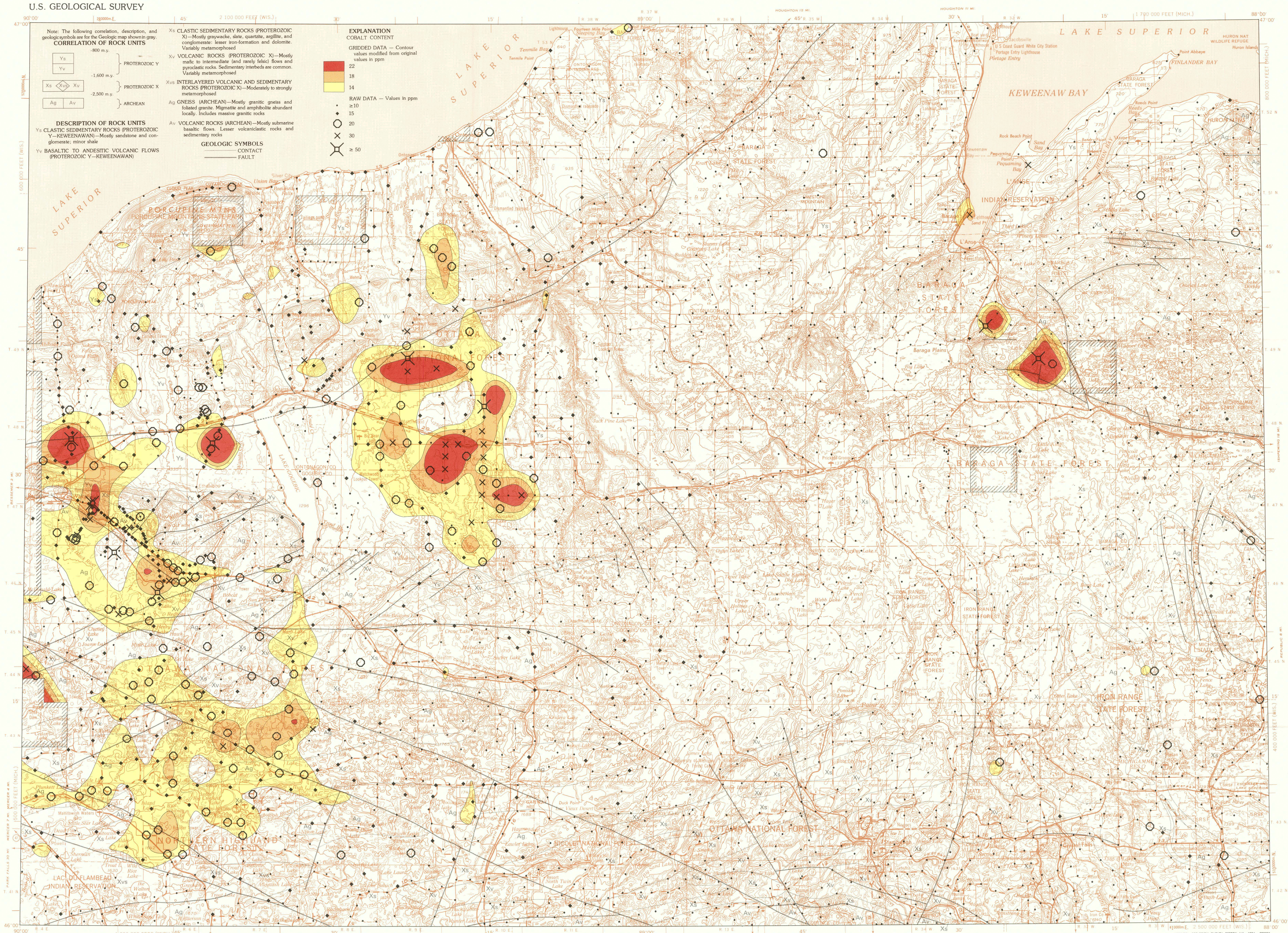
DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

MISCELLANEOUS INVESTIGATIONS SERIES
MAP I-1360-J



Base from U.S. Geological Survey 1958–67

Geology simplified from Cannon, 1984

SCALE 1:250 000

CONTOUR INTERVAL 50 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

INTRODUCTION

This map is part of a folio of 1:250,000-scale maps of the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, prepared as a project of the Conterminous United States Mineral Assessment Program. A list of maps (U.S. Geological Survey Miscellaneous Investigations Series Maps I-1360-A–N) for the complete folio follows.

MAP

- I-1360-A Mineral resources of the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by W. F. Cannon.
- I-1360-B Bedrock geologic map of the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by W. F. Cannon.
- I-1360-C Surficial geologic map of the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by W. L. Peterson.
- I-1360-D Structural and tectonic map of the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by W. F. Cannon.
- I-1360-E Bouguer gravity anomaly map and geologic interpretation of the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by J. S. Klasner and W. J. Jones.
- I-1360-F Aeromagnetic map of the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by E. R. King.
- I-1360-G Metamorphic map of the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by Karen Wier.
- I-1360-H Copper distribution in B-horizon soils in the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by H. V. Alminas, J. D. Hoffman, and R. T. Hopkins.
- I-1360-I Chromium distribution in B-horizon soils in the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by H. V. Alminas, J. D. Hoffman, and R. T. Hopkins.
- I-1360-J Cobalt distribution in B-horizon soils in the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by J. D. Hoffman, H. V. Alminas, and R. T. Hopkins.
- I-1360-K Nickel distribution in B-horizon soils in the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by J. D. Hoffman, H. V. Alminas and R. T. Hopkins.
- I-1360-L Silver distribution in B-horizon soils in the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by R. T. Hopkins, H. V. Alminas, and J. D. Hoffman.
- I-1360-M Molybdenum distribution in B-horizon soils in the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by R. T. Hopkins, H. V. Alminas, and J. D. Hoffman.
- I-1360-N Interpretive geochemical map of the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by H. V. Alminas, J. D. Hoffman, R. T. Hopkins.

The field, analytical, and interpretational work pertaining to this map was conducted in 1978–80. The analytical data were entered and stored in the U.S. Geological Survey computer storage system (RASS), (VanTrump and Miesch, 1977). A table format listing of the data was published in 1981 (Hopkins, 1981).

AREA DESCRIPTION

The Iron River 1° x 2° quadrangle encompasses the area bounded by 46°–47° latitude and 88°–90° longitude. It includes most of the western part of the Michigan Upper Peninsula as well as a segment of northern Wisconsin in its southwestern corner. Of the 17,222 km^2 (6,624 mi^2) delineated by these boundaries, some 15,454 km^2 (5,944 mi^2) is land surface; Lake Superior encompasses 1,768 km^2 (680 mi^2).

The climate within this region is cool and moist. Long severe winters and short summers with moderate temperatures are characteristic. The average annual precipitation is approximately 86 cm (34 in.). Topographically, the region as a whole is a highland and headwater drainage area although locally the topography is quite variable. It has been greatly modified by repeated glacial action, which generally rounded and leveled the high areas and scoured and then filled the valleys.

The entire area is covered by a wide range of glacial materials ranging in thickness from 0 through >90 m (>300 ft), probably averaging in the 20–30 m (70–100 ft) range.

SAMPLING DESIGN

Previous studies (Alminas, 1975) in areas of similar climatic, topographic, and geologic setting have indicated that B-horizon soils can serve as an effective sample medium in an environment exemplified by the Upper Peninsula of Michigan. Also, this sample medium provides operational advantages in that samples can be collected rapidly and easily throughout broad areas with a relatively uniform distribution of sample sites.

For this study, B-horizon soils were collected at 3,156 localities, or at an approximate density of one sample per 5.1 km^2 (2 mi^2). An attempt was made to obtain as uniform a distribution of sample sites as possible, along roads, along rivers and lake shores, and in remote areas (accessible by helicopter). Wherever possible, only seemingly undisturbed soils were sampled. In some agricultural areas, however, it was impossible to avoid sampling in cleared fields.

SAMPLE COLLECTION

Samples were collected in 1978 and 1979 by two sample collectors working a six-week period in May and June and a four-week period in September of each year.

The B-horizon soil samples were collected at a depth range of 7.6 to 71 cm (3–28 in.), although the great majority were collected at a depth between 30.5 cm and 43 cm (12–17 in.). Approximately 1/2 kg (1 lb) of soil was collected at each site, using an impact-type post-hole digger and a small crowbar. The samples were stored in Kraft[1] paper bags. The following information (primarily visually determined) pertaining to the soil and site setting was coded at each location:

1. Slope at sample site
2. Depth at which sample was collected
3. A-horizon thickness
4. Soil color
5. Soil moisture content
6. Soil organic content
7. Soil clay content
8. Soil silt content
9. Soil sand content
10. Angularity of fine fragments
11. Soil pebble content
12. Soil cobble content

Several 5.0-kg (11 lb) B-horizon soil samples were collected at selected sites for heavy-mineral separation.

[1]Use of commercial trade names is for descriptive purposes only and does not imply endorsement by the U.S. Geological Survey.

SAMPLE PREPARATION

The soil samples were oven-dried overnight at 100°C in the original paper bags. Extremely clay-rich samples were disaggregated in a crusher, using a wide jaw setting. All of the soils were then sieved through an 80-mesh (177-micron opening) sieve, and an 84-g (3-oz) sample of the fine fraction was saved for analysis.

The 5-kg B-horizon samples were washed, panned, and dried. The remaining light-mineral fraction was removed by Bromoform (sp. gr. 2.85) separation.

ANALYTICAL METHODS

Element concentrations were determined by a semi-quantitative spectrographic method described by Grimes and Marranzino (1968). Results of these spectrographic analyses are reported within geometric intervals having the boundaries of 1,200, 830, 560, 380, 260, 180, 120, all in ppm, but are shown in the histograms by approximate geometric midpoints, such as 1,000, 700, 500, 300, 200, 150, and 100 (Mosier, 1972). Precision of a reported value is approximately plus or minus one interval at the 68 percent confidence level, or plus or minus two intervals at the 95 percent confidence level (Motooka, 1976). Table 1 shows the elements analyzed for and individual detection limits.

Table 1.—*Elements analyzed for and limits of detection*

Element	Unit of measure	Limit of detection
Fe	percent	0.5
Mg	percent	.02
Ca	percent	.05
Ti	percent	.002
Mn	ppm	10
Ag	ppm	.5
As	ppm	200
Au	ppm	10
B	ppm	10
Ba	ppm	20
Be	ppm	1
Bi	ppm	10
Cd	ppm	20
Co	ppm	5
Cr	ppm	10
Cu	ppm	5
La	ppm	20
Mo	ppm	5
Nb	ppm	20
Ni	ppm	5
Pb	ppm	10
Sb	ppm	10
Sc	ppm	5
Sn	ppm	10
Sr	ppm	100
V	ppm	10
W	ppm	50
Y	ppm	10
Zn	ppm	200
Zr	ppm	10
Th	ppm	100

DATA PRESENTATION

Data on cobalt content are presented on the map by symbols and by isopleths, providing the reader with specific information on the cobalt content of individual samples (symbols) as well as regional soil cobalt content trends (isopleths). Both presentations were computer generated.

Locations of all the sample sites are shown using different symbols to indicate certain cobalt content classes (see explanation).

For the isopleth map, the data within the map area were gridded, using a weighted average of circle search (Fife, 1981, unpublished computer program). This gridding method is equivalent to a first-order finite difference scheme. Where data are insufficient for the above method, as along the edges of the sampled area, techniques such as weighted average estimation were used.

For this particular plot, the map area was subdivided into uniform-size square cells with 51 divisions along the longitudinal axis and 37 divisions along the latitudinal axis, giving a total of 1,887 cells. Of these, 1,705 or 90.4 percent were valid, that is they contained sufficient information to continue a contour through the cell. Each cell, therefore, contained about two sample sites. Most of the invalid cells occur in the area occupied by Lake Superior and other large lakes. Areas of invalid cells are shown by hachures.

Gridding of the data tends to reduce variance and generates values that are not equal to the observed spectrographic values. In addition, because calculations are made on a cell basis, isopleth shifts within a cell are possible. The effect of gridding on the cobalt data can be seen below:

	Original data	Gridded data
Co minimum	5	3
Co maximum	150	42
Co mean	9	9
Standard deviation	6	4
Number of points	3,156	1,705

Subsequent to gridding, the data were contoured by computer and plotted on a flat bed plotter, using the mapping program STPMAP within the STATPAC system (VanTrump and Miesch, 1977).

NATURE AND DISTRIUBTION OF SOILS

Soils are the products of weathering. The nature of a soil is determined by a combination of several factors acting through time within the area of soil formation. Probably the most important of these are:

a. The composition of the parent material
b. The topographic setting (especially slope)
c. The climate
d. The amount of vegetational cover
e. The length of time over which the above factors operated

Within the Iron River 1° x 2° quadrangle, essentially all the parent material was deposited by glaciers or glacial melt water, and it ranges in texture from gravel to clay. The soil textures are variable over the map area and could be important in interpreting soil geochemistry. In figure 1, areas of B-horizon soils that are predominantly clay, silt, or sand are delineated.

A comparison of the mean of cobalt values from clay-rich soils (13.2 ppm) with that from sand-rich soils (9.6 ppm) suggests that soil texture is a controlling factor in cobalt localization and retention. A further comparison of the mean of cobalt values from clay-rich soils in the northwestern quarter of the map area (13.6 ppm) with that of clay-rich soils from the eastern half of the map area (8.3 ppm) indicates that the cobalt-soil texture relationship is spurious. That is, that clays coincidentally predominate in areas (such as the predominantly Keweenawan northeastern quarter of the map area) that are cobalt rich.

Topographic setting ranges from flat to hilly; slopes are as great as 40 percent. Slope determines the position of the sample site relative to the water table, an important factor inasmuch as the geochemical patterns within this area are interpreted as being predominantly hydromorphic. A map of the soil moisture conditions found at each sample site is figure 2.

Factors c, d, and e can be considered to be constant throughout the map area.

STATISTICAL DISTRIBUTION OF COBALT IN SOILS

Cobalt content of the 3,156 B-horizon soils ranges from "not detected" (at 5 ppm) through 150 ppm. A histogram of cobalt concentrations (fig. 3) shows an essentially normal unimodal distribution with a 35.4 percent mode at the 7 ppm cobalt content class. The geometric mean is 8.9 ppm, and the geometric deviation is 1.5. A list of the 25th through 99th percentiles appears below:

Percentile	ppm Co
25	6
50	8
75	11
90	15
95	18
99	29

The gridded cobalt content data represent 1,705 valid cells and have a range of 3.6-41.0 ppm. A histogram of the gridded data (fig. 4) shows a positively skewed unimodal distribution with a 53.8 percent mode in the 6.5-ppm class.

AREAL DISTRIBUTION OF COBALT CONTENT

Cobalt content of ≥70 ppm in the B-horizon soils in the Iron River 1° x 2° quadrangle is considered to be anomalous. This limit is based on the frequency distribution of the soil cobalt values as well as the coincidence of areas with these cobalt values and anomalies in other metals, as copper (Alminas and others, 1984a) or nickel (Hoffman and others, 1984). On this basis, the soils at 174 (4.2 percent) of the 3,156 sample sites within the area contain anomalous concentrations of cobalt.

Gridded data cannot be used interchangeably with the original data because gridded data are generated by averaging calculations performed on cell units. As a result, variance is strongly reduced, and the upper end of the value distribution is very compressed. However, gridded data are effective in delineating regional cobalt content trends and areas of significantly elevated cobalt contents in these soils. Regional trends are delineated by 14-ppm isopleths and anomalies by 18-ppm isopleths.

The great majority of the cobalt anomalies occur in the western half of the map area. The major ones occur in the Matchwood area over Keweenawan Jacobsville Sandstone. Two other cobalt anomalies, at Thomaston and near Wapato Creek, occur in similar geologic settings.

Further to the south, cobalt anomalies are seen at Wakefield, Dunham, and near Morton Lake. These occur over a great variety of rock types.

The only substantial anomaly in the east occurs at Little Summit Lake, where the cobalt values are presumably associated with amphibolites. The symbol plot indicates a slight cobalt halo around the granitic outcrop area. The mafic intrusives in the southeastern corner of the map area show no appreciable cobalt association in the soils.

DISCUSSION

The broad, regional cobalt distribution pattern in the Iron River 1° x 2° quadrangle is believed to be predominantly hydromorphic in origin (see Alminas and others, 1984a).

In the northwestern quarter of the map area, cobalt anomalies coincide with copper anomalies only when they occur over the Jacobsville Sandstone, as in the Matchwood area and at Thomaston. The copper-cobalt correlation coefficient is quite low ($r = 0.24$) for the northwestern quarter of the map, but it is substantially higher ($r = 0.63$) in the southwestern quarter. Overall, cobalt correlates best with nickel, then copper, and lastly, chromium. The copper-cobalt association, as defined by the Relative Element Magnitude (REM) program (VanTrump, 1978), is shown graphically in figure 5. The extent and implications of their association are discussed by Alminas and others (1984b).

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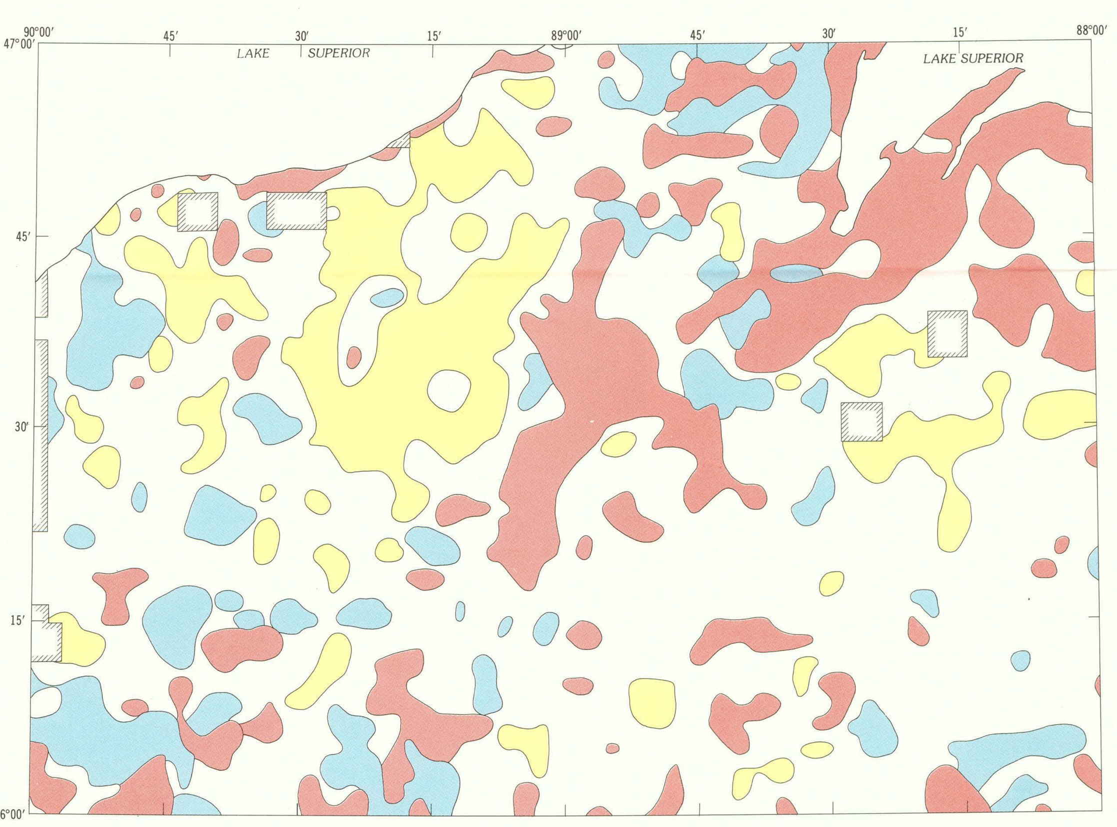

Figure 1.—AREAS OF PREDOMINANTLY SAND (RED), SILT (BLUE), CLAY (YELLOW) AND MIXED SOILS (WHITE). Scale 1:750,000; 1 in. equals approximately 12 mi.

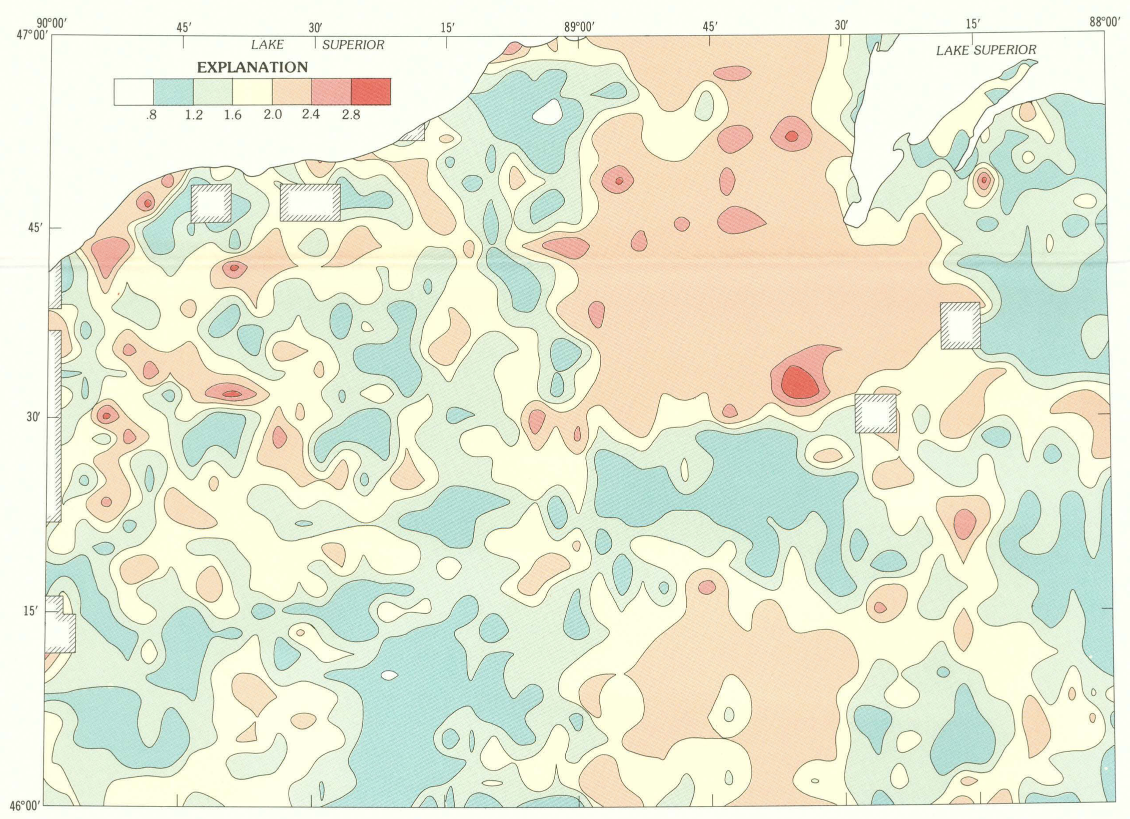

Figure 2.—RELATIVE SOIL MOISTURE CONTENT. Higher values indicate wetter areas. Scale 1:750,000; 1 in. equals approximately 12 mi.

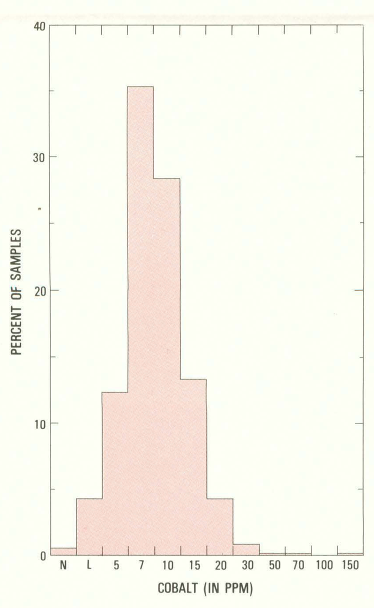

Figure 3.—DISTRIBUTION OF COBALT VALUES IN B-HORIZON SOILS; RAW DATA. N, not detected; L, detected but below lowest standard.

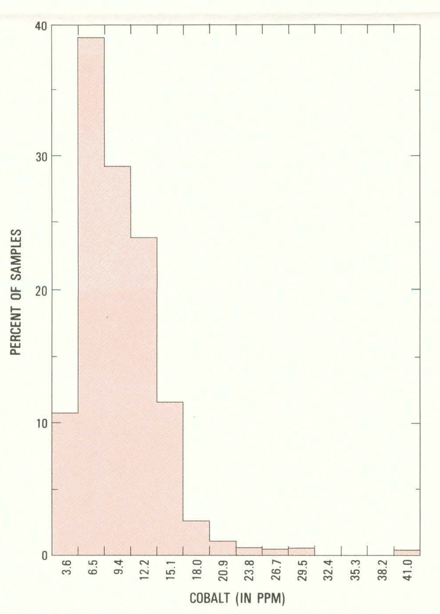

Figure 4.—DISTRIBUTION OF COBALT IN B-HORIZON SOILS; GRIDDED DATA.

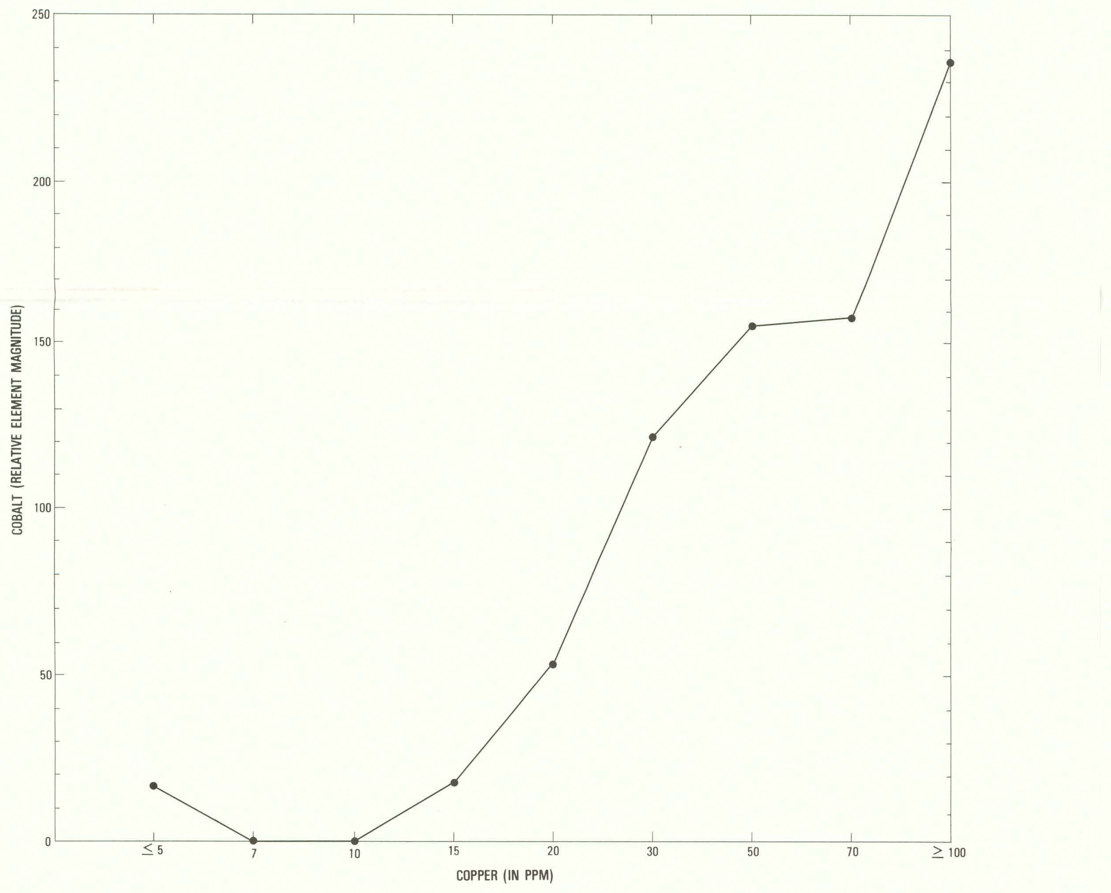

Figure 5.—COPPER-COBALT ASSOCIATION FOR ALL SAMPLES IN THE IRON RIVER 1° x 2° QUADRANGLE.

COBALT DISTRIBUTION IN B-HORIZON SOILS, IRON RIVER 1° x 2° QUADRANGLE, MICHIGAN AND WISCONSIN

By

J. D. Hoffman, H. V. Alminas, and R. T. Hopkins

1984

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