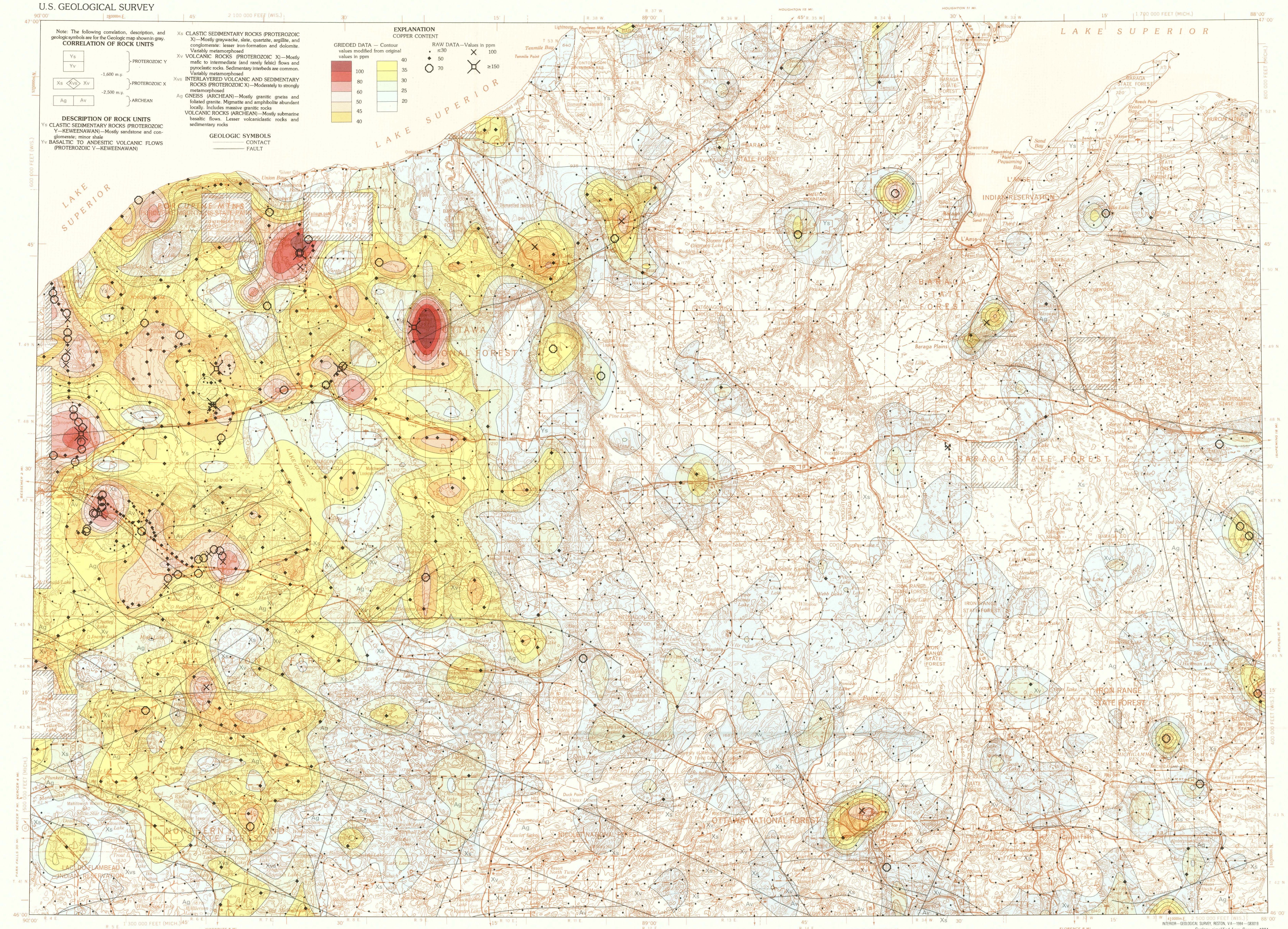

SCALE 1:250 000

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	100
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 copper content are presented on the map by symbols and by isopleths, providing the reader with specific information on the copper content of individual samples (symbols) as well as regional soil copper content trends (isopleths). Both presentations were computer generated.

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

For the isopleth map, the data within the map area were gridded, using a weighted average of circle search. This gridding method is equivalent to a first-order finite difference scheme (Fife, 1981, unpublished computer program). Where data is 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 data 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 copper data can be seen below:

	Original data	Gridded data
Cu minimum	5	3
Cu maximum	700	133
Cu mean	24	23
Standard deviation	20	11
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 DISTRIBUTION 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 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 copper values from clay-rich soils (31 ppm) with that from sand-rich soils (21 ppm) suggests that soil texture is a controlling factor in soil copper localization and retention. However, further comparison of the frequency distributions of copper contents of clay-rich soils (fig. 2A) and sand-rich soils (fig. 2B) from the northwestern quarter of the map (copper-rich area) with the equivalent frequency distributions (figs. 3A, 3B) derived from the eastern half (copper-poor area) of the map area indicates that the copper content-soil texture relationship is probably spurious. That is, it indicates that the clays coincidentally predominate in areas that are copper rich (such as the predominantly Keweenawan northwestern quarter of the map).

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 4. Statistically, no relationship between soil water saturation and copper content is evident.

The climate (humid, cool) and the vegetational cover (hardwood, coniferous, and mixed forests) are virtually constant over the map area. Although, the time available for soil formation can vary locally, as in areas of stream overflow, on a regional scale this factor can be considered a constant (about 10,000 years).

STATISTICAL DISTRIBUTION OF COPPER IN SOILS

Copper content of the 3,156 B-horizon soils ranges from "not detected" (at 5 ppm) through 700 ppm. A histogram of the copper concentrations (fig. 5) shows a somewhat positively skewed unimodal distribution with a mode of 37.8 percent at the 20 ppm copper content class. The geometric mean is 21.6 ppm and the geometric deviation is 1.6. A list of the 25th through 99th percentiles appears below:

Percentile	ppm Cu
25	16
50	21
75	29
90	41
95	50
99	76

The gridded copper content data represent 1,705 valid cells and have a range of 3–133.5 ppm. A histogram of these data (fig. 6) shows a strongly positively skewed unimodal distribution with a mode of 53.8 percent at the 17.0-ppm class.

AREAL DISTRIBUTION OF COPPER CONTENT

Copper content of ≥ 70 ppm in 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 soil copper concentrations as well as the geographic coincidence of soils with this copper content and areas of known mineralization. On this basis, the soils at 79 (2.5 percent) of the 3,156 sample sites have anomalous concentrations of copper.

Gridded data cannot be used interchangeably with the original data because they are generated by averaging calculations performed on cell units. As a result, the variance is strongly reduced, and the upper end of the value distribution is very compressed. However, gridded data are effective in delineating regional copper content trends and areas of significantly elevated copper contents in these soils. "Average" trends are delineated by a 30-ppm isopleth and anomalies by a 45-ppm isopleth.

Most of the copper anomalies occur in the northwestern quarter of the map area, in soils over rocks of the Keweenawan Supergroup. Most occur over the Proterozoic Y Portage Lake Volcanics and Nonesuch Shale outcrop belt. Within this area, there is an especially good correlation between the surficial copper patterns and areas of known mineralization, as at the Porcupine Mountains, White Pine, Norwich Lookout Tower, Rockland-C-Shaft Hill, Greenland-Mass Station, and Winona. However, several anomalies occur in areas with no known mineralization, such as Ahmodi Falls, Underwood Lookout Tower-Cherry Creek area, Bergland, and Cabin. Virtually no anomalous areas are found over the Proterozoic Freda Sandstone, although several occur over the Proterozoic Jacobsville Sandstone which is not part of the Keweenawan Supergroup, as at Connorville, the Matchwood-Tennille Creek area, and Pelkie.

The southwestern quarter of the map area contains several anomalies that are unrelated to Keweenawan rocks. The major ones are in the vicinity of Wakefield and the Presque Isle-Little Giant River area, within a generally northwest-trending copper-rich belt. The Wakefield anomaly overlies a number of rock types ranging from Keweenawan volcanic flows through Archean granite; the Presque Isle River-Little Giant River anomaly occurs primarily over Archean granites; and the Owl Lake, Rudolph Lake, Boulder Lake, the Wolverine Falls anomalies overlie a variety of rock types. In brief, outside the area of Keweenawan rocks, there appears to be no coincidence between specific rock types and high copper content in soils.

Only a few scattered copper anomalies occur in the eastern half of the map area. The most extensive one is in the Iron River-Stambaugh area. Isolated anomalies occur at Peavy Pond and Witch Lake. In the northeastern corner of the map area, relatively high copper values are arranged in a semicircular pattern around the granitic outcrop area.

DISCUSSION

The broad, regional patterns of copper distribution in the Iron River 1° x 2° quadrangle are predominantly hydromorphic in origin. A hydromorphic origin is indicated by the following five factors:

1. The ability of very weak chemical extractants (cold, 30-second agitation in 0.2 percent oxalic acid or 0.1 percent hydrochloric acid) to extract from the soils most of the copper content not related to silicate minerals.
2. The higher copper values were obtained by leaching the sand-sized portion of soils. Apparently, the copper contents are related to the iron and manganese oxide coatings of silicate mineral grains.
3. Copper content of heavy-mineral separates are not appreciably higher than those obtained from the total soils. This indicates that the copper is not present in the soils in the form of sulfides or in association with discrete particles of iron or manganese oxides.
4. Geochemical patterns show no geographic relationship to either the soil types or their parent materials.
5. No evidence of large-scale glacial drag (relative to the sample-site density) is seen within the area as a whole, although anomalies at White Pine and the Wakefield-Presque Isle River-Little Giant Creek area possibly show glacial displacement.

Copper shows an association with a broad range of elements. This association is surprisingly similar throughout the Iron River 1° x 2° quadrangle. It is discussed in depth by Alminas and others (1984).

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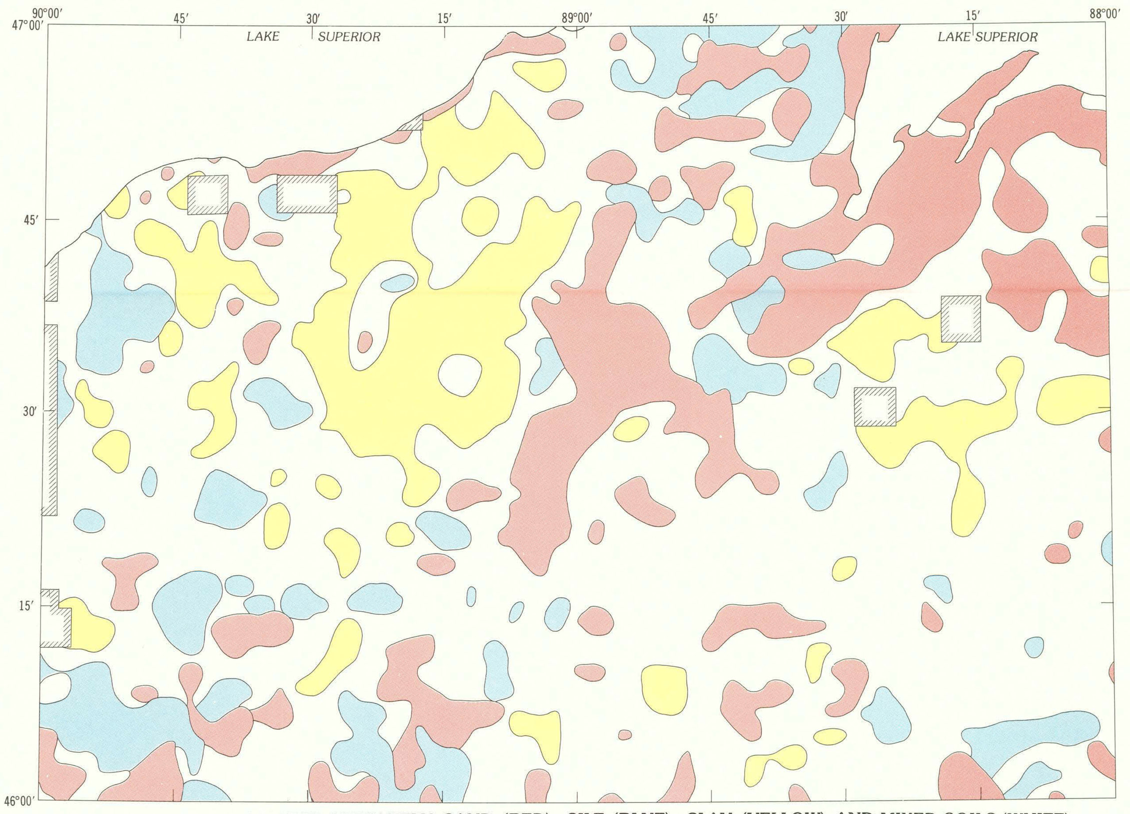

Figure 1.—AREAS OF PREDOMINANTLY SAND (RED), SILT (BLUE), CLAY (YELLOW) AND MIXED SOILS (WHITE). Scale 1:750,000; 1 in. equals approximately 12 mi.

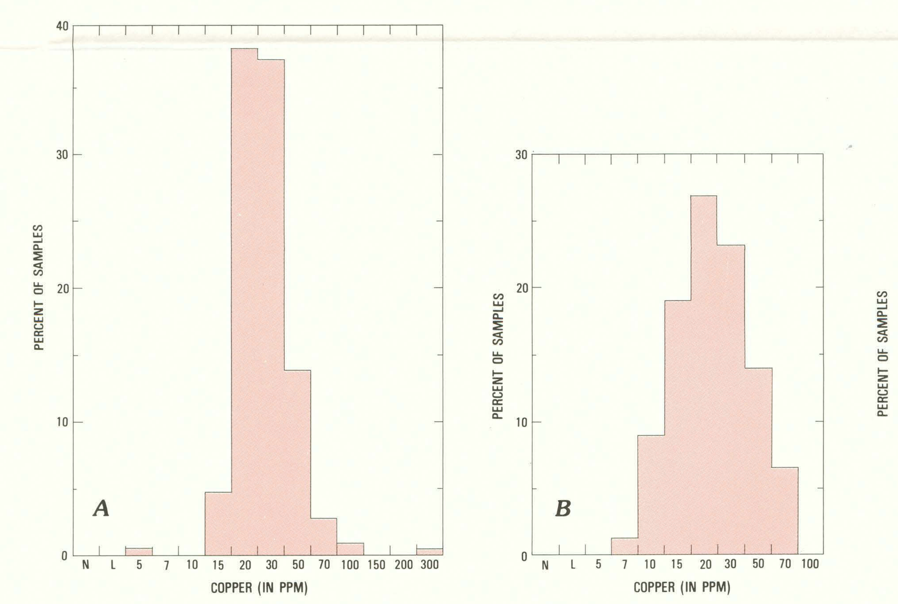

Figure 2.—COPPER CONTENT OF B-HORIZON SOILS IN THE NORTHWESTERN QUARTER OF THE MAP AREA. N, indicates not detected; L, detected but below value shown. A, in clayey soils; B, in sandy soils.

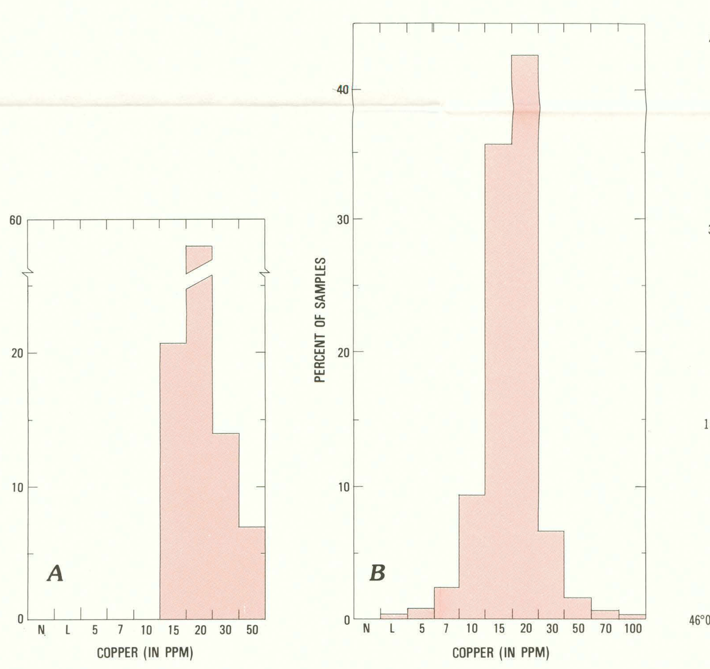

Figure 3.—COPPER CONTENT OF B-HORIZON SOILS IN THE EASTERN HALF OF THE MAP AREA. N, indicates not detected; L, detected but below value shown. A, in clayey soils; B, in sandy soils.

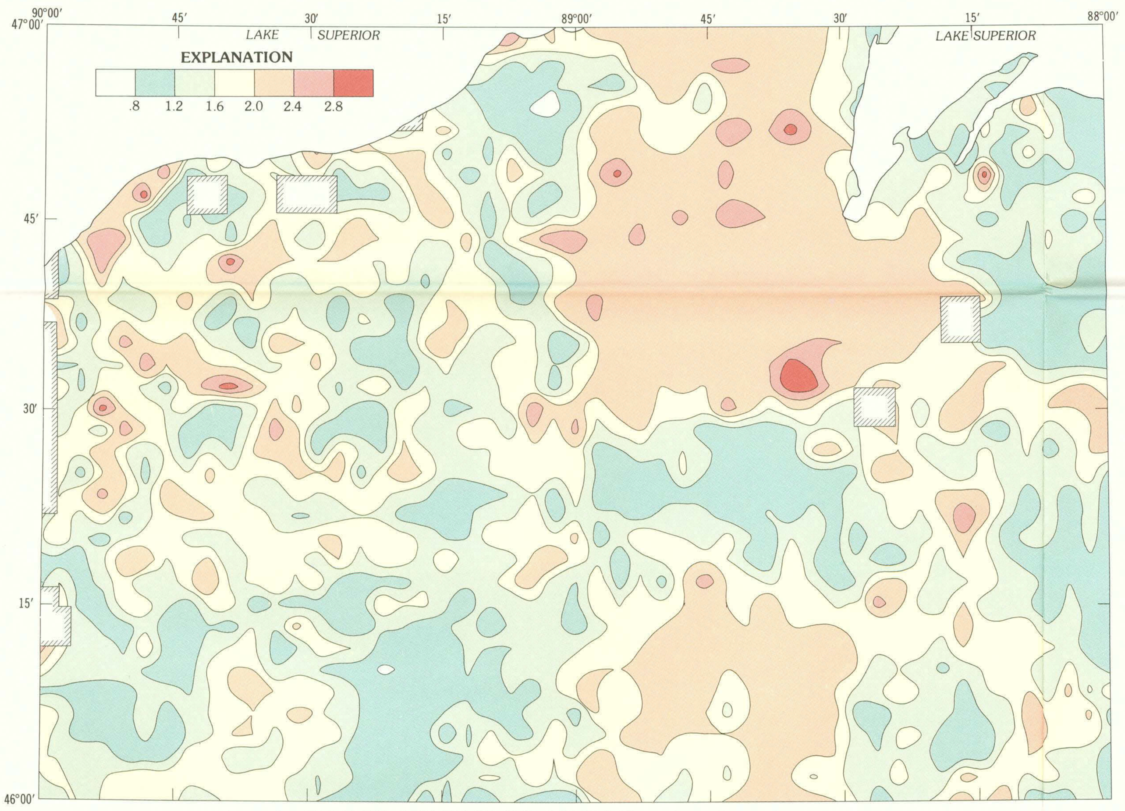

Figure 4.—RELATIVE SOIL MOISTURE CONTENT. Higher values indicate wetter areas. Scale 1:750,000; 1 in. equals approximately 12 mi.

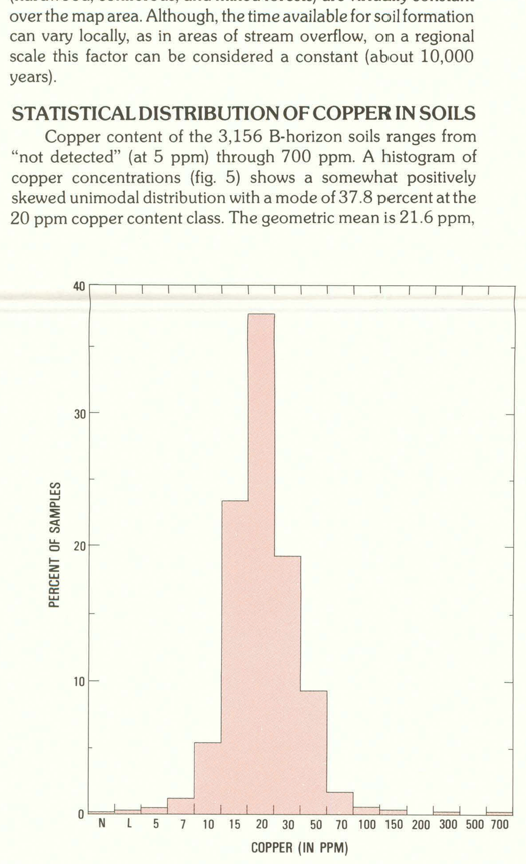

Figure 5.—COPPER CONTENT IN B-HORIZON SOILS; RAW DATA. N, not detected; L, detected but below lowest standard.

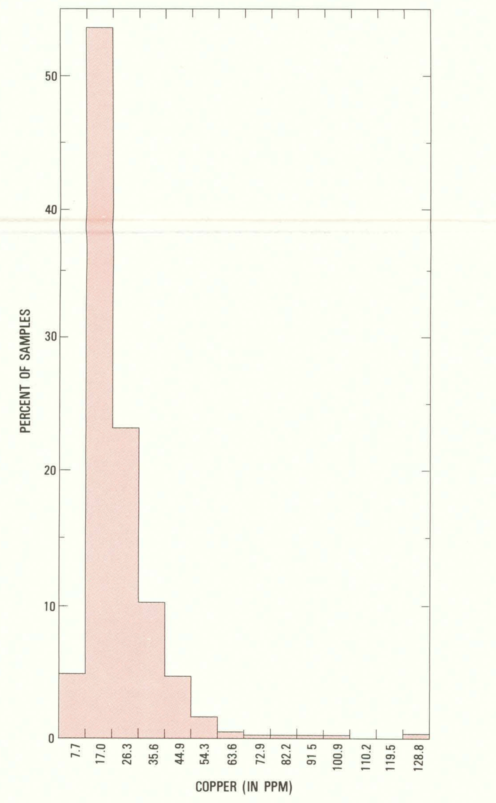

Figure 6.—COPPER CONTENT IN B-HORIZON SOILS; GRIDDED DATA.

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

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

1984