

GEOCHEMISTRY

40. REGIONAL GEOCHEMICAL EXPLORATION OF THE
COPPERMINE BASALTS: COPPER AND ZINC IN
LAKE AND STREAM WATERS AND SEDIMENTS
UNDER CONTINUOUS PERMAFROST CONDITIONS

Project 700046

R. J. Allan

Objectives

This study is a continuation of a program to develop regional geochemical exploration techniques, employing surficial materials as the sample media, in Canada's zone of continuous permafrost. The study involved both a regional program and a detailed control study for the regional program, and was carried out in the central part of the Coppermine basalts during late June, July, August and early September, of 1970. The objectives of the regional study were: to outline on a regional scale a Cu-rich basalt group; to delineate within this group, members, or areas of members, with greater Cu mineralization; to show the position of those structures in which Cu may have accumulated; to evaluate sites of known mineralization; and to evaluate the Cu distribution in areas where considerable diamond drilling has been carried out based on geological and geophysical exploration methods. The objectives of the detailed control study involving a total of 22 lakes were to determine: the variations in Cu concentration in lake waters during the entire sampling season, as determined by climatic changes, mainly rainfall; the variations in Cu concentration in lake water with position in the lake; the effect of changes in Cu concentration of water in inflowing and outflowing streams on the Cu concentration of the lakes; the variation in Cu concentration in the lake bottom sediments with position around the lake; the Cu distribution in waters and sediments from selected lakes which were found to be anomalous with respect to Cu, in the regional study.

Sample Media

The samples collected were of lake and stream waters and lake and stream sediments. The use of lake waters for regional geochemical exploration in the Coppermine Group was indicated by a pilot study during the summer of 1969¹.

Area Covered, Sample Site Density and Helicopter Efficiency
in the Regional Program

The regional program was experimental in that only a guess could be made at the site density required to fulfill the objectives outlined above. Because of this, the site density varied for adjoining 1-mile map-sheets.

The total area covered was 6 one-mile map-sheets (Table 1). Total lake sites visited in the regional program was 637. Total water samples collected was 945 and sediments 706. Total helicopter time used was 114 hours.

TABLE I

Nts ¹ Sheet	Approx. Area	No. of ² Sites	Site Density	Regional ³ Site Density	Helicopter Time Per Sheet	Helicopter ⁴ Time Per Site
	Sq. Miles		Sq. Miles Per Site	Sq. Miles Per Site	Hours	Minutes
86-0-12	240	38	6.2	25	8	12.6
86-N-1						
&86-0-4	240	22	10.7	25	4.75	12.9
86-N-7	240	75	3.1	9	15	12.0
86-0-5	240	138	1.5	4	25	10.9
86-N-8	240	271	0.9	1	40	9.9

¹ 93 water and 45 sediment samples were also collected from sheet 86-N-9. Helicopter time on this sheet was 20 hours, as the base camp was moved to Coppermine because of the weather. The water samples were collected regionally at one site per 3 square miles. Sediments came from lakes in two strips; one in the basalts, below the unconformity to the overlying sediments and one in the overlying sediments above the unconformity.

² At every site a lake water and lake bottom sediment was collected.

³ This is the density that will be used to assess the sample densities that may be used in other areas. The actual site density is much greater due to the fact that samples were also collected along all major structures, aeromagnetic lineaments and in the vicinity of known mineralization.

⁴ Time per site is very low and is attributed to the fact that the helicopter pilot assisted with the sampling and in essence was an integral member of the sampling team. Under normal circumstances this rate of sample collection could not be maintained.

Detail Control Study for the Regional Program

There were 3 types of detail study involved:

1. One anomalous lake closest to the 47-Zone Cu deposit, and one lake in a background area, were studied. At these lakes sediment samples were collected from all the inflowing and outflowing streams and from the lake bottoms at intervals around the lakes. Water samples were taken from all the streams and from the lakes at the point of inflow or outflow of all streams every 4 days during the period July 2 to September 15.

backg
analy:
bottor

every
not cc
was s

Cu co
for de
from
strea

recor

86-N-
field
tion o
cold I
are fo
minec
Sieve
were

along
will i
in the
sedin
mine:
bedro
infer:

2. Seventeen lakes were selected, ranging in concentration from background to anomalous. These were 17 of the 25 lakes for which water analyses for Cu were available². Sediments were collected from the lake bottoms around each of these lakes.

Water samples were taken at an outflowing stream if one existed every 10 days during the period July 4 to September 15. On July 1, ice had not completely melted on some of the lakes and on September 15, the ground was snow covered and many of the lakes were frozen over.

3. Of the 22 lakes which were eventually found to have anomalous Cu concentrations in both their water and sediment samples, 3 were selected for detailed study. This involved collection of lake waters and sediments from around the lake, and stream waters and sediments from inflowing streams.

To assist in interpretation of the detailed results, a daily climatic record was maintained from July 1 to September 15.

Analytical Methods

All samples of waters and sediments, except for those from sheet 86-N-9 were analyzed in the field. Sediments were dried and sieved in the field to <80 mesh (<177 μ). For both types of samples, the field determination of Cu was made with 2-2' biquinoline; the sediments were leached with cold HCl. The field concentrations found for Cu in both water and sediments are for extractable Cu only; the total Cu, and Zn contents have been determined in Ottawa for the sediments and will be determined for the waters. Sieved sediment samples were returned to Ottawa by air-mail as soon as they were analyzed in the field. No Zn analyses were done in the field.

Field Results and General Conclusions

Eventually all the results will be placed on computer punch cards along with the co-ordinates of each sample site on the sample grid. The data will include: 1) partial determinations for Cu in waters and sediments made in the field laboratory; 2) total determinations for Cu and Zn in waters and sediments made in the Ottawa laboratory; 3) pH of the water samples determined in the field laboratory 4) data concerning the sample site, namely bedrock geology, glacial geology, positions on geologically or geophysically inferred structures and proximity to known mineral showings.

Table 2

Site Density Sq. Miles Per Site	Approx. Area Sq. Miles
25	1500
10	1000
5	750
1	250

Total
es
114

copter⁴
ne Per
Site

notes

2.6

2.9
2.0
0.9
9.9

-N-9.
oved to
ted
as in
g sedi-

at may
to the
omag-

ster
ber of
col-

id one
nples
the
a from
all

From these data, computer-drawn contour maps will be constructed from sites selected randomly by the computer, at site densities as listed (Table 2) and for other controls, e. g. all lakes on faults.

At this stage, however, no computer drawn contour maps are available but, based on the field determinations of Cu in waters and sediments and the Cu and Zn concentrations in sediments determined in Ottawa, the following general conclusions can be drawn.

1. The concentration of Cu in lake sediments as determined in the field (partial Cu) reflects the Cu concentration in the underlying bedrock. This is attributed to the fact that although the drift cover is extensive, it is often not deep and there are numerous outcrops. The range in Cu concentrations is in the order: underlying dolomite \leq overlying sediments $<$ lower basalt member \leq middle basalt member $<$ upper basalt member. This variation in the Cu concentrations for the basalt members was previously demonstrated by analysis of rock chip samples³.

2. The concentration of Cu in lake sediments as determined in the laboratory at Ottawa (total Cu) reflects the same pattern as outlined under (1), but seems on rough inspection to produce a more even pattern (more easily contoured).

3. The concentration of Zn in lake sediments as determined in Ottawa (total Zn) shows that this element is distributed over a greater thickness and therefore greater area of the basalts.

4. A zone with greater Cu and Zn concentrations in the sheets studied runs from the northeast corner of sheet 86-N-7 diagonally across the middle of sheet 86-N-8 and dies out in the southwest corner of sheet 86-0-5. This zone is crudely oval in shape with a major axis of about 20 miles long running northwest and a minor axis of about 10 miles long, running northeast.

5. The concentration of Cu in lake waters, as determined in the field, only shows the presence of the Cu-rich zone in the upper basalt member. The Cu concentrations for the waters, at least those obtained in the field, do not distinguish between the other rocks mentioned in (1). It is expected that the total Cu determinations made by atomic absorption spectroscopy in Ottawa will provide some degree of differentiation.

6. Because of (5), it could be said from a purely exploration viewpoint that the Cu-rich zone in the upper basalts could have been crudely located by analysis of lake waters alone. Had the sample density been dropped even to 1 sample for 10 square miles, this would probably still be true, although the final computer-drawn contour maps will determine this without bias. Of course, it is assumed that once 3 or 4 lakes with higher copper concentration are located adjacent to each other in 10-square-mile grid intersections, more detailed sampling would be carried out before conclusions were drawn.

7. In the total 1,500-square-mile area covered, 22 highly anomalous lakes i. e. as anomalous or more anomalous than the 2 lakes at the 47-zone, were found. These lakes were separated on the basis of combined

anoma
that w
suar
in the

of kno
l at th
known
explai
is sho
ure di
shown
imate
There
in (4)
sedim
dle ba
found

the no
the we
high C
relate
cia or
remai
its lak
high c
tions
strea
proba
of gro

larger
of lak
about
seriou
from
with o
sedim
that C
entire
increa

cold d
move
portec
fed by
ble co

anomalous Cu in both water and sediment. There were, in addition, 23 lakes that were anomalous for Cu in either water or sediment, within the 1,500 square-mile-survey area. The majority of these anomalous lakes are located in the upper basalt member.

8. Of the 22 anomalous lakes, (a) 4 were in the immediate vicinity of known copper mineralization i. e. 2 at the 47-Zone, 1 at the Lars showing, 1 at the East Grid; (b) another 8 were approximately 1 mile or less from known minor sites of mineralization; (c) 10 anomalous lakes could not be explained by any known Cu occurrences. The exact position of 20 of the lakes is shown on Figure 1. Accurate locations can be obtained by placing this figure directly over a 4-mile to one inch map-sheet. The 2 anomalous lakes not shown are located in the extreme southwest corner of sheet 86-0-5 at approximate positions 67° 19'N, 115° 38'W and 67° 16'N, 115° 36'W respectively. There were many sites of known mineralization, outside the zone described in (4) which did not produce anomalous Cu concentrations in either waters or sediments of nearby lakes. This was especially true for the lower and middle basalt members where on diamond drilling most of these showings were found to be only very minor occurrences.

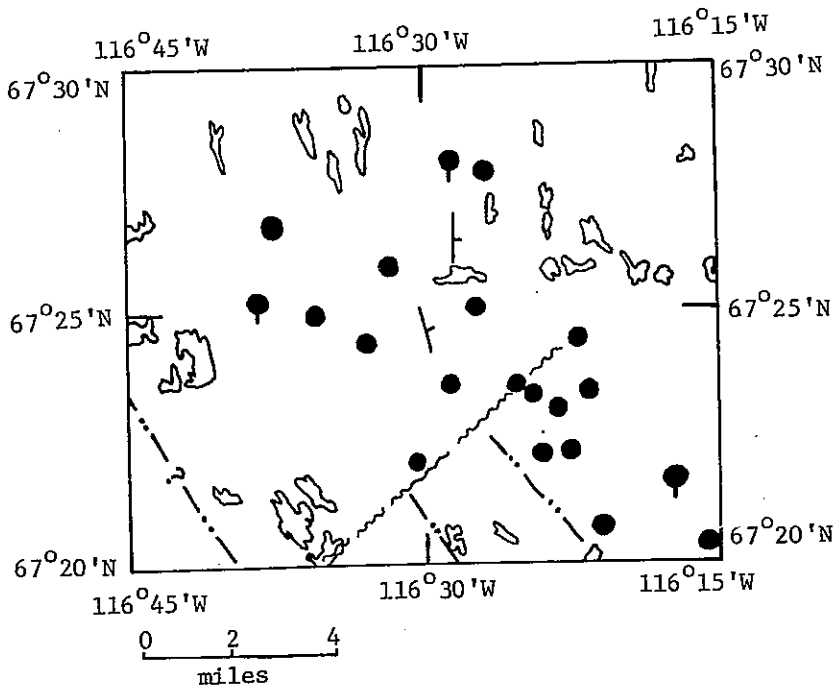
9. Of the three anomalous lakes studied in detail (Fig. 1) the one to the north was the most interesting. The high Cu concentration of the one to the west was found to be due to some influence from its northern end. The high Cu concentration in the one to the east was found on detail study to be related to the extensive occurrence of Cu mineralization in pieces of a breccia or more likely a mineralized flow top in which the lake was situated. The remaining lake, that to the north, was found to have the highest Cu content in its lake water of all 637 lakes analyzed, including those at the 47-Zone. The high concentration in the lake water was found to be due to high concentrations in the water of streams entering this lake from its eastern side. These streams flowed from a scarp slope trending south-southwest at the very probable position of a major fault. This lake would definitely merit the use of ground geophysics in its vicinity.

10. The detailed control studies both (1) and (2) showed that in larger lakes there could be a considerable variation in the Cu concentration of lake sediments at different points around the lake bottom. On small lakes, about 1,000 feet in diameter, this was not the case or at least it was less serious. It did show that a direction towards a showing could be obtained from samples collected around the lake bottom. It also implies that lakes with only anomalous Cu in the water should be revisited to check the bottom sediments before they are discounted. Both detailed control studies showed that Cu concentration in lake waters remained virtually constant during the entire sampling season. Exceptions to this were anomalous lakes which increase the Cu concentration in their waters after heavy rainfall.

11. The following conclusions on weathering in this high latitude cold desert can be drawn from the data of the detailed studies: (a) copper is moved very quickly into lakes after heavy rainfall; (b) this copper is transported in stream waters; probably as carbonate-bicarbonate complexes and fed by run off above the permafrost table; (c) considerable quantities of soluble copper must be available for transport in the streams and it is likely that

the form of this is copper sulphate; (d) weathering of outcropping and sub-outcropping sulphide deposits in the permafrost environment is considerable. Much of this movement of economic elements from sulphide deposits in permafrost conditions, in the form of sulphates, has been recently hinted at in the U. S. S. R.⁴.

12. There appears at first glance to be no relationship between type of glacial deposits and Cu or Zn distribution. This is attributed to two facts: (1) although the drift cover is fairly complete, there is reasonable outcrop in most areas of the basalts surveyed and (2) the till in the area is usually "reworked" and the outwash is often "dirty", the net result being that the textural and mineralogical differences in the surficial cover are only slight.



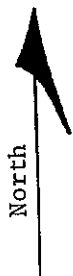





-  outlines of larger lakes in the area to allow accurate location of the anomalous lakes
-  anomalous lake referred to in the text
-  Teshierpi fault
-  bedrock dip direction
-  geological boundary (after Baragar, 1969)
-  detailed study of anomalous lake

Figure 1. Location map of the 20 anomalous lakes referred to in the text.

1
or elsewh
unsuccess
physical s
especially

1
aline. Th
appears to
and its co

1
Where els
wishing to
control st
method to
Cape Smit
methods f
jects. Tv
now that v
persion in

1
Hornbro
s
F

2 Allan, R
r
A

3 Baragar
S

4 Pitul'ko,
F
c
M

13. There are numerous sites in favourable geological structures or elsewhere, particularly in sheet 86-N-7, where considerable, largely unsuccessful, diamond drilling has been carried out, based on ground geophysical surveys. These areas were shown to be essentially barren of Cu, especially when compared with the Cu-rich zone described under (4).

14. The field-determined pH values of the lake waters were all alkaline. They ranged from 7.1 to 9.2 with most around the 8.2. There appears to be very little relationship, if any, between pH of the lake water and its concentration of Cu.

15. This method apparently works in the Coppermine basalt group. Where else can it be applied? Assuming that those exploration companies wishing to use this method regionally did a small initial pilot study and also a control study during the sampling season, it should be possible to apply this method to the volcanics of Bathurst Inlet, Victoria Island, Borden Peninsula, Cape Smith-Wakeham Bay belt and Labrador Trough. Applications of similar methods for other types of rocks will necessitate more detailed pilot projects. Two or three such studies could probably be done during one summer now that we have considerably more numbers relating to geochemical dispersion in the surficial permafrost environment.

-
- ¹ Hornbrook, E. H. W., and Allan, R. J.: Geochemical exploration feasibility study within the zone of continuous permafrost, Coppermine River Region, N. W. T.; Geol. Surv. Can., Paper 70-36, 35 pp. (1970).
 - ² Allan, R. J., and Hornbrook, E. H. W.: Development of geochemical techniques in permafrost, Coppermine River Region; Can. Mining J., April, pp. 45-48 (1970).
 - ³ Baragar, W. R. A.: The geochemistry of Coppermine River Basalts; Geol. Surv. Can., Paper 69-44, 43 pp. (1969).
 - ⁴ Pitul'ko, V. M., and Shilo, N. A.: Geochemistry of frozen terrain and prospecting for ore deposits. Translations of the Northeastern Multi-disciplinary Scientific Section, Academy of Sciences of the U. S. S. R., Magadan, 33 pp. (1970).
-

41. STUDIES OF THE FREQUENCY DISTRIBUTION
 OF ORE ELEMENTS IN CERTAIN ROCK UNITS
 OF THE CANADIAN SHIELD

Project 690050

E.M. Cameron

The frequency distribution by size of genetically related ore deposits within a given area or rock unit obeys probability laws; often this approximates a lognormal distribution. The writer has previously argued that these observed distributions are but the artificially truncated tail of a more general probability distribution of ore minerals within the given geological unit¹. By determining the frequency distribution of the smaller and more frequent size components ("microdeposits") of this general distribution, important clues to the ore potential of a given geological unit may be obtained. This approach has already been applied with encouraging results to a comparison of the copper-bearing Coppermine Group and portions of the Yellowknife Group¹ where no copper deposits or showings are known; and to the discrimination of ultramafic rocks associated with nickel-copper sulphide ores from barren ultramafic intrusions².

In the case of the Coppermine Group, copper in samples of these volcanic rocks has been shown to be distributed lognormally, with a high log variance, the frequency distribution curve being continuous into the thousands of ppm Cu. On the evidence of this curve, it has been suggested that the copper sampled in the volcanic rocks and the copper of the copper deposits and showings were formed and distributed by the same geological process, namely magmatic segregation. The copper contained in the ore deposits may, however, have been secondarily redistributed. Since the copper of the rocks and the copper of the ore deposits are so closely related, the frequency distribution of Cu in the rocks may be used to predict ore potential. For the Archean volcanic rocks of the Yellowknife Group, which were compared with the Coppermine samples, the frequency distribution of copper is normal rather than lognormal; only one sample exceeds 273 ppm Cu. For the ultramafic study it has been similarly possible to separate ore-associated ultramafics from barren rocks. The former have distribution curves for copper and/or nickel sulphides which are continuous into higher ranges than is the case with the barren ultramafics.

These favourable results encouraged a comparison of the frequency distribution of copper in the rocks of a mineralized Archean greenstone belt with the previously analyzed Yellowknife Group samples. Thus 701 samples of volcanic rock were collected from two traverses in the Noranda camp. The first traverse, nine miles in length, is immediately south and east of the town of Noranda. The second, 19 miles long, is an east-west traverse 8 miles north of Noranda. The distribution of copper in the samples from Noranda and from the Yellowknife Group has been found to be basically similar. Both groups of analyses are principally composed of a normal frequency distribution of moderate and similar dispersion. It is tentatively suggested that this distribution is that of copper sulphide in the volcanics which is unrelated to any copper ore deposits. For the Noranda data, there is mixed with this distribution a second and distinct distribution of high copper values. This second frequency distribution, which has a high variance, is believed to be related to the ore deposits of the area. It comprises about 5 per cent of the Noranda samples.

apart f
potenti
Geolog
geoche
muds a
E. H. W
Copper
be reas
spacing
(R. J. .
copper
primar
spacing
directl
same f
Group
enclosi
copper
majori
sulphid
phides,
confine
passed
ments
belts,
anomal
travers
twentie
chemic
closer

¹ Came

² Came

³ Hornl

⁴ Allan

The results very briefly outlined above have important implications apart from that of relating frequency distribution of ore elements to the ore potential of the sampled geological unit. The Geochemistry Section of the Geological Survey has been attempting to devise reconnaissance methods of geochemical exploration within the Canadian Shield using lake waters and muds and stream sediments. Studies carried out by R. J. Allan and E. H. W. Hornbrook³ in 1969 and by Allan⁴ in 1970 have shown that at Coppermine the area containing the known copper deposits and showings can be readily outlined using widely-spaced samples of lake waters or muds. A spacing of 1 sample per 10 square miles has been suggested as adequate (R. J. Allan, pers. comm.). At this spacing the geochemical pattern for copper in the lake waters or muds is not due to the ore deposits; it represents primarily the areal variation of copper in the bedrock. This highly efficient spacing is possible in the Coppermine area because copper in the bedrock is directly related to copper in the ore bodies and showings; all are part of the same frequency distribution. On the basis of the data from the Yellowknife Group and the Noranda belt, this is not the case for the volcanic rocks enclosing the massive sulphide deposits of the Archean greenstone belts. The copper (and presumably zinc and other "ore" elements) contained in the majority of rock samples taken from these belts is unrelated to the massive sulphide ores. In terms of a volcanic-exhalative origin for the massive sulphides, copper values directly associated with these deposits are likely to be confined to the walls of the pipes through which the mineralized solutions passed and to the stratigraphic zones in the volcanics and associated sediments where the metals were precipitated. Thus in the Archean greenstone belts, geochemical sampling of surficial materials must rely on discovering anomalies due to mineralized pipes and stratigraphic zones. In the Noranda traverses these mineralized pipes and zones account for approximately a twentieth of the rock sampled. Thus it appears that reconnaissance geochemical sampling in these greenstone belts must be made at a considerably closer spacing than is the case with the Coppermine Group.

-
- ¹ Cameron, E. M., and W. R. A. Baragar: Distribution of ore elements in rocks for evaluating ore potential: Frequency distribution of copper in the Coppermine Group and Yellowknife Group volcanic rocks, N. W. T., Canada. Proc. Third Intern. Geochem. Explor. Symp., Toronto, April, 1970 (1970).
- ² Cameron, E. M., G. Siddeley, and C. C. Durham: Distribution of ore elements in rocks for evaluating ore potential: Nickel, copper, cobalt, and sulphur in ultramafic rocks of the Canadian Shield. Proc. Third Intern. Geochem. Explor. Symp., Toronto, April, 1970 (1970).
- ³ Hornbrook, E. H. W., and R. J. Allan: Geochemical exploration feasibility study within the zone of continuous permafrost; Copper River region, N. W. T. Geol. Surv. Can., Paper 70-36 (1970).
- ⁴ Allan, R. J.: Regional geochemical exploration of the Coppermine Basalts: Copper and zinc in the lake and stream waters and sediments, above the Arctic Circle, under continuous permafrost conditions (this publication No. 40).
-

deposits
proximate
at these
a general
unit¹. By
ent size
clues to
approach
the
group¹
nation of
arren

these
high log
thousands
the copper
s and
s,
sits may,
the rocks
icity dis-
r the
red with
mal
e ultra-
ultra-
copper
is the

frequency
ne belt
samples
mp.
st of the
se 8
om
ly
nal fre-
ely sug-
s which
e is
copper
e, is
bout 5

42. GEOLOGY OF CANADIAN NICKEL AND PLATINUM
GROUP DEPOSITS

Project 630037

O. R. Eckstrand

The field component of this project was continued by visiting nickel deposits in the northern Labrador Trough, at Lake Renzy in the Grenville subprovince, in the Sudbury, Wawa, Thunder Bay, and Kenora - Fort Frances areas of Ontario, in the Werner Lake - Bird River area of western Ontario and eastern Manitoba, and in the Thompson and Lynn Lake areas of northern Manitoba. The general aim in each instance was to gain an appreciation of the general geological environment and the nature of mineralization, and to sample the ores and host rocks for various supplementary laboratory studies and comparison purposes.

Because they represent such a distinctive but little known type of nickel occurrence, and because they are receiving renewed exploration interest, some deposits of the Labrador Trough are described here in preliminary form.

Disseminated nickel-copper mineralization in "blotchy"
metagabbro sills of the northern Labrador Trough

General Geology - Numerous deposits of low-grade disseminated nickel-copper mineralization occur in "blotchy" metagabbro sills that are common in the northern Labrador Trough between the Koksoak River and Hopes Advance Bay. The sills intrude the predominantly basaltic volcanic rocks of the Kaniapiskau Group, generally seeking out the thin, shaly interflow sediments or their contacts with the volcanic rocks. The sills themselves range in thickness from a few tens of feet to about 200 feet, and are relatively extensive. They have been folded into very elongate synclines and metamorphosed along with the enclosing rocks.

The actual "blotchy" metagabbro appears to be the central portions or cores of larger intrusive units, the border zones of which are a more basic and normally textured hornblende metagabbro. Minor interlayering of "blotchy" metagabbro and normal metagabbro is common. Some occurrences of "blotchy" metagabbro are structurally more complex, with re-entrant embayments of border zone metagabbro, and isolated blocks or tongues of "blotchy" metagabbro in the border zone metagabbro. Most of these features are believed to be primary.

The "blotchy" metagabbro is made up of about 50 to 75 per cent 1/2 inch to 1 1/2 inch equant or slightly lenticular "blotches" of felsic material. Originally these were probably pure feldspar, but now they are a fine-grained metamorphic assemblage that probably involves albite-clinozoisite-sericite. The boundaries of the blotches are only moderately sharp, apparently rendered "fuzzy" by metamorphic recrystallization. Mafic minerals in the interstitial gabbroic material are sensibly the same as those in the border zone metagabbro, and may include hornblende, biotite, chlorite and pyroxene (? , olivine? , serpentine?) depending on regional metamorphic grade.

be the
matri
"blotc
cent,
consis
the no
in spa
miner
major

massi
eralog
much
feet in
phide
borde:

indivi
with g
ratios
feasib
enough

laritie
of Mar
crysta
Upon t
were c
abrad
tion of
segreg

the "b
clear
ever,
was on

lation
observ
known
to min
sulphi
"blotc
occur
adjace
sulphi
intrud
the vo

the ga
sulphi

Mineralization - Pyrrhotite, pentlandite and chalcopyrite appear to be the principal sulphide minerals, and these are disseminated in the gabbroic matrix interstitial to the feldspathic "blotches". Sulphide content of the "blotchy" metagabbro ranges from as high as 25 per cent to less than 1 per cent, and distribution tends to be somewhat erratic. However the sulphides consistently tend to be more abundant in the "blotchy" core of the sill than in the non-"blotchy" border zones. Within the "blotches", sulphides occur only in sparse seams and cleavage cracks. Not uncommonly, the disseminated mineralization extends into the adjacent metagabbroic border zones, but the majority is in the "blotchy" metagabbro.

In several of the occurrences, roughly conformable sinuous veins of massive sulphides constitute a second mode of mineralization. Their mineralogy and grades are similar to the disseminated mineralization despite the much higher sulphide content. They range in size from a few inches to a few feet in width and a few tens to a few hundreds of feet long. The massive sulphide veins usually occur along the contact between "blotchy" metagabbro and bordering metagabbro.

A moderate amount of drilling has demonstrated that tonnage in individual presently known deposits attains the order of tens of million tons, with grades of about 0.8 to 1.0 per cent combined nickel plus copper. Ni:Cu ratios range from 1:2 to 1:4 and average about 1:3. Eventual production feasibility would seem to depend on the discovery of several deposits close enough to each other to be treated in a single mill.

Genetic Speculations - The "blotchy" gabbro itself bears many similarities to orbicular anorthosite sills in the Bird River and Cross Lake areas of Manitoba. An appealing model is that the "blotches" were derived from a crystallized anorthositic mass which existed in a deep magmatic chamber. Upon tectonism, the anorthosite suffered fragmentation and the fragments were caught up in the gabbroic magma. The latter, in its upward transport, abraded and sorted the anorthosite fragments to produce a well-sized collection of "blotches". The process of flow differentiation¹ could have led to their segregation as central cores in the sills which were eventually emplaced.

It seems fairly clear that the mineralization is intimately related to the "blotchy" metagabbro, and therefore must be magmatic in origin. Less clear is the control of its distribution, both disseminated and massive. However, it seems reasonable that the sulphur content expressed by the sulphides was originally dissolved in the magma.

There is a contrasting theory that the sulphur is derived by assimilation of iron sulphides of apparent syngenetic origin which are in many cases observed in the adjacent interflow sediments. However, cases are also known where sulphides were essentially lacking in these sediments adjacent to mineralized "blotchy" metagabbro sills, and conversely, where abundant sulphides were present in the sediments, but the immediately adjacent "blotchy" metagabbro sill was unmineralized. The rather common co-occurrence of disseminated nickel-copper sulphides in the sills and closely adjacent iron sulphides in the sediments may result simply from the facts that sulphides in interflow sediments are common, and the sills preferentially intrude the interflow sediments rather than the massive and pillowed flows of the volcanic pile.

The disseminated nickel-copper sulphides probably separated out of the gabbroic magma as immiscible sulphide droplets. The fact that these sulphides occur principally in the "blotchy" core of the sill suggests that the

nickel
sill
Francis
Ontario
northern
ion of
and to
studies

type of
on inter-
liminary

dated
are
and
canic
inter-
nem-
id are
nes and

portions
ore
ring of
irreances
ant
es of
features

ent
aterial,
-grained
ericite.
ren-
e inter-
zone
ene

immiscible droplets (like the felsic "blotches") were segregated by flow differentiation during magma transport so that they became concentrated in the central portion of the sill. It is possible that the massive sulphide veins represent further segregation of the droplets to the point where a significant body of homogeneous liquid sulphide formed. This sulphide melt would then act as a separate unit in the moving fluid system represented by the gabbroic magma and its load of anorthositic "blotches". Because of its distinctive physical properties (mainly the probably lower viscosity), the sulphide melt may be localized at the juncture of the "blotchy" core and the border zones. The fact that the massive sulphide veins are quasi-conformable rather than sharply cross-cutting features supports the view that they were emplaced while the magma or part of it was still appreciably fluid.

¹ Bhattacharji, S., and Smith, C.H.: Flowage differentiation; Science, vol. 45, No. 3628, pp. 150-153 (1964).

Mine

molyb

trace
molyb

galena
sphale
arsenc
pyrite

galena

trace
molyb

44. I

43. REGIONAL GEOCHEMICAL CENSUS OF PLUTONIC ROCKS
IN EASTERN YUKON TERRITORY

Project 690036

R.G. Garrett

Ennada
Northw

region
ting la
square
geoche
rences
and tes
operati

ples w

and zir
the foll
waters
zinc ar
cation
confirr

was su
water
of one
was in
free fr
requir

All the major bodies of acid plutonic rocks, 74 intrusives, northeast of the Tintina Trench and between 62° 40'N and 64° 40'N were sampled. In addition representative collections were made of the host rocks of the intrusives. A detailed sampling program was carried out around the AMAX Mount Allan property in order to investigate the relationships between the intrusive, the host sediments and the skarn tungsten deposits. The information yielded by the detailed study will be used in aiding the interpretation of the regional data. In total, some 2800 samples were collected and these are being analyzed for a wide range of elements.

The intrusives are predominantly quartz monzonite and granodiorite; some true granite occurs and syenite was observed in three areas (Tombstone Mountain area, Syenite Range and Rogue Range). Two gross regional features are of interest, firstly, disseminated sulphides within the intrusives are most commonly found in the southeast of the area investigated, i. e. the McMillan Pass area; secondly, tourmaline, as knots and veins, was commonly found only in the McMillan Pass area.

Sulphide mineral showings were noted in several areas and are listed in Table 1. These showings were all minor and are presented as it is believed they have not been noted previously.

Table I

Mineral(s)	Association	Host	Map Sheet	UTM
molybdenite	on joint faces	quartz monzonite	105 M	08 481100 7039700
trace molybdenite	tourmaline vein	granite	105 O	09 428100 6999100
galena, sphalerite, arsenopyrite, pyrite	quartz vein	granodiorite	105 I	09 475100 6984600
galena, pyrite	tourmaline vein	granite	105 I	09 504400 6976000
trace molybdenite	in granite sill	granite	105 O	09 435900 7036600

44. DEVELOPMENT OF BIOGEOCHEMICAL EXPLORATION METHODS FOR WINTER USE FOR METALLIC MINERAL DEPOSITS

Project 700062

E. H. W. Hornbrook

Field studies were conducted in the vicinity of Kaminak Lake in the Ennadai-Rankin belt of volcanic and sedimentary rock, Keewatin District, Northwest Territories.

The objective of the study was to determine the effectiveness of regional geochemical methods, particularly hydrogeochemistry, in delineating large (in excess of 100 square miles) anomalous areas within the 2,300-square mile study area. More detailed studies were carried out to examine geochemical dispersion haloes in the vicinity of known metal element occurrences. Further, manual and electrical pumping systems were developed and tested to increase the sample collection rate with resultant reduced operational costs.

Approximately 1,000 water samples and 400 sediment or soil samples were collected.

The results of an examination of the field area and of a few copper and zinc determinations completed in a field analytical laboratory revealed the following: The existence of large geochemical haloes in the drainage waters is doubtful and the waters, contrary to expectations, contain only low zinc and little or no copper in solution (see report by A. Nigrini, this publication No. 46). Analysis of all samples collected for several elements will confirm or modify the above preliminary findings.

The manual pumping system attached to the float of the helicopter was successfully used all summer, permitting a collection rate of one lake water sample per 4 to 7 minutes respectively with sample collection densities of one sample per square mile or 10 square miles. The electrical system was installed, tested, and proven to be operationally successful but a pump free from internal contamination and with a higher pumping capacity will be required.

45. GEOCHEMICAL DISTRIBUTION OF MERCURY AND ASSOCIATED METALS IN SOIL SAMPLES FROM CLYDE MAP-AREA, ONTARIO

Project 690091

I. R. Jonasson

Soil sampling over a small anomaly in an area where mercurial tetrahedrite and cinnibar have been found has been completed. The property, prospected by Carndesson Mines and located near Clyde Forks, Lanark Co., covers a number of small disseminated sulphide prospects associated with barite veins in Grenville marbles. Soil samples taken at a given site included humus and organic materials, B horizons and where available, C horizons. These were analyzed for mercury by a newly modified atomic absorption technique and for 26 other elements. Humic samples were used subsequently for a series of extraction studies designed to elucidate the nature of the mercury compounds present. Similar work is in progress on other types of soil samples.

The elements which best map the location of mineralization include mercury; zinc, arsenic, barium, boron, manganese and copper. Mercury levels in this area range from a background for humus of about 100 ppb up to anomalous values of 2 ppm with a high in one location of 250 ppm. In B and C horizons corresponding values at the same site are generally lower by factors of 2 (in background areas) to 10 (for anomalies).

Current field work encompasses a sampling program for soil gases in the same site areas.

46. TRANSPORT AND DEPOSITION OF ORE INDICATOR ELEMENTS IN STREAMS AND SEDIMENTS

Project 690039

A. Nigrini

Sampling of waters and sediments near known mineral occurrences, near gossans, and in anomalous lakes and streams was undertaken in the Bathurst area (21 O/7E, 21 O/9W) of New Brunswick, and the Hope Lake (86N/8, 9) and Kaminak Lake (55L) areas of the Northwest Territories. Water chemistry was investigated in order to evaluate its effect on ore element dispersion haloes in these regions. Temperature, pH, Eh, Cu^{++} and HCO_3 were measured in the field. Water samples were returned to Ottawa for detailed analysis for the major cations and anions as well as Fe, Mn, Cu, Pb and Zn.

In the Bathurst area, where groundwaters were observed equilibrating with the atmosphere, copper values were found to decrease, with increasing pH (from pH 3 to pH 7) until a maximum of about 1 ppb was achieved at pH 7. Concomitant copper precipitation suggests that Cu^{++} concentrations in water are buffered by copper minerals in the sediments. In the Kaminak Lake area pH values average about 7 and it is probable that a similar buffering action is maintaining low copper values in these waters.

higher
correl.
approx
in the
plexes
copper

explor:
cal. I
having
levels
trictio:
maxim
contin

TED
ARIO

Copper levels in the waters of the Hope Lake area are generally higher than those in the Kaminak Lake and Bathurst areas. These levels correlate with higher pH values which, in the Hope Lake area, average approximately 8 and suggest that the copper is carried as a hydroxyl complex in the water. Thermodynamic considerations indicate that hydroxyl complexes of copper dominate at pH's greater than 7.3 and allow higher total copper levels with increasing pH.

The foregoing observations suggest that for regional geochemical exploration programs based on water sampling, pH measurements are critical. In this instance, low copper values (on the order of 1 ppb) in waters having pH's of 7 to 7.5 should not be interpreted negatively since these low levels represent the thermodynamic maxima in this pH range. Similar restrictions may also apply to other ore elements, but probably not at the same maximum levels or in the same pH range. Further work in this direction is continuing.

rial tet-
perty,
ark Co.,
d with
included
rizons.
tion
sequently
the mer-
s of soil

include
rcury
pb up to
1 B and
r by fac-

il gases

INTS

rences,
the
ake
s. Water
ent dis-
O₃ were
etailed
and Zn.
uilibrat-
increas-
ved at
ations in
inak
: buffer-