STOCK NO. 13804

Ministry of Northern Development and Mines

Ontario

MINES AND MINERALS DIVISION
ONTARIO GEOLOGICAL SURVEY

MAP 80 806

GEOCHEMICAL SURVEY

HANES LAKE AREA

NTS References: 41 O/4, 41 J/13

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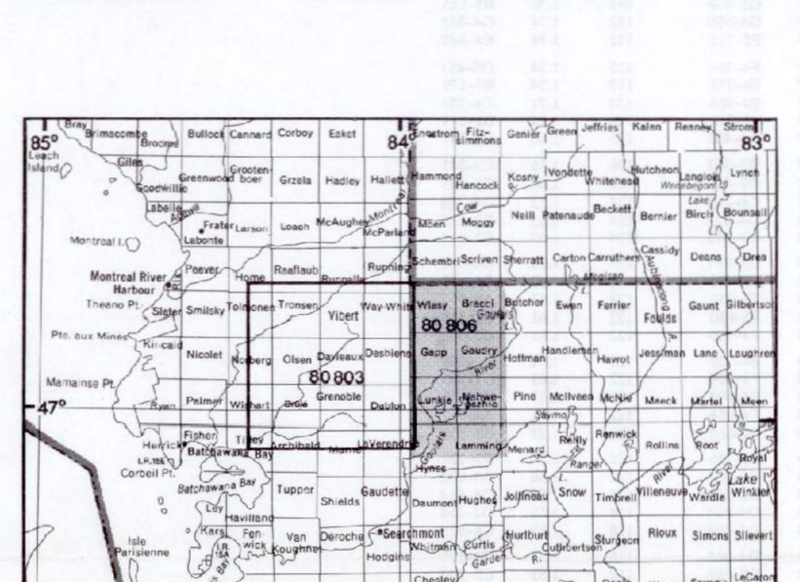
CANADA ONTARIO Mineral Development Exploration Minérale

This project is part of the five-year Canada-Ontario 1985 Mineral Development Agreement (COMDA), a subsidiary agreement to the Economic and Regional Development Agreement (ERDA) signed by the governments of Canada and Ontario.



"Static geochemistry, which deals with the distribution of the elements in various geological objects, is the basis for dynamic geochemistry studying migration, concentration, and dispersion of the elements due to geological processes."

A.A. Beus (1976, p.41)

INTRODUCTION

The Hanes Lake geochemical map area is a part of a regional geochemical survey of the entire Batchawana greenstone belt being completed by the Ontario Geological Survey (OGS) over a multi-year period (*see* Location Map). The Hanes Lake area is adjacent to, and east of, the Trout Lake area. A geochemical survey of the Trout Lake area was released previously (Fortescue and Vida 1989).

The geochemical map described here is based on results obtained using standardized field, laboratory and data processing methodologies (Figure 3). The format of geochemical maps in this series was standardized for comparative purposes as discussed by Fortescue, Vida and Nakashima (1989).

Regional geochemical maps are primarily designed for mineral resource appraisal purposes. They provide a more accurate description of the geochemistry of an area than the traditional reconnaissance geochemical mapping techniques applied in Ontario during the 1970s and 1980s (Friske 1985). Another aim of the regional geochemical maps is to provide geochemical information of a comparable scientific standard to data obtained from regional geological and geophysical maps completed in the same area. This is particularly important when geoscience image processing and geographical information systems (GIS) are used (Figure 2).

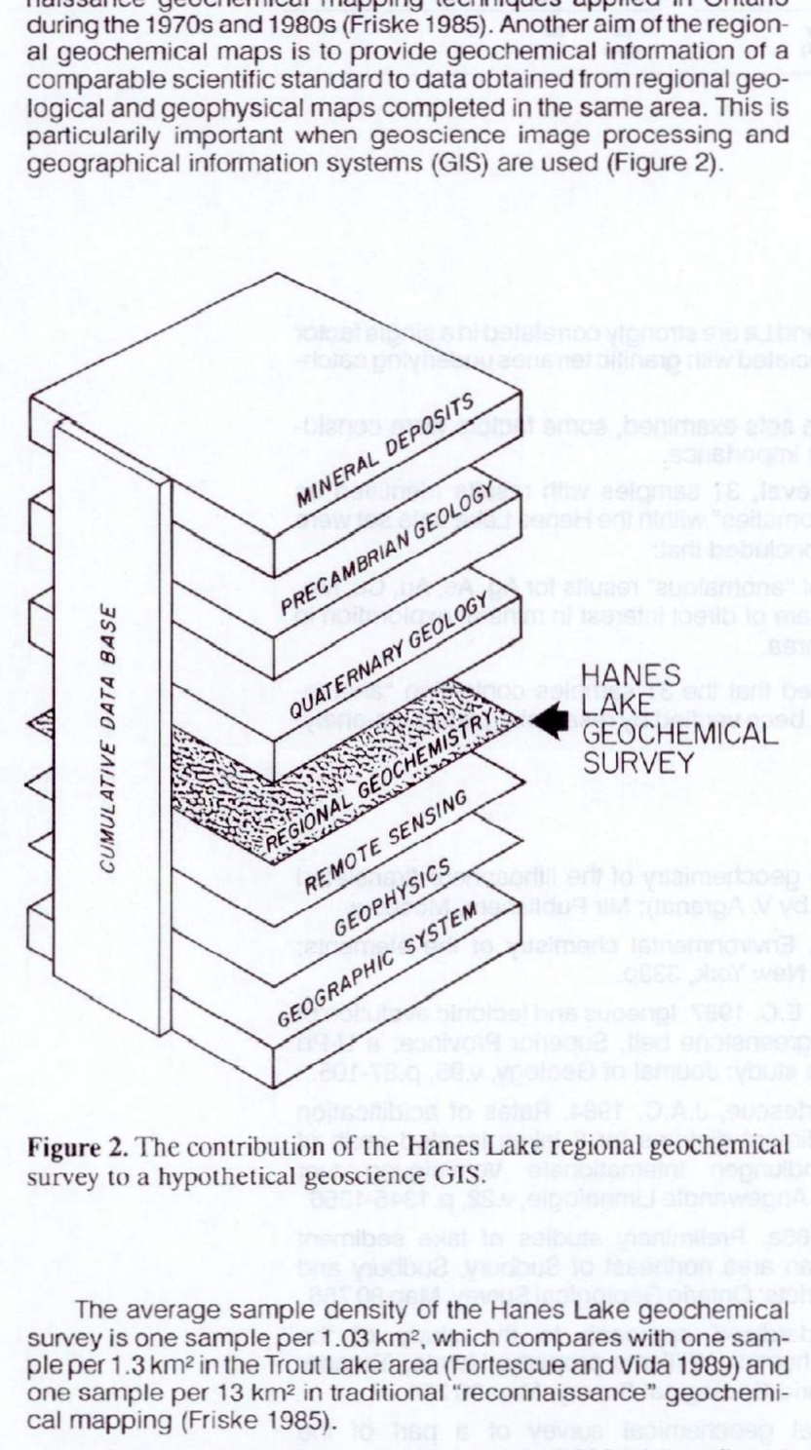


Figure 2. The contribution of the Hanes Lake regional geochemical survey to a hypothetical geoscience GIS.

The average sample density of the Hanes Lake geochemical survey is one sample per 1.03 km², which compares with one sample per 1.3 km² in the Trout Lake area (Fortescue and Vida 1989) and one sample per 13 km² in traditional "reconnaissance" geochemical mapping (Friske 1985).

In August and September 1989, a total of 896 lake sediment cores and water samples were collected from the Hanes Lake area. Sediment collection included 1) 683 pre-*Ambrosia* samples, 2) 95 mixed pre- and post-*Ambrosia* samples, and 3) 118 post-*Ambrosia* samples. Refer to Figure 1 for the locations of the three different kinds of lake sediment core samples. Information stored on the data base diskette(s) includes all geochemical data for the three types of lake sediment in separate files.

This preliminary interpretation of the geochemical data obtained from the Hanes Lake area is based on the 683 pre-*Ambrosia* lake sediment samples. Lake water sample data were also used in the compilation of this geochemical map.

All chemical analyses of lake sediment collected from both the Trout Lake and Hanes Lake area were completed by Chemex Labs Ltd. of Mississauga, under contract to the OGS. Identical sample preparation techniques and methods of chemical analysis were employed by the contractor for both projects (Figure 3).

The concentrations of 35 elements (plus loss on ignition (LOI)) were determined in each of the lake sediment samples. The pH of cooled lakewater samples was measured within 24 hours of their collection. Levels of Ca and Mg in the waters were determined by the OGS Geoscience Laboratories in Toronto.

The entire Hanes Lake geochemical map data base is available on diskette(s) in ASCII format on request from the Geophysics/Geochemistry Section, OGS. Information stored on the diskette(s) also includes some tabulated data referred to in the marginal notes but not listed in full on this sheet.

For readers without access to a computer, a list of the 100 highest geochemical results for each of the 35 elements included in the survey is provided on Table 1 (on the reverse side of this map). Table 1 was assembled by: 1) ranking all 683 sample results for an element from highest to lowest, and 2) listing the top 100 values in ppm and Clarkes (*see* below) with their respective sample code information. The lake codes facilitate fast location of sample sites of interest, listed on Table 1 and plotted on Figure 1 (see caption for Table 1 for explanation). Also, on Table 1, the pH data for 99 lakewater samples are listed. They include the lowest 49 and the highest 50 pH values within the entire data set, and are accompanied by their respective Ca and Mg values. Similarly, the LOI data were ranked from the lowest (i.e., mineral rich) value, to the highest (i.e., organic rich) value. The lowest 100 LOI values are included in Table 1 to indicate mineral-rich samples.

A comprehensive interpretation of the geochemical data base, using advanced statistics, image processing and/or a geographical information system (GIS) is beyond the scope of this broadsheet.

Geochemical sampling in support of this map sheet was carried out during August and September 1989 by J.A.C. Fortescue, E.A. Vida, A. Nakashima and G. Lillie. This broadsheet was prepared during the spring and summer of 1990.

OBJECTIVES

The Hanes Lake geochemical survey had the following objectives:

1. to complete a regional-level, mineral resource appraisal, geochemical survey of a 20 km by 35 km area in the eastern part of the Batchawana greenstone belt
2. to determine the concentrations of 35 elements (Ag, Al, As, Au, Ba, Be, Bi, Br, Ca, Cd, Co, Cr, Cu, Fe, Hf, K, La, Lu, Mg, Mn, Mo, Na, Ni, P, Pb, Sb, Sc, Sr, Ta, Th, Ti, U, V, W and Zn), plus LOI, in pre-*Ambrosia* lake sediments collected from all lakes and ponds in the survey area, and to determine the pH, and Ca and Mg contents of lakewaters collected from each sample site
3. using the standardized format, to provide an introduction to the interpretation of element patterns in the geochemical data base at the global (provincial), regional and detailed levels
4. at the detailed level of investigation, to identify geochemical targets of possible importance in mineral exploration

DESCRIPTION OF THE HANES LAKE AREA

Location

The Hanes Lake area is in the Batchawana greenstone belt some 50 km northeast of Sault Ste Marie (*see* Location Map).

The 700 km² area includes all of Bracci, Gaudry and Nahwegezhic townships, most of Wlasy, Gapp, Lunkie, Hynes and Lamming townships and very small portions of Butcher, Hoffman, Pine and Menard townships.

Bedrock Geology

Grunsky (1980, 1981, 1982, 1983, 1984, in prep.), described the geology and geological setting of the Hanes Lake area as a part of the Batchawana Synoptic Project. The Welcome Lake–Ranger Lake sheet provided the 1:50 000 scale geological map for the entire Hanes Lake area (Grunsky 1987). The geology near Cowie Lake, in the extreme southern part of the Hanes Lake area, was described by Grunsky (1980). The Cowie Lake report also includes a 1:31 680 scale geological map.

The geology of the entire Batchawana greenstone belt, including the Hanes Lake area, was described in a comprehensive report by Grunsky (in prep.). Details of age relationships among the lithologic units of the Batchawana greenstone belt are described by Corfu and Grunsky (1987). These references should be consulted for detailed geological information in the Hanes Lake area.

The Hanes Lake map area incorporates the eastern limit of the Batchawana greenstone belt, which is bounded by granitic terranes. The greenstone belt is composed of Archean metavolcanic and metasedimentary rocks. These rocks were structurally deformed, metamorphosed, hydrothermally altered, faulted and intruded by felsic plutonic rocks. Later on, the entire area was intruded by mafic intrusive rocks (gabbro) and by many diabase dikes. The predominant strike of the dikes is 330° with secondary dikes striking 55° (Grunsky, in prep.).

Figure 1 shows the general geology in the Hanes Lake area. Diabase dikes were omitted from Figure 1 because they usually contribute little to the volume and geochemistry of the rocks in catchment areas where they are found.

The geology of the Batchawana greenstone belt and its surrounding granitic rocks are divided by Grunsky (1983) into four major lithotectonic domains. Three of these domains; 1) the Algoma plutonic domain, 2) the Ramsey gneiss domain, and 3) the Batchawana metavolcanic domain underlie the Hanes Lake area.

Granitic rocks of the Algoma plutonic domain occur in the southern part of the Hanes Lake area. Gneissic rocks of the Ramsey gneiss domain are located along the northern and eastern boundaries of the map area (Figure 1). The eastern metavolcanic domain, which is the youngest volcanic cycle in the greenstone belt, occurs in the west central area of the Hanes Lake area. The rocks in this unit range in composition from mafic to felsic.

The metasedimentary rocks in the eastern metavolcanic domain are bounded by mafic metavolcanic rocks on the north side and by felsic metavolcanic rocks on the south side (Figure 1). The Goulais River iron range is a large northwesterly trending mass of chemically deposited iron oxide facies (ironstone) within the eastern metavolcanic rocks (Grunsky, in prep.). The bedrock geology in the Hanes Lake area is further complicated by late massive felsic intrusive rocks in the Ramsey gneiss domain (Corfu and Grunsky 1987).

Further details of geology, geochemistry and age relationships among different rock types in the Hanes Lake area are described in the references cited above.

A total of 51 mineral occurrences have been reported in the Hanes Lake area (Figure 1). Further details of these occurrences may be obtained from the Resident Geologist's office, Ministry of Northern Development and Mines, Sault Ste. Marie.

Quaternary Geology

The Quaternary geology of the Hanes Lake area was described by VanDine (1980) and Roed and Hallett (1980). VanDine (1980) described the Quaternary geology of the Hanes Lake area from its southern margin to lat. 47°00′N. Roed and Hallett (1980) described the Quaternary geology of the rest of the area. (Figure 1). These references should be consulted for information beyond this summary.

In the Hanes Lake area, the last glacial advance was towards the south-southwest. The advancing ice collected all types of sediment and boulders, and this material was later deposited as moraines of various types. In some areas, ground moraines composed of tills were deposited as thin discontinuous layers. During deglaciation, meltwaters from the decaying ice mass laid down sand and gravel upon the outwash plains, further complicating the statigraphy of surficial deposits in the area. In the west-central part of the Hanes Lake map area, the ground moraine complex covers most of the mafic metavolcanic rocks and parts of the felsic metavolcanic rocks (Figure 1).

Since deglaciation, flood-plain alluvium has been deposited along the rivers and streams in the area. These deposits are mainly composed of silty sand and gravel. In addition, organic deposits have accumulated in bedrock depressions and in poorly drained river valleys.

In summary, because thick Quaternary cover is relatively uncommon in the Hanes lake area, the conditions are favourable for regional geochemical mapping. The one exception is the area of discontinuous ground moraine covering the eastern mafic metavolcanic rocks (Figure 1).

The relief in the Hanes Lake area is usually greater than 60 m, except in the morainal terrains where it ranges between 15 and 60 m, and in the glaciofluvial terrains where it is usually less than 15 m (Roed and Hallet 1980). These relief features favour regional geochemical mapping.

The Hanes Lake area now supports a zonal forest soil associated with vigorous deciduous, coniferous and mixed-wood forest growth. There has been extensive logging during the past 100 years and there is clear evidence of recent major forest fires in the southern part of the area.

METHODOLOGY

This description of the Hanes Lake geochemical survey is largely based on pre-*Ambrosia* lake sediment core and water data. All samples were collected by staff of the OGS using a Bell 206 helicopter equipped with floats. The sediment was collected using a gravity core sampler described by Fortescue (1988). At each lake site, the lake sediment cores were extruded from the core sampler on the helicopter float (*see* Fortescue 1988).

Geochemical data from 683 pre-*Ambrosia* lake sediment samples and water samples are the basis for the Hanes Lake map sheet. Data for the 95 mixed sediments and 118 post-*Ambrosia* sediments are included on the data base diskette(s) in separate files. Their locations are displayed on Figure 1.

Figure 3 is a flow diagram of the standardized methodology employed for the Hanes Lake survey. Details of the techniques involved are further described in Fortescue and Stahl (1988).

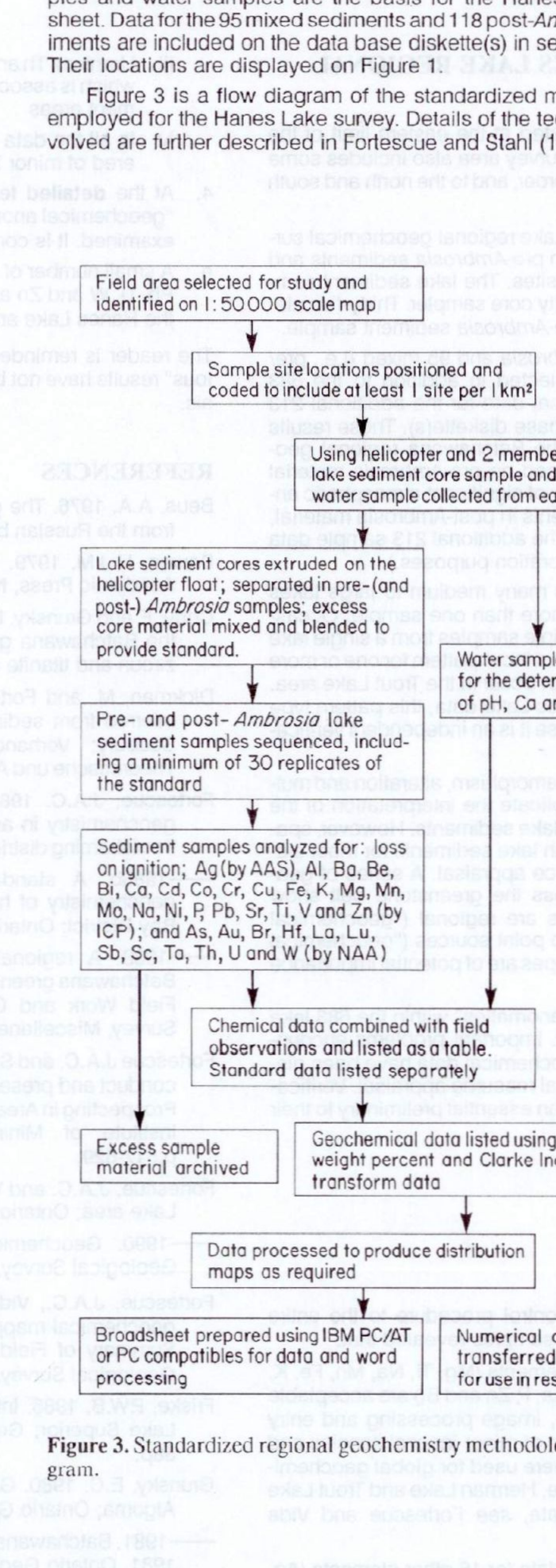


Figure 3. Standardized regional geochemistry methodology flow diagram.

Pre-*Ambrosia* Sediment

Detailed palynological investigations of lake sediment cores collected from central Ontario (completed by Professor Dickman and his research team from Brock University working with the OGS) indicated that the "*Ambrosia* pollen rise" in mid-basin lake-sediment cores is always 14 to 18 cm below the water-sediment interface (Dickman and Fortescue 1984; Fortescue 1985a). This "*Ambrosia* pollen rise" is known to be associated with an ecological event which took place over 100 years ago.

Geochemical studies by limnologists, and others, have established that after deposition, vertical movement of elements in central lake-basin sediments is minimal. Consequently, midlake basin pre-*Ambrosia* material is the preferred sample medium for regional geochemical surveys.

Chemical Analyses of Lake Sediment Samples

Prior to chemical analyses, each sample was 1) dried at 80°C, 2) pulverized (using a zirconium oxide ring pulverizer) and, for some elements, 3) subjected to a hot acid leach (including HF). The concentrations of 35 elements were determined in each sample using a combination of Atomic Absorption Spectroscopy (AAS), Inductively Coupled Plasma Spectrometry (ICP) and Neutron Activation Analysis (NAA) methods (*see* Table 1). Note that Zr is not determined in the lake sediment samples using this methodology.

The Clarke Index-1

The Hanes Lake geochemical data set is described in these notes using weight % units (i.e., % or ppm) and Clarke index units (K) (*see* Table 1). In order to simplify the interpretation of regional geochemical patterns, weight % data for each element were normalized using the Clarke Index-1 (Fortescue 1985b). The Clarke Index-1 values were derived from Ronov and Yaroshevski (1972) and Bowen (1979) and they have been used in all OGS geochemical mapping publications since 1980.

RESULTS AND DISCUSSION

The diskette(s) available with this broadsheet contains full details of 1) water and lake sediment geochemistry, 2) locational information (i.e., latitude and longitude and Universal Transverse Mercator (UTM) co-ordinates), and 3) field observations (e.g., Secchi depth and lake depth), for the 683 sample sites in the Hanes Lake area. Other data base files containing the same type of information as above are included on the diskette(s) for the 95 mixed samples and 118 post-*Ambrosia* samples. The chemical data recorded in the data base are exactly as they were received from the contractor and are assumed to be correct. None of the data have been verified by resampling or by repeat analysis of selected samples.

General information on the abundance of each element in the entire Hanes Lake data set is provided in summary statistics printed below each element column on Table 1. The Clarke Index-1 values in ppm units are also included in Table 1.

PERFORMANCE OF THE ANALYTICAL METHOD

Replicates of two lake sediment reference standards are sequenced with the Hanes Lake unknown samples for quality control purposes. The data derived from these standards are included on the data base diskette(s) as 1) the raw quality control data ("StdHanes" file) and 2) summary statistics derived from these data (Table 2). These tables are the basis for a discussion of the performance of the analytical methods.

During geochemical mapping and interpretation, it is important to know the reliability of data for each element. Consequently, each regional geochemical mapping project includes appropriate rules for describing the performance of the analytical methods used. "Acceptable" element data sets for detailed statistical analysis are identified using this criteria. The data listed on Table 2 (on the data base diskette(s)) were used for assessing details of the performance of the chemical methodology on a element to element basis.

In the current OGS regional geochemical map series, data for an element is considered acceptable if the coefficient of variation (C.V.) for that element in a reference standard is less than 16 %. Two reference standards (Hanes 1, n = 69 and Hanes 2, n = 15) are replicated in the Hanes Lake area unknowns (n = number of samples). The results from these analyses are the determining factors for element acceptability for statistical analysis of the complete data base.

Using these criteria, 15 elements (Cu, La, V, and Zn in the first grouping on Table 2; Al, Ca, Fe, K, Mg, Mn, Na, P, Sr and Ti in the second grouping; and Br in the third grouping) were "acceptable" in both Hanes Lake sediment standards.

In comparison with the performance data for the Trout Lake map area (Fortescue and Vida 1989), the data in the Hanes Lake area for Ba, Th, Sc and U are not "acceptable" because their C.V. is greater than 16%. This suggests that the reference standards used in the Hanes Lake data set may not be completely mixed. To accomodate these elements in geochemical signatures, the C.V. limit of 16% used in the Trout Lake data set was raised to 20% in the Hanes Lake data.

When this 20% limit is applied to the Hanes Lake performance data, the following additional elements, As, Ba, Co, Cr, Lu, Ni and Th were "acceptable". Note, Lu was completely "unacceptable" in the Trout Lake standard quality control data.

In a previous map sheet (Trout Lake), a Global Datum Signature (GDS) was created from the 19 "acceptable" analytical performance quality control elements (i.e., Al, Ca, Mg, Na, K, Mn, P, Sr, Ti, Ba, Cu, La, Sc, U, V, Zn, Fe, Th and Br (Fortescue and Vida 1989)). The GDS explained below was used for comparative purposes among the lake sediment data sets. Because the analytical performance of the Hanes Lake standards was very similar to the performance measured previously, it was decided to use the "acceptable" elements from the Trout Lake data to make identical geochemical signatures in both map sheets.

Other elements have 1) low levels in the standards 2) a small range of values and 3) a relatively high C.V. This group includes Mo and Sb (Table 2) which are clearly close to the detection limit of the analytical methods.

Data for Ag and Au are particularly important for the success of regional geochemistry. The range of Ag levels listed in Table 2 is clearly unsatisfactory. For this reason, only Ag values greater or equal to 2 ppm are considered to be acceptable in the Hanes Lake data. The gold values in the quality control data set have a relatively high detection limit of around 2 ppb. Coefficients of variation of 393.25% (largely due to a single high value of 342 ppb) at the 10.45 ppb mean level (Hanes 1), and 41.82% at the 64.33 ppb mean level (Hanes 2) indicate the performance of the analytical method at these low Au ppb levels. Because 40 Au values are greater than 5 ppb in the unknown samples from the Hanes Lake data set, values greater than this level are considered acceptable for consideration in mineral resource appraisal.

Six of the elements in the third group in Table 2 (Be, Bi, Cd, Hf, Ta and W) rarely met the performance standard discussed above. These elements are included in the geochemical discussion because they are of particular importance in mineral resource appraisal.

Previous work has shown that Br is usually accumulated by organic lake sediments independently of the presence of mineral deposits (Fortescue and Vida 1989,1990). For this reason, this element was included in the third group in Table 2, even though the Br data were relatively reliable.

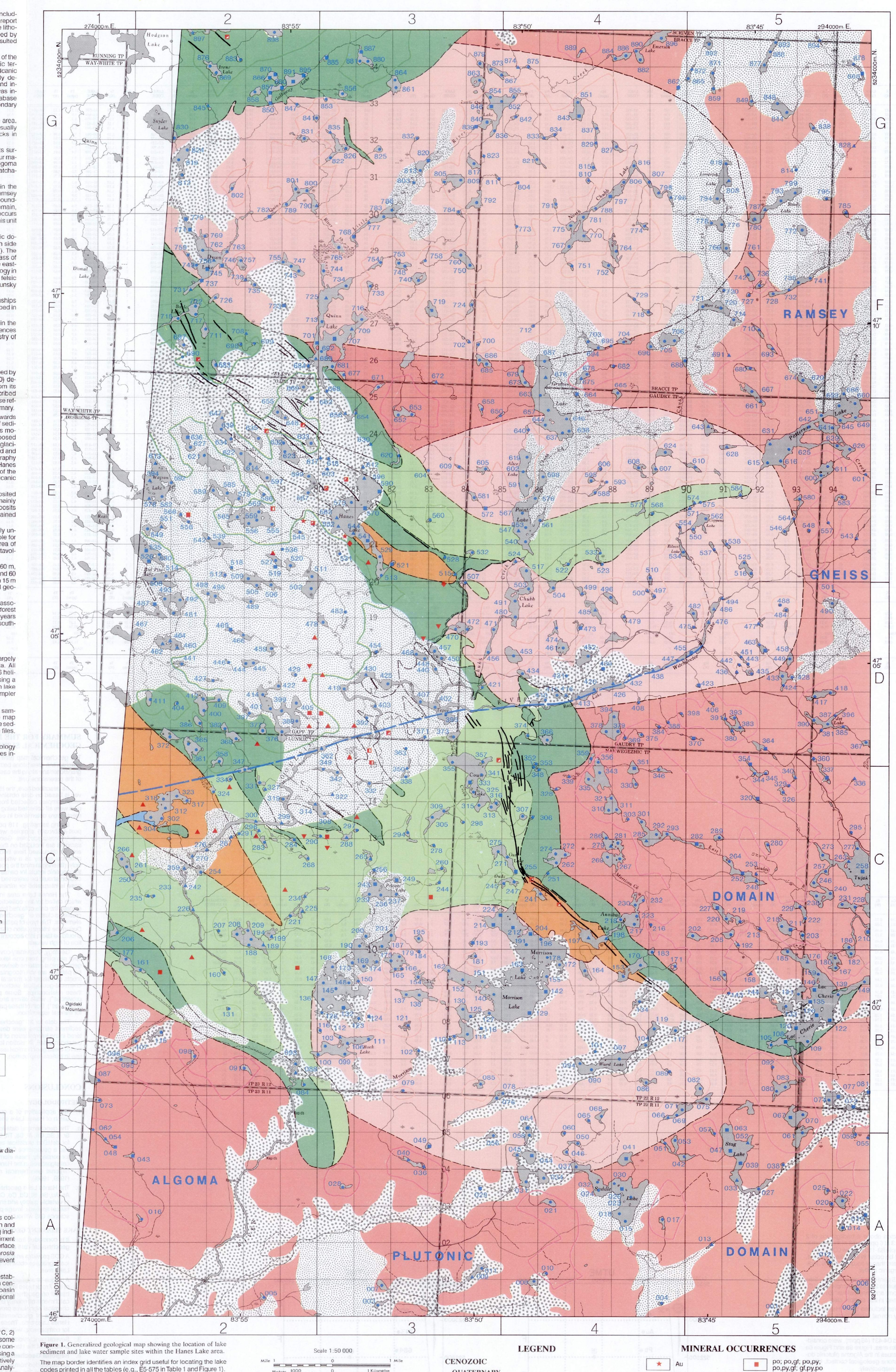


Figure 1. Generalized geological map showing the location of lake sediment and lake water sample sites within the Hanes Lake area.

The map border identifies an index grid useful for locating the lake codes printed in all the tables (e.g., E5-575 in Table 1 and Figure 1).

UPPER CASE LETTER (northing index lines) = the first letter in the lake code column in the tables.

SECOND NUMBER (easting index lines) = the second number in the lake code column in the tables.

LEGEND

CENOZOIC

QUATERNARY

- **Morainal:** ground moraine
- **Glaciofluvial:** outwash plain, valley train
- **Organic:** organic terrain

PRECAMBRIAN

PROTEROZOIC

- **Mafic Intrusive Rocks:** gabbro

ARCHEAN

- **Massive Felsic Intrusive Rocks**
- **Felsic Intrusive and Metamorphic Rocks**
- **Chemical Metasediments:** magnetite-chert ironstone
- **Clastic Metasediments**
- **Felsic Metavolcanic Rocks**
- **Mafic Metavolcanic Rocks**

SYMBOLS

- Geological contact
- Fault
- •016 Pre-*Ambrosia* lake sediment core sample location, with reference number
- ▲054 Post-*Ambrosia* lake sediment core sample location, with reference number
- ■487 Mixed pre/post-*Ambrosia* lake sediment core sample location, with reference number

MINERAL OCCURRENCES

- Au
- cp
- Cu,Au,Ag,py,cp; Cu,Zn,Pb,Py,Ni,Ag, Au
- Fe; Mag
- po; po,gf; po,py; po,py,gf; gf,py,po
- py; py,cp; py,gf; py,po
- py,po,cp; py,po,Cu; py,Cu,Pb,Ag,Au; py,Cu,Pb,Au,Ag
- Zn,Pb; Pb,Zn,Cu,py,po,gn, sp,cp,gf

ABBREVIATIONS

Ag	silver	mag	magnetite
Au	gold	Ni	nickel
cp	chalcopyrite	Pb	lead
Cu	copper	po	pyrrhotite
Fe	iron	py	pyrite
gn	galena	spec	specularite
gf	graphite	Zn	zinc

DESCRIPTION OF THE GEOCHEMICAL PATTERNS

Global Level

INTRODUCTION

The term "global" in the OGS geochemical surveys refers to a province-wide (rather than a world-wide) comparison of geochemical data sets.

The objective of the global level interpretation of the Hanes Lake area lake sediment geochemical data is 1) to provide a "global datum signature" (GDS) to facilitate visual comparisons among element abundances and 2) to summarize general relationships among the abundance of the elements listed on Table 3 (on the data base diskette(s)).

A GLOBAL DATUM SIGNATURE (GDS) FOR ONTARIO

A GDS for Ontario-wide, pre-*Ambrosia* lake sediments was constructed as described in Fortescue and Vida (1989). To provide a GDS for the 19 element pre-*Ambrosia* sample data base: 1) elements the Trout Lake and Herman Lake data bases (Fortescue and Vida 1989, 1990) were transformed into Clarke Index-1 units (Fortescue 1985b), 2) both data bases were combined (1688 samples), 3) median (K) values were calculated and ranked from the lowest to the highest values, and 4) median values were graphed on semi-log paper (Figure 4a).

To facilitate map-to-map comparisons, the 19 "acceptable" elements from the Trout Lake area were used for the GDS in the Hanes Lake area. Except for Sc and U in the Hanes Lake quality control data, there is very little difference between the two data sets when C.V. is less than 20% (see above).

USE OF THE GLOBAL DATUM SIGNATURE

The GDS (Figure 4a) was used as a basis for comparisons among the geochemistry of rock types. In order to do this, pre-*Ambrosia* lake sediment sample results from not less than 19 catchments underlain by the same rock type were 1) combined, 2) median values calculated and 3) plotted on the same graph as the GDS (Figures 4b-h).

The coloured lines on Figure 1 represent the limits of catchment area clusters selected to represent a single rock type. It was discovered that the geochemical signatures may vary significantly from rock type to rock type. Small variations in geochemical signatures can easily be recognized.

Figure 4 includes signatures for the GDS and 1) eastern mafic metavolcanic rocks (Figure 4b), 2) felsic metavolcanic rocks (Figure 4c), 3) Ramsey gneiss domain (Figure 4d), 4) Algoma plutonic domain (Figure 4e), 5) northern felsic intrusive rocks (Figure 4f), 6) central felsic intrusive rocks (Figure 4g), and 7) southern felsic intrusive rocks (Figure 4h). Together, these diagrams provide general information on the abundance of the 19 elements in the lake sediments associated with the 7 rock types described above.

During the preliminary stages of the interpretation of geochemical data sets, major and minor differences in geochemical signatures can focus attention on the behaviour of individual elements. Such variations may provide clues of considerable significance in mineral resource appraisal, environmental or forest nutrition studies.

In summary, the 19 element GDS for 1688 pre-*Ambrosia* lake sediments was calculated, graphed and combined with a geochemical signature representing each of the 7 principal rock types in the Hanes Lake area. Variations in the abundance of the 19 elements were observed from rock type to rock type. It was concluded that the GDS-geochemical signature is a useful aid to the general comparison of multielement geochemical data sets.

To facilitate further use of the GDS, a detailed table of the global values for elements analyzed in pre-*Ambrosia* lake sediments is included on the data base diskette(s) as the "globhane" file.

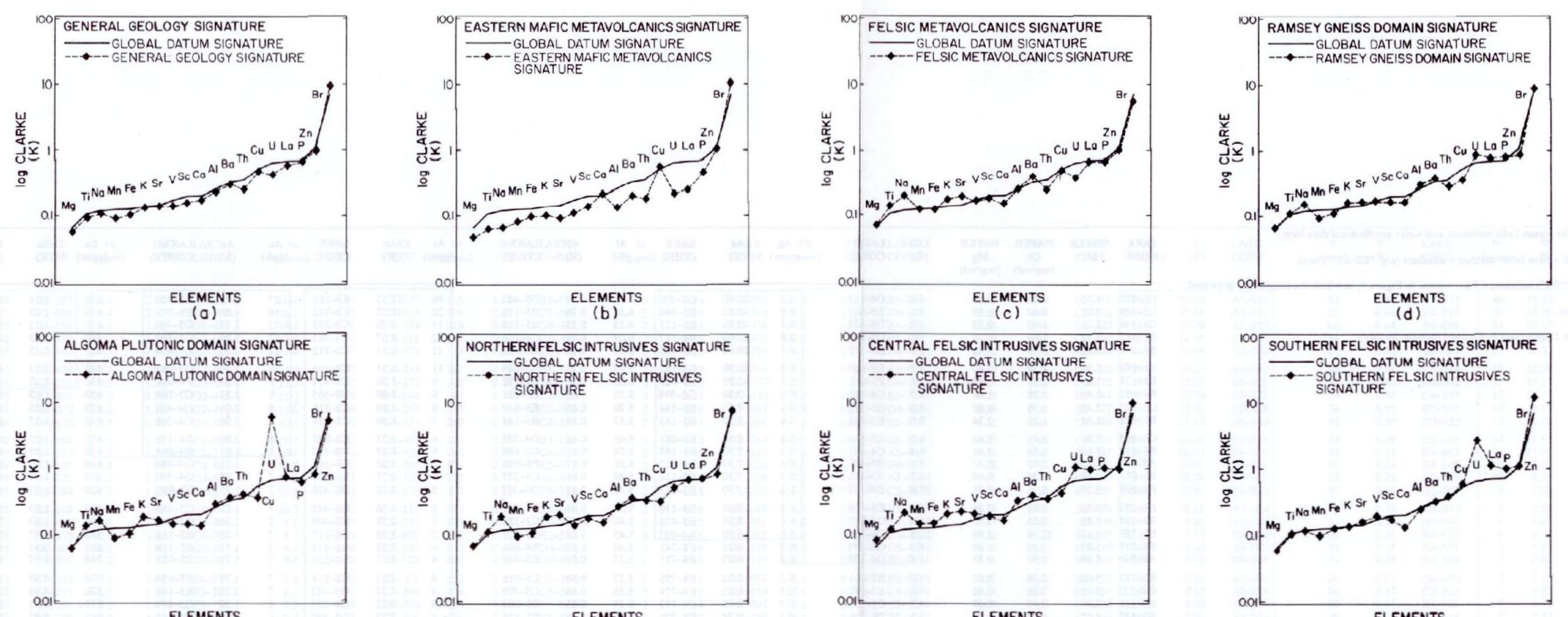


Figure 4. Global multielement Clarke signatures for the Hanes Lake map area including the Global Datum Signature (GDS) and **a)** general geology, **b)** eastern mafic metavolcanic rocks **c)** felsic metavolcanic rocks **d)** Ramsey gneiss domain, **e)** Algoma plutonic domain, **f)** northern felsic intrusive rocks, **g)** central felsic intrusive rocks, and **h)** southern felsic intrusive rocks.

Regional Level

INTRODUCTION

The regional level interpretation of the Hanes Lake geochemical data base has three parts: 1) a description of **regional map patterns** for a) pH, Ca and Mg levels in water samples and b) high values of selected elements in sediments; 2) a description of **geochemical-geological relationships for selected elements** within 5 km map strips for the entire map; and 3) a **principal components analysis (PCA)** of relationships among the 683 pre-*Ambrosia* lake sediment samples.

1. REGIONAL PATTERNS

When the waters and selected element results from the Hanes Lake geochemical survey (Table 1) are plotted, some exhibit more distinct patterns than others. In this section we draw attention to a few representative patterns which may relate to mineral resource appraisal and/or environmental geochemistry of the area.

Lakewaters

Three parameters, pH, Ca and Mg, were measured in the Hanes Lake area waters. These parameters were plotted on base maps showing Quaternary deposits and lake sample sites (Figure 5).

The pH values greater than or equal to 7.7 are seen in Figure 5a. The pH values were high in 1) the outwash plain (west- central map boundary) and 2) the large ground moraine (on the west-central portion of the map).

Previous experience in the Trout Lake area (Fortescue and Vida 1989) showed high pH levels in lake waters were associated with a continuous cover of calcium-rich glacial deposits. In the Hanes Lake area, the plot of pH values less than or equal to 6.0 in Figure 5b substantiates this observation.

Relatively high "Ca" and "Mg" values (greater than or equal to 10 mg/ml and 1.5 mg/ml respectively) in the Hanes Lake water samples are plotted on Figures 5c and 5d. High Ca levels in the lake waters are associated with calcium-rich surficial material in the catchments. Isolated calcium-rich waters in the map area (Figure 5c) are probably associated with the local accumulation of marl in lake sediment.

As expected, Mg levels in areas of calcium-rich glacial deposits are relatively low. Figure 5d shows scattered high water Mg values away from the calcium-rich Quaternary deposits just described.

Pre-*Ambrosia* Lake Sediments

Geochemical patterns derived from mapping high values for 16 elements from Table 1 (boxed areas) are plotted in Figure 6. The 16 geochemical maps include the patterns for U, La, Th, Hf, Mo, W, Bi, Mg, Cu, Pb, Zn, Cd, As, Au, Sb and Ag. "High values" for each individual element were plotted as large dots on a base map for the Hanes Lake area delineating geological contacts, faults and iron ranges of the area. The small dots in the map panels (Figure 6) indicate all 683 pre-*Ambrosia* lake sites sampled in the area. The sample sites for mixed (pre/post) and post-*Ambrosia* samples plotted on Figure 1 are not included in Figure 6.

Regional Map Patterns for U, La, Th and Hf

Regional geochemical patterns for U, La, Th and Hf (Figures 6a, 6b, 6c and 6d) generally indicate areas underlain by granitic terranes. In the Hanes Lake area, the Algoma plutonic domain exhibits higher U values (Figure 6a) than the Ramsey gneiss domain. On the Trout Lake map sheet (Fortescue and Vida 1989), lake sediment analyses in the Algoma plutonic domain indicated there are two lithologic units. This U pattern is also present in the Hanes Lake area.

High Th and La values occur in the massive felsic intrusive rocks and at geological contacts within the granitic terranes (Figures 6b and 6c). The few scattered high La and Hf values in the metavolcanic rocks may by related to the large east-west fault and/or glacial smearing (Figures 6b and 6c).

High Hf values in Figure 6d are scattered in the two granitic terranes and in the massive felsic intrusive rocks. A cluster of high Hf values also occurs in Patterson Lake (eastern limit of the map area).

In fact, high values for Hf, Mg and Bi were discovered in all 10 samples collected from Patterson Lake. This is an example of the delineation of a small multielement geochemical province by repetitive sampling of the same lake. This example also provides independent information on the verification of the lake sediment collection and analyses from a single lake.

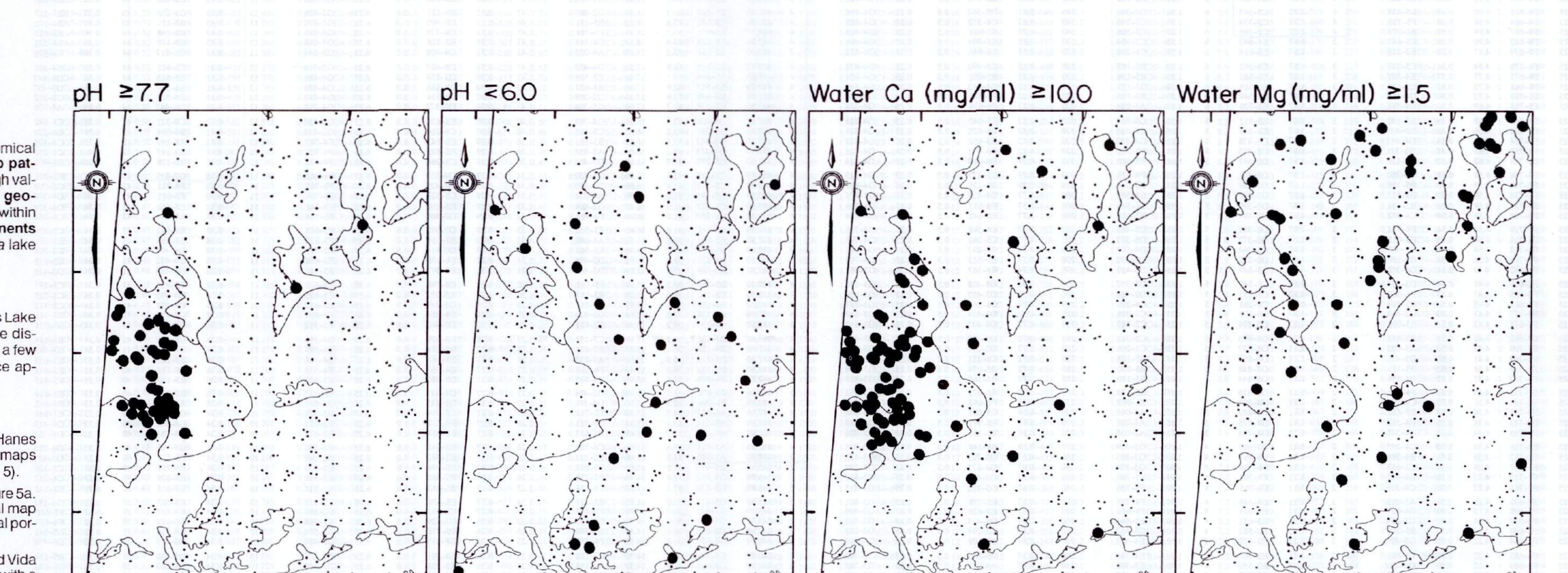


Figure 5. Regional map patterns for pH, Ca and Mg in lakewaters **a)** pH greater than or equal to 7.7, **b)** pH less than or equal to 6.0, **c)** Water Ca greater than or equal to 10.0 mg/ml, and **d)** Water Mg greater than or equal to 1.5 mg/ml.

THESE SMALL MAPS ARE DESIGNED TO DRAW ATTENTION TO GEOCHEMICAL FEATURES OF THE HANES LAKE AREA PRIOR TO THEIR IDENTIFICATION AND STUDY ON FIGURE 1.

TICK MARKS REPRESENTING THE 5 KM² INDEX CODE ON FIGURE 1 ARE ADDED TO EACH MAP PANEL TO FACILITATE LOCATION OF SITES OF INTEREST.

Also of interest is the multielement (Hf, Mg, Th, U) "geochemical linear" along the Goulais River iron range. This linear feature, coinciding with the Goulais River iron range, is best revealed in the Hf (Figure 6d) and Mg (Figure 6h) plots. Note that the Mg linear extends further northwest than the Hf linear.

Regional Map Patterns for Mo, W, Bi and Mg

Clusters of high Mo values occur in the Ramsey gneiss domain, along the granite-greenstone geological contact and in the southern felsic intrusive rocks (Figure 6e).

High W values were found in the area of the Goulais River iron range, at the northern felsic intrusive rocks-Ramsey gneiss domain geological contact, and in the central felsic intrusive rocks (Figure 6f). Other scattered high W values occur in the southern portion of the Ramsey gneiss domain and in the mafic metavolcanic rocks.

In Figure 6g, high Bi clusters occur: 1) at the geological contacts of the two granitic terranes and the massive felsic intrusive rocks; 2) in the area of the Mo cluster in the southern felsic intrusive rocks; 3) associated with the high W clusters in the northern felsic intrusive rocks; and 4) in Patterson Lake discussed previously.

High Mg values are scattered throughout the Hanes Lake area except in the calcium-rich ground moraine on the mafic metavolcanic rocks (Figure 6h).

Regional Map Patterns for Cu, Pb, Zn and Cd

High Cu values are found 1) in the mafic metavolcanic rocks, 2) felsic metavolcanic rocks, 3) near the Goulais River iron range, and 4) at the granite-greenstone contact (Figure 6i).

Seven high Pb values are associated with the granite-greenstone contact and near the Goulais River iron range (Figure 6j). The same number of high Cd values were found in the vicinity of the Goulais River iron range (Figure 6l).

High Zn values occur 1) mainly in the felsic metavolcanic rocks, 2) along the Goulais River iron range, and 3) at the southern felsic intrusive rocks-felsic metavolcanic rocks contact (Figure 6k). High Cu values are generally found in the same location as high Zn values. An exception occurs in the area of the ground moraine discussed above (Figures 6i and 6k).

Regional Map Patterns for As, Au, Sb and Ag

Many high As values occur in mafic metavolcanic rocks covered by calcium-rich surficial deposits. Other high As values are found along the major east-west fault (Figure 6m). The patterns for high As and Sb (Figures 6m and 6o) are similar.

High Au values occur as a geochemical linear, almost parallel to the Goulais River iron range (Figure 6n). The nature of the Quaternary cover over the mafic metavolcanic rocks may explain why no high Au values are associated with this rock type. These Au values should always be verified prior to any exploration activity.

A cluster of relatively high Ag values was discovered in the southern felsic intrusive rocks (Figure 6p).

SUMMARY

The geology of the Hanes Lake area is very complex, especially in the vicinity of the major east-west fault. In such areas, lake catchments are usually underlain by more than one rock type. Exceptions occur in the granitic areas surrounding the greenstone belt. In these areas, U, La and Th patterns usually show a relationship between the geochemistry of underlying rocks and pre-*Ambrosia* lake sediment.

In the Hanes Lake area, multiple samples were collected from many of the large lakes. In theory, this is a limitation of lake sediment regional geochemical mapping because of the resulting cluster effect. In practice, geochemical provinces, such as that described for Patterson Lake, may accentuate the importance of a particular catchment for mineral resource appraisal.

Figures 6a to 6p provide a general introduction to the interpretation of regional geochemical patterns in the Hanes Lake data base set. The objective of these small map panels is to draw attention to sample sites of interest which may be a) identified on Figure 1, and b) examined in Table 1 for their geochemical values. A detailed interpretation of an area, on a sample-to-sample basis is always required to extract all geochemical information from the data base.

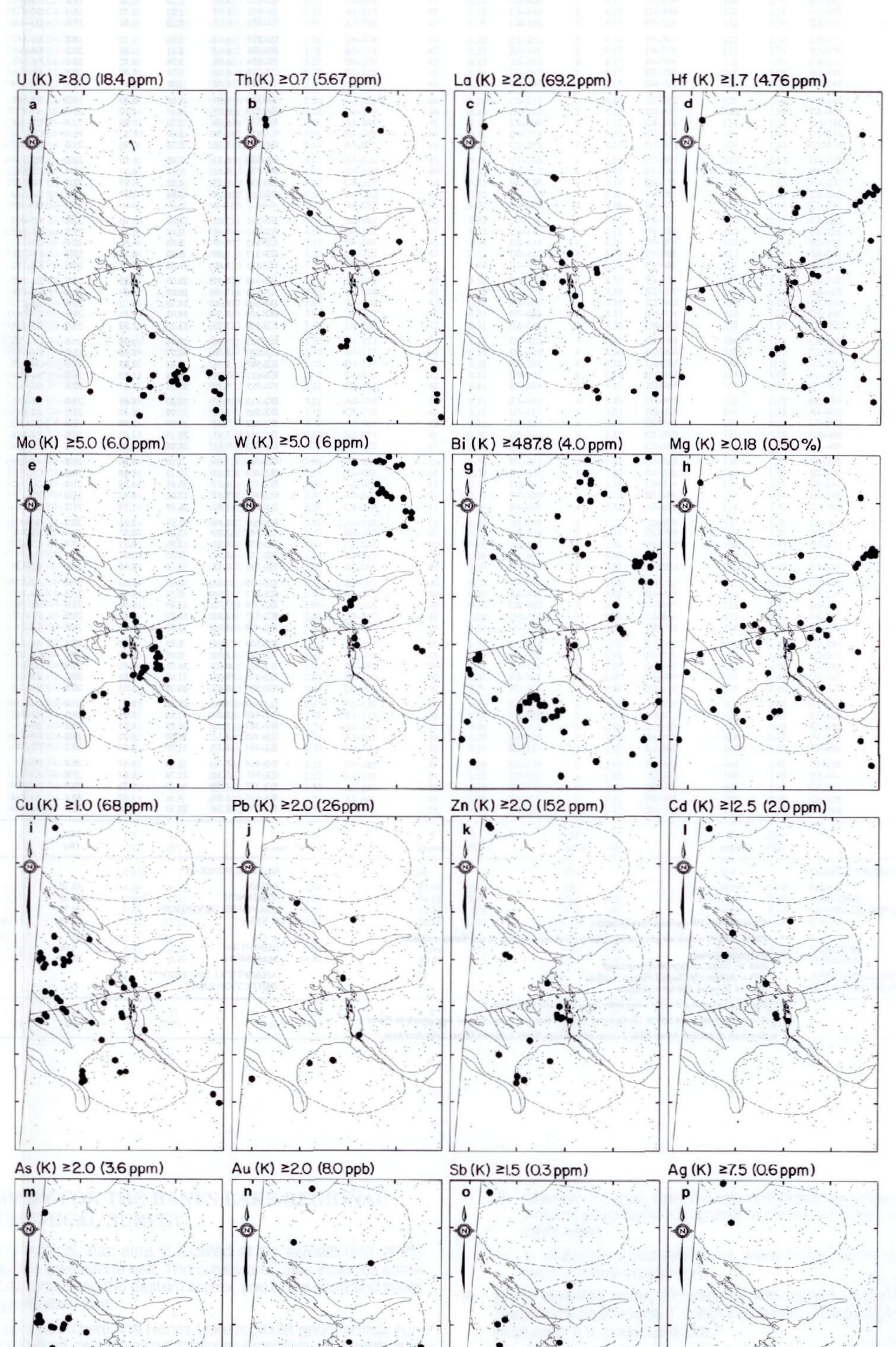


Figure 6. Regional map patterns for elements in pre*Ambrosia* lake sediments. *See* text for explanation.

THESE SMALL MAPS ARE DESIGNED TO DRAW ATTENTION TO GEOCHEMICAL FEATURES OF THE HANES LAKE AREA PRIOR TO THEIR IDENTIFICATION AND STUDY ON FIGURE 1. TICK MARKS REPRESENTING THE 5 KM² INDEX CODE ON FIGURE 1 ARE ADDED TO EACH MAP PANEL TO FACILITATE LOCATION OF SITES OF INTEREST.

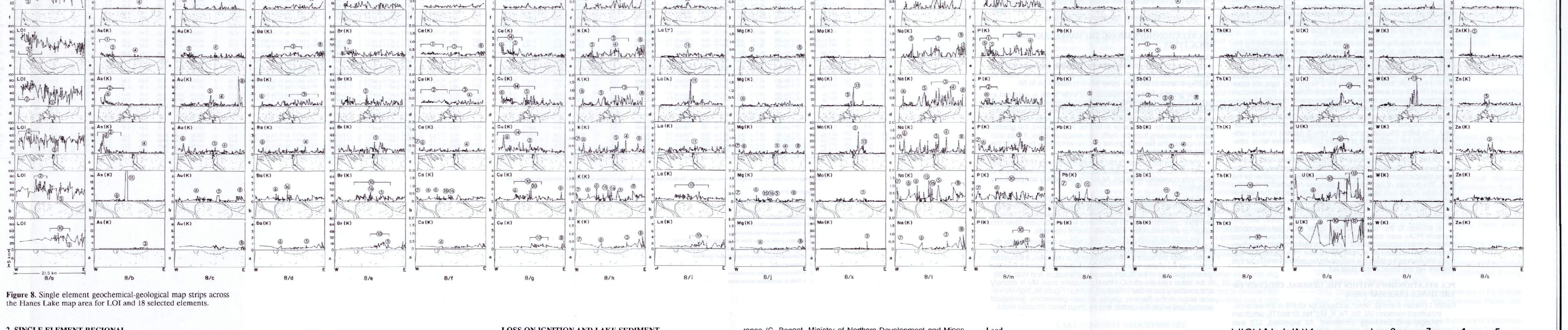


Figure 8. Single element geochemical-geological map strips across the Hanes Lake map area for LOI and 18 selected elements.

2. SINGLE ELEMENT REGIONAL GEOCHEMICAL-GEOLOGICAL MAP STRIPS

A second method of regional interpretation is using Geochemical-Geological Map Strips (G-GMS). The G-GMS are used to display regional relationships between the lake sediment geochemical data and the geological data for an entire map area (Fortescue and Vida 1990).

Figures 7/a to 7/c display the water pH, water Ca and water Mg G-GMS, plotted with the Quaternary geology of the Hanes Lake area. Figures 8/a to 8/s display LOI and 18 elements (As, Au, Ba, Br, Ca, Cu, K, La, Mg, Mo, Na, P, Pb, Sb, Th, U, W and Zn) plus the bedrock geology of the area in 5 km strips.

For readers without a computer, **all** 683 pre-*Ambrosia* sediment geochemical data for selected elements are included in the G-GMS to provide graphical information and preliminary interpretation of the entire data set.

In order to create a single G-GMS for a selected element: 1) an uncoloured 1:50 000 map of the area was reduced to 1:250 000 map scale; 2) the 1:250 000 map was cut into seven 5 km (south to north) by 21.5 km (west to east) strips; 3) the Hanes Lake pre-*Ambrosia* geochemical data base was separated into the same 5 km strips from south to north, and sorted from west to east; 4) for each 5 km map strip, the geochemical data were plotted as sawtooth graphs for each element; 5) the geological map strips were positioned below their respective sawtooth graphs; and 6) each single element cross section was arranged with map strip g/sawtooth graph at the tops of Figures 8/a to 8/s, and map strip a/sawtooth graph at the bottoms. In conformity with the index code from Figure 1, the northern limit of the Hanes Lake area was labelled as map strip g and the southern boundary, map strip a.

The G-GMS for the water pH, water Ca, water Mg, LOI and 18 selected elements are described below. For more detailed information, consult Figure 1, Figures 5a to 5d, Figures 6a to 6p, Table 1, Table 7 and the data base diskette(s).

To facilitate the description of geochemical patterns in Figures 7/a to 7/c and Figures 8/a to 8/s, element peaks and geochemical provinces are identified by a simple element:number code. For example, the positive W values in Figure 8/r are identified as [W:13] on map strip d.

LAKEWATERS

Water pH

The pH levels in the Hanes Lake area range between 4 and 10. Areas of high pH are associated with the large outwash plain and ground moraine on the western border of the map area (Figure 1). Both deposit types appear to be calcium-rich. On Figure 7/a, these deposits are identified as [water pH:1] and [water pH:2] respectively.

High Ca levels in the lake waters (Figure 7/b) mirror the pH patterns, thus confirming the presence of calcium-rich glacial deposits. The outwash plain pattern is [water Ca:1] and the ground moraine is [water Ca:2]. Pattern [water Ca:3] in Figure 7/b appears to be related to a linear feature such as a fault. This pattern is also repeated in [water Mg:3] in Figure 7/c. The peak [water Ca:5] is likely to be an isolated marl lake.

As expected, the Mg levels in the lake waters are low in the outwash plain and the ground moraine. However, the magnetitechert ironstone range (identified as pattern [water Mg:4] in Figure 7/c) was found to be high in Mg.

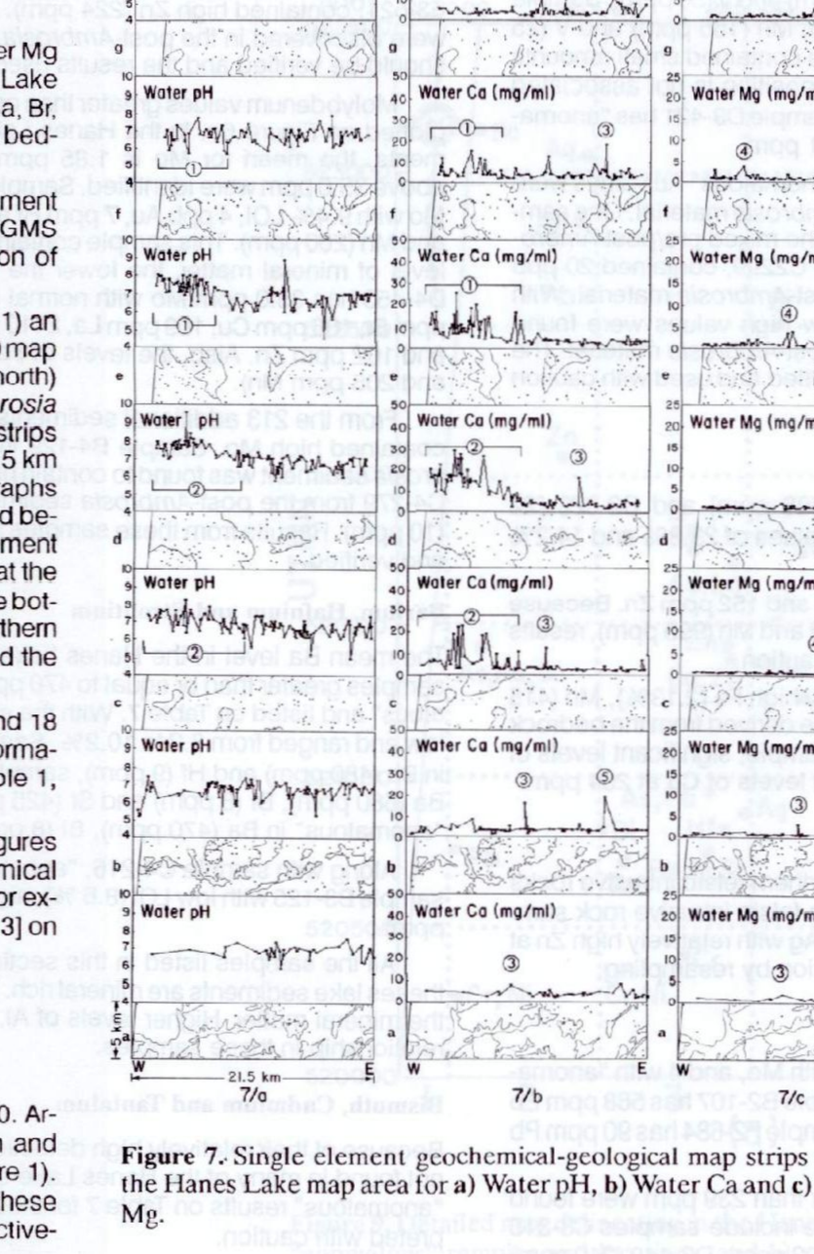


Figure 7. Single element geochemical-geological map strips across the Hanes Lake map area for **a)** Water pH, **b)** Water Ca and **c)** Water Mg.

LOSS ON IGNITION AND LAKE SEDIMENT GEOCHEMISTRY

Loss on Ignition

The LOI in the pre-*Ambrosia* lake sediment samples ranges from less than 10% (mineral rich) to greater than 80% (organic rich). The data on Figure 8/a shows LOI has a more or less random variation spatially. The few exceptions are [LOI:1] and [LOI:2], representing calcium-rich deposits discussed previously. Pattern [LOI:5] depicts low LOI levels in the vicinity of the Goulais River iron range.

Calcium, Magnesium, Potassium and Sodium

Patterns from Ca, Mg, K and Na are more subtle. On the basis of the Clarke index values, the concentrations of Ca and Mg in the pre-*Ambrosia* lake sediments are lower than those of K and Na.

In Figures 8/f and 8/j, Ca and Mg lake sediment patterns mimic the Ca and Mg patterns in waters described above. Slightly higher Ca levels appear in the outwash plain [Ca:1] and in the ground moraine [Ca:2]. A weak Ca geochemical province is found in the central felsic intrusive rocks [Ca:3]. Also, three linear features are defined in the Ca and Mg patterns as [Ca:4] or [Mg:4], [Ca:6] or [Mg:6] and [Ca:7] or [Mg:7]. The Ca or Mg patterns 6 and 7 appear to be related to parallel linear features. On map strip e, patterns [Ca:8] and [Mg:8] show the small geochemical province associated with Patterson Lake (described above). Slightly higher Ca and Mg levels [Ca:15] or [Mg:15] are associated with "anomalous" [As:15] and [Pb:15]. The patterns [Ca:16] and [Mg:16] are associated with "anomalous" [Ba:16], [Bi;16] and [Sr:16]. The pattern [Mg:5] delineates the Goulais River iron range.

A potassium (K) geochemical province (Figure 8/h) for the central felsic intrusive rocks is found on map strips d and e, [K:3]. The three linear features mentioned in the Ca description are more clearly defined in the K and Na patterns. The Goulais River iron range or the granite-greenstone geological contact is delineated by the peaks [K:5] and [Na:5]. The potassium-enriched granodiorite-granite of the Ramsey gneiss domain is well defined in [K:8] and [Na:8]. Map strip e for both [K:8] and [Na:8] shows the small geochemical province described previously for other elements at Patterson Lake. The patterns [K:9] and [Na:9] are associated with the northern felsic intrusive rocks.

Arsenic

Arsenic patterns in Figure 8/b are more spectacular than Au (Figure 8/c). On map strips c and d, [As:2] and map strip e, [As:1], relatively high As levels occur in the eastern mafic metavolcanics. Antimony [Sb:2] is relatively high in the area also. Pattern [As:4] on map strips c to g indicates a persistent linear feature. The linear feature ([As:6]) on map strips b, c and d, indicates a similar feature perpendicular to the major east-west fault. Pattern [As:6] on map strip c is due to high As in sample C2-323 which is also high in Au and Cu (*see* below). Small As peaks [As:5] are associated with the Goulais River iron range.

Gold

Aspects of the Au patterns are similar to those for the elements just described. For example, the Au patterns [Au:4] and [Au:6] in Figure 8/c mimic the As linear patterns discussed previously. Pattern [Au:5] establishes a relationship between Au in lake sediments and the Goulais River iron range. The area represented by map strip d, peak [Au:5], is located southeast of a recently discovered Au occurrence (G. Bennet, Ministry of Northern Development and Mines, personal communication, 1990). Significant Au values occur at the Algoma plutonic domain-Ramsey gneiss domain contact ([Au:8] on map strips a and b). The peak at [Au:18] (map strip f) is located in the northern felsic intrusive rocks. These Au results should be verified prior to any exploration activity based upon them.

Barium, Bromine, Copper and Phosphorus

In Figure 8/d, a Ba geochemical province is present in the central felsic intrusive rocks ([Ba:3], map strip d). A northwest-trending linear feature extending for some 20 km is identified on map strips a to d as [Ba:6]. The [Ba:8] (map strip e) geochemical province is located at Patterson Lake (discussed previously). Barium levels are high in the Ramsey gneiss domain and the Algoma plutonic domain ([Ba:8]). On map strip b, [Ba:16] represents an "anomalous" value associated with high levels of several other elements.

In Figure 8/e, Br is seen to be variable throughout the Hanes Lake map area. The significance of [Br:5], [Br:10] and [Br:16] in relation to mineral exploration is not known at the time of writing.

In Figure 8/g, [Cu:5] is likely to be associated with either the Goulais River iron range or the granite-greenstone contact. Pattern [Cu:6] is a linear feature which also was detected in 9 other element patterns (As, Au, Ba, Ca, K, Mg, Na, P and Pb). The peak at [Cu:6], on map strip c, is associated with a Cu "anomaly" in the eastern mafic metavolcanic rocks (sample C2-323, *see* below). On map strips a and b, the peak ([Cu:8]) occurs at the geological contact between the two granite domains. A weak geochemical province ([Cu:10]) is associated with the southern felsic intrusive rocks. A Cu geochemical province ([Cu:14]) is also present in the greenstone belt along with [As:2] and [Sb:2] described previously. "Anomalous" Cu is found at [Cu:20].

In Figure 8/m, a weak P geochemical province occurs in the mafic metavolcanic rocks as [P:1], map strip e; and [P:2], map strip d. Three stronger patterns of this type [P:3], [P:9] and [P:10], occur in the 1) central felsic intrusive rocks, 2) the northern felsic intrusive rocks and 3) the southern felsic intrusive rocks, respectively. The pattern [P:6] is a linear feature with less contrast than [Ba:6]. A parallel linear feature occurs on map strips a to c as [P:7].

Antimony

Antimony peaks (Figure 8/o) occur in many of the locations discussed previously for other elements. Patterns [Sb:1] and [Sb:2] delineate a geochemical province in the eastern mafic metavolcanic rocks and [Sb:4] defines a linear feature in the Sb data. Like other elements, an Sb pattern [Sb:5] is associated with the Goulais River iron range. Small Sb peaks also occur on map strip d ([Sb:8]), and relatively high Sb occurs at [Sb:15] in the southern felsic intrusive rocks. In general, the Sb patterns are relatively weak in the Hanes Lake map area.

Molybdenum

Two distinct Mo patterns are included in Figure 8/k. The major Mo pattern ([Mo:5]), on map strips a to d, is associated with the Goulais River iron range. A second Mo "anomaly" ([Mo:13]) is found in the central felsic intrusive rocks.

Lead

In many respects, the Pb patterns (Figure 8/n) are similar to those of other elements. The Goulais River iron range is delineated by [Pb:5] and [Pb:19]. Four isolated peaks, [Pb:6], [Pb:7], [Pb:15] and [Pb:19] occur at various locations across the Hanes Lake area. Peaks [Pb:6] and [Pb:7] may indicate two faults described by Grunsky (in prep.).

Tungsten

Tungsten, Figure 8/r, has two "anomalies" of interest, [W:13] and [W:17]. The pattern at [W:13] involves a cluster of 7 positive W values at the same location as [Mo:13] just described. The other W "anomaly" [W:17], which occurs over a strike length of 5 km, is in the northeast of the map area at the northern felsic intrusive rocks-Ramsey gneiss domain contact.

Zinc

In relation to the Trout Lake area (Fortescue and Vida 1989), the Zn patterns illustrated in Figure 8/s are not so well defined. The best Zn "anomaly" is an isolated high value ([Zn:5]), on map strip e. A small geochemical province ([Zn:5]) on map strips c and d is associated with the Goulais River iron range.

Uranium, Lanthanum and Thorium

Relatively high levels of U, La, and Th in lake sediments are usually found in areas underlain by granitic rocks. Figures 6a, 6b and 6c, and Figures 8/i, 8/p and 8/q exhibit this relationship clearly.

As usual, U (Figure 8/q) is the best indicator of change within the granitic terranes. A very well-defined geochemical province [U:10] is associated with the southern felsic intrusive rocks. Further east, [U:12] is a another province associated with the Algoma plutonic domain-Ramsey gneiss domain geological contact. The smaller geochemical province [U:21] is associated with the central felsic intrusive rocks-Ramsey gneiss domain geological contact. Peaks [U:6] and [U:7] are located in the area of the two faults mentioned earlier.

Like U, La (Figure 8/i) has a geochemical province ([La:10]), associated with the southern felsic intrusive rocks. A La geochemical linear, on map strips c to f ([La:11]), is in the vicinity of the granite-greenstone contact. The "anomalous" sample site at [La:11] on map strip d is coincident with "anomalous" Au, ([Au:5]).

In comparison with U and La, the Th patterns included in Figure 8/p are relatively poorly defined. The only pattern of significance for Th is [Th:10] which occurs in the southern felsic intrusive rocks.

SUMMARY

The G-GMS technique just described is a very convenient way of displaying regional patterns in the entire Hanes Lake data base for each geochemical parameter of interest. This method of preliminary pattern recognition may be further investigated by readers with or without a computer, using a combination of Figures 1, 6, 7/a to 7/c, 8/a to 8/s and Table 1.

Our aim has been to deliberately draw attention to both strong and weak patterns in the geochemical data. Patterns which are considered in mineral exploration should be verified by further sampling.

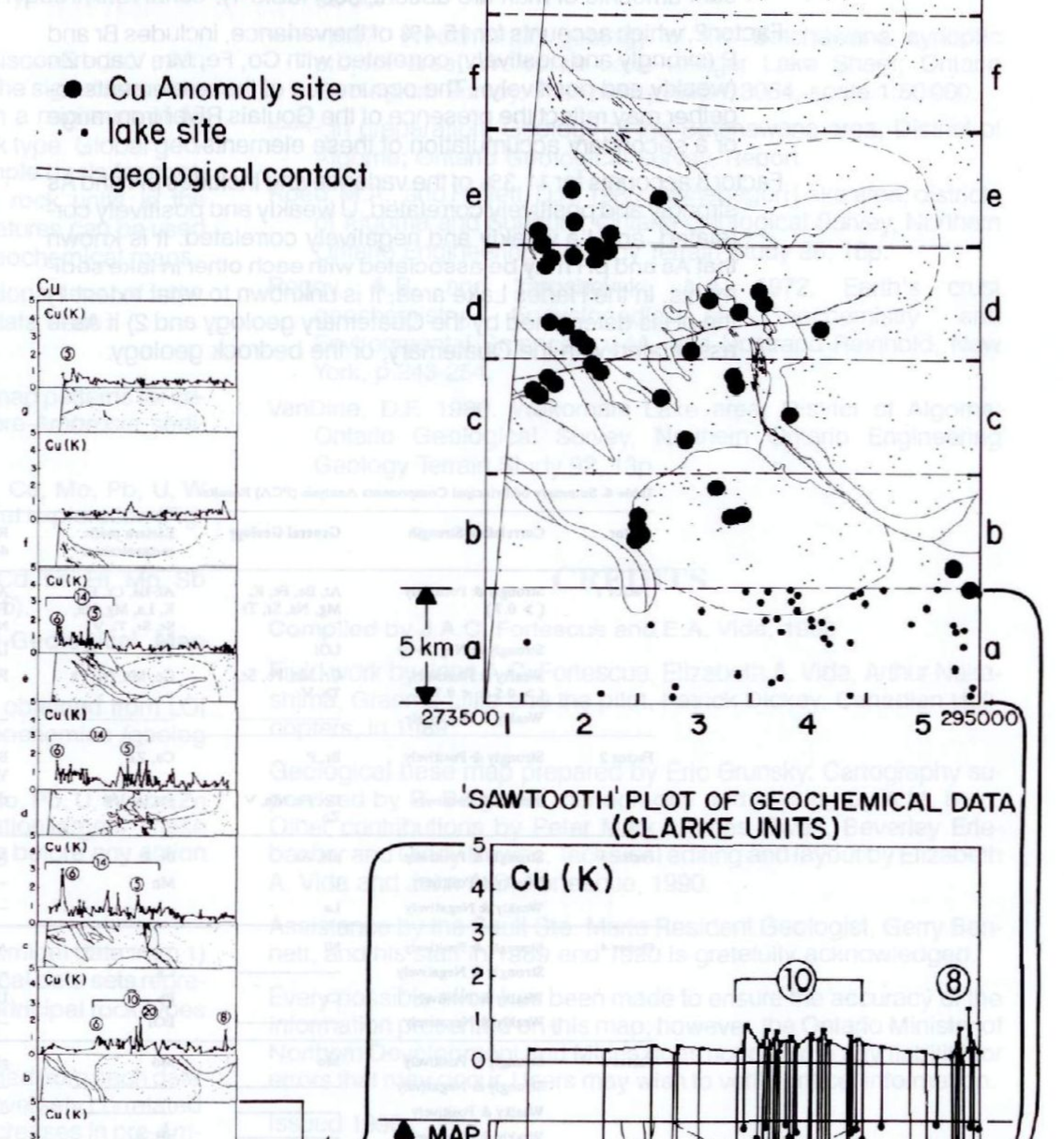


Table 1. General summary table to the Hanes Lake sediment and water geochemical data base.

ALL LAKE SAMPLE SITE CODES have letter number – numbers (e.g. "E5-575") code.

The LETTER NUMBER code (e.g. "E5") indicates a 5 km square in Figure 1, in which the sample site is located.

"E" indicates the 5 km northing index.
"5" indicates the 5 km easting index.
"575" refers to the sample within the 5 km square in Figure 1 (printed in blue).

LAKE CODE	WATER pH	WATER Ca (mg/ml)	WATER Mg (mg/ml)	LOI (%)	LAKE CODE	Ag (ppm)	Ag (K)	LAKE CODE	Al (%)	Al (K)	LAKE CODE	As (ppm)	As (K)	LAKE CODE	Au (ppb)	Au (K)	LAKE CODE	Ba (ppm)	Ba (K)	LAKE CODE	Be (ppm)	Be (K)	LAKE CODE	Bi (ppm)	Bi (K)	LAKE CODE	Br (ppm)	Br (K)	LAKE CODE	Ca (%)	Ca (K)	LAKE CODE	Cd (ppm)	Cd (K)	LAKE CODE	Co (ppm)	Co (K)	LAKE CODE	Cr (ppm)	Cr (K)	LAKE CODE	Cu (ppm)	Cu (K)	LAKE CODE	Fe (%)	Fe (K)	LAKE CODE	Hf (ppm)	Hf (K)	LAKE CODE	K (%)	K (K)	LAKE CODE	La (ppm)	La (K)	LAKE CODE	Lu (ppm)	Lu (K)	LAKE CODE	Mg (%)	Mg (K)	LAKE CODE	Mn (ppm)	Mn (K)	LAKE CODE	Mo (ppm)	Mo (K)	LAKE CODE	Na (%)	Na (K)	LAKE CODE	Ni (ppm)	Ni (K)	LAKE CODE	P (ppm)	P (K)	LAKE CODE	Pb (ppm)	Pb (K)	LAKE CODE	Sb (ppm)	Sb (K)	LAKE CODE	Sc (ppm)	Sc (K)	LAKE CODE	Sr (ppm)	Sr (K)	LAKE CODE	Ta (ppm)	Ta (K)	LAKE CODE	Th (ppm)	Th (K)	LAKE CODE	Ti (%)	Ti (K)	LAKE CODE	U (ppm)	U (K)	LAKE CODE	V (ppm)	V (K)	LAKE CODE	W (ppm)	W (K)	LAKE CODE	Zn (ppm)	Zn (K)	LAKE CODE
[illegible]																																																																																																																					

* Blank cells or -999 indicate missing values.
** Clarke Index-1 values are given in the units of the element column in which they are found.
*** Analytical Method
AAS = Atomic Absorption Spectroscopy
ICP = Inductively Coupled Plasma Analysis
NAA = Neutron Activation Analysis
**** Elements are arranged in the same order as on data base diskette(s).
+ Results in boxed areas refer to Clarke index-1 values included in the regional map panels in Figure 6.
++ Summary of statistics below Table 1 summarizes results for the complete Hanes Lake data base.

3. PRINCIPAL COMPONENTS ANALYSIS

Only catchments without significant Quaternary cover were selected for inclusion in Principal Conponents Analysis (PCA). The one exception is the eastern mafic metavolcanic rock area which is totally covered by a ground moraine and/or outwash plain.

The PCA technique called for 1) normality inspections of all frequency distributions for parameters to be included, 2) a log transform to be applied if the data was skewed, and 3) a varimax rotation to be applied on preliminary PCA results. In all cases, the outcome of the PCA indicated that the first six factors accounted for about 80% of the variation in a data set. The six factors obtained from each PCA are listed in full on Tables 4 and 5 (see data base diskette(s)). All the PCA data are summarized on Table 6.

Table 4 lists the PCA results for catchments representing the major rock types of the entire Hanes Lake area. Data for general geology (Table 4 and summarized in Table 6) included a random selection of 151 samples drawn from all the rock type data sets described below. The PCA results for groups of lake sediments derived from catchments underlain by a single rock type are tabulated in Table 5 and summarized in Table 6. These are 1) the eastern mafic metavolcanic rocks, 2) the Ramsey gneiss domain, 3) felsic intrusive rocks 4) central felsic intrusive rocks and 5) northern felsic intrusive rocks. Other rock types were not included because fewer than the required 29 sample sites were available for PCA calculations. The felsic intrusive rocks (rock type 3, above) include samples from all the catchments underlain by the massive felsic intrusive rocks in the Hanes Lake area.

On the Trout Lake map sheet (Fortescue and Vida 1989), all the lake sediment analyses from the catchments completely underlain by the felsic intrusive rocks (stocks) were combined together for the PCA. The number of lake sediment samples collected in the Trout Lake area, in this rock type, were insufficient to execute the multivariate statistics. For this reason, for comparative purposes with the Trout Lake data, the lake sediment analyses from the Hanes Lake area massive felsic intrusive rocks were also combined together.

In additon to the "felsic intrusive rocks" PCA just described, separate PCAs were carried out for the northern and central felsic intrusive rocks because each of these rock types contain more than the minimum required 29 sample points. The PCA for the northern felsic intrusive rocks does not include As because all results for this element set are equal in this data set.

PCA RELATIONSHIPS WITHIN THE GENERAL GEOLOGY OF THE HANES LAKE MAP AREA

Factor 1 (Tables 4 and 6), which accounts for 42.8% of the variance, includes 8 elements (Al, Ba, Fe, K, Mg, Na, Sr and Ti), which are strongly and positively correlated. As expected, LOI was strongly and negatively correlated in this factor. In addition, 6 elements (Cr, Mn, Pb, Sc, Th and V), were weakly and negatively correlated. These results show that the higher the level of mineral matter in lake sediment, the lower the LOI (provided significant amounts of marl are absent, *see* Table 1).

Factor 2, which accounts for 15.4% of the variance, includes Br and P (strongly and postively) correlated with Co, Fe, Mn, V and Zn (weakly and positively). The occurrence of these elements together may reflect the presence of the Goulais River iron range or a secondary accumulation of these elements.

Factor 3 accounts for 11.3% of the variance and includes pH and As strongly and positively correlated, U weakly and positively correlated, and La weakly and negatively correlated. It is known that As and pH may be associated with each other in lake sediments. In the Hanes Lake area, it is unknown to what extent 1) the pH is determined by the Quaternary geology and 2) if As is associated with the Quaternary, or the bedrock geology.

Factor 4, which accounts for 5.3% of the variance, includes Ni strongly and positively correlated, and Cr weakly and positively correlated. This factor may reflect the presence of diabase dikes.

Factor 5 accounts for 3.7% of the variance and includes Mo strongly and positively correlated.

Factor 6 accounts for 3.2% of the variance and includes Au strongly and positively correlated. In the Trout Lake general geology PCA, Au occured as Factor 6 also (Fortescue and Vida 1989). The exact relationship is unknown at this time.

PCA RELATIONSHIPS AMONG THE HANES LAKE AREA ROCK TYPES

As in the general geology PCA just described, Factor 1 (Tables 5 and 6) is explained by the **negative relationship between LOI and mineral matter**. Factor 1 accounts for greater than or equal to 44.2% variance in the rock types listed in Tables 5a to 5e.

The **granitic factor** (Fortescue and Vida 1989) is reflected in Factor 2 in Table 5e (northern felsic intrusive rocks) and Factor 3 in Tables 5c and 5d (felsic intrusive and central felsic intrusive rocks respectively). The percentage of variation from rock type to rock type accounts for this change in factors. As expected, the granitic factor was missing from the mafic metavolcanic rocks. It was also missing from the Ramsey gneiss domain which may be due to the effect of Quaternary cover.

Factor 2 in the eastern mafic metavolcanic rocks (Table 5a) accounts for 12.3% of the variance. Copper and Zn are strongly and positively correlated while pH, As and Ni are weakly and positively correlated.

Factor 2 in the Ramsey gneiss domain, the felsic intrusive and the central felsic intrusive rocks (Tables 5b to 5d) accounts for greater than or equal to 16.2% of the variance. The elements (Table 6) and their correlation may be associated with the Goulais River Iron range, or with secondary accumulations of elements.

Element relationships within other factors are less clearly defined. For example, the correlation of Au as Factor 6 in all the rock types except the felsic intrusives (Table 6) is unknown. It should be noted that Au is also strongly correlated (0.89) in Factor 6 from the general geology of the Trout Lake area (Fortescue and Vida 1989). In the felsic intrusive rocks of the Hanes Lake area, Mo is strongly and positively correlated in Factor 6. Note, in Figure 6e, high Mo values occur at the Ramsey gneiss domain-greenstone geological contact and within the central and southern felsic intrusive rocks.

SUMMARY

The PCA for a data set representative of the entire Hanes Lake area was described and compared with PCA data obtained from catchments underlain by four of its principal rock types. Several element groupings were common to both the area-wide PCA and the four individual rock type PCAs.

COMMENTS

The PCA reveals general statistical relationships between groups of elements in the Hanes Lake pre-*Ambrosia* sediments. This information is a preliminary step to a detailed interpretation of the geochemical data. Also, the PCA is important for comparative purposes with other map sheets in this series.

Table 6. Summary of Principal Components Analysis (PCA) Results.

Factor	Correlation Strength	General Geology	Eastern mafic metavolcanics	Ramsey gneiss domain	Felsic intrusives	Central felsic intrusives	Northern felsic intrusives*
Factor 1	Strongly & Positively (> 0.7)	Al, Ba, Fe, K, Mg, Na, Sr, Ti	Al, Ba, Cr, Fe, K, La, Mg, Na, Sc, Sr, Ti, V	Al, Ba, Ca, Cr Fe, K, Mg, Mn Na, Sr, Th, Ti	Al, Ba, Ca, Cr Fe, K, Mg, Mn Na, Sr, Ti	Al, Ba, Ca, Cr, Fe, K, Mg, Mo, Na, Sc, Sr, Ti	Al, Ba, Cr, Fe K, Mg, Mn, Na, Sr, Ti
	Strongly & Negatively	LOI	LOI	LOI	LOI	LOI	LOI
	Weakly & Positively (> 0.5 & < 0.7)	Cr, Mn, Pb, Sc, Th, V	Co, Mn, Ni, Th	Pb, Sc, V	Co, Sc, Th, V	Co, La, Th, V	Ca, Th, V
	Weakly & Negatively	————	————	————	————	————	Cu
Factor 2	Strongly & Positively	Br, P	Cu, Zn	Br, Cu, Mo, P, V, Zn	Br, P, V, Zn	Br, P, V, Zn	Co, La, Ni, Sc
	Weakly & Positively	Co, Fe, Mn, V Zn	pH, As, Ni	Co, Fe, Mn	Fe	————	Cr, Cu, Th, U
Factor 3	Strongly & Positively	pH, As	Br, P	Ni	U	Ca, U	Br, P
	Weakly & Positively	U	Mn	————	Ca, La, Th	La, Mo, Th	V
	Weakly & Negatively	La	————	————	————	————	————
Factor 4	Strongly & Positively	Ni	————	As	Ni	As, Pb	Mo
	Strongly & Negatively	————	Ca	————	————	————	————
	Weakly & Positively	Cr	Pb	U	pH, Co	————	————
	Weakly & Negatively	————	LOI	————	————	————	————
Factor 5	Strongly & Positively	Mo	Mo	pH	As, Pb	pH	————
	Strongly & Negatively	————	————	————	————	————	Pb
	Weakly & Positively	————	————	————	————	————	pH
	Weakly & Negatively	————	pH, As	————	————	————	————
Factor 6	Strongly & Positively	Au	Au	Au	Mo	Au	————
	Weakly & Positively	————	————	————	————	————	Au

* In the Northern felsic intrusives, the element "As" was not included in the varimax-rotated factor matrix calculations because "As" is a constant value.
** Refer to Tables 4 and 5 for the complete PCA.

Table 7. Detailed geochemistry of 31 "anomalous" pre-Ambrosia sediment samples from the Hanes Lake area.

ANOMALOUS ELEMENTS	LAKE CODE	LATITUDE	LONGITUDE	UTM EASTINGS	UTM NORTHINGS	SECCHI DEPTH (m)	WATER DEPTH (m)	WATER pH	WATER Ca (mg/ml)	WATER Mg (mg/ml)	GEOLOGY
Ag	G2-800	47 11 39.0	83 54 31.0	279675	5230625	1.0	1.0	6.49	3.82	1.09	6a
Ag	B3-140	46 59 58.1	83 49 51.4	284775	5208775	3.0	19.5	7.38	3.01	0.68	-
As,Pb	B3-162	47 0 17.7	83 50 50.4	283550	5209425	4.5	7.6	7.53	3.68	0.73	-
As,Au,Cu	C2-323	47 2 43.3	83 56 48.9	276150	5214200	4.0	3.7	7.56	6.67	0.72	-
Au	D5-428	47 4 46.5	83 43 42.5	292875	5217400	0.3	0.3	7.13	5.78	1.48	-
Au	F2-743	47 10 28.4	83 54 36.6	279475	5228450	0.5	0.5	6.75	4.88	1.53	-
Au,La	D3-421	47 4 27.1	83 50 21.0	284450	5217100	0.3	0.3	7.07	5.29	1.35	-
Ba,Hf	C4-216	47 1 4.5	83 46 32.4	289050	5210675	1.0	1.2	6.09	2.74	0.57	-
Ba,Bi,Sr	B3-110	46 59 16.2	83 50 46.0	283575	5207525	0.9	0.9	6.82	3.43	0.75	-
Bi	F4-663	47 8 46.9	83 49 21.3	286000	5225075	3.0	10.1	6.73	4.30	1.06	-
Bi	B3-128	46 59 35.6	83 53 31.5	280100	5208250	1.5	1.5	6.92	3.30	0.69	-
Cd,Zn	C3-315	47 2 43.4	83 50 20.2	284350	5213900	3.7	3.7	7.31	3.98	0.62	-
Cr	A3-036	46 57 22.9	83 51 14.2	282850	5204050	0.6	0.6	7.32	7.90	2.17	5b
Cr,Ni	A3-028	46 57 1.8	83 52 56.0	280675	5203475	2.1	2.1	6.73	2.91	0.64	5b
Cr,Ni	A2-016	46 56 27.7	83 57 12.0	275225	5202625	0.3	0.3	6.66	5.77	1.28	5b
Hf	B3-125	46 59 37.1	83 50 22.2	284100	5208150	0.9	0.9	7.00	15.86	3.14	-
La,U	A5-059	46 58 5.5	83 42 0.4	294600	5204950	-999	-999	-999	-999	-999	5b
Mo	D4-453	47 4 58.0	83 49 42.3	285300	5218025	9.0	26.5	7.06	3.59	0.78	6b
Mo	C4-272	47 2 3.3	83 48 26.8	286700	5212575	1.2	1.2	6.74	3.09	0.68	-
Pb	B2-107	46 59 5.2	83 57 29.0	275050	5207500	1.0	2.1	6.85	3.12	0.79	-
Pb	F2-684	47 9 6.2	83 54 19.1	279750	5225900	0.5	0.5	7.07	11.98	1.73	-
Sc	G2-819	47 12 2.2	83 57 19.8	276150	5231475	0.3	0.3	6.97	5.46	1.16	-
Sc	C5-277	47 2 18.0	83 42 9.6	294675	5212750	4.0	11.3	6.79	3.28	0.73	5a
Ta	B3-099	46 58 59.9	83 52 58.8	280750	5207125	2.5	15.5	7.10	3.15	0.70	-
U	A4-051	46 57 51.6	83 46 4.6	289425	5204700	1.2	1.2	6.85	4.85	0.89	-
W	D4-431	47 4 41.0	83 48 33.9	286725	5217450	0.2	0.2	7.07	7.25	1.57	-
W	D4-353	47 3 22.4	83 49 8.8	285900	5215050	0.9	0.9	5.78	2.09	0.36	-
Zn	E2-527	47 6 12.8	83 54 52.3	278850	5220575	4.0	12.2	7.96	13.22	1.27	1
Zn	D3-440	47 4 42.5	83 51 22.3	283175	5217625	2.0	7.9	6.89	9.14	0.87	-
Zn	C4-307	47 2 35.9	83 49 23.0	285550	5213625	4.5	10.4	6.73	3.24	0.53	2
Zn	C3-325	47 2 35.4	83 50 26.8	284225	5214275	4.0	4.0	7.29	3.94	0.65	-

LAKE CODE	LOI (%)	Ag (ppm)	Ag (K)	Al (%)	Al (K)	As (ppm)	As (K)	Au (ppb)	Au (K)	Ba (ppm)	Ba (K)	Be (ppm)	Be (K)	Bi (ppm)	Bi (K)	Br (ppm)	Br (K)	Ca (%)	Ca (K)	Cd (ppm)	Cd (K)	Co (ppm)	Co (K)	Cr (ppm)	Cr (K)	Cu (ppm)	Cu (K)	Fe (%)	Fe (K)
G2-800	29.6	1.8	22.50	2.90	0.35	1	0.56	1	0.25	140	0.36	0.5	0.25	2	243.90	7.9	3.16	0.60	0.13	0.5	3.13	4	0.14	26	0.21	13	0.19	0.72	0.12
B3-140	27.4	1.0	12.50	4.69	0.56	1	0.56	4	1.00	270	0.69	0.5	0.25	2	243.90	22.9	9.16	1.07	0.23	1.5	9.38	13	0.45	48	0.39	43	0.63	2.02	0.32
B3-162	23.8	0.8	10.00	2.83	0.34	96	53.33	3	0.75	100	0.26	0.5	0.25	2	243.90	12.4	4.96	0.81	0.17	1.0	6.25	7	0.24	39	0.32	77	1.13	4.09	0.66
C2-323	14.2	0.5	6.25	5.46	0.65	22	12.22	13	3.25	410	1.05	0.5	0.25	2	243.90	12.3	4.92	1.83	0.39	1.0	6.25	15	0.52	58	0.48	204	3.00	2.13	0.34
D5-428	45.2	0.5	6.25	1.52	0.18	1	0.56	37	9.25	110	0.28	0.5	0.25	2	243.90	10.6	4.24	0.62	0.13	0.5	3.13	5	0.17	15	0.12	16	0.24	0.40	0.06
F2-743	41.4	0.5	6.25	1.77	0.21	1	0.56	16	4.00	100	0.26	0.5	0.25	2	243.90	10.3	4.12	0.56	0.12	0.5	3.13	3	0.10	14	0.11	17	0.25	0.39	0.06
D3-421	34.6	0.5	6.25	2.08	0.25	1	0.56	13	3.25	140	0.36	0.5	0.25	2	243.90	10.5	4.20	0.76	0.16	0.5	3.13	8	0.28	33	0.27	101	1.49	0.72	0.12
C4-216	8.2	0.5	6.25	6.04	0.72	1	0.56	3	0.75	480	1.23	0.5	0.25	2	243.90	2.3	0.92	1.40	0.30	0.5	3.13	11	0.38	54	0.44	8	0.12	2.04	0.33
B3-110	10.2	0.6	7.50	6.38	0.76	1	0.56	4	1.00	680	1.74	0.5	0.25	8	975.61	4.0	1.60	1.70	0.36	0.5	3.13	11	0.38	39	0.32	10	0.15	2.02	0.32
F4-663	25.8	0.5	6.25	4.14	0.50	1	0.56	1	0.25	270	0.69	0.5	0.25	8	975.61	24.7	9.88	1.19	0.26	0.5	3.13	7	0.24	34	0.28	14	0.21	1.25	0.20
B3-128	40.8	0.2	2.50	6.13	0.73	1	0.56	4	1.00	470	1.21	0.5	0.25	8	975.61	17.3	6.92	1.93	0.41	0.5	3.13	12	0.41	62	0.51	68	1.00	2.43	0.39
C3-315	60.0	0.5	6.25	2.89	0.35	1	0.56	1	0.25	90	0.23	0.5	0.25	2	243.90	39.2	15.68	0.70	0.15	2.5	15.63	18	0.62	34	0.28	105	1.54	1.61	0.26
A3-036	37.8	0.2	2.50	1.15	0.14	1	0.56	4	1.00	80	0.21	0.5	0.25	2	243.90	15.3	6.12	0.46	0.10	0.5	3.13	4	0.14	120	0.98	26	0.38	0.51	0.08
A3-028	33.4	0.2	2.50	1.18	0.14	1	0.56	4	1.00	70	0.18	0.5	0.25	2	243.90	10.6	4.24	0.47	0.10	0.5	3.13	4	0.14	120	0.98	29	0.43	0.34	0.05
A2-016	26.0	0.2	2.50	4.26	0.51	1	0.56	4	1.00	250	0.64	0.5	0.25	4	487.80	6.6	2.64	0.83	0.18	0.5	3.13	8	0.28	104	0.85	21	0.31	1.07	0.17
B3-125	8.6	0.2	2.50	5.21	0.62	1	0.56	3	0.75	410	1.05	0.5	0.25	4	487.80	8.2	3.28	1.65	0.35	0.5	3.13	9	0.31	47	0.39	113	1.66	1.60	0.26
A5-059	26.8	0.2	2.50	3.68	0.44	1	0.56	2	0.50	220	0.56	0.5	0.25	2	243.90	25.9	10.36	1.30	0.28	0.5	3.13	4	0.14	32	0.26	92	1.35	0.75	0.12
D4-453	40.0	0.5	6.25	3.51	0.42	2	1.11	8	2.00	230	0.59	0.5	0.25	2	243.90	43.9	17.56	0.89	0.19	1.0	6.25	10	0.34	49	0.40	106	1.56	1.32	0.21
C4-272	9.4	0.5	6.25	5.49	0.66	1	0.56	4	1.00	430	1.10	0.5	0.25	2	243.90	5.4	2.16	1.61	0.35	1.0	6.25	8	0.28	48	0.39	82	1.21	1.74	0.28
B2-107	33.6	0.5	6.25	3.00	0.36	1	0.56	3	0.75	180	0.46	0.5	0.25	2	243.90	15.3	6.12	0.92	0.20	1.5	9.38	10	0.34	36	0.30	35	0.51	1.60	0.26
F2-684	42.2	0.5	6.25	2.90	0.35	1	0.56	1	0.25	200	0.51	0.5	0.25	2	243.90	11.6	4.64	1.26	0.27	0.5	3.13	4	0.14	15	0.12	8	0.12	0.95	0.15
G2-819	63.8	0.2	2.50	2.20	0.26	4	2.22	2	0.50	110	0.28	0.5	0.25	2	243.90	13.2	5.28	1.18	0.25	1.5	9.38	11	0.38	37	0.30	59	0.87	1.67	0.27
C5-277	27.4	0.5	6.25	4.84	0.58	1	0.56	1	0.25	310	0.79	0.5	0.25	4	487.80	18.7	7.48	1.23	0.26	0.5	3.13	15	0.52	41	0.34	19	0.28	2.22	0.36
B3-099	33.4	0.2	2.50	4.43	0.53	1	0.56	4	1.00	360	0.92	0.5	0.25	4	487.80	27.9	11.16	1.29	0.28	1.0	6.25	11	0.38	48	0.39	45	0.66	1.97	0.32
A4-051	36.8	0.2	2.50	2.43	0.29	1	0.56	2	0.50	160	0.41	0.5	0.25	2	243.90	13.6	5.44	1.04	0.22	1.0	6.25	8	0.28	24	0.20	37	0.54	0.71	0.11
D4-431	4.0	0.5	6.25	6.03	0.72	1	0.56	3	0.75	400	1.03	0.5	0.25	2	243.90	3.4	1.36	1.59	0.34	0.5	3.13	8	0.28	33	0.27	5	0.07	1.29	0.21
D4-353	10.8	0.5	6.25	5.65	0.68	1	0.56	2	0.50	410	1.05	0.5	0.25	4	487.80	3.0	1.20	1.34	0.29	0.5	3.13	7	0.24	40	0.33	18	0.26	1.45	0.23
E2-527	51.0	0.5	6.25	1.84	0.22	6	3.33	1	0.25	90	0.23	0.5	0.25	2	243.90	51.0	20.40	0.91	0.20	2.0	12.50	13	0.45	19	0.16	130	1.91	1.41	0.23
D3-440	62.8	0.5	6.25	1.94	0.23	2	1.11	2	0.50	100	0.26	0.5	0.25	2	243.90	66.6	26.64	1.29	0.28	2.0	12.50	9	0.31	15	0.12	114	1.68	1.21	0.19
C4-307	56.6	0.5	6.25	1.97	0.24	1	0.56	4	1.00	90	0.23	0.5	0.25	2	243.90	71.2	28.48	0.54	0.12	2.0	12.50	14	0.48	17	0.14	66	0.97	1.02	0.16
C3-325	49.0	0.5	6.25	3.79	0.45	1	0.56	4	1.00	150	0.38	0.5	0.25	2	243.90	36.3	14.52	0.80	0.17	2.0	12.50	19	0.66	41	0.34	73	1.07	1.98	0.32

LAKE CODE	Hf (ppm)	Hf (K)	K (%)	K (K)	La (ppm)	La (K)	Lu (ppm)	Lu (K)	Mg (%)	Mg (K)	Mn (ppm)	Mn (K)	Mo (ppm)	Mo (K)	Na (%)	Na (K)	Ni (ppm)	Ni (K)	P (ppm)	P (K)	Pb (ppm)	Pb (K)	Sb (ppm)	Sb (K)	Sc (ppm)	Sc (K)	Sr (ppm)	Sr (K)	Ta (ppm)	Ta (K)	Th (ppm)	Th (K)	Ti (%)	Ti (K)	U (ppm)	U (K)	V (ppm)	V (K)	W (ppm)	W (K)	Zn (ppm)	Zn (K)	ANOMALOUS ELEMENTS
G2-800	2	0.71	0.45	0.24	30	0.87	0.2	0.37	0.25	0.09	125	0.12	1.0	0.83	0.67	0.30	9	0.09	870	0.78	10	0.77	0.1	0.50	4.9	0.20	93	0.24	1	0.59	4.6	0.57	0.09	0.14	2.4	1.04	23	0.17	1	0.83	26	0.34	Ag
B3-140	4	1.43	0.68	0.37	16	0.46	0.4	0.74	0.43	0.16	830	0.78	6.0	5.00	0.98	0.43	21	0.21	1460	1.30	6	0.46	0.1	0.50	3.2	0.13	143	0.37	1	0.59	6.3	0.78	0.16	0.25	6.3	2.74	50	0.37	1	0.83	148	1.95	Ag
B3-162	4	1.43	0.64	0.35	25	0.72	0.1	0.19	0.42	0.15	995	0.94	1.0	0.83	0.68	0.30	25	0.25	510	0.46	52	4.00	0.4	2.00	1.8	0.07	94	0.24	2	1.18	2.4	0.30	0.18	0.28	0.5	0.22	35	0.26	1	0.83	152	2.00	As,Pb
C2-323	6	2.14	1.21	0.66	30	0.87	0.4	0.74	0.69	0.25	415	0.39	1.0	0.83	2.21	0.97	42	0.42	590	0.53	6	0.46	0.4	2.00	11.8	0.47	291	0.76	2	1.18	5.4	0.67	0.25	0.40	1.6	0.70	50	0.37	2	1.67	68	0.89	As,Au,Cu
D5-428	1	0.36	0.24	0.13	25	0.72	0.1	0.19	0.13	0.05	55	0.05	1.0	0.83	0.25	0.11	15	0.15	330	0.29	6	0.46	0.1	0.50	3.3	0.13	56	0.15	1	0.59	2.3	0.28	0.06	0.09	1.9	0.83	12	0.09	1	0.83	42	0.55	Au
F2-743	1	0.36	0.25	0.14	28	0.81	0.2	0.37	0.13	0.05	40	0.04	1.0	0.83	0.27	0.12	14	0.14	450	0.40	6	0.46	0.1	0.50	4.1	0.16	51	0.13	1	0.59	2.2	0.27	0.05	0.08	1.9	0.83	11	0.08	1	0.83	44	0.58	Au
D3-421	4	1.43	0.38	0.21	283	8.18	0.5	0.93	0.27	0.10	80	0.08	9.0	7.50	0.49	0.22	19	0.19	450	0.40	4	0.31	0.1	0.50	2.5	0.10	85	0.22	2	1.18	3.2	0.40	0.08	0.13	3.4	1.48	26	0.19	1	0.83	46	0.61	Au,La
C4-216	9	3.21	1.50	0.82	19	0.55	0.2	0.37	0.69	0.25	370	0.35	1.0	0.83	2.42	1.07	18	0.18	270	0.24	14	1.08	0.2	1.00	10.2	0.41	282	0.73	1	0.59	3.7	0.46	0.28	0.44	2.7	1.17	46	0.34	5	4.17	46	0.61	Ba,Hf
B3-110	5	1.79	1.38	0.75	16	0.46	0.1	0.19	0.80	0.29	475	0.45	1.0	0.83	3.00	1.32	17	0.17	460	0.41	16	1.23	0.1	0.50	7.9	0.32	425	1.11	2	1.18	2.3	0.28	0.21	0.33	1.0	0.43	43	0.32	1	0.83	60	0.79	Ba,Bi,Sr
F4-663	3	1.07	0.85	0.46	34	0.98	0.2	0.37	0.41	0.15	225	0.21	1.0	0.83	1.16	0.51	14	0.14	1130	1.01	8	0.62	0.1	0.50	6.3	0.25	172	0.45	1	0.59	3.6	0.44	0.13	0.21	1.4	0.61	36	0.26	1	0.83	62	0.82	Bi
B3-128	1	0.36	1.46	0.79	49	1.42	0.3	0.56	1.03	0.37	395	0.37	1.0	0.83	2.30	1.01	30	0.30	630	0.56	6	0.46	0.1	0.50	6.1	0.24	302	0.79	1	0.59	4.3	0.53	0.31	0.49	2.7	1.17	60	0.44	2	1.67	56	0.74	Bi
C3-315	1	0.36	0.20	0.11	56	1.62	0.4	0.74	0.13	0.05	215	0.20	7.0	5.83	0.21	0.09	32	0.32	770	0.69	8	0.62	0.1	0.50	8.2	0.33	49	0.13	1	0.59	5.6	0.69	0.06	0.09	1.6	0.70	30	0.22	1	0.83	344	4.53	Cd,Zn
A3-036	1	0.36	0.14	0.08	28	0.81	0.2	0.37	0.10	0.04	55	0.05	1.0	0.83	0.12	0.05	44	0.44	430	0.38	8	0.62	0.1	0.50	3.0	0.12	33	0.09	1	0.59	2.9	0.36	0.04	0.06	3.4	1.48	15	0.11	1	0.83	48	0.63	Cr
A3-028	1	0.36	0.17	0.09	26	0.75	0.3	0.56	0.11	0.04	50	0.05	3.0	2.50	0.16	0.07	64	0.65	380	0.34	4	0.31	0.1	0.50	2.7	0.11	36	0.09	1	0.59	2.1	0.26	0.04	0.06	29.2	12.70	16	0.12	1	0.83	44	0.58	Cr,Ni
A2-016	2	0.71	0.66	0.36	25	0.72	0.2	0.37	0.33	0.12	195	0.18	1.0	0.83	0.86	0.38	61	0.62	850	0.76	16	1.23	0.2	1.00	4.3	0.17	132	0.34	1	0.59	5.1	0.63	0.16	0.25	18.4	8.00	29	0.21	1	0.83	84	1.11	Cr,Ni
B3-125	9	3.21	1.27	0.69	48	1.39	0.3	0.56	0.61	0.22	325	0.31	4.0	3.33	2.08	0.92	22	0.22	470	0.42	10	0.77	0.1	0.50	4.4	0.18	285	0.74	2	1.18	7.7	0.95	0.22	0.35	7.8	3.39	36	0.26	1	0.83	48	0.63	Hf
A5-059	3	1.07	0.82	0.45	98	2.83	1.4	2.59	0.36	0.13	135	0.13	1.0	0.83	1.30	0.57	11	0.11	380	0.34	10	0.77	0.1	0.50	6.0	0.24	157	0.41	1	0.59	3.5	0.43	0.12	0.19	195.5	85.00	17	0.13	4	3.33	28	0.37	Lu,U
D4-453	3	1.07	0.57	0.31	109	3.15	0.4	0.74	0.34	0.12	205	0.19	35.0	29.17	0.48	0.21	20	0.20	2410	2.15	10	0.77	0.2	1.00	10.6	0.42	143	0.37	1	0.59	8.0	0.99	0.12	0.19	6.2	2.70	40	0.29	5	4.17	102	1.34	Mo
C4-272	7	2.50	1.41	0.77	38	1.10	0.4	0.74	0.65	0.24	260	0.25	41.0	34.17	2.34	1.03	23	0.23	450	0.40	10	0.77	0.1	0.50	11.3	0.45	289	0.75	1	0.59	7.7	0.95	0.23	0.36	8.2	3.57	38	0.28	3	2.50	42	0.55	Mo
B2-107	1	0.36	0.40	0.22	33	0.95	0.2	0.37	0.44	0.16	230	0.22	1.0	0.83	0.70	0.31	29	0.29	790	0.71	568	43.69	0.1	0.50	5.9	0.24	94	0.24	1	0.59	2.2	0.27	0.13	0.21	3.9	1.70	54	0.40	1	0.83	121	1.59	Pb
F2-684	2	0.71	0.58	0.32	11	0.32	0.1	0.19	0.28	0.10	160	0.15	1.0	0.83	1.14	0.50	6	0.06	430	0.38	90	6.92	0.1	0.50	4.3	0.17	157	0.41	1	0.59	1.5	0.19	0.07	0.11	0.3	0.13	16	0.12	1	0.83	72	0.95	Pb
G2-819	2	0.71	0.28	0.15	104	3.01	0.6	1.11	0.24	0.09	90	0.08	6.0	5.00	0.30	0.13	26	0.26	370	0.33	4	0.31	0.1	0.50	16.2	0.65	59	0.15	1	0.59	7.3	0.90	0.07	0.11	4.4	1.91	29	0.21	1	0.83	138	1.82	Sc
C5-277	4	1.43	0.83	0.45	48	1.39	0.3	0.56	0.42	0.15	425	0.40	1.0	0.83	1.16	0.51	18	0.18	1320	1.18	6	0.46	0.1	0.50	16.4	0.66	165	0.43	1	0.59	3.3	0.41	0.16	0.25	2.6	1.13	46	0.34	1	0.83	96	1.26	Sc
B3-099	3	1.07	0.74	0.40	54	1.56	0.3	0.56	0.63	0.23	435	0.41	1.0	0.83	1.35	0.59	21	0.21	1480	1.32	14	1.08	0.1	0.50	7.8	0.31	216	0.56	3	1.76	3.9	0.48	0.21	0.33	2.6	1.13	52	0.38	2	1.67	118	1.55	Ta
A4-051	3	1.07	0.45	0.24	4	0.12	0.6	1.11	0.29	0.10	105	0.10	1.0	0.83	0.58	0.26	13	0.13	430	0.38	12	0.92	0.1	0.50	2.5	0.10	98	0.26	1	0.59	3.8	0.47	0.10	0.16	69.6	30.26	20	0.15	1	0.83	76	1.00	U
D4-431	6	2.14	1.26	0.68	15	0.43	0.1	0.19	0.55	0.20	245	0.23	1.0	0.83	2.48	1.09	13	0.13	250	0.22	8	0.62	0.1	0.50	4.5	0.18	318	0.83	1	0.59	2.6	0.32	0.13	0.21	0.7	0.30	24	0.18	46	38.33	32	0.42	W
D4-353	5	1.79	1.22	0.66	22	0.64	0.1	0.19	0.62	0.22	250	0.24	1.0	0.83	2.07	0.91	16	0.16	330	0.29	10	0.77	0.1	0.50	3.7	0.15	275	0.72	1	0.59	3.8	0.47	0.21	0.33	0.9	0.39	30	0.22	30	25.00	40	0.53	W
E2-527	1	0.36	0.23	0.13	13	0.38	0.1	0.19	0.18	0.07	465	0.44	2.0	1.67	0.18	0.08	27	0.27	1370	1.22	8	0.62	0.3	1.50	6.1	0.24	35	0.09	1	0.59	2.5	0.31	0.05	0.08	0.4	0.17	28	0.21	1	0.83	952	12.53	Zn
D3-440	1	0.36	0.18	0.10	29	0.84	0.2	0.37	0.16	0.06	215	0.20	4.0	3.33	0.12	0.05	14	0.14	2260	2.02	8	0.62	0.1	0.50	1.5	0.06	37	0.10	1	0.59	2.3	0.28	0.04	0.06	0.7	0.30	43	0.32	1	0.83	240	3.16	Zn
C4-307	1	0.36	0.13	0.07	29	0.84	0.2	0.37	0.09	0.03	290	0.27	5.0	4.17	0.13	0.06	14	0.14	1030	0.92	16	1.23	0.1	0.50	5.3	0.21	27	0.07	1	0.59	2.7	0.33	0.04	0.06	0.7	0.30	22	0.16	1	0.83	402	5.29	Zn
C3-325	2	0.71	0.37	0.20	52	1.50	0.4	0.74	0.27	0.10	275	0.26	4.0	3.33	0.49	0.22	30	0.30	830	0.74	6	0.46	0.1	0.50	8.2	0.33	80	0.21	1	0.59	5.0	0.62	0.11	0.17	1.5	0.65	34	0.25	2	1.67	282	3.71	Zn

* The geology column above indicates sample sites below one rock type. The dashes represent sample sites (and catchment basins) below more than one lithologic unit.

EARLY PROTEROZOIC
7 = Mafic intrusive rocks (gabbro)
ARCHEAN
6a = Northern massive felsic intrusives
6b = Central massive felsic intrusives
6c = Southern massive felsic intrusives
5a = Ramsey gneiss domain: Felsic intrusive and metamorphic rocks
5b = Algoma plutonic domain: Felsic intrusive and metamorphic rocks
4 = Chemical metasediments (Magnetite-chert ironstone)
3 = Metasediments
2 = Felsic to intermediate metavolcanics
1 = Mafic to intermediate metavolcanics

Detailed Level

Thirty-one "geochemical anomalies" among the 683 Hanes Lake pre-*Ambrosia* lake sediment samples were selected for detailed discussion (Table 7). Results in Table 7 are printed as obtained from the contractor and have not been verified by reanalysis of the original samples or from results obtained after resampling.

Table 7 includes data for 1) "anomalous" elements in each of the 31 samples and 2) corresponding background levels for the remaining elements, which may be used for comparative purposes.

Identification of "anomalous" element occurences and sample site locations for the 31 samples from Table 7 are plotted on Figures 9a and 9b. The cluster of "anomalous" values is located mainly to east and south of the eastern mafic metavolcanic rocks. Because of the large area of Quaternary deposits (ground moraine and outwash plain), "anomalous" values may not be recognized in the eastern mafic metavolcanic rocks. Results in this section of the map area should be examined carefully for subtle clues concerning patterns for elements of interest.

Clearly, not all of the "anomalous" values listed on Table 7 and positioned on Figure 9a are of equal importance for mineral exploration. For example, sample C2-323, with "anomalous" As, Au and Cu, was collected near an area of known mineral occurences (Figure 1). Sample D3-421, with "anomalous" Au and La, was discovered just southeast of 2 new Au occurences. Similarly, sample A2-016, which was collected in the vicinity of a large diabase dike, was found to contain "anomalous" Cr and Ni.

THE PROBLEM OF SECONDARY Fe AND Mn

It has been shown in previous geochemical maps in this series (Fortescue and Vida 1989,1990), that significant levels of secondary Fe and Mn in samples may complicate the interpretation of "anomalous" element values in pre-*Ambrosia* lake sediments. High Fe and Mn oxides may scavenge trace elements from lake waters and accumulate secondary geochemical "anomalies".

In the Trout Lake area (Fortescue and Vida 1989), pre-*Ambrosia* levels of Fe and Mn greater than or equal to 2.5% and/or 500 ppm were considered to be associated with secondary geochemical anomalies. Using this criteria for the Hanes Lake area data, it was discovered that only 1 iron-rich and 2 manganese-rich samples were present (Table 7). Sample B3-162 ([As, Pb]), which was high in both Fe and Mn, should not be included in a detailed statistical analysis of the entire data set.

"ANOMALOUS" GEOCHEMICAL RESULTS WHICH REQUIRE VERIFICATION

Samples containing "anomalous" concentrations for elements of interest are grouped alphabetically by element on Table 7. Each group will now be described briefly, sample by sample.

Gold

A total of 6 high Au values, greater than or equal to 10 ppb, were found amounng the Hanes Lake samples (Table 1). Four samples, C2-323 (13 ppb), D3-421 (13 ppb), D5-428 (37 ppb), and F2-743 (16 ppb), were considered "anomalous". Sample C2-323 contained moderately high Fe (2.13 %), Mn (415 ppm) and V (50 ppm). Sample Df-528 was found to contain Fe (0.99%), Mn (156 ppm) and V (25 ppm). All other "anomalous" Au samples contained small amounts of Fe, Mn, and V, suggesting their composition is not associated with the presence of an iron formation. Sample D3-421 has "anomalous" La at 283 ppm with high Cu at 101 ppm.

It should be noted that a total of 3 "anomalous" Au values were found in the post- and mixed pre/post-*Ambrosia* material. One sample, B3-132, contained 10 ppb Au from the mixed pre/post-*Ambrosia* material. Two samples, A1-054 and C2299, contained 20 ppb and 12 ppb Au respectively from the post-*Ambrosia* material. With respect to elements other than Au, few high values were found among the 213 mixed (pre/post-) and post-*Ambrosia* material. The results from all 3 samples should be verified and used with caution because of their sediment type.

Arsenic

Two "anomalous" As values (B3-162 [96 ppm] and C2-323 [22 ppm]) are included in Table 7 with LOI values of 23.8% and 14.2% respectively.

Sample B3-162 contains 52 ppm Pb and 152 ppm Zn. Because sample B3-162 contains high Fe (4.09%) and Mn (995 ppm), results from this sample should be used with caution.

Sample C2-323 includes moderately high Fe (2.13%), Mn (415 ppm) and V (50 ppm). The high As may be derived from the bedrock and/or the Quaternary geology. In this sample, significant levels of Au (13 ppb) were found along with high levels of Cu at 204 ppm.

Silver

Sample G2-800 was collected in the northern felsic intrusive rocks and contains 1.8 ppm Ag. The southern felsic intrusive rock samples include sample B3-140 at 1.0 ppm Ag with relatively high Zn at 148 ppm. These values require verification by resampling.

Lead, Zinc and Molybdenum

Two samples with "anomalous" Pb, 2 with Mo, and 4 with "anomalous" Zn are included in this group. Sample B2-107 has 568 ppm Pb with 121 ppm Zn and 35 ppm Cu; and sample F2-684 has 90 ppm Pb with 72 ppm Zn.

Five "anomalous" Zn values greater than 239 ppm were found among the Hanes Lake samples. These include samples C3-315 (344 ppm), C3-325 (282 ppm), C4-307 (402 ppm), D3-440 (240 ppm) and E2-527 (952 ppm). Figure 6k, which plots Zn values greater than or equal to 152 ppm, and Figure 9a, show high Zn values occur along the Goulais River iron range. Sample E2-527 contains relatively high Mn (465 ppm) but low Fe (1.41%) and Mn (462 ppm), which may result from secondary accumulation. Copper (greater than 65 ppm) is relatively high in these samples also.

In the mixed pre/post-*Ambrosia* sediments, one sample, E3-521, contained high Zn (224 ppm). No "anomalous" Zn values were discovered in the post-*Ambrosia* sediments. Sample E3-521 should be verified and the results used with caution.

Molybdenum values greater than or equal to 5.0 K (6.0 ppm) are plotted on Figure 6e. In the Hanes Lake pre-*Ambrosia* lake sediments, the mean for Mo is 1.85 ppm. Two "anomalous" values above 35.0 ppm were identified. Sample C4-272 contains 41.0 ppm Mo with 9.4% LOI, 4 ppb Au, 7 ppm Hf and low levels of Fe (1.74%), and Mn (260 ppm). This sample contains low LOI and the higher the level of mineral matter, the lower the LOI of an sample. Sample D4-453 has 35.0 ppm Mo with normal LOI at 40%, 8 ppb Au, 43.9 ppm Br, 106 ppm Cu, 109 ppm La, 2410 ppm P, 1.0 ppm Sb, 5 ppm W and 102 ppm Zn. Also, the levels of Fe and Mn are low (1.32% Fe and 205 ppm Mn).

From the 213 additional sediments collected, 2 other samples contained high Mo. Sample B4-129 from the mixed pre/post-*Ambrosia* sediment was found to contain high Mo (11 ppm) and sample C4-279 from the post-*Ambrosia* sediment also contained high Mo (10 ppm). Results from these samples should be used with caution and verified.

Barium, Hafnium and Strontium

The mean Ba level in the Hanes Lake area is 156.16 ppm. Three samples greater than or equal to 470 ppm were considered "anomalous" and listed on Table 7. With the exception of B3128, LOI was low and ranged from 8.2 to 10.2%. Sample C4-216 is "anomalous" in Ba (480 ppm) and Hf (9 ppm), sample B3-110 is "anomalous" in Ba (680 ppm), Bi (8 ppm) and Sr (425 ppm) and sample B3-128 is "anomalous" in Ba (470 ppm), Bi (8 ppm) and Sr (302 ppm).

Along with sample C4-216, "anomalous" Hf (9 ppm) occurs in sample B3-125 with low LOI (8.6 %), high Ba (410 ppm) and Cu (113 ppm).

All the samples listed in this section have low LOI, indicating theses lake sediments are mineral rich. The lower the LOI, the higher the mineral matter. Higher levels of Al, K, Mg and Na confirm this relationship in these samples.

Bismuth, Cadmium and Tantalum

Because of their relatively high detection limits, Bi, Cd and Ta were not found in many of the Hanes Lake samples. Consequently, any "anomalous" results on Table 7 for these elements should be interpreted with caution.

Seventy Bi values were detected above a background of 2 ppm. Fifty values occur at 4 ppm, 13 at 6 ppm and 3 at the "anomalous" value of 8 ppm. Because sample B3-110 has low LOI (10.2%), a high level of mineral matter must be occur in this lake sediment. The other two samples had LOI greater than or equal to 25.8 %, indicating a higher concentration of organic matter.

For Cd, the background was 1.5 ppm with 7 values greater than 2 ppm and 1 "anomalous" value equal to 2.5 ppm (sample C3-315). Relatively high levels of Cu (105 ppm) and "anomalous" Zn values (mentioned previously) are contained in this sample also.

One high Ta result (B3-099) was included in the Hanes Lake data. LOI (33.4%) was at relatively normal levels (Table 7).

Tungsten

Two samples, D4-353 (30 ppm) and D4-431 (46 ppm), were considered "anomalous" in the Hanes Lake area. Figure 9a and Figure 6e both show a clustering of high W values in the Algoma plutonic domain and along the granite-greenstone geological contact. LOI in the samples are low, 10.8 and 4.0 respectively.

From the 213 additional sediments collected, 3 other samples contained high W. Sample G4-862, from the mixed pre/post*Ambrosia* sediments, was found with high W (10 ppm) and samples G4-874 and F3-702, from the post-*Ambrosia* sediments, contained high W at 15 ppm and 11 ppm respectively. It is important to verify the analyses for these samples because of the type of sediment they were collected in.

Uranium, Lutecium, and Lanthanum

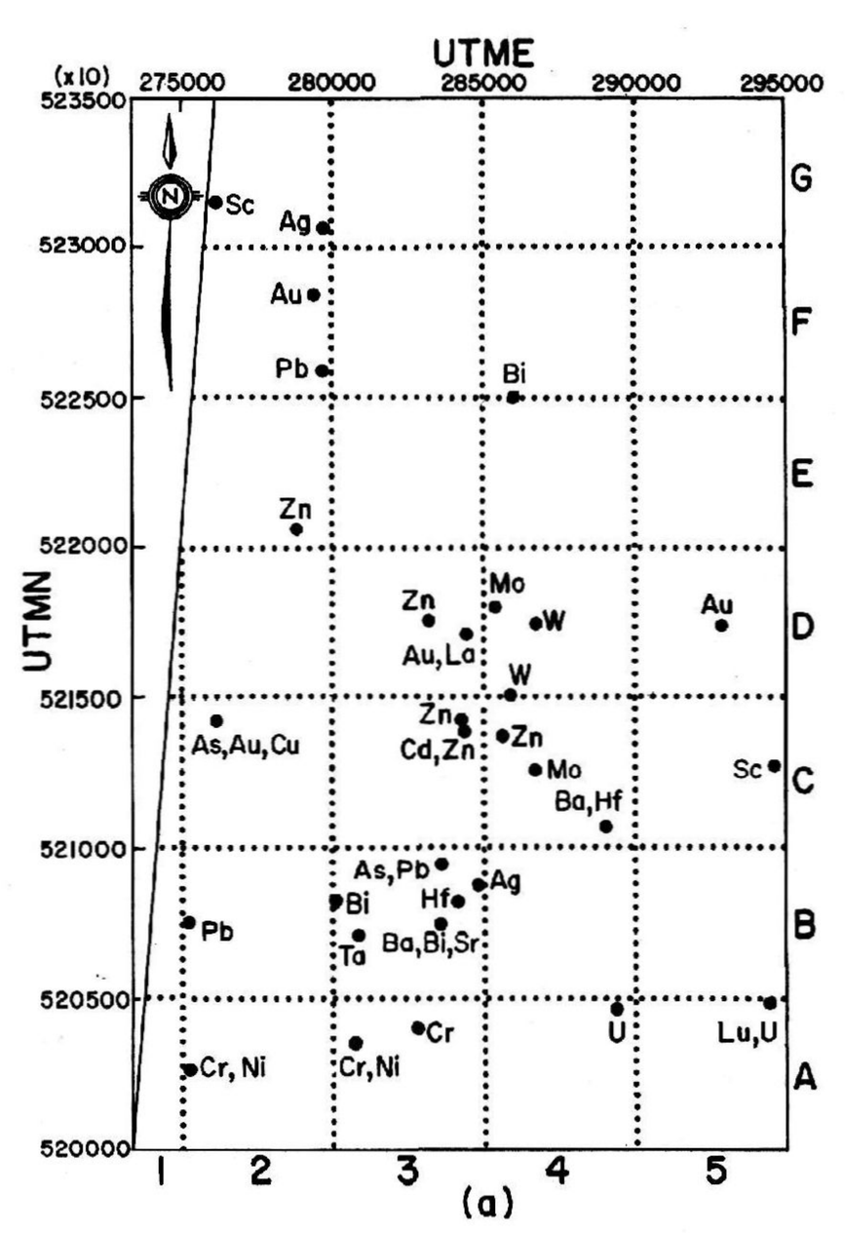
The "anomalous" results for U, Lu, and La are of general interest and their significance in mineral exploration is as yet unclear.

In the Hanes Lake area, 26 samples contain high U levels (greater than or equal to 18.4 ppm, Figure 6a). Samples A4-051 and A5-059 were considered "anomalous" with 69.6 ppm U and 195.5 ppm U, respectively. Lanthanum and Lu were correspondingly high in the latter sample (98 ppm La and 1.4 ppm Lu). Note, this is the only sample in the Hanes Lake data base set with Lu greater than 1 ppm.

Sample D3-421 has "anomalous" La (283 ppm) and Au. Twenty samples have La levels greater than 69.2 ppm in total (*see* Figure 6c). The "anomalous" samples occur on the Algoma plutonic domain and in the granite-greenstone contact.

SUMMARY

The geochemistry of the 31 "selected" lake sediment samples just described has provided a series of "targets" for mineral exploration in the Hanes Lake area. These descriptions should be interpreted in conjunction with regional geological and geophysical maps of the area. It is strongly recommended that all "anomalous" values described here are should be verified by resampling during the mineral resource appraisal.



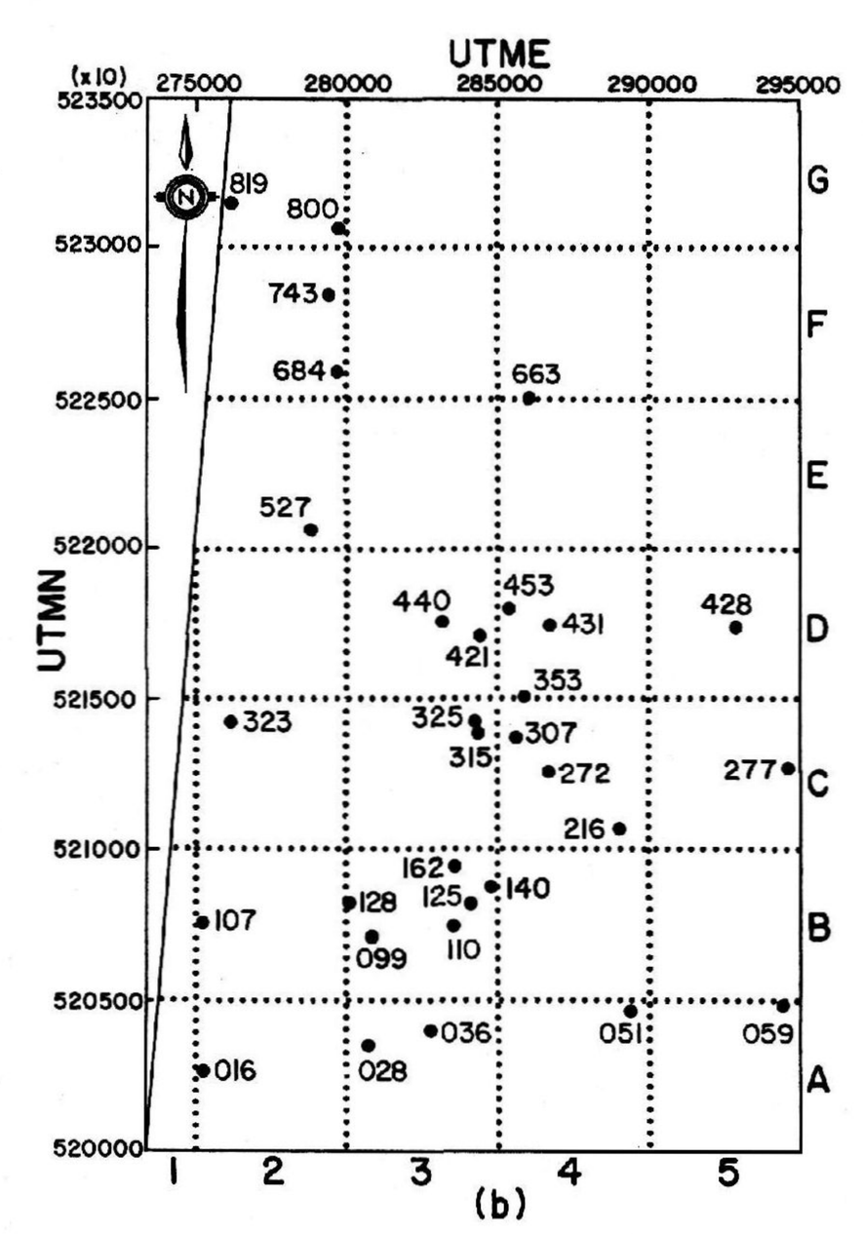


Figure 9. Detailed map delineating in the Hanes Lake area: **a)** the 31 "anomalous" samples and locations, and **b)** sample site codes and their locations.

SUMMARY FOR THE HANES LAKE REGIONAL GEOCHEMICAL SURVEY

The geochemical map area is located at the eastern limit of the Batchawana greenstone belt. The survey area also includes some granitic terrane along the eastern border, and to the north and south of the greenstone belt.

As described here, the Hanes Lake regional geochemical survey is based on data obtained from pre-*Ambrosia* sediments and water samples collected from 683 sites. The lake sediment samples were all collected using a gravity core sampler. Thirty-five elements were determined in each pre-*Ambrosia* sediment sample.

During sampling, 118 post-*Ambrosia* and 95 mixed (i.e., pre/post-*Ambrosia*) samples were collected in addition to the 683 pre-*Ambrosia* samples. Geochemical data for the additional 213 samples are included on the data base diskette(s). These results are not discussed here because the Batchawana regional geochemical survey as a whole is based on pre-*Ambrosia* material only. (Bearing in mind the possibility of significant atmospheric anthropogenic inputs for certain elements in post-Ambrosia material, caution should be exercised when the additional 213 sample data base is interpreted for mineral exploration purposes.)

The Hanes Lake area includes many medium to large lakes which called for the collection of more than one sample. Occassionally the data obtained from multiple samples from a single lake created a cluster or "geochemical province" pattern for one or more elements. This type of pattern did not occur in the Trout Lake area. During the interpretation of the Hanes Lake data, this pattern type should be taken into account because it is an independent verification of high values.

Geology, Quaternary cover, metamorphism, alteration and multiple sampling from one lake complicate the interpretation of the geochemical patterns derived from lake sediments. However, spatial patterns are still recognizeable in lake sediments for most elements of interest for mineral resource appraisal. A series of geochemical-geological sections across the greenstone belt show these relationships. Some patterns are regional ("geochemical provinces"), while others are due to point sources ("geochemical anomalies"). Both of these pattern types are of potential importance for mineral exploration.

The data for 31 "geochemical anomalies" within the 683 lake sediment samples were described. Important problems encountered in the interpretation of this geochemical data have been discussed in detail, in relation to mineral resource appraisal. Verification of these geochemical results is an essential preliminary to their use in mineral exploration.

CONCLUSIONS

METHODOLOGY

1. The application of a quality control procedure to the entire batch of Hanes Lake sediment samples revealed that:

a. The geochemical data for 19 elements (Mg, Ti, Na, Mn, Fe, K, Sr, V, Sc, Ca, Al, Ba, Th, Cu, U, La, P, Zn and Br) are acceptable for detailed statistical analysis, image processing and entry into a geoscience GIS. (In spite of minor inconsistencies and for continuity, these elements were used for global geochemical signatures in the Hanes Lake, Herman Lake and Trout Lake regional geochemical map data, *see* Fortescue and Vida (1989, 1990)).

b. The Hanes Lake geochemical data for 16 other elements (Ag, As, Au, Be, Bi, Cd, Co, Cr, Hf, Lu, Mo, Ni, Pb, Sb, Ta and W) are of variable quality and should not be subjected to detailed statistical analysis, image processing or incorporated into a geoscience GIS without careful consideration.

LAKE SEDIMENT GEOCHEMISTRY

2. It is concluded from the **global level** study of the Hanes Lake geochemical data that:

a. A GDS provides an effective basis of comparison for geochemical signatures obtained from 7 different rock types in the Hanes Lake area.

b. A unique 19 element global signature was discovered for each of the 7 rock types in the Hanes Lake area. The signatures were based on geochemical data obtained from a minimum of 19 catchments all entirely underlain by one rock type. Global geochemical signatures provide a relatively simple basis for comparisons of geochemistry among varying rock units in the Hanes Lake area. These geochemical signatures can be used for comparisons with other OGS regional geochemical maps.

3. Several conclusions were drawn from a regional level of interpretation of the Hanes Lake geochemical data base.

a. **Regional Geochemical Map Patterns**

It is concluded from an analysis of regional map patterns for selected elements using Hanes Lake area pre-*Ambrosia* sediments that:

i. Patterns for nine elements, Ag, As, Au, Cu, Mo, Pb, U, W and Zn may be of direct interest in mineral exploration (Figure 6).

ii. Patterns for seven other elements, Bi, Cd, La, Hf, Mg, Sb and Th are of less significance (Figure 6).

b. **Single Element Regional Geochemical-Geological Map Strips**

It is concluded on the basis of information obtained from LOI and 18 selected single element regional geochemica /geolog ·ical map strips that:

i. Patterns for one or more of Au, As, Cu, Mo, Pb, U, W and Zn (Figure 8) may indicate possible exploration targets. These results should be verified by resampling before any action is taken.

c. **Principal Components Analysis (PCA)**

A PCA was applied to pre-*Ambrosia* geochemical data from 1) the entire Hanes Lake area and 2) geochemical data sets representative of catchment areas underlain by principal rock types in the map area. It was concluded that:

i. The first and most important factor extracted from each data set showed LOI is always strongly and inversely correlated with mineral matter. As mineral matter increases in pre-*Ambrosia* sediment samples, organic matter decreases.

ii. Iron and Mn may be strongly correlated with one or more trace elements in a single factor. (This evidence, which indicates secondary accumulation of Fe, Mn and other elements, is not so strong in the Hanes Lake area as the Trout Lake area, *see* Fortescue and Vida 1989).

iii. Uranium, Th and La are strongly correlated in a single factor which is associated with granitic terranes underlying catchment areas

iv. In all the data sets examined, some factors were considered of minor importance.

4. At the **detailed level**, 31 samples with results identified as "geochemical anomalies" within the Hanes Lake data set were examined. It is concluded that:

a. A small number of "anomalous" results for Ag, As, Au, Cu, Mo, Pb, U, W and Zn are of direct interest in mineral exploration in the Hanes Lake area.

The reader is reminded that the 31 samples containing "anomalous" results have not been verified by resampling and/or re-analysis.

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CREDITS

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Assistance by the Sault Ste. Marie Resident Geologist, Gerry Bennett, and his staff in 1989 and 1990 is gratefully acknowledged.

Issued 1990.

Information from this publication may be quoted if credit is given. It is recommended that reference to this map be made in the following form:

Fortescue, J.A.C. and Vida, E.A. 1990. Geochemical survey, Hanes Lake area; Ontario Geological Survey, Map 80 806.