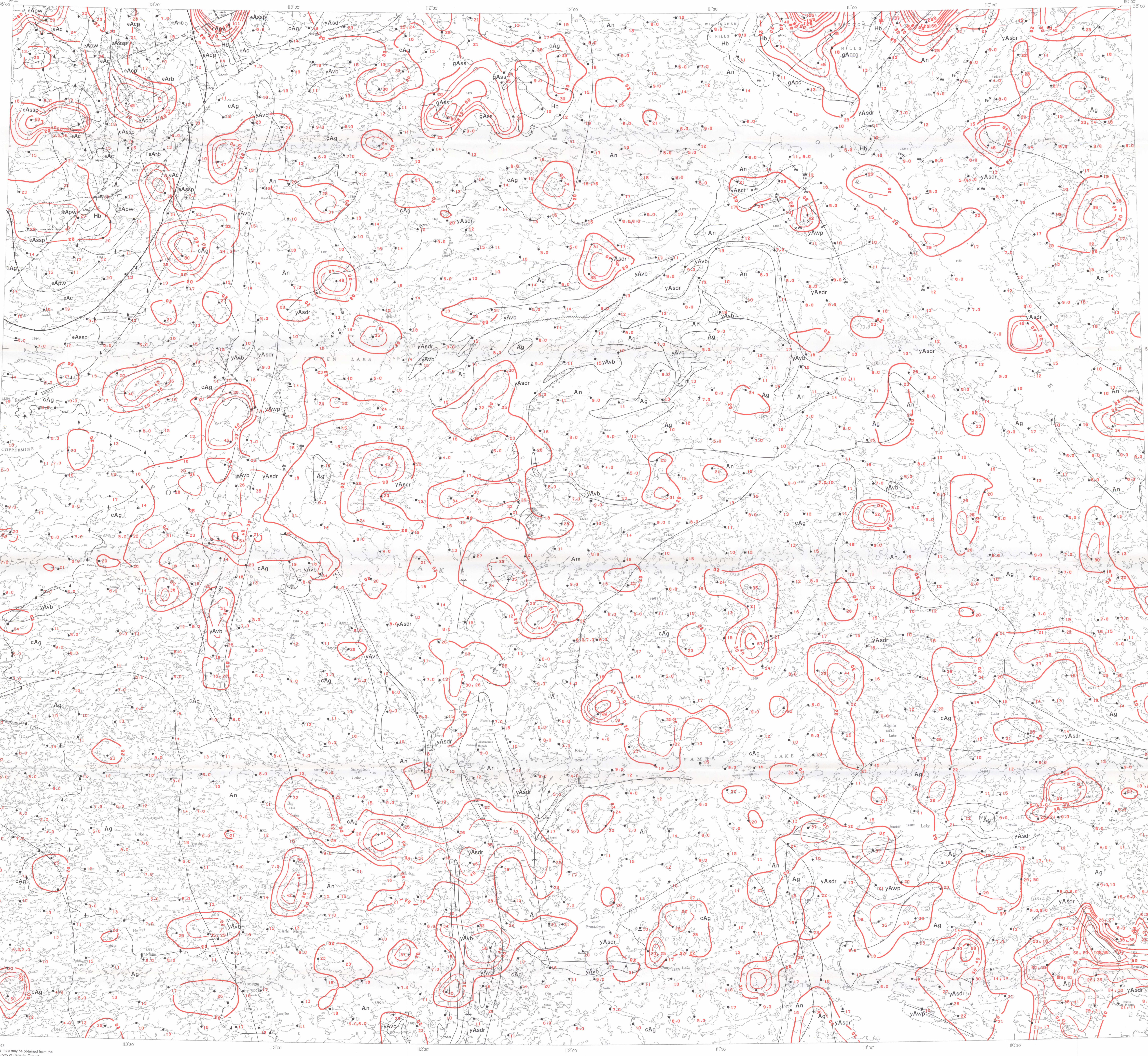
PRELIMINARY SERIES

GEOLOGICAL SURVEY OF CANADA
DEPARTMENT OF ENERGY, MINES AND RESOURCES



LEGEND

PROTEROZOIC

HADRYNIAN

Hb	Gabbro sheets, sills

APHEBIAN

GOULBURN GROUP

gAss	BROWN SOUND FORMATION: red siltstone, shale, sandstone
gApc	PEACOCK HILLS FORMATION: shale, dolomite, sandstone
gAqcg	BURNSIDE RIVER FORMATION: quartzite, conglomerate

EPWORTH GROUP

eArb	TAKIYUAK FORMATION: red sandstone, shale
eAcp	COWLES LAKE FORMATION: limestone, shale
eApw	RECLUSE FORMATION: argillite, shale, greywacke
eAc	ROCKNEST FORMATION: dolomite
eAssp	ODJICK FORMATION: sandstone, shale, argillite, andesite

ARCHEAN

Ag	Quartz diorite, quartz monzonite, granodiorite, granite. In part porphyritic
An	Granitic gneiss, migmatite, mixed gneisses involving Yellowknife rocks
cAg	Complex of plutonic granitic rocks that may be, in part, older than Yellowknife Supergroup

YELLOWKNIFE SUPERGROUP

yAwp	Greywacke, shale
yAsdr	Cordierite-andalusite bearing knotted schist and other metamorphic equivalents of yAwp
yAvb	Intermediate to basic lava, tuff, agglomerate, and undifferentiated acidic volcanic rocks

Boundary between Bear and Slave geological provinces

Fault, observed or assumed

Approximate position of treeline

Syncline

Mineral prospect showing principal element(s) .... Au ×

Lake sample site and metal concentration (sediment sieved to minus 250 mesh) 15

Lake sample site and metal concentration (sediment sieved to minus 100 mesh) 20

Geochemical concentration contours as ppm 10

MINERALS

Copper	Cu	Iron	Fe
Gold	Au	Nickel	Ni

Geology after unpublished map compiled by J. C. McGlynn, 1971

Field work by R. J. Allan, E. M. Cameron, C. C. Durham, R. Benson, R. Colley, B. Cumming, G. Lund, D. Mann, C. Pride, G. Thomas and B. Woronuk

Analyses by J. J. Lynch, R. Horton, W. H. Nelson, W. Alexander and A. Martineau

Marginal notes by R. J. Allan and E. M. Cameron

Geochemical contours and metal concentration numbers drawn by computer drum plotter

Geological cartography by the Geological Survey of Canada

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

Base-map assembled by the Geological Survey of Canada from maps published at the same scale by the Army Survey Establishment R. C. E. in 1962, 1964

Copies of the topographical maps covering this map-area may be obtained from the Canada Map Office, 615 Booth Street, Ottawa, Ontario K1A 0E9

Mean magnetic declination 1972, 34°20' East, decreasing 8.2' annually. Readings vary from 31°54' in the SE corner to 37°11' in the NW corner of the map-area

Elevations in feet above mean sea-level

MARGINAL NOTES*

Lake Sediment Geochemistry The use of lake sediments as an aid to mineral exploration and geological mapping within the Canadian Shield is based on two principal concepts of their origin. The first is that the detrital portion of a fine-grained lake sediment is a good composite sample of the rocks in the vicinity of the lake. In perhaps a majority of cases, the material forming the sediment has passed through an intermediate stage as a component of locally derived tills or other glacial sediments before being transported to the lake. The second concept is that the fine-grained particles of the sediment are an excellent medium for the sorption of metal ions released during the weathering of nearby sulphide ore deposits or similar mineralization. Most of the known sulphide deposits in the Bear-Slave survey area show moderate to high degrees of oxidation.

At the wide, reconnaissance, sampling interval used, it is unlikely that many samples will be taken from lakes within the limits of the secondary dispersion halo of a single ore deposit. However, country containing such deposits may be defined by the trace element dispersion from the much more extensive non-economic mineralization that is often associated with economic deposits. Similar trace metal patterns may also be derived from mineralization that is not associated with ore deposits or from rock units of unusual chemical composition.

Lake Sediment Sampling The lake sediment samples were collected by post-hole auger from a helicopter. They were taken near the edge of the lake in water 3 to 8 feet deep. They comprise approximately the top 8 inches of sediment, less the surface layer. Of the variety of sediment types that may occur in lakes, the type of sample sought was of clay to silt grade and low in organic material.

Environment Effects Certain heavy metals, such as uranium, zinc, and copper, may be enriched in sediment samples containing organic matter or iron and manganese oxides. The content of Fe and Mn has been determined for all samples, together with an index of the organic content (optical density). These data will be released separately in the form of a composite map. These data may be examined when assessing anomalous areas on this map. It should be recognised, however, that metal enrichment on these materials is a highly variable phenomenon that depends on a variety of factors, principally the availability of metals in the environment. Also the Fe and Mn content of a sediment is not a direct measure of the amount of free oxides present. For these reasons the maps for the heavy metals are not presented on a statistically "corrected" basis. Further, since manganese and iron may be associated with these metals in the original rocks or primary mineralization, "correcting" the data may remove evidence of mineralization from the resulting map. If it is suspected that free oxides or organic material have created a false anomaly, then for those who do not have access to the original samples, the most satisfactory method of checking is to resample the area of the anomaly.

Sample Preparation and Analysis The sediment samples were dried, then sieved to minus 250 mesh to give a powder suitable for analysis. A few coarse samples were sieved to minus 100 mesh, then ball-milled. Copper was analyzed by direct-reading emission spectrometry. The technique summarized below has been described by Timperley, Horton and Lynch, (1973).

A 100 mg sediment sample was mixed with buffer composed of 1 part Na_2CO_3 and 7 parts graphite and containing Pd and In as internal standards. The sample mixture was packed in 3/16" preformed anodes. These were burned in a D.C. arc enclosed in a chamber, through which there was a flow of oxygen-argon. The arc burnt at 5 amps for 10 sec. and 15 amps for 50 sec. An 8K minicomputer terminated measurement of the Cu 3274 line after volatilization of this metal was complete, but prior to development of excessive background. The minicomputer converted the accumulated light energy of the Cu line to ppm Cu in real time using calibration curves derived from standards. Background corrections were made and In 3039 served as an internal standard. A control standard was run after every tenth sample. For 254 replicate analyses of a lake sediment sample containing 53.5 ppm Cu a standard deviation of 7.4 ppm was obtained. This is equivalent to a coefficient of variation of 13%.

Copper in Rocks and Ores of the Survey Area During the 1971 orientation survey (Allan, Cameron, and Durham, 1972) rock samples were collected from a number of areas within the Bear and Slave Provinces. A selection of the data for these rocks and lake sediments from the same area are given below as an aid to the interpretation of the lake sediment data. The analyses were made after an HNO_3-HCl attack. Copper values shown on this map are total contents and are therefore likely to be higher than the values from the orientation survey.

	Number of Samples	Arithmetic Mean	Geometric Mean	Median	90 Percentile
			ppm Cu		
SLAVE PROVINCE					
High Lake:					
basic volcanics	22	73.4	40.6	44	181
intermediate volcanics	54	62.9	31.6	39	83
acid volcanics	16	72.1	25.0	30	182
lake sediments	31	55.5	46.9	51	-
Hackett River:					
volcanics and sedimentary	37	28.4	17.1	23	59
lake sediments	28	34.1	24.7	22	-
Indin Lake:					
basic volcanics	55	98.2	80.8	93	160
intermediate volcanics	21	23.0	10.3	16	84
acid volcanics	31	6.7	5.0	4	15
sedimentary rocks	81	42.2	34.8	35	83
granites	5	24.2	21.1	32	42
lake sediments	35	37.7	31.5	31	-
BEAR PROVINCE					
Bode Lake:					
porphyries	57	16.3	5.3	4	31
lake sediments	12	23.2	19.8	30	-
Terra Mine:					
volcanic, sedimentary and intrusive rocks	65	89.6	10.7	7	282
lake sediments	39	31.6	29.3	34	-

The arithmetic mean for copper in the acidic volcanic rocks at High Lake (72 ppm Cu) is roughly double the geometric mean and median contents. This is due to scattered mineralization associated with the massive Cu-Zn sulphide deposit of this area. The arithmetic mean of the dominantly acidic volcanic rocks and associated sedimentary rocks at Hackett River is much lower at 28 ppm. The Hackett River massive sulphide body is believed to have a relatively low copper content (210 ppm Cu in an ore sample analyzed by us that contains 28% Zn). At Indin Lake the volcanic rocks show the normal geochemical trend of decreasing copper content with increasing acidic character of the rocks. The acidic volcanics, that are here not associated with known massive sulphide occurrences have a mean copper content of 6.7 ppm. The statistical data for rocks from the Terra Mine area, given in the above table, indicates the presence of scattered copper mineralization known to occur here. Similarly, the data for Bode Lake indicates the relative absence of such mineralization within the rocks sampled.

The lake sediment data for all these areas are in good agreement with the rock data, although it will be noted that the averaging effects of weathering, transportation and depositional processes within the surficial environment has markedly lowered the statistical dispersion of the data. The highest values are obtained from the High Lake region, that contains a known copper-bearing massive sulphide body.

In the Bear Province, copper is a common constituent of the epigenetic vein mineralization, in association with uranium, silver, zinc, lead, nickel, cobalt, arsenic and other elements. There are other potential ore occurrences in this region that may contain copper, including porphyry-type mineralization or sulphides associated with volcanic rocks.

Copper-bearing massive sulphides of probable volcanic-exhalative origin are the most economically attractive exploration targets within the Slave Province; the High Lake occurrence is an excellent example. This mineralization is generally associated with the more acidic volcanic rocks. In the Slave Province the volcanic rocks generally occur near the base of the rock sequence within the sedimentary volcanic belts, that is along the margins of these belts. Since there may be unrecognized volcanic rocks within the sedimentary sequence, the margins of these belts are prospective, even in the absence of mapped volcanic rocks. On the basis of orientation surveys around the High Lake and Hackett River deposits it was argued (Allan, Cameron and Durham, 1972) that this type of deposit was best outlined by a hierarchy of geochemical indicators in lake sediments:

(1) By indicators that suggest that the area is underlain by acidic volcanic rocks (e.g. high Si or K, low Mg).
(2) Within (1) zones underlain by exhalative facies rocks such as carbonates and iron-rich sediments (e.g. high Mn and Fe) or zones of rock alteration associated with mineralization (e.g. high Mg, high Ni).
(3) Anomalies due to massive sulphide mineralization (e.g. high Zn, Cu, Pb or Ag).

Lake sediments containing relatively high values of copper may result from either a large uniform source containing greater than average amounts of this element (e.g. basic rocks) or from mineralized rocks or zones. In many cases it will be possible to resolve this question by considering the geology of the area and the element association, as described above. In some cases, however, it may be necessary to sample the rocks of the area.

Copper in the Surficial Environment Copper may occur in sulphides in both the cuprous, e.g. chalcocite, Cu_2S, and cupric, e.g. chalcopyrite, $CuFeS_2$, forms. It may also occur as a minor constituent of other sulphides such as pyrrhotite. These various sulphides dominate the geochemistry of copper in igneous rocks, although copper does substitute for Fe^{2+} and Mg^{2+} in ferromagnesian and other silicates. Since it occurs mainly in the form of sulphides, copper is relatively easily leached from weathering rocks.

When copper-bearing compounds are oxidized, they form sulphates, which may then be converted to secondary carbonates. The sulphates are highly soluble, but the carbonates are only soluble at low pH. Because of this carbonates only occur at an advanced stage of oxidation. This stage has been reached in permafrost areas of northern Canada, where malachite occurs at copper showings.

Copper mobility is low in neutral to alkaline water but increases with increasing acidity. At lower pH copper may migrate in ionic solution or as fulvic acid (~pH6) or humic acid (~pH3) complexes. The soils of permafrost areas generally have an acidic pH. Lakes in the survey area generally have a near neutral pH within which copper may be precipitated. Precipitation of copper may be as hydroxides along with free manganese and iron oxides; as ions sorbed onto clays; or bound to insoluble organic compounds. Clays strongly bind copper, whereas organic compounds may hold it in a more readily available form.

Of the elements analyzed during this project, copper is perhaps the most likely to have been affected by surficial processes of sorption by organic and inorganic materials and complexing by soluble organic compounds. Copper also occurs in most types of sulphide mineralization known or suspected within the survey area. For these reasons the distribution of copper across the survey area is likely the result of the interaction of a variety of factors, only some of which are directly related to the geology or metallogeny of the region.

Copper in Lake Sediments, This Sheet The lake sediments overlying the Archean rocks of this sheet have a generally lower copper content than the Proterozoic rocks of Sheet 1. Most parts of Sheet 2 have copper levels of less than 20 ppm. The Proterozoic sediments in the northwest corner of the sheet and along the northern boundary of the sheet have rather higher levels. In part, this may be related to basic sills which occur in some of these areas, and in part to the presence of moderately copper-rich shales.

The lake sediments from the granitic area in the southeast corner of the sheet have some of the highest copper contents. This area is also marked by scattered anomalies for other elements, including potassium, uranium, zinc, lithium, lead and nickel. The granitic area northwest of Yamba Lake in the centre of the map-sheet which is associated with a similar grouping of anomalous metals, contains only a subdued copper anomaly, with a small area enclosed by the 40 ppm contour.

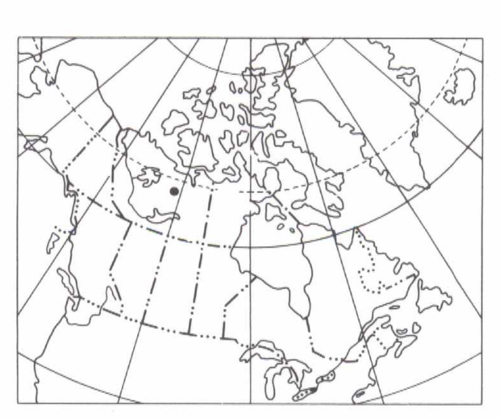
The greenstone belt which passes north-south through the western portion of the map-sheet contains a number of large, low level anomalies. These occur most frequently along the margins of this belt in association with higher than average zinc levels. These are undoubtedly related to the presence of volcanic rocks along the margin of this greenstone belt. The other major greenstone belt, that passes east-west across the northern half of this sheet, contains fewer anomalous areas. The most significant of these are small anomalies northwest of Contwoyto Lake.

Scattered, one-point anomalies that occur near granite-greenstone contacts should be assessed in the context of the hierarchy of indicators proposed in previous marginal notes for massive sulphides in the Slave Province. However, because copper is an element apparently affected by environmental factors, one-point anomalies should be treated with extreme caution.

---

* Geological Survey Paper 72-50, contains a detailed description of the experimental basis for lake sediment sampling in the Shield; the geology and metallogeny of the region; the organization, methods, and costs of the sampling operation; the methods of sample analysis and the references for the articles quoted above.

Published, 1973
Copies of this map may be obtained from the Geological Survey of Canada, Ottawa



INDEX MAP

MAP 13 - 1972

SHEET 2

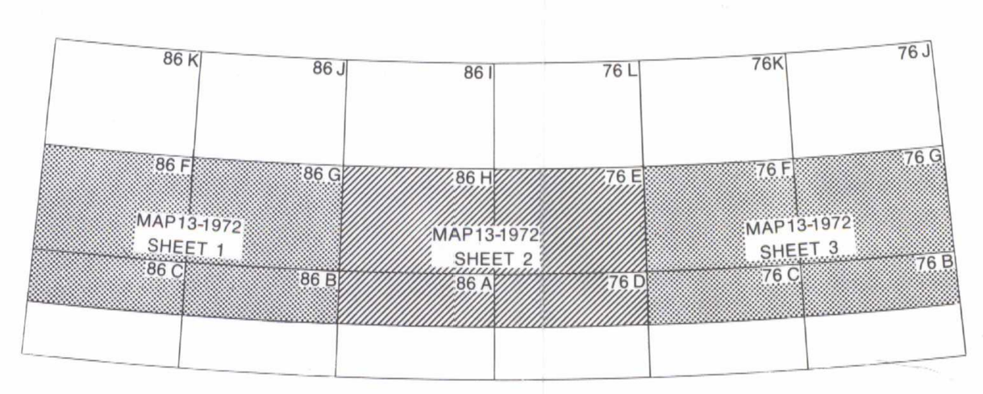
COPPER CONTENT OF LAKE SEDIMENTS BEAR-SLAVE OPERATION

DISTRICT OF MACKENZIE

Scale 1:250,000

Miles 4 0 4 8 12 Miles

Kilometres 6 0 6 12 18 Kilometres



NATIONAL TOPOGRAPHIC SYSTEM REFERENCE AND INDEX TO ADJOINING GEOLOGICAL SURVEY OF CANADA MAPS

MAP 13 - 1972
SHEET 2
COPPER
BEAR-SLAVE OPERATION
DISTRICT OF MACKENZIE