Natural Resources Canada / Ressources naturelles Canada

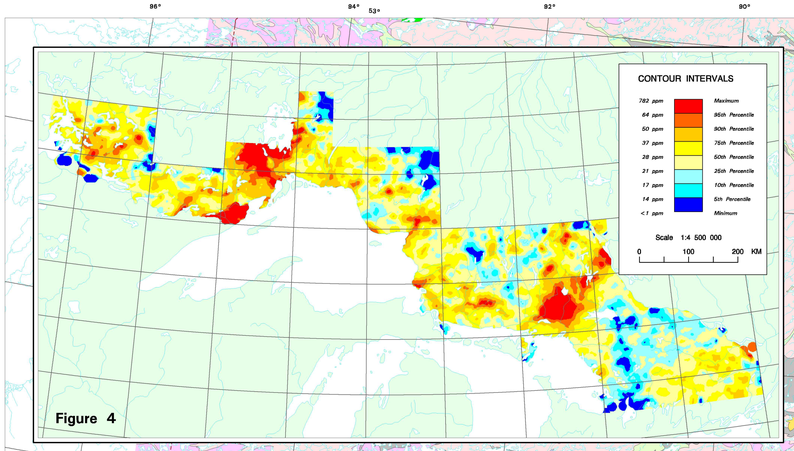

Figure 4

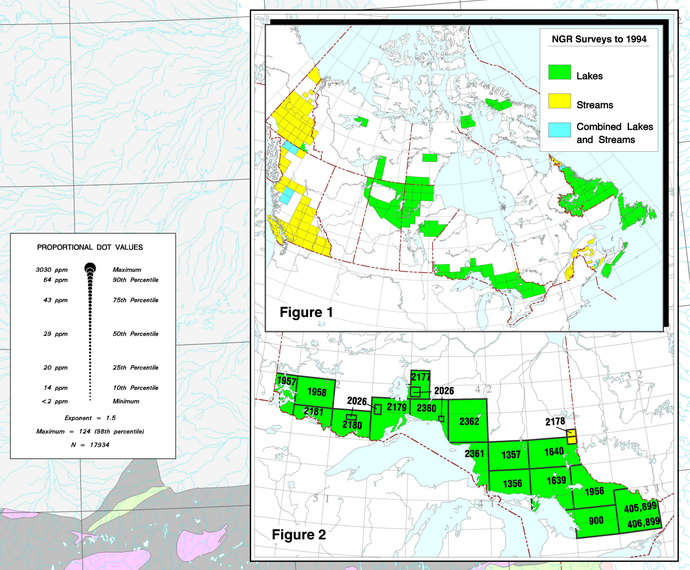

Figure 1

Figure 2

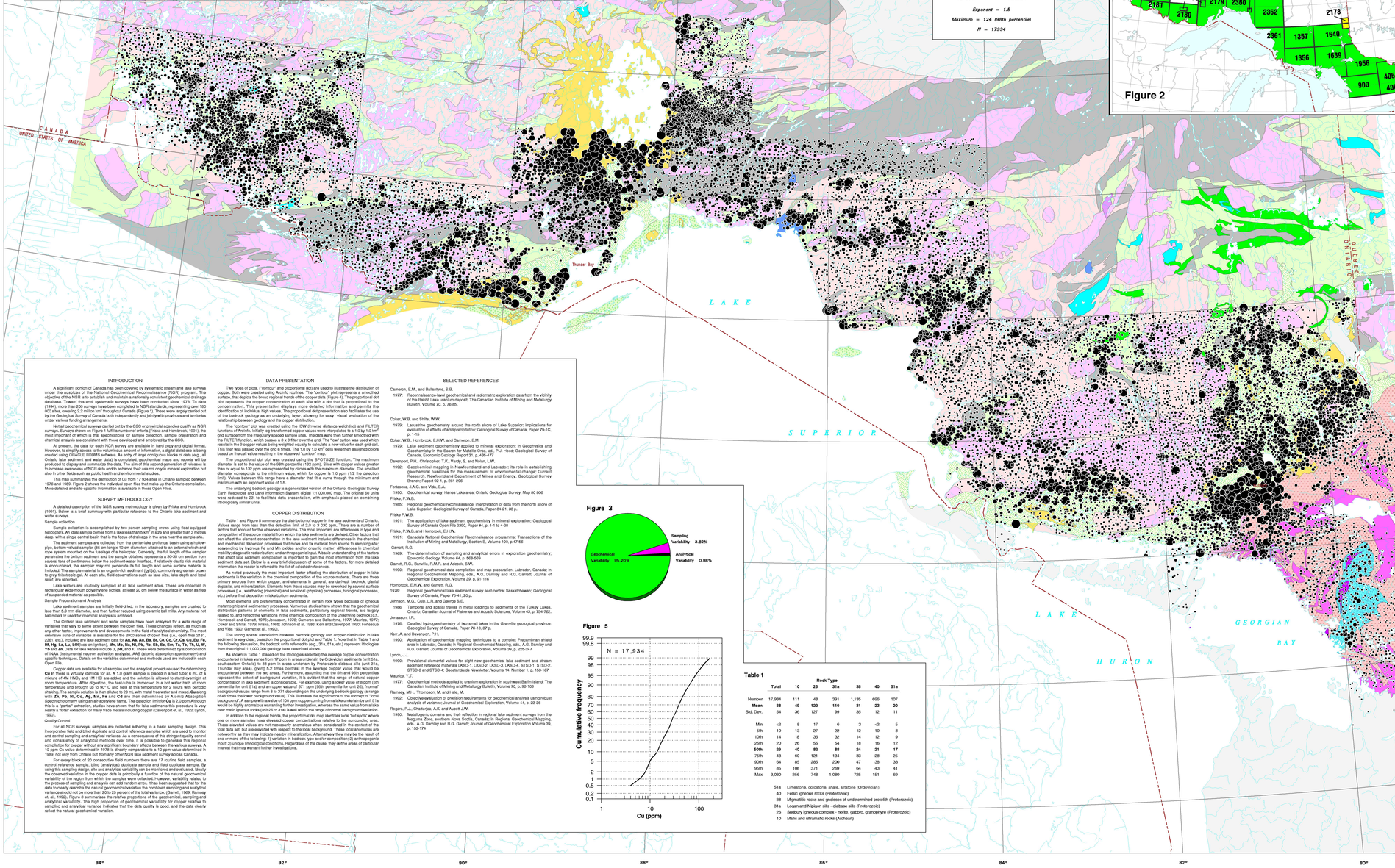

Figure 3

Figure 5

Table 1

	Rock Type						
	Total	10	26	31a	38	40	51a
Number	17,934	111	48	391	1,135	696	107
Mean	**38**	**49**	**122**	**110**	**31**	**23**	**20**
Std. Dev.	54	36	127	99	35	12	11
Min	<2	8	17	6	3	<2	5
5th	10	13	27	22	12	10	8
10th	14	18	36	32	14	12	9
25th	20	26	55	54	18	16	12
50th	**29**	**40**	**82**	**88**	**24**	**21**	**17**
75th	43	60	121	134	33	28	25
90th	64	85	285	200	47	38	33
95th	85	108	371	299	64	43	41
Max	3,030	256	748	1,080	725	151	69
	51a	Limestone, dolostone, shale, siltstone (Ordovician)					
	40	Felsic igneous rocks (Proterozoic)					
	38	Migmatitic rocks and gneisses of undetermined protolith (Proterozoic)					
	31a	Logan and Nipigon sills - diabase sills (Proterozoic)					
	26	Sudbury igneous complex - norite, gabbro, granophyre (Proterozoic)					
	10	Mafic and ultramafic rocks (Archean)					

INTRODUCTION

A significant portion of Canada has been covered by systematic stream and lake surveys under the auspices of the National Geochemical Reconnaissance (NGR) program. The objective of the NGR is to establish and maintain a nationally consistent geochemical drainage database. Toward this end, systematic surveys have been conducted since 1973. To date (1994), more than 200 surveys have been completed to NGR standards, representing over 180 000 sites, covering 2.2 million km² throughout Canada (Figure 1). These were largely carried out by the Geological Survey of Canada both independently and jointly with provinces and territories under various funding arrangements.

Not all geochemical surveys carried out by the GSC or provincial agencies qualify as NGR surveys. Surveys shown on Figure 1 fulfill a number of criteria (Friske and Hornbrook, 1991), the most critical being that the recommendations for sample collection, sample preparation and chemical analysis are consistent with those developed and employed by the GSC.

At present, the data for each NGR survey are available in hard copy and digital format. However, to simplify access to the voluminous amount of information, a digital database is being created using ORACLE RDBMS software. As entry of large contiguous blocks of data (e.g., all Ontario lake sediment and water data) is completed, geochemical maps and reports will be produced to display and summarize the data. The aim of this second generation of releases is to increase awareness of NGR data and to enhance their use not only in mineral exploration but also in other fields such as public health and environmental studies.

This map summarizes the distribution of Cu from 17 934 sites in Ontario sampled between 1976 and 1989. Figure 2 shows the individual open files that make-up the Ontario compilation. More detailed and site-specific information is available in these Open Files.

SURVEY METHODOLOGY

A detailed description of the NGR survey methodology is given by Friske and Hornbrook (1991). Below is a brief summary with particular reference to the Ontario lake sediment and water surveys.

Sample collection

Sample collection is accomplished by two-person sampling crews using float-equipped helicopters. An ideal sample comes from a lake less than 5 km² in size and greater than 3 metres deep, with a single central basin that is the focus of drainage in the area near the sample site.

The sediment samples are collected from the center-lake profundal basin using a hollow-pipe, bottom-valved sampler (85 cm long x 10 cm diameter) attached to an external winch and rope system mounted on the fuselage of a helicopter. Generally, the full length of the sampler penetrates the bottom sediment and the sample obtained represents a 30-35 cm section from several tens of centimetres below the sediment-water interface. If relatively clastic rich material is encountered, the sampler may not penetrate its full length and some surface material is included. The sample material is an organic-rich sediment (gyttja), commonly a greenish brown to gray thixotropic gel. At each site, field observations such as lake size, lake depth and local relief, are recorded.

Lake waters are routinely sampled at all lake sediment sites. These are collected in rectangular wide-mouth polyethylene bottles, at least 20 cm below the surface in water six free of suspended material as possible.

Sample Preparation and Analysis

Lake sediment samples are initially field-dried. In the laboratory, samples are crushed to less than 0.5 mm diameter, and then further reduced using ceramic ball mills. Any material not ball milled or used for chemical analysis is archived.

The Ontario lake sediment and water samples have been analyzed for a wide range of variables that vary to some extent between the open files. These changes reflect, as much as possible, the analytical requirements of exploration in the field of analytical chemistry. The most extensive suite of variables is available for the 2000 series of open files (i.e., open files 2181, 2361, etc.), included are lake sediment data for **Ag, As, Au, Ba, Br, Ce, Co, Cr, Cs, Cu, Eu, Fe, Hf, Hg, La, Lu, LOI**(loss-on-ignition), **Mn, Mo, Na, Ni, P, Pb, Rb, Sb, Sc, Sm, Ta, Th, Ti, U, W, Yb** and **Zn.** Data for lake waters include **U, pH,** and **F.** These were determined by a combination of INAA (instrumental neutron activation analysis), AAS (atomic absorption spectrometry) and specific techniques. Details on the variables determined and methods used are included in each Open File.

Copper data are available for all samples and the analytical procedure used for determining **Cu** in these is virtually identical for all. A 1.0 gram sample is placed in a test tube; 2 mL of a mixture of 4M HNO_3 and 1M HCl are added and the solution is allowed to stand overnight at room temperature. The samples are then placed in a hot water bath for 2 hours at 90° C maximum temperature and brought up to 90° C and held at this temperature for 2 hours with periodic shaking. The sample solution is then diluted to 20 mL with metal free water and mixed. **Cu** along with **Zn, Pb, Ni, Co, Ag, Mn, Fe** and **Cd** are then determined by Atomic Absorption Spectrophotometry using an air-acetylene flame. The detection limit for **Cu** is 2.0 ppm Although this is a "partial" extraction, studies have shown that for lake sediments this procedure is very nearly a "total" extraction for many trace metals including copper (Davenport et. al., 1992; Lynch, 1990).

Quality Control

For all NGR surveys, samples are collected adhering to a basic sampling design. This incorporates field and blind duplicate and control reference samples which are used to monitor and control sampling and analytical variance. As a consequence of this stringent quality control and consistency of analytical methods over time, it is possible to generate this regional compilation for copper without any significant boundary effects between the various surveys. A 10 ppm Cu value determined in 1978 is directly comparable to a 10 ppm value determined in 1989, not only from Ontario but from any other NGR lake sediment survey across Canada.

For every block of 20 consecutive field numbers there are 17 routine field samples, a control reference sample, a field duplicate and a blind duplicate. The control reference sample is used to monitor the sampling design, site and analytical variability can be monitored and evaluated, ideally the observed variation in the copper data is principally a function of the natural geochemical variability of the region from which the samples were collected. However, variability related to the process of sampling and analysis can add random error. It has been suggested that for the data to clearly describe the natural geochemical variation the combined sampling and analytical variance should not be more than 20 to 25 percent of the total variance. (Garrett, 1969; Ramsey et. al., 1992). Figure 3 summarizes the relative proportions of the geochemical, sampling and analytical variability. The high proportion of geochemical variability for copper relative to sampling and analytical variance indicates that the data quality is good, and the data clearly reflect the natural geochemical variation.

DATA PRESENTATION

Two types of plots, ("contour" and proportional dot) are used to illustrate the distribution of copper. Both were created using Arcinfo routines. The "contour" plot represents a smoothed surface, that depicts the broad regional trends of the copper data (Figure 4). The proportional dot plot represents the copper concentration at each site with a dot that is proportional to the concentration. This presentation displays more detailed information and permits the identification of individual high values. The proportional dot presentation also facilitates the use of the bedrock geology as an underlying layer, allowing for easy visual evaluation of the relationship between geology and the copper distribution.

The "contour" plot was created using the IDW (inverse distance weighting) and FILTER functions of Arcinfo. Initially log-transformed copper values were interpolated to a 3.2 by 1.2 km² cell using the IDW function with default parameters. The data were then further smoothed with the FILTER function, which passes a 3 x 3 filter over the grid. The "low" option was used which results in the 9 copper values being weighted equally to calculate a new value for each grid cell. This filter was passed over the grid 6 times. The 1.0 by 1.0 km² cells were then assigned colors based on the cell value resulting in the observed "contour" map.

The proportional dot plot was created using the SPOTDIZE function. The maximum diameter is set to the value of the 98th percentile (132 ppm). Sites with copper values greater than or equal to 132 ppm are represented by circles with the maximum diameter. The smallest diameter corresponds to the minimum value, which for copper is 1.0 ppm (1/2 the detection limit). Values between this range have a diameter that fit a curve through the minimum and maximum with an exponent value of 1.5.

The underlying bedrock geology is a generalized version of the Ontario, Geological Survey Earth Resources and Land Information System, digital 1:1,000,000 map. The original 60 units were reduced to 22, to facilitate data presentation, with emphasis placed on combining lithologically similar units.

COPPER DISTRIBUTION

Table 1 and Figure 5 summarize the distribution of copper in the lake sediments of Ontario. Values range from less than the detection limit of 2.0 to 3 030 ppm. There are a number of factors that account for the observed variations. The most important are differences in type and composition of the source material from which the lake sediments are derived. Other factors that affect the final element concentration in the lake sediment include differences in the physical and mechanical sorting of material during transport and its relative abundance, scavenging by hydrous Fe and Mn oxides and organic matter, differences in chemical mobility/ diagenetic redistribution and anthropogenic input. A basic understanding of the factors that affect lake sediment composition is important to gain the most information from the lake sediment data set. Below is a very brief discussion of some of the factors, for more detailed information the reader is referred to the list of selected references.

As noted previously the most important factor effecting the distribution of copper in lake sediments is the variation in the chemical composition of the source material. There are three primary sources from which copper, and elements in general, are derived: bedrock, glacial deposits, and mineralization. Elements from these sources may be reworked by several surface processes (i.e., weathering [chemical] and erosional [physical] processes, biological processes, etc.) before final deposition in lake bottom sediments.

Most elements are preferentially concentrated in certain rock types because of igneous metamorphic and sedimentary processes. Numerous studies have shown that the geochemical composition of lake sediments can be directly related to the bedrock over which the lake has eroded to, and reflect the variations in the chemical composition of the underlying bedrock (cf., Hornbrook and Garrett, 1976; Jonasson, 1976; Cameron and Ballantyne, 1977; Maurice, 1977; Coker and Shilts, 1979; Friske, 1985; Johnson et al. 1986; Kerr and Davenport 1990; Fortescue and Vida 1990; Garrett et al., 1990).

The strong spatial association between bedrock geology and copper distribution in lake sediment is very clear, based on the proportional dot plot and Table 1. Note that in Table 1 and the following discussion, the bedrock units referred to (e.g., 31a, 51a, etc.) represent lithologies from the original 11,000,000 geology base described above.

As shown in Table 1 (based on the lithologies selected) the average copper concentration encountered in lakes varies from 17 ppm in areas underlain by Ordovician sediments (unit 51a, southeastern Ontario) to 88 ppm in areas underlain by Proterozoic diabase sills (unit 31a, Thunder Bay area), giving 5.2 times contrast in the average copper value that would be encountered between the two areas. Furthermore, assuming that the 5th and 95th percentiles represent the extent of background variation, it is evident that the range of natural copper concentrations in lake sediment is quite large. For example, the lake sediment data with a 5th percentile for unit 51a) and an upper value of 371 ppm for unit 26), "normal" background values range from 8 to 371 depending on the underlying bedrock geology (a range of 46 times the lower background value). This illustrates the significance of the concept of "local background". A sample with a value of 100 ppm copper coming from a lake underlain by unit 51a would be highly anomalous warranting further investigation, whereas the same value from a lake over mafic igneous rocks (unit 26 or 31a) is well within the range of normal background variation.

In addition to the regional trends, the proportional dot map identifies local "hot spots" where one or more samples have elevated copper concentrations relative to the surrounding area. These elevated values are not necessarily anomalous when considered in the context of the total data set, but are elevated with respect to the local background. These local anomalies are commonly a function of the local geochemical environment. Anomalies may be the result of one or more of the following: 1) variation in bedrock type and/or composition, 2) anthropogenic input, 3) unique limnological conditions. Regardless of the cause, they define areas of particular interest that may warrant further investigations.

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OPEN FILE 2959

National Geochemical Reconnaissance

ONTARIO COMPILATION COPPER IN LAKE SEDIMENT

ONTARIO

Scale 1:1 500 000 - Échelle 1/1 500 000

Kilometres 50 0 50 100 150 Kilomètres

Lambert Conic Conformal Projection
Standard Parallels 49°N and 77°N
CM 85.5°W, Scale Factor 1.0
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Projection conique conforme de Lambert
Parallèles d'échelle conservée 49°N et 77°N
M.C. 85.5°, facteur d'échelle 1,0
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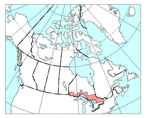
Digital cartography by T.D. West, Geological Survey of Canada

Any revisions or additional information known to the user would be welcomed by the Geological Survey of Canada

Background geological information modified from Map 2545, Bedrock Geology of Ontario, Geology of Ontario digital map series

Please note that the digital background geology was not originally compiled on Digital Chart of the World topographic maps and has been adjusted (rubber-sheeted) by the GSC to fit this base. Slight geometric distortion of the original geological contacts relative to topography may exist in some areas

Base map assembled from Digital Chart of the World, 1:1 000 000 scale



LOCATION MAP

OPEN FILE
DOSSIER PUBLIC
2959
GEOLOGICAL SURVEY OF CANADA
COMMISSION GÉOLOGIQUE DU CANADA
OTTAWA
11/1994

LEGEND

PHANEROZOIC

Sedimentary rocks

PRECAMBRIAN

GRENVILLE PROVINCE

PROTEROZOIC

Migmatitic rocks and gneisses

Carbonate metasedimentary rocks

Clastic metasedimentary rocks

Anorthosite and allalic igneous rocks

Felsic plutonic rocks

Mafic to ultramafic plutonic rocks

Mafic to felsic metavolcanic rocks

SUPERIOR AND SOUTHERN PROVINCES

Intrusive rocks

Carbonatite-alkalic intrusive rocks

Mafic intrusive rocks

Felsic intrusive rocks

Supracrustal rocks

Metasedimentary rocks and minor metavolcanic rocks

Metavolcanic rocks and minor metasedimentary rocks

SUPERIOR PROVINCE

ARCHEAN

Intrusive rocks

Diorite-nepheline syenite suite

Massive to foliated granodiorite to granite

Foliated to gneissic tonalite to granodiorite

Mafic and ultramafic rocks

Supracrustal rocks

Metasedimentary rocks and derived gneisses

Mafic to felsic metavolcanic rocks and metasedimentary rocks

Mafic to ultramafic metavolcanic rocks and metasedimentary rocks

Copies of this map may be obtained
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Canada

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