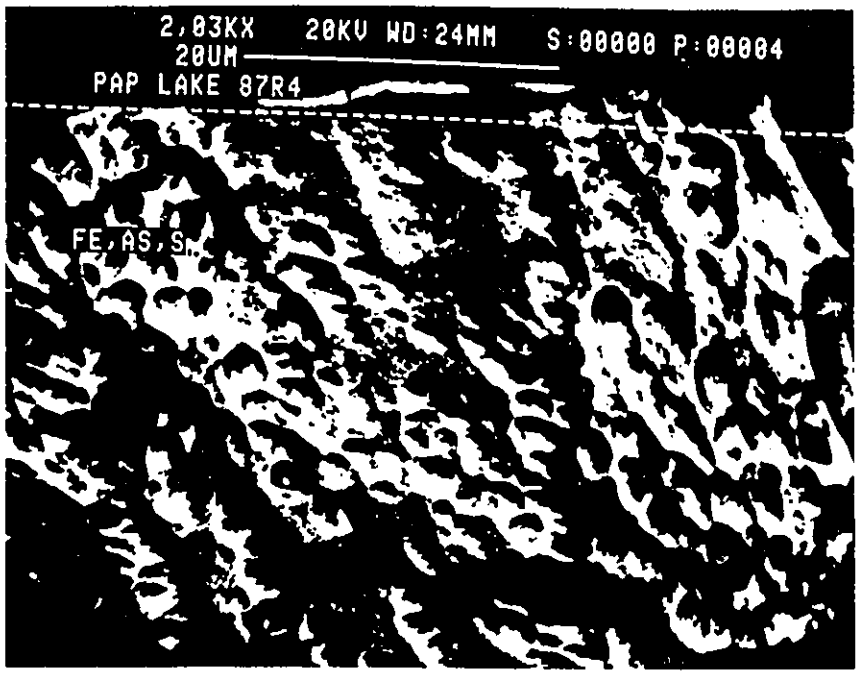


Fig. 10. Scanning electron microscope image of the surface of an intensely oxidized arsenopyrite grain from exposed PAP Lake shear zone, showing abundant ovoid pits caused by acid dissolution.

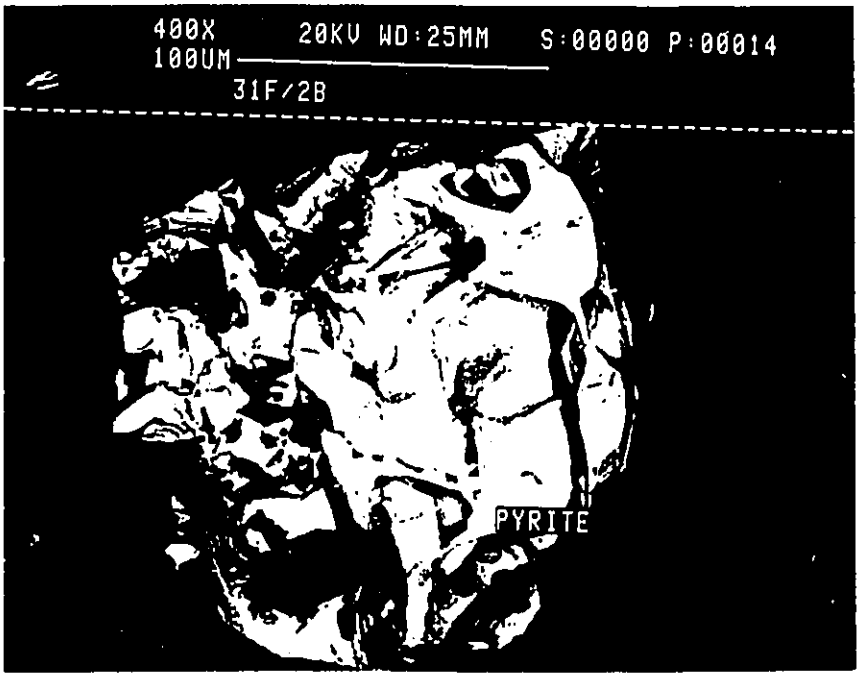


Fig. 11. Scanning electron microscope image of an intensely oxidized pyrite grain showing dissolution textures in circum-neutral sdto alkaline conditions from exposed mineralization at Napier Lake from the Robertson shear zone.

There is a slight increase in Au from 0.3 to 0.8 ng L^{-1} and in SO_4^{2-} across the subcrop of the mineralization. These levels for Au persist into Napier Lake and increase in the lower part of the drainage in L. Napier Creek. Downstream of Napier Lake, Napier Creek flows intermittently through glaciofluvial sand and gravel along part of its length during summer and early autumn. Kharouba (1987) identified Au concentrations of 2.3 and 4.1 ng L^{-1} from water in the mid-reach of this creek. The increase in Au in stream sediments and waters below Napier Lake, which contains 2 ppb Au in lake-bottom sediments and 0.8 ng L^{-1} in lake water, suggests additional clastic and hydromorphic input from down-ice transported auriferous till from several discontinuous auriferous quartz-pyrite lenses 150 to 300 m up-ice. Gold occurrences west of Little Green Lake similarly may be responsible for elevated Au in waters below this lake, which also contains low concentrations of Au in profundal sediments. The downstream variation of Au in waters and sediments, at similar sites, relative to pH and SO_4^{2-} is summarized in Figure 2. Gold in water shows peak values translated downstream of the sediment high, and weak association with SO_4^{2-} and conductivity.

5.5.3b Pap Lake: In the area surrounding PAP Lake (Fig. 5), along the main shear zone, rocks and tills are ubiquitously enriched in Au (22 ppm measured from a sample of a 20 cm by 5 m arsenopyrite-rich vein) and As, and contain locally elevated concentrations of Cr, Ni, Cu, Ag, Sb, Co, and Mo (Chapter 4). Drill hole waters (Table 4), are strongly anomalous in Au to 401 ng L^{-1}. The largest of several acidic (pH 4.1 - 5.7), oxidizing, ephemeral ponds (1 - 10 m^2) overlying the main shear zone contained 5.7 ng L^{-1} Au (Plates 14,15 and 16). Parts of this ridgetop had been exposed by hydraulic methods several years previously. The catchment area for the pond covers an area < 100 m^2 and consists of an unvegetated ridgetop of hornblende diorite with zones of quartz-carbonate alteration, intense shearing and oxidation. Prior to sampling there had been no rain for three days. Lower Au contents, to a maximum 1.8 ng L^{-1}, were determined for partially-stagnant, organic-rich bog waters located along the

contact of an expansive bog-fen area with the mineralized shear zones. The Au content of the water is derived largely from the active oxidation of nearby semi-massive auriferous arsenopyrite-pyrite mineralization and limited percolation of groundwater through a thin veneer of lodgement till. The down-dip extension of this vein system was intersected in drill holes by CAMECO. The strongly anomalous drill hole waters in contact with mineralized intersections (typical maximum assay, 30 ppm Au) are alkaline and had a strong sulphide odor. The Au content of PAP Lake surface water analyzed by GFAAS is < 1.0 ng L^{-1}, the higher detection limit being due to smaller amounts of water being submitted. Au equivalent to 0.039 ng L^{-1} of lake water was determined for particulates > 1.2 μm filtered from 128.8 L of PAP Lake water (Appendix 6).

5.5.3c Foster Lake: For the Foster Lake area, water samples taken at 10 m depth from drill holes (Fig. 7, Table 5) contain 0.9 to 1.7 ng L^{-1} Au, less than for the Pap Lake area. Water chemistry is similar to the PAP Lake groundwaters, although a sulphide odor was not present. Bulk waters could not be obtained from greater depths because the holes were partly caved, although with some persistence, 250 mL samples obtained from 33 m depth indicated the presence of alkaline, high SO_4^{2-}, low Cl^- waters.

The distribution of Au in surface waters from the Foster Lake area is similar to PAP Lake; acidic surface waters are the most Au-enriched (up to 13.3 ng L^{-1}). Elevated contents of Au in peat, black spruce (picea mariana) twigs, till and humus were measured along the shear zone (Chapter 3). Gold values decline 50 to 300 m down the bog drainage system to a 0.3 to 1 ng L^{-1} range in areas covered progressively by thicker organic and till deposits. North of the west end of Foster Lake, several trenches on the Johnson shear zone with semi-stagnant weakly acid waters contained up to 2.3 ng L^{-1} Au. The adjacent 1 m wide quartz-sericite-ankerite vein contained 39.7 ppm Au in a grab sample.

Foster Lake receives surface drainage from the mineralized ridge of the Johnson shear zone and from a number of streams. Three weakly-acidic streams draining into the south side of Foster Lake contain 0.9, 3.2 and 6.4 ng L^{-1} Au. These waters drain low-lying organic deposits overlying till initially thought to represent "background". However, re-examination of geophysical data indicate the presence of undrilled east-west striking conductors in mafic to intermediate volcanic rocks (Sherritt Gordon Mines, 1983; and SherrGold, personal communication, 1987). The strongly anomalous Au contents of profundal lake sediments from Foster Lake (up to 30 ppb, compared to a median regional value of < 1 ppb) is thus consistent with the several sources for Au in waters draining into the lake.

Reservoir Creek, draining Foster Lake, and Reservoir Lake both have Au in water of 0.3 ng L^{-1}. The > 1.2 μm suspensate in the latter contains the equivalent of 0.17 ng L^{-1} Au. The bottom sediments within this lake, ranging between 4 and 17 ppb, are anomalous. Waters further down-drainage in Expansion Lake and Bay Lake have higher contents of 1.1 and 0.9 ng L^{-1} Au in lake water, perhaps reflecting surface drainage from mineralization to the south. Figures 12 and 13 summarize the overall relationships between Au in water and SO_4^{2-} and pH. Gold shows a weak positive correlation with sulphate and related conductivity, but shows no obvious correlation with Cl^- content. Elevated Au values occur over the entire range of pH values of 5.1 to 8.3 encountered in these surficial and groundwater environments providing an important indicator of the widespread mobility of Au in the hydrological environment.

5.6 DISCUSSION AND CONCLUSIONS

To be an effective indicator of mineralization in lake sediment or water surveys in the Canadian Shield it is necessary that an element travel in solution or adsorbed on suspensates (Timperley and Allan, 1974; Cameron, 1978, 1980; Coker et al., 1979; and Bogle and Nichol, 1981). Low-relief and disorganized drainage patterns over much

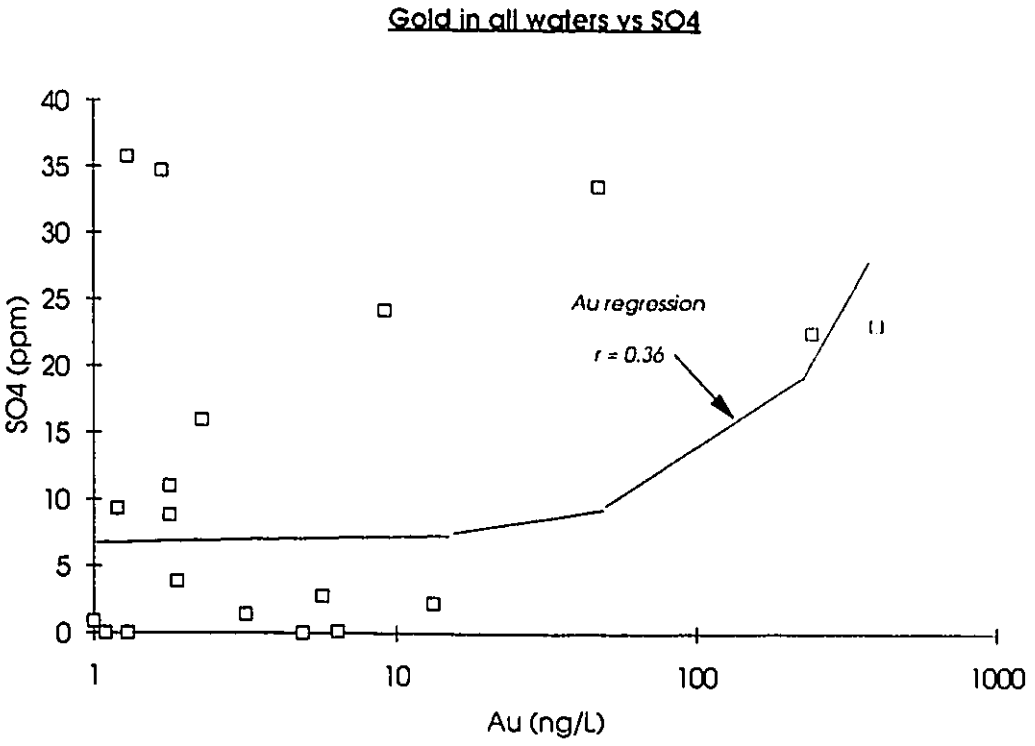


Fig. 12. Gold in all waters vs SO4.

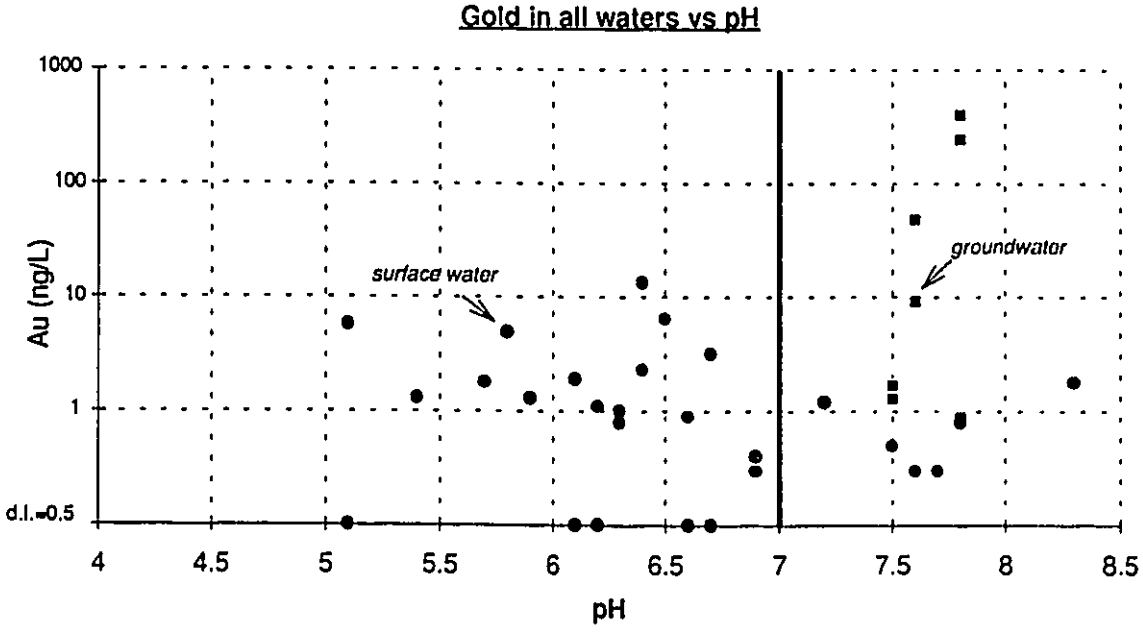


Fig. 13. Gold in all waters vs pH.

of this region; there is minimal postglacial clastic dispersal, superimposed on region-wide glaciation processes. This restricts the migration of metals and/or gives erratic distributions. Gold has been widely considered as relatively immobile in the surficial environment, which has discouraged its application in lake sediment surveys in the Canadian Shield. However, organic-rich profundal lake sediments often contain anomalous contents of Au in the vicinity of Au-bearing mineralization (Coker et al., 1982; Rogers, 1988; Davenport and Nowlan, 1989), suggesting that Au may enter the lake in a mobile form and be fixed in these sediments. The analysis of water in this study confirm that Au is dissolved during the oxidation of Au-bearing mineralization and that it is mobilized from mineralization in solution and adsorbed on suspensates.

Groundwaters taken from drill holes that penetrate mineralization at PAP Lake contain up to 401 ng L^{-1} Au. Surface waters proximal to mineralization within the Johnson, Robertson and PAP Lake shear zones vary from 1.5 to 13.3 ng L^{-1}. This includes a wide range of pH (5.1 to 8.3) and variable dissolved organic and inorganic contents. In lake waters, Au contents range from non-detectable to 1.1 ng L^{-1}.

PAP Lake and Reservoir Lake have anomalous contents of Au in profundal lake sediments of up to 35 and 17 ppb respectively. Samples of > 1.2 μm suspended particulates in water from these lakes are equivalent to 0.039 and 0.17 ng Au L^{-1} respectively. The corresponding lake waters measured < 1.0 and 0.3 ng L^{-1} Au respectively (the variation in detection limits is due to different volumes of water being supplied to the analyst, see earlier section).

SEM observation of some filtered suspensates from Reservoir Lake noted a predominance of indistinct felted and fibrous organic material, with lesser amounts of clay, feldspar and quartz particles. The observations and chemical data suggest that Au in suspensates may occur partly as stable Au-humic complexes.

Understanding the geochemistry of Au dissolved in lake waters is handicapped by the current analytical detection limits, which are above the contents present in most

lake waters from the study areas. PAP Lake and Reservoir Lake waters measure < 1.0 and 0.3 ng L^{-1} Au respectively (the variation in detection limits is due to different volumes of water being supplied to the analyst, see section 5.4.4). The value for Reservoir Lake, at the detection limit, is however sufficient to generate an anomaly in the associated lake sediments. Reservoir Creek is the principal stream serving this lake. Based on a number of measurements during three summers, the mean annual flow rate is estimated at 500 L/sec. This water contains 0.3 ng L^{-1} Au, which, on an annual basis amounts to 4.7 g Au carried into the lake in solution. The mean of three samples of profundal lake sediment from Reservoir Lake is 7.3 ppb Au, which is anomalous relative to a regional median content of < 1 ppb Au. Since the dried samples, as analyzed, represent a 4:1 weight reduction over the wet samples, as collected, the mean Au content of the gyttja is taken to be 1.8 ppb. The areal extent of profundal sediment within Reservoir Lake is 2.5 ha. A sedimentation rate of 0.046 cm/year has been estimated by Webb and Webb (1988) for organic sediment in northern lakes. This is similar to the 0.04 to 0.06 cm/year estimated by Timperley and Allan (1974). Applying 0.046 cm/yr to the 2.5 ha of Reservoir Lake, 11.5 t of gyttja are deposited in this lake each year. Given the 1.8 ppb content of Au in gyttja (0.0018 g/t), 0.021 g Au is deposited in the lake each year. The flux of Au (4.7 g) carried into the lake in solution is thus far greater than that required to deposit the anomalous levels of Au found in the organic lake sediment.

Recent thermodynamic and Au solubility data (Webster, 1986; Renders and Seward, 1989; Vlassopoulos and Wood, 1990) and related field studies by Pitul'ko (1976), Taisaev and Plyusnin, 1984, Webster and Mann (1984), Stoffregen (1986), Plyusnin (1987), and Benedetti and Boulegue (1991) indicate that Au forms complexes in surface waters with the following ligands: HS^- in sulphur-bearing acid or alkaline reducing environments; $S_2O_3^{2-}$ in sulphur-bearing alkaline oxidizing environments; OH^- in acid to alkaline oxidizing environments; and Cl^- in acidic, oxidizing saline

waters. Other ligands, including CN^- (Lakin et al.,1974; Vlassopoulos et al., 1990), NH^{3-} (Groen et al., 1990), and S,N, and O-donor humic and fulvic acids (Baker, 1986; Boyle et al., 1975) appear to be of some importance, but their relevance to this study is difficult to evaluate because of lack of experimental data.

The study of Vlassopoulous and Wood (1990) suggests that for most freshwater compositions, Au^+ principally combines with OH^- to form $AuOH(H_2O)^o$. The solubility of Au in this form is well above that detected in natural waters, which may indicate that the amount of Au measured in natural waters reflects a balance between the availability of Au in the environment and the processes (e.g., adsorption on organic solids) that cause its precipitation. While $AuOH(H_2O)^o$ may be the dominant species in waters where the S activity is low, other species, including $Au(HS)^{2-}$, $Au(HS)^o$ and $Au_2S_2^{2-}$ become more important in S-bearing waters (Vlassopolous and Wood, 1990). For the study areas discussed here, such high-S environments include groundwater in the vicinity of oxidizing sulphide mineralization, water in ponds and seeps above mineralization, and sulphidic bog water. It is probably relevant that groundwater with the highest content of Au measured during this study (401 ng L^{-1}) had a sulphide odor.

Organic-rich waters, such as in bogs, contain a variety of organic complexes, colloids, and particulates that affect the mobility of Au. Some complexes may enhance the solubility of the metal, while others may cause Au to be fixed. An intermediate condition is where Au is fixed to suspensates, which permit at least limited down-drainage dispersion of Au.

In this study organic-rich drainage systems appear to give longer dispersion than organic-deficient alkaline streams. For example, north of Foster Lake, Au content of organic-rich bog waters decline gradually from 13.3 ng L^{-1} adjacent to mineralization, to about 1 ng L^{-1} over a distance of 300 m downstream, upon entering Expansion Lake which contains 0.9 to 1.1 ng L^{-1}. Efficient downstream dispersion of Au by organic-complexation is also suggested by the Au influx/accumulation data for Reservoir Lake.

In the Napier Lake area, Au content of organic-deficient alkaline stream waters show decline from anomalous to background over shorter distances, and no translation of measurable Au in lake waters from one lake to another. The mobilization of Au in this environment may be dominated by Au-hydroxy species that are locally destabilized by changing pH and Eh conditions, with inconclusive downstream dispersion patterns.

Taisaev and Plyusnin (1984) and Plyusnin (1987) in studies of Au hydrogeochemistry in northern mountainous terrains observed that high Au values adjacent to mineralization indicated dissolved Au-inorganic species, whereas downstream Au colloid and suspensate types predominated. Their downstream Au contents of about 1 ng L^{-1} compare with that of the present study. Gold may also be carried into the lake as clastic particles in areas of the Shield with moderate relief; or where shore processes erode and redistribute auriferous tills. Particulate Au in lake sediments have been identified by Rogers (1988) and by Schmitt (in prep.) during SEM studies of sediments from the Meguma terrane, Nova Scotia and Waddy Lake, Saskatchewan respectively. Gold carried in this form can be expected to give variable results on repeated analyses from the same site. This may explain the difficulty in obtaining consistent results in some lake sediment surveys (Thomas, 1986; Schmitt and Friske, 1987).

Lake sediments in the acidic-dominated supergene environments of Foster and PAP Lakes are significantly enriched in Au. In the Foster Lake area, Au contents range up to 30 ppb, compared to a background content of < 1 ppb Au for lake sediments in this region (Geological Survey of Canada, 1989). Reservoir Lake, with a mean Au content of 7.3 ppb, contains the highest LOI lake sediments, and greatest concentration of suspended organic material relative to Foster and downstream lakes. Low LOI (silty) lake sediments from Foster Lake display erratic Au contents of < 1 to 22 ppb, suggesting the prescence of particulate Au. Schmitt (unpub.) cites an example of Au occluded to a detrital pyrite grain separated from Waddy Lake, Saskatchewan. This low

LOI lake sediment measured < 1 to 65 ppb Au on repeat analysis, a situation analogous to some low LOI lake sediments from Foster Lake.

PAP Lake profundal sediments contain up to 35 ppb Au with a mean of 4.6 ppb. Lake shore sediments in PAP Lake contain up to 499 ppb Au resulting from the wave erosion of adjacent Au-bearing tills. The dispersal of PAP Lake shore sediments into the lake basin is an important control on Au distribution in this lake's bottom sediments. Additional Au is input from vegetation and low pH Au-bearing organic-rich surface waters. There is also some evidence that alkaline groundwaters with Au contents measured up to 401 ng L^{-1} ,in underlying and adjacent mineralized shear zones, may be contributing Au to PAP lake sediments. Groundwater discharge in to lake basins through the perilimnion (Rogers, 1986) is suggested by the alkaline nature of PAP Lake bottom waters and widespread marly sediments.

In the alkaline-dominant supergene environment of Napier Lake area, Au contents of lake sediments are at or slightly above detection levels of 1 ppb with a weak concentration of maximum values of 3 to 4 ppb immediately downstream of oxidized and stream-eroded mineralization. The Au contents of lake sediments in this alkaline environment, despite clastic input of stream sediments measuring up to 150 ppb Au, only weakly reflect catchment basin Au mineralization. The low Au concentrations in these lake sediments may result from Au mobilized into Napier Lake being diluted by Au-poor allochthanous material, or ineffective precipitation processes, i.e. Au remains in solution and is dispersed downstream, as suggested by persistent Au contents in stream waters.

In conclusion, Au may be transported in both clastic and soluble form, with the local environment determining the relative importance. Lake sediments with gold in clastic form can be expected to give variable results on repeated analyses from the same site, and explains the inconsistent results on some lake sediment surveys. Where clastic dispersal is predominant, follow-up surveys should utilize stream and till geochemical

sampling to improve their effectiveness and aid in interpretation. In very low energy, organic-rich environments found in many parts of the Canadian Shield, Au transport in soluble form or on a suspensate is more important. Under acidic conditions near mineralized environments with abundant S and humic substances, Au solubility may by enhanced by Au-fulvic acid complexes (Vlassopoulos et al., 1990) and precipitation may occur as insoluble Au-humic acid complexes. Where organic material is less abundant, Au-hydroxide species may control the dispersion of Au, with the accumulation of this metal in lake sediments being less pronounced, as was observed at Napier Lake.

The successful follow-up of Au anomalies in lake sediments requires an integrated sampling and analytical approach tailored to the lake catchment basin environment. An exploration strategy should incorporate knowledge of geology, hydrology, limnology, glaciation history (i.e. ice-movement direction, deposit stratigraphy, local and regional variables) and superimposed post-glacial supergene weathering processes. For example, the results of this study suggest that more detailed sampling may be required for alkaline versus acid-dominated organic-rich hydrological environments to overcome erratic or suppressed geochemical contrast for Au.

If hydromorphic dispersion of Au seems important, then during follow-up surveys there is merit in collecting and analyzing lake, stream and surface waters for Au, pH, SO_4^{2-}, conductivity and alkalinity. Collection of 1 L water samples, with no requirement for field treatment, is a rapid and efficient sampling method. Subsequent Br_2-HCl extraction and GFAAS analyses provide a 0.5 ng L^{-1} detection level, appropriate for stream and surface waters in mineralized areas. Contents of Au in lake waters are generally below this detection level, limiting the use of this medium. For example, recent studies (G.E.M. Hall, upublished data) in the Baie Verte Peninsula of Newfoundland showed that 10% of lake water samples contained > 0.5 ng L^{-1} Au, although other sampling media are anomalous for this element.

6.0 CHAPTER SIX

SUMMARY OF CONCLUSIONS, RECOMMENDATIONS FOR FUTURE RESEARCH AND EXPLORATION STRATEGIES

6.1 SUMMARY OF CONCLUSIONS:

This chapter summarizes the principal conclusions of the study and presents a synthesized model of Au mobilization into lake sediments. Additionally, future areas of research are identified which could contribute to this understanding, and strategies for Au exploration using lake sediments are proposed.

Geochemical exploration methods utilizing surficial media contribute significantly to the detection of concealed mineral deposits in glaciated terrain. In the Canadian Shield, analyses of Au from lake sediments have been used since the mid-1980's to explore for Au mineralization. The efficacy of this technique relies on the element's ability to migrate in solution or adsorbed on suspensates in areas of low relief and disorganized drainage in the boreal forest zone. Au mobility in this environment is evidenced by anomalous Au concentrations in organic-rich profundal lake sediments adjacent to Au mineralization. This study examined Au mobility and dispersion under acid and alkaline hydrologic conditions to improve on the understanding of the physico-chemical processes, and to develop better exploration strategies.

Three field areas were selected for study, based on office and initial field examination which indicated similarities in bedrock and surficial geology, Au in lake sediment response, but contrasting hydrogeochemical environments. Analyses of mineralized and unmineralized rock, till, humus, spruce twigs confirmed that Au is being mobilized from bedrock through: supergene oxidation and dissolution of Au-bearing sulphides, glacial erosion and dispersal including physical comminution; and, vegetative uptake and physical re-distribution of organic debris. Upon release from its primary bedrock source, Au was transported to lake environments in part through glacial and post-glacial mechanical dispersal, and physical dispersal of organic materials. The study concludes:

i) The three study areas contain similiar styles of Au mineralization with analogous major element depletion and enrichment trends associated with increasing alteration and Au concentration. For all areas, increasing SiO_2, decreasing MnO, mobilization of Fe into Fe-sulphides, and mobility (generally depletion) of TiO_2, MgO, CaO, Na_2O and K_2O accompany increasing intensity of alteration, structural deformation and quartz-carbonate veining. CO_2 and H_2O initially increase in concentration with increased alteration intensity, and then appear to decrease, possibly due to volatilization. Au concentrations up to 40 ppm occur in surface mineralization. Trace element associations vary for each area;

- Napier Lake Au mineralization is enriched with B, Cu, Mo, and Sm, and variably associated with Zn, As and Sb.

- At PAP Lake, Au mineralization is strongly enriched with Cu, Mo, and Pb; B, As, and Sb are variably associated, whereas Li, Sm, Co, Ni and Zn are relatively depleted.

- Foster Lake Au mineralization is strongly enriched with B, Cu, Zn, Ag, Sb, and W; Li, Sm, Co, As and Sb show inconclusive associations.

ii) Resistant silica-rich mineralized shear zones oriented transversely or at oblique, high angles to latest glacial ice direction facilitated broad physical dispersal of primary mineralization in glacial till. Gold concentrations in fan and ribbon-like till dispersal trains attain 474 ppb in <0.063 mm till fractions, and > 18,000 ppb in total heavy mineral concentrates (>3.32 g cm^{-3}). Trace elements positively correlated with Au in bedrock are similarily correlated in till, however the relationships are less pronounced and more variable, suggesting preferential re-distribution by physical or chemical processes such as adsorption onto Fe and Mn oxide surfaces or dissolution by groundwaters. For some elements, spatial distribution patterns provide a better indication of elemental association than statistical analyses indicate.

iii) Gold uptake in spruce twigs was documented from directly over auriferous mineralization and till, with concentrations of 125 ppb measured in ashed samples. Peat and humus contained up to 372 ppb Au in ashed material, with wider dispersion evident than canopy vegetation. In areas of Au mineralization and widespread Au in tills, biogenic processes make Au available for physical dispersal and expose Au to degraded organic materials containing metal-complexing agents such as fulvic and

humic acids.

iv) The mobilization processes and patterns documented in surficial materials and vegetation provide a variety of adequate source materials for subsequent Au mobilization into lake sediments by further physical or chemical processes.

Hydrogeochemical and water-borne sediment analyses confirm that Au is dissolved during oxidation of Au-bearing mineralization, tills and organic matter, and that it disperses subsequently in solution and adsorbed on suspensates of organic and inorganic composition.

Water samples were collected over and adjacent to mineralization from bogs, streams, trenches and shallow bedrock depressions, lakes and exploration drill-holes. The chemistry of these waters closely reflect their surrounding environment and represent a wide range of pH values from 5.1 to 8.3, alkalinity, conductivity and SO_4^{2-} concentrations. Elevated concentrations of Au in water (i.e. > 2 ng L^{-1}) were documented close to mineralization and decline serially away as dilution, precipitation and adsorption processes occur. Groundwaters taken from drill holes contain up to 401 ng L^{-1}, surface waters contain up to 13.3 ng L^{-1}, and lake waters contain up to 1.1 ng L^{-1}. Lake water suspensates from PAP and Reservoir lakes, immediately downstream of mineralized shear zones, contain Au contents equivalent to 0.039 and 0.17 ng L^{-1} respectively. For Reservoir Lake it was determined that the annual flux of Au carried into the lake in solution or suspended, is far greater than that required to deposit the anomalous levels of Au found in organic lake sediment. This indicates the importance of hydrogeochemical mobilization of Au in low-energy shield environments. Field-based hydrogeochemical data from this study and a review of theoretical and experimental studies on Au thermodynamics and solubility permit the following conclusions to be made:

i) Gold in the boreal forest zone of the glaciated Canadian Shield exhibits solubility and transport under a wide range of ambient chemical conditions. Significant amounts of Au are transported in solution as adsorbed or complexed species. Fluviatile transport and concentration of particulate and occluded Au diminishes considerably in importance with low-energy organic-rich shield lake environments. Higher relief Shield environments may have a mixture of transport types.

ii) In high-S environments sampled in this study, such as; groundwaters close to

oxidizing mineralization, water in ponds and seeps above mineralization, and sulphidic bog water, the dominant Au solubility species are likely $Au(HS)^{2-}$, $Au(HS)^{0}$, and $Au(S_2O_3)^{2-}$.

iii) Au-hydroxy species, such as $AuOH(H_2O)^{0}$, appear to play an important role in Au solubility and transport in the organic-deficient, alkaline pH surface environments sampled.

iv) Efficient downstream dispersion of Au by organic-complexation is suggested by Au concentrations in organic-rich bog waters, and by Au influx/accumulation data for Reservoir Lake. Gold-bearing suspensates filtered from Reservoir Lake and examined by scanning electron microscopy revealed a dominant organic component, with lesser clay and inorganic particulates. Gold transported annually into Reservoir Lake in solution and adsorbed on suspensates, significantly exceeds that which is required to generate the lake bottom sediment Au content. In surface waters, Au is dispersed more persistently at higher concentrations, and over longer distances, in organic-rich, acidic to circum-neutral pH drainage systems than organic-deficient alkaline drainage systems.

v) Groundwaters in contact with mineralization can dissolve significant quantities of Au. At PAP Lake, alkaline, S-rich groundwaters with up to 401 ng L^{-1} Au are contained in mineralized shear zones and may be discharging through the lake perilimnion, to mix with acidic surface waters, contributing to a stratified lake water pH profile, acidic pH at surface, alkaline pH at depth, precipitation of marly lake bottom sediments, and precipitation of Au from surface water and groundwater sources. This complex processes have contributed, in combination with wave and ice-generated shoreline erosion of auriferous till, to widespread elevated concentrations of Au in PAP Lake's bottom sediments.

vi) Under acidic conditions near mineralized environments with abundant S and humic substances, Au precipitation may occur as insoluble Au-humic acid complexes, and Au solubility may be enhanced by Au-fulvic acid complexes as reported in the literature.

vii) Lake sediments into which Au has been transported as discrete grains, or occluded particles can be expected to give variable results on repeated analyses. By

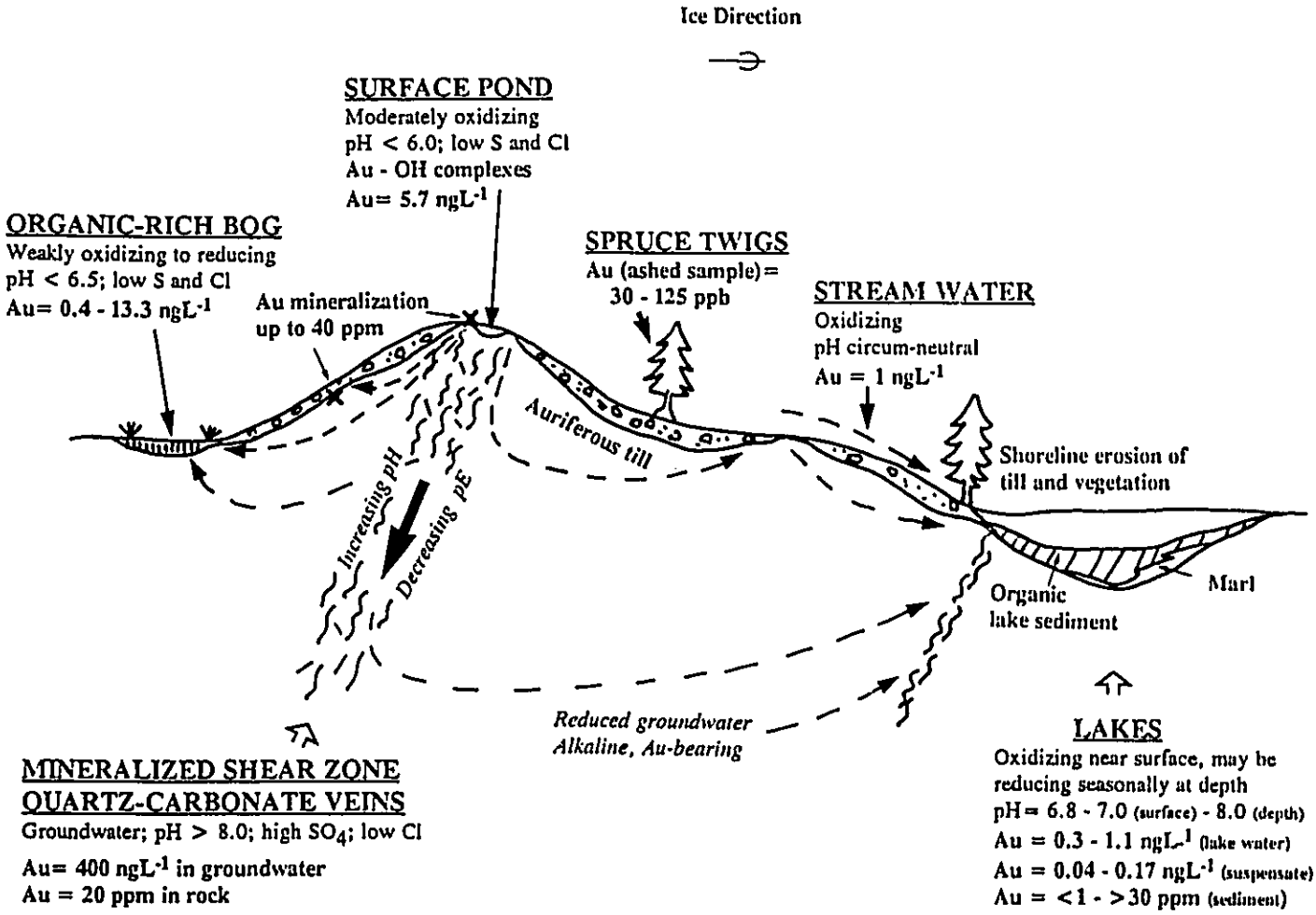
comparison, where Au is significantly transported as dissolved and adsorbed components and precipitated, such as some of the lakes sampled in this study, replicate Au analyses on individual samples indicate a high degree of correlation, reflecting low intra-site variability over a broad range of LOI values.

viii) At Napier Lake, stream erosion of bedrock mineralization and overlying derived till has resulted in well-defined trace element distributions of Au, Fe, Mn, and chalcophile elements in sediments, and SO_4^{2-}, Au, and conductivity in water. Distribution of Au appears to be independant of adsorption influence of Fe and Mn-hydroxides and organics, such as that observed for chalcophile elements in these oxidizing, alkaline streams. Downstream dispersal of Au in these stream sediments and through the intervening lake basins is erratic, compared to the gradual increase in Au in water over the corresponding drainage. The reason for this is summarized in iii) above.

ix) In lake bottom sediments, the study did not document strong inter-relationships between Au and Fe, Mn, LOI, pH or depth. Distribution of Au appears to be influenced largely by the type and degree of transport into the lake basin, and the nature of physical re-distribution processes. This contrasts with the commonly associated chalcophile elements which are strongly influenced by adsoprtion phenomena due to presence of Fe and Mn-hydroxides and organic content.

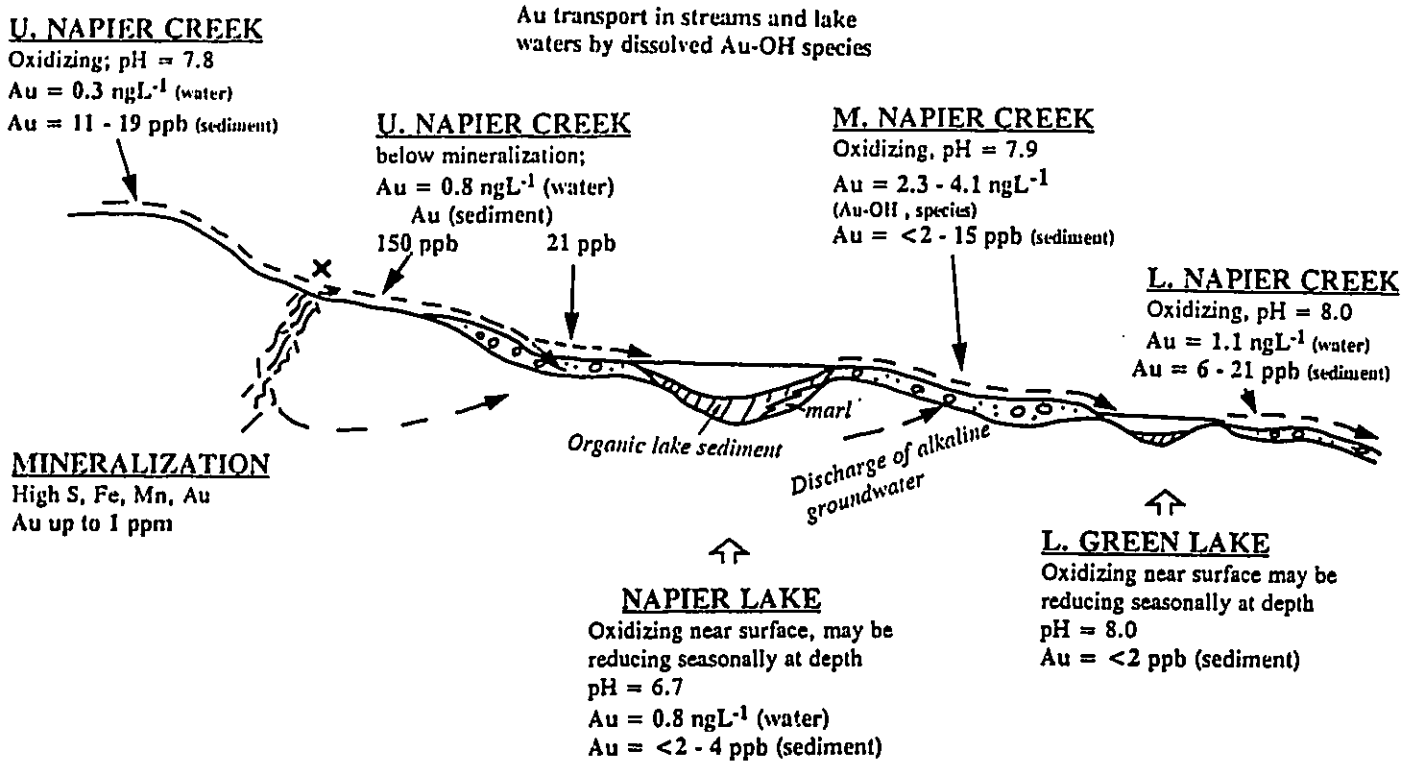
x) The Au content of lake bottom sediments in the Canadian Shield can be used as an effective exploration tool for Au mineralization.

Based on the foregoing conclusions, the following schematic diagrams were prepared for both the Foster - PAP lake, and Napier Lake areas to summarize some of the pathways of Au from mineralization to lake sediments (Fig. 1 and 2).



SCHEMATIC DIAGRAM OF Au MOBILITY IN ACIDIC AND CIRCUM-NEUTRAL ENVIRONMENTS

Fig. 1



SCHEMATIC DIAGRAM OF Au MOBILITY IN ALKALINE NAPIER LAKE ENVIRONMENT

Fig. 2.

6.2 RECOMMENDATIONS FOR FUTURE RESEARCH:

This study has identified several possible areas of further research which could contribute to the objectives of: a) improving explanation of Au in lake sediment anomalies, b) providing improved understanding of Au transport chemistry, and c) improving exploration strategies.

i) Direct evidence of field pE/pH conditions would contribute to understanding Au speciation in the types of acid and alkaline environments identified herein.

ii) A greater understanding of Au distribution in groundwaters, and possible contribution to lake bottom sediments through the perilimnion is necessary to improve on understanding the relative mass transport by surface and groundwaters.

iii) There is a need to better understand why some lake sediments in Au mineralized areas are devoid of Au geochemical response. Are there chemical barriers to Au mobility or precipitation?

iv) A comparison of Au mobilization into lake sediments from a greater variety of mineralized environments, including low Fe, S variants, or areas with widespread exotic non-auriferous till, is warranted.

v) Examination of Au mobility in acidic and alkaline, low-energy, organic deficient, sub-arctic lake environments is warranted to assist with exploration strategies in northern environments.

6.3 EXPLORATION STRATEGIES FOR FOLLOWING UP Au ANOMALIES IN LAKE SEDIMENTS:

The successful follow-up of Au anomalies in lake sediments requires an integrated sampling and analytical approach tailored to the lake catchment basin environment. An exploration strategy should incorporate knowledge of geology,

hydrology, limnology, glaciation history (i.e. ice-movement direction, deposit stratigraphy and chemistry, local and regional variables) and superimposed post-glacial supergene weathering processes. For example, the results of this study suggest that more detailed sampling may be required for alkaline versus acid-dominated organic-rich hydrological environments to overcome possible erratic or suppressed geochemical contrast for Au. A two-stage strategy is recommended for either environment to follow-up regional lake sediment surveys with initial sampling densities of 1 site per 5 to 13 km^2. The recommendations expand on those suggested earlier by Coker et al., (1982).

The objective of the first stage would be to select specific Au anomalies worthy of detailed and more costly follow-up. Can the anomaly be repeated on re-sampling? What are the characteristics of the lake sediment? Verification of an anomaly requires repeat sampling, including site duplicates, at multiple sites. Sample sites should include centre-lake bottom sediments, perilimnion zone lake bottom sediments, and nearshore sediments ideally parallel to ice direction and along the shore on the up-ice end of the lake. Repeat analyses employing analytical techniques with detection levels for Au of 1ppb permit evaluation of inter- and intra-site variability and discrimination of a hydromorphic or clastic-dominant control on Au mobilization. Collection of drainage sediments and surface waters entering the lake margin is recommended at this stage to support preliminary interpretation.

Following verification of a Au anomaly, the next objective is to trace the anomaly to its bedrock source. The sampling strategy must consider the catchment basin geomorphology and hydrology to determine the best initial combination of surficial media (water, till, humus, vegetation) and sample site density. If hydromorphic controls on Au mobilization appear dominant, then there is merit in collecting and analyzing lake, stream and surface waters for Au, pH, SO_4, conductivity, and alkalinity. Collection of 1 L water samples, with no requirement for field treatment, is a rapid and efficient sampling method. Subsequent Br_2-HCl

extraction and GFAAS analyses provide a 0.5 ng L^{-1} or better, detection level appropriate to the level of Au content of water in mineralized areas. Microscopic examination of mineral concentrates from till, drainage sediments, soil, and humus, can provide mineralogical information as well as aid in selecting an appropriate analytical fraction for maximum geochemical contrast. The use of pathfinder elements As, Cu, Zn, Fe, S, Mo, W, Co, Ni, Sb, Te, Hg, Ag, B, and Br in lake sediments and other surficial materials, is applicable for certain types of mineral deposits. The ultimate success of the program ability to detect Au mineralization will depend on the effective integration of a catchment basin model with a robust geochemical sampling strategy.

7.0 CHAPTER SEVEN

REFERENCES

Armstrong, D.C., and Parslow, G.R., 1988. Geochemistry and gold metallogenic studies, Sulphide-Pap Lakes area. Summary of Investigations 1987, Saskatchewan Geol. Surv., Misc. Rept. 87-4:52-57.

Aslin, G.E.M., 1976. The determination of arsenic and antimony in geological materials by flameless atomic absorption spectrophotometer. J. Geoch. Ex. 6: 321-330.

Averill, S.A., 1988. Regional variations in the gold content of till in Canada. In: D.R. MacDonald (Editor), Prospecting in Areas of Glaciated Terrain - 1988. Canadian Inst. Min. Metall., Proc. Symp., Halifax: 271-284.

Baker, W.E. 1973. The role of humic acids from Tasmanian podzolic soils in mineral degradation and metal mobilization: Geochimica et Cosmochimica Acta, v. 37, p. 269-281.

Baker, W.E., 1978. The role of humic acid in the transport of gold. Geochim. Cosmochim. Acta, 42: 645-649.

Baker, W.E., 1986. Humic substances and their role in the solubilization and transport of metals. In: D. Carlisle, W. L. Berry, I. R. Kaplan, and J. R. Watterson (Editors). Mineral Exploration - Biological Systems and Organic Matter, Rubey Vol. V., Prentice-Hall, N.J.: 377-407.

Baldwin, D.A., 1987. Gold mineralization associated with the Johnson shear zone . Lynn Lake, Manitoba. Manitoba Energy and Mines, Rept. of Field Activities, 1987: 7-11.

Baldwin, D.A., Parbery, D., Boden, S., and Michielsen, A., 1985. Mineral studies in the Lynn Lake and Barrington Lake areas. Manitoba Energy and Mines, Rept. of Field Activities, 1985:20-28.

Banville, R.M.P., 1987. Biogeochemical studies of gold in Darling Township, Ontario. Univ. Ottawa, unpub. B.Sc. thesis.

Benedetti, M. and Boulegue, J. 1991. Mechanism of gold transfer and deposition in a supergene environment. Geochim. Cosmochim. Acta, 55: 1539-1547.

Bernier, M.A., and Webber, G.R., 1989. Mineralogical and geochemical analysis of shallow overburden as an aid to gold exploration in southwestern Gaspesie, Quebec, Canada. J. Geochem. Explor., 34: 115-145.

Bogle, E.W., and Nichol, I., 1981. Metal transport, partitioning and fixation in drainage waters and sediments in carbonate terrane in southeastern Ontario. J. Geochem. Explor., 15: 405-422.

Boulanger, A., Evans, D.J.R., and Raby, B.F., 1975. Uranium analyses by neutron activation delayed neutron counting; Proceedings of the 7th Annual Symposium of Canadian Mineral Analysts, Thunder Bay, Ontario; 22-23/09/1975.

Boyle, R.W., 1979. The geochemistry of gold and its deposits. Geol. Surv. Can., Bull. 280: 584 pp.

Boyle, R.W., Alexander, W.M., and Aslin, G.E.M., 1975. Some observations on the solubility of gold. Geol. Surv. Can., Pap. 75-24: 6 pp.

Brereton, W.E., Briggs, D,N., and Rollinson, J.P., 1988. Till prospecting in the area of the Farley Lake gold deposits, northwestern Manitoba, Canada. In: D.R. MacDonald (Editor), Prospecting in Areas of Glaciated Terrain - 1988. Canadian Inst. Min. Metall., Proc. Symp., Halifax:225-239.

Brooks, R.R., Chaterjee, A.K. and Ryan, D.E., 1981. Determination of gold in natural waters at the parts-per-trillion (pg cm-3) level. Chem. Geol., 33: 163-169.

Cameron, E.M. 1977. Geochemical dispersion in lake waters and sediments from massive sulphide mineralization, Agricola Lake area, Northwest Territories; Journal of Geochemical Exploration, v. 7(3), p. 327-348.

Cameron, E.M., 1978. Hydrogeochemical methods for base metal exploration in the Northern Canadian Shield. J. Geochem. Explor., 10: 219-243.

Cameron, E.M., 1980. Geochemical exploration for uranium in northern lakes. J. Geochem. Explor., 13: 221-250.

Carter, T.R. and Colvine, A.C., 1979. The geology and preliminary metallogenetic classification of metallic mineral deposits of the Grenville Province of southeastern Ontario. In: Ont. Geol. Surv., Summary of Field Work, 1979, Misc. Paper 90: 199-207.

Clark, J.S., 1992. Detection of bedrock-related geochemical anomalies at the surface of transported

overburden. Explore, 76, July 1992: 1-11.

Cloke, P.L., and Kelly, C., 1964. Solubility of gold under inorganic supergene conditions. Econ. Geol. 59: 259-270.

Coker, W.B., 1981. Gold in lake sediments (part of NTS 64D) - regional lake sediment geochemical reconnaissance data, east-central Saskatchewan; Geol. Surv. Can, Open File 683, 16 p.

Coker, W.B. and Dunn. C.E., 1983. Lake water and lake sediment geochemistry, NEA/IAEA Athabasca test area. In: E.M. Cameron (Editor) Uranium Exploration in Athabasca Basin, Saskatchewan, Canada, Geol. Surv. Can., Spec. Paper 82-11: 117-125.

Coker, W.B., Fox, J.S., and Sopuck, V.J., 1982. Organic centre-lake sediments - Application in the geochemical exploration for gold in the Canadian Shield of Saskatchewan. In: R.W. Hodder and W. Petruk (Editors), Geology of Canadian Gold Deposits. Canadian Inst. Min. Metall., Spec. Vol. 24: 267-280.

Coker, W.B., Hornbrook, E.H., and Cameron, E.M., 1979. Lake sediment geochemistry applied to mineral exploration. In: P. J. Hood (Editor), Geophysics and Geochemistry in the Search for Metallic Ores. Geol. Surv. Can., Econ. Geol. Rept. 31: 434-477.

Coker, W.B. and Nichol, I., 1975. The relation of lake sediment geochemistry to mineralization in the northwestern Ontario region of the Canadian Shield. Econ. Geol., 70: 202-218.

Coombe, W., 1986. Gold in Saskatchewan. Saskatchewan Geol. Surv., Open File Rept. 84-1: 134 pp.

Curtin, G.C. and King, H.D. 1986. Utility of mull in geochemical exploration. In: D. Carlisle et al. (Editors) Mineral Exploration-Biological Systems and Organic Matter, Rubey Vol. V.:357-376.

Davenport, P.H. and Nowlan, L.W., 1989. Mapping the regional distribution of gold in Newfoundland using lake sediment geochemistry. Geol. Surv. Nfld., Current Res. 1989. Rept. 89-1:259-266.

DiLabio, R.N.W., 1988. Residence sites of gold, pge and rare lithophile elements in till. In: D.R. MacDonald (Editor), Prospecting in Areas of Glaciated Terrain - 1988. Canadian Inst. Min. Metall., Proc. Symp., Halifax: 121-140.

DiLabio, R.N.W. and Coker, W.B., (Editors), 1989. Drift Prospecting. Geol. Surv. Can., Paper 89-20, 169 pp.

Drake, L.D., 1983. Ore plumes in till. J. Geol., 91: 707-713.

Dunn, C.E. 1984. Biogeochemical method and surveys, southern LaRonge belt; in Summary of Investigations, 1984, Saskatchewan Geological Survey, Miscellaneous Report 84-4, p. 95-103.

Dunn, C.E., 1986a. Application of biogeochemical methods to mineral exploration in the boreal forests of central Canada. In: D. Carlisle et al., (Editors) Mineral Exploration - Biological Systems and Organic Matter, Rubey Vol. V.: 133-149.

Dunn, C.E., 1986b. Biogeochemistry as an aid to exploration for gold, platinum, and palladium in the northern forests of Saskatchewan, Canada. J. Geochem. Explor., 25: 21-40.

Dunn, C.E., 1988. Reconnaissance level biogeochemical surveys for gold in Canada; in Prospecting in Areas of Glaciated Terrain - 1988, ed. D.R. MacDonald, Canadian Institute of Mining and Metallurgy, p. 433-448.

Dunn, C.E., 1992. Biogeochemical exploration for deposits of the noble metals; Chapter 3, In: Noble Metals and Biological Systems, R.R. Brooks (Editor), CRC Press,: 47-89.

Fedikow, M.A.F., Baldwin, D.A., and Taylor, C., 1986. Gold mineralization associated with the Agassiz Metallotect and the Johnson shear zone, Lynn Lake greenstone belt, Manitoba. In: L.A. Clark (Editor) Gold in the Western Shield. Canadian Inst. Min. Metall., Spec. Vol. 38:361-378.

Ferreira, K., 1986. Geological investigations in the Foster Lake - Wasekwan area. Manitoba Energy Mines, Rept. of Field Activities 1986: 13-17.

Ficklin, W.H., 1970. A rapid method for the determination of fluoridein rocks and soils, using an ion selective electrode. U.S. Geol. Surv. Pap. 700C: C186-C188.

Fox, J.S., Eagles, T.E., and Brooker, E.J., 1985. The application of lake sediment surveying to Au exploration in Ontario. Ontario Geol. Surv., Misc. Pap. 125: 85-94.

Friske, P.W.B. and Hornbrook, E.H.W., 1991. Canada's National Geochemical Reconnaissance programme. Trans. Inst. Metall., Sect. B, 100: 47-56.

Gadd, N.R., 1980. Late-glacial regional ice-flow patterns in eastern Ontario. Canadian Jour. Earth Sci., 11: 1439-1453.

Geological Survey of Canada 1984. Regional lake sediment and water geochemical reconnaissance data,

Manitoba, 1983; Open File 999, NTS 64C.

Geological Survey of Canada, 1985. Regional lake sediment and water geochemical reconnaissance data, south-central Saskatchewan, 1984; Open File 1129, parts of NTS 63L, M, 73 I, O, and P.

Geological Survey of Canada, 1986. Regional lake sediment and water geochemical reconnaissance data, Manitoba, 1985. Geol. Surv. Can., Open File 1288, NTS 64C.

Geological Survey of Canada, 1988. Regional lake sediment and water geochemical reconnaissance data, Manitoba, 1987; Open File 1641, NTS 63H(NE), 63I, 63P(SE).

Geological Survey of Canada, 1989. Geochemical results and interpretation of a lake sediment and water survey in the Lynn Lake - Leaf Rapids region, northern Manitoba. Geol. Surv. Can., Open File 1959, parts of NTS 64C and 64B.

Gilbert, H.P., Syme, E.C., and Zwanzig, H.V., 1980. Geology of the metavolcanic and volcaniclastic rocks in the Lynn Lake area. Manitoba Dept. Energy and Mines.,Geol. Paper GP80 - 1, 118 p.

Gleeson, C.F., Rampton, V.N., Thomas, R.D. and Paradis, S., 1984. Grant 065, development and adaptation of geochemical techniques to gold exploration in glacial drift. Ontario Geol. Surv., Misc. Pap. 120: 129-149.

Gleeson, C.F., Rampton, V.N., Thomas, R.D., Paradis, S., and Corden, S.G., 1988. Peatlands and gold exploration. In: D.R. MacDonald (Editor), Prospecting in Areas of Glaciated Terrain. Canadian Inst. Min. Metall., Proc. Symp., Halifax: 403-431.

Gosling, A.W., Jenne, E.A. and Chao, T.T., 1971. Gold content of natural waters from Colorado. Econ. Geol., 66: 309-313.

Groen, J.C., Craig, J.R. and J.D. Rimstidt, 1990. Gold-rich rim formation on electrum grains in placers. Canadian Miner., 28: 207-228.

Hall, G.E.M., 1979. A study of the stability of uranium in waters collected from various geological environments in Canada. In Curr. Res. part A, Geol. Surv. Can. Pap. 79-1A: 361-365.

Hall, G.E.M., Vaive, J.E., and Ballantyne, S.B., 1986. Field and laboratory procedures for determining gold in natural waters: relative merits of pre-concentration with activated charcoal. J. Geochem. Explor., 26: 191-202.

Hamilton, T.W., Ellis, J., Florence, T.M., and Fardy, J.J., 1983. Analysis of gold in surface waters from Australian goldfields: An investigation into direct hydrogeochemical prospecting for gold. Econ. Geol. 78: 1335-1341.

Hornbrook, E.H.W., and Garrett, R.G., 1976. Regional geochemical lake sediment survey East-central Saskatchewan. Geol. Surv. Can., Pap. 75-41: 20pp.

Jonasson, I.R., Lynch, J.J., and Trip, L.J., 1973. Field and laboratory methods used by the Geological Survey of Canada in geochemical surveys; No. 12, Mercury in Ores, Rocks, Soils, Sediments and Water. Geol. Surv. Can. Pap. 73-21.

Kaszycki, C.A., and DiLabio, R.N.W., 1986. Surficial geology and till geochemistry, Lynn Lake - Leaf Rapids region, Manitoba. Geol. Surv. Can., Pap. 86-1B: 245-256.

Kharouba, N, 1987. Geochemical exploration in lake and stream sediments: an example from Lanark County. unpublished B.Sc. thesis, Univ. of Ottawa, 61 p.

Klassen, R.W., 1985. Surficial geology of north-central Manitoba. Geol. Surv. of Can., Mem. 419:57 p.

Lakin, H.W., Curtin, G.C., and Hubert, A.E., 1974. Geochemistry of gold in the weathering cycle. U.S. Geol. Surv., Bull. 1330, 80 pp.

Lewry, J.F., 1984a. Continental platforms and suspect terrains in the Lower Proterozoic Trans-Hudson Orogen. Geol. Assn. Can.- Mineral. Assn. Can., Prog. with Abstracts, p. 84.

Lewry, J.F., 1984b. Bedrock compilation Lac La Ronge - Wapawekka areas (NTS 73P/73I). Summ. of Invest. 1984, Saskatchewan Energy and Mines, 84-4: 34-41.

Mann, A.N. 1984. Mobility of gold and silver in lateritic weathering profiles - some observations from western Australia; Economic Geology, v. 39, p. 38-49.

Maurice, Y.T., 1985. Interpretation of data from Nonacho Lake - east arm of Great Slave Lake region, District of Mackenzie. Geol. Surv. Can., Paper 84-12: 17p.

McConnell, J., 1984. Reconnaissance and detailed geochemical surveys for base metals in Labrador. Nfld. Dept. Energy and Mines., Rept. 84-2: 114 p.

McHugh, J.B., 1984. Gold in natural water: a method of determination by solvent extraction and electrothermal atomization. J. Geochem. Explor., 20: 303-310.

McHugh, J.B., 1988. Concentration of gold in natural waters. J. Geochem. Explor., 30: 85-94.

Mining Journal, 1990. Preview Lake Work Resumes: 124-126.

Nicholson, R.V., Gillham, R.W., and Reardon, E.J., 1988. Pyrite oxidation in carbonate-buffered solution: 1. Experimental kinetics. Geochim. Cosmochim. Acta., 52: 1077-1085.

Nielsen, E. and Graham, D.C., 1985. Preliminary results of till petrographical and till geochemical studies at Farley Lake, Manitoba. Manitoba Energy and Mines. Open File 85-3: 62 p.

Nielsen, E. and Fedikow, M.A.F., 1987. Glacial dispersal of trace elements in Wisconsinan till in the Dot Lake-MacLellan mine area, Manitoba. Manitoba Energy and Mines. Open File 87-2: 73p.

Pitul'ko, V.M., 1976. The behaviour of gold in the oxidized zones of deposits in the far north. Geochem. Intl., 13: 157-163.

Plyusnin, A.M., 1987. Formation of aqueous dispersal-flows at gold deposits in bald-mountain landscapes. Geokhimiya, 8: 1153-1158.

Renders P.J. and Seward, T.M., 1989. The stability of hydro-sulphido- and sulphido-complexes of Au(I) and Ag(I) at 250C. Geochem. Cosmochim. Acta, 53: 245-253.

Rogers, P.J., 1988. Gold in lake sediments; implications for precious metal exploration in Nova Scotia. In: D.R. MacDonald (Editor), Prospecting in Areas of Glaciated Terrain. Canadian Inst. Min. Metall., Proc. Symp., Halifax: 357-381.

Rogers, P.J., Stea, R.R., and MacDonald, M.A., 1987. Statistical investigation of the geochemical reflection of Au mineralization in the tills and lake sediments of the Eastern shore region of Nova Scotia. Nova Scotia Dept. Mines and Energy, Summ. Invest.: 137-151.

Rose, A.W., Hawkes, H., and Webb, J.S., 1979. Geochemistry in Mineral Exploration. Acad. Press, 2nd Ed.: 657 p.

Schmitt, H.R., 1989. A preliminary report on the distribution of gold in lake sediments and surficial materials at Foster Lake, Manitoba. Geol. Surv. Can., Pap. 89-1C: 255-262.

Schmitt, H.R., and Friske, P.W.B., 1987. Regional geochemical surveys and gold in lake sediment investigations in Saskatchewan. In: C.F. Gilboy and L.W. Vigrass (Editors) Economic Minerals of Saskatchewan, Saskatchewan Geol. Soc., Spec. Pub. 8: 66-77.

Schmitt, H.R., Cameron, E.M., Hall, G.E.M., and Vaive, J.E., in press. Mobilization of gold into lake sediments from acid and alkaline mineralized environments in the southern Canadian Shield: Gold in lake sediments and natural waters. submitted to J. Geochem. Explor. 1993.

Schnitzer, M., 1986. Reaction of humic substances with metals and minerals. In: C. Carlisle et al., (Editors), Mineral Exploration - Biological Systems and Organic Matter, Rubey Vol. V., Prentice Hall, N.J.: 408-444.

Schreiner, B.T., and Alley, D.W., 1984. Quaternary Geology of Lac la Ronge Area, NTS 73P, Saskatchewan. Saskatchewan Energy and Mines, Open File Rept. 84-4: 1:250,000.

Sherman, G.R., Samson, I.M., and Holm, P.E., 1989. Deformation, veining and gold mineralization along part of the Johnson shear zone, Lynn Lake greenstone belt, Manitoba. Manitoba Energy and Mines, Rept. of Field Activities, 1989,: 16-18.

Sherritt Gordon Mines, 1983. Geological map of the Foster Lake area. internal company map, 1:4800.

Sibbald, T.I.I., 1986. Bedrock geological mapping, Sulphide Lake area (part of NTS 73P/7), Saskatchewan Geol. Surv., Misc. Rept. 86-4: 63-64.

Smith, B.L. and Peach, P.A., 1958. Geology of the Clarendon - Dalhousie area. Ontario Dept. Mines, Ann. Rept. 1956, Vol. 55, part 7.

Sopuck, V., Schreiner B., and Averill, S. 1986. Drift prospecting for gold in Saskatchewan - use of heavy mineral concentrates in till. In: L.A. Clark (Editor) Gold in the Western Shield. Canadian Inst. Min. Metall., Spec. Vol. 38: 435-469

Stoffregen, R., 1986. Observations on the behaviour of gold during supergene oxidation at Summitville, Colorado, U.S.A., and implications for electrum stability in the weathering environment. App. Geochem., 1: 549-558.

Taisaev, T.T. and Plyusnin, A.M., 1984. Hydrogeochemical prospecting for gold in an alpine bald mountain zone. J. Geochem. Explor. 21: 355-360.

Thomas, M.W., 1986. Lake sediment gold anomalies; follow-up survey. Saskatchewan Geol. Surv., Misc. Rept. 86-4: 72-75.

Timperley, M.H. and Allan, R.J., 1974. The formation and dispersion of metal dispersion halos in organic lake sediments. J. Geochem. Explor. 3: 167-190.

Vlassopoulos, D. and Wood, S.A., 1990. Gold speciation in natural waters: I. Solubility and hydrolysis reactions of gold in aqueous solution. Geochim. Cosmochim. Acta., 54(1): 3-12.

Vlassopoulos, D., Wood, S.A., and Mucci, A., 1990. Gold speciation in natural waters II: The importance of organic complexing - Experiments with some simple model ligands. Geochim. Cosmochim. Acta., 54(6): 1575-1586.

Watters, B.R., 1986. Geochemistry and geochronology of metavolcanic and plutonic rocks in the Central Metavolcanic belt. Summary of Investigations 1986, Saskatchewan Geol. Surv., Saskatchewan Energy and Mines, Misc. Rept. 86-4: 76-83.

Webb, R.S. and Webb, T., 1988. Rates of sediment accumulation in pollen cores from small lakes and mires in eastern North America. Quaternary Research, 30: 284-297.

Webster, J.G., 1986. The solubility of gold and silver in the system Au-Ag-S-O2-H2O at 250C and 1 atm. Geochim. Cosmochim. Acta., 50: 1837-1845.

Webster, J.G., and Mann, A.N., 1984. The influence of climate, geomorphology and primary geology on the supergene migration of gold and silver. J. Geochem. Explor., 22: 21-42.

White, D.E., Hem, J.D., and Waring, G.A., 1963. Chemical composition of sub-surface waters. U. S. Geol. Surv., Prof. Pap. 440-F.

Wright, D.F., Bonham-Carter, G.F., and Rogers, P.J., 1988. Spatial data integration of lake sediment geochemistry, geology and gold occurrences, Meguma Terrane, eastern Nova Scotia. In: D.R. MacDonald (Editor), Prospecting in Areas of Glaciated Terrain. Canadian Inst. Min. Metall., Proc. Symp., Halifax: 501-515.

Zwanzig, H.V., Parker, J.S.D., Schledewitz, D.C.P., and Van Schmus, W.R. 1985. Lynn Lake regional compilation and geochronology; in Report of Field Activities, 1985; Manitoba Energy and Mines, p. 6-8.

APPENDIX ONE

LITHOGEOCHEMICAL DATA

LITHOGEOCHEMICAL DATA FILE CODE

ROCKID: rock sample number
LOCATION: field sample area
ROCKTYPE: summary sample description

ELEMENT	DETECTION LEVEL	METHOD
SiO_2	0.01 %	Borate fusion/DCP-AES
TiO_2	0.01 %	-"-
$Al2O_3$	0.01 %	-"-
Fe_2O_3	0.01 %	-"-
FeO	0.01 %	-"-
MnO	0.01 %	-"-
MgO	0.01 %	-"-
CaO	0.01 %	-"-
Na_2O	0.01 %	-"-
K_2O	0.01 %	-"-
P_2O5	0.01 %	-"-
CO_2	0.01 %	-"-
H_2O	0.01 %	gravimetric
LOI	0.05 %	gravimetric
TOTALPCT	0.01 %	
B	10 ppm	NaOH fusion/ DCP
Na	variable %	instrumental neutron activation
Fe	variable %	-"-
Cr	50 ppm	instrumental neutron activation
Co	10 ppm	-"-
Ni	20 ppm	-"-
As	2 ppm	-"-
Sb	0.2 ppm	-"-
Au	5 ppb	-"-
Br	1 ppm	-"-
Rb	10 ppm	-"-
Te	10 ppm	-"-
Cs	1 ppm	-"-
Ba	100 ppm	-"-
La	5 ppm	-"-
Ce	10 ppm	-"-
Sm	0.2 ppm	-"-
W	2 ppm(variable)	-"-
U	0.5 ppm	-"-
Cu	1 ppm	HF:$HClO_4$:HCl:HNO_3 digestion - AAS
Zn	1 ppm	-"-
Pb	1 ppm	-"-
Mo	1 ppm	-"-
Ag	0.1 ppm	-"-
Cd	0.2 ppm	-"-
Li	1 ppm	-"-
S	0.001 %	Leco Induction Furnace

ROCKID	LOCATION	ROCKTYPE	SIO2	TIO2	AL203	FE203	FEO	MNO	MGO	CAO	NA20	K20	P205	H20	CO2	LOI
88nl1	napier lake	gabbro	44.30	3.47	11.60	20.00	14.78	0.28	6.09	7.70	2.97	0.28	0.16	0.25	0.69	1.00
88nl2	napier lake	gabbro, qz-tourm-py vns	72.70	0.07	12.20	2.29	0.44	0.05	0.15	2.34	6.73	0.39	0.15	0.01	1.61	0.25
88nl3	napier lake	gabbro, sheared	59.40	0.16	10.30	17.60	0.25	0.13	0.45	0.26	6.73	3.11	<0.01	2.23	0.04	5.95
88nl4	napier lake	15 cm py vn in gabbro	69.70	0.15	8.91	9.28	0.76	0.01	0.38	0.31	0.15	3.00	<0.01	0.17	0.02	6.00
88nl5	napier lake	gabbro, wkly alt'd	49.00	0.53	12.90	11.40	6.91	0.20	3.16	7.33	3.32	1.68	0.15	<0.01	11.21	7.90
88nl6	napier lake	gabbro, mod alt'd	83.80	0.05	5.60	5.67	0.22	0.03	0.18	0.19	0.24	1.54	0.01	0.25	0.46	0.55
pap87r1	pap lake	quartz vn	68.80	0.01	0.30	14.00	0.70	<0.01	0.04	0.04	0.01	0.06	<0.01	0.06	0.03	15.20
pap87r2	pap lake	felsic metavolc, qz vn	85.90	0.05	6.92	0.98	0.43	0.01	0.24	0.45	2.70	0.79	<0.01	0.02	0.11	<0.05
pap87r4	pap lake	20 cm qz-py-arsenopy vn	27.20	0.07	1.48	35.40	1.19	0.01	0.33	0.26	0.14	0.32	<0.01	1.53	0.02	33.30
pap87r11	pap lake	hornblende diorite	55.60	0.69	15.60	8.21	5.16	0.11	5.30	6.43	3.44	1.31	0.11	0.10	0.01	0.75
pap87r12	pap lake	hornblende diorite, ankeritic	53.30	0.70	17.30	7.54	4.95	0.11	5.34	6.67	3.77	1.73	0.09	0.14	0.01	0.55
pap87r20	pap lake	diorite, alterod-shear'd	69.20	0.45	11.60	4.82	1.97	0.06	3.16	3.71	2.65	1.06	0.08	0.38	0.03	0.65
pap87r21a	pap lake	2.5 cm qz vn	68.30	0.30	5.48	3.39	1.78	0.05	2.02	2.78	1.07	0.31	0.07	0.06	0.02	14.65
papbl4e 00N 50E	pap lake	diorite, qz-ankerite vns	63.60	0.11	3.65	5.04	3.63	0.24	6.09	16.10	0.39	0.13	0.04	0.16	14.16	2.20
64c1087r1	foster lake	int. metavolc.	52.30	1.28	12.60	12.80	9.45	0.24	5.22	9.23	3.27	0.21	0.09	0.16	2.14	0.50
64c1087r2	foster lake	int. metavolc.	46.10	1.81	13.10	16.90	14.21	0.21	7.09	7.15	2.54	0.28	0.11	0.09	0.33	2.25
64c1087r8	foster lake	int. metavolc, mod alt'd	58.70	0.67	14.10	8.35	6.25	0.16	2.60	4.91	1.34	3.14	0.14	0.12	1.59	2.95
64c1087r9	foster lake	30 cm qz-py vns	78.40	0.37	6.61	5.42	2.95	0.11	2.33	0.92	0.35	1.46	0.11	0.51	0.06	2.40
64c1087r9v	foster lake	qz-pyrite vns	92.80	0.07	1.60	1.36	0.83	0.03	0.54	0.48	0.07	0.31	0.18	0.07	0.17	0.50
64c1087r14	foster lake	int. metavolc., wk sulph.	57.40	0.68	15.50	8.38	4.57	0.14	4.72	6.61	1.89	2.10	0.24	0.19	0.02	1.10
64c1087jjb	foster lake	qz-seric vn, cpy,py, gn, sph	95.00	0.03	0.83	0.77	0.22	<0.01	0.09	0.12	0.07	0.16	0.01	0.01	0.02	0.55
64c1087rlv	reservoir lk	qz vn, py,cpy,sph	89.40	0.11	2.16	2.19	1.42	0.02	0.66	1.67	0.62	0.26	0.01	0.01	1.21	0.70
64c1087374e25s	foster lake	metavolc, shr'd, py,mag	51.00	0.64	14.70	11.30	6.08	0.19	7.15	8.38	1.71	1.49	0.30	0.09	0.15	0.90
64c1088r39	foster lake	int. metavolc., alt'd	56.40	1.07	13.70	14.20	9.81	0.24	3.06	5.62	3.27	0.26	0.10	0.05	0.05	1.40
64c1088376e22s	foster lake	amphibolite, wk sulph	41.70	0.84	11.60	9.53	7.27	0.19	4.73	10.50	6.50	0.33	0.13	0.02	15.56	11.40

ROCKID	TOTALPCT	NA_PCT	CR_PPM	FE_PCT	CO_PPM	NI_PPM	AS_PPM	BR_PPM	RB_PPM	SB_PPM	TE_PPM	CS_PPM	BA_PPM	LA_PPM	CE_PPM
88nl1	97.85	1.80	87	13.0	52	<20	36	<1	<10	6.4	<20	<1	<100	8	16
88nl2	97.32	4.60	51	1.8	12	<20	19	<1	<10	3.2	<20	<1	<100	56	150
88nl3	97.62	0.23	58	12.0	<10	61	6	<1	65	3.2	<20	<1	570	15	24
88nl4	97.89	0.14	94	6.4	34	58	4	<1	58	4.2	<20	<1	560	21	39
88nl5	97.57	2.30	<50	7.7	32	30	11	<1	36	1.9	<20	<1	190	7	13
88nl6	97.86	0.20	<50	4.1	11	21	100	1	32	3.9	<20	<1	210	11	20
pap87r1	98.47	<9.4	<50	10.0	110	88	83800	<119	<10	118.0	<54	<1	<100	<5	<10
pap87r2	98.05	1.80	<50	0.6	<10	47	2060	<25	13	3.2	<20	<1	140	11	23
pap87r4	98.52	<8.2	<50	21.0	68	140	90000	<172	<24	5.2	<76	<1	<100	<5	<25
pap87r11	97.55	<2.2	250	6.3	35	98	11400	<8	30	3.6	<20	<1	460	14	28
pap87r12	97.10	2.50	170	5.6	28	120	1740	<11	35	0.8	<20	<1	450	11	31
pap87r20	97.45	1.90	130	3.6	15	51	693	5	27	0.8	<20	<1	290	7	19
pap87r21e	98.41	0.75	<50	2.3	11	25	193	1	<10	1.2	<20	<1	<100	<5	<10
papbl4e 00N 50E	97.59	0.32	120	3.7	11	<20	307	3	<10	1.2	<20	<1	<100	7	16
64c1087r1	97.74	2.30	<50	9.0	51	44	82	1	<10	0.6	<20	<1	<100	<5	<10
64c1087r2	97.54	1.90	<50	12.0	67	27	111	<1	<10	0.4	<20	<1	<100	5	11
64c1087r8	97.06	1.00	<50	5.9	23	<20	46	<1	78	0.5	<20	2	620	6	12
64c1087r9	98.48	0.28	<50	3.8	14	<20	23	<1	37	0.5	<20	<1	240	<5	<24
64c1087r9v	97.95	0.06	<50	1.0	<10	<20	26	<1	<10	0.4	<20	<1	<100	<5	<10
64c1087r14	98.76	1.60	130	6.8	35	44	12	<1	43	0.C	<20	2	780	9	23
64c1087jjb	97.63	0.05	<50	0.7	<10	<20	62	9	<10	212.0	<60	<1	<100	<5	<55
64c1087rlv	97.79	0.48	<50	1.7	11	27	20	<1	<10	6.1	<20	<1	110	<5	<28
64c1087374e25s	97.76	1.30	280	8.0	43	93	25	<1	48	1.6	<20	1	950	8	<10
64c1088r39	99.32	2.30	<50	10.0	29	<20	17	<1	<10	1.5	<20	<1	<100	<5	<10
64c1088376e22s	97.45	4.50	110	6.5	37	<20	13	<1	<10	0.6	<20	<1	<100	<5	<10

ROCKID	SM_PPM	W_PPM	AU_PPB	TH_PPM	U_PPM	CU_PPM	ZN_PPM	MO_PPM	AG_PPM	CD_PPM	PB_PPM	LI_PPM	B_PPM
88nl1	7.4	<2	<5	<0.5	<0.5	22	50	4	0.2	<0.2	18	10	<10
88nl2	34.1	<2	974	6.0	2.1	3	7	1	0.5	<0.2	9	5	924
88nl3	3.9	<2	24	3.2	1.6	59	8	6	0.3	<0.2	17	7	157
88nl4	4.9	2	29	3.4	2.3	13	4	12	1.2	<0.2	23	6	124
88nl5	4.9	<2	440	<0.5	0.5	74	42	4	0.2	<0.2	7	5	17
88nl6	3.3	3	270	1.8	0.6	32	10	72	<0.2	<0.2	4	3	22
pap87r1	0.5	<85	4120	<0.5	<2.2	2115	11	3	25.7	<0.2	16	1	11
pap87r2	4.6	<2	130	2.7	1.1	67	36	1	0.7	0.2	6	5	14
pap87r4	0.5	<120	22200	<1	<3.2	17	8	37	1.6	<0.2	20	3	12
pap87r11	3.5	<55	510	2.7	2.1	31	35	3	0.1	<0.2	6	17	37
pap87r12	3.5	<2	76	1.3	0.6	54	73	3	<0.2	<0.2	2	20	<10
pap87r20	2.1	<2	5900	1.5	1.0	248	43	2	0.6	<0.2	3	16	18
pap87r21a	1.0	3	20500	<0.5	<0.5	303	61	<1	1.5	0.2	4	5	31
papbl4e 00N 50E	2.1	<2	240	<0.5	<0.5	44	32	7	<0.2	<0.2	7	6	80
64c1087r1	3.1	<2	26	<0.5	<0.5	49	18	2	<0.2	<0.2	2	10	<10
64c1087r2	4.7	<2	10	<0.5	<0.5	21	30	2	0.2	<0.2	3	15	<10
64c1087r8	3.4	8	140	0.7	0.6	111	105	4	0.7	<0.2	8	20	135
64c1087r9	2.4	9	36000	<0.5	<0.5	84	54	1	4.0	<0.2	109	10	66
64c1087r9v	0.9	3	1910	<0.5	<0.5	25	20	2	0.5	<0.2	15	3	64
64c1087r14	3.1	4	100	1.3	0.5	65	74	3	0.1	<0.2	4	18	92
64c1087jjb	<0.2	<2	39700	<1.5	<1.1	599	626	<1	87.2	4.4	3390	<1	14
64c1087rlv	0.7	7	16200	<0.5	<0.5	403	693	1	8.5	4.6	333	2	483
64c1087374e25s	3.1	2	290	1.7	0.9	76	62	4	0.8	<0.2	25	16	22
64c1088r39	2.8	<2	120	<0.5	<0.5	132	126	1	0.7	<0.2	17	10	12
64c1088376e22s	2.2	73	220	<0.5	<0.5	46	108	5	0.1	0.3	10	3	<1

APPENDIX TWO

TILL GEOCHEMICAL DATA

TILL GEOCHEMICAL DATA FILE CODE

TILLID:	till sample number;PAP from PAP Lake area,88 = collection year 31f2 and 64c10 refer to NTS map areas corresponding to Napier Lake and Foster Lake areas
LOCATION:	field sample area, some are identified by established grid coordinates
DEPTH:	depth in metres to sampled horizon
TYPE:	nature of sample; cly=clay;snd=sandy;stn=stoney;pbl=pebbly;cbl=cobbly;peaty;org=organic-rich
COLOUR:	brn=brown;olv=olive;gry=grey;yel=yellowish;orn=orange;tan=tan;
OXIDAT_INT:	oxidation intensity of till; weak, moderate or high
GEOL:	nature of exposed bedrock in vicinity

ELEMENT	DETECTION LEVEL	METHOD
Analyses on -250 mesh (<0.63 mm) subsample		
Cr	20 ppm	instrumental neutron activation (INAA)
Fe	0.02%	-"-
Co	5 ppm	-"-
Ni	10 ppm	-"-
As	0.5 ppm	-"-
Br	1 ppm	-"-
Sb	0.2 ppm	-"-
Ba	100 ppm	-"-
La	1ppm	-"-
Ce	5 ppm	-"-
Sm	0.1 ppm	-"-
W	1 ppm	-"-
Au	2 ppb	-"-
Th	0.5 ppm	-"-
U	0.5 ppm	-"-
T_250WT_G (wt of sample)		gravimetric
Analyses on heavy mineral concentrate from subsample >3.32 gcm^3		
Cr_HMC	10 ppm (variable)	instrumental neutron activation (INAA)
Fe_HMC	0.02%	-"-
Co_HMC	5 ppm (variable)	-"-
Ni_HMC	200 ppm (variable)	-"-
As_HMC	2 ppm (variable)	-"-
Br_HMC	5 ppm (variable)	-"-
Sb_HMC	<0.1 ppm (variable)	-"-
La_HMC	1 ppm	-"-
Ce_HMC	3 ppm	-"-
Sm_HMC	0.1 ppm	-"-
Ta_HMC	<0.5 ppm (variable)	-"-
W_HMC	1 ppm (variable)	-"-
Au_HMC	5 ppb (variable)	-"-
Th_HMC	0.5 ppm	-"-
U_HMC	0.5 ppm (variable)	-"-

HMC_WT_G	weight in grams of analysed total heavy mineral concentrate
RASAWT_KG	weight in kilograms of original field till sample
HMC_TWT_G	weight in grams of total heavy mineral concentrate, initial measurement prior to analyses, HMCWT represents reweighed sample
T_250WT_KG	weight in kilograms of -250 mesh subsample

TILL SAMPLE PREPARATION PROCEDURES:

Till samples were collected in the field from hand-dug pits down to 1.5 m deep which is the practical limit of a cost and time-effective sample hole. In most instances till sample depth was less than this because of the thinness of the till veneer in the sample areas, a reason for choosing them.

Till samples weighed between 5 and 10 kg, they were placed in durable 20L polyethelene bags on collection, numbered and secured. Till samples were subsequently air-dried under controlled conditions to avoid air-borne contamination. Thereafter they were manually coned and a 500 g to 1 kg subsample prepared. From this subsample, a +10 mesh, -10 mesh to +250 mesh, and -250 mesh (<0.063 mm) size fractions were prepared by a commercial laboratory. All size fractions were weighed. The <0.063 mm fraction was sub-sampled and submitted for instrumental neutron activation analysis for Au plus 33 other elements as indicated in the data file list.

The remainder of the coned sample was used to prepare a heavy mineral concentrate by the following procedure. The sample was rebagged and labelled and sent to a commercial laboratory specializing in heavy mineral concentration procedures. The till sample was weighed, and preconcentrated using a circular gold wheel. Thereafter the preconcentrate was further concentrated with care using a Wifley table, with adjustments being made in slope, water flow and feed rates to optimize concentrate. Lights and intermediate density fractions were retained for examination of quality control. The resultant heavy mineral concentrate was further concentrated to a fraction with specific gravity < 3.32 g cm-3 using methylene iodide, washed, dried and vialed. All intermediate dry weights were recorded. The total sample was submitted for instrumental neutron acitivation analysis for Au plus 33 elements. Once irradiated samples had decayed sufficiently for safe handling, they were returned for selective examination using a binocular microscope. Samples with very high concentrations of Au or other chalcophile elements typically contained fragments of sulphides. These were hand-picked utilizing surgical forceps or extremely fine sewing needles, and mounted on scanning-electron-microscope mounts on a patch of double-sided tape. These were subsequently examined through the SEM.

TILLID	LOCATION	DEPTH	TYPE	COLOUR	OXIDAT_INT	GEOL	CR_PPM	FE_PCT	CO_PPM	NI_PPM	AS_PPM	BR_PPM	SB_PPM
psp88-t1							110	3.6	19	47	38.0	2.7	3.4
psp88-t2		0.3	stncly	olvgry	weak	diorite	180	6.2	27	29	23.0	4.2	0.8
psp88-t3	12+90N 3+20E	1.1	pblsnd	gryolv	weak	diorite	170	4.5	22	38	109.0	1.4	0.6
psp88-t4	12+90N 3+40E	0.8	cblsnd	yelorn	moderate	diorite	190	5.2	23	38	100.0	3.9	0.6
psp88-t5	12+75N 3+50E	0.3	pblsnd	brn	moderate	diorite	400	5.9	16	21	220.0	3.2	0.9
psp88-t6		0.3	pblslt	brn	moderate	diorite	330	7.5	47	72	55.1	4.4	0.9
psp88-t7		0.8	pblcly	olvbrn	weak	diorite	160	4.7	17	33	45.0	0.8	0.6
psp88-t8		0.9	pblslt	ornbrn	moderate	diorite	170	6.1	25	25	184.0	4.3	0.6
31f2-t1							110	13.0	99	32	155.0	32.0	3.2
31f2-t2							82	11.0	44	19	44.0	8.7	3.6
31f2-t3							72	9.3	58	24	53.0	20.0	1.8
31f2-t4							54	9.2	56	38	104.0	8.1	1.3
31f2-t5							120	12.0	84	<10	106.0	5.5	3.3
31f2-t6							91	12.0	76	50	127.0	11.0	2.3
31f2-t7							95	17.0	39	28	91.5	10.0	2.2
31f2-t8							71	12.0	30	38	976.0	16.0	2.1
64c10-88-t1	374E 26.5S	0.4	sndbld	gryyel	weak		110	5.0	29	25	4.5	0.8	0.2
64c10-88-t2	374E 27.8S	0.5	stn	olvgry	weak		61	3.2	14	19	2.0	<0.5	0.2
64c10-88-t3	374E 19.4S	1.1	bldcly	yelgry	weak		71	3.3	10	<10	3.5	0.6	0.3
64c10-88-t4	374E 18.7S	0.3	sndslt	ornbrn	moderate		110	7.4	26	16	35.0	4.5	0.5
64c10-88-t5	374E 18.2S	0.4	snd	ornbrn	moderate		65	3.2	12	14	3.1	4.3	0.2
64c10-88-t7	374E 16.7S	0.8	clystn	olvgry	weak		81	5.0	19	<10	27.0	1.0	0.2
64c10-88-t8	374E 16.0S	0.8	clystn	olvgry	weak		69	3.5	12	19	2.0	1.5	0.2
64c10-88-t9	378E 28.0S	1.3	pblslt	grytan	weak		76	2.6	7	<10	3.2	1.5	0.2
64c10-88-t10u	378E 26.0S	0.9	pblslt	grytan	weak		58	3.2	11	15	1.6	0.9	0.2
64c10-88-t10l	378E 26.0S	1.1	sltcly	olvgry	weak		46	2.8	8	23	1.2	<0.5	0.2
64c10-88-t11	378E 25.0S	1.2	clystn	olvgry	weak		46	1.9	9	<10	1.7	0.7	0.2
64c10-88-t12	378E 24.0S	0.6	pblsnd	gry	weak		55	1.8	6	<10	1.8	<0.5	0.2
64c10-88-t12l	378E 24.0S	1.1	sndcly	gry	weak		57	3.1	8	<10	1.3	1.0	0.2
64c10-88-t13u	378E 23.0S	0.9	sndstn	ornbrn	moderate		110	4.2	19	21	3.1	0.6	0.2
64c10-88-t13l	378E 23.0S	1.0	sndcly	grybrn	weak		75	3.4	11	20	3.0	0.6	0.2
64c10-88-t19	376e 26.0s	0.9	cblsnd	olvgry	weak		46	2.6	10	18	1.3	<0.5	0.1
64c10-88-t20	376e 22.0s	0.5	orgsnd	brn	moderate		190	5.2	28	53	5.1	4.5	0.3
64c10-88-t21	372e 26.6s	0.7	clysnd	olvgry	weak	erratics	130	5.6	17	15	4.2	3.2	0.3
64c10-88-t22	372e 26.0s	0.9	clystn	olvbrn	no		61	3.1	12	21	1.5	0.9	0.2
64c10-88-t23	372e 25.0s	0.9	clystn	olvgry	no		160	7.4	35	2	2.6	5.2	0.3
64c10-88-t24	372e 24.0s	0.5	peaty	yelblk	weak		<20	0.4	<5	<10	0.6	10.0	0.2
64c10-88-t25	372e 23.0s	0.5	peaty	yelblk	weak		<20	0.4	6	<10	<0.5	6.3	0.2
64c10-88-t26	372e 22.0s	0.8	clystn	olvgry	weak		59	10.0	53	37	6.2	3.8	0.7
64c10-88-t27	372e 21.0s	0.6	clysnd	ornbrn	high	metavolc	180	14.0	79	69	7.4	3.4	0.6
64c10-88-t28	372e 20.0s	0.7	sndstn	ornbrn	moderate		130	6.6	31	34	28.0	3.7	0.3
64c10-88-t29	372e 19.0s	0.7	sltsnd	grybrn	moderate		140	5.9	23	<10	6.0	7.9	0.2
64c10-88-t30	372e 18.0s	0.3	clystn	olvgry	weak		500	4.7	29	89	46.0	3.5	0.3
64c10-88-t32	310e 25.0s	0.7	stn	olvbrn	moderate		150	6.7	31	30	3.1	1.4	0.3
64c10-88-t33	310e 26.0s	0.4	snd	brn	moderate	quartz vn	410	7.7	37	42	1.9	0.9	0.3
64c10-88-t34	310e 20.0s	0.1	orgsnd	olvbrn	moderate		180	11.0	45	<10	43.0	3.8	0.7
64c10-88-t35	310e 19.0s	0.6	cblsnd	brngry	moderate		180	7.2	27	42	42.0	2.6	0.3

64c10-88-t36	308e 19.0s	0.8	stnsnd	ornbrn	moderate		110	8.5	29	22	86.5	1.4	0.2
64c10-88-t37	308e 20.0s	0.5	stnsnd	brn	moderate		140	6.8	27	22	18.0	3.5	0.4
64c10-88-t38	308e 21.0s	0.4	stnsnd	brn	moderate		130	8.4	33	19	42.0	1.8	0.6
64c10-88-t39	308e 22.0s	1.3	clystn	yelbrn	weak	andesite	130	6.0	25	19	49.0	3.7	0.4
64c10-88-t40	308e 23.0s	0.4	orgsnd	olvbrn	moderate		110	4.2	10	<10	2.8	16.0	0.4
64c10-88-t41	308e 24.0s	1.0	cblsnd	olvbrn	weak		790	10.0	78	260	12.0	1.7	1.3
64c10-88-t42	308e 25.0s	0.8	sndbld	ornbrn	moderate		310	7.6	35	64	7.3	2.1	0.5
64c10-88-t43	308e 26.0s	0.8	sndstn	ornbrn	moderate		130	5.5	22	<10	4.6	3.0	0.4
64c10-88-t44	312e 19.0s	1.1	pblsnd	ornbrn	moderate		100	6.7	25	26	67.7	1.6	0.1
64c10-88-t45	312e 20.0s	0.4	sltcly	brn	moderate		81	8.1	38	<10	21.0	2.0	0.5
64c10-88-t46	312e 21.0s	0.3	sndcly	brn	moderate		290	10.0	49	49	14.0	2.2	0.4
64c10-88-t47	312e 22.0s	0.3	sndcly	ornbrn	moderate		72	8.4	33	16	8.8	3.8	0.3
64c10-88-t48	312e 23.0s	0.4	stnsnd	ornbrn	moderate		170	6.8	29	38	9.3	3.2	0.3
64c10-88-t49	312e 24.0s	0.3	clyslt	ornbrn	moderate		110	6.1	13	<10	3.3	9.2	0.5
64c10-88-t50	312e 25.0s	0.3	clyslt	ornbrn	moderate		180	6.7	19	38	2.2	3.8	0.6
64c10-88-t51	312e 27.0s	1.1	bldcly	olvgry	weak		140	5.3	25	38	6.4	2.9	0.3
64c10-87-t1	373.5e 19.8s	0.5	sndcly	yelgry	moderate		64	5.1	24	32	14.0	2.0	0.3
64c10-87-t2b	373.5e 20.5s	0.2	pblcly	ornbrn	moderate		76	7.1	37	26	15.0	4.9	0.3
64c10-87-t2c	373.5e 20.5s	0.7	stncly	olvbrn	moderate		53	3.5	11	<20	5.2	2.6	0.2
64c10-87-t9	374e 25.0s	0.3	clysnd	ornbrn	moderate		81	3.4	20	<20	1.8	3.9	0.3
64c10-87-t9b	374e 25.0s	0.4	clysnd	yelbrn	moderate		99	4.7	22	<20	2.6	4.3	0.4
64c10-87-t10	374e 25.5s	0.3	sndcly	ornbrn	moderate		160	6.3	29	33	3.6	3.3	0.4
64c10-87-t11	375e 20.0s	0.6	bldcly	yelbrn	weak		72	4.7	27	24	9.3	3.0	0.2
64c10-87-t12	375.3e 25.5s	0.5	stncly	tangry	weak		51	3.2	10	<20	2.1	<2	0.2
64c10-87-t15	310e 20.5s	0.3	stncly	ornbrn	moderate		50	6.8	32	<20	9.4	4.4	0.3
64c10-87-t16	310e 21.0s	0.2	pblcly	ornbrn	moderate		47	8.2	33	20	35.0	2.4	0.5
64c10-87-t17	310e 21.5s	0.2	sltcly	ornbrn	high		49	11.0	37	<20	4.9	2.3	0.5
64c10-87-t18	310e 22.0s	0.2	sltcly	ornbrn	high		61	8.6	25	<20	20.0	5.5	1.0
64c10-87-t19u	309.6e 22.6s	0.5	cblsnd	ornbrn	high		150	7.3	29	40	29.0	5.0	0.5
64c10-87-t19l	309.6e 22.6s	0.8	stnsnd	grybrn	moderate		100	5.3	27	34	26.0	4.7	0.3
64c10-87-t20	310.2e 23.3s	1.3	stncly	yelbrn	moderate		120	5.3	23	30	26.0	3.1	0.3
64c10-87-t21	310e 24.3s	0.4	stncly	brn	moderate		260	5.9	30	73	5.2	2.3	0.5
pap-87-r4					high		<130	11.0	25	83	999.9	99.9	9.9
pap-87-t1		0.8	bldcly	yelgry	moderate		170	5.3	23	38	244.0	3.6	0.7
pap-87-t2		0.7	sndcly	ornbrn	moderate		150	5.8	28	41	241.0	6.6	0.6
pap-87-t3		0.3	sltsnd	gry	weak		220	6.9	53	100	94.0	5.7	1.2
pap-87-t4		0.5	bldslt	ornbrn	moderate		120	4.7	19	41	132.0	7.8	0.5
pap-87-t5		0.8	sndslt	ornbrn	moderate		120	4.1	17	39	86.0	3.4	0.5
pap-87-t6		0.3	bldslt	grybrn	moderate		290	7.0	42	90	59.4	<2	1.0
pap-87-t7		0.5	bldsnd	gry	moderate		250	6.8	28	77	161.0	2.3	0.6
pap-87-t8		0.4	sltcly	ornbrn	high		740	7.6	30	61	293.0	4.2	1.2
pap-87-t9		0.6	pblcly	grybrn	weak		210	5.9	43	120	662.0	8.8	1.6
pap-87-t10		0.5	cblcly	yelgry	moderate		150	4.5	17	35	58.2	<2	0.6
pap-87-t11		0.5	cblcly	ornbrn	moderate		110	3.5	17	29	95.2	3.0	0.3
pap-87-t12		0.7	sndcly	orngry	moderate		240	5.1	45	49	24.0	<2	0.5
pap-87-t13		0.4	sndcly	ornbrn	moderate		130	4.2	18	49	22.0	<2	0.4

TILLID	BA_PPM	LA_PPM	CE_PPM	SM_PPM	W_PPM	AU_PPB	TH_PPM	U_PPM	T_250WT_G	CR_HMC_PPM	FE_HMC_PCT	CO_HMC_PPM	NI_HMC_PPM
psp88-t1	810	30	55	5.50	1	38	8.5	2.7	8.85	620	34.1	35	61
psp88-t2	260	12	20	2.30	2	203	3.1	1.6	8.56	730	22.0	54	57
psp88-t3	700	36	53	5.70	<1	98	6.9	2.4	9.77	760	37.1	42	86
psp88-t4	540	30	53	5.40	<1	86	6.1	2.4	9.32	640	38.0	39	68
psp88-t5	140	6	16	1.70	2	474	2.2	1.5	7.89	280	24.8	34	72
psp88-t6	290	15	36	3.00	<1	28	3.4	1.7	8.93	250	27.9	59	<28
psp88-t7	640	28	55	4.90	1	10	5.8	2.4	9.82	610	36.3	31	<33
psp88-t8	510	23	34	4.60	2	76	5.3	2.4	9.52	470	31.5	27	<33
31f2-t1	620	38	55	10.00	<1	20	3.4	1.1	8.10	150	31.0	46	<25
31f2-t2	550	18	44	4.60	<1	36	3.5	1.3	5.02	120	32.1	120	85
31f2-t3	580	35	63	8.70	<1	25	4.5	1.6	7.72	39	28.8	21	<24
31f2-t4	620	23	68	6.10	<1	6	4.9	1.4	8.62	86	27.1	46	<29
31f2-t5	560	44	72	12.00	<1	21	4.6	1.6	7.92	170	29.2	58	<31
31f2-t6	550	32	81	8.10	2	10	4.8	1.7	7.80	150	31.2	68	56
31f2-t7	580	23	51	4.40	<1	17	8.4	1.6	6.36	180	35.5	56	<33
31f2-t8	680	27	47	6.30	2	47	6.0	2.7	6.45	140	34.2	50	51
64c10-88-t1	880	54	97	8.80	5	15	16.0	3.1	5.83	300	22.0	33	33
64c10-88-t2	900	59	120	8.30	<1	<2	22.1	5.2	6.99	330	25.3	29	<27
64c10-88-t3	940	61	100	9.10	2	4	25.1	3.5	6.04	420	28.4	33	<27
64c10-88-t4	540	25	44	4.70	2	<2	8.8	2.5	7.35	290	26.1	30	<36
64c10-88-t5	860	52	100	8.20	1	<2	19.0	3.7	9.15	360	23.0	32	<23
64c10-88-t7	840	67	110	9.50	2	10	21.9	3.5	6.07	310	22.0	45	<46
64c10-88-t8	890	69	110	8.20	1	<2	21.9	3.4	7.53	260	24.0	26	<37
64c10-88-t9	960	68	150	11.00	1	<2	25.7	4.6	11.15	300	27.3	34	<21
64c10-88-t10u	870	64	130	8.90	3	3	21.2	3.8	10.65	340	27.9	32	<24
64c10-88-t10l	870	59	110	7.70	1	<2	19.0	3.2	6.75	400	31.5	38	<25
64c10-88-t11	920	49	110	7.80	<1	4	18.0	3.6	10.69	300	26.5	37	<22
64c10-88-t12	920	51	110	8.20	2	<2	18.0	3.6	8.49	300	25.1	34	<20
64c10-88-t12l	920	48	41	6.30	2	<2	18.0	3.3	7.72	270	22.1	32	<36
64c10-88-t13u	870	53	120	8.60	<1	<2	19.0	3.6	9.81	260	23.8	30	<38
64c10-88-t13l	890	62	110	8.30	2	<2	21.7	3.0	6.46	280	25.6	32	<21
64c10-88-t19	920	64	120	10.00	2	<2	21.6	4.2	12.02	340	26.1	35	<21
64c10-88-t20	170	5	<5	2.60	78	82	0.6	0.7	6.16	1200	51.8	120	99
64c10-88-t21	860	47	92	7.60	4	15	17.0	3.7	9.36	380	26.4	31	<21
64c10-88-t22	880	52	110	6.90	<1	11	17.0	3.6	6.73	520	29.1	34	<31
64c10-88-t23	660	43	63	7.50	10	180	11.0	3.0	7.02	220	40.0	21	70
64c10-88-t24	91	4	<14	1.20	<1	16	1.0	1.7	1.62	<500	41.0	<50	740
64c10-88-t25	220	10	<11	2.30	<1	9	2.7	0.8	2.60	<180	11.0	<150	<1300
64c10-88-t26	1100	27	42	6.70	32	85	8.4	1.5	7.50	220	23.3	41	59
64c10-88-t27	790	13	18	5.10	42	73	2.1	0.7	9.19	270	34.2	400	500
64c10-88-t28	660	35	64	5.60	3	24	13.0	2.5	8.87	420	30.5	36	<40
64c10-88-t29	660	200	370	28.70	3	6	82.0	9.9	10.87	530	34.2	34	<20
64c10-88-t30	820	39	82	6.10	2	<2	14.0	2.7	6.94	470	23.6	24	<47
64c10-88-t32	650	17	27	3.40	5	5	4.7	1.5	8.03	630	18.0	17	54
64c10-88-t33	930	9	18	1.50	5	24	2.7	1.6	7.63	880	25.9	31	<44
64c10-88-t34	160	7	10	2.30	3	<2	2.3	0.5	6.85	190	20.9	100	120
64c10-88-t35	520	34	58	5.70	4	30	6.5	2.0	8.23	580	22.3	33	68

64c10-88-t36	370	60	120	7.60	4	12	4.1	2.1	11.76	750	28.9	39	77
64c10-88-t37	550	23	44	4.00	3	5	7.9	2.1	9.59	730	25.1	42	<32
64c10-88-t38	410	15	25	3.30	13	24	4.8	1.7	6.50	590	26.8	42	55
64c10-88-t39	720	34	69	6.20	8	120	11.0	2.2	8.18	490	29.9	36	55
64c10-88-t40	490	30	52	5.40	4	21	7.5	2.7	5.17	290	7.5	<5	<24
64c10-88-t41	520	45	77	7.10	4	40	5.8	1.4	8.03	5610	47.8	85	580
64c10-88-t42	770	17	35	3.10	12	60	3.8	1.5	9.08	1600	37.1	48	98
64c10-88-t43	750	29	54	4.50	4	27	6.9	2.6	9.69	770	29.8	33	<37
64c10-88-t44	610	30	56	4.80	<1	18	5.5	1.9	9.97	590	24.1	33	<33
64c10-88-t45	470	13	21	2.90	<1	<2	4.9	1.3	3.18	160	22.8	46	<29
64c10-88-t46	160	4	<5	1.00	27	21	1.4	0.5	9.82	830	27.0	88	110
64c10-88-t47	480	21	34	3.00	7	67	6.8	1.9	7.62	470	24.0	36	75
64c10-88-t48	460	17	24	3.20	4	42	5.6	1.4	6.91	610	24.1	27	<33
64c10-88-t49	510	18	37	3.10	3	10	5.3	1.5	7.85	670	44.2	53	86
64c10-88-t50	560	21	39	3.70	<1	<2	5.5	1.8	7.68	1400	48.2	33	70
64c10-88-t51	780	48	97	6.30	2	47	12.0	2.7	9.79	610	31.5	38	<35
64c10-87-t1	820	75	125	9.20	3	160	29.8	4.8	9.05	520	39.7	51	<32
64c10-87-t2b	700	27	51	3.80	30	38	9.2	1.9	8.49	410	44.8	87	95
64c10-87-t2c	880	51	103	6.10	4	6	19.0	2.9	7.00	490	40.0	40	<34
64c10-87-t9	730	37	70	4.60	4	18	13.0	2.3	8.23	480	33.1	51	41
64c10-87-t9b	690	29	51	3.70	5	43	10.0	2.0	8.72	870	48.3	40	44
64c10-87-t10	330	19	32	2.70	6	58	3.0	1.0	8.32	880	66.1	76	86
64c10-87-t11	700	37	70	4.80	2	11	12.0	2.3	8.28	1000	42.1	52	50
64c10-87-t12	910	53	92	5.90	1	10	19.0	3.0	7.96	340	31.8	30	<37
64c10-87-t15	510	27	49	3.80	<1	4	9.2	1.7	8.81	470	38.5	65	60
64c10-87-t16	400	16	22	2.50	6	4	4.9	1.2	6.65	n.d.	n.d.	n.d.	n.d.
64c10-87-t17	360	9	13	1.30	21	70	2.9	0.8	8.94	n.d.	n.d.	n.d.	n.d.
64c10-87-t18	430	22	39	3.10	6	87	7.2	1.6	7.69	n.d.	n.d.	n.d.	n.d.
64c10-87-t19u	560	30	53	4.40	8	140	7.1	2.0	9.58	1000	42.8	52	38
64c10-87-t19l	630	28	55	4.30	4	98	8.6	1.9	9.99	620	41.7	50	<29
64c10-87-t20	710	41	71	5.70	5	65	12.0	2.4	10.67	630	36.9	32	38
64c10-87-t21	570	21	35	3.00	3	13	5.3	1.3	8.70	3830	50.9	54	110
pap-87-r4	950	42	65	5.60	0	999	2.7	2.3	10.51	<20	32.8	160	130
pap-87-t1	590	23	37	3.50	<1	410	6.1	2.1	9.02	870	47.4	45	64
pap-87-t2	590	24	47	3.70	1	110	7.1	2.3	8.57	870	51.2	66	100
pap-87-t3	550	32	49	5.50	<1	110	5.6	2.1	8.77	n.d.	n.d.	n.d.	n.d.
pap-87-t4	570	25	38	3.70	1	82	6.2	2.1	9.45	750	47.6	55	<56
pap-87-t5	690	38	68	5.70	<1	94	10.0	2.7	11.26	930	54.1	39	36
pap-87-t6	390	17	31	2.70	1	58	4.1	1.7	7.43	750	42.8	78	<51
pap-87-t7	470	23	35	3.50	1	32	6.8	2.2	10.43	960	53.9	54	68
pap-87-t8	210	9	12	1.50	2	111	0.9	0.9	8.28	n.d.	n.d.	n.d.	n.d.
pap-87-t9	680	41	76	6.70	2	208	6.4	3.3	7.79	530	43.2	43	65
pap-87-t10	660	32	60	4.80	1	35	6.0	2.2	8.97	770	47.4	35	70
pap-87-t11	720	34	64	5.20	<1	246	8.7	2.4	10.88	750	49.4	39	81
pap-87-t12	590	26	37	3.90	<1	6	7.3	2.3	7.56	700	34.8	36	<47
pap-87-t13	640	29	49	4.20	1	17	8.7	2.4	8.23	770	39.4	34	<36

TILLID	AS_HMC_PPM	BR_HMC_PPM	SB_HMC_PPM	LA_HMC_PPM	CE_HMC_PPM	SM_HMC_PPM	TA_HMC_PPM	W_HMC_PPM	AU_HMC_PPB	TH_HMC_PPM
pap88-t1	160.0	3.4	1.2	220	340	45.7	8.6	5	1390	96.4
pap88-t2	58.4	12.0	3.6	55	100	15.4	10.0	10	2900	27.7
pap88-t3	32.0	1.5	1.5	236	400	48.5	10.0	13	2950	89.5
pap88-t4	37.0	4.2	1.2	190	320	39.2	8.1	9	1140	76.4
pap88-t5	681.0	5.8	3.3	24	40	6.0	12.0	77	18000	8.6
pap88-t6	14.0	5.8	1.7	46	77	10.7	13.0	5	2570	19.0
pap88-t7	27.0	0.8	1.1	160	250	29.6	8.7	9	2320	61.3
pap88-t8	63.6	3.1	1.5	120	200	24.3	10.0	138	2270	48.4
31f2-t1	23.0	12.0	3.8	42	81	17.6	4.2	3	226	8.4
31f2-t2	82.2	49.0	14.7	28	48	12.2	3.4	5	1570	5.2
31f2-t3	10.0	23.0	2.1	23	41	9.5	3.0	<2	43	3.9
31f2-t4	36.0	12.0	2.7	21	34	9.1	3.2	<1	249	4.6
31f2-t5	27.0	21.0	4.2	37	71	18.1	4.4	<2	64	8.9
31f2-t6	42.0	29.0	4.8	32	66	13.1	4.2	3	68	6.3
31f2-t7	50.0	86.7	5.4	32	50	10.9	4.3	<2	71	7.4
31f2-t8	601.0	92.8	6.1	56	84	15.0	3.9	<40	49	11.0
64c10-88-t1	<12	7.4	0.4	646	1120	110.0	15.0	<53	110	298.0
64c10-88-t2	<17	<8	0.3	735	1270	126.0	16.0	<74	150	380.0
64c10-88-t3	<18	<8	0.4	859	1370	141.0	20.0	<75	67	467.0
64c10-88-t4	4.7	8.5	0.4	459	760	79.6	11.0	15	150	230.0
64c10-88-t5	<15	8.7	0.4	742	1250	127.0	20.0	<67	1060	404.0
64c10-88-t7	231.0	1.8	0.7	243	450	50.9	8.0	154	896	120.0
64c10-88-t8	1.8	1.7	0.4	478	806	98.2	11.0	11	120	245.0
64c10-88-t9	<14	<6.5	0.2	703	1130	134.0	18.0	<61	61	396.0
64c10-88-t10u	<16	<7.5	0.4	777	1320	129.0	19.0	<70	<14	448.0
64c10-88-t10l	<18	<7.9	0.4	1040	1570	168.0	22.0	<76	64	532.0
64c10-88-t11	<16	<7.1	0.2	658	1170	120.0	15.0	<69	87	346.0
64c10-88-t12	<15	<6.7	0.2	651	1140	118.0	15.0	<66	110	338.0
64c10-88-t12l	1.5	0.6	0.4	461	815	90.4	10.0	43	42	225.0
64c10-88-t13u	1.4	3.2	<0.1	373	678	79.1	12.0	<4	83	172.0
64c10-88-t13l	<15	<6.9	0.4	574	1020	106.0	21.0	<69	100	300.0
64c10-88-t19	<16	<7.1	0.3	782	1300	144.0	18.0	<72	60	380.0
64c10-88-t20	18.0	29.0	0.8	8	<11	4.1	<0.5	978	1260	1.9
64c10-88-t21	<17	12.0	0.5	648	1170	117.0	17.0	<76	543	341.0
64c10-88-t22	<1.2	1.0	0.4	270	470	59.4	6.5	69	170	139.0
64c10-88-t23	2.2	18.0	0.5	62	97	17.8	1.5	355	120	26.2
64c10-88-t24	<19	<56	<1	350	<430	53.0	9.3	960	140	160.0
64c10-88-t25	88.0	<420	<4.7	450	<2200	74.0	<22	1210	380	180.0
64c10-88-t26	2.8	14.0	0.9	305	538	58.2	8.7	799	2990	139.0
64c10-88-t27	33.0	177.0	5.1	264	490	49.7	6.0	719	12600	130.0
64c10-88-t28	4.9	14.0	0.3	614	1020	104.0	13.0	41	68	308.0
64c10-88-t29	<27	12.0	0.7	1630	2580	227.0	35.0	<120	214	877.0
64c10-88-t30	6.7	4.3	0.3	890	1470	143.0	17.0	234	52	441.0
64c10-88-t32	3.3	9.0	1.2	110	210	26.1	2.2	203	666	49.8
64c10-88-t33	4.2	5.1	0.7	391	655	63.9	15.0	106	1460	224.0
64c10-88-t34	19.0	41.0	4.7	27	32	5.8	4.8	9	<5	16.0
64c10-88-t35	11.0	18.0	0.7	319	545	70.1	12.0	152	1050	192.0

64c10-88-t36	35.0	30.0	0.6	375	668	69.3	9.0	34	160	190.0
64c10-88-t37	7.6	30.0	0.7	231	410	41.0	7.5	30	939	136.0
64c10-88-t38	11.0	24.0	1.7	329	539	62.0	14.0	100	680	200.0
64c10-88-t39	8.8	6.5	0.6	423	710	81.4	12.0	97	1210	210.0
64c10-88-t40	<1.4	10.0	0.9	37	68	9.4	0.7	34	34	16.0
64c10-88-t41	2.1	13.0	1.9	100	170	21.9	3.1	24	71	47.2
64c10-88-t42	5.4	13.0	1.0	80	160	17.4	2.9	571	7370	36.7
64c10-88-t43	2.4	9.3	0.7	379	671	68.1	13.0	193	394	205.0
64c10-88-t44	297.0	9.4	0.5	341	641	71.7	9.4	75	1170	161.0
64c10-88-t45	9.3	15.0	1.6	110	170	18.8	6.8	11	834	61.8
64c10-88-t46	30.0	22.0	8.8	230	300	30.0	8.3	1270	3260	121.0
64c10-88-t47	<2.5	16.0	0.6	304	545	48.5	11.0	531	4870	152.0
64c10-88-t48	2.9	6.1	0.7	325	551	53.5	11.0	112	926	162.0
64c10-88-t49	2.0	41.0	0.7	64	93	10.9	1.6	35	2500	30.6
64c10-88-t50	2.1	31.0	0.6	65	92	12.7	1.1	7	55	28.4
64c10-88-t51	<2.4	7.5	0.5	357	619	63.1	12.0	30	1160	186.0
64c10-87-t1	31.0	23.0	0.7	596	1090	93.1	12.0	25	359	283.0
64c10-87-t2b	37.0	100.0	4.0	1260	2280	192.0	32.0	1350	904	604.0
64c10-87-t2c	5.2	23.0	0.5	1090	1950	177.0	17.0	204	902	545.0
64c10-87-t9	7.2	16.0	0.8	836	1520	142.0	17.0	243	538	405.0
64c10-87-t9b	6.5	37.0	1.0	607	1140	108.0	17.0	391	30	319.0
64c10-87-t10	<1.9	25.0	0.3	140	240	22.2	1.6	105	626	73.1
64c10-87-t11	15.0	29.0	0.5	409	829	114.0	15.0	85	86	192.0
64c10-87-t12	<4.9	13.0	0.4	692	1310	123.0	11.0	83	<13	322.0
64c10-87-t15	10.0	62.0	0.7	658	1160	93.9	9.5	78	468	354.0
64c10-87-t16	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c10-87-t17	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c10-87-t18	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c10-87-t19u	14.0	14.0	1.4	302	551	53.2	7.2	224	6660	130.0
64c10-87-t19l	12.0	39.0	0.6	521	930	82.4	10.0	213	965	239.0
64c10-87-t20	8.1	4.7	0.6	752	1340	128.0	16.0	41	1900	355.0
64c10-87-t21	4.1	33.0	0.9	140	240	23.4	2.1	67	251	61.2
pap-87-r4	999.9	<120	54.0	<13	<40	3.5	<0.5	<250	38000	4.4
pap-87-t1	534.0	15.0	2.1	209	370	36.8	8.2	39	7340	80.6
pap-87-t2	164.0	7.6	1.6	306	537	50.7	12.0	23	2130	126.0
pap-87-t3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
pap-87-t4	98.0	6.9	1.2	210	390	36.0	8.3	<25	2000	86.5
pap-87-t5	29.0	3.0	1.3	399	727	70.4	10.0	<16	5630	159.0
pap-87-t6	60.4	3.6	3.1	190	350	37.0	12.0	<22	2340	84.5
pap-87-t7	561.0	7.2	1.1	290	534	50.0	6.6	<16	3120	111.0
pap-87-t8	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	1110	n.d.
pap-87-t9	172.0	5.4	1.6	180	330	34.2	9.1	<25	2290	67.6
pap-87-t10	39.0	3.8	1.3	245	440	42.5	8.8	<16	1220	95.2
pap-87-t11	32.0	<5.2	0.9	298	556	55.1	9.2	<16	554	133.0
pap-87-t12	12.0	<8.8	0.9	204	320	39.6	5.0	<22	4170	97.6
pap-87-t13	11.0	4.1	0.8	266	490	51.2	5.6	<17	743	114.0

TILLID	U_HMC_PPM	HMC_WT_G	RASAWT_KG	HMC_TWT_G	T_250WT_KG
psp88-t1	17.0	23.65	7.70	23.4	0.66
psp88-t2	16.0	5.81	4.80	5.4	0.66
psp88-t3	18.0	22.70	9.10	22.9	0.57
psp88-t4	15.0	18.40	11.00	18.5	0.21
psp88-t5	5.4	6.53	6.50	6.8	0.66
psp88-t6	8.7	16.05	5.10	15.9	0.60
psp88-t7	13.0	13.71	8.20	14.0	0.50
psp88-t8	11.0	12.59	6.10	13.0	0.52
31f2-t1	4.9	72.81	8.20	72.8	0.28
31f2-t2	3.5	44.81	8.00	44.9	0.46
31f2-t3	2.7	63.59	8.40	63.9	0.39
31f2-t4	3.1	63.37	7.50	63.5	0.41
31f2-t5	5.4	72.87	8.70	73.1	0.32
31f2-t6	4.1	54.48	6.70	54.7	0.37
31f2-t7	4.5	58.60	10.00	58.8	0.26
31f2-t8	5.3	55.08	9.80	55.2	0.27
64c10-88-t1	46.6	28.48	7.70	28.6	0.49
64c10-88-t2	53.2	15.67	6.30	15.9	0.72
64c10-88-t3	65.1	19.83	5.90	20.2	1.06
64c10-88-t4	32.0	18.16	5.70	18.0	0.29
64c10-88-t5	53.3	22.02	7.10	22.4	0.28
64c10-88-t7	21.4	6.89	7.80	7.1	1.01
64c10-88-t8	40.1	15.58	10.10	15.3	1.14
64c10-88-t9	55.9	26.34	3.80	26.1	0.13
64c10-88-t10u	58.5	15.59	6.60	15.6	0.13
64c10-88-t10l	77.3	27.41	11.00	27.6	0.78
64c10-88-t11	49.4	17.56	4.70	17.8	0.46
64c10-88-t12	49.7	20.23	5.50	20.3	0.44
64c10-88-t12l	34.1	9.62	7.30	9.6	1.07
64c10-88-t13u	26.7	7.36	3.70	7.2	0.03
64c10-88-t13l	40.8	18.98	7.40	19.1	0.71
64c10-88-t19	59.8	32.98	9.10	32.8	0.40
64c10-88-t20	0.6	7.35	5.60	7.5	0.43
64c10-88-t21	47.3	20.02	8.00	19.6	0.17
64c10-88-t22	21.9	28.97	10.00	28.9	1.05
64c10-88-t23	4.4	28.18	4.30	28.2	0.64
64c10-88-t24	<9.6	0.09	1.30	0.1	0.03
64c10-88-t25	<31	0.02	2.60	0.1	0.15
64c10-88-t26	21.3	5.95	7.50	5.6	0.41
64c10-88-t27	18.0	3.45	9.60	3.4	0.64
64c10-88-t28	42.2	10.76	5.70	10.4	0.17
64c10-88-t29	100.0	37.84	5.30	38.1	0.09
64c10-88-t30	57.2	8.39	8.00	8.4	0.59
64c10-88-t32	10.0	18.56	8.40	18.4	0.40
64c10-88-t33	30.0	4.44	4.50	4.6	0.53
64c10-88-t34	1.9	9.15	2.90	9.4	0.35
64c10-88-t35	29.4	11.29	3.50	11.2	0.22

64c10-88-t36	27.6	6.86	5.70	6.8	0.67
64c10-88-t37	20.1	11.43	5.80	11.3	0.40
64c10-88-t38	23.8	13.61	5.80	13.8	0.23
64c10-88-t39	30.6	18.64	10.30	19.0	0.16
64c10-88-t40	3.9	24.19	6.60	24.5	0.70
64c10-88-t41	8.6	36.14	7.20	36.2	0.29
64c10-88-t42	7.0	8.77	4.70	8.7	0.31
64c10-88-t43	27.1	14.32	7.80	14.7	0.19
64c10-88-t44	27.3	18.47	9.40	18.3	0.48
64c10-88-t45	8.4	14.46	5.00	14.6	0.56
64c10-88-t46	14.0	0.49	6.90	0.5	0.75
64c10-88-t47	23.4	3.85	6.80	3.8	0.62
64c10-88-t48	20.7	12.70	8.70	12.4	0.25
64c10-88-t49	4.3	10.02	6.10	9.7	0.71
64c10-88-t50	4.6	25.96	4.50	25.7	1.32
64c10-88-t51	27.2	10.38	6.40	10.5	0.11
64c10-87-t1	40.8	2.39	4.30	2.4	0.25
64c10-87-t2b	72.4	1.09	1.20	1.1	0.13
64c10-87-t2c	65.4	3.34	3.80	3.3	0.31
64c10-87-t9	50.3	3.48	3.00	3.5	0.40
64c10-87-t9b	38.5	2.77	1.70	2.7	0.26
64c10-87-t10	7.1	9.38	4.60	9.4	0.50
64c10-87-t11	43.1	3.68	6.70	3.7	0.21
64c10-87-t12	40.6	1.93	2.90	1.9	0.27
64c10-87-t15	33.3	1.18	2.50	1.2	0.22
64c10-87-t16	n.d.	n.d.	2.10	0.1	0.22
64c10-87-t17	n.d.	n.d.	2.20	0.3	0.33
64c10-87-t18	n.d.	n.d.	3.80	0.2	0.12
64c10-87-t19u	21.9	4.77	11.80	4.8	0.32
64c10-87-t19l	36.6	3.64	8.00	3.6	0.22
64c10-87-t20	48.3	6.34	7.50	6.3	0.35
64c10-87-t21	8.9	10.63	7.60	10.6	0.52
pap-87-r4	<5.3	4.05	3.20	4.0	0.06
pap-87-t1	15.0	2.10	2.60	2.1	0.26
pap-87-t2	20.0	2.37	2.20	2.4	0.22
pap-87-t3	n.d.	n.d.	2.00	0.6	0.20
pap-87-t4	14.0	0.86	1.40	0.9	0.20
pap-87-t5	25.3	2.87	2.20	2.9	0.16
pap-87-t6	16.0	1.14	1.60	1.1	0.19
pap-87-t7	17.0	2.61	2.30	2.6	0.08
pap-87-t8	n.d.	n.d.	1.30	0.2	0.07
pap-87-t9	12.0	1.01	1.00	1.0	0.10
pap-87-t10	16.0	2.37	2.70	2.4	0.23
pap-87-t11	19.0	2.46	2.00	2.4	0.15
pap-87-t12	13.0	1.03	1.60	1.0	0.18
pap-87-t13	17.0	2.08	1.30	2.1	0.20

APPENDIX THREE

VEGETATION, HUMUS, AND PEAT GEOCHEMICAL DATA

VEGETATION, HUMUS AND PEAT GEOCHEMICAL DATA FILE CODE

SAMPLEID:	sample number; prefix represents location or NTS map code, followed by year of collection, and sample identification code
LOCATION:	general location or grid coordinates on property where available
TYPE:	type of sample; aquatic wd - aquatic plant collected over marly substrate not conclusively identified blksprtwig - <5-8 years growth of black spruce twig (*picea mariana*) humus (may be differentiated as upper or lower where possible) bogwatorg - organic material filtered from bog waters
RASAWT:	weight in grams of air-dried raw sample used for analysis
ASHWT:	weight in grams of ash following about 12 hour @ 450°C corresponding to RASAWT
VIALASHWT:	weight in grams of ash encapsulated for analysis
ASHPCT:	percentage ash of RASAWT
LOI:	loss-on-ignition, of RASAWT

ELEMENT	DETECTION LEVEL	METHOD
Au	5 ppb	instrumental neutron activation (INAA)
As	0.5 ppm	-"-
Ba	5 ppm	-"-
Br	1 ppm	-"-
Ca	0.1%	-"-
Co	1 ppm	-"-
Cr	1 ppm	-"-
Cs	0.5 ppm	-"-
Fe	0.5 %	-"-
K	0.01 %	-"-
Mo	2 ppm	-"-
Na	100 ppm	-"-
Ni	50 ppm	-"-
Sb	0.1 ppm	-"-
Sc	0.1 ppm	-"-
Zn	20 ppm	-"-
La	0.1 ppm	-"-
Ce	3 ppm	-"-

The following additional elements were analyzed as part of the INAA package but exhibited nil geochemical contrast and are not included in the data file:

Ag, Hf, Hg, Ir, Rb, Se, Sr, Th, U, Nd, Sm, Eu, Tb, Yb, and Lu.

PEAT SAMPLE PREPARATION:

Peat samples were prepared for analyses by the author in biogeochemical sample preparation laboratory of the Geological Survey of Canada. Air-dried peat samples were cleaned of woody parts, homogenized and a 50 to 100 gram subsample ashed for a minimum 12 hours at 470 ^{o}C. All samples were ashed to as uniform a possible state. Approximately 1 gram of ash was encapsulated in a numbered polyethelene vial and analyzed by instrumental neutron acitivation by a commercial laboratory.

HUMUS SAMPLE PREPARATION:

Humus samples weighing between 0.3 to 0.6 kg were air-dried under controlled non-contaminating conditions. Air-dry samples were cleaned of woody parts and manually seived through a $<$2mm (10 mesh) screen. Fifty to 150 grams fo seived material were ashed at 470 ^{o}C for 12 to 30 hours until completion and consistency. Approximately 1 gram of ash was placed in a number polyethelene vial and submitted to a commercial laboratory for instrumental neutron activation analysis.

VEGETATION SAMPLE PREPARATION:

Black spruce (*picea mariana*) needles and twigs were collected from most till sites from several trees within a 10m2 area. Twigs represented 5 to 8 years growth as recommended by Dunn. Air-dried twigs were cleaned of any moss, resinous samples removed, and a 30 to 50 gram subsample ashed overnight at 470 ^{o}C. Approximately 1 gram of ashed sample was encapsulated in a number polyethelene vial and submitted to a commercial laboratory for instrumental neutron activation analysis.

For biogeochemical samples, research standards were kindly donated by Dr. C.E. Dunn at the Geological Survey of Canada to assist with quality control monitoring.

Ash material is currently archived.

SAMPLEID	LOCATION	TYPE	RAWSAWT	ASHWT	VIALASHWT	ASHPCT	LOI	AU PPB	AS PPM	BA PPM
pap 87 aq1	pap lake	aquatic wd	66.84	47.75	1.13	71.44	28.56	<5	2.3	160
pap 87 aq1a	pap lake	aquatic wd	113.69	83.04	1.19	73.04	26.96	<5	2.3	150
pap 87 aq1b	pap lake	aquatic wd	94.57	69.77	1.07	73.78	26.22	<5	2.1	160
pap 87 b1	pap lk grid	blksprtwig	71.18	1.53	1.05	2.15	97.85	7	4.8	2600
pap 87 b2	pap lk grid	blksprtwig	53.64	1.15	0.90	2.14	97.86	10	3.8	1400
pap 87 b2a	pap lk grid	blksprtwig	58.59	2.05	0.76	3.50	96.50	<5	4.2	1300
pap 87 b3	pap lk grid	blksprtwig	70.75	1.79	0.96	2.53	97.47	7	7.8	2100
pap 87 b4	pap lk grid	blksprtwig	80.13	1.67	0.82	2.08	97.92	5	11.0	2400
pap 87 b5	pap lk grid	blksprtwig	72.87	2.01	0.88	2.76	97.24	<5	5.6	2500
pap 87 b6	pap lk grid	blksprtwig	60.84	1.54	1.09	2.53	97.47	<5	4.5	2400
pap 87 b7	pap lk grid	blksprtwig	93.98	2.58	0.85	2.75	97.25	<5	4.8	1400
pap 88 b1	pap lk grid	blksprtwig	45.13	1.19	1.16	2.64	97.36	14	5.2	2800
pap 88 b2	pap lk grid	blksprtwig	35.71	0.96	0.92	2.69	97.31	20	6.0	3100
pap 88 b3	12+90n 3+20e	blksprtwig	41.39	1.15	1.14	2.78	97.22	24	4.4	1800
pap 88 b4	12+90n 3+40e	blksprtwig	46.16	1.08	1.05	2.34	97.66	30	4.3	2100
pap 88 b5	12+75n 3+50e	blksprtwig	40.60	1.29	1.28	3.18	96.82	14	5.0	3000
pap 88 b6	pap lk grid	blksprtwig	50.44	1.27	1.21	2.52	97.48	27	13.0	3000
pap 88 b7	pap lk grid	blksprtwig	56.09	1.96	1.13	3.49	96.51	17	2.6	1200
pap 88 b8	pap lk grid	blksprtwig	50.23	1.37	1.10	2.73	97.27	14	7.5	1300
64c10 87 b1	373.5e 19.8s	blksprtwig	52.65	0.93	0.91	1.77	98.23	9	6.0	2300
64c10 87 b2	373.5e 10.5s	blksprtwig	81.68	1.64	0.97	2.01	97.99	<5	3.3	1800
64c10 87 b3	374e 21.5s	blksprtwig	80.28	1.76	1.00	2.19	97.81	7	3.2	2000
64c10 87 b4	374e 22.5s	blksprtwig	67.47	1.43	0.98	2.12	97.88	5	4.4	2100
64c10 87 b5	374e 22.0s	blksprtwig	69.45	1.43	1.07	2.06	97.94	7	4.9	2000
64c10 87 b6	374e 23.0s	blksprtwig	50.24	0.99	0.87	1.97	98.03	9	7.3	970
64c10 87 b7	374e 24.0s	blksprtwig	64.28	1.72	0.98	2.68	97.32	8	4.3	3500
64c10 87 b8	374e 24.4s	blksprtwig	72.90	1.72	1.20	2.36	97.64	39	4.2	1000
64c10 87 b9	374e 25.0s	blksprtwig	88.94	1.70	1.00	1.91	98.09	10	5.3	2000
64c10 87 b10	374e 25.5s	blksprtwig	68.62	1.24	1.12	1.81	98.19	5	3.1	1500
64c10 87 b11	375e 20.0s	blksprtwig	59.25	1.18	0.99	1.99	98.01	5	4.6	2500
64c10 87 b12	375.3e 25.5s	blksprtwig	62.41	1.17	1.05	1.87	98.13	7	7.8	2600
64c10 87 b15	310e 20.5s	blksprtwig	78.77	1.62	1.00	2.06	97.94	6	6.6	1800
64c10 87 b16	310e 21.0s	blksprtwig	86.22	1.82	0.95	2.11	97.89	8	4.3	2500
64c10 87 b17	310e 21.5s	blksprtwig	78.54	1.59	1.04	2.02	97.98	8	4.7	2700
64c10 87 b18	310e 22.0s	blksprtwig	71.95	1.51	1.00	2.10	97.90	7	6.6	2300
64c10 87 b19	309.6e 22.6s	blksprtwig	69.96	1.40	0.84	2.00	98.00	6	4.1	2300
64c10 87 b20	310.2e 23.3s	blksprtwig	51.36	1.04	0.93	2.02	97.78	9	5.7	1900
64c10 87 b21	310e 24.3s	blksprtwig	76.25	1.44	0.95	1.89	98.11	14	4.7	2900
64c10 87 t1b	373.5e 19.8s	blksprbark	60.30	1.25	0.98	2.07	97.93	28	11.0	1700
64c10 87 t3a	374e 21.5s	humus	145.71	34.38	0.75	23.59	76.41	14	5.2	1100
64c10 87 t4a 1	374e 22.5s	humus	134.65	21.20	0.70	15.74	84.26	39	12.0	1100
64c10 87 t4a 2	374e 22.5s	humus	70.16	10.30	0.71	14.68	85.32	46	13.0	1100
64c10 87 t4a 3	374e 22.5s	humus	99.22	15.24	0.77	15.36	84.64	45	14.0	1200
64c10 87 t4b	374e 22.5s	bogwat org	18.63	2.65	0.72	14.22	85.78	34	9.6	1100
64c10 87 t5a	374e 22.0s	humus	137.09	35.10	0.84	25.60	74.40	25	7.0	1000
64c10 87 t6a	374e 23.0s	humus	101.06	10.48	0.69	10.37	89.63	29	7.6	860
64c10 87 t7a 1	374e 24.0s	humus	106.88	31.40	0.87	29.38	70.62	31	6.0	850
64c10 87 t7a 2	374e 24.0s	humus	121.02	31.50	1.02	26.03	73.97	26	6.1	640
64c10 87 t8a	374e 24.4s	humus	164.22	67.48	0.94	41.09	58.91	35	4.5	770
64c10 87 t9a	374e 25.0s	lowr humus	88.10	61.13	1.15	69.39	30.61	114	1200.0	500
64c10 88 b1	374e 26.5s	blksprtwig	31.66	0.62	0.59	1.96	98.04	39	4.9	1600
64c10 88 b2	374e 27.8s	blksprtwig	54.93	1.08	1.06	1.97	98.03	35	6.3	1400
64c10 88 b3	374e 19.4s	blksprtwig	27.88	0.64	0.60	2.30	97.70	25	4.3	1600
64c10 88 b4	374e 18.7s	blksprtwig	31.49	0.72	0.67	2.29	97.71	12	4.7	1400
64c10 88 b5	374e 18.2s	blksprtwig	25.83	0.56	0.50	2.17	97.83	17	4.7	3300
64c10 88 b6	374e 17.5s	blksprtwig	31.47	0.56	0.53	1.78	98.22	15	4.6	1900
64c10 88 b7	374e 16.7s	blksprtwig	30.18	0.52	0.50	1.72	98.28	45	6.8	1800
64c10 88 b8	374e 16.0s	blksprtwig	31.27	0.56	0.54	1.79	98.21	14	5.2	1200
64c10 88 b9	378e 28.0s	blksprtwig	33.38	0.59	0.58	1.77	98.23	19	4.2	2600
64c10 88 b10	378e 26.0s	blksprtwig	31.41	0.62	0.59	1.97	98.03	27	3.3	2700
64c10 88 b11	378e 25.0s	blksprtwig	31.20	0.53	0.50	1.70	98.30	15	4.5	3300

64c10 88 b12	378e 24.0s	blksprtwig	31.92	0.71	0.66	2.22	97.78	19	3.3	1500
64c10 88 b13	378e 23.0s	blksprtwig	42.30	0.79	0.76	1.87	98.13	26	5.1	2400
64c10 88 b14	376e 26.0s	blksprtwig	40.34	0.83	0.80	2.06	97.94	14	4.7	1500
64c10 88 b15	376e 25.0s	blksprtwig	32.63	0.67	0.65	2.05	97.95	17	4.4	760
64c10 88 b16	376e 24.0s	blksprtwig	31.25	0.63	0.60	2.02	97.98	11	4.7	800
64c10 88 b17	376e 23.0s	blksprtwig	38.50	0.87	0.83	2.26	97.74	20	5.0	730
64c10 88 b18	376e 22.0s	blksprtwig	39.51	0.79	0.77	2.00	98.00	21	5.2	1600
64c10 88 b19	376e 21.0s	blksprtwig	50.44	0.97	0.96	1.92	98.08	13	5.0	1200
64c10 88 b20	376e 20.0s	blksprtwig	44.11	1.15	1.03	2.61	97.39	22	8.4	1500
64c10 88 b21	372e 26.6s	blksprwtig	34.96	0.79	0.75	2.26	97.74	23	19.0	1300
64c10 88 b22	372e 26.0s	blksprtwig	40.01	0.76	0.72	1.90	98.10	115	77.0	1500
64c10 88 b23	372e 25.0s	blksprtwig	45.29	0.67	0.66	1.48	98.52	22	5.7	2400
64c10 88 b24	372e 24.0s	blksprtwig	50.45	1.10	1.06	2.18	97.82	14	5.2	700
64c10 88 b25	372e 23.0s	blksprtwig	39.52	0.88	0.84	2.23	97.77	16	5.3	1100
64c10 88 b26	372e 22.0s	blksprtwig	32.71	0.60	0.58	1.83	98.17	18	6.6	2000
64c10 88 b27	372e 21.0s	blksprtwig	33.89	0.85	0.82	2.51	97.49	9	6.0	1900
64c10 88 b28	372e 20.0s	blksprtwig	39.58	0.78	0.76	1.97	98.03	12	4.4	1600
64c10 88 b29	372e 19.0s	blksprtwig	40.36	0.72	0.68	1.78	98.22	27	13.0	1800
64c10 88 b30	372e 18.0s	blksprtwig	35.10	0.69	0.66	1.97	98.03	13	5.0	3000
64c10 88 b31	372e 17.0s	blksprtwig	35.43	0.67	0.64	1.89	98.11	86	4.3	2300
64c10 88 b32	310e 25.0s	blksprtwig	40.37	0.76	0.73	1.88	98.12	63	5.0	2000
64c10 88 b33	310e 26.0s	blksprtwig	51.06	1.03	1.01	2.02	97.98	38	4.8	2900
64c10 88 b34	310e 20.0s	blksprtwig	42.67	0.73	0.70	1.71	98.29	35	5.9	2800
64c10 88 b35	310e 19.0s	blksprtwig	38.78	0.83	0.80	2.14	97.86	41	2.3	2000
64c10 88 b36	308e 19.0s	blksprtwig	50.79	0.97	0.94	1.91	98.09	33	3.8	2300
64c10 88 b37	308e 20.0s	blksprtwig	55.92	0.98	0.94	1.75	98.25	48	6.9	1700
64c10 88 b38	308e 21.0s	blksprtwig	31.27	0.64	0.60	2.05	97.95	47	3.3	2300
64c10 88 b39	308e 22.0s	blksprtwig	38.83	0.72	0.68	1.85	98.15	32	4.1	2800
64c10 88 b40	308e 23.0s	blksprtwig	41.92	0.74	0.72	1.77	98.23	34	4.4	2100
64c10 88 b41	308e 24.0s	blksprtwig	43.01	0.73	0.71	1.70	98.30	21	4.9	3200
64c10 88 b42	308e 25.0s	blksprtwig	39.93	0.71	0.68	1.78	98.22	25	4.4	3800
64c10 88 b43	308e 26.0s	blksprtwig	36.07	0.67	0.64	1.86	98.14	23	5.5	1900
64c10 88 b44	312e 19.0s	blksprtwig	41.93	0.77	0.74	1.84	98.16	18	5.1	2600
64c10 88 b45	312e 20.0s	blksprtwig	45.07	0.79	0.76	1.75	98.25	15	5.5	2600
64c10 88 b46	312e 21.0s	blksprtwig	31.39	0.60	0.57	1.91	98.09	14	4.6	1800
64c10 88 b47	312e 22.0s	blksprtwig	38.28	0.70	0.67	1.83	98.17	125	3.3	2100
64c10 88 b48	312e 23.0s	blksprtwig	37.93	0.66	0.64	1.74	98.26	22	5.0	2400
64c10 88 b49	312e 24.0s	blksprtwig	51.06	0.86	0.83	1.68	98.32	21	3.7	1500
64c10 88 b50	312e 25.0s	blksprtwig	39.29	0.81	0.78	2.06	97.94	30	6.6	3800
64c10 88 b51	312e 27.0s	blksprtwig	46.47	0.86	0.82	1.85	98.15	51	6.9	2100
31f2 88 h1	napier lake	humus	112.85	22.54	1.08	19.97	80.03	<5	33.0	1200
31f2 88 h2	napier lake	humus	109.45	44.81	1.28	40.94	59.06	<5	40.0	670
31f2 88 h3	napier lake	humus	150.65	25.92	1.01	17.21	82.79	25	34.0	1400
31f2 88 h4	napier lake	humus	147.69	41.96	1.03	28.41	71.59	16	38.0	1600
31f2 88 h5	napier lake	humus	145.74	60.32	1.33	41.39	58.61	14	33.0	1200
31f2 88 h6	napier lake	humus	104.36	34.48	1.16	33.04	66.96	48	46.0	1100
31f2 88 h7	napier lake	humus	153.56	42.32	1.23	27.56	72.44	<5	33.0	1400
64c10 87 h1	373.5e 19.5s	humus	80.77	17.86	1.32	22.11	77.89	8	5.1	640
64c10 87 h2	373.5e 10.5s	humus	111.01	15.84	1.28	14.27	85.73	26	5.1	680
64c10 87 h3	374e 21.5s	humus	106.51	13.65	0.68	12.82	87.18	14	16.0	1100
64c10 87 h4	374e 22.5s	humus	118.27	11.34	0.76	9.59	90.41	20	21.0	670
64c10 87 h5	374e 22.0s	humus	133.88	10.48	0.86	7.83	92.17	21	16.0	700
64c10 87 h6	374e 23.0s	humus	127.21	9.46	0.74	7.44	92.56	13	11.0	830
64c10 87 h7	374e 24.0s	humus	75.89	4.26	0.80	5.61	94.39	72	9.4	250
64c10 87 h8	374e 24.4s	humus	119.48	10.93	0.78	9.15	90.85	40	16.0	980
64c10 87 h9	374e 25.0s	humus	60.44	5.86	1.35	9.70	90.30	50	13.0	1100
64c10 87 h10	374e 25.5s	humus	114.54	11.20	1.20	9.78	90.22	60	6.0	1500
64c10 87 h11	375e 20.0s	humus	97.38	11.46	0.66	11.77	88.23	25	35.0	520
64c10 87 h12	375.3e 25.5s	humus	110.80	53.78	1.77	48.54	51.46	7	0.8	630
64c10 88 h1	374e 26.5s	humus	134.60	72.51	1.47	53.87	46.13	<5	1.7	550
64c10 88 h2	374e 27.8s	humus	83.21	10.68	1.15	12.83	87.17	<5	2.2	1000
64c10 88 h3	374e 19.4s	humus	65.63	6.36	0.95	9.69	90.31	17	40.0	830

64c10 88 h4	374e 18.7s	humus	79.99	5.71	0.90	7.14	92.86	<5	22.0	1000
64c10 88 h5	374e 18.2s	humus	154.63	28.90	0.99	18.69	81.31	6	14.0	1300
64c10 88 h6	374e 17.5s	humus	161.73	46.99	1.59	29.05	70.95	<5	5.0	610
64c10 88 h7	374e 16.7s	humus	121.84	44.91	1.55	36.86	63.14	14	29.0	710
64c10 88 h8	374e 16.0s	humus	118.13	48.05	1.56	40.68	59.32	6	0.9	670
64c10 88 h9	378e 28.0s	humus	119.17	35.17	1.80	29.51	70.49	<5	1.0	750
64c10 88 h10	378e 26.0s	humus	98.24	50.08	1.49	50.98	49.02	<5	5.3	660
64c10 88 h11	378e 25.0s	humus	152.65	61.79	1.63	40.48	59.52	<5	3.3	650
64c10 88 h12	378e 24.0s	humus	125.61	34.89	1.49	27.78	72.22	<5	8.3	690
64c10 88 h13	378e 23.0s	humus	192.15	82.90	1.42	43.14	56.86	<5	0.6	780
64c10 88 h14	376e 26.6s	humus	181.69	40.71	0.84	22.41	77.59	<5	2.8	810
64c10 88 h15	376e 25.0s	humus	159.06	10.43	0.70	6.56	93.44	5	2.7	820
64c10 88 h16	376e 24.0s	humus	75.43	6.76	0.71	8.96	91.04	8	6.2	760
64c10 88 h17	376e 23.0s	humus	118.53	15.71	0.94	13.25	86.75	16	27.0	1100
64c10 88 h18	376e 22.0s	humus	129.63	19.58	0.81	15.10	84.90	20	36.0	1300
64c10 88 h21	372e 26.6s	humus	81.60	6.98	1.18	8.55	91.45	14	3.9	1200
64c10 88 h22	372e 26.0s	humus	108.59	27.06	1.10	24.92	75.08	9	1.1	1000
64c10 88 h23	372e 25.0s	humus	82.54	7.72	1.13	9.35	90.65	39	10.0	1300
64c10 88 h24	372e 24.0s	humus	107.49	12.73	0.68	11.84	88.16	55	3.9	500
64c10 88 h25	372e 23.0s	humus	120.82	13.54	0.69	11.21	88.79	19	4.0	890
64c10 88 h25t	372e 23.0s	humus	67.91	7.62	0.64	11.22	88.78	20	5.1	940
64c10 88 h26	372e 22.0s	humus	187.31	39.71	1.16	21.20	78.80	22	7.2	1200
64c10 88 h27	372e 21.0s	humus	79.70	12.33	1.34	15.47	84.53	14	1.5	1300
64c10 88 h28	372e 20.0s	humus	80.36	12.23	1.56	15.22	84.78	17	17.0	670
64c10 88 h29	372e 19.0s	humus	161.28	69.93	1.27	43.36	56.64	<5	5.6	680
64c10 88 h30	372e 18.0s	humus	122.22	73.90	1.37	60.47	39.53	7	8.2	700
64c10 88 h31	372e 17.0s	humus	127.07	37.19	1.74	29.27	70.73	<5	8.5	830
64c10 88 h32	310e 25.0s	humus	90.01	14.54	1.21	15.88	84.12	<5	18.0	890
64c10 88 h33	310e 26.0s	humus	106.77	41.16	1.33	38.55	61.45	12	1.9	900
64c10 88 h34	310e 20.0s	humus	128.98	13.23	1.22	10.26	89.74	30	8.2	470
64c10 88 h35	310e 19.0s	humus	92.36	4.97	0.74	5.38	94.62	30	17.0	1200
64c10 88 h36	308e 19.0s	humus	113.16	6.45	0.92	7.70	94.30	10	11.0	2000
64c10 88 h37	308e 20.0s	humus	75.84	4.06	0.92	5.35	94.65	19	10.0	840
64c10 88 h38	308e 21.0s	humus	76.58	20.68	1.49	27.00	73.00	23	1.1	670
64c10 88 h39	308e 22.0s	humus	79.77	6.73	1.16	8.44	91.56	18	25.0	1100
64c10 88 h40	308e 23.0s	humus	147.19	33.19	0.96	22.55	77.45	29	4.8	1200
64c10 88 h41	308e 24.0s	humus	117.48	26.32	1.57	22.40	77.60	13	2.0	970
64c10 88 h42	308e 25.0s	humus	142.13	26.90	1.04	18.93	81.07	15	13.0	1900
64c10 88 h43	308e 26.0s	humus	81.64	6.02	1.02	7.37	92.63	26	8.7	1200
64c10 88 h44	312e 19.0s	humus	188.85	46.23	1.47	24.48	75.52	10	10.0	760
64c10 88 h45	312e 20.0s	humus	145.70	28.42	1.57	19.51	80.49	<5	6.8	580
64c10 88 h46	312e 21.0s	humus	100.88	18.81	1.28	18.65	81.35	12	9.8	710
64c10 88 h47	312e 22.0s	humus	114.88	30.93	1.41	26.92	73.08	42	11.0	540
64c10 88 h48	312e 23.0s	humus	127.16	12.71	0.82	10.00	90.00	140	13.0	2200
64c10 88 h49	312e 24.0s	humus	138.78	12.54	1.20	9.04	90.96	17	12.0	1600
64c10 88 h50	312e 25.0s	humus	151.89	29.19	1.35	19.22	80.78	<5	9.3	1300
64c10 88 h51	312e 27.0s	humus	60.92	4.72	1.06	7.75	92.25	15	14.0	1000

SAMPLEID	BR PPM	CA PCT	CO PPM	CR PPM	CS PPM	FE PCT	K PCT	MO PPM	NA PPM	NI PPM	SB PPM	SC PPM
pap 87 aq1	16	34.4	1	4	<0.5	0.09	0.82	<2	825	<50	0.1	0.3
pap 87 aq1a	16	32.9	2	3	<0.5	0.08	0.78	<2	906	<50	0.1	0.3
pap 87 aq1b	16	34.0	1	4	<0.5	0.08	0.85	<2	833	<50	0.1	0.3
pap 87 b1	24	17.4	4	9	0.8	0.34	20.00	<2	1170	<50	0.5	1.0
pap 87 b2	15	19.5	9	18	1.1	0.54	11.90	<2	1910	<50	0.4	1.8
pap 87 b2a	8	17.4	5	17	1.2	0.39	20.20	2	1290	<50	0.3	1.4
pap 87 b3	10	19.9	4	17	1.1	0.71	10.90	<2	2550	<50	0.7	2.3
pap 87 b4	17	17.1	4	16	0.9	0.52	15.90	3	1660	<50	0.3	1.7
pap 87 b5	19	5.6	5	12	0.9	0.31	22.30	<2	1040	<50	0.2	1.0
pap 87 b6	32	16.7	9	17	1.2	0.69	12.50	2	2640	<50	0.5	2.3
pap 87 b7	14	16.2	4	17	0.7	0.63	8.84	<2	2010	<50	0.5	2.1
pap 88 b1	25	15.9	12	14	1.6	0.69	14.90	<2	3130	<50	0.4	2.2
pap 88 b2	19	16.3	14	17	2.4	0.78	12.30	<2	3540	<50	0.5	2.7
pap 88 b3	23	4.2	8	13	1.9	0.64	15.40	<2	2890	<50	0.7	2.1
pap 88 b4	28	13.3	8	11	1.7	0.51	15.50	<2	2250	<50	0.3	1.7
pap 88 b5	13	15.1	7	13	1.5	0.56	18.30	<2	2420	<50	0.3	1.9
pap 88 b6	16	14.0	12	22	1.8	0.92	11.40	<2	4160	<50	0.5	3.2
pap 88 b7	13	13.2	3	6	1.7	0.23	18.10	<2	963	<50	0.1	0.8
pap 88 b8	15	15.5	9	11	0.9	0.57	12.10	<2	2290	<50	0.3	1.8
64c10 87 b1	34	16.3	12	23	6.5	0.68	15.00	<2	1880	130	0.9	2.1
64c10 87 b2	28	15.8	7	16	1.6	0.57	13.50	3	1760	75	0.6	1.9
64c10 87 b3	10	18.6	3	20	1.0	0.59	16.60	2	1650	<50	0.5	1.8
64c10 87 b4	26	18.6	5	21	1.7	0.74	13.30	2	2010	66	0.6	2.3
64c10 87 b5	28	18.3	5	19	1.6	0.72	11.00	<2	1960	86	0.5	2.1
64c10 87 b6	33	16.0	6	29	1.9	0.97	12.10	<2	2650	99	1.0	3.0
64c10 87 b7	12	18.0	5	24	1.1	0.86	9.72	2	2380	<50	0.8	2.7
64c10 87 b8	20	18.7	5	22	1.1	0.77	9.18	2	2300	130	0.7	2.5
64c10 87 b9	27	15.9	8	26	2.3	0.97	14.90	<2	2760	140	0.8	3.0
64c10 87 b10	27	6.6	6	37	4.0	1.06	17.20	<2	3300	130	0.9	3.0
64c10 87 b11	48	18.8	7	27	5.0	0.59	17.80	<2	1840	110	0.7	1.6
64c10 87 b12	44	16.8	9	24	7.0	0.68	18.60	<2	2380	100	0.9	2.0
64c10 87 b15	12	22.8	8	27	9.4	0.70	11.40	<2	2300	78	0.9	2.2
64c10 87 b16	21	16.7	17	23	6.3	0.77	13.20	3	2050	81	0.6	2.3
64c10 87 b17	44	16.2	14	24	2.0	0.65	14.80	<2	1870	120	0.4	2.1
64c10 87 b18	37	16.0	14	22	4.3	0.71	13.50	<2	2090	85	0.7	2.3
64c10 87 b19	27	15.2	7	23	4.4	0.61	13.80	<2	1720	99	0.5	1.9
64c10 87 b20	34	15.0	8	24	4.5	0.73	12.80	<2	2060	120	1.0	2.3
64c10 87 b21	57	15.7	9	22	7.0	0.61	15.70	3	1870	110	0.6	1.9
64c10 87 t1b	21	14.5	17	68	8.5	1.86	5.31	<2	5570	250	3.0	5.9
64c10 87 t3a	23	21.0	15	30	0.9	1.82	1.17	<2	6570	<50	0.7	12.0
64c10 87 t4a 1	42	21.8	25	32	1.6	4.45	0.62	20	3770	<50	2.1	14.0
64c10 87 t4a 2	37	20.8	26	37	<0.5	4.56	0.85	24	4210	<50	2.1	14.0
64c10 87 t4a 3	29	23.1	24	34	1.3	4.44	0.50	26	3640	<50	2.3	14.0
64c10 87 t4b	51	21.6	17	31	1.8	3.19	0.71	20	3420	<50	1.5	13.0
64c10 87 t5a	21	16.5	26	49	1.3	0.80	<0.33	7	12600	50	1.0	27.0
64c10 87 t6a	38	27.6	49	23	1.2	6.14	<0.17	10	1130	<50	0.4	4.6
64c10 87 t7a 1	18	11.8	11	58	3.4	3.07	3.88	0	14700	<50	0.5	12.0
64c10 87 t7a 2	16	9.4	11	39	2.8	2.88	1.88	0	13300	<50	0.5	12.0
64c10 87 t8a	14	13.5	17	57	2.2	2.61	1.66	12	12600	54	0.4	14.0
64c10 87 t9a	25	4.6	36	120	1.9	3.10	1.25	<2	16600	52	3.8	15.0
64c10 88 b1	42	17.3	6	14	2.5	0.53	12.50	<2	1720	85	0.7	1.5
64c10 88 b2	48	15.4	7	19	2.3	0.80	13.30	<2	2450	90	0.8	2.4
64c10 88 b3	27	18.9	7	16	5.6	0.50	13.50	<2	1680	92	0.4	1.5
64c10 88 b4	39	15.8	8	16	3.3	0.73	12.30	<2	2430	93	0.6	2.2
64c10 88 b5	36	16.5	12	9	1.4	0.50	16.50	<2	1560	120	0.4	1.5
64c10 88 b6	21	15.1	5	13	1.9	0.54	15.40	<2	1860	64	0.4	1.7
64c10 88 b7	27	16.7	6	12	1.6	0.63	14.00	<2	1860	64	0.4	1.7
64c10 88 b8	36	13.8	7	14	2.9	0.71	13.90	<2	2190	83	0.5	2.1
64c10 88 b9	43	17.7	6	14	4.5	0.58	12.60	<2	1790	130	0.4	1.7
64c10 88 b10	38	17.3	5	10	3.7	0.47	13.50	<2	1560	110	0.4	1.4
64c10 88 b11	30	17.5	6	15	7.8	0.77	13.00	2	2320	<50	0.8	2.1

64c10 88 b12	50	17.8	6	12	4.4	0.46	13.30	<2	1520	120	0.4	1.4
64c10 88 b13	49	17.9	6	19	3.8	0.80	12.60	<2	2260	150	0.5	2.3
64c10 88 b14	38	14.9	5	14	1.6	0.76	12.90	2	2290	53	0.5	2.3
64c10 88 b15	25	19.7	5	21	1.5	0.76	11.40	<2	2300	59	0.5	2.3
64c10 88 b16	43	16.5	6	17	1.4	0.74	14.80	<2	2140	16	0.5	2.1
64c10 88 b17	22	17.2	4	15	1.9	0.80	10.70	2	2410	<50	0.6	2.4
64c10 88 b18	31	16.2	6	17	1.5	0.68	10.10	<2	2200	<50	0.6	2.0
64c10 88 b19	38	15.6	5	15	3.8	0.68	13.40	<2	2140	88	0.6	2.0
64c10 88 b20	30	16.0	6	13	3.4	0.44	9.55	<2	1630	69	0.6	1.5
64c10 88 b21	33	20.0	7	15	2.9	0.69	10.20	<2	2150	75	0.7	2.0
64c10 88 b22	48	17.8	7	15	2.8	0.73	13.20	<2	1940	76	0.9	1.8
64c10 88 b23	48	13.4	16	16	3.6	0.63	17.40	<2	2070	<50	0.5	1.9
64c10 88 b24	34	18.5	5	16	1.7	0.74	11.90	<2	2290	65	0.5	2.2
64c10 88 b25	29	18.7	5	18	2.7	0.77	9.96	<2	2380	100	0.6	2.3
64c10 88 b26	42	15.3	7	19	1.3	0.84	14.50	3	2730	90	0.6	2.6
64c10 88 b27	27	11.6	15	33	2.5	2.08	9.86	<2	9310	<50	0.6	6.7
64c10 88 b28	45	15.1	9	12	7.7	0.54	13.40	<2	1710	78	0.4	1.6
64c10 88 b29	17	20.1	9	17	7.0	0.70	9.24	<2	2420	140	0.7	2.0
64c10 88 b30	24	17.6	7	16	3.0	0.66	14.00	<2	2110	57	0.5	1.9
64c10 88 b31	60	15.1	7	15	4.8	0.61	15.00	<2	2290	130	0.4	1.7
64c10 88 b32	38	13.6	9	14	5.3	0.64	16.80	<2	2030	<50	0.5	1.9
64c10 88 b33	38	17.7	7	17	4.2	0.63	12.80	<2	2070	<50	0.5	1.9
64c10 88 b34	29	17.2	12	16	21.0	0.71	10.10	<2	2440	63	0.7	2.4
64c10 88 b35	26	16.0	10	16	2.9	0.66	13.60	<2	2350	86	0.5	2.1
64c10 88 b36	29	15.4	9	13	2.2	0.68	14.70	<2	2150	<50	0.6	2.0
64c10 88 b37	31	17.6	8	20	5.7	0.80	11.40	<2	2560	96	0.6	2.4
64c10 88 b38	36	17.3	12	11	1.9	0.47	15.30	<2	1490	<50	0.3	1.3
64c10 88 b39	53	17.5	27	15	2.5	0.59	15.70	<2	1840	<50	0.4	1.7
64c10 88 b40	41	17.9	6	12	4.4	0.62	16.20	<2	1910	99	0.4	1.8
64c10 88 b41	37	18.4	7	15	4.6	0.64	15.70	<2	1990	<50	0.5	1.9
64c10 88 b42	29	18.4	8	17	5.4	0.65	12.40	<2	2670	84	0.6	2.1
64c10 88 b43	39	16.6	6	16	4.1	0.78	15.30	<2	2480	53	0.5	2.3
64c10 88 b44	28	16.9	7	19	3.3	0.70	12.50	<2	2180	93	0.5	2.1
64c10 88 b45	31	16.6	14	16	10.0	0.65	12.20	3	1900	79	0.6	1.9
64c10 88 b46	30	18.4	12	17	4.2	0.66	14.70	<2	2040	73	0.6	2.0
64c10 88 b47	33	19.6	9	10	2.8	0.48	14.90	<2	1570	81	0.3	1.5
64c10 88 b48	24	18.2	8	19	3.5	0.78	14.50	3	2260	54	0.6	2.3
64c10 88 b49	47	15.7	9	13	2.5	0.55	16.80	<2	1710	71	0.5	1.6
64c10 88 b50	50	17.3	10	10	2.5	0.80	13.90	2	2440	73	0.8	2.4
64c10 88 b51	37	15.6	6	18	3.1	0.76	15.50	<2	2400	97	0.6	2.3
31f2 88 h1	58	9.7	18	43	1.8	2.60	1.55	<2	9940	<50	4.2	10.0
31f2 88 h2	19	4.3	26	55	1.8	5.27	0.81	<2	13700	<50	2.9	16.0
31f2 88 h3	44	7.8	21	49	2.9	3.50	1.61	3	7920	<50	5.9	15.0
31f2 88 h4	30	8.5	19	52	1.8	3.49	1.25	<2	10300	<50	3.6	12.0
31f2 88 h5	23	5.8	24	52	2.0	3.90	0.53	<2	12500	<50	3.1	14.0
31f2 88 h6	33	6.7	29	57	1.7	3.97	0.77	<2	10300	<50	3.9	12.0
31f2 88 h7	33	6.9	21	58	1.8	4.43	0.84	<2	10200	<50	4.4	11.0
64c10 87 h1	9	2.0	19	52	2.3	4.21	0.85	<2	14900	<50	1.1	19.0
64c10 87 h2	17	4.1	25	58	1.8	3.53	1.21	<2	14300	<50	1.8	18.0
64c10 87 h3	74	25.4	8	20	1.2	0.85	1.21	13	6630	<50	1.7	5.2
64c10 87 h4	70	22.7	28	23	2.4	1.49	1.28	14	5040	<50	2.3	5.2
64c10 87 h5	77	23.3	17	16	1.3	0.90	1.52	33	6130	<50	2.5	4.2
64c10 87 h6	92	25.5	29	13	1.0	2.15	0.91	16	5060	<50	1.7	2.7
64c10 87 h7	89	11.7	8	23	1.5	0.66	2.59	94	4990	<50	1.5	11.0
64c10 87 h8	87	26.5	20	21	1.5	1.16	0.82	84	5170	<50	1.4	6.2
64c10 87 h9	27	4.5	19	100	2.2	3.33	0.93	<2	11000	<50	2.6	20.0
64c10 87 h10	21	2.3	12	56	2.4	2.45	0.74	0	12000	<50	3.1	14.0
64c10 87 h11	150	17.7	16	23	<0.5	3.84	0.81	71	9680	<50	2.4	2.9
64c10 87 h12	3	1.4	8	43	3.1	2.22	0.58	<2	21200	<50	0.6	9.9
64c10 88 h1	11	1.6	9	54	0.8	2.57	0.58	<2	20200	<50	0.3	15.0
64c10 88 h2	18	2.6	16	38	3.2	1.72	1.98	<2	15600	78	1.2	9.6
64c10 88 h3	19	1.9	32	42	3.8	3.57	1.78	<2	11800	79	1.9	17.0

64c10 88 h4	39	4.7	59	47	4.3	5.32	1.69	<2	8900	94	2.4	17.0
64c10 88 h5	37	10.0	34	28	3.1	4.39	0.97	<2	11800	<50	1.0	15.0
64c10 88 h6	10	2.5	4	17	0.9	0.97	0.48	<2	19000	<50	0.4	5.4
64c10 88 h7	11	2.5	11	69	0.9	3.29	0.23	<2	19700	62	0.5	17.0
64c10 88 h8	7	1.8	7	31	1.7	2.02	0.63	<2	20800	<50	0.6	8.8
64c10 88 h9	8	1.1	5	21	1.3	1.01	0.65	<2	19300	<50	0.8	4.5
64c10 88 h10	8	1.1	3	19	1.5	1.13	1.06	<2	21300	<50	0.9	4.7
64c10 88 h11	7	1.2	4	20	1.3	1.05	1.07	<2	18500	<50	0.6	4.8
64c10 88 h12	11	1.6	7	27	1.8	1.45	1.06	<2	19000	<50	1.2	6.9
64c10 88 h13	16	1.2	6	28	0.7	2.39	0.44	0	17300	<50	0.4	9.5
64c10 88 h14	65	16.9	6	19	0.9	2.02	0.62	14	4700	<50	0.6	5.9
64c10 88 h15	76	24.2	16	15	1.1	1.51	0.40	59	2640	<50	1.6	2.5
64c10 88 h16	58	24.5	19	9	<0.5	4.44	0.46	49	3010	<50	0.5	2.4
64c10 88 h17	57	16.0	30	30	1.2	7.43	0.74	11	5460	<50	1.6	9.6
64c10 88 h18	140	22.0	32	28	0.7	5.23	0.48	40	1920	<50	1.7	8.0
64c10 88 h21	15	2.2	14	51	5.1	1.86	1.64	<2	11800	66	2.5	8.9
64c10 88 h22	23	1.2	18	57	4.8	3.56	0.61	<2	15300	57	0.9	14.0
64c10 88 h23	36	4.3	26	63	2.8	2.74	1.09	<2	11400	<50	1.5	12.0
64c10 88 h24	93	26.9	16	11	<0.5	0.90	0.41	21	1610	<50	1.0	7.0
64c10 88 h25	64	22.5	20	25	1.8	2.12	0.60	5	2390	<50	0.8	11.0
64c10 88 h25t	68	20.5	23	26	1.5	2.30	0.83	<2	2370	<50	0.9	13.0
64c10 88 h26	32	8.3	15	59	1.1	2.97	0.28	<2	19500	<50	0.8	18.0
64c10 88 h27	13	2.0	24	54	1.8	4.02	0.40	<2	17400	<50	1.5	17.0
64c10 88 h28	12	2.0	12	47	3.1	2.61	0.61	<2	15300	<50	1.6	10.0
64c10 88 h29	15	1.3	7	23	1.3	1.07	1.12	<2	18700	<50	0.8	7.0
64c10 88 h30	12	2.3	19	160	5.6	3.52	0.65	<2	15200	74	0.8	13.0
64c10 88 h31	11	1.2	9	44	1.8	1.91	0.41	<2	19600	52	1.3	10.0
64c10 88 h32	17	2.6	16	120	1.7	2.63	0.30	<2	23200	77	2.0	15.0
64c10 88 h33	14	1.2	9	33	2.5	1.59	0.51	<2	14300	<50	0.9	8.0
64c10 88 h34	39	6.8	52	91	2.0	4.73	0.67	<2	12600	73	2.1	28.0
64c10 88 h35	54	1.9	40	42	2.0	5.31	2.37	<2	10300	120	2.6	19.0
64c10 88 h36	47	4.3	43	55	1.8	2.51	2.19	<2	10200	99	2.6	11.0
64c10 88 h37	46	7.2	32	79	4.2	2.65	2.23	<2	11200	160	2.6	11.0
64c10 88 h38	21	3.7	26	90	1.4	3.87	0.28	<2	18200	64	1.0	19.0
64c10 88 h39	31	4.0	30	79	2.3	2.83	1.05	<2	14900	84	2.3	13.0
64c10 88 h40	27	1.4	19	84	2.8	4.08	1.02	<2	8240	<50	1.0	27.0
64c10 88 h41	18	3.3	20	150	1.3	3.12	0.51	<2	21700	93	1.1	17.0
64c10 88 h42	25	1.7	18	55	4.8	2.60	0.79	<2	17800	81	1.3	12.0
64c10 88 h43	21	1.4	26	66	2.7	2.55	1.50	0	15300	72	2.9	12.0
64c10 88 h44	15	2.9	11	61	1.3	2.39	0.47	<2	17700	59	1.2	13.0
64c10 88 h45	17	3.8	40	77	1.3	5.63	0.21	<2	25100	68	1.1	34.0
64c10 88 h46	14	2.3	20	100	1.1	4.47	0.64	<2	15300	<50	1.7	25.0
64c10 88 h47	18	2.4	19	47	2.0	4.02	0.76	<2	16100	<50	0.8	19.0
64c10 88 h48	50	5.8	35	190	3.0	4.56	1.32	<2	18200	99	2.7	23.0
64c10 88 h49	40	3.7	23	130	2.1	2.96	1.05	0	15200	<50	0.1	16.0
64c10 88 h50	19	2.7	17	71	2.0	3.16	0.59	<2	20000	<50	0.9	13.0
64c10 88 h51	25	2.7	17	56	4.4	2.54	2.75	2	9720	<50	2.8	9.3

SAMPLEID	ZN_PPM	LA_PPM	CE_PPM
pap 87 sq1	<20	0.3	<3
pap 87 sq1a	<20	0.2	<3
pap 87 sq1b	31	0.2	<3
pap 87 b1	2300	6.2	12
pap 87 b2	900	5.0	9
pap 87 b2a	1200	3.6	8
pap 87 b3	1300	7.7	14
pap 87 b4	1700	4.7	10
pap 87 b5	1500	2.5	6
pap 87 b6	1400	6.9	12
pap 87 b7	1200	6.2	11
pap 88 b1	1400	4.9	7
pap 88 b2	1100	8.4	15
pap 88 b3	1600	5.7	10
pap 88 b4	1500	4.9	7
pap 88 b5	1500	5.9	10
pap 88 b6	1100	8.7	16
pap 88 b7	1300	1.9	4
pap 88 b8	1000	5.7	11
64c10 87 b1	1700	5.7	11
64c10 87 b2	1900	5.8	10
64c10 87 b3	3400	5.5	9
64c10 87 b4	2600	6.9	14
64c10 87 b5	2500	7.2	12
64c10 87 b6	2300	8.8	16
64c10 87 b7	2200	8.6	16
64c10 87 b8	2200	7.6	13
64c10 87 b9	3000	9.5	17
64c10 87 b10	2600	9.6	19
64c10 87 b11	2100	4.7	9
64c10 87 b12	2000	6.2	12
64c10 87 b15	2100	7.9	13
64c10 87 b16	1800	6.2	12
64c10 87 b17	2000	5.5	9
64c10 87 b18	1900	6.4	12
64c10 87 b19	1700	4.9	11
64c10 87 b20	1800	6.3	12
64c10 87 b21	1900	5.0	9
64c10 87 t1b	1600	14.0	25
64c10 87 t3a	63	18.0	32
64c10 87 t4a 1	130	31.0	53
64c10 87 t4a 2	150	34.0	56
64c10 87 t4a 3	140	31.0	55
64c10 87 t4b	160	27.0	43
64c10 87 t5a	86	19.0	35
64c10 87 t6a	45	7.9	15
64c10 87 t7a 1	69	59.0	110
64c10 87 t7a 2	<22	49.0	85
64c10 87 t8a	54	34.0	45
64c10 87 t9a	35	47.0	80
64c10 88 b1	2500	5.1	8
64c10 88 b2	2300	8.9	16
64c10 88 b3	1800	5.1	9
64c10 88 b4	1400	7.1	13
64c10 88 b5	1700	4.4	9
64c10 88 b6	2000	5.8	8
64c10 88 b7	1500	6.0	11
64c10 88 b8	3100	7.0	12
64c10 88 b9	2200	5.7	11
64c10 88 b10	2900	4.9	10
64c10 88 b11	3100	7.6	14

64c10 88 b12	2400	4.6	7
64c10 88 b13	2700	7.3	12
64c10 88 b14	3100	8.0	15
64c10 88 b15	2300	7.6	15
64c10 88 b16	2500	7.2	11
64c10 88 b17	2400	8.4	15
64c10 88 b18	2200	6.8	11
64c10 88 b19	2500	6.8	13
64c10 88 b20	2100	4.8	8
64c10 88 b21	1800	7.2	13
64c10 88 b22	2100	6.1	11
64c10 88 b23	2000	6.1	11
64c10 88 b24	2400	8.0	15
64c10 88 b25	2500	8.4	14
64c10 88 b26	3300	8.5	15
64c10 88 b27	1300	11.0	20
64c10 88 b28	1800	5.0	10
64c10 88 b29	1900	6.5	12
64c10 88 b30	2100	6.2	12
64c10 88 b31	2500	6.1	11
64c10 88 b32	2000	5.8	10
64c10 88 b33	2200	6.3	11
64c10 88 b34	1800	7.7	13
64c10 88 b35	1500	5.8	11
64c10 88 b36	1400	5.9	12
64c10 88 b37	2200	7.2	13
64c10 88 b38	1600	3.7	7
64c10 88 b39	1700	5.5	11
64c10 88 b40	1900	6.2	11
64c10 88 b41	1600	6.4	12
64c10 88 b42	2100	6.7	12
64c10 88 b43	1800	8.0	13
64c10 88 b44	1500	6.2	11
64c10 88 b45	1900	5.5	11
64c10 88 b46	1900	6.0	12
64c10 88 b47	2100	4.6	10
64c10 88 b48	1700	7.0	12
64c10 88 b49	2400	5.2	9
64c10 88 b50	2300	7.7	14
64c10 88 b51	2000	7.1	12
31f2 88 h1	690	26.0	35
31f2 88 h2	320	15.0	27
31f2 88 h3	730	21.0	32
31f2 88 h4	630	17.0	31
31f2 88 h5	440	16.0	30
31f2 88 h6	680	19.0	41
31f2 88 h7	880	23.0	35
64c10 87 h1	230	42.0	61
64c10 87 h2	320	22.0	35
64c10 87 h3	520	9.1	15
64c10 87 h4	390	15.0	19
64c10 87 h5	610	13.0	16
64c10 87 h6	360	11.0	14
64c10 87 h7	370	10.0	14
64c10 87 h8	490	21.0	23
64c10 87 h9	520	16.0	25
64c10 87 h10	450	23.0	34
64c10 87 h11	370	8.3	10
64c10 87 h12	120	33.0	50
64c10 88 h1	85	24.0	42
64c10 88 h2	550	29.0	51
64c10 88 h3	290	49.0	80

64c10 88 h4	420	98.0	170
64c10 88 h5	170	99.0	180
64c10 88 h6	120	25.0	43
64c10 88 h7	170	14.0	26
64c10 88 h8	120	29.0	52
64c10 88 h9	140	22.0	38
64c10 88 h10	160	20.0	33
64c10 88 h11	110	20.0	34
64c10 88 h12	190	22.0	38
64c10 88 h13	78	55.0	94
64c10 88 h14	140	35.0	62
64c10 88 h15	240	9.7	19
64c10 88 h16	450	6.9	12
64c10 88 h17	190	32.0	54
64c10 88 h18	160	17.0	28
64c10 88 h21	280	20.0	35
64c10 88 h22	170	99.8	200
64c10 88 h23	330	28.0	53
64c10 88 h24	280	12.0	20
64c10 88 h25	170	37.0	51
64c10 88 h25t	160	37.0	51
64c10 88 h26	140	41.0	64
64c10 88 h27	160	17.0	33
64c10 88 h28	310	25.0	44
64c10 88 h29	92	31.0	54
64c10 88 h30	110	58.0	86
64c10 88 h31	210	24.0	36
64c10 88 h32	140	17.0	25
64c10 88 h33	110	65.0	90
64c10 88 h34	360	12.0	18
64c10 88 h35	370	60.0	84
64c10 88 h36	160	32.0	42
64c10 88 h37	610	22.0	32
64c10 88 h38	160	20.0	29
64c10 88 h39	240	31.0	43
64c10 88 h40	160	57.0	94
64c10 88 h41	110	25.0	47
64c10 88 h42	220	48.0	84
64c10 88 h43	200	73.0	100
64c10 88 h44	340	21.0	39
64c10 88 h45	190	9.0	14
64c10 88 h46	160	17.0	30
64c10 88 h47	440	19.0	34
64c10 88 h48	530	26.0	48
64c10 88 h49	310	18.0	27
64c10 88 h50	140	35.0	61
64c10 88 h51	450	41.0	73

APPENDIX FOUR

STREAM SEDIMENT GEOCHEMICAL DATA

STREAM SEDIMENT GEOCHEMICAL DATA FILE CODE

STREAMSEDID:	stream sediment field number; NTS map area followed by year (19xx) and sample number
REPSTAT:	replicate status; 0=individual sample; 10=first of field duplicate; 20=second of field duplicate
LOCATION:	field location
WIDTH:	channel width in metres
DEPTH:	stream water depth in decimetres
FLOW:	rate of flow; nil,slow, moderate, fast
WATERCOL:	water colour

n.s. = no sample field data
n.d. = no analytical data

*Analytical methods are detailed in Appendix 6 along with lake sediment analytical methods.

ELEMENT	DETECTION LEVEL	METHOD
Zn	2 ppm	HNO_3/HCl digestion/AAS
Cu	2 ppm	-"-
Pb	2 ppm	-"-
Ni	2 ppm	-"-
Co	2 ppm	-"-
Ag	0.2 ppm	-"-
Mn	5 ppm	-"-
Fe	0.02%	-"-
As	1 ppm	-"-
Mo	2 ppm	-"-
V	2 ppm	-"-
Cd	0.2 ppm	-"-
Hg	10 ppb	Hatch and Ott;cold vapour/AAS
As	1 ppm	hydride evol./AAS
Sb	0.2 ppm	-"-
U	0.2 ppm	neutron activation
F	10 ppm	ion specific electrode
W	2 ppm	Zn dithiol/spectrophotometry
Sn	2 ppm	fusion extraction/AAS
LOI	0.1%	550C furnace/gravimetric
Ba	100 ppm	instrumental neutron activation(INAA)
Cr	5 ppm	-"-
As_INA	1 ppm	-"-
Br	1 ppm	-"-
Sb_INA	0.1 ppm	-"-
La	1 ppm	-"-
Ce	3 ppm (variable)	-"-
W_INA	1 ppm	-"-
Au_INA	2 ppb (variable)	-"-
Th	0.5 ppm	-"-
U2_INA	0.5 ppm	-"-

INAWT_GM weight to nearest 0.01 gram of sample aliquot analyzed by INAA

STRMSEDID	REPSTAT	LOCATION	WIDTH(M)	DEPTH(DM)	FLOW	WATERCOL	ZN PPM	CU PPM	PB PPM	NI PPM	CO PPM	AG PPM	MN PPM
31f2 881030	10	l. green lk outflow	5.0	0.1	mod	clear	61	17	20	10	4	<0.2	258
31f2 881031	20	l. green lk outflow	5.0	0.1	mod	clear	51	13	17	6	5	<0.2	230
31f2 881032	10	l. green lk outflow	7.0	0.1	mod	clear	77	36	15	17	12	0.5	327
31f2 881033	20	l. green lk outflow	7.0	0.1	mod	clear	63	29	13	15	11	<0.2	329
31f2 881034	10	l. green lk inflow	3.0	0.1	slow	clear	22	20	9	7	5	0.5	257
31f2 881035	20	l. green lk inflow	3.0	0.1	slow	clear	24	23	13	7	5	<0.2	279
31f2 881036	10	napier lk inflow	2.0	0.1	slow	clear	67	11	5	17	11	0.2	377
31f2 881037	20	napier lk inflow	2.0	0.1	slow	clear	75	14	29	9	7	<0.2	564
31f2 881038	10	napier ck	2.0	0.1	slow	clear	123	22	17	13	17	0.6	2000
31f2 881039	20	napier ck	2.0	0.1	slow	clear	124	23	16	13	17	<0.2	2375
31f2 881040	0	napier ck	2.0	0.1	slow	clear	183	36	34	18	22	<0.2	6850
31f2 881041	0	napier ck	3.0	0.1	slow	clear	189	27	40	11	18	0.4	7050
31f2 881042	0	napier ck	2.0	0.1	slow	clear	110	17	21	10	14	<0.2	3150
31f2 881043	0	napier ck	2.0	0.1	slow	clear	152	18	22	11	16	<0.2	3825
31f2 881044	0	napier ck	2.0	0.1	slow	clear	107	23	17	10	16	<0.2	5400
31f2 881045	0	seep	0.5	0.1	slow	clear	63	11	5	18	9	<0.2	399
31f2 881046	0	napier ck	1.0	0.1	slow	clear	143	29	16	13	21	0.2	1975
31f2 881047	0	napier ck	1.0	0.1	slow	clear	170	n.d.	n.d.	24	34	n.d.	n.d.
31f2 881048	0	napier ck	1.0	0.1	slow	clear	170	n.d.	n.d.	30	35	n.d.	n.d.
31f2 881049	0	napier ck	1.0	0.1	nil	n.s	120	n.d.	n.d.	32	23	n.d.	n.d.
64c10 881013	10	expnsn lk	1.0	0.2	slow	lt brn	22	12	2	n.d.	2	<0.2	365

STRMSEDID	AS_PPM	MO_PPM	FE_PCT	HG_PPB	LOI_PCT	U_PPM	F_PPM	V_PPM	CD_PPM	SB_PPM	W_PPM	BA_PPM	SN_PPM	CR_PPM	AS_INA_PPM	BR_PPM
31f2 881030	4.0	<2	0.97	30	6.2	1.2	532	25	<0.2	0.2	2	364	14	49	8.5	57.0
31f2 881031	3.0	<2	0.91	25	5.4	1.4	562	25	<0.2	0.2	2	348	11	59	6.9	47.0
31f2 881032	4.0	<2	1.71	28	5.8	1.3	591	39	<0.2	0.3	2	444	9	68	9.0	24.0
31f2 881033	4.0	<2	1.70	19	2.8	1.7	588	36	<0.2	0.3	2	393	6	71	8.2	13.0
31f2 881034	5.0	<2	1.12	17	3.0	2.0	564	28	<0.2	0.2	8	272	12	57	10.0	37.0
31f2 881035	5.0	<2	1.27	19	4.8	1.6	516	33	<0.2	0.2	2	266	20	84	12.0	45.0
31f2 881036	1.0	<2	1.69	50	4.6	4.0	271	19	<0.2	<0.2	2	639	3	110	1.9	6.1
31f2 881037	7.0	<2	1.07	30	7.8	1.5	595	29	<0.2	0.2	2	383	10	68	14.0	45.0
31f2 881038	19.0	<2	3.03	50	14.0	1.5	460	71	0.3	0.4	2	564	6	67	44.0	26.0
31f2 881039	24.0	<2	3.02	50	13.7	1.4	454	73	0.2	0.3	2	565	5	68	42.0	23.0
31f2 881040	53.0	<2	4.12	69	23.6	1.5	548	86	0.5	0.7	2	736	6	73	93.1	76.3
31f2 881041	43.0	<2	3.61	83	31.2	1.6	357	80	0.5	0.3	2	717	7	42	73.3	79.5
31f2 881042	34.0	<2	2.79	41	12.0	1.4	444	77	<0.2	0.3	2	464	5	83	52.1	28.0
31f2 881043	36.0	<2	3.38	50	14.0	1.1	320	91	0.2	0.3	2	572	5	76	67.4	40.0
31f2 881044	33.0	<2	3.21	39	10.8	1.1	427	94	<0.2	0.4	2	680	6	50	55.7	28.0
31f2 881045	1.0	<2	1.76	44	5.4	3.7	307	22	<0.2	<0.2	2	657	2	98	1.8	6.3
31f2 881046	40.0	<2	4.11	50	13.2	1.1	432	124	<0.2	0.5	2	394	5	50	67.8	23.0
31f2 881047	n.d.	n.d.	12.00	n.d.	n.d.	n.d.	n.d.	n.d.	<5	n.d.	n.d.	1300	4	28	76.8	50.0
31f2 881048	n.d.	n.d.	9.50	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	1700	n.d.	55	90.3	42.0
31f2 881049	n.d.	n.d.	5.20	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	500	n.d.	67	12.0	49.0
64c10 881013	n.d.	<2	0.41	21	22.2	2.1	88	6	<0.2	<0.2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.

STRMSEDID	SB_INA_PPM	LA_PPM	CE_PPM	W_INA_PPM	AU_INA_PPB	TH_PPM	U2_INA_PPM	INAWT_GM
31f2 881030	0.8	13	26	2	10	2.0	1.1	26.12
31f2 881031	0.8	13	30	2	6	1.8	1.2	35.36
31f2 881032	1.0	15	33	<1	21	2.3	1.2	37.75
31f2 881033	0.9	15	28	<1	7	2.3	1.1	35.09
31f2 881034	0.9	17	29	<1	7	2.7	1.5	38.64
31f2 881035	0.9	17	28	4	15	2.8	1.5	32.07
31f2 881036	0.2	37	72	<1	15	1.0	3.5	27.03
31f2 881037	1.0	13	27	<1	<2	2.1	1.1	14.79
31f2 881038	1.4	21	43	<1	21	3.3	1.3	28.62
31f2 881039	1.3	18	35	<1	24	3.0	1.3	19.73
31f2 881040	1.8	18	31	<1	15	3.7	1.3	15.73
31f2 881041	1.4	16	34	<2	<4	2.0	1.1	16.59
31f2 881042	1.5	17	28	<2	150	2.8	1.1	21.44
31f2 881043	1.6	18	29	3	19	2.1	1.1	27.36
31f2 881044	1.7	16	28	<2	11	1.9	0.8	31.73
31f2 881045	0.1	39	76	<1	11	11.0	3.6	26.06
31f2 881046	1.8	16	23	<2	<2	1.9	0.9	15.85
31f2 881047	1.7	10	<10	<1	<2	0.5	0.7	6.95
31f2 881048	1.7	9	<5	<1	<4	1.0	0.5	7.02
31f2 881049	1.3	34	35	<1	21	2.9	1.8	7.16
64c10 881013	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.

APPENDIX FIVE

LAKE SEDIMENT DATA

LAKE SEDIMENT DATA FILE CODE

LKSEDID: lake sediment field number; NTS map area followed by collection year and sample number
REPSTAT: replicate status; 0=individual sample; 10= 1st of field duplicate; 20=2nd of field duplicate
LOCATION: sampled lake
DEPTH: depth in metres to lake bottom
SEDCOL: ambient sediment colour; grn=green; brn=brown; gry-grey; yel=yellow; tan=tan
TYPE: sediment characteristic; sil=silty; org=organic; cly=clayey; snd=sandy; cal=calcareous
n.d.= no analytical data

ELEMENT	DETECTION LEVEL	METHOD
Zn	2 ppm	HNO_3/HCl digestion/AAS
Cu	2 ppm	-"-
Pb	2 ppm	-"-
Ni	2 ppm	-"-
Co	2 ppm	-"-
Ag	0.2 ppm	-"-
Mn	5 ppm	-"-
Fe	0.02%	-"-
As	1 ppm	-"-
Mo	2 ppm	-"-
V	2 ppm	-"-
Cd	0.2 ppm	-"-
Hg	10 ppb	Hatch and Ott;cold vapour/AAS
As	1 ppm	hydride evol./AAS
Sb	0.2 ppm	-"-
U	0.2 ppm	neutron activation
F	10 ppm	ion specific electrode
W	2 ppm	Zn dithiol/spectrophotometry
Sn	2 ppm	fusion extraction/AAS
LOI	0.1%	550C furnace/gravimetric
Ba	100 ppm	instrumental neutron activation(INAA)
Cr_INA	<20 ppm	-"-
As_INA	1 ppm	-"-
Br_INA	1 ppm	-"-
Sb_INA	0.1 ppm	-"-
Mo_INA	<2 ppm	-"-
La_INA	2 ppm	-"-
Ce_INA	5 ppm (variable)	-"-
Sm_INA	0.2 ppm	-"-
W_INA	1 ppm	-"-
Th_INA	0.5 ppm	-"-
U_INA	0.5 ppm	-"-
S_TOT	0.001%	Leco induction furnace
Cl	0.001%	neutron activation

cont'd:

ELEMENT	DETECTION LEVEL	METHOD
Au analyses represent multiple analyses on the same sample (INAA) or splits of sample(FANA):		
Au_1NA	2 ppb (variable)	-"-
Au_1NA_WT	weight in grams of sample used for INAA of Au and other elements	
Au_1FA	1 ppb	fire assay/neutron activation (FANA)
Au_2FA	1 ppb	-"-
Au_3FA	1 ppb	-"-
Au_1,2,3FA_WT	weight in grams of sample split analysed	

ANALYTICAL PROCEDURES

Lake sediment and stream sediment analytical procedures differ in extraction methods but are similar in analytical procedure.

Stream sediment analyses for trace metals utilize total extraction with hot HCl-HNO_3-HF acid prior to AAS determinations.

Lake sediment analyses for trace metals utilized partial extraction methods with HNO_3-HCl at room temperature prior to completion and AAS determinations.

Zn, Cu, Pb, Ni, Co, Ag, Mn, Fe, Cd, and As:

For the determination of these elements a 1 gram sample was reacted with 6mL of a mixture of 4M HNO_3 and M HCl in a test tube overnight at room temperature. After digestion the test tube was immersed in a hot water bath at room temperature and brought up to 90°C and held at this temperature for 2 hours with periodic shaking. The samle solution was then diluted to 20 mL with metal free water and mixed. Zn, Cu, Pb, Ni, Co, Ag, Mn, Fe and Cd were determined by atomic absorption spectroscopy using an air-acetylene flame. Background corrections were made for Pb, Ni, Co, Ag and Cd.

Arsenic was detemined by atomic absorption using a hydride evolution method wherein the hydride (AsH_3) is evolved and passed through a heated quartz tube in the light path of an atomic absorption spectrophotometer. The method is described by Aslin (1976).

Mo and V:

Molybdenum and Vanadium were determined by atomic absorption spectroscopy using a nitrous oxide acetylene flame. A 0.5 gram sample was reacted with 1.5 mL concentrated HNO_3 at 90°C for 30 minutes. At this point 0.5 mL concentrated HCl was added and the digestion continued at 90°C for an additional 90 minutes. After cooling, 8 mL of 1250 ppm Al solution were added and the sample solution was diluted to 10 mL before aspiration.

Hg:

Mercury was determined by the Hatch and Ott method with some modifications. The method is described by Jonasson et al. (1973). A 0.5 gram sample was reacted with 20 mL concentrated HNO_3 and 1 mL concentrated HCl in a test-tube for 10 minutes at room temperature prior to 2 hours of digestion with mixing at 90°C in a hot water bath. After digestion, the sample solutions were cooled and diluted to 100 mL with metal free water. The Hg present was reduced to the elemental state by the addition of 10 mL 10% w/v $SnSO_4$ in M H_2SO_4. The Hg vapour was then flushed by a stream of air into an absorption cell mounted in the light path of an atomic absorption spectrophotometer. Absorption measurements were made at 253.7 nm.

Loss-on Ignition (LOI):

Loss on ignition was determined using a 500 mg sample. The sample, weighed in 30 ml beaker, was placed in a cold muffle furnace and brought up to 500°C over a period of 2 to 3 hours, then left at this temperature for

4 hours, then allowed to cool to room temperature for weighing.

U:

Uranium was determined using neutron activation method with delayed neutron counting. A detailed description of the method is provided by Boulanger et al, (1975). Essentially, a 1 gram sample is weighed into a 7 dram polyethelene vial, capped and sealed. The irradiation is provided by the Slowpoke reactor with an operating flux of 10^{12} neutrons/cm2/sec. The samples are pneumatically transferred from an automatic loader to the reactor where each sample is irradiated for 60 seconds. After irradiation, the sample is again transferred pneumatically to the counting facility where after a 10 second delay the sample is counted for 70 seconds with six BF_3 detector tubes embedded in paraffin. Counted samples are automatically ejected into a shielded storage container. Calibration is carried out twice daily, minimum, using natural materials of known uranium concentration.

F:

Flourine was determined in lake sediments as described by Ficklin (1970). A 250 mg sample is sintered with 1 gram flux consisting of two parts by weight sodium carbonate and one part by weight potassium nitrate. The residue is then leached with water. The sodium carbonate is neutralized with 10 mL 10% w/v citric acid and the resulting solution is diluted to 100 mL with water. The pH of the resulting solution should be from 5.5 to 6.5. The flouride content of the test solution is then measured using a flouride ion electrode. Standard solutions contain sodium carbonate and citric acid in the same quantities as the sample solution.

Sb:

Antimony was determined in lake sediments as described by Aslin (1976). A 500 mg sample is placed in a test tube; 3 mL concentrated HNO_3 and 9 mL conentrated HCl are added and the mixture is allowed to stand overnight at room temperature. The mixture is heated slowly from room temperature to 90°C for at least 90 minutes. The solution is cooled and diluted to 10 mL with 1.8 M HCl. The Sb in an aliquot of this dilute solution is then determined by hydride evolution - atomic absorption spectrometry.

W:

A 0.2 gram sample of lake sediment was fused with 1 gram $K_2S_2O_7$ in a rimless test tube at 575°C for 15 minutes in a furnace. The cooled melt was then leached with 10 mL concentrated HCl in a water bath heated to 85°c. After the soluble material had completely dissolved, the insoluble material was allowed to settle and an aliquot of 5mL was transferred to another test tube. 5 mL of 20% $SnCl_2$ solution were then added to the sample aliquot, mixed and heated for 10 minutes at 85°C in a hot water bath. A 1 mL aliquot of Zn dithiol solution (1% dithiol in iso-amyl acetate) was added to the test solution which was then heated to 4 - 6 hours at 80 - 85°C in a hot water bath. The test solution was then removed from the hot water bath, cooled and 2.5 mL of kerosene added to dissolve the globule. The colour intensity of the kerosene solution was measured at 630 nm using a spectrophotometer. The method is described by Quin and Brooks (1972).

Ba:

Barium was determined as follows: A 0.25 gram sample was heated with 5 mL concentrated HF, 5 mL concentrated $HClO_4$ and 2 mL concentrated HNO_3. To fumes of $HClO_4$, 3 mL of concentrated $HClO_4$ were

added and heated to light fumes; 5 mL of water were added and the solution was transferred to a calibrated test tube and diluted to 25 mL with water. Barium was determined by Direct current plasma emission spectroscopy.

Barium was also determined by instrumental neutron activation as part of the multi-element INAA suite.

Sn:

Tin was determined as follows: A 200 mg sample was heated with NH_4I; the sublined SnI_4 was dissolved in acid and the tin determined by atomic absorption spectrometry.

Au: (FANA)

Gold was usually determined on a 10 gram sample; depending on the amount of sample available, lesser weights were sometimes used. This resulted in a variable detection limit: 2ppb for a 5 g sample, 1 ppb for a 10 g sample. The sample was fused to produce a lead button, collecting any gold in the sample, which was cupelled in a muffle furnace to produce a silver (dore) bead. The silver beads were irradiated in a neutron flux for 1 hour, cooled for four hours, and counted by gamma ray spectrometry. Calibration was carried out using standard and blank beads, and results monitored with well documented standards.

LKSEDID	REPSTAT	LOCATION	DEPTH	SEDCOL	TYPE	ZN PPM	CU PPM	PB PPM	NI PPM	CO PPM
3112 881002	10	napier lk	0.0			240	43	28	13	12
3112 881003	20	napier lk	0.0			249	45	39	15	12
3112 881004	10	napier lk	0.0			204	40	16	13	11
3112 881005	20	napier lk	0.0			167	36	6	12	12
3112 881006	10	napier lk	0.0			149	31	4	13	12
3112 881007	20	napier lk	0.0			114	34	17	20	16
3112 881008	0	napier lk	0.0			88	12	5	11	5
3112 881009	10	napier lk	0.0			119	14	5	13	5
3112 881010	20	napier lk	0.0			116	12	4	12	5
3112 881011	10	napier lk	0.0			108	14	3	9	5
3112 881012	20	napier lk	0.0			255	69	8	24	24
3112 881013	10	napier lk	0.0			59	15	17	3	2
3112 881014a	20	napier lk	0.0			77	17	16	3	6
3112 881014b	10	napier lk	0.0			n.d.	n.d.	n.d.	n.d.	n.d.
3112 881015	20	napier lk	0.0			27	6	13	<2	<2
3112 881016	10	l green lk	0.0			10	6	3	<2	<2
3112 881017	20	l green lk	0.0			12	5	3	<2	<2
3112 881018	0	l green lk	0.0			9	5	3	<2	<2
3112 881019	10	l green lk	0.0			19	10	8	3	<2
3112 881020	20	l green lk	0.0			15	9	8	2	<2
3112 881022	10	nichols lk	0.0			49	15	4	2	2
3112 881023	20	nichols lk	0.0			58	17	3	4	<2
3112 881024	10	nichols lk	0.0			64	19	7	3	3
3112 881025	20	nichols lk	0.0			91	26	3	6	2
3112 881026	10	nichols lk	0.0			77	24	5	4	2
3112 881027	20	nichols lk	0.0			84	23	6	4	3
3112 881028	10	grassy lk	0.0			84	21	2	5	4
3112 881029	20	grassy lk	0.0			75	20	3	4	5
64c 871001	0	foster lk	2.0	grnbrn	silorg	94	25	7	9	7
64c 871002	0	foster lk	4.0	grnblk	silty	55	11	4	8	8
64c 871003	0	foster lk	1.0	grngry	silorg	12	3	<2	2	2
64c 871004	0	foster lk	3.0	grngry	silorg	42	13	6	11	5
64c 871005	0	foster lk	3.0	grngry	silorg	58	16	4	8	6
64c 871006	0	foster lk	5.0	grngry	silorg	110	19	8	11	12
64c 871007	0	foster lk	4.0	grngry	silorg	30	5	2	5	6
64c 871008	0	foster lk	4.0	grngry	silorg	42	6	3	5	8
64c 871009	0	foster lk	4.0	grngry	silty	73	22	11	21	10
64c 871011	0	foster lk	4.0	grngry	orgcly	78	22	11	22	11
64c 871012	0	foster lk	5.0	grn	silorg	45	7	4	96	7
64c 871013	0	foster lk	5.0	grngry	silcly	57	13	7	12	9
64c 871014	0	foster lk	7.0	grngry	sil	189	33	9	17	13
64c 871015	0	foster lk	7.0	grnbrn	silorg	146	22	9	16	13
64c 871015L	0	foster lk	7.1	grygrn	clysil	102	20	11	22	9
64c 871016	0	foster lk	9.0	grn	orggel	158	28	7	13	10
64c 871017	0	foster lk	7.0	grn	org	141	30	8	17	12
64c 871018	0	foster lk	2.0	grnbrn	silsnd	58	17	9	16	11
64c 871022	0	reservr lk	2.0	grnbrn	silorg	109	29	7	15	10
64c 871023	0	reservr lk	1.0	grnbrn	silorg	92	41	6	15	6
64c 871024	0	reservr lk	2.0	grnbrn	silorg	95	34	6	16	6
64c 881002	10	bay lk	1.0	yelbrn	org	79	33	4	11	4
64c 881003	20	bay lk	1.0	yelbrn	org	81	30	3	10	4
64c 881004	10	bay lk	1.0	yelbrn	org	71	25	4	9	3
64c 881005	20	bay lk	1.0	yelbrn	org	71	28	2	9	4
64c 881006	10	expansn lk	1.0	yelbrn	org	77	35	4	9	4
64c 881007	20	expansn lk	1.0	yelbrn	org	68	34	2	9	5
64c 881008	10	expansn lk	1.0	yelbrn	org	81	30	<2	9	3
64c 881009	20	expansn lk	1.0	yelbrn	org	71	33	4	9	4
64c 881010	10	expansn lk	1.0	brn	org	70	38	5	9	5
64c 881011	20	expansn lk	1.0	brn	org	63	31	3	6	3
64c 881014	0	resexp bog	1.0	grnbrn	silorg	29	15	3	2	3

64c 881015	0	resexp bog	1.5	brn	silorg	73	36	6	9	5
64c10 851001	10	foster lk	5.0	grnbrn	silorg	135	32	8	16	13
64c10 851002	20	foster lk	5.0	grnbrn	silorg	135	27	9	15	12
64c10 851003	10	foster lk	7.0	grnbrn	silorg	46	8	6	5	8
64c10 851004	20	foster lk	7.0	grnbrn	silorg	109	20	6	10	11
64c10 851005	10	foster lk	7.0	grnbrn	silorg	30	5	1	3	4
64c10 851006	20	foster lk	6.0	grnbrn	silorg	29	4	3	3	3
64c10 851007	10	foster lk	6.0	grngry	silorg	157	35	5	20	13
64c10 851008	20	foster lk	6.0	grngry	silorg	157	33	4	19	13
64c10 851009	10	foster lk	4.0	grnbrn	silorg	38	8	6	4	5
64c10 851010	20	foster lk	4.0	grnbrn	silorg	25	4	4	3	5
64c11 851001	10	foster lk	3.0	grnbrn	sndsil	41	17	6	12	7
64c11 851002	20	foster lk	3.0	grnbrn	silorg	37	12	2	6	6
64c11 851003	10	foster lk	3.0	grnbrn	sndsil	101	30	9	18	11
64c11 851004	20	foster lk	5.0	grnbrn	silorg	109	31	9	17	11
73p 871002	0	pap lk	2.0	yelbrn	silorg	46	23	8	10	2
73p 871003	0	pap lk	3.0	yelbrn	silorg	78	36	3	23	4
73p 871004	0	pap lk	3.0	yelbrn	orggel	97	52	3	26	6
73p 871005	0	pap lk	3.0	grnbrn	silorg	51	29	4	17	4
73p 871006	0	pap lk	4.0	yelbrn	silorg	91	49	3	26	5
73p 871007	10	pap lk	6.0	yelbrn	org	99	51	5	28	7
73p 871008	20	pap lk	6.0	yelbrn	org	93	48	5	28	6
73p 871009	0	pap lk	6.0	grnbrn	silorg	98	51	5	28	7
73p 871011	0	pap lk	3.0	tanbrn	calsil	33	19	5	6	<2
73p 871012	0	pap lk	3.0	tangry	calsil	72	17	5	9	2
73p 871013	0	pap lk	6.0	grnbrn	silorg	79	44	5	30	7
73p 871014	0	pap lk	11.0	grnbrn	silorg	105	46	4	23	7
73p 871015	0	pap lk	4.0	grnbrn	silorg	76	40	4	24	6
73p 871016	0	pap lk	2.0	brn	org	50	24	4	12	2
73p 871017	0	pap lk	3.0	grnbrn	silorg	62	30	5	17	4
73p 871017L	0	pap lk	3.1	gry	silcly	75	31	8	26	7
73p 871018	0	pap lk	6.0	grnbrn	silorg	93	51	5	29	7
73p 871019	0	pap lk	11.0	grnbrn	orggel	84	48	6	26	7
73p 871020	0	pap lk	11.0	grnbrn	orggel	88	48	5	32	8
73p 871022	0	pap lk	13.0	grnblk	orggel	98	46	7	24	6
73p 871023	0	pap lk	9.0	grnbrn	silorg	82	47	5	28	8
73p 871024	0	pap lk	2.0	grnbrn	silorg	55	24	5	18	7
73p 871025	0	pap lk	5.0	tangry	calsil	47	19	4	20	7
73p 871026	0	pap lk	7.0	grnbrn	silorg	75	33	6	24	7
73p 871027	0	pap lk	6.0	grnbrn	org	98	51	4	27	8
73p 871028	0	pap lk	2.5	grngry	silorg	36	17	4	10	3
73p 871029	0	pap lk	6.0	grnbrn	silorg	80	46	3	29	8
73p 871030	0	pap lk	10.0	grnbrn	silorg	94	51	6	31	8
73p 871031	0	pap lk	6.0	grnbrn	silorg	62	35	5	23	6
73p 871032	0	pap lk	6.0	grnbrn	silorg	100	55	5	30	7
73p 871033	0	pap lk	4.0	tangry	calorg	65	35	7	16	3
73p 871034	0	pap lk	2.0	grnbrn	org	62	27	6	15	4
73p 871034L	0	pap lk	2.1	gry	calorg	62	28	6	17	5
73p 871s1	0	pap lk shr	0.1	grybrn	silt	25	22	3	18	8
73p 871s2	0	pap lk shr	0.5	grybrn	silt	29	26	4	10	2
73p 871s3	0	pap lk shr	0.5	grnbrn	silt	18	121	2	36	10
73p 871s4	0	pap lk shr	0.5	grnbrn	silt	40	17	3	11	4
73p 871s5	0	pap lk shr	0.5	grnbrn	silt	73	20	4	11	<2
73p 871s6	0	pap lk shr	0.5	grnbrn	silt	45	31	2	55	14

LKSEDID	AG_PPM	MN_PPM	AS_PPM	MO_PPM	FE_PCT	HG_PPB	LOI_PCT	U_PPM	F_PPM	V_PPM	CD_PPM	SB_PPM
31f2 881002	0.3	497	7.0	<2	1.55	<10	2.6	1.7	108	26	1.6	<0.2
31f2 881003	<0.2	449	13.0	<2	1.72	<10	3.0	1.7	92	29	2.1	<0.2
31f2 881004	<0.2	456	9.0	<2	1.58	22	9.0	1.6	95	28	1.4	<0.2
31f2 881005	<0.2	441	7.0	<2	1.67	<10	3.8	2.3	85	33	1.1	<0.2
31f2 881006	0.4	265	8.0	<2	1.49	34	18.8	1.6	111	21	0.7	<0.2
31f2 881007	<0.2	1487	10.0	<2	3.50	34	19.8	2.3	112	44	0.2	<0.2
31f2 881008	<0.2	92	<1	<2	0.65	28	14.7	0.5	154	12	0.2	<0.2
31f2 881009	<0.2	77	<1	<2	1.02	19	11.2	0.5	104	13	0.3	<0.2
31f2 881010	<0.2	111	<1	<2	0.93	37	17.1	<0.5	95	14	0.3	<0.2
31f2 881011	<0.2	73	<1	<2	0.56	24	16.1	0.9	96	8	0.3	0.2
31f2 881012	<0.2	514	40.0	2	2.83	36	25.7	2.5	164	38	1.2	0.2
31f2 881013	0.2	245	3.0	7	0.65	36	24.6	1.0	101	25	0.6	0.2
31f2 881014a	0.6	20	5.0	8	1.03	48	39.1	1.8	127	26	0.4	0.2
31f2 881014b	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
31f2 881015	0.3	84	<1	7	0.09	20	10.1	0.5	115	22	0.5	<0.2
31f2 881016	0.2	27	<1	7	0.11	<10	5.8	0.6	101	23	0.3	<0.2
31f2 881017	0.4	21	<1	7	0.11	<10	4.6	0.5	119	22	0.2	<0.2
31f2 881018	1.3	22	<1	6	0.11	<10	5.2	0.5	100	19	0.2	<0.2
31f2 881019	0.4	32	<1	4	0.19	20	8.5	<0.5	130	20	0.3	<0.2
31f2 881020	0.3	27	<1	5	0.16	16	7.2	0.6	104	22	0.3	<0.2
31f2 881022	1.0	315	1.0	5	0.47	38	37.1	0.7	112	21	<0.2	<0.2
31f2 881023	1.0	213	2.0	5	0.71	44	44.8	0.9	101	17	<0.2	<0.2
31f2 881024	0.3	101	2.0	4	0.57	46	52.9	1.3	85	17	<0.2	<0.2
31f2 881025	0.2	80	2.0	3	0.68	58	72.9	1.7	82	11	0.2	<0.2
31f2 881026	<0.2	98	3.0	3	0.68	50	64.4	2.2	75	11	<0.2	0.2
31f2 881027	0.2	85	2.0	3	0.68	52	59.9	1.5	61	11	0.2	0.2
31f2 881028	<0.2	130	2.0	<2	0.69	59	76.3	1.1	64	13	<0.2	<0.2
31f2 881029	<0.2	171	3.0	<2	0.84	58	79.6	1.3	131	10	<0.2	0.2
64c 871001	0.2	676	2.0	<2	2.78	65	26.2	2.6	190	22	0.4	<0.2
64c 871002	<0.2	498	2.0	<2	2.21	25	7.2	2.1	210	19	<0.2	0.2
64c 871003	<0.2	83	<1	<1	0.40	<10	2.6	1.4	160	<5	<0.2	<0.2
64c 871004	<0.2	242	2.0	<2	1.42	10	1.4	3.9	605	31	<0.2	<0.2
64c 871005	0.2	683	1.0	<2	2.12	15	11.6	2.7	190	19	<0.2	0.2
64c 871006	<0.2	1160	2.0	<2	5.72	15	15.0	3.0	260	34	<0.2	0.2
64c 871007	<0.2	194	1.0	<2	1.04	<10	2.8	1.4	140	8	<0.2	<0.2
64c 871008	<0.2	402	1.0	<2	1.40	10	4.6	2.0	210	15	<0.2	<0.2
64c 871009	<0.2	570	1.0	<2	2.72	<10	2.2	4.0	535	41	<0.2	<0.2
64c 871011	<0.2	674	1.0	<2	3.24	30	4.0	4.0	555	40	<0.2	0.2
64c 871012	<0.2	469	2.0	<2	1.86	35	4.0	2.4	215	17	<0.2	<0.2
64c 871013	<0.2	575	1.0	<2	2.57	35	2.4	3.4	380	33	<0.2	<0.2
64c 871014	<0.2	1440	2.0	<2	6.76	75	24.2	3.8	275	55	0.2	0.2
64c 871015	<0.2	1360	2.0	<2	6.38	50	13.8	3.3	340	48	<0.2	0.2
64c 871015L	<0.2	618	1.0	<2	2.96	40	2.8	3.9	540	51	<0.2	<0.2
64c 871016	<0.2	895	1.0	<2	5.25	100	20.8	2.9	290	43	0.3	<0.2
64c 871017	<0.2	1240	2.0	<2	4.90	50	17.8	3.5	350	40	<0.2	<0.2
64c 871018	<0.2	377	1.0	<2	2.26	25	2.2	3.5	380	24	<0.2	0.2
64c 871022	<0.2	700	3.0	<2	2.48	90	30.0	1.6	215	33	0.3	0.2
64c 871023	<0.2	707	2.0	<2	1.40	60	49.2	2.4	130	13	0.5	0.3
64c 871024	<0.2	609	2.0	<2	1.60	60	37.8	2.2	180	10	0.2	0.2
64c 881002	<0.2	302	1.0	<2	0.82	44	48.8	2.1	76	12	<0.2	<0.2
64c 881003	<0.2	315	<1	<2	0.77	36	46.9	2.3	75	10	<0.2	<0.2
64c 881004	<0.2	636	<1	<2	0.81	58	57.7	2.3	71	11	0.2	<0.2
64c 881005	<0.2	619	<1	<2	0.86	55	54.6	2.0	79	12	0.2	<0.2
64c 881006	<0.2	398	<1	<2	0.72	51	47.7	2.0	86	11	0.2	<0.2
64c 881007	<0.2	402	<1	<2	0.78	47	49.2	2.4	84	12	<0.2	<0.2
64c 881008	<0.2	267	<1	<2	0.63	47	48.6	2.3	65	12	0.2	<0.2
64c 881009	0.3	308	<1	<2	0.67	47	49.4	2.1	74	10	0.2	<0.2
64c 881010	<0.2	1264	1.0	<2	0.96	74	58.8	2.8	81	12	0.4	<0.2
64c 881011	<0.2	1239	1.0	<2	60.00	586	2.7	91.0	12	2	<0.2	n.d.
64c 881014	<0.2	412	1.0	<2	0.54	35	20.7	2.0	96	6	<0.2	<0.2

64c 881015	<0.2	720	1.0	<2	1.13	67	52.3	3.0	109	13	0.4	<0.2
64c10 851001	<0.2	150	4.0	3	5.00	36	22.9	2.8	400	44	<0.2	<0.2
64c10 851002	<0.2	1300	4.0	3	5.80	41	21.3	2.6	450	48	<0.2	<0.2
64c10 851003	<0.2	1200	2.0	3	3.90	4	4.4	0.8	225	22	0.1	<0.1
64c10 851004	<0.2	1350	0.0	3	6.70	<10	n.d.	2.2	305	42	0.1	n.d.
64c10 851005	<0.2	320	0.8	1	1.70	14	2.2	1.5	185	14	0.1	<0.1
64c10 851006	<0.2	370	0.0	1	1.90	<10	n.d.	1.3	280	14	0.1	n.d.
64c10 851007	<0.2	1450	3.2	3	6.50	63	26.9	3.0	410	48	0.4	<0.2
64c10 851008	<0.2	1100	3.2	3	6.00	54	26.3	2.8	430	48	<0.2	<0.2
64c10 851009	<0.2	550	1.6	2	2.40	14	3.4	1.1	245	20	<0.2	<0.2
64c10 851010	<0.2	550	0.0	<2	1.20	<10	2.5	1.0	253	20	<0.2	n.d.
64c11 851001	<0.2	470	2.8	1	2.30	23	3.2	2.5	335	26	0.1	<0.2
64c11 851002	<0.2	470	0.0	1	1.90	<10	n.d.	1.3	205	16	0.1	n.d.
64c11 851003	<0.2	1700	4.7	3	5.30	50	25.2	2.4	380	40	<0.2	<0.2
64c11 851004	<0.2	1600	0.0	5	6.00	<10	22.8	2.4	360	36	<0.2	n.d.
73p 871002	<0.2	215	28.0	<2	0.77	40	30.2	1.8	190	15	0.2	<0.2
73p 871003	<0.2	306	43.0	<2	1.22	30	41.8	4.7	175	18	<0.2	<0.2
73p 871004	<0.2	363	63.0	2	1.51	30	53.4	6.2	215	21	<0.2	<0.2
73p 871005	<0.2	371	29.0	2	1.10	30	20.4	3.9	310	23	<0.2	<0.2
73p 871006	<0.2	334	62.0	2	1.51	65	46.8	5.7	200	20	<0.2	0.4
73p 871007	<0.2	401	33.0	2	1.72	65	50.2	4.7	260	25	<0.2	<0.2
73p 871008	<0.2	386	44.0	2	1.62	55	52.0	4.4	225	25	<0.2	<0.2
73p 871009	<0.2	497	50.0	2	1.91	30	48.8	3.9	240	28	<0.2	<0.2
73p 871011	<0.2	424	20.0	9	0.44	25	25.0	2.3	260	42	<0.2	<0.2
73p 871012	<0.2	577	11.0	10	0.53	15	9.6	1.7	315	52	<0.2	<0.2
73p 871013	<0.2	502	27.0	<2	2.00	20	44.4	3.5	325	30	0.2	<0.2
73p 871014	<0.2	986	28.0	<2	2.29	40	44.2	3.2	275	31	<0.2	<0.2
73p 871015	<0.2	422	39.0	<2	1.86	40	36.8	4.4	305	20	<0.2	<0.2
73p 871016	<0.2	470	30.0	<2	0.98	65	50.2	3.0	160	10	0.2	<0.2
73p 871017	<0.2	451	15.0	<2	1.32	50	15.6	3.5	365	27	<0.2	<0.2
73p 871017L	<0.2	422	8.0	<2	1.89	35	5.4	4.2	435	44	<0.2	<0.2
73p 871018	<0.2	434	41.0	<2	2.01	45	48.4	4.9	280	19	0.2	<0.2
73p 871019	<0.2	998	23.0	<2	2.50	50	46.4	3.3	295	25	<0.2	<0.2
73p 871020	<0.2	620	23.0	<2	2.37	35	45.2	3.4	270	28	0.2	<0.2
73p 871022	<0.2	1660	37.0	<2	2.39	25	44.6	2.8	255	21	<0.2	<0.2
73p 871023	<0.2	508	20.0	<2	2.07	30	40.2	4.3	325	28	0.2	<0.2
73p 871024	<0.2	427	13.0	<2	1.95	30	11.8	2.9	275	24	<0.2	<0.2
73p 871025	<0.2	565	20.0	<2	1.75	25	6.8	2.3	370	21	<0.2	<0.2
73p 871026	<0.2	475	25.0	<2	2.30	55	22.7	2.7	325	20	<0.2	<0.2
73p 871027	0.2	466	40.0	<2	2.16	85	43.4	4.5	250	21	<0.2	<0.2
73p 871028	<0.2	214	14.0	<2	0.90	40	11.2	1.8	215	9	<0.2	<0.2
73p 871029	0.4	470	47.0	<2	2.18	90	40.8	3.1	320	23	<0.2	<0.2
73p 871030	<0.2	495	29.0	<2	2.36	70	49.0	3.4	275	27	<0.2	<0.2
73p 871031	0.2	448	37.0	<2	2.00	45	29.4	3.6	255	19	<0.2	<0.2
73p 871032	0.3	464	68.0	2	2.36	50	48.6	5.0	235	22	<0.2	<0.2
73p 871033	<0.2	530	39.0	6	1.19	20	30.4	6.3	255	25	<0.2	<0.2
73p 871034	<0.2	300	62.0	2	1.27	50	37.8	2.9	200	19	0.3	<0.2
73p 871034L	<0.2	426	29.0	3	1.71	10	20.0	3.6	280	25	<0.2	<0.2
73p 87ls1	0.2	190	20.0	<2	1.19	55	18.6	1.3	160	14	<0.2	0.2
73p 87ls2	<0.2	105	34.0	2	0.52	120	87.8	2.5	60	16	<0.2	<0.2
73p 87ls3	0.3	120	164.0	<2	1.24	45	8.4	2.1	190	15	<0.2	0.2
73p 87ls4	0.2	217	23.0	<2	1.14	35	29.6	2.3	265	14	<0.2	<0.2
73p 87ls5	<0.2	106	19.0	<2	0.75	90	79.8	3.9	75	13	<0.2	<0.2
73p 87ls6	<0.2	184	11.0	<2	2.41	25	9.0	1.7	480	25	<0.2	<0.2

LKSEDID	W PPM	BA PPM	SN PPM	CR INA PPM	AS INA PPM	BR INA PPM	MO INA PPM	SB INA PPM
31f2 881002	n.d.	n.d.	n.d.	<20	<0.5	12.0	3	<0.1
31f2 881003	n.d.	n.d.	n.d.	<20	<0.5	16.0	2	<0.1
31f2 881004	n.d.	n.d.	n.d.	<20	1.7	13.0	2	0.2
31f2 881005	n.d.	n.d.	n.d.	<20	0.7	5.5	2	0.2
31f2 881006	n.d.	n.d.	n.d.	22	4.0	23.0	3	0.5
31f2 881007	n.d.	n.d.	n.d.	<20	3.7	27.0	3	0.5
31f2 881008	n.d.	n.d.	n.d.	<20	4.1	17.0	4	0.4
31f2 881009	n.d.	n.d.	n.d.	26	3.4	18.0	3	0.5
31f2 881010	n.d.	n.d.	n.d.	<20	3.3	17.0	3	0.4
31f2 881011	n.d.	n.d.	n.d.	<20	3.2	14.0	3	0.3
31f2 881012	n.d.	n.d.	n.d.	26	6.7	35.0	4	0.8
31f2 881013	n.d.	n.d.	n.d.	<20	6.1	26.0	4	0.7
31f2 881014a	n.d.	n.d.	n.d.	<20	11.0	45.0	6	1.2
31f2 881014b	n.d.	n.d.	n.d.	<20	1.7	6.5	2	0.3
31f2 881015	n.d.	n.d.	n.d.	<20	1.6	7.6	4	0.3
31f2 881016	n.d.	n.d.	n.d.	<20	0.8	7.7	3	0.2
31f2 881017	n.d.	n.d.	n.d.	<20	0.7	5.8	2	0.1
31f2 881018	n.d.	n.d.	n.d.	<20	0.5	6.2	3	0.1
31f2 881019	n.d.	n.d.	n.d.	<20	1.3	20.0	3	0.3
31f2 881020	n.d.	n.d.	n.d.	<20	1.2	23.0	2	0.2
31f2 881022	n.d.	n.d.	n.d.	<20	3.5	10.0	3	0.4
31f2 881023	n.d.	n.d.	n.d.	<20	6.2	14.0	4	0.4
31f2 881024	n.d.	n.d.	n.d.	<20	6.1	35.0	5	0.9
31f2 881025	n.d.	n.d.	n.d.	<20	8.2	43.0	6	1.3
31f2 881026	n.d.	n.d.	n.d.	<20	9.1	39.0	6	1.9
31f2 881027	n.d.	n.d.	n.d.	<20	7.1	39.0	5	1.1
31f2 881028	n.d.	n.d.	n.d.	<20	7.3	35.0	4	0.5
31f2 881029	n.d.	n.d.	n.d.	<20	7.2	33.0	4	0.5
64c 871001	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871002	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871003	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871004	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871005	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871006	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871007	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871008	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871009	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871011	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871012	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871013	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871014	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871015	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871015L	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871016	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871017	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871018	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871022	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871023	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871024	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 881002	n.d.	n.d.	n.d.	<20	3.5	32.0	3	0.1
64c 881003	n.d.	n.d.	n.d.	37	3.1	28.0	5	0.1
64c 881004	n.d.	n.d.	n.d.	30	2.3	31.0	4	0.2
64c 881005	n.d.	n.d.	n.d.	20	2.7	30.0	4	0.2
64c 881006	n.d.	n.d.	n.d.	26	2.4	32.0	5	0.1
64c 881007	n.d.	n.d.	n.d.	23	3.0	34.0	5	<0.1
64c 881008	n.d.	n.d.	n.d.	28	2.5	33.0	6	0.1
64c 881009	n.d.	n.d.	n.d.	<20	2.6	31.0	3	<0.1
64c 881010	n.d.	n.d.	n.d.	24	2.8	28.0	4	0.1
64c 881011	n.d.	n.d.	n.d.	<20	2.3	24.0	3	0.2
64c 881014	n.d.	n.d.	n.d.	30	1.6	12.0	3	0.1

64c 881015	n.d.	n.d.	n.d.	36	3.4	27.0	5	0.1
64c10 851001	2	589	6	n.d.	n.d.	n.d.	n.d.	n.d.
64c10 851002	2	601	5	n.d.	n.d.	n.d.	n.d.	n.d.
64c10 851003	1	716	n.d.	10	n.d.	n.d.	n.d.	n.d.
64c10 851004	1	617	n.d.	27	n.d.	n.d.	n.d.	n.d.
64c10 851005	1	788	n.d.	7	n.d.	n.d.	n.d.	n.d.
64c10 851006	2	755	n.d.	7	n.d.	n.d.	n.d.	n.d.
64c10 851007	<2	559	8	n.d.	n.d.	n.d.	n.d.	n.d.
64c10 851008	<2	563	4	n.d.	n.d.	n.d.	n.d.	n.d.
64c10 851009	<2	761	1	n.d.	n.d.	n.d.	n.d.	n.d.
64c10 851010	<2	770	4	n.d.	n.d.	n.d.	n.d.	n.d.
64c11 851001	2	785	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c11 851002	1	717	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c11 851003	<2	534	5	n.d.	n.d.	n.d.	n.d.	n.d.
64c11 851004	2	568	4	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871002	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871003	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871004	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871005	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871006	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871007	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871008	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871009	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871011	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871012	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871013	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871014	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871015	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871016	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871017	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871017L	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871018	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871019	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871020	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871022	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871023	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871024	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871025	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871026	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871027	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871028	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871029	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871030	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871031	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871032	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871033	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871034	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871034L	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 87ls1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 87ls2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 87ls3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 87ls4	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 87ls5	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 87ls6	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.

LKSEDID	BA_INA_PPM	LA_INA_PPM	CE_INA_PPM	SM_INA_PPM	TH_INA_PPM	U_INA_PPM	AU_INA_PPB	AU_INA_WT
3112 881002	830	<2	<5	<0.2	<0.2	<0.2	<2	18.98
3112 881003	800	<2	<5	0.22	0.3	<0.2	<2	19.15
3112 881004	670	<2	<5	0.51	0.3	0.2	4	20.24
3112 881005	700	<2	<5	<0.2	<0.2	<0.2	<2	24.84
3112 881006	690	4	<5	1.00	0.5	0.6	2	18.65
3112 881007	610	2	<5	0.55	0.3	0.5	2	20.03
3112 881008	660	4	7	1.10	0.5	0.6	4	18.11
3112 881009	680	2	<5	0.62	0.2	0.5	<2	19.10
3112 881010	650	<2	<5	0.49	0.5	0.4	<2	19.49
3112 881011	580	<2	<5	0.34	<0.2	0.4	<2	18.48
3112 881012	570	3	<5	1.00	0.6	0.9	3	16.82
3112 881013	580	3	<5	0.70	0.5	0.7	3	18.20
3112 881014a	570	4	<5	1.00	0.6	1.5	4	16.68
3112 881014b	800	<2	<5	<0.2	<0.2	0.3	<2	20.14
3112 881015	790	<2	<5	<0.2	<0.2	0.3	<2	16.01
3112 881016	750	<2	<5	<0.2	<0.2	0.3	<2	21.34
3112 881017	870	<2	<5	<0.2	<0.2	<0.2	<2	23.86
3112 881018	830	<2	<5	0.23	<0.2	0.3	<2	22.58
3112 881019	670	<2	<5	0.42	<0.2	0.3	<2	20.10
3112 881020	660	<2	<5	0.37	<0.2	0.3	<2	19.87
3112 881022	440	9	<5	2.40	0.4	0.5	<2	16.54
3112 881023	450	13	8	3.20	0.8	0.7	3	17.00
3112 881024	280	9	8	1.80	0.6	1.0	<2	23.19
3112 881025	320	15	<5	3.10	0.7	1.2	<2	13.98
3112 881026	240	11	13	2.30	0.8	1.5	4	16.43
3112 881027	250	10	<5	2.20	0.6	1.1	<2	17.71
3112 881028	200	10	12	2.20	0.8	0.6	<2	15.38
3112 881029	170	9	<5	2.10	0.6	0.6	4	17.73
64c 871001	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871002	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871003	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871004	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871005	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871006	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871007	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871008	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871009	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871011	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871012	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871013	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871014	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871015	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871015L	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871016	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871017	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871018	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871022	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871023	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871024	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 881002	200	21	26	3.60	3.8	1.7	5	12.09
64c 881003	160	20	33	3.20	3.4	1.5	<2	7.89
64c 881004	260	21	37	3.10	3.5	1.7	3	11.99
64c 881005	260	22	39	3.30	3.7	1.8	<2	12.45
64c 881006	200	22	48	3.60	4.0	1.5	<2	8.33
64c 881007	210	25	38	3.80	4.2	1.8	<2	9.15
64c 881008	180	21	30	3.20	3.5	1.5	<2	8.22
64c 881009	140	19	25	3.00	3.5	1.4	3	9.78
64c 881010	300	23	45	3.50	4.5	2.3	2	8.98
64c 881011	320	23	46	3.50	4.5	2.0	<2	11.65
64c 881014	780	25	54	3.50	5.6	1.7	<2	22.56

64c 881015	260	27	53	4.10	4.3	2.3	4	9.83
64c10 851001	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c10 851002	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c10 851003	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c10 851004	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c10 851005	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c10 851006	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c10 851007	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c10 851008	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c10 851009	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c10 851010	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c11 851001	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c11 851002	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c11 851003	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c11 851004	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871002	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871003	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871004	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871005	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871006	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871007	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871008	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871009	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871011	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871012	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871013	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871014	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871015	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871016	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871017	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871017L	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871018	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871019	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871020	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871022	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871023	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871024	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871025	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871026	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871027	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871028	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871029	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871030	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871031	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871032	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871033	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871034	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 871034L	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 87ls1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 87ls2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 87ls3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 87ls4	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 87ls5	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
73p 87ls6	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.

LKSEDID	AU_1FA_PPB	AU_1FA_WT	AU_2FA_PPB	AU_2FA_WT	AU_3FA_PPB	AU_3FA_WT	S_TOT_PCT	CL_PCT
31f2 881002	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
31f2 881003	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
31f2 881004	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
31f2 881005	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
31f2 881006	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
31f2 881007	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
31f2 881008	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
31f2 881009	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
31f2 881010	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
31f2 881011	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
31f2 881012	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
31f2 881013	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
31f2 881014a	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
31f2 881014b	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
31f2 881015	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
31f2 881016	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
31f2 881017	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
31f2 881018	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
31f2 881019	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
31f2 881020	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
31f2 881022	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
31f2 881023	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
31f2 881024	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
31f2 881025	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
31f2 881026	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
31f2 881027	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
31f2 881028	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
31f2 881029	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 871001	2	10.00	1	10.00	n.d.	n.d.	0.39	0.005
64c 871002	2	10.00	1	10.00	n.d.	n.d.	0.15	0.004
64c 871003	<1	10.00	<1	10.00	n.d.	n.d.	0.03	0.004
64c 871004	2	10.00	<1	10.00	n.d.	n.d.	0.14	0.003
64c 871005	2	10.00	<1	10.00	n.d.	n.d.	0.24	0.002
64c 871006	n.d.	n.d.	<1	10.00	6	10.00	0.22	0.002
64c 871007	<1	10.00	<1	10.00	n.d.	n.d.	0.12	0.002
64c 871008	<1	10.00	<1	10.00	n.d.	n.d.	0.11	0.004
64c 871009	4	10.00	<1	10.00	n.d.	n.d.	0.03	0.003
64c 871011	2	10.00	1	10.00	<1	10.00	0.05	0.003
64c 871012	2	10.00	<1	10.00	n.d.	n.d.	0.08	0.003
64c 871013	2	10.00	2	10.00	n.d.	n.d.	0.04	0.003
64c 871014	5	10.00	4	10.00	4	10.00	0.20	0.003
64c 871015	4	10.00	2	10.00	n.d.	n.d.	0.04	0.004
64c 871015L	2	10.00	2	10.00	n.d.	n.d.	0.19	0.004
64c 871016	2	10.00	4	10.00	1	10.00	0.18	0.003
64c 871017	4	10.00	1	10.00	2	10.00	0.22	0.003
64c 871018	2	10.00	<1	10.00	n.d.	n.d.	0.23	0.006
64c 871022	n.d.	n.d.	6	10.00	10	10.00	0.29	0.005
64c 871023	6	10.00	2	10.00	4	10.00	0.61	0.005
64c 871024	8	10.00	17	10.00	5	10.00	0.44	0.004
64c 881002	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 881003	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 881004	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 881005	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 881006	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 881007	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 881008	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 881009	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 881010	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 881011	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c 881014	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.

64c 881015	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c10 851001	1	7.50	5	10.00	4	10.00	0.32	0.010
64c10 851002	n.d.	n.d.	2	10.00	<1	10.00	0.27	0.008
64c10 851003	n.d.	n.d.	<1	10.00	4	10.00	0.14	0.006
64c10 851004	n.d.	n.d.	<1	10.00	<1	10.00	0.21	0.007
64c10 851005	n.d.	n.d.	<1	10.00	<1	10.00	0.07	0.004
64c10 851006	n.d.	n.d.	<1	10.00	<1	10.00	0.08	0.001
64c10 851007	2	10.00	30	10.00	4	10.00	0.25	0.004
64c10 851008	n.d.	n.d.	3	10.00	2	10.00	0.25	0.003
64c10 851009	n.d.	n.d.	22	10.00	<1	10.00	0.11	0.003
64c10 851010	n.d.	n.d.	<1	10.00	<1	10.00	0.07	0.004
64c11 851001	n.d.	n.d.	<1	10.00	1	10.00	0.50	0.004
64c11 851002	n.d.	n.d.	<1	10.00	<1	10.00	0.15	0.006
64c11 851003	n.d.	n.d.	18	10.00	2	7.50	0.31	0.005
64c11 851004	n.d.	n.d.	7	10.00	2	10.00	2.71	0.004
73p 871002	4	10.00	1	10.00	n.d.	n.d.	0.91	0.005
73p 871003	5	10.00	9	10.00	6	10.00	1.38	0.004
73p 871004	9	10.00	5	10.00	n.d.	n.d.	1.87	0.004
73p 871005	7	10.00	2	10.00	n.d.	n.d.	1.04	0.003
73p 871006	11	10.00	6	10.00	n.d.	n.d.	1.61	0.005
73p 871007	7	10.00	11	10.00	13	10.00	1.71	0.004
73p 871008	10	10.00	18	10.00	n.d.	n.d.	1.66	0.003
73p 871009	15	10.00	6	10.00	n.d.	n.d.	1.81	0.004
73p 871011	2	10.00	<1	10.00	n.d.	n.d.	0.91	0.004
73p 871012	2	10.00	<1	10.00	n.d.	n.d.	0.48	0.005
73p 871013	7	10.00	4	10.00	n.d.	n.d.	1.77	0.005
73p 871014	6	10.00	2	10.00	n.d.	n.d.	1.90	0.005
73p 871015	6	10.00	1	10.00	n.d.	n.d.	1.60	0.005
73p 871016	8	10.00	<1	10.00	10	10.00	1.46	0.006
73p 871017	3	10.00	6	10.00	n.d.	n.d.	1.03	0.005
73p 871017L	5	10.00	4	10.00	n.d.	n.d.	1.50	0.005
73p 871018	8	10.00	n.d.	3.00	10	n.d.	1.64	0.005
73p 871019	8	10.00	4	10.00	n.d.	n.d.	1.98	0.008
73p 871020	18	10.00	4	10.00	n.d.	n.d.	1.78	0.007
73p 871022	10	10.00	6	10.00	8	10.00	1.89	0.005
73p 871023	8	10.00	11	10.00	n.d.	n.d.	1.53	0.006
73p 871024	7	10.00	5	10.00	n.d.	n.d.	0.90	0.005
73p 871025	5	10.00	4	10.00	n.d.	n.d.	0.59	0.005
73p 871026	7	10.00	3	10.00	13	10.00	1.39	0.007
73p 871027	9	10.00	4	10.00	n.d.	n.d.	1.65	0.005
73p 871028	14	10.00	4	10.00	n.d.	n.d.	0.55	0.012
73p 871029	11	10.00	6	10.00	n.d.	n.d.	1.69	0.013
73p 871030	24	10.00	11	10.00	31	10.00	1.96	0.005
73p 871031	11	10.00	10	10.00	n.d.	n.d.	1.42	0.007
73p 871032	19	10.00	12	10.00	n.d.	n.d.	2.25	0.008
73p 871033	5	10.00	1	10.00	7	10.00	1.25	0.006
73p 871034	72	10.00	25	10.00	33	10.00	1.48	0.007
73p 871034L	4	10.00	15	10.00	n.d.	n.d.	2.00	0.007
73p 87ls1	168	10.00	57	10.00	31	10.00	0.31	0.008
73p 87ls2	6	10.00	1	10.00	5	10.00	0.71	0.005
73p 87ls3	248	10.00	499	10.00	310	10.00	2.11	0.007
73p 87ls4	4	10.00	1	10.00	5	10.00	0.31	0.005
73p 87ls5	2	10.00	<1	10.00	7	10.00	0.75	0.005
73p 87ls6	<1	10.00	<1	10.00	2	10.00	0.22	0.003

APPENDIX SIX

HYDROGEOCHEMICAL DATA

HYDROGEOCHEMICAL DATA FILE CODE

SAMPLEID: water sample field number; location or NTS map area followed by collection year and sample number or descriptor
SAMPLETYPE: nature of water body sampled
LOCATION: specific location descriptor; project area, closest grid coordinates if available, or geological reference
n.d. = no analytical data

ELEMENT OR PARAMETER	DETECTION LEVEL	METHOD
Au_B (Au leached from bottle walls)	0.5 ppt (ngL^{-1})-variable	HBr:MIBK:AAS
Au_W (Au in water after 0.45micron filter)	0.5 ppt variable	-"-
Au_TOT (total Au in field sample, Au_B + Au_W)	0.5 ppt variable	-"-

(for Au analyses, a value of <0.1 indicates an analyses for bulk samples where a trace of Au may be present as determined by the AAS response, but is clearly below detection level)

Ca	0.5 ppm	ICP-ES/direct aspiration
Mg	0.05 ppm	-"-
F	40 ppb	Ion selective electrode
SO_4	0.01 ppm	Ion chromatography
Cl	0.01 ppm	Ion chromatography
pH	0.1 log units	glass calomel electrode/pH meter
ALK (alkalinity)	1 ppm	titration
COND (conductivity)	<1 mmhos/cm	meter

ANALYTICAL METHODS

pH:

Hydrogen ion activity was measured with a combination glass-calomel electrode and a pH meter. pH measurements were also taken in the field whenever possible using a portable pH meter, but reported samples represent laboratory measurements.

F:

Fluoride in water samples was determined using a fluoride electrode. Prior to measurement an aliquot of the sample was mixed with an equal volume of TISAB II buffer solution (total ionic strength adjustment buffer). The TISAB II buffer solution is prepared by adding to 50 mL metal free water, 57 mL glacial acetic acid, 58 gm NaCl and 4 gm CDTA (cyclohexylene dinitrilo tetraacetic acid). Stir to dissolve and cool to room temperature. Using a pH meter, adjust the pH between 5.0 and 5.5 by slowly adding 5 M NaOH solution. Cool and dilute to 1 L in a volumetric flask.

U:

Uranium in waters was determined by a laser-induced fluorometric method using a Scintrex UA-3 uranium analyser. A complexing agent, known commercially as fluran and composed of sodium pyrophosphate and sodium monophosphate (Hall, 1979) is added to produce the uranyl pyrophosphate species which fluoresces when exposed to the laser. Since organic matter in the sample can cause unpredictable behaviour, a standard addition method was used. Further there have been recorded instances by the Geological Survey of Canada wherein the reaction of uranium with fluran is either delayed or sluggish; for this reason an arbitrary 24 hours time delay between addition of fluran and counting is incorporated into the procedure. In practice, 500 mL of fluran solution were added to a 5 mL sample and allowed to stand for 24 hours. At the end of this period fluorescence readings were made with the addition of 0.0, 0.2, and 0.4 ppb U. For high samples the additions were 0.0, 2.0, and 4.0 (20 mL aliquots of either 55 or 550 ppb U were used). All readings were taken against a sample blank.

Alkalinity:

Alkalinity in waters was determined by titrating a 25 mL aliquot of the sample with 0.02 N H_2SO_4 using a Corning combination electrode and Corning model 135 pH meter. The end point was pH 4.5.

Ca, Mg:

Calcium and Magnesium were determined by inductively coupled plasma emission spectroscopy (ICP). An aliquot from the sample bottle was transferred to a separate container and aspirated directly into the ICP spectrometer (Instrumentation Laboratory Model 200). The instrument was calibrated with aqueous standards.

SAMPLEID	SAMPLETYPE	LOCATION	AU B PPT	AU W PPT	AU TOT PPT	CA PPM	MG PPM	F PPB	PH LOG	ALK PPM	COND UMCM	SO4 PPM	CL PPM
pap87-1	bog	papswzonea	<0.1	1.3	1.3	5.0	1.15	40	5.4	6	n.d.	n.d.	n.d.
pap87-z1-1	pond	papshrzone	<0.1	5.7	5.7	0.5	0.55	30	5.1	7	25	2.75	0.90
pap87-z1-2	pond	papshrzone	<0.1	<0.1	<0.1	<0.5	0.30	20	5.1	2	n.d.	n.d.	n.d.
pap87-z1-3	pond	papshrzone	n.d.	n.d.	n.d.	0.5	0.55	20	5.5	7	32	1.93	0.38
pap87-pit1	bog	papaspyvn	<0.1	1.8	1.8	10.0	2.30	30	5.7	16	63	8.80	0.90
pap87-pit1a	bog	papaspyvn	<0.1	1.3	1.3	11.0	2.50	40	5.9	22	n.d.	n.d.	n.d.
pap87-pit2	bog	papaspyvn	<0.1	<0.1	<0.1	15.0	1.95	50	6.1	30	n.d.	n.d.	n.d.
pap87-pit4	bog	papcamp	<0.1	1.0	1.0	16.0	3.00	70	6.3	47	96	0.83	0.23
73p-872002	lake	pap lake	n.d.	n.d.	n.d.	34.0	4.45	50	6.8	100	n.d.	n.d.	n.d.
73p-872005	lake	pap lake	n.d.	n.d.	n.d.	34.0	4.50	50	6.8	100	n.d.	n.d.	n.d.
73p-872009	lake	pap lake	n.d.	n.d.	n.d.	34.0	4.60	50	6.9	99	208	4.95	0.53
73p-872013	lake	pap lake	n.d.	n.d.	n.d.	34.0	4.50	70	6.8	100	n.d.	n.d.	n.d.
73p-872016	lake	pap lake	n.d.	n.d.	n.d.	34.0	4.50	60	6.9	99	n.d.	n.d.	n.d.
73p-872022	lake	pap lake	n.d.	n.d.	n.d.	34.0	4.50	60	6.8	101	n.d.	n.d.	n.d.
73p-872027	lake	pap lake	n.d.	n.d.	n.d.	34.0	4.50	60	6.9	99	n.d.	n.d.	n.d.
73p-872031	lake	pap lake	n.d.	n.d.	n.d.	34.0	4.50	50	6.9	99	205	4.95	0.68
64c10-872022	lake	foster lk	n.d.	n.d.	n.d.	6.5	1.05	30	6.2	22	n.d.	n.d.	n.d.
64c10-872023	lake	foster lk	n.d.	n.d.	n.d.	7.7	1.10	30	6.2	23	n.d.	n.d.	n.d.
64c10-872024	lake	foster lk	<0.1	<0.1	<0.1	7.0	1.10	30	6.2	22	n.d.	n.d.	n.d.
64c10-87t3	bog	fos-l14e	n.d.	n.d.	n.d.	63.0	11.00	40	6.7	182	333	25.30	0.68
64c10-87t4	bog	fos-l14e	4.9	<0.1	4.9	15.0	1.80	30	5.8	43	n.d.	n.d.	n.d.
64c10-87t4a	bog	fos-l14e	1.0	<0.1	1.9	13.5	1.30	20	6.1	26	66	3.85	0.30
64c10-87t7	bog	fos-l14e	1.1	<0.1	1.1	31.0	2.10	30	6.2	74	n.d.	n.d.	n.d.
64c10-87t7a	bog	fos-l14e	<0.1	<0.1	<0.1	33.0	2.30	40	6.6	86	171	5.23	0.45
64c10-87t13	bog	foster lk	n.d.	n.d.	n.d.	15.0	0.80	30	6.2	34	n.d.	n.d.	n.d.
64c10-87-jjb2	trench	foster lk	2.3	<0.1	2.3	22.0	1.25	50	6.4	44	112	15.95	0.53
64c10-87-jjb3	trench	foster lk	<0.1	<0.1	<0.1	35.0	2.40	40	6.7	84	168	7.15	1.05
64c10-87-jjb4	trench	foster lk	<0.1	n.d.	<0.1	17.5	1.35	30	6.1	32	n.d.	n.d.	n.d.
64c10-852001	lake	foster lk	n.d.	n.d.	n.d.	4.4	0.70	40	6.7	13	33	1.00	0.95
64c10-852003	lake	foster lk	n.d.	n.d.	n.d.	4.8	0.70	<40	6.7	14	33	0.90	0.21
64c10-852005	lake	foster lk	n.d.	n.d.	n.d.	4.8	0.70	40	6.8	18	34	0.80	0.33
64c10-852007	lake	foster lk	n.d.	n.d.	n.d.	4.8	0.70	40	6.8	14	34	0.90	0.20
64c10-852009	lake	foster lk	n.d.	n.d.	n.d.	4.9	0.70	40	7.0	14	34	0.90	0.28
64c10-852011	lake	foster lk	n.d.	n.d.	n.d.	4.9	0.80	40	6.9	14	37	0.90	0.24
64c11-852001	lake	foster lk	n.d.	n.d.	n.d.	4.8	0.80	40	6.7	14	34	1.00	0.24
64c11-852003	lake	foster lk	n.d.	n.d.	n.d.	4.4	0.70	40	6.7	14	34	1.00	0.24
64c10-882002	lake	bay lake	n.d.	n.d.	n.d.	n.d.	n.d.	30	6.6	n.d.	45	2.48	0.38
64c10-882004	lake	bay lake	n.d.	n.d.	n.d.	n.d.	n.d.	30	6.8	n.d.	46	3.30	0.30
64c10-882006	lake	expansn lk	n.d.	n.d.	n.d.	n.d.	n.d.	30	6.5	n.d.	44	2.20	0.30
64c10-882008	lake	expansn lk	n.d.	n.d.	n.d.	n.d.	n.d.	30	6.4	n.d.	45	2.20	0.30
64c10-882010	lake	expansn lk	n.d.	n.d.	n.d.	n.d.	n.d.	30	6.8	n.d.	42	2.20	0.30
64c10-882012	bog	377e 24s	n.d.	n.d.	n.d.	n.d.	n.d.	30	6.5	n.d.	64	4.40	0.45
64c10-882019	bog	378e 19s	n.d.	n.d.	n.d.	n.d.	n.d.	50	7.6	n.d.	159	11.00	0.23
64c10-882022	bog	376e 22s	n.d.	n.d.	n.d.	n.d.	n.d.	50	7.5	n.d.	157	6.60	0.45
64c10-886001	lake	reserv lk	n.d.	n.d.	0.3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c10-886002	lake	bay lk	n.d.	n.d.	0.9	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c10-88bw3	bog	foster lk	n.d.	n.d.	0.5	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.

SAMPLEID	SAMPLETYPE	LOCATION	AU_B_PPT	AU_W_PPT	AU_TOT_PPT	CA_PPM	MG_PPM	F_PPB	PH_LOG	ALK_PPM	COND_UMCM	SO4_PPM	CL_PPM
64c10-88bw4	bog	foster lk	n.d.	n.d.	0.6	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c10-88resck	stream	reserv ck	n.d.	n.d.	0.3	n.d.	n.d.	50	6.9	n.d.	40	1.93	0.53
64c10-87rck1	stream	reserv ck	n.d.	n.d.	n.d.	48.0	6.60	30	7.1	145	n.d.	n.d.	n.d.
64c10-87rck2	stream	reserv ck	n.d.	n.d.	n.d.	5.0	0.85	30	6.2	17	n.d.	n.d.	n.d.
64c10-87rck3	stream	reserv ck	n.d.	n.d.	n.d.	7.5	1.15	30	6.0	23	n.d.	n.d.	n.d.
64c10-882027	stream	burn ck	n.d.	n.d.	n.d.	n.d.	n.d.	40	7.1	n.d.	70	0.83	0.45
64c10-886006	lake	expansn lk	n.d.	n.d.	1.1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c10-88bw7	bog	foster lk	n.d.	n.d.	0.6	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c10-88bwgl	lake	grouse lk	n.d.	n.d.	0.8	n.d.	n.d.	50	6.3	n.d.	30	1.10	0.30
64c10-88-jjb2	trench	foster lk	n.d.	n.d.	1.2	n.d.	n.d.	60	7.2	n.d.	101	9.35	0.30
64c10-88bw10	bog	378e21+25s	n.d.	n.d.	0.5	n.d.	n.d.	60	7.5	n.d.	133	8.80	0.30
64c10-88bw24	bog	373e 24s	n.d.	n.d.	0.4	n.d.	n.d.	50	6.9	n.d.	106	9.35	0.38
64c10-88bw12	bog	377e 24s	n.d.	n.d.	1.1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64c10-88bw13	bog	378e 23s	n.d.	n.d.	0.3	n.d.	n.d.	50	7.6	n.d.	133	12.65	0.38
64c10-88bw25	bog	372e 23s	n.d.	n.d.	13.3	n.d.	n.d.	60	6.4	n.d.	70	2.20	0.45
64c10-88bws1	stream-1	foster lk	n.d.	n.d.	0.9	n.d.	n.d.	80	6.6	n.d.	36	0.10	0.45
64c10-88bws2	stream-2	foster lk	n.d.	n.d.	6.4	n.d.	n.d.	50	6.5	n.d.	31	0.10	0.30
64c10-88bws3	stream-3	foster lk	n.d.	n.d.	3.2	n.d.	n.d.	50	6.7	n.d.	42	1.38	0.45
fos-87-1-10m	drill hole	foster grd	n.d.	n.d.	1.3	n.d.	n.d.	220	7.5	n.d.	300	35.75	0.30
fos-87-1a-33m	drill hole	foster grd	n.d.	n.d.	n.d.	n.d.	n.d.	150	7.9	n.d.	328	38.50	0.30
fos-87-1b-33m	drill hole	foster grd	n.d.	n.d.	n.d.	n.d.	n.d.	170	7.6	n.d.	323	38.50	0.45
wask-86-6-10m	drill hole	374e 20s	n.d.	n.d.	0.9	n.d.	n.d.	50	7.8	n.d.	282	18.70	3.45
wask-86-6-33m	drill hole	374e 20s	n.d.	n.d.	n.d.	n.d.	n.d.	790	7.7	n.d.	285	19.80	3.60
wask-86-23-10m	drill hole	374e 18s	n.d.	n.d.	1.7	n.d.	n.d.	830	7.5	n.d.	369	34.65	0.53
wask-86-23-33m	drill hole	374e 18s	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	369	28.05	0.53
pr87-29-30m	drill hole	pap lake	n.d.	n.d.	400.6	n.d.	n.d.	210	7.8	n.d.	370	23.10	0.30
pr87-29-50m	drill hole	pap lake	n.d.	n.d.	47.9	n.d.	n.d.	430	7.6	n.d.	287	33.55	0.30
pr87-29-75m	drill hole	pap lake	n.d.	n.d.	9.2	n.d.	n.d.	450	7.6	n.d.	372	24.20	0.23
pr87-30-70m	drill hole	pap lake	n.d.	n.d.	244.0	n.d.	n.d.	270	7.8	n.d.	356	22.55	0.23
pr87-46-20m	drill hole	pap lake	n.d.	n.d.	n.d.	n.d.	n.d.	280	7.7	n.d.	253	6.05	0.75
31f2-88bw1	lake	napier lk	n.d.	n.d.	0.8	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
31f2-882002	lake	napier lk	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	331	12.10	0.75
31f2-882004	lake	napier lk	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	337	12.10	0.60
31f2-882006	lake	napier lk	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	320	12.10	0.60
31f2-882008	lake	napier lk	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	288	11.85	0.60
31f2-882014	lake	napier lk	n.d.	n.d.	n.d.	n.d.	n.d.	50	6.7	n.d.	262	11.55	0.75
31f2-882016	lake	l green lk	n.d.	n.d.	n.d.	n.d.	n.d.	50	8.2	n.d.	279	11.55	0.60
31f2-882018	lake	l green lk	n.d.	n.d.	n.d.	n.d.	n.d.	40	8.1	n.d.	320	11.55	0.60
31f2-882019	stream	l green lk	n.d.	n.d.	n.d.	n.d.	n.d.	40	8.2	n.d.	331	11.55	0.90
31f2-882020	lake	l green lk	n.d.	n.d.	n.d.	n.d.	n.d.	40	8.0	n.d.	326	12.10	0.68
31f2-882022	lake	nichols lk	n.d.	n.d.	n.d.	n.d.	n.d.	60	7.8	n.d.	215	7.70	0.30
31f2-882024	lake	nichols lk	n.d.	n.d.	n.d.	n.d.	n.d.	100	7.8	n.d.	218	7.70	0.30
31f2-882026	lake	nichols lk	n.d.	n.d.	n.d.	n.d.	n.d.	80	7.7	n.d.	209	7.70	0.30
31f2-882028	lake	grassy lk	n.d.	n.d.	n.d.	n.d.	n.d.	70	7.7	n.d.	198	8.25	0.38
31f2-882030	stream	l green ck	n.d.	n.d.	1.8	n.d.	n.d.	60	8.3	n.d.	320	11.00	0.53
31f2-882032	stream	l green ck	n.d.	n.d.	n.d.	n.d.	n.d.	60	7.6	n.d.	326	13.20	0.75
31f2-882034	seep	napier ck	n.d.	n.d.	n.d.	n.d.	n.d.	60	7.9	n.d.	343	14.85	1.20

SAMPLEID	SAMPLETYPE	LOCATION	AU_B_PPT	AU_W_PPT	AU_TOT_PPT	CA_PPM	MG_PPM	F_PPB	PH_LOG	ALK_PPM	COND_UMCM	SO4_PPM	CL_PPM
31f2-882036	stream	napier ck	n.d.	n.d.	n.d.	n.d.	n.d.	50	7.7	n.d.	285	14.30	0.75
31f2-882042	stream	napier ck	n.d.	n.d.	0.8	n.d.	n.d.	60	7.8	n.d.	227	14.85	0.75
31f2-882043	stream	napier ck	n.d.	n.d.	n.d.	n.d.	n.d.	50	7.9	n.d.	221	14.85	0.68
31f2-882045	seep	napier ck	n.d.	n.d.	n.d.	n.d.	n.d.	50	7.6	n.d.	308	12.65	0.60
31f2-882046	stream	napier ck	n.d.	n.d.	n.d.	n.d.	n.d.	50	7.5	n.d.	227	11.00	0.68
31f2-882047	stream	napier ck	n.d.	n.d.	n.d.	n.d.	n.d.	50	7.9	n.d.	227	11.00	0.60
31f2-882048	stream	napier ck	n.d.	n.d.	0.3	n.d.	n.d.	50	7.7	n.d.	215	11.00	0.83
31f2-882048	stream	napier ck			10.4								

APPENDIX 6 - PART B

Gold concentration (ng)[a] of aqua regia leach of $>1.2\ \mu$ suspensate filtered from Reservoir and PAP Lake water.

Sample site	Lake water volume[b](L)	Au(ng)[c]
Reservoir Lake	1	1.11
	1.5	0.89
	6	1.61
	10	2.95
	10	1.11
	12	2.05
	12	0.96
	14	2.72
	17	1.03
Total Reservoir Lake	83.5 L	14.43

Mean Au concentration of Reservoir Lake particulates[d] $>1.2\mu$ = 0.17 ngL^{-1}
Au concentration of 1 L Reservoir Lake water = 0.3 ng L^{-1}

PAP Lake	6	0.12
	8.5	0.01
	9	0.01
	9	0.01
	9	0.01
	9	0.12
	12	0.12
	9	0.47
	9	0.89
	10	1.61
	12	0.75
	12	0.26
	14.25	0.68
Total PAP Lake	128.75 L	5.02

Mean Au concentration of PAP Lake particulates $>1.2\mu$ = 0.039 ng L^{-1}
Au concentration of 1 L PAP Lake water = <1.0 ng L^{-1}

a Au analyses by GFAAS, J. Vaive analyst

b volumes may correspond to 1-5 filter papers which were leached in aggregate

c Values of 0.01 ng are not used in total

d S.E.M. examination of particulates observed primarily filamentous and pollen-like organics, with lesser clay particles, and other inorganics, including rare 2 μ clusters of secondary pyrite cubes.

APPENDIX 6 - PART C

Instrument parameters

P-E Model 5000 atomic absorption spectrophotometer:

Wavelength	242.8 nm
Spectral slit width	0.7 nm
Calibration mode	Absorbance, peak height
Background correction	Deuterium arc

P-E Model HGA 500 graphite furnace atomiser:

Dry	100^{o}C/10s
Char	450^{o}C/10s
Atomize	2400^{o}C/5s
Purge gas	Argon, interrupt at atomisation
Sample volume	40 μL

APPENDIX SEVEN

PLATES

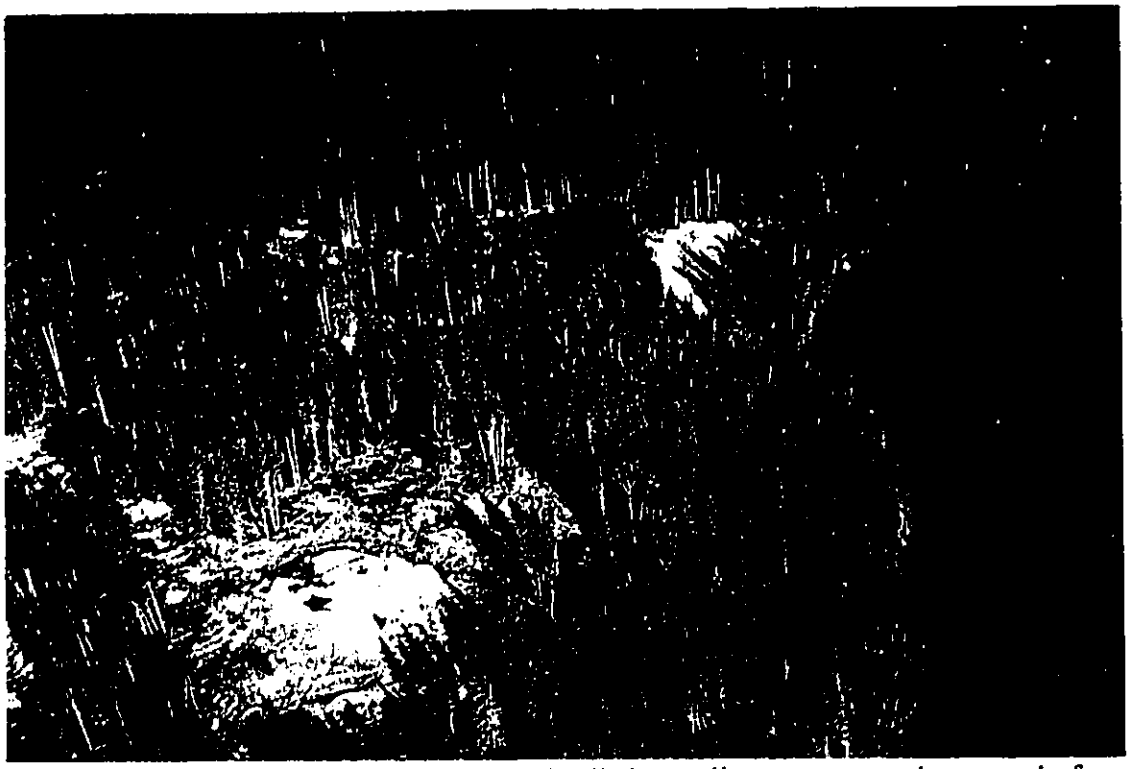


Plate 1. PAP Lake, view northwest over detailed sampling area at southwest end of lake. Lake shore samples taken along lake margin; till and vegetation sample area on forested slope between lake and exposed bedrock. Mineralized shear zone shown.

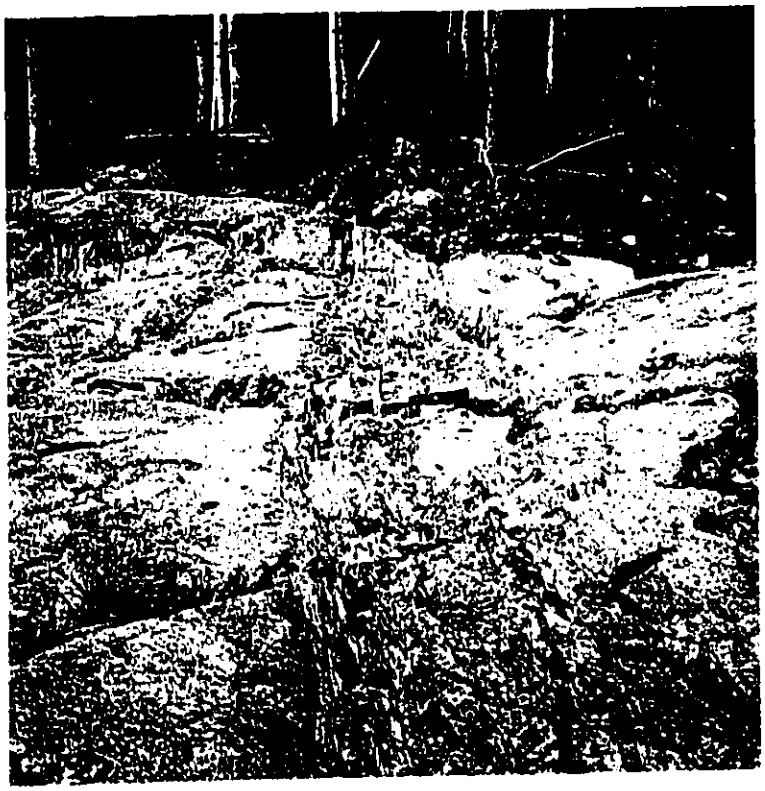


Plate 2. PAP Lake shear zone in diorite with quartz-carbonate alteration, for location see bedrock area in Plate 1.

Plate 3. PAP Lake polyphase shearing and quartz-carbonate alteration in diorite.

Plate 4. PAP Lake 30 cm quartz-arsenopyrite vein; sample 87R4, Au = 22,200 ppb.

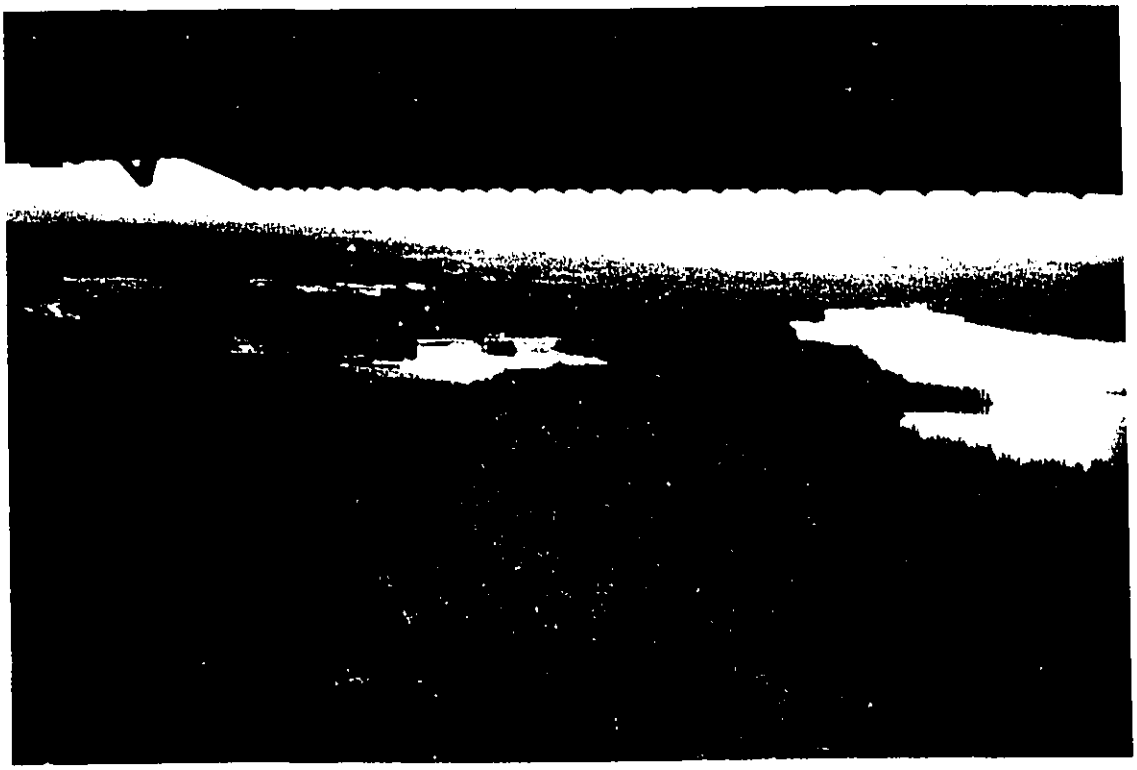


Plate 5. Foster Lake aerial view looking east over Johnson Shear zone, Foster Lake at right and Reservoir Lake in centre left. Location of two sampled grids shown.

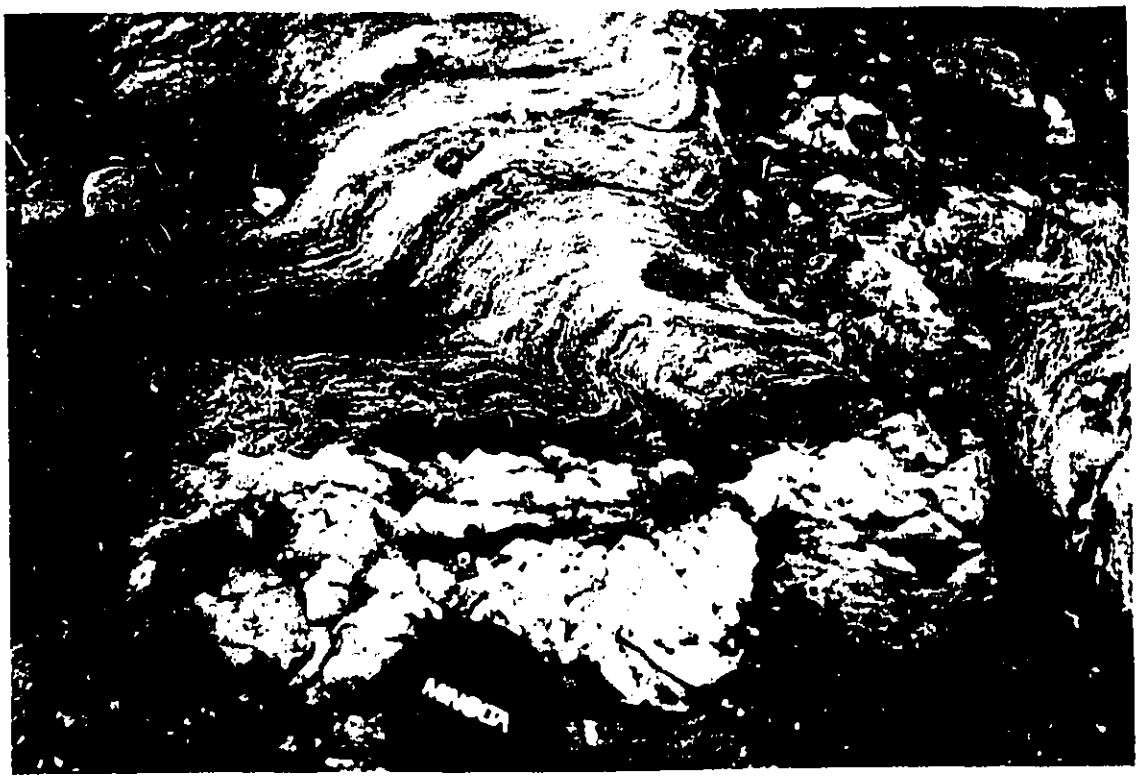


Plate 6. Foster Lake; Quartz veining in deformed metavolcanics in Johnson Shear zone.

Plate 7. Foster Lake; Sample 64C10RLV Reservoir Lake quartz veins in altered shear; Au - 16,200 ppb, Cu - 403 ppm, Zn - 693 ppm, B - 483 ppm.

Plate 8. Foster Lake; Oxidized lodgement till with locally derived bedrock fragments ovelain by weakly developed humic layer and boulder lag deposit.

Plate 9. Foster Lake; L310E, 21.5S ; trench across Johnson Shear zone, illustrating thin veneer of oxidized till, immature boreal forest.

Plate 10. Reservoir Lake, collecting lake sediment samples from inflatable boat.

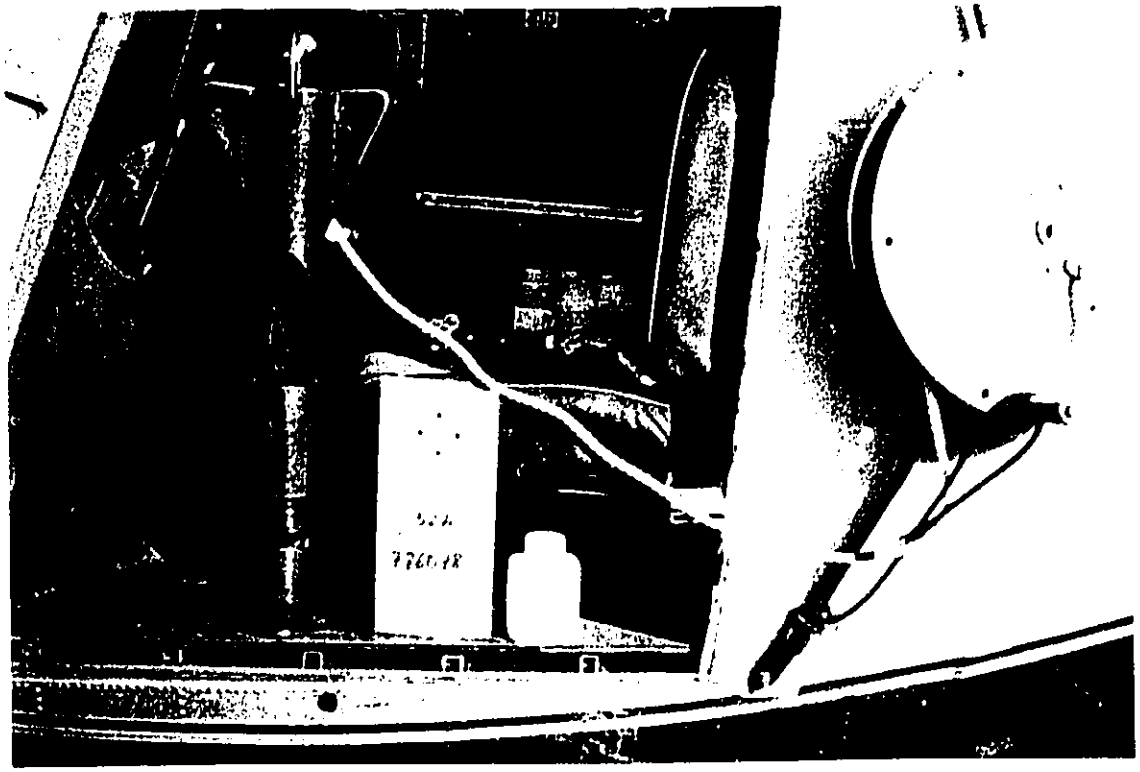


Plate 11. Lake sediment sampling apparatus; torpedo-shaped sampler, numbered high wet strength kraft sample bag, 250ml water bottle. In this case mounted externally on a float-equipped helicopter for regional reconnaissance surveys.

Plate 12. Measuring pH in perennial bogs, Foster Lake L374E.

Plate 13. Measuring temperature and conductivity on L374E, Foster Lake.

Plate 14. PAP Lake, pond on diorite overlying main shear zone, sample PAP z1-1; Au - 5.7 ngL^{-1}, pH - 5.1.

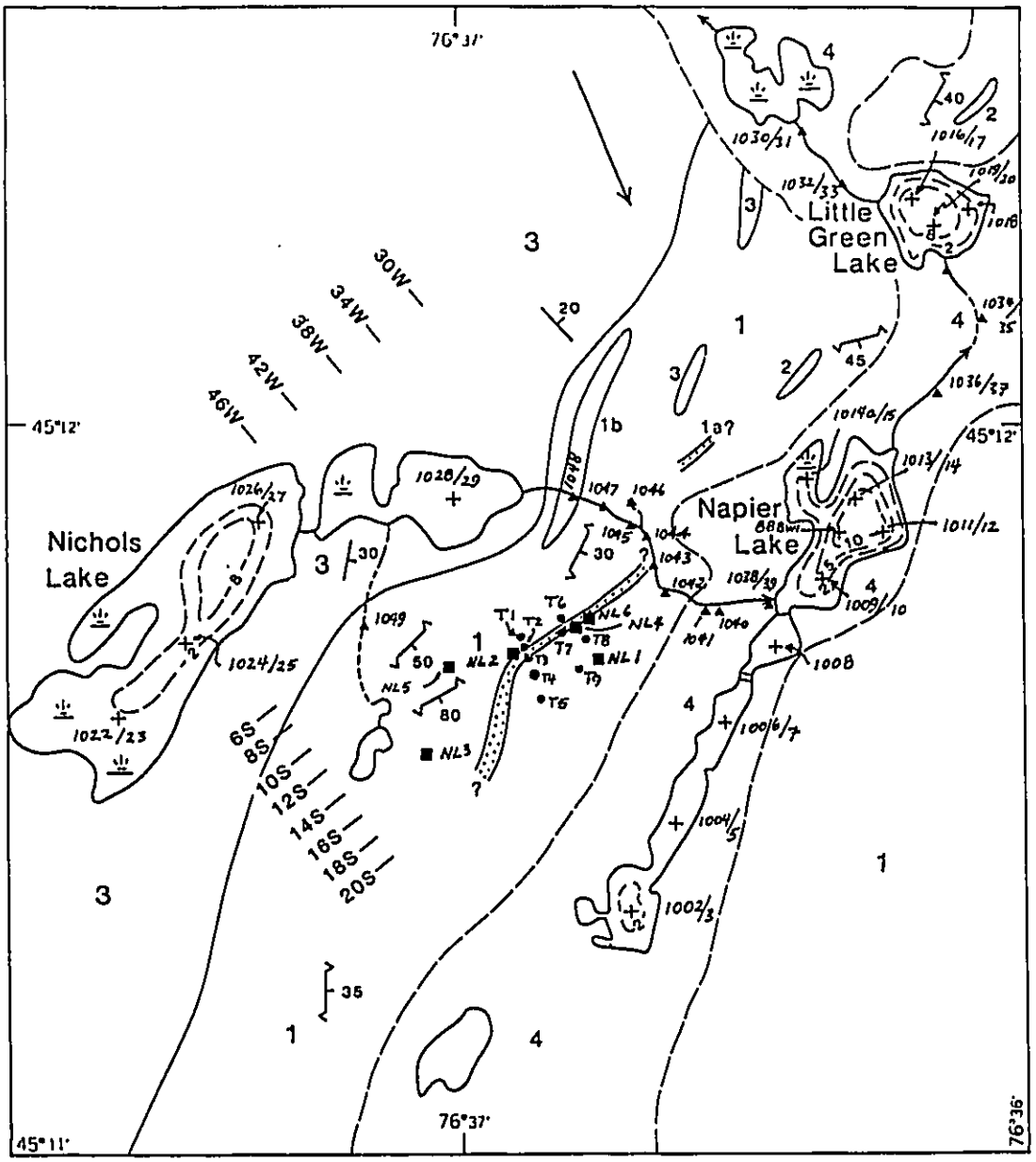
Plate 15. PAP Lake, closeup of pond on diorite, note quartz vein, Samples PAP87R 11,12,20,21a taken in vicinity.

Plate 16. PAP Lake aerial view looking northeast across lake, brown boggy area in centre left is location of drill holes sampled for groundwater, azimuth is towards lake to intersect shear zone located between bog and lake. Ice direction from top left to bottom right.

APPENDIX EIGHT

SAMPLE LOCATION MAPS

SAMPLE LOCATION MAP: NAPIER LAKE



QUATERNARY

4 Glaciofluvial sand and gravel

PROTEROZOIC

3 Sandy dolostone

2 Leucogranite

1 Mafic volcanics:
1a–auriferous quartz-pyrite
1b–gabbro

Mineralized zone

Lake-bottom depth (m)

Bedding 20

Foliation and shearing 30

Ice movement direction

0 Metres 300

0 Feet 1000

GSC

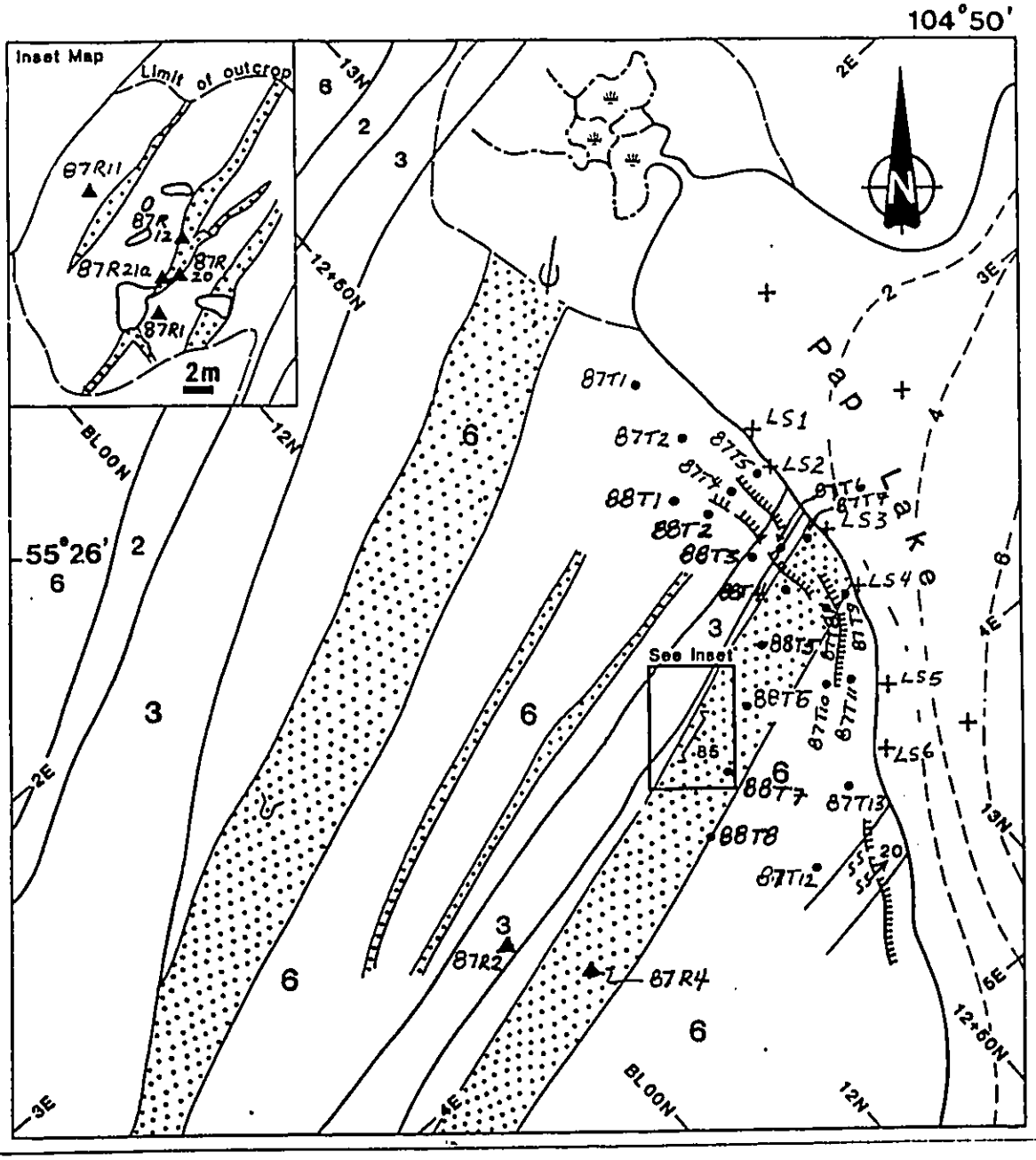
+ Lake sediment (1xxx) and lake water (2xxx) site

▲ Stream sediment (1xxx) and stream water (3xxx) site

■ Lithogeochemical sample site

● Till sample site

SAMPLE LOCATION MAP: PAP LAKE, WEST END



LEGEND

APHEBIAN

6	Gabbro, diorite
5	Andesitic rocks; flows, layered tuffs
4	Dacitic rocks; flows, tuffs
3	Rhyolitic rocks; tuffs, derived sediments
2	Iron formation; sulphide and silicate facies, amphibolite
1	Carbonate rocks; in part diopsidic altered volcanics

Mineralized shear zone .....

Lake bottom depth (metres). . . 2

Ice movement direction .....

Lake sediment, ...+

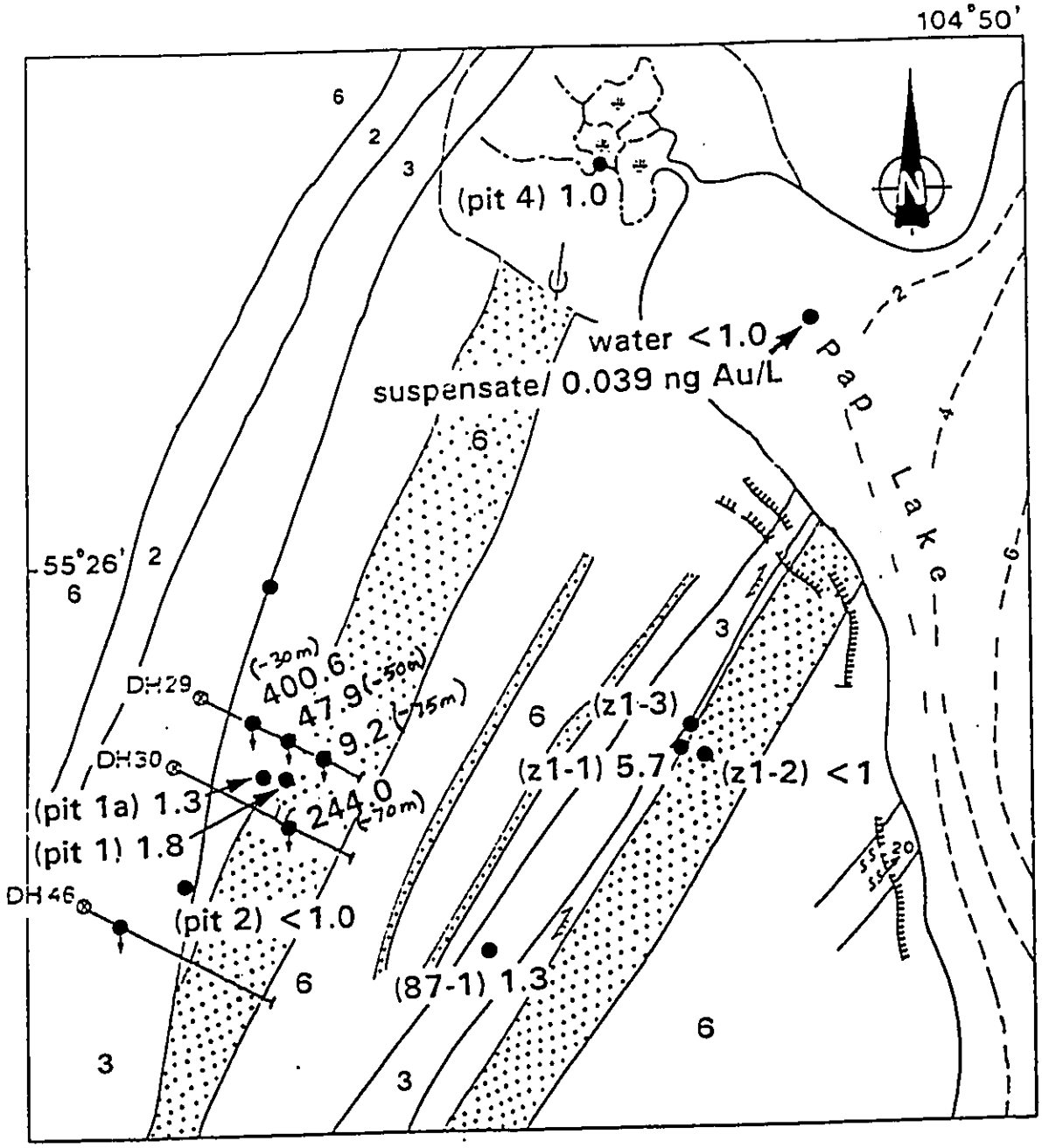
Rock, ... ▲

Multi-media site ..... ●

0 Metres 100

0 Feet 300

SAMPLE LOCATION MAP: PAP LAKE, WATERS



LEGEND

APHEBIAN

- 6 Gabbro, diorite
- 5 Andesitic rocks; flows, layered tuffs
- 4 Dacitic rocks; flows, tuffs
- 3 Rhyolitic rocks; tuffs, derived sediments
- 2 Iron formation; sulphide and silicate facies, amphibolite
- 1 Carbonate rocks; in part diopsidic altered volcanics

Mineralized shear zone .....

Lake bottom depth (metres). . . 2

Ice movement direction .....

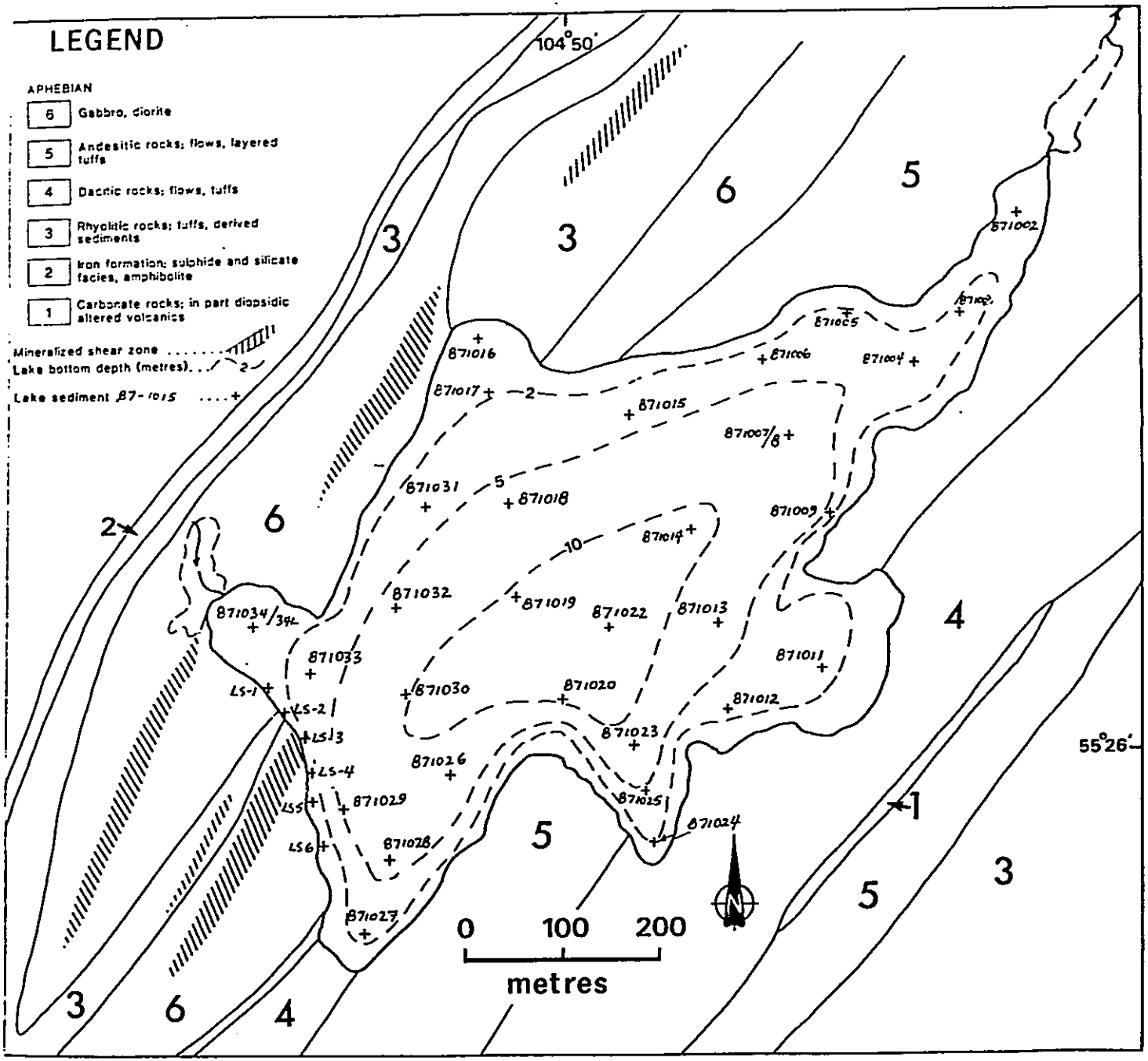
Water ,. . Au (ng/L) - surface .....

- groundwater. .

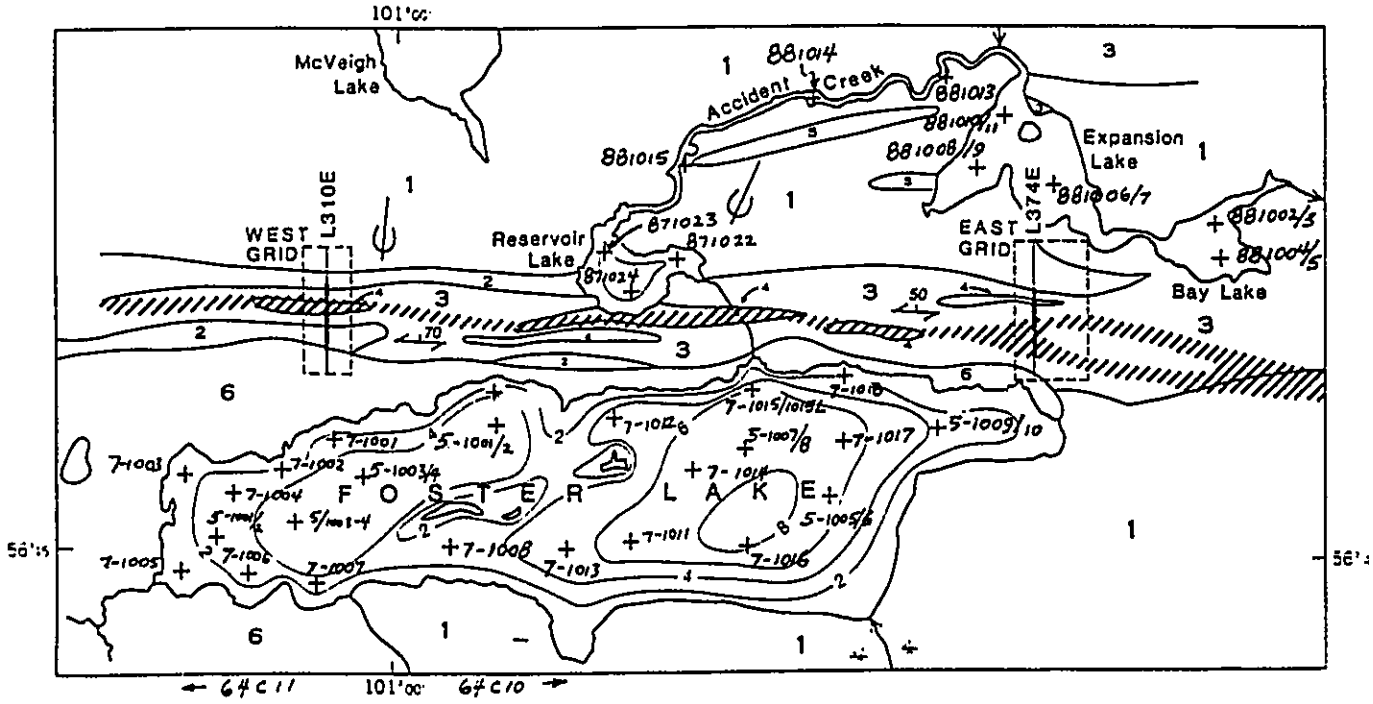
0 Metres 100

0 Feet 300

SAMPLE LOCATION MAP: PAP LAKE, LAKE SEDIMENTS



SAMPLE LOCATION MAP: FOSTER LAKE



LEGEND

APHEBIAN

6	Alkali granite
5	Gabbro
4	Felsic metasedimentary rocks
3	Intermediate to mafic metasedimentary rocks
2	Mafic sedimentary rocks
1	Mafic to intermediate volcanic rocks

Depth (metres) 5

Multi-media profile sampled in 1987 .....

Multi-media grid sampled in 1988 .....

Johnson shear zone .....

Ice movement direction .....

Site locations, LAKE SEDIMENTS .....

0 Metres 400

SAMPLE LOCATION MAP: FOSTER LAKE DETAILED GRIDS

- ● Till, Humus and Spruce Twig site (7-xx = 1987; 8-xx = 1988)
- ▼ Water sample location site