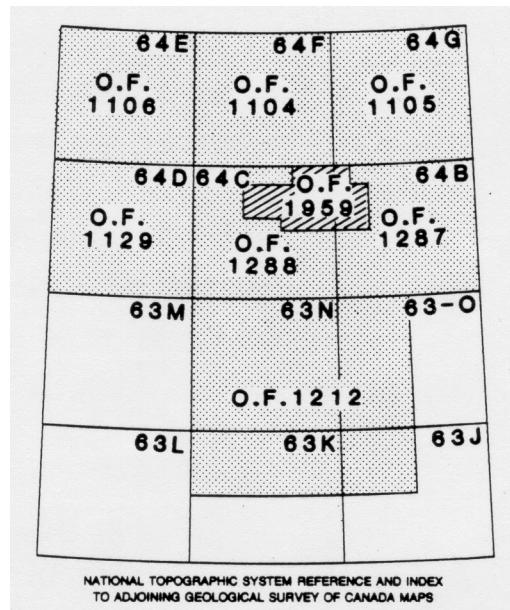


GEOLOGICAL SURVEY OF CANADA OPEN FILE 1959

(PARTS OF NTS 64B AND 64C)

CANADA - MANITOBA MINERAL DEVELOPMENT AGREEMENT (1984 - 1989)

GEOCHEMICAL RESULTS AND INTERPRETATION OF A LAKE SEDIMENT AND WATER SURVEY
IN THE LYNN LAKE - LEAF RAPIDS REGION, NORTHERN MANITOBA



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INTRODUCTION

Open File 1959 presents geochemical lake sediment and water data from the Lynn Lake - Leaf Rapids region of northern Manitoba. The Open File contains data from: nearly 350 sites sampled in 1987; about 50 sites sampled in 1985 and 1988 adjacent to and south of the Johnson shear zone; and regional geochemical data previously published as G.S.C. Open Files 999,1103,1287 and 1288. Open File 1959 displays data for the first infill lake sediment survey conducted in Manitoba designed to augment existing geochemical data in areas of high mineral potential.

The overall objectives of the survey are:

- a) to provide a detailed geochemical database for the mineral exploration industry to identify areas of high mineral potential
- b) to evaluate trace element response in lake sediments and lake waters in areas of similar geology, overlain by compositionally dissimilar surficial deposits (e.g. carbonate-rich vs. non-carbonate tills), and
- c) to provide baseline environmental geochemical data.

The survey area covers parts of map sheets 64B and 64C between 56°30'N to 57°N and 99°30'W to 101°15'W (figure 1). Average sample density is 1 sample per 4.2 square kilometres throughout the 3500 square kilometre survey area.

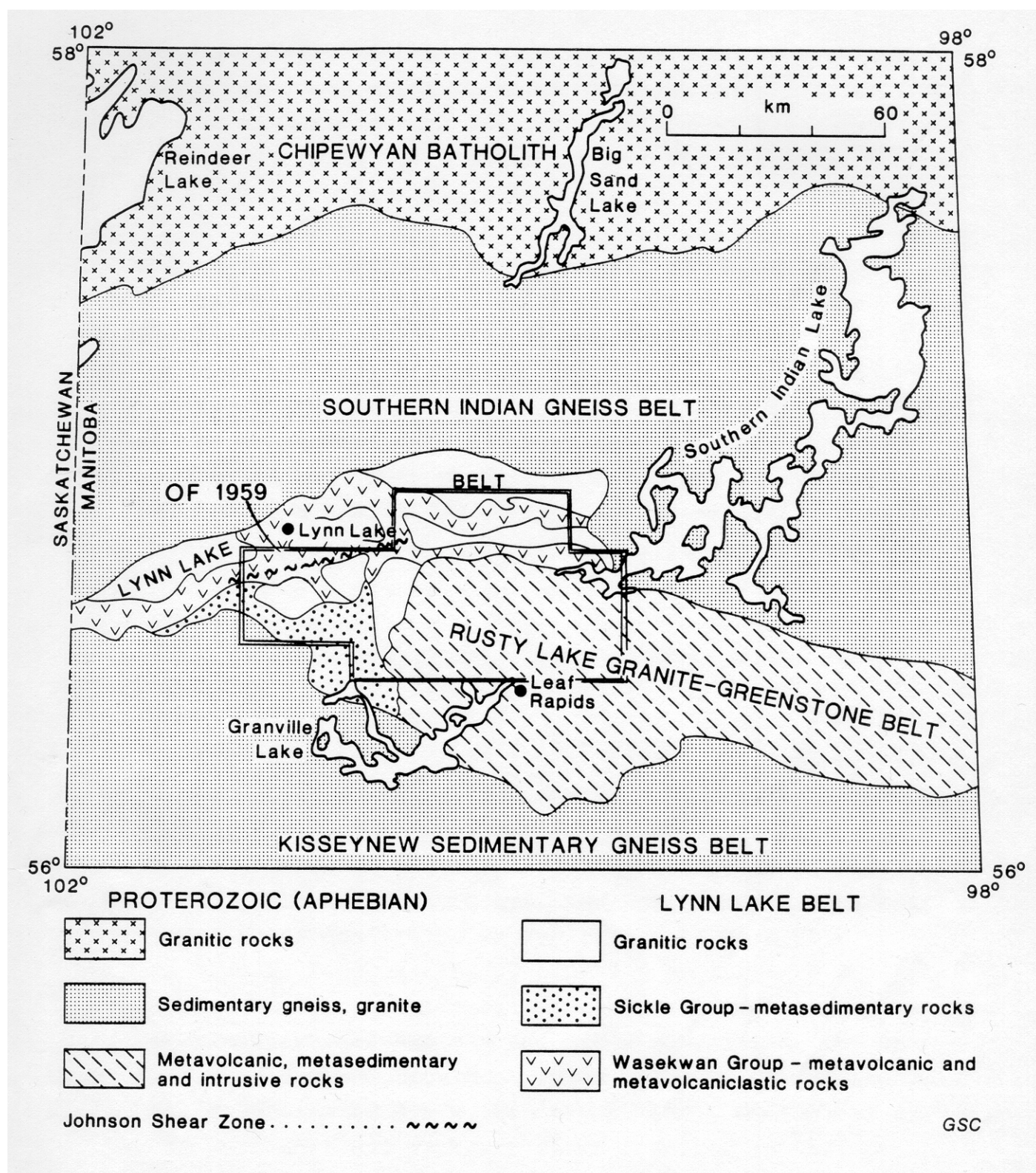


Figure 1: Location and regional geology of Open File 1959 (after Zwanzig et al., 1985).

Open File 1959 is one of nine geochemical surveys covering parts of central and northern Manitoba which were carried out as part of the Canada-Manitoba Mineral Development Agreement (1984 - 1989). The Open File lists data for up to 20 elements in lake bottom sediments, and up to 12 elements in surface lake waters.

The survey contributes to a National Geochemical Reconnaissance (NGR) database which is used for resource assessment, mineral exploration, geological mapping, environmental and health studies. Sample collection, processing and analytical procedures are strictly specified and controlled. In this way consistent data are systematically obtained in different areas over many years from different analytical laboratories. The unanalyzed portion of the sample is carefully catalogued and archived so that it is available for future non-destructive testing for additional elements, and mineralogical research.

ACKNOWLEDGEMENTS

The 1987 Lynn Lake - Leaf Rapids infill geochemical sampling program was designed and carried out by H.R. Schmitt under the direction of E.H.W. Hornbrook and P.W.B. Friske of the Exploration Geochemistry Subdivision, Geological Survey of Canada. A.C. Galletta, H.A. Gross, and F. Williams are especially thanked for their dedication in assisting the Open File production. C.A. Kaszycki kindly provided preliminary surficial geological data for the Open File. Previous regional geochemical data covering parts of NTS 64B and 64C incorporated into Open File 1959 were derived from contracted NGR surveys carried out under the direction of E.H.W. Hornbrook, GSC. Geological Survey of Canada personnel and contract firms involved in various aspects of the past and present surveys are listed below.

Sample Collection: 64B;64C - GSC, H.R. Schmitt, D.J. Scholtz (1985/87)
64B - Marshall, Macklin Monaghan, Toronto (1984)
64C - Wollex Exploration, Calgary (1983)

Sample Preparation: 64B;64C - Golder Associates, Ottawa (1984 - 1988)

Sediment Analysis: 64B;64C - Chemex Labs Ltd., Vancouver (Au only, 1985, 1987, 1988)
64B - Bondar-Clegg and Company, Ltd., Ottawa (1987)
Barringer Magenta Ltd., Rexdale (1984 - 1985)

- 64C - Acme Analytical Laboratories,
Toronto (1983)
- Barringer Magenta Ltd., Rexdale (Sb
only, 1985)
- Water Analysis: 64B;64C - Chemex Labs Ltd., Vancouver (1983,
1987)
- Geological Survey of Canada (1985)
- Ward TSL, Winnipeg (1984 - 1985)
- 64B - Barringer Magenta (Alberta) Ltd.,
Calgary (pH, U, F, 1984)
- 64C - Bondar-Clegg and Company
Ltd., Ottawa (1988)
- Data Processing and
Presentation: - GSC; A.C. Galletta, H.A. Gross,
D.F.Wright
- Cartography: - GSC, Geological Information
Division; F.Williams, J.Yelle
- Terra Surveys Ltd., Ottawa
- Reproduction: - Ashley Reproductions Inc., Ottawa

DESCRIPTION OF THE SURVEY AREA

BEDROCK GEOLOGY

The following discussion of the regional geology is based largely on Manitoba Energy and Mines (1986a,b) and Cameron (1988).

The survey area is within the Churchill Structural Province and is underlain by early Proterozoic (Aphebian) rocks. Parts of four geological domains are encompassed, each represented by a unique succession of supracrustal rocks.

- a) the southern margin of the Southern Indian Domain
- b) the eastern half of the Lynn Lake Domain
- c) the western part of the Leaf Rapids Domain
- d) the northern margin of the Kisseynew Domain

These domains are considered to have evolved in a tectonic environment with oceanic volcanic arc affinities. Geochemical, structural and geochronological studies indicate that a complex history involving collision tectonics, crustal anatexis, and arc magmatism resulted in the present regional geological patterns.

The geological units referred to in the discussion below are indicated on the geology base accompanying the sample location and gold value map in the pocket at the rear.

The Southern Indian Domain is exposed in the northeast corner of the survey area and east of Opachuanau Lake where it is represented by unit 1 and 2, SIW and N. Rocks are comprised predominantly foliated granitic and greywacke-derived gneiss, migmatite and metasandstone, intruded by early Proterozoic megacrystic to porphyritic granite, unit 33, G.

The Leaf Rapids Domain underlies the eastern and central parts of the survey area. South of the Churchill River the dominant rock types, Units 3 to 10, are part of the northern block of the Rusty Lake volcanic belt. They include volcanic-derived metasedimentary rocks, polymictic volcanic conglomerate, turbidites, Ruttan Group basalt flows (unit 3 - RVr), mafic volcaniclastic rocks (unit 4 - RVf), metagreywacke with sulphide-facies iron formation (unit 9 - LRW), and hypabyssal gabbro (unit 10 - LBD).

The western part of the Leaf Rapids Domain is underlain almost entirely by Outlaw Bay tonalite (unit 28 - T), the Eden Intrusive suite which includes tonalite, quartz monzodiorite, granodiorite, monzogranite, aegerine-augite syenite, pegmatite (locally fluorite or andradite bearing) (units 32 - GA; 33 - G; 34 - EZ; and 35 - X), and granodiorite (unit 30 - GC). Minor units occurring in the western part of the domain include amphibolite (unit 5 - LRA), chemical sediments (unit 7 - K) and metagreywacke (unit 9 - LRW) southeast of Black Trout Lake, and various mafic to felsic metavolcanic rocks, amphibolite, and metasedimentary rocks (unit 5 - LRA) generally south of Eden Lake.

The Lynn Lake Domain occupies the western and northern part of the survey area. It consists of metamorphosed volcanic, sedimentary and plutonic rocks. The oldest part of the domain is represented by the Wasekwan Group metavolcanic and volcanic-derived metasedimentary rocks (units 11 - 18). Wasekwan Group rocks occur as prominent northern and southern belts striking east-west, with smaller splays and outliers. Mafic volcanic and volcaniclastic rocks of the northern belt may represent the uppermost part of the southern belt stratigraphic succession. In the central part of the northern belt high alumina and high magnesia tholeiitic basalts, referred to as the Agassiz Metallotect, host significant gold mineralization (Fedikow et al,

1986). In the southern belt, the contact between Wasekwan Group rocks and granitoid rocks to the south coincides closely with the Johnson Shear Zone, a narrow zone over 50 kilometres long of deformation and quartz-carbonate alteration associated with numerous gold occurrences. The northern and southern belts are separated by intermediate to felsic intrusives of the Poole Lake intrusive suite (units 20 - PD; 21 - PG; and 22 - PT), older gabbro and diorite (unit 19 -B).

Metasedimentary rocks of the Sickie Group (units 23 - SC; 24 - SSH; and 25 - SS) unconformably overlie the Poole Lake intrusions and earlier Wasekwan Group rocks. The Sickie Group consists of a basal polymictic conglomerate overlain by a fining-upward sandstone sequence.

The Kiseynew Domain is a sedimentary gneiss belt south of the Lynn Lake and Leaf Rapids domains. The northern Kiseynew margin is exposed along the southwestern-most part of the survey area where it is underlain by gneissic tonalite, granodiorite and granite of the Glasspole Lake Complex.

SURFICIAL GEOLOGY

Bedrock in the survey area is mantled by late Wisconsinan surficial deposits derived from Keewatin ice flow centred to the west, and Hudson lobe ice originating from the east. The zone of lobe ice convergence is marked by the discontinuous Leaf Rapids interlobate moraine (Figure 2, Klassen, 1983; Kaszycki and DiLabio, 1986;).

West of the moraine, Keewatin ice flow directions ranging from 190° to 210° deposited predominantly till of variable thickness, and lesser glaciofluvial and nearshore glacio-lacustrine deposits (Kaszycki et al., 1986). East of the interlobate moraine, Hudson lobe ice directions ranged from 225° to 260°. Hudson glaciation deposited Paleozoic carbonate-bearing till, stratified glaciofluvial deposits, nearshore and offshore glacio-lacustrine deposits. Deglaciation in the region resulted in the deposition of proglacial Lake Agassiz clay and silt, littoral sand, and gravel and boulder deposits resulting from erosion and reworking of older till and glaciofluvial deposits (Kaszycki and DiLabio, 1986; Nielsen and Graham, 1985).

Organic deposits are ubiquitous, occupying most depressions; lake margins; extensive areas of subdued terrain east of Barrington Lake, and southeast of the Churchill River system. Bedrock is variably exposed, but generally amounts to less than 25% of the surface area.

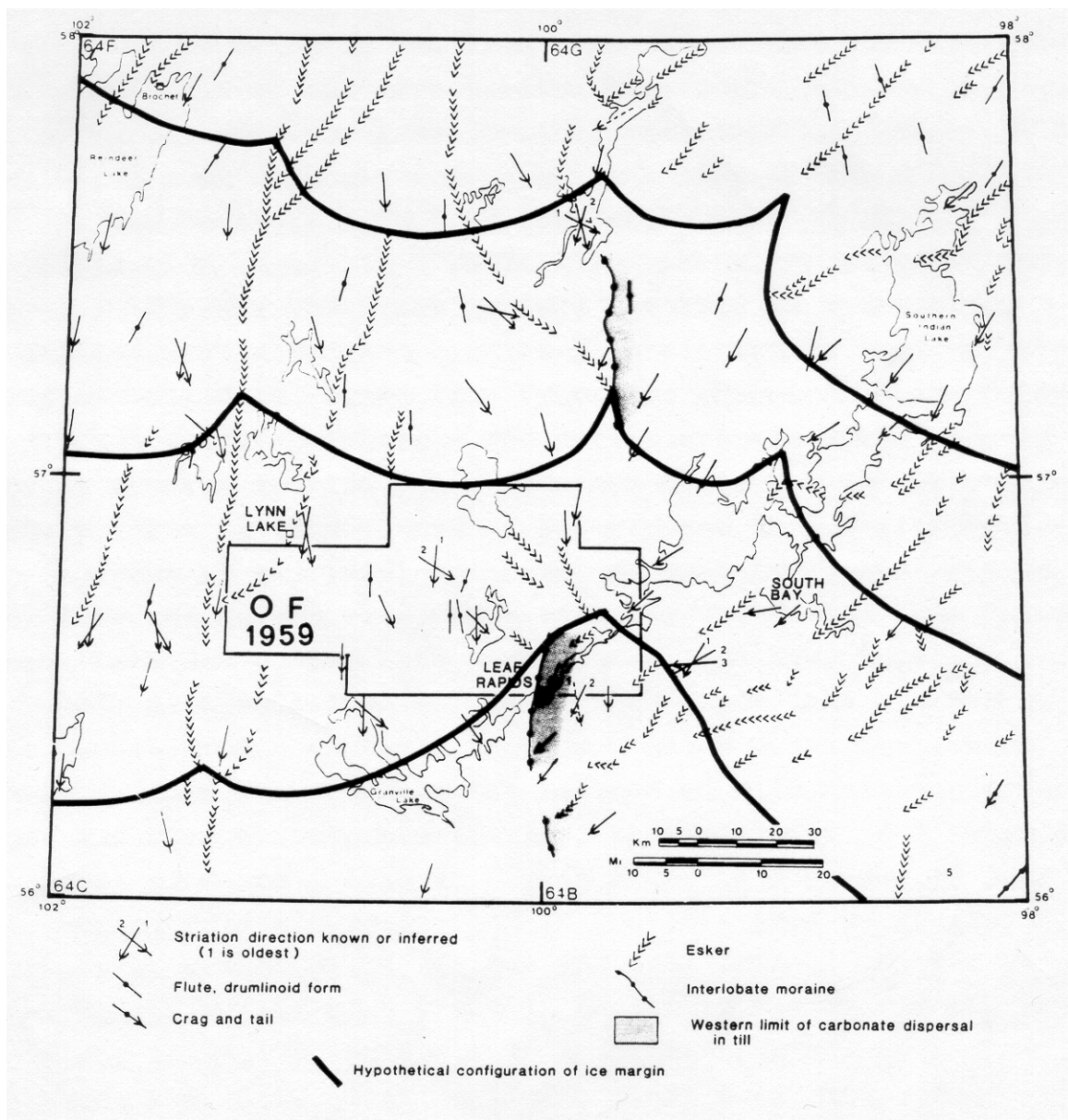


Figure 2. Regional ice movement directions, hypothetical ice margin configurations, and position of Leaf Rapids interlobate moraine (after Kaszycki and DiLabio, 1986).

MINERAL DEPOSITS

The locations and references to over 30 occurrences and deposits in the survey area are shown on the 1:100,000 scale sample location and element value maps accompanying the Open File.

Mineralization occurs throughout the survey area, although the greatest number of occurrences are in metavolcanic and metasedimentary rocks of the Lynn Lake and Leaf Rapids Domains. The known mineral deposits can be classified into two broad categories, each with specific structural, lithologic and geochemical associations. The categories are gold deposits and base metal massive sulphide deposits.

Gold mineralization is predominantly associated with metamorphosed Wasekwan Group volcanic and sedimentary rocks in

the Lynn Lake Domain. Gold mineralization occurs in quartz-carbonate veins and quartz-filled shears, gold-bearing sulphides in sulphide or oxide facies iron formations, or as disseminated gold in silicified and carbonatized host rock. Pyrite, pyrrhotite, magnetite, arsenopyrite, chalcopyrite, galena, and sphalerite most commonly accompany gold mineralization.

In the northern Lynn Lake greenstone belt, gold mineralization occurs in a regionally extensive, well defined sequence of rocks which may include basaltic to ultramafic komatiites, siliceous and biotite-rich siltstones, and sulphide, oxide and silicate facies iron formation (Richardson and Ostry, 1987). Magnetite, pyrrhotite and pyrite are the dominant gold-bearing mineral species. This sequence hosts the MacLellan Mine deposit (2.9 million tonnes of 5.2 g/tonne Au and 11.8 g/tonne Ag; Fedikow et al, 1986) northeast of Lynn Lake, and extends east into the survey area where it hosts the Farley Lake deposit, Nickel Lake and Spider Lake occurrences (Fedikow, 1986).

Gold mineralization in the southern Lynn Lake greenstone belt occurs predominantly along the Johnson Shear Zone which nearly defines the contact zone between ductile Wasekwan Group rocks and more brittle pre-Sickle intrusions. The zone extends from west of Gemmell Lake to Hughes River, a distance of over 50 kilometres. Gold mineralization is characterized by pyrite, pyrrhotite, arsenopyrite, galena and sphalerite in quartz veins or carbonate-quartz-rich zones in competent Wasekwan Group rocks or felsic intrusive rocks within or close to shear zones (Richards and Ostry, 1987; Baldwin, 1987; Peck, 1984; and Ferreira, 1986). Amor (pers. comm) and Schmitt (1989) have found anomalous concentrations of W, Sb and Mo in lake sediments and tills locally associated with gold mineralization in the Foster - Wasekwan Lakes area. Gold deposits along the Johnson Shear Zone include T1A, Burnt Timber, and Cartwright Lake.

The Lynn Lake - Leaf Rapids region contains 4 significant **base metal massive sulphide** deposits, all of which lie just outside the present geochemical survey area. These include the producing Ruttan Cu-Zn deposit east of Leaf Rapids, and past producing Fox (Cu-Zn), A (Ni-Cu-Co), and EL (Ni-Cu) mines. The deposits are hosted by metavolcanic or associated gabbroic intrusions of the Lynn Lake or Leaf Rapids Domains. In the survey area 15 base metal mineral localities are hosted by similar rocks. Mineralization consists mostly of disseminated to semi-massive pyrite and/or pyrrhotite with variable amounts of chalcopyrite and sphalerite (Baldwin, et al., 1985). At Nickel Lake, Fedikow and Eccles (1985, 1987) reported mineralization enriched in Fe and Cu with variable Au, Ag, and W in high Mg-Cr volcanic and sulphide-rich metasedimentary rocks analogous to the MacLellan Mine and Farley Lake deposit stratigraphy.

In the southeastern-most part of the survey area, south of Rusty Lake, exploration drilling of several sub-parallel geophysical conductors delineated disseminated to semi-massive

Fe-sulphide layers with traces of chalcopyrite in schistose to gneissic metasedimentary rocks (Baldwin, 1982).

The following types of mineralization, while not reported from the survey area, are potential exploration targets based on geology and known occurrences outside the survey area.

- a) U,F and rare earth element (La,Ce,Sm,Tb,Yb,Lu) mineralization in alkaline intrusions and pegmatites especially in the Eden Lake area (McRitchie, 1988).
- b) Au paleoplacer deposits in basal polymictic conglomerates of the Sickie Group (Baldwin, 1980).
- c) Au,Ag,W in granitoid-hosted quartz-vein shear environments. Several significant Au deposits have recently been discovered in granitoid rocks in and adjacent to the LaRonge greenstone belt (Thomas and Watters, 1987; Yaychuk, 1987), considered to be the Saskatchewan extension of the Lynn Lake Domain. Similar deposits may be hosted in granitoid rocks adjacent to the Lynn Lake and Leaf Rapids Domains.

The following table summarizes mineral deposit types, lithology and geochemical signatures which may be reflected as possible element associations in the centre-lake sediments.

DEPOSIT TYPE	LITHOLOGIES	ELEMENT ASSOCIATION
Gold: vein, disseminated, shear zone sulphide/oxide/silicate facies Fe formation	Wasekwan Group metavolcanics, metasediments, ultramafic to felsic intrusions	Au,Fe,Ag,Cu,As Zn,Pb,Sb,W,Mo Mg,Cr,Fe,As
Base metal: disseminated to massive	Basaltic to rhyolitic meta-volcanics and derived meta-sediments. Ultramafic to basic intrusions	Fe,Cu,Zn,Pb,Cd Ag,Au Cu,Ni,Co
Gold paleoplacer	Sickie Group, basal polymictic conglomerate	Au,W?,Sn?
Uranium and REEs	Differentiated felsic and alkaline intrusions, pegmatites	U,F,Mo,Sn,W La,Ce,Sm,Tb,Yb, Lu,Li,Ta,Be,Cs, Nb

SURVEY METHODOLOGY

Infill lake sediment and water samples were collected during a helicopter-supported program by GSC personnel in 1987, and during a limited float plane and inflatable boat supported program in 1985 and 1988. In 1983 and 1984 lake sediment and water samples were collected by contract survey firms (see acknowledgements) according to instructions and specifications administered by the Geological Survey of Canada. Sampling rates for helicopter-supported phases of the program ranged from 12 to 18 sites per hour.

Augmentation of the original surveys by the infill sample collection resulted in a nominal sample site density of 1 site per 3.5 square kilometres, although actual site density ranges from >1 site per 1 square kilometre along the Johnson Shear Zone and in the Farley Lake area, to 1 site per 8 square kilometres west of Eden Lake.

Preferred sample sites consisted of the profundal basin of a lake 1 - 5 square kilometres in area, 3 - 5 metres deep, and part of an active drainage system. During the 1987 infill survey however, water bodies ranging from <.5 square kilometres to major bays of lakes >20 square kilometres were sampled in order to achieve effective representation of specific geological units.

Lake sediments were collected using a modified model of the GSC 1976 lake sediment sampler (Coker et al, 1979). The top several centimetres of the sediment column was discarded, retaining thixotropic gel-like material which was placed in high wet-strength paper bags for drying and transport to the sample preparation laboratory. Less common sample types included H₂S-rich organic gels and organic-deficient silty material.

Lake waters were routinely collected at sediment sites in 250 mL Nalgene bottles from at least 30 centimetres below the water surface.

To monitor and control sampling and analytical variance, each block of twenty samples included a field duplicate, blind duplicate (sample split) and control reference sample.

SAMPLE AND FIELD DATA PROCESSING

Sample processing was carried out by qualified contract firms under the supervision of GSC personnel. Lake sediments were air dried at no greater than 35°C, ball-milled and sieved to -177 micron size. Next, duplicate and reference samples were inserted, and samples analyzed by contract analytical firms for some or all of Zn, Cu, Pb, Ni, Co, Ag, Mn, As, Mo, Fe, Hg, U, F, V, Cd, Sb, W, Ba, Sn, Au, and loss-on-ignition (a measure of organic content). Repeat analyses were requested for an analytical block of twenty samples if control sample values fell outside accepted ranges. Repeat analyses were requested for Au for nearly all samples, for some samples a total of three analyses were

performed. All analytical methods are summarized in Appendix 1.

Lake waters were shipped to Ottawa where GSC personnel verified and inserted control reference samples prior to shipment to the contract laboratory. Water samples were analyzed for some or all of pH, U, F, Ca, Mg, Alkalinity, plus a multi-element suite by ICP spectrometry for the 1987 samples which provided detectable levels for Na, Sr, and Ba. As, Hg, Mn, and Pb values were below or just at the detection level. Water analytical methods are summarized in Appendix 1.

Field data were coded on standard GSC lake sediment and water cards. The keypunched file was transferred from the VAX 1180 computer to an Olivetti 386 micro-computer for merging with analytical data and file editing. Sample sites were transferred from 1:250,000 field traverse maps to a stable base at the same scale, digitized at the GSC, and the UTM location file merged with field and analytical data. Sample location plots for verification were produced with a Cyber 730 computer linked to a Calcomp drum plotter.

Data were processed for listings and summary statistics using software developed by H.A. Gross in the Exploration Geochemistry Subdivision.

Regional symbol-trend maps were produced by A.C.Galletta using APPMAP (Geochemistry Subdivision designed graphics utilizing UNIRAS software) and final plots prepared by the OPTRONIX Laser plotter located at Environment Canada, Canada Lands Data Systems (CLDS) in Hull, Quebec. Reproduction of the Open File material was carried out at Ashley Reproductions in Ottawa prior to final assembly at the GSC.

PRELIMINARY DATA INTERPRETATION

GENERAL CONSIDERATIONS

The geochemistry of lake sediments and lake waters depends largely on the chemical composition of surrounding geology and composition of adjacent surficial deposits which provide the main sources of trace elements. The degree of mobility of trace elements is influenced by the nature of the interactions between these geologic units and surface or groundwaters in the weathering environment. Base and precious metals are typically released to the environment through the oxidation and breakdown of sulphide minerals in bedrock and surficial deposits.

pH and alkalinity concentrations in lake waters, and Fe, Mn, and LOI (organic content) of lake sediments provide us with evidence for assessing the degree of mobility and scavenging processes that may influence trace element concentrations (Friske, 1985; Maurice, 1984).

Areas of low relief typically have higher concentrations of decomposing organic matter. The low relief throughout much of the survey area suggests that hydromorphic and metal-organic processes likely dominate over mechanical processes in controlling secondary dispersion patterns. Organic matter can enhance or retard metal mobility by forming soluble or insoluble colloidal compounds and sulphides by bacterial reduction. The sympathetic relationship between Hg and LOI is an illustration of one of these processes. For the survey area, surficial environments are characterized by oxidizing, pH 5 - 8 conditions. Following Rose (1979) and Friske (1985), the relative mobility of elements can therefore be given as:

Mo > F ≈ Zn ≈ Ag ≈ F ≈ U ≈ As ≈ Hg ≈ Sb > Mn ≈ Pb ≈ Cu ≈ Ni ≈ Co
> Cd ≈ W > Fe > Sn ≈ Au

However, the element distribution patterns from this Open File and other recent workers (Davenport and Nolan, 1989; Schmitt, 1989) have shown that even the "immobile" elements such as Au and Sn show significant surficial dispersion patterns in lake sediments.

Hydrous Fe and Mn oxides are well-known for their ability to scavenge trace elements such as Co, Ni, Zn, and As, thus creating false anomalies unrelated to local background concentrations. This effect is generally diminished in deeper, organic-rich lakes where reducing conditions prevail, causing the Fe-Mn oxides to destabilize. Nevertheless there may be a general trend for increased Fe and Mn concentrations to occur in areas underlain by mafic meta-volcanics, basic intrusives, and argillaceous or Fe-rich metasedimentary rocks.

Multivariate statistical analysis can be used effectively to discriminate between element concentrations in lake sediments that are likely to represent actual mineralization or geological units that exhibit significant mineral potential, and environmental effects (Wright et al, 1988). Although such analyses are beyond the scope of this report, the element-symbol-trend plots included with the Open File are the first step towards a qualitative preliminary interpretation of the data. The data were plotted using an inverse distance function ($1/d^3$) applied to the nearest 5 data points. The effect of this moving average technique is to accentuate regional features and de-emphasize minor irregularities (noise) that may be attributable to local environmental controls. Combined with the symbols, the plots are effective in delineating major rock units with elevated chemical concentrations or chemically distinctive surficial units. Clusters of symbols designating upper percentile values within a prominent regional trend may represent mineral deposits exposed to the weathering environment.

The following discussions are based on some of these general considerations, and a review of the element-symbol trend plots along with reference to local geology and mineral deposits.

ELEMENT DISPERSION PATTERNS IN LAKE SEDIMENTS

LOSS ON IGNITION

Loss on ignition provides a measure of the organic content of the lake sediment. 76% of the samples have values that fall between 15% and 60% LOI. In this concentration range, trace metal response is relative insensitive to organic content (Lynch et al, 1973). At lower and higher LOI values trace metal response may be suppressed; high metal contents in these sediments may therefore be considered anomolous given average concentrations of Fe, Mn and other environmental factors. Still other elements are relatively unaffected by very high or low concentrations of organic material. In low lying areas where organic-rich lake sediments tend to predominate, metal-organic interactions may exert controls on the mobility of metals.

Fe and Mn

High concentrations of Fe and Mn appear to be related to oxidizing, low LOI, large lake environments rather than to bedrock geologic factors. Thus a few very high Fe and Mn values exert a profound effect on these element regional distribution patterns. This feature is especially notable for samples collected from large bays around the periphery of Opachuanau Lake. Elsewhere, Fe and Mn are typically low adjacent to Fe-formations such as those within the Agassiz Metallotect and south of Rusty Lake. These areas are low lying and contain small, organic-rich lakes where reducing conditions likely predominate in lake-bottom sediments.

Co and Ni

These two siderophile elements have generally coincident patterns with Fe and Mn, with which they are commonly associated in bedrock environments. In addition, Co and Ni readily co-precipitate with hydrous Fe-Mn oxides, so some of the high values may represent "false anomalies".

Ni exhibits two trends that appear to be related to basic intrusions. East of Sickie Lake, elevated Ni values in lake sediments most likely reflect elevated Ni contents in a large gabbro body (unit 19-B). South of Anson Lake, high Ni values are related to Wasekwan Group metavolcanic and amphibolite rocks, or possibly unmapped basic phases of the Poole Lake intrusive suite.

Cu, Pb, Zn, Cd, and Hg

The chalcophile elements Cu, Pb, Zn, Cd, and to some degree, Mo, As, and Ag are contained in a variety of base metal sulphide and precious metal deposits. These elements behave similarly under surficial chemical conditions, and hence their secondary dispersion patterns are often similar.

Areas of low concentrations of these elements in the central survey area coincide with neutral pH, high alkalinity waters, suggesting that secondary dispersion is inhibited due to relatively less favourable conditions for the formation of

soluble complexes. By comparison adjacent areas of lower pH and lower alkalinity exhibit enhanced concentrations of the chalcophile elements.

West of Opachuanau Lake, Pb, Cu, Zn, As, and to a lesser extent, Au, are enriched in organic-poor lakes with acid to alkaline waters. The pronounced coincident trace metal response suggests a major bedrock control, possibly related to Wasekwan amphibolites nearby and in the up-ice direction.

North of the Barrington River, a 10 kilometre east-west trend of elevated Pb concentrations is coincident with a granitoid pluton. Since no other elevated chalcophile elements are associated with this trend, the high Pb values probably represent elevated natural background levels in a potassic granite.

A cluster of elevated Zn concentrations in the vicinity of Hughes Lake coincides with elevated Fe, Mn, and As values adjacent to several Fe-Cu occurrences (nos, 13, 14, and 15) hosted by Wasekwan metavolcanic rocks. The element distribution patterns suggest that additional metavolcanic-hosted mineralization may exist to the north, east of Chepil Lake.

East of Barrington Lake, elevated Cu, Cd, As, and Hg occur several kilometres east and in the up-ice direction of documented Fe-Cu occurrences in Wasekwan metalvolcanic rocks. The zone of multi-element anomalies suggests that nearby amphibolite and mafic metavolcanic rocks are enriched in these chalcophile elements and may host polymetallic base metal sulphide mineralization.

Southwest of Barrington Lake, elevated Cu concentrations at Nickel Lake are related to mineralization along the Agassiz Metallotect and adjacent mafic volcanic rocks.

The other major Cu-elevated zone occurs east of Sickie Lake to southeast of Black Trout Lake. Local geology includes gabbro, diorite, and amphibolite cross-cut by several major north-trending regional faults. The area also contains anomalous concentrations of Cd, Hg, Mo, Zn, Ni, and Au which indicates potential for a variety of polymetallic mineralization styles. It is perhaps notable that no occurrences are documented from this area, considering the strength of the multi-element anomaly.

Cd values are typically low throughout much of the survey, however, a prominent trend of elevated concentrations extends for over 10 kilometres southeast of the Johnson Shear Zone from the vicinity of Foster and Wasekwan Lakes. At Foster and Reservoir Lakes, elevated Cd values are closely associated with elevated Zn in lake sediments adjacent to observed disseminated sphalerite mineralization along the Johnson Shear Zone. The regional Cd trend therefore probably indicates analogous mineralization styles in Wasekwan metavolcanic rocks extending southeast of Wasekwan Lake. The linear and lobate shape of the trend also indicates a degree of glacial transport influence on the Cd distributions.

Ag

Ninety-eight percent of the survey samples have Ag concentrations at or below the detection level. A cluster of 5 detectable concentrations occur west of Barrington Lake in areas underlain by the northern Lynn Lake greenstone belt. Three of these samples lie along the Agassiz Metallotect, which is known to contain Ag-bearing sulphide mineralization.

As, Mo

The distribution of As and Mo in lake sediments is generally similar in the western part of the survey; in the east half, broad zones of moderately elevated As concentrations occur, whereas Mo concentrations are generally low.

Surficial weathering of sulphide-facies iron formation units at Gordon and Farley Lakes has given rise to a major coincident As, Mo anomaly in lake sediments. In addition, high concentrations of Mo occur in granitoid rocks at their contacts with metavolcanic rocks, suggesting vein-type or disseminated mineralization different from the Agassiz Metallotect style of mineralization. The elevated As and Mo concentrations extend to the south for nearly 20 kilometres. This feature may reflect glacial transport processes of major regional proportions. However, the underlying geological units are locally enriched in Mo and As, and contain mineral occurrences with variable concentrations of Mo and As. Hence, the geochemical patterns cannot be easily explained, certainly they represent a complex overlap of Mo/As-enriched bedrock sources, glacial dispersion and post-glacial weathering processes.

A major concentration of high As values at the western edge of the survey straddles the western end of the Johnson Shear Zone, and is the southern extension of a major regional elevated As trend that covers the western end of the Lynn Lake greenstone belt (GSC OF 1288). Numerous occurrences of Fe-S-As>Cu>Zn-Pb>Ag-Au mineralization associated with mafic to felsic metavolcanic rocks, volcanic-derived metasediments and basic to felsic intrusions along the Johnson Shear Zone and outside the western survey boundary are the likely source of the As. Glacio-fluvial processes may also have contributed to the widespread dispersion of As as evidenced by several esker complexes. The strength of the As anomaly indicates a favourable geological environment for discovery of further As (Au)-enriched deposits.

Au

Several recent studies on the distribution of Au in lake sediments (Davenport and Nolan, 1989; Schmitt and Friske, 1987; and Schmitt, 1989) illustrate that the problems posed by low Au concentrations in lake sediments (measurable concentrations are typically only a few ppb above detection levels) combined with sampling and analytical errors, can be overcome. Increased sampling density, repeat analysis of all samples, especially low LOI sediments, and application of smoothing techniques to display data, can all be used to achieve meaningful interpretation of the

data. Most importantly, major gold deposits may be reflected by only a few ppb Au in lake sediments. For example, the nearest sampled lake to the Burnt Timber deposit has a value of 3 ppb, whereas Farley Lake downstream of the Farley Lake deposit which is buried beneath thick surficial deposits, returned values in the 1 to 3 ppb range.

The regional distribution of Au in lake sediments in the survey area is characterized by numerous single point anomalies and several clusters of high values, only one of which can be adequately explained by known mineralization.

Cluster 1: The Foster - Wasekwan - Reservoir Lake area contains Au values ranging from <1 to 30 ppb. They are derived from auriferous sulphide-bearing quartz veins and disseminations along the Johnson Shear Zone. Elevated concentrations of As, Sb, Mo, and W are locally associated with Au. A broad zone of Au values in the 80 - 90 percentile range south of the Johnson Shear Zone may be related to granitoid-hosted quartz vein mineralization such as that documented for granitoid rocks within and adjacent to the LaRonge greenstone belt (Thomas and Watters, 1987).

Cluster 2: East of Sickie Lake, one Au value >98 percentile is flanked to the northwest and southwest by numerous values in the 70 - 90 percentile range of the data set. The underlying geology consists of gabbro, tonalite and amphibolite cross-cut by major northerly trending faults. Cu, Cd, Hg, Mo, and Zn are also elevated in lake sediments from this area.

Cluster 3: A cluster of high Au values (1 > 98 percentile, 3 in the 95 - 98 percentile range, and 4 in the 90 - 95 percentile range) trends across Highway 391 north of the Churchill River. The anomalous trend lies along the eastern contact of a large megacrystic granitic pluton with a tonalite intrusion. None of the chalcophile elements are similarly elevated in this area, despite acid pH levels in lake waters which indicate that these elements would be mobile in this environment. The Au anomaly appears unrelated to exposures of metavolcanic rocks about 10 kilometres to the northeast, and therefore suggests the possibility of hitherto unrecognized granitoid-hosted Au mineralization, or Au-enriched intrusions.

Sn

Sn analyses of lake sediments were restricted to the infill samples. Little is known about the controls on the distribution of Sn in lake sediments and so only general observations can be made.

Elevated Sn concentrations near Hunter Lake occur where Sickie Group sandstone and quartzo-feldspathic gneiss are intruded by Black Trout Lake diorite.

A pronounced zone of high Sn values northeast of Eden Lake is underlain by megacrystic granite, pegmatites, and uraniferous rare earth element-bearing alkaline intrusions (Cameron, 1988; McRitchie, 1988).

U and F

U in lake sediments and waters, and F in lake waters, exhibit the most pronounced regional concentrations above background values. A zone of anomalous U up to 20 kilometres wide and nearly 40 kilometres long coincides with the Eden intrusive suite in the west and tonalite in the east near Opachuanau Lake. The high U and F concentrations appear to be influenced by a variety of factors including; high background values in bedrock, exposed alkaline intrusions that buffer water pH and allow soluble U and F complexes to form, and calcareous tills in the east that similarly enhance U and F mobility.

ELEMENT DISPERSION PATTERNS IN LAKE WATERS

pH

pH of surface lake waters ranges from 4.8 to 8.7. Nearly 75% of lake waters exhibit pH values in the neutral range of 6.4 to 7.5, although the mean value of all samples is 6.7. Prominent clusters of acidic ($\text{pH} < 6.3$) waters occur overlying the large gabbro body east of Sickie Lake, along the Agassiz Metallotect, and over various intrusive rocks partly exposed or mantled by a thin veneer of surficial deposits. Alkaline ($\text{pH} > 7.7$) lake waters occur where calcareous metasediments of the Sickie Group are exposed, and elsewhere throughout the central and east parts of the survey area where carbonate-bearing tills have been documented (Kaszycki and Dilabio, 1986).

Ca, Mg, Na, Sr, and Alkalinity

Ca, Mg, Na, Sr, and Alkalinity display generally similar distribution patterns, they are higher in the eastern part of the survey area, reflecting the presence of carbonate-bearing tills. Within this regional high are interspersed low alkalinity waters which may indicate thin to patchy carbonate-bearing till cover where bedrock compositions exert greater influence on surface water compositions.

In the Farley Lake area high Mg, Ca and alkalinity waters are related to calcareous metasediments, high Mg basalts, and possibly carbonate alteration zones. The concentration of these elements in waters along the Agassiz Metallotect may be an important local constraint on the mobility of certain chalcophile elements.

As, Hg, Pb, Mn, and Ba

The concentrations for these elements were generally at or below the detection level of the ICP analytical method employed, hence element-symbol plots are not included.

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APPENDIX 1

ANALYTICAL PROCEDURES

LAKE SEDIMENTS:

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

For the determination of Zn, Cu, Pb, Ni, Co, Ag, Mn, Fe, Cd, and As a 1 gram sample was reacted with 6 mL of a mixture of 4 M HNO₃ 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 sample 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. Detection levels for Zn, Cu, Pb, Ni, and Co = 1 ppm. Detection level for Ag = 0.2ppm.

Arsenic was determined by atomic absorption using a hydride evolution method wherein the hydride (AsH₃) 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). Detection limit = 1 ppm.

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 HNO₃ at 90°C for 30 minutes. At this point 0.5 mL concentrated HCl was added and the digestion was 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. Detection limit = Mo 2 ppm; V 5 ppm.

Hg

Mercury was determined by the Hatch and Ott Procedure with some modifications. The method is described by Jonasson et al. (1973). A 0.5 gram sample was reacted with 20 mL concentrated HNO₃ 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 SnSO₄ in M H₂SO₄. 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. Detection limit = 10 ppb.

LOI

Loss on ignition was determined using a 500 mg sample. The sample, weighed into 30 ml beaker, was placed in a cold muffle furnace and brought up to 500°C over a period of 2 - 3 hours. The sample was left at this temperature for 4 hours, then allowed to cool to room temperature for weighing. Detection limit = 1.0 pct.

U

Uranium was determined using a neutron activation method with delayed neutron counting. A detailed description of the method is provided by Boulanger et al (1975). In brief, a 1 gram sample is weighed into a 7 dram polyethylene vial, capped and sealed. The irradiation is provided by the Slowpoke reactor with an operating flux of 10^{12} neutrons/sq cm/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 60 seconds with six BF₃ detector tubes embedded in paraffin. Following counting, the samples are automatically ejected into a shielded storage container. Calibration is carried out twice a day as a minimum, using natural materials of known uranium concentration. Detection limit = 0.5 ppm.

F

Fluorine was determined in lake sediments as described by Ficklin (1970). A 250 mg sample is sintered with 1 g of a 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 fluoride content of the test solution is then measured using a fluoride ion electrode. Standard solutions contain sodium carbonate and citric acid in the same quantities as the sample solution. Detection limit = 20 ppm.

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 concentrated HCl are added and the mixture is allowed to stand overnight at room temperature. The mixture is heated slowly to 90°C and maintained at this temperature for at least 90 minutes. The solution is cooled and diluted to 10 mL with 1.8 M HCl . The antimony in an aliquot of this dilute solution is then determined by hydride evolution - atomic absorption spectrometry. Detection limit = 0.2 ppm.

W

Tungsten was determined as follows: A 0.2 g sample of lake sediment was fused with 1 g $\text{K}_2\text{S}_2\text{O}_7$ 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 5 mL 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 dithiol solution (1% dithiol in iso-amyl acetate) was added to the test solution and the test solution was then heated for 4 - 6 hours at $80 - 85^\circ\text{C}$ 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). Detection level = 2 ppm.

Ba

Barium was determined as follows: A 0.25g 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 DCP emission spectroscopy. Detection level = 40 ppm.

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. Detection level = 1 ppm.

Au

Gold was usually determined on a 10 g lake sediment sample; depending on the amount of sample available, lesser weights were sometimes used. This resulted in a variable detection limit: 2

ppb 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 one hour, cooled for four hours, and counted by gamma ray spectrometry. Calibration was carried out using standard and blank beads.

LAKE WATERS:

pH

Hydrogen ion activity (pH) was measured with a combination glass-calomel electrode and a pH meter.

F

Fluoride in lake 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 as follows: to 50 mL metal free water add 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 one litre in a volumetric flask. Detection limit = 20 ppb.

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 instances at the GSC where the reaction of uranium with fluran is either delayed or sluggish; for this reason an arbitrary 24 hour time delay between the addition of the fluran and the actual reading was incorporated into this method. 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. Detection limit = 0.05 ppb.

Alkalinity

Alkalinity in waters was determined by titrating a 25 mL aliquot of the sample with 0.02 N H₂SO₄ using a Corning combination electrode and a Corning model 135 pH meter. The end point was pH 4.5. Detection level = 2 ppm.

Ca, Mg, As, Ba, Hg, Mn, Na, Pb, and Sr

Ca, Mg, As, Ba, Hg, Mn, Na, Pb, and Sr in waters 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. Detection level = Ca 0.2 ppm; Mg 0.02 ppm; As 0.05 ppm; Ba 0.1 ppm; Hg 0.01 ppm; Mn 0.01 ppm; Na 1 ppm; Pb 0.05 ppm; Sr 0.01 ppm.

APPENDIX 2

PRESENTATION AND INTERPRETATION OF GOLD DATA

The following discussion reviews the format used to present the Au geochemical data and outlines some important points to consider when interpreting this data. This discussion is included in recognition of the special geochemical behaviour and mode of occurrence of Au in nature and the resultant difficulties in obtaining and analyzing samples which reflect the actual concentration level at a given site.

To correctly interpret Au geochemical data from regional stream sediment or lake sediment surveys requires an appreciation of the unique chemical and physical characteristics of Au and its mobility in the surficial environment. Key properties of Au that distinguish its geochemical behaviour from most other elements include (Harris, 1982):

- (1) Au occurs most commonly in the native form which is chemically and physically resistant. A high proportion of the metal is dispersed in micron-sized particulate form. Gold's high specific gravity results in heterogeneous distribution, especially in stream sediment and clastic-rich (low LOI) lake sediment environments. Au distribution appears to be more homogeneous in organic-rich fluvial and lake sediment environments.
- (2) Gold typically occurs at low concentrations in the ppb range. Whereas gold concentrations of only a few ppm may represent economic deposits, background levels encountered from stream and centre-lake sediments seldom exceed 10 ppb, and commonly are near the detection limit of 1 ppb.

These factors result in a particle sparsity effect wherein very low concentrations of Au are heterogeneously enriched in the surficial environment. Hence, a major problem facing the geochemist is to obtain a representative sample. In general, the lower the actual concentration of Au the larger the sample size, or the smaller the grain size required to reduce uncertainty over whether subsample analytical values truly represent actual values. Conversely, as actual Au concentrations increase or grain size decreases, the number of Au particles to be shared in random subsamples increases and the variability of results decreases (Clifton et al., 1969; Harris, 1982). The limited amount of material collected during the rapid, reconnaissance-style regional surveys and the need to analyze for a broad spectrum of elements, precludes the use of a significantly large sample weight for the Au analyses.

Therefore, to the extent that sample representivity can be

increased, sample grain size is reduced by sieving and ball milling of all samples.

The following control methods are currently employed to evaluate and monitor the sampling and analytical variability which are inherent in the analysis of Au in geochemical mediums:

- (1) For each block of twenty samples:
 - (a) random insertion of a standard reference sample to control analytical accuracy and long-term precision;
 - (b) collection of a field duplicate (two samples from one site) to control sampling variance;
 - (c) analysis of a second subsample (blind duplicate) from one sample to control short-term precision.
- (2) For both stream sediments and lake sediments, routine repeat analyses on a second subsample are performed for all samples having values that are statistically above approximately the 90th percentile of total data set. This applies only to gold analyses by fire assay preconcentration followed by neutron activation. Such routine repeat analyses are not performed for INA analyses of archived samples.
- (3) For lake sediments only, a routine repeat analysis on a second subsample is performed on those samples with LOI values below 10%, indicating a large clastic component. On-going studies suggest that the Au distribution in these samples is more likely to be variable than in samples with a higher LOI content. Again, routine repeat analyses are performed only when the fire assay preconcentration/neutron activation method is used.

Au data presentation, statistical treatment and the value map format are different than for other elements. Au data listed in the open file may include initial analytical results, values determined from repeat analyses, together with sample weights and corresponding detection limits for all analyzed samples. The gold, statistical parameters and regional symbol trend plots are determined using the following data population selection criteria:

- (1) Only the first analytical value is utilized.
- (2) Au values determined from sample weights less than 10 g are excluded, except where determined by instrumental neutron activation analyses.

- (3) Au values less than the detection limit (<1 ppb) for 10 g samples are set to 0.5 ppb.

On the value map, repeat analysis values, where determined (not field duplicates), are placed in brackets following the initial value determination. All values determined on a sample less than 10 g are denoted by an asterisk. Actual sample weight used can be determined from the text. Following are possible variations in data presentation on a value map:

*	no data
+27	single analysis, 10 g sample weight
+27*	single analysis, <10 g sample weight
+27(14)	repeat analysis, both samples 10 g
+27(14*)	repeat analysis, first sample 10 g, repeat <10 g
+<1	single analysis, 10 g sample, less than detection limit of 1 ppb

In summary, geochemical follow-up investigations for Au should be based on a careful consideration of all geological and geochemical information, and especially a careful appraisal of gold geochemical data and its variability. In some instances, prospective follow-up areas may be indirectly identified by pathfinder element associations in favourable geology, although a complementary Au response due to natural variability may be lacking. Once an anomalous area has been identified, field investigations should be designed to include detailed geochemical follow-up surveys and collection of large representative samples. Subsequent repeat subsample analyses will increase the reliability of results and permit a better understanding of natural variability which can then be used to improve sampling methodology and interpretation.

APPENDIX 3

FIELD DATA DESCRIPTIONS

The following list presents sample field record definitions and text codes where applicable.

RECORD	DEFINITION	CODE
MAP	NTS lettered quadrangle	
SAMPLE ID	Year	19XX
	Field Crew	1,3,5,7,9
	Sample sequence number	001-999
UTM	Universal Transverse Mercator coordinate system; digitized location	
ZN	Zone	7-22
EASTING	in metres	XXXXXX
NORTHING	in metres	XXXXXX
ROCK TYPE	Major rock type of lake catchment area, see geology map for legend	X to XXXX
AGE	Stratigraphic age of rock type	XX
LAKE AREA	Pond, 1/4 to 1 sq. km, 1 to 5 sq km., >5 sq km.	
LAKE DEPTH	metres	
REP STAT	Replicate status, relationship of sample to others in the sequence;	
	routine field sample	00
	first of field duplicate	10
	second of field duplicate	20

RELIEF	Relief of the catchment basin;	
	low	lw
	medium	md
	high	hi
CONT	Sample contamination;	
	none	-
	work	wo
	camp	ca
	fuel	fu
	gossan	go
SAMPLE COLOUR	Sediment sample colour, up to 2 colours may be chosen;	
	tan	tn
	yellow	yl
	green	gn
	grey	gy
	brown	br1
	black	bk
SUSP MATL	Suspended matter in water;	
	none	-
	heavy	hvy
	light	lgt