Sampling of copper-bearing Keweenawan rocks of northwestern Wisconsin

by

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Abstract.--Metallic copper or copper minerals are locally present in flows, conglomerate, siltstone, and shale of Keweenawan age that underlie about 3,000 square miles of northwestern Wisconsin. Representative samples taken from 24 of the reported occurrences in lava or conglomerate contain 0.0075 to 0.69 percent copper; 10 of them have more than 0.10 percent. No study was made to appraise the geologic settings of the sampled sites as guides to possibly more significantly mineralized rock. The siltstone and shale sequence is sparingly exposed in Wisconsin but was not sampled; exploratory drilling has shown that it is mineralized locally.

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Introduction

Metallic copper or copper minerals are locally present in extrusive and sedimentary rocks of Keweenawan age in a part of northwestern Wisconsin that is approximately 40 miles wide, 50 to 100 miles long, and that trends about N. 55° E. (fig. 1). The northeastern and southwestern limits are about 60 and 100 miles, respectively, from Superior, Wis. The area includés much of Douglas and Bayfield Counties and part of Washburn, Burnett, and Polk Counties. Part of Ashland County is also underlain by rocks of Keweenawan age, but no occurrences of copper or copper minerals are known in them.

The Keweenawan rocks continue southwestward from Michigan where they contain minable deposits of metallic copper or copper minerals, and occurrences of these minerals at many localities in Wisconsin have been reported. A preliminary appraisal of the reported occurrences versus outcrops in which no copper minerals had been reported was sought in 1968 by chemical and spectographic analyses of 69 chip samples from 43 localities (fig. 1). The results (tables 1 and 2) are less encouraging than anticipated, but the relation of the localities to possible geologic controls for more favorable mineralization may warrant investigation.

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Reports by Chamberlain and others (1880), Irving (1883), and Grant (1901) are mainly of interest as historical accounts of early recognition and interpretation of general geologic features of the area. Aldrich (1929) briefly summarized the lithologic, stratigraphic, and structural features of the formations of Keweenawan age, some of which are northwest of the Gogebic iron district, the principal subject of his report. Smith (1947) gave a summary of work at an exploration about 1906 and of a reexamination by the U.S. Bureau of Mines and U.S. Geological Survey in 1944-45. Leighton (1954) discussed a gabbro-granophyre complex in the eastern part of the area. Holliday (1955) described the investigation of a copper-nickel prospect. Sedimentologic features of upper Keweenawan rocks in Wisconsin were discussed by Hite (1968). Olmsted (1966, 1969) studied mafic intrusive masses, and Katzman (1968) described a granitic mass near Mellen, Wis. Hubbard (1968) proposed alternative interpretations of stratigraphy and structure, as will be mentioned later. Felmlee (1970) interpreted relations near Mellen to indicate that lower Keweenawan strata lie with structural conformity but stratigraphic disconformity upon Animikean strata.

Geologic, magnetic, and gravity data concerning the Keweenawan area and the Precambrian rocks in other parts of Wisconsin have been compiled from many sources and interpreted by Dutton and Bradley (1970).

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The Wisconsin Geological and Natural History Survey series of township maps and reports are based on the work of field parties in the Keweenawan area during the period 1922 to 1930. Along traverses a half mile apart, outcrops were mapped, the lithology was described, specimens were taken which are still available, and magnetic dip-needle observations were made. These materials were the basis for the selection of the locations for sampling (fig. 1).

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General geology

The area of Keweenawan rocks in northwestern Wisconsin is geologically divided into northern and southern parts underlain by some lava of lower Keweenawan age and by much lava and some conglomerate of middle Keweenawan age; a central part is underlain by sediments of upper Keweenawan age or younger (fig. 1). The general structure is the northeast-plunging Ashland or Lake Superior syncline. The northern limit of the area and undetermined amounts of the western part of the southern limit may be reverse faults or possibly unconformities along which rocks of Keweenawan age are adjacent to those of later Keweenawan or Cambrian age. The eastern part of the southern limit is at the conformable, unconformable, or fault contact mainly with north-dipping older rocks of Animikie age in the adjacent Gogebic iron district.

The inferred areal extent of the lavas is based mainly on the distribution and trend of magnetic anomalies related to a thick sequence of massive fine- to medium-grained intermediate and felsic flows with associated conglomerate of probably minor amount. Except locally, outcrops are small and scattered; they are estimated to constitute 5 percent or less of the area in most sectional units of land but are at least 25 percent of the area in several sections. Outcrops are scarce or absent within the area in which copper occurrences have been reported in 8 of the 22 townships or parts of townships in the northern part and in 17 of the 45 townships or parts of townships in the southern part.

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The inferred areal extent of upper Keweenawan strata in the central part of the area is based on a few outcrops at the northern and southern limits and mainly on the absence of magnetic anomalies comparable to those in areas underlain by lavas. Exploration by drilling has confirmed the extent of the sedimentary sequence under part of the area.

Rocks of Keweenawan age in the Lake Superior region have been studied by Hubbard (1968); he proposed that the lavas in Michigan constitute two distinct subdivisions which have been recognized in Wisconsin and whose distribution has been partly determined by reconnaissance. The relationship of the other Keweenawan volcanic rocks of Wisconsin to these is uncertain. He further proposed that the syncline of Keweenawan rocks is bounded on the south by an unconformity rather than a reverse fault as proposed by Aldrich (1929); the north limit of the syncline may also be an unconformity (H. A. Hubbard, oral commun., 1969).

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Copper in the southern part of the Keweenawan area

The southern part of the copper-containing area is in the south limb of the Ashland syncline that continues from Michigan across Wisconsin and into Minnesota; the Wisconsin part is about 10 miles wide and 100 miles long. This part is discussed first in accordance with the sample numbers in tables 1 and 2--progressively north by townships, west by ranges, and then by section number.

Samples 1 through 23 are from the lava sequence in the southwestern part for which no specific geologic report or map exists. Material selected from seven sites where copper minerals had been reported contained 0.012 to 0.18 percent copper (table 1). Samples from 16 sites where no copper had been reported or was seen at the time of sampling contained 0.007 to 0.020 percent copper. Semi-quantitative analyses of all samples are shown in table 2.

Samples 24 through 50 are from the middle section; the geology of that section has been shown by Grant (1901, pl. 13) and Aldrich (1929, pl. 1). The flows dip 30°-40°NW., and several interflow conglomerates are in the upper part of the lava sequence, which is overlain by sandstone, shale, and conglomerate.

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Grant (1901) gives accounts of three early explorations at the Mudge, Weyerhauser, and Montrose localities. (1) The Mudge location is in NE¼ and SE¼ sec. 5, T. 42 N., R. 10 W. According to Grant (p. 55), some copper was found in the NE¼ in epidotized and brecciated rock by stripping and shallow trenching in 1900. Copper was found at several places in the SE¼ along and on both sides of the contact of a thin conglomerate and overlying flow. (2) The Weyerhauser location is in the NW¼SE¼ sec. 12, T. 43 N., R. 10 W. The exploratory work in 1900 described by Grant (p. 55-57) consisted of two pits, 40 and 60 feet deep, and some trenches. Copper was present in a series of fractured and epidotized amygdaloidal diabase flows. Several masses weighed 1 to 3 pounds each; the largest weighed 7 pounds. Smith (1947) reported that extensive exploration began about 1906, and the length of 55 diamond-drill holes totaled almost 20,000 feet. Three shafts were sunk, and 1,950 feet of workings were excavated. A small mill was built to evaluate the material being explored, but work stopped in 1914. Smith (1947) described the pertinent features of this area and the examination of it by the U.S. Bureau of Mines and U.S. Geological Survey in 1944-45. A shaft and related workings were dewatered; 16 samples were taken from the first level at a vertical depth of about 90 feet, 5 samples from the second level about 40 feet deeper, and 1 sample from the fourth level at a depth of 225 feet. It is reported that: "Within the area examined native copper occurs sporadically as irregular grains and small masses in the more fragmental portions of the amygdaloid. The fragmental portions of the amygdaloid are quite erratic in occurrence. The percentage

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of copper in the rock is low" (Smith, 1947, p. 6). The copper content of 20 samples that were analyzed ranged from 0.003 to 0.959 percent: 8 samples ranged from 0.003 to 0.090 percent copper, 11 samples from 0.114 to 0.500 percent, and 1 sample had 0.959 percent. (3) The Montrose location is in the NW¼NW¼ sec. 12, T. 44 N., R. 9 W. Grant (1901, p. 58-59) presented a sketch map and section showing the location of outcrops and test pits and the related inferred geology. Some copper was found in and outside of amygdules in epidotized diabase, especially in brecciated rock, in a shaft reported to be 87 feet deep. A 15-foot drift in conglomerate at the bottom of a pit 80 feet deep was reported to have contained considerable copper.

Grant (1901, pl. 13) showed the location of outcrops and copper occurrences and the areal geology in part of the area mapped later by Aldrich but also showed that the lava sequence continued 9 miles farther southwest. Five of the 10 copper occurrences indicated are in or adjacent to the only conglomerate layer shown, which is probably at or near the northern limit of the middle section of the southern area. This part of the area is so poorly accessible that the occurrences of copper were not sampled.

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The map of the middle section of the southern part of the Keweenawan area by Aldrich shows the location and general lithology of outcrops and also the location and classification, as metallic or sulfide, of occurrences of copper as recorded in field notebooks of the mineral land classification by the Wisconsin Geological Survey. Samples 24 through 30 are from lava in the southwestern part of the area shown by Aldrich. Sample 24 contained 0.74 percent copper but was probably not representative material, as indicated by associated sample 25 with 0.029 percent copper. Samples 27 and 29 with visible copper minerals contained 0.41 to 0.69 percent copper, nearby samples 28 and 30 without visible copper minerals contained 0.22 to 0.31 percent copper, and sample 26 of presumably unmineralized lava contained 0.01 percent copper. Sample 46 is from lava in about the same stratigraphic position as those just discussed and contained 0.0045 percent copper. Samples 47 and 48 are from conglomerate between the two preceding localities; mineralized rock contained 0.14 percent copper, and rock with no visible copper minerals contained 0.014 percent copper.

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Other occurrences that are lower in the lava sequence, in conglomerate, and in younger gabbro are south of but near the fault or unconformity. Most are indicated as sulfide, but azurite and some malachite are now most evident. Some explorations by test pits in NW¼NW¼ sec. 6, T. 44 N., R. 5 W., NE¼NW¼ sec. 2, T. 44 N., R. 6 W., and NE¼SE¼ sec. 15, T. 44 N., R. 9 W., are described in the township reports of the mineral lands survey. Samples 31 through 45, and 49 and 50 (fig. 1) are from these occurrences and test pits. Samples 31 and 32 are mainly material selected to give data about presumably unmineralized lava and contained 0.023 to 0.37 percent copper; samples 34 and 35 were slightly mineralized lava that had 0.081 to 0.15 percent copper; and samples 33 and 36 (1.05 and 6.05 percent copper, respectively) are from the same general locality and contained visible minerals which is rare. Sample 37 was gabbro and contained only 0.033 percent copper. Samples 38-40, 44-45, and 49-50 are from the lava sequence: mineralized rock contained 0.14 to 0.52 percent copper, associated rock contained 0.074 to 0.21 percent copper, and material collected as presumably unmineralized lava contained 0.034 percent copper. Conglomerate in samples 41-43 contained 0.008 to 0.76 percent copper. An analysis of one sample taken from 660 feet across the strike of the conglomerate in sec. 11, T. 44 N., R. 6 W. was reported (Wisconsin Geological Survey, unpub. data) as 0.033 percent copper, 0.36 ounce of silver per ton, and 0.004 ounce of gold per ton. An analysis of another sample from the above locality was reported as 0.59 percent copper, 1.74 ounces of silver per ton, and a trace of gold.

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Copper in the northern part of the Keweenawan area

The northern part of the area (fig. 1) is 2 to 30 miles wide and 50 miles long.

Samples 51 through 54 are from along roads in the southwestern part of Douglas County and were collected because fresh presumably unmineralized lava was readily accessible. The copper content ranges from 0.005 to 0.012 percent.

Plate 7 in the report by Grant (1901) is a geologic map of a 15-mile southwestern segment of the southern edge of the northern area underlain by lavas of middle Keweenawan age; a narrow strip of sedimentary rocks of upper Keweenawan age to the south is also shown. The lavas and sediments dip southeast 12° to 18° and 8° to 15°, respectively. Six of the nine occurrences of copper minerals shown on Grant's plate 7 are at or within a half mile of the southern limit of the lavas in T. 43 N., R. 13 and 14 W. Four of these occurrences were not feasibly accessible, and another one could not be found; sample number 55 is from the sixth site, but the very small copper content (0.0043 percent) suggests that representative mineralized material was probably not collected.

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Notes of the mineral land classification by the Wisconsin Geological Survey also refer to "particles of copper" at 22 locations in a tract 5½ miles long and within 1½ miles of the upper limits of the lava sequence in T. 44 N., R. 13 W. The field notes also report "specks of copper" in drill core from a hole in sec. 6, T. 43 N., R. 12 W., but no occurrences of copper minerals in outcrops in this section are mentioned. Analyses of samples 55 through 58 from lava at or near the reported occurrences of copper minerals along the southern edge of the northern area are given in table 1. The copper content ranges from 0.0024 to 0.0075 percent, so the adequacy of sampling or the validity of the reported presence of copper is questioned.

Plates 8 and 9 in the report by Grant (1901) are geologic maps of the western 75 percent of the northern 3 miles of the northern area underlain by the lava sequence. Copper minerals are indicated at 24 localities.

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The township maps compiled from data of the mineral land survey indicate 49 reported copper occurrences in 25 sections; 22 of the reported occurrences are in eight sections in T. 47 N., R. 13 W. The outcrops in this township are parallel ridges of south-dipping massive diabase that are probably separated by the less massive part of flows. Locally amygdaloids that contain sulfides are common to abundant along the southern part of outcrops, and the best potential areas presumably underlie the covered strips. Comparable but less obvious relations may exist in other areas containing outcrops of the lava sequence.

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Grant gives brief descriptions of nine explorations in the "Douglas Range," that is, the north part of the northern area of Keweenawan lavas. (1) The North Wisconsin or Chippewa location is in the SW¼ sec. 3 and NW¼ sec. 10, T. 47 N., R. 12 W., but little work had been done and little copper was seen at the time of Grant's visit. Holliday (1955) reports that by 1901 a shaft had been sunk to a depth of 200 feet, and 1,532 feet of horizontal workings had been excavated. Eight samples from near and in the mine had been reported to contain $18.68 to $27.86 per ton in gold, silver, copper, and nickel. The shaft was dewatered and repaired in 1953 by the U.S. Bureau of Mines in order to appraise the potential of this locality, and 519 samples of 25 pounds each from 1,814 feet of workings at a depth of 171 feet were examined. Copper was mainly in amygdaloidal parts of flows or near faults; associated minerals were quartz, calcite, prehnite, and epidote. The amount of copper was insufficient to warrant further investigation at that time. Most of the samples contained less than 0.01 percent copper, some had 0.03, and a very few had 0.05. Handsorted samples contained 0.155 to 0.504 percent copper, 0.0008 to 0.0033 percent nickel, 0.030 ounce of silver per ton, and 0.0001 to 0.0004 ounce of gold per ton. (2) The Starkweather location, also known as the Edwards or Wisconsin mine, is in the NW¼NW¼ sec. 2, T. 47 N., R. 13 W. Native copper and some malachite were in amygdules but more commonly in veinlike cement of brecciated rock. (3) The Fond du Lac location is in the NE¼ sec. 8, T. 47 N., R. 13 W. It was explored by two shafts 60 and 80 feet deep and by several shallow pits and trenches, and

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considerable stripping. Grant (p. 36) states that ". . . the work here resulted in an examination of a larger amount of rock in which copper might occur than at any other of the recent explorations on the Douglas Range." One occurrence of copper was irregularly distributed in a veinlike mass that appeared to be igneous rock intruded along a fissure, and copper also occurs in the amygdaloidal upper part of a flow. (4) The Amnicon location is in the NW¼ sec. 11, T. 47 N., R. 13 W., where chalcopyrite, chalcocite, and malachite were in a vein from 2 to 18 inches wide and in amygdules at several adjacent outcrops. (5) The Copper Creek location is in the SW¼ sec. 14 and SE¼ sec. 15, T. 47 N., R. 14 W. Copper was in amygdules at the top of some flows and in vein material--quartz, calcite, and prehnite--of breccia between flows. The occurrences were seen in outcrops, pits, and a trench. (6) The Culligan location is in the SW¼ sec. 29 and SE¼ sec. 30 and NE¼ sec. 31, T. 47 N., R. 14 W. Malachite was in breccia penetrated by test pits. Occurrences of native copper with quartz in amygdules and small veins in an exposure, a trench, and pits were sufficiently encouraging that Grant thought they should be prospected more fully. No samples were obtained in 1968 from this mineralized area because of poor accessibility. (7) The Percival location is in the SW¼NE¼ sec. 27, T. 48 N., R. 10 W. A shaft about 90 feet deep penetrated an amygdaloidal rock in which epidotized areas contained copper in the amygdules and cracks and as disseminated particles. (8) The Astor location is in the NW¼ sec. 28 and NE¼ sec. 29, T. 48 N., R. 10 W.; chalcopyrite was present in a few exposures of amygdaloidal rock and shallow pits. (9) The Catlin

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location, in the SE¼ sec. 34, T. 48 N., R. 13 W., had a small amount of exploration, but no copper was reported by Grant.

Samples 59 through 69 (fig. 1) are from selected occurrences of reported copper minerals in lava in the northern part of the northern limb of the Ashland syncline. The copper content of the samples ranged from 0.016 to 0.050 percent as shown in table 1. Rock presumed to be unmineralized contained 0.0060 to 0.018 percent copper.

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Copper in the central part of the Keweenawan area

The central part of the area of Keweenawan rocks in northwestern Wisconsin is underlain by a thick sequence of very sparingly exposed sediments of upper Keweenawan age. A thin unit, the Nonesuch Shale, contains copper locally. This formation contains sufficient copper in northwestern Michigan to be ore grade at the White Pine mine; very fine chalcocite (Cu_2S) is in two extensive mineralized siltstone units that contain 1 to 3 percent copper, but the overall grade of mined ore is about 1 percent. The Nonesuch Shale in Wisconsin was explored about 1960 by almost 50 drill holes in adjacent parts of Bayfield, Douglas, and Washburn Counties. The mineralized areas were too small or were too low in copper content for development; neither mineralized rock nor the Nonesuch Shale itself is continuous within the area explored.

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Summary

Lavas and conglomerates that contain valuable deposits of copper in Michigan extend southwestward into Wisconsin, where further appraisal of the potential may be advisable even though former explorations were not commercially successful and reconnaissance sampling was not as significant as anticipated.

Samples from 24 reported occurrences of copper contained 0.0075 to 0.69 percent copper; 10 of the 24 samples contained more than 0.10 percent.

Adjacent rock associated with seven samples but having no visible copper minerals ranged from 0.016 to 0.074 percent copper.

Samples from 33 localities presumed to be unmineralized, inasmuch as no copper minerals had been reported or were visible as material was being collected, contained 0.0005 to 0.17 percent copper. The median value was 0.01 percent copper; about half the lower group was clustered at 0.005 to 0.008 percent, and about half the upper group was at 0.014 to 0.018 percent.

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The sites sampled and presumably those explored were selected on the basis of readily visible occurrences or reported occurrences of copper minerals, but the sites may not be indicative of or representative of the full potentialities of the area. A more adequate appraisal will require a comprehensive geologic and geophysical study of the stratigraphic and structural controls that influenced localization of the minerals.

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Table 1.--Amount of copper in chip samples of Keweenawan rocks of Wisconsin

[Copper determined by HNO_3 acid boil-atomic absorption, by J. A. Thomas, Claude Hoffman, Jr., and J. P. Cahill, U.S. Geol. Survey, Denver, Colo.]

Sample number	Location: Township North	Location: Range West	Location: Section	Percent copper in type of material sampled: Mineralized rock[1/]	Associated rock	Presumably unmineralized rock
1	33	18	5			0.015
2	do	do	do			0.015
3	do	19	14			0.0005
4	35	18	4			0.0098
5	do	do	do			0.008
6	do	do	9			0.011
7	do	do	do			0.018
8	do	do	do			0.014
9	do	do	do			0.007
10	36	18	10			[2/]0.007
11	37	16	7	0.021		
12	do	do	9	0.18		
13	do	do	13			0.014
14	do	do	14	0.14		
15	do	do	18	0.012		
16	do	do	do		0.042	

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Table 1.--Amount of copper in chip samples of Keweenawan rocks of Wisconsin--Continued

Sample number	Location: Township North	Location: Range West	Location: Section	Percent copper in type of material sampled: Mineralized rock[1/]	Associated rock	Presumably unmineralized rock
35	do	do	do			0.081
36	do	do	do	[5/]6.05		
37	44	6	1			gb 0.033
38	do	do	2	0.19		
39	44	6	2		0.074	
40	do	do	4			0.034
41	do	do	10			cg 0.008
42	do	do	11		[3/]cg 0.76	
43	do	do	do			cg 0.17
44	44	7	29	0.52		
45	do	do	do		0.21	
46	44	9	12			0.0045
47	do	do	28	cg 0.14		
48	do	do	do		cg 0.014	
49	45	6	36	0.14		
50	do	do	do		0.016	
51	43	14	5-6	0.0080		
52	do	do	6			0.0050

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Table 1.--Amount of copper in chip samples of Keweenawan rocks of Wisconsin--Continued

Sample number	Location: Township North	Location: Range West	Location: Section	Percent copper in type of material sampled: Mineralized rock[1]	Associated rock	Presumably unmineralized rock
17	do	do	23	0.11		
18	do	do	25-36	0.12		
19	do	do	28			0.009
20	37	17	30			0.008
21	do	do	do			0.011
22	do	do	31			0.012
23	do	18	36			0.020
24	43	9	16	[3]0.74		
25	do	do	do		[4]0.029	
26	do	do	do			0.01
27	do	10	12	0.41		
28	do	do	do		0.22	
29	do	do	do	0.69		
30	do	do	do		0.31	
31	44	5	6			0.023
32	do	do	do			0.037
33	do	do	do	[3]1.05		
34	do	do	do			0.15

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Table 1.--Amount of copper in chip samples of Keweenawan rocks of Wisconsin--Continued

Sample number	Location: Township North	Location: Range West	Location: Section	Percent copper in type of material sampled: Mineralized rock[1/]	Associated rock	Presumably unmineralized rock
53	do	do	9	0.012		
54	do	do	do			0.0050
55	44	13	14			0.0043
56	do	do	16	0.0075		
57	do	do	23			0.0050
58	44	13	23			0.0024
59	47	12	3	0.016		
60	do	do	6	0.018		
61	do	13	1	0.027		
62	do	do	do	0.020		
63	do	do	do	0.041		
64	do	do	do			0.0060
65	do	do	do	0.050		
66	do	do	17	0.035		
67	48	10	24			0.018
68	do	do	30	0.025		
69	do	12	29	0.032		

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Table 2.--Semiquantitative analyses of chip samples from reported

[See figure 1 for sample localities. Six-step semiquantitative analyses were made by Harriet Neiman. Results are reported in the value is approximately plus or minus one bracket at 68% or two brackets at 95% confidence. Symbols: L, element detected

	Semiquantitative spectrographic analyses											
	(percent)				(ppm)							
Sample	Cu[1]	Fe	Mn	Ca	Ti	Mo	Ni	Be	Co	Cr	Cu	La
01	0.015	10	2	5	1	700	150	---	30	100	300	---
02	0.015	10	3	7	1	700	150	---	50	150	200	---
03	0.005	10	1.5	7	2	500	500	1	50	100	100	30
04	0.001	10	5	7	1	1,000	70	---	50	150	150	---
05	0.006	10	5	5	1	1,000	300	---	50	150	150	---
06	0.011	10	5	7	1	1,000	200	---	50	150	200	---
07	0.018	10	5	5	2	1,000	500	---	50	150	300	---
08	0.014	10	5	7	1	1,000	150	---	50	150	200	---
09	0.007	10	2	7	1	1,000	150	---	50	100	150	---
10	0.007	10	5	5	1	1,000	150	---	50	150	150	---
11	0.021	10	2	5	1	1,000	150	---	50	100	300	---
12	0.018	10	5	5	1	1,000	200	---	50	150	200	---
13	0.014	10	2	5	1	500	200	---	50	150	200	---
14	0.014	10	2	5	1	1,000	150	---	50	100	300	---
15	0.042	10	5	5	1	1,000	150	---	50	150	700	---
16	0.020	10	2	5	1	1,000	200	---	50	100	200	---
17	0.011	10	5	5	1	1,000	100	---	50	200	200	---
18	0.012	10	2	5	2	1,000	500	1	50	150	200	70
19	0.019	10	2	5	1	700	150	---	50	100	100	---
20	0.008	10	5	5	1	1,000	300	---	50	100	200	---
21	0.011	10	5	7	1	1,000	300	---	50	150	200	---
22	0.012	10	5	5	1	1,000	300	---	50	150	200	---
23	0.023	10	5	5	1	1,000	200	---	50	100	300	---
24	0.74	10	5	10	1	700	150	---	50	200	7,000	---
25	0.029	10	5	10	1	700	150	---	50	200	500	---
26	0.01	10	5	7	1	700	150	---	50	200	200	---
27	0.041	10	10	5	1	1,000	150	---	50	200	500	---
28	0.022	10	1.5	10+	0.7	1,000	15	---	20	200	150	---
29	0.69	10	5	2	1	500	70	---	50	150	7,000	---
30	0.031	10	5	7	1	1,000	150	---	50	150	500	---
31	0.023	10	5	5	2	1,000	200	1	50	100	300	30
32	0.37	10	5	3	2	1,000	500	1	50	70	5,000	50
33	1.05	7	3	5	1.5	1,000	700	1	30	50	10,000	70
34	0.15	10	5	5	2	1,000	300	1	50	70	1,000	30
35	0.081	5	1	5	0.7	500	700	1.5	20	30	500	100
36	6.05	10	5	7	2	1,000	100	1	50	70	70,000	30
37	0.033	10	2	7	3	1,000	150	1	50	100	300	---
38	0.19	10	5	5	2	1,000	500	1	50	50	2,000	50
39	0.074	10	5	5	2	1,000	700	1	50	50	1,000	50
40	0.034	10	1.5	5	1	1,000	200	1	30	70	300	30
41	0.001	10	1.5	1.5	1	700	500	2	20	50	15	70
42	0.76	7	1.5	1	1	500	1,500	---	30	50	7,000	70
43	0.17	7	0.7	1	1	500	1,500	2	20	50	2,000	100
44	0.32	10	2	5	2	1,000	200	1	50	100	7,000	---
45	0.21	10	2	5	2	1,000	300	1	50	70	3,000	30
46	0.004	10	1.5	5	1.5	700	500	---	50	20	100	30
47	0.14	3	0.7	1	0.5	500	1,000	3	10	30	1,500	300
48	0.014	3	0.7	1.5	0.5	500	1,000	3	10	30	200	150
49	0.14	10	5	7	2	700	150	---	50	200	2,000	50
50	0.016	10	5	5	2	700	500	1	50	150	300	50
51	0.008	10	2	5	1.5	700	500	1	50	30	150	50
52	0.004	10	5	7	1	700	150	---	50	200	100	---
53	0.012	10	5	7	1	500	200	---	50	200	150	---
54	0.005	10	7	7	1	500	150	---	50	200	100	---
55	0.004	10	5	7	1	500	300	---	50	150	70	---
56	0.007	7	7	7	0.5	500	150	---	50	150	100	---
57	0.005	10	7	7	1	500	150	---	50	200	150	---
58	0.002	10	5	7	1	500	500	---	50	150	50	---
59	0.016	10	2	3	2	1,000	500	1	50	100	200	50
60	0.018	10	2	7	1.5	700	300	1	50	200	300	30
61	0.027	10	2	5	1.5	700	300	---	70	150	500	---
62	0.029	10	2	5	1.5	700	150	1	50	100	300	---
63	0.041	10+	2	5	1.5	700	200	1	50	100	500	50
64	0.006	10	2	3	1	700	150	---	50	150	100	---
65	0.050	10	2	3	1.5	1,000	500	1	50	2	500	50
66	0.035	10+	1.5	3	2	700	500	1	50	2	500	50
67	0.018	10	3	5	1.5	1,000	200	1	50	150	300	---
68	0.025	10	3	2	2	500	100	1	50	100	300	30
69	0.032	10	2	5	1.5	1,000	500	1	50	100	500	50

[1] Copper, gold, nickel, and silver analyses were made by atomic absorption by J. P. Cahill, Claude Huffman, Jr., and J. A. Thomas.

Six samples had 2 to 5 ppm silver, and others had less than 2 ppm.

Table 1.--Amount of copper in chip samples of Keweenawan rocks of Wisconsin--Continued

1/ Samples were believed to contain visible copper minerals in diabase, except as noted: gb, gabbro; cg, conglomerate.

2/ Grab sample from dump of shallow exploratory shaft.

3/ Mineralized joint surface and probably not sufficient adjacent rock taken to be representative sample.

4/ From same joint surface as sample 24, but no copper mineralization visible.

5/ Fine-grained mafic rock containing metallic copper along joints. Only one fragment on test pit dump composed of diabase and conglomerate.

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series 1, 0.7, 0.5, 0.3, 0.2, 0.15, 0.1, etc. that are midpoints of bracket limits on a geometric scale. The precision of a reported in amount below sensitivity limit; -, element not detected.]

Semiquantitative spectrographic analyses--Continued

(ppm)

Sample	Mo	Ni	Ni[1]	Pb	Sc	SR	V	Y	Zr	Rock type
01	--	100	135	--	20	200	200	20	70	Basaltic and andesitic flows except as noted. Texture is commonly asphanitic or ophitic, and amygdaloids are present locally.
02	--	150	150	--	30	200	300	30	100	
03	L	50	67	10	50	500	500	70	200	
04	--	100	138	--	30	300	300	30	100	
05	--	100	165	--	30	200	300	30	100	
06	--	100	152	--	30	500	500	30	100	
07	--	100	138	--	30	300	500	30	100	
08	--	100	165	--	30	300	300	30	100	
09	--	70	75	--	30	200	500	50	100	
10	--	100	133	--	30	500	300	30	100	
11	--	100	100	--	30	300	500	50	150	
12	--	150	165	--	30	300	200	30	100	
13	--	100	155	--	30	200	300	30	100	
14	--	100	155	--	20	300	500	20	100	
15	--	100	112	--	30	300	500	30	100	
16	--	100	109	--	30	500	500	30	100	
17	--	150	150	--	30	200	300	30	100	
18	10	100	107	--	30	200	300	100	300	
19	--	70	95	--	30	200	500	50	150	
20	--	100	124	--	30	300	300	30	100	
21	--	200	208	--	30	300	300	20	70	
22	--	150	134	--	30	300	500	30	100	
23	--	100	143	--	30	300	300	30	70	
24	--	150	178	--	30	500	200	20	70	
25	--	150	179	--	30	500	200	20	70	
26	--	100	181	--	30	500	500	30	70	
27	--	200	222	--	30	200	300	20	70	
28	--	150	187	--	30	700	700	20	70	
29	--	150	100	--	20	150	500	30	100	
30	--	150	190	--	30	500	700	30	100	
31	15	100	140	--	30	200	200	70	200	
32	15	70	105	10	20	200	300	70	200	
33	20	50	72	--	20	200	200	70	200	
34	10	70	143	10	20	150	200	70	200	
35	30	20	53	15	10	300	150	100	700	Conglomerate.
36	10	100	135	10	20	200	200	50	200	
37	10	70	70	--	50	200	500	70	150	Gabbro.
38	10	70	113	--	30	150	300	70	200	
39	15	70	113	--	30	150	300	70	200	
40	10	20	65	--	30	150	300	50	150	
41	20	70	60	10	20	150	200	70	300	Conglomerate.
42	30	30	65	10	20	100	200	70	500	Do.[2]
43	30	20	40	L	20	150	200	100	500	Do.
44	10	30	55	10	50	150	300	70	200	
45	L	30	49	--	50	200	300	70	200	
46	--	50	60	--	30	300	500	50	200	
47	70	20	33	10	10	150	100	200	500	Conglomerate.
48	70	20	33	L	10	150	100	150	500	Do.
49	10	150	201	L	30	300	300	70	200	
50	10	100	135	--	30	300	300	70	200	
51	--	70	70	10	30	300	500	50	200	
52	--	150	190	--	30	500	300	20	70	
53	--	150	170	--	30	300	300	20	70	
54	--	150	225	--	30	300	200	20	70	
55	--	100	190	--	30	300	300	20	70	
56	--	150	235	--	30	200	200	15	30	
57	--	150	250	--	30	200	300	20	70	
58	--	150	230	--	30	300	300	20	70	
59	10	50	55	10	30	150	200	70	200	
60	L	70	105	--	30	200	300	50	150	Gabbro.
61	L	100	110	--	30	300	500	50	150	
62	10	50	90	--	30	200	300	50	150	
63	10	50	60	--	50	300	500	50	200	
64	10	50	85	--	30	150	500	30	150	
65	10	10	50	--	30	150	500	50	150	
66	10	10	25	10	30	150	300	70	200	
67	--	70	110	10	30	200	300	50	100	
68	10	30	50	15	30	150	300	70	200	
69	10	50	60	15	30	150	300	70	200	

[1] Sample 42 contained 7 ppm of silver and 0.10 ppm of gold.

Sample 43 contained 0.08 ppm of gold, and others had less than 0.05 ppm.

Table 3.--Name and location of explorations in Keweenawan rocks of Wisconsin

Name of exploration	Location			
	Township North	Range West	Section	Quarters
Mudge	42	10	5	NE¼
				SE¼
Weyerhauser	43	10	12	NW¼SE¼
Test pits	44	5	6	NW¼NW¼
Test pits	44	6	2	NE¼NW¼
Montrose	44	9	12	NW¼NW¼
Test pits	44	9	15	NE¼SE¼
North Wisconsin or Chippewa	47	12	3	SW
			10	NW
Starkweather or Edwards or Wisconsin	47	13	2	NW¼NW¼
Fond du Lac	47	13	8	NE
Amnicon	47	13	11	NW
Copper Creek	47	14	14	SW
			15	SE
Culligan	47	14	29	SW
			30	SE
			31	NE
Percival	48	10	27	SW¼NE¼
Astor	48	10	28	NW
			29	NE
Catlin	48	13	34	SE

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