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LITHOLOGIC, GEOPHYSICAL, AND MINERAL COMMODITY MAPS OF PRECAMBRIAN ROCKS IN WISCONSIN

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INTRODUCTION

The purpose of this report is to present and explain a series of maps of the Precambrian rocks of Wisconsin that have been assembled to make more readily available a great amount of unpublished data on file at the Wisconsin Geological and Natural History Survey. The maps and report also contain pertinent summary information from published reports. The three principal maps of northern Wisconsin (sheets 1, 2, 3) show respectively: (1) lithologic data, (2) magnetic anomalies and Bouguer gravity anomalies, and (3) inferred areal geology of principal lithologic units. Map units shown on sheet 3 are explained on sheet 4. Sheet 5 shows combined lithologic, geologic, and geophysical information for the southern part of Wisconsin. The principal map features and their interpretation are discussed in the text.

A wide variety of valuable metallic and nonmetallic mineral deposits have been found in Precambrian rocks in various parts of the Canadian Shield, but iron ore and stone quarried for construction and industrial use have been the only known mineral deposits exploited in the Precambrian rocks of Wisconsin. A better knowledge of the kinds of Precambrian rocks present, their distribution, and their relationships, as discussed in this report, should be of aid in evaluating the mineral potential of the area underlain by these rocks and in searching for new mineral deposits.

Precambrian rocks in Wisconsin constitute the bedrock in most of the northern part of the State (fig. 1) and, except locally, are overlain by Paleozoic rocks in the southern part of the State. The Paleozoic strata are gently inclined east, south, or west toward adjacent States. The relations of bedrock and physiographic divisions are shown in figure 2. The slope of the Precambrian bedrock surface upon which the Paleozoic strata rest is shown in figure 3. Glacial deposits are widely distributed over the State (fig. 4), but Precambrian rocks are exposed at many places in the northern part because they either were not covered by drift or were uncovered by post-glacial erosion.

Results of geochronologic investigations of Precambrian rocks in and adjacent to Wisconsin have been published by Aldrich and others (1959, 1960, 1965), Goldich and others (1961, 1966), and Banks and Cain (1969). Table 1 summarizes information from these sources in addition to a small amount of unpublished data. This table is keyed to sheets 3 and 5 which show the numbered sample sites. Age determinations were by Rb-Sr and K-Ar in biotite, except as noted in the table.

Information about metamorphic zones is presented on sheet 6. Mineral localities are listed in table 2 and indicated on sheet 6.

LITHOLOGY OF PRECAMBRIAN ROCKS IN NORTHERN WISCONSIN

The lithologic map of northern Wisconsin (sheet 1) shows the location and general lithologic classification of outcrops and of material penetrated by drilling or digging; it also shows lines that join maximum positive or negative magnetic values obtained by dip-needle surveys. It presents a compilation of all available data concerning Precambrian rocks in northern Wisconsin which was used in preparation of the areal geology map (sheet 3).

Early reports that provide significant data on the Precambrian geology of Wisconsin are as follows: Irving (1877, 1880a, and 1880b), Pumpelly (1880), Strong (1880), Sweet (1880), Wright (1880), Irving and Van Hise (1882), King (1882), Strong and others (1882), Irving and Van Hise (1892), Irving (1883), Weidman (1907), and Van Hise and Leith (1911). More recent publications that contain information about regional geology are cited in the discussion that follows.

The principal sources of information for preparation of sheet 1 are the many field notebooks, collections of specimens and thin-sections, and file reports of the Wisconsin Geological and Natural History Survey. Most of this information was gathered when northern Wisconsin was examined between 1913 and 1930 as part of a mineral land classification survey. Additional unpublished information has been provided by geologists cited and by mineral exploration programs of Ashland Mining Co., Bear Creek Mining Co., Inland Steel Co., and Jones and Laughlin Steel Corporation. Data on many wells were obtained from the records of the Wisconsin Geological and Natural History Survey and the Wisconsin Department of Natural Resources.

During the mineral land classification survey most of the Precambrian area in the State, except the part northwest of Green Bay, was examined. The work was done by traverses at half-mile intervals made along north-south lines. Data that were recorded in field notebooks included (1) lines of traverse; (2) location, size, and lithologic classification of outcrops; (3) specimen number, if sampled; (4) classification of bedrock penetrated in wells; and (5) local magnetic values obtained by dip-needle survey. These data were compiled on township maps at a scale of 2 inches per mile (1:31,680), of which prints still are available.

Specimens related to this series of maps were examined in the present study to confirm or revise the earlier identifications, and annotated prints of township maps were prepared. The review of maps, notes, and specimens was supplemented by a moderate amount of field work to check on lithologic classifications and distribution of rock exposures. Supplementary information for some rocks has come from examination of selected thin sections, but no further petrographic study has been made.

Sheet 1 shows the predominant lithologic rock types, as determined megascopically in most cases, found in many outcrops, drill holes, and wells. This map was compiled on the 1:500,000 State of Wisconsin base map with the aid of a plotting grid to assure as approximate location as scale permitted, and the positions of most symbols differ not more than their own dimensions from the location shown on the township maps or reported in other sources. Also because of limitations of space relative to size and number of symbols, locations of some symbols are approximate. All data could not be shown, and where choice was necessary, the symbol for the principal rock type was selected. Samples or information of doubtful location were omitted.

The reliability of the lithologic map is dependent upon the selection of representative rock specimens during the mineral land survey. In most cases the specimens and notebook information give a good idea of the principal rock type of a general locality, but detailed differences in classification versus exposed rocks are likely to be very common, and some disagreements in classification are to be expected.

The lines of magnetic anomaly from dip-needle surveys were transferred from the township maps.

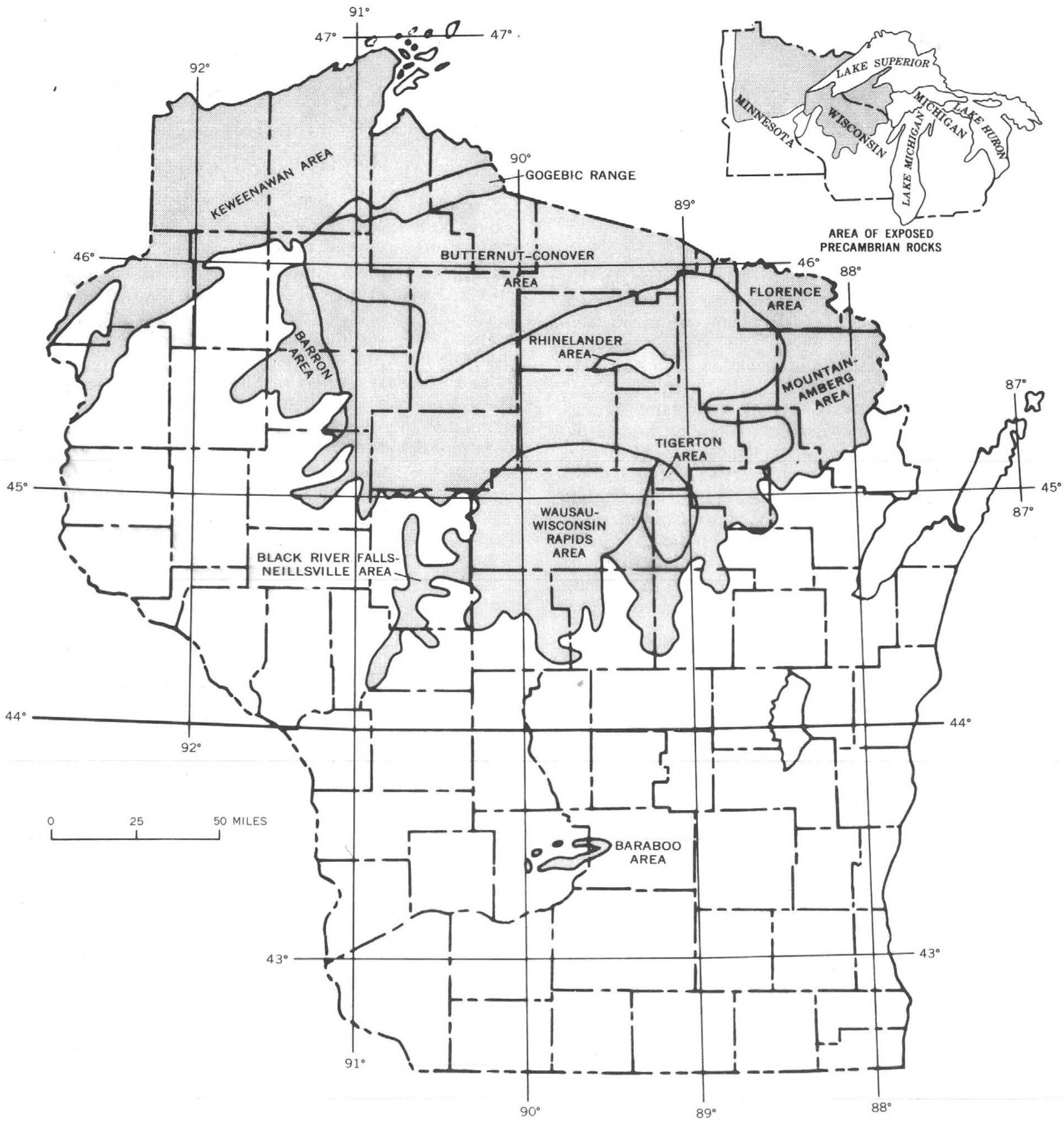

FIGURE 1.—Principal areas (shaded) of exposed Precambrian rocks in Wisconsin. Unshaded areas are underlain mainly by Paleozoic rocks.

AEROMAGNETIC AND GRAVITY DATA OF NORTHERN WISCONSIN

The aeromagnetic map (sheet 2) was prepared from maps compiled by Patenaude (1964, 1966) at a scale of approximately 9 miles per inch and a contour interval of 400 gammas. The data are based on flights at barometric altitude of 3,000 feet above sea level, in north and south directions at east-west intervals of 6 miles, coinciding with the range lines of the land subdivision system. More closely spaced flights were made in a few small areas of special interest. Absolute magnetic values were measured by a proton precession magnetometer at intervals of about 1,000 feet along the flight lines. All observed values were decreased four gammas per mile northward for the regional gradient, and the average value of 59,200 gammas was chosen as datum for the State. Contours shown on Patenaude's maps are based on the differences of the adjusted values to the datum and indicate the configuration and magnitude of anomalous features as shown on the aeromagnetic map. The present aeromagnetic map (sheet 2) differs from the one prepared by Patenaude in that intermediate contour intervals (at 100 or 200 gammas and –100 gammas) have been added by interpolation from his data along the flight lines.

Where identity of Precambrian rocks is known, the general aeromagnetic pattern has a rather well defined relation to the lithologic data presented on sheet 1 and will be considered in the discussion of areal geology.

The gravity pattern shown on sheet 2, which is similar to part of that shown on the map prepared by the American Geophysical Union and the U.S. Geological Survey (1964).

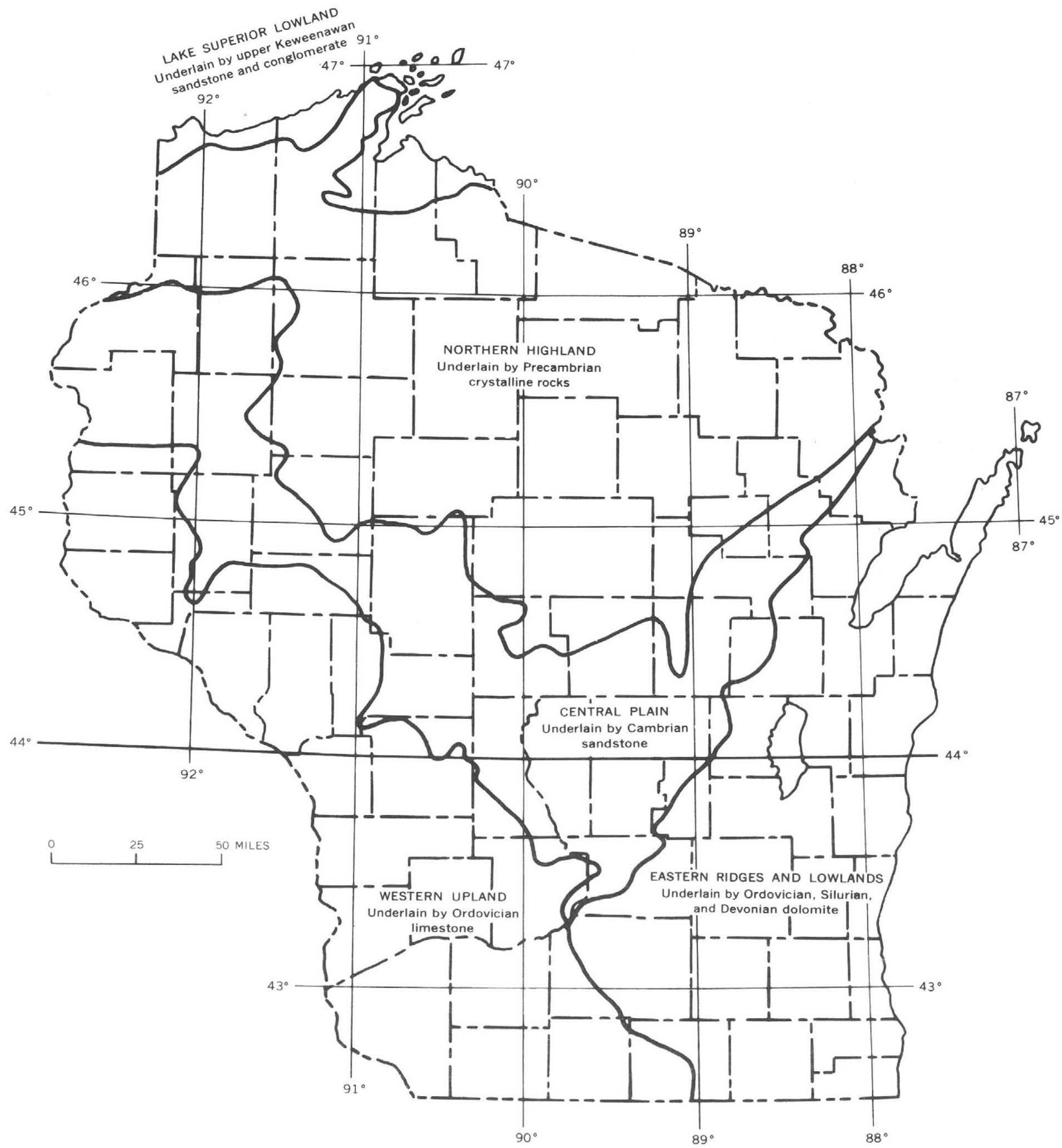

FIGURE 2.—Physiographic divisions of Wisconsin and their relations to bedrock. Modified from Martin, 1932.

has been compiled from Thiel (1956), Mack (1957), Coons (1966), and unpublished data by R. J. Wold and N. A. Ostenso. It is based on Bouguer anomalies at about 850 stations that were relatively evenly dispersed over the whole area. In addition, several detailed traverses were made in the northwestern part of the State. The expected value of the Bouguer anomaly for the State is about −40 milligals. Departures from this value are presumed to be related to geological phenomena whether our present geological knowledge allows a correlation or not, as considered in the discussion of areal geology.

AREAL GEOLOGY OF PRECAMBRIAN ROCKS IN NORTHERN WISCONSIN

The areal geology shown on sheet 3 is an interpretation of the probable distribution of the dominant lithologic units in northern Wisconsin as inferred from lithologic data and dipneedle magnetic data (sheet 1) and aeromagnetic and gravity surveys (sheet 2). All contacts are inferred because they are generally obscured by glacial or alluvial deposits. No attempt was made to plot intricate configurations of contacts and as a consequence limits of lithologic units in areas of closely spaced data may deviate from locations indicated by symbols.

The areal geology shown on sheet 3 is similar in many respects to that shown on a map by Leith, Lund, and Leith (1935). The maps are based mainly on the same sources of information, but more geologic data were used for the present interpretation and greater detail of geology is apparent at places.

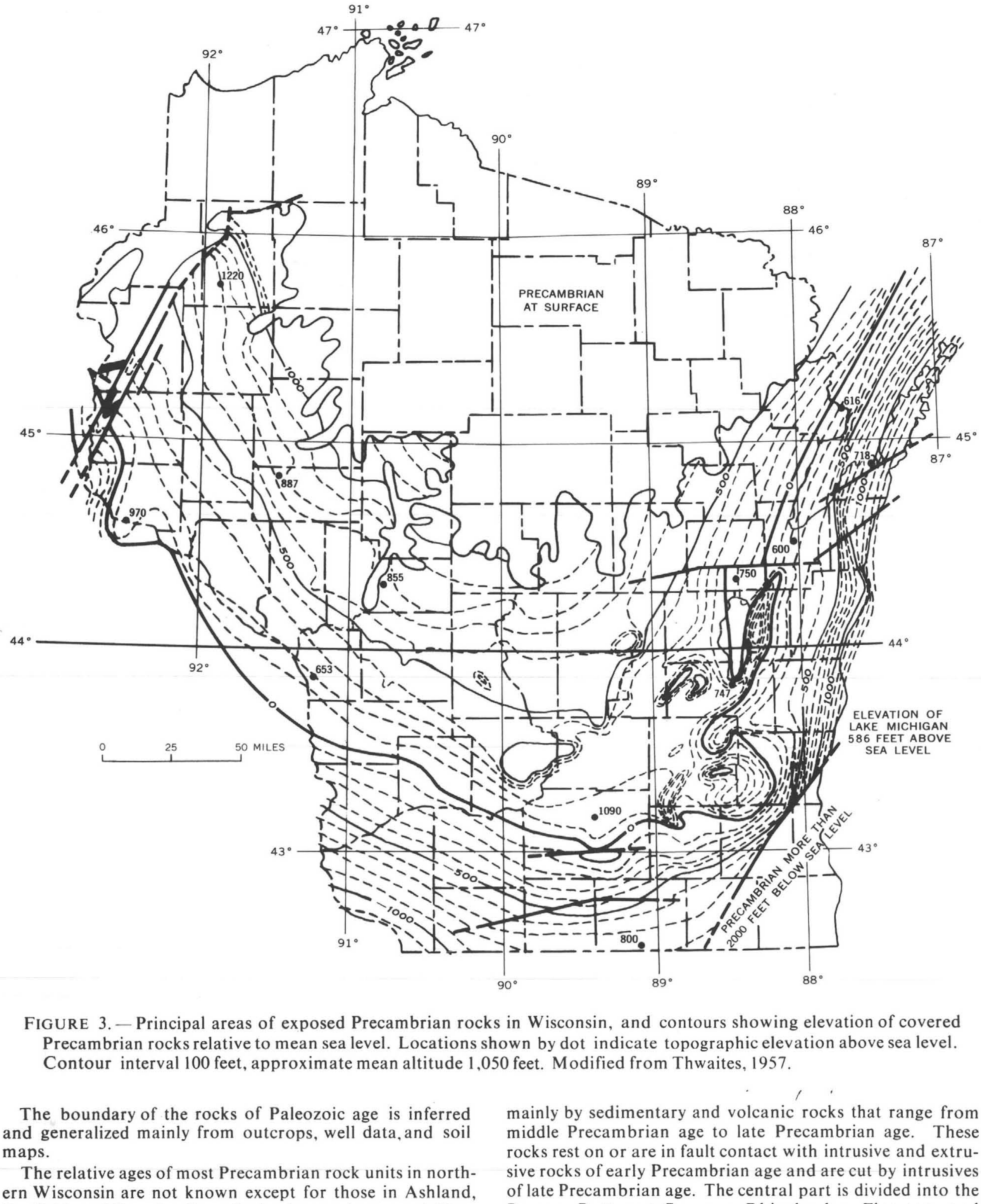

FIGURE 3.—Principal areas of exposed Precambrian rocks in Wisconsin, and contours showing elevation of covered Precambrian rocks relative to mean sea level. Locations shown by dot indicate topographic elevation above sea level. Contour interval 100 feet, approximate mean altitude 1,050 feet. Modified from Thwaites, 1957.

The boundary of the rocks of Paleozoic age is inferred and generalized mainly from outcrops, well data, and soil maps.

The relative ages of most Precambrian rock units in northern Wisconsin are not known except for those in Ashland, Bayfield, and Douglas Counties in the northwest and Florence and Marinette Counties in the northeast (sheets 3; 4, part B). The youngest known Precambrian rocks are sedimentary rocks of late Keweenawan age which are underlain by lavas and interbedded sedimentary rocks of middle Keweenewan age. The geologic age of part of the other Precambrian rock units (sheets 3; 4, part A) is not known.

For purposes of discussion, the geology shown on sheet 3 consists of three parts. The northern part, divided into the Keweenawan area and Gogebic Range (fig. 1), is underlain mainly by sedimentary and volcanic rocks that range from middle Precambrian age to late Precambrian age. These rocks rest on or are in fault contact with intrusive and extrusive rocks of early Precambrian age and are cut by intrusives of late Precambrian age. The central part is divided into the Barron, Butternut-Conover, Rhinelander, Florence, and Mountain-Amberg areas (fig. 1). It contains metasedimentary rocks and granite, mostly of probable middle Precambrian age, some quartzite that may be of late Precambrian age, and greenstone chiefly of early Precambrian age but some of which may be of middle Precambrian age. The southern part contains the Black River Falls-Neillsville, Wausau-Wisconsin Rapids, and Tigerton areas (fig. 1), as well as one large and one small area not named or described because of the sparse geologic data available. Rocks

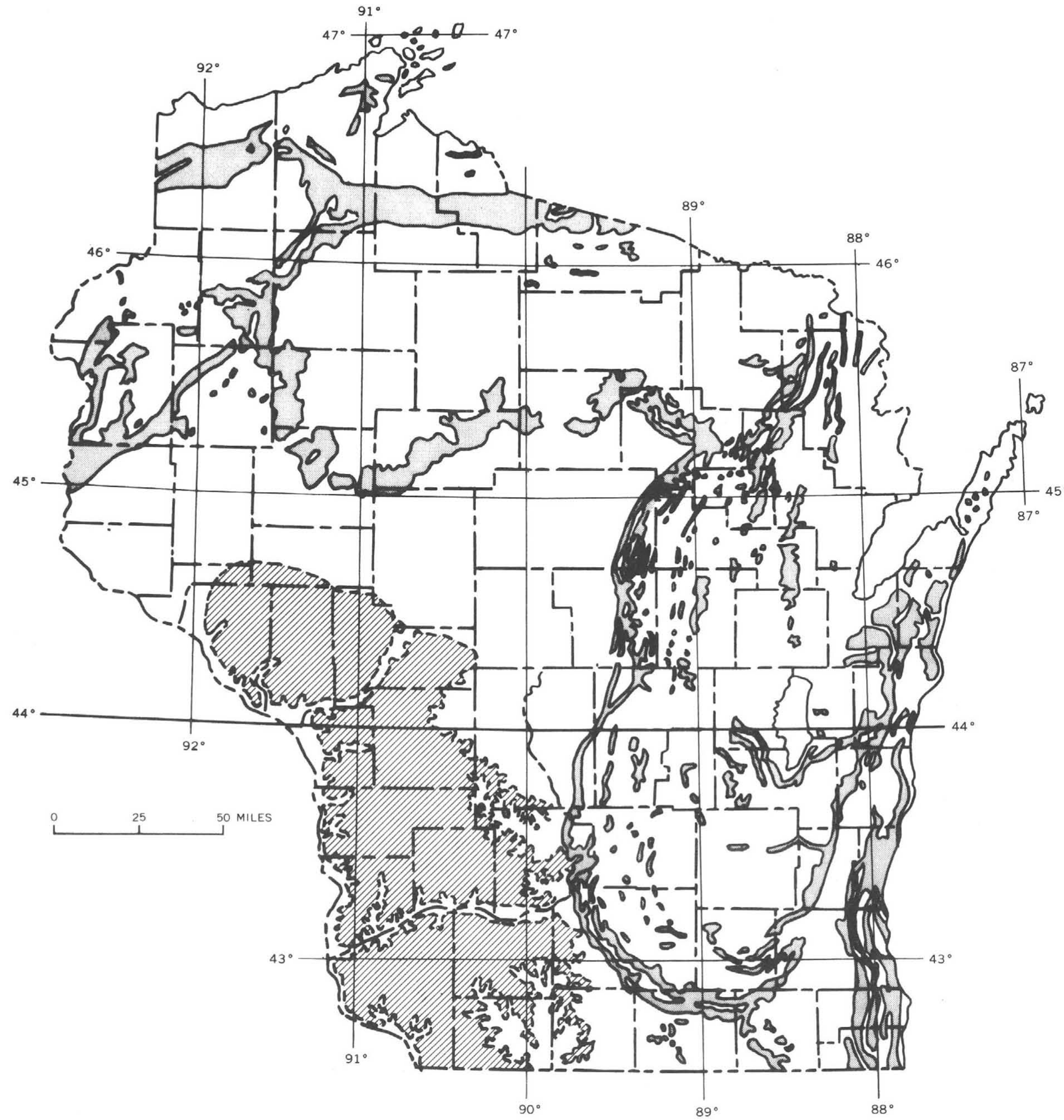

FIGURE 4.—Location of end moraines (stippled) and the Driftless Area (lines) in Wisconsin. Unpatterned areas are covered by ground moraine, outwash, and glacial lake deposits. Modified from Thwaites, 1964.

in the named areas are mainly a complex of extrusive and intrusive rocks with metasedimentary rocks present locally. Most of the rocks are probably of middle Precambrian age. Two granite units have been determined to be 1,430 and 1,600 million years old (sheet 3 and table 1), but relative ages of nearby rocks are not known.

South of the Tigerton area, small inliers of granite within the area of Paleozoic rocks are at Mukwa, Marion, and Spring Lake.

KEWEENAWAN AREA

The Keweenawan area in northwestern Wisconsin is widely underlain by thick sequences of sedimentary rocks and older volcanic rocks that extend eastward into the northern peninsula of Michigan; these rocks are also in northeast Minnesota adjacent to Lake Superior. The upper part of the sedimentary unit is 4,300 feet thick (Ostrom, 1967) and consists of sandstone that is probably of late Precambrian age (sheet 4). The lower part consists of interbedded sandstone, shale, and conglomerate of probable late Precambrian age, having an aggregate thickness of about 17,500 feet in Wisconsin. The volcanic sequence is more than 20,000 feet thick in Wisconsin and is of middle Keweenawan age. It consists mainly of massive basalt and andesite flows that may have vesicular, amygdaloidal, or brecciated upper zones. Interflow conglomerates are present locally. The geology and copper deposits of the Keweenawan rocks in the Lake Superior region are discussed by Irving (1883), Butler and others (1929), and White and Wright (1954). Grant (1901) and Van Hise and Leith (1911) discuss general geology, and Grant the copper deposits, of Keweenawan rocks in Wisconsin. Thwaites (1912) and Hite (1968) describe the upper sedimentary unit.

TABLE 1.—Geochronologic data of Precambrian rocks, Wisconsin

No.	Location		Geologic data	Age in million years		
	Town or other location	Sec. T.-R.		Biotite		Other
				Rb-Sr	K-Ar	
1	Mellen	24-45N-3W	Granite porphyry	....	990	....
2	Aurora	38N-19E	Granite	....	1160	....
3	Hogarty	4-29N-10E	Pegmatite in granite	1200	...	....
4	Wausau	10-29N-6E	Pegmatite in syenite	1230	...	....
5	Mountain	31N-16E	Rhyolite porphyry	....	...	1300[1]
6	Stevens Point	31-24N-8E	Gneiss and schist	1320	...	....
7	Aurora	11-38N-18E	Quinnesec Formation	1350	1340	....
8	Prairie R. Dells	14-32N-7E	Gray granite	1370	...	....
9	Marion	18N-11E	Coarse schist in granite	1390	...	....
10	Rib River	31-30N-5E	"Hamburg slate" (Weidman)	1390	...	....
11	Waterloo	9N-13E	Muscovite in granite	....	...	1410[2]
12	Big Falls	26-25N-12E	Granite	1420	...	....
13	Lohrville	18-18N-12E	Granite	1420	...	....
14	Praire R. Dells	14-32N-7E	Mafic dike in granite	1420	...	....
15	Stevens Point	18-24N-8E	Granite	....	...	1430[3]
16	Waterloo	9N-13E	Pegmatite in quartzite	....	...	1440[4]
17	Waupaca	29-22N-12E	Rapikivi granite	1440	1430	....
18	Marion	18N-11E	Granite	1440	...	....
19	Mosinee Hills	22-28N-7E	Microgranite	....	...	1450±10[3]
20	Plover River	9-23N-8E	Granite	1460	...	....
21	Utley	36-15N-13E	Rhyolite porphyry	....	...	1490[3]
22	Marion	18N-11E	Inclusion in granite from locality no. 18	1520	...	....
23	Wausau	23-29N-6E	Moonstone pegmatite	1530	...	....
24	Wausau	22-29N-6E	Biotite-rich gneiss	1530	...	....
25	Plover	8-23N-8E	Gneiss and schist	1540	...	....
26	Neillsville	14-24N-2W	Gneiss and schist	1570	...	....
27	Athens	5-29N-4E	"Hamburg slate" (Weidman)	1250	...	1600[4]
28	Wausau	34-30N-8E	Red granite	....	...	1600[3]
29	Baraboo	21 and 22 12N-7E	Rhyolite under quartzite	....	...	1600[3]
30	Black River Falls	15-21N-4W	Gneiss and schist	1610	...	....
31	Port Edwards	36-22N-5E	Gneiss and schist	1620	...	....
32	Nekoosa	3-21N-5E	Gneiss and schist	1640	...	....
33	Monico	21-36N-11E	Rhyolite	....	...	1640[3]
34	Wausau	19-29N-8E	Rhyolite	....	...	1640[3]
35	Mosinee	4-26N-7E	Rhyolite	....	...	1640[3]
36	Butternut	29-41N-1W	Granite cuts iron-formation	....	...	1660
37	Niagara	18-38N-20E	Hoskin Lake Granite	1360± 10	1230	1350[2] 1500[4] 1520± 300[1] 1720[5]
38	Powell	25-42N-3E	Kyanite-mica schist	....	1720	....
39	Trapp River	18-30N-8E	Highly altered slate(?)	1720	...	....
40	Merrill	18-31N-7E	"Hamburg slate" (Weidman)	1510	...	1800[4]
41	Amberg	5-36N-20E	Newingham granodiorite and Amberg Granite 30-33N-20E.	....	...	1860±15[6]
42	Aurora	19-38N-20E	Marinette Quartz Diorite	1350	1370	1870[5]
43	Dunbar	13-37N-18E	Dunbar Gneiss	....	...	1880±15[6]
44	Fisher Lake	34-38N-19E	Hoskin Lake Granite	....	...	1890±15[6]
45	Conant Rapids	8-23N-8E	Gneiss and schist	1900	...	....
46	Mill Creek	15-23N-7E	Gneiss and schist	1940	...	....

[1] Rb-Sr in feldspar
[2] K-Ar in muscovite
[3] Rb-Sr in whole rock
[4] Rb-Sr in muscovite
[5] Pb 207/Pb 206
[6] U-Pb in zircons

Data references, by sample location:

Aldrich, L. T., and others, 1959, samples 3, 4, 6, 8, 9, 10, 12, 13, 14, 16, 17 (1440 m.y.), 18, 20, 22, 23, 24, 25, 26, 27, 30, 31, 32, 39, 40, 45, 46.

______1960, samples 7, 37 (all data except 1720 m.y.), 42 (1350-1370 m.y.).

______1965, samples 37 (1720 m.y.), 42 (1870 m.y.).

Banks, P. O., and Cain, J. A., 1969, samples 41, 43, 44.

Dott, R. H., Jr., 1968, written commun., sample 29.

Goldich, S.S., and others, 1961, samples 1, 17 (1430 m.y.), 36, 38.

______1966, samples 2, 5, 11, 21.

Peterman, Z. E., 1967, written commun., samples 15, 19, 28, 33, 34, 35.

The major structure in the Keweenawan area is the northeasterly plunging Ashland syncline of White (1966a), or part of the Lake Superior syncline as shown on the tectonic map of the United States (U.S. Geological Survey and American Association Petroleum Geologists, 1962). The location of the syncline is shown on sheet 3. In accordance with prevalent published interpretations, the Douglas fault and cross faults are in the north limb of the syncline and the Lake Owen fault is in the south limb. The continuation of the Douglas fault eastward through the upper Keweenawan strata to Ashland, as proposed by Thwaites (1935), is believed to be refuted by gravity data (Thiel, 1956) and by aeromagnetic data (Patenaude, 1966). Nevertheless, the eastward extension of the Douglas fault south of Ashland is shown by White (1966a, 1966b) and is "speculatively projected northeast" (White, 1966b, p. 36) on the basis of gravity data, a seismic profile, and symmetry of regional geologic features. H. A. Hubbard (oral commun., 1968) believes that these two supposed faults are unconformities.

The northern half of the southeastern limb of the syncline is generally in contact with intrusive rocks of early Precambrian age, which are mainly south of the Gogebic Range. The southern half of the synclinal limb is overlain unconformably by strata of Cambrian age.

The magnetic pattern in the Keweenawan area parallels the northeasterly trend of the bedrock structure and is somewhat similarly divided into three units based on differences of magnetic intensity, namely, high magnetic intensity over the south limb, intermediate intensity over the non-magnetic sedimentary rocks, and low intensity over the north limb. An aeromagnetic map by Kirby and Petty (1966) which includes much of northwestern Wisconsin shows similar configurations of magnetic intensity.

A pronounced gravity high in the Keweenawan area is caused by density contrasts of the mafic extrusive and intrusive rocks of late Keweenawan age (Thiel, 1956, p. 1088) adjacent to sedimentary rocks of early Paleozoic and possibly late Keweenawan ages and granite of Precambrian age. A less extensive and less prominent magnetic high in the Keweenawan area also is related to these geologic conditions. Sharp decreases of as much as 70 milligals and 1,000 gammas in Wisconsin and Minnesota at the east and west margins of the high are believed to indicate the edges of a raised block (Thiel, 1956; Craddock, Thiel, and Gross, 1963; and Sims and Zietz, 1966).

The prominent gravity low north of the eastern projection of the Douglas fault results from a thick sequence of upper Keweenawan sedimentary rock (Thiel, 1956, p. 1088) on a buried ridge of pre-Keweenawan rock north of the axis of the Ashland syncline (White, 1966a, p. 19).

Copper deposits.—The rocks in the Keweenawan area of Wisconsin contain native copper and copper sulphides at many places (sheets 1 and 6 and table 2), but the geologic controls of these occurrences and their economic potential are not adequately known. In Michigan, where occurrences are presumed to be similar, the deposits of economically minable copper are mostly metallic copper in lava and conglomerate and sulphides in siltstone.

In the Michigan deposits metallic copper has filled openings (vesicular or brecciated tops, and fissures) in lava flows or the interstices in the conglomerates. The exploitable ore that formed has averaged about 1 percent copper, and the total production from 1845 to 1965 was 5,200,000 tons of metallic copper.

Exploration for metallic copper has been undertaken in Wisconsin but no commercial deposits have been found. Nevertheless, the potentialities of Wisconsin have not yet been fully appraised. Description of the general geology, copper occurrences, and features at nine areas of exploration in Douglas County are given by Grant (1901). Maps and reports by township units for most areas underlain by the lava sequence are in the files of the Wisconsin Geological Survey, but no published report is available concerning the geology and copper occurrences in areas in Wisconsin other than Douglas County. The known occurrences of copper are shown on sheets 1 and 6 and have an interesting pattern of general distribution and also of sulphide versus metallic predominance for which no explanations are known.

The Nonesuch Shale, of late Precambrian age, contains important copper deposits in Michigan (White and Wright, 1954) but little or no copper in Wisconsin. An extensive area in Michigan is underlain by two mineralized siltstone layers 14½ and 7½ feet thick, separated by 4½ feet of sandstone that is mineralized only locally. Ores from these layers contain from 1 to 3 percent of copper, mainly as disseminated very fine grained chalcocite (Cu_2S), but the overall grade of mined ore is about 1 percent. The total amount of copper metal produced from the beginning of mining in 1954 to 1965 was 500,000 tons. Extended exploration for this type of copper deposit in Wisconsin revealed that the Nonesuch Shale was absent in part of the area or where present had insufficient copper to be considered mineralized.

Holliday (1955) discusses a copper-nickel prospect in Douglas County. Favorable results of work in 1901 had been reported but these were not corroborated by examination in 1953. Smith (1947) describes a copper prospect.

Quarries.—Basalt is quarried at Dresser Junction in Polk County and processed for use as construction aggregate and railroad ballast.

GOGEBIC RANGE

The Gogebic Range is in the northwestern part of Wisconsin south of the Keweenawan area. The sequence of middle Precambrian rocks in this area (sheet 4) includes the Ironwood Iron-Formation which is 650 feet thick. The Ironwood is underlain by a sequence of fine- to medium-grained clastic rocks about 450 to 550 feet thick and overlain by a similar sequence of clastic rocks 10,000 feet thick. These rocks strike northeasterly and dip steeply northwest toward the axis of the Ashland Syncline. They are displaced by longitudinal and cross faults, rest unconformably on metabasalt and granite of early Precambrian age, and are cut by intrusives of late Precambrian age.

Outcrops are moderately abundant and much subsurface information is available due to extensive exploratory drilling for and mining of iron ore.

The general geology and iron-ore deposits of the Gogebic Range are described by Van Hise and Leith (1911), Aldrich (1929), and Hanson, 1967.

The aeromagnetic map (sheet 2) shows a close correlation of a pronounced linear positive magnetic anomaly with the known distribution of the Ironwood Iron-Formation in the Gogebic area. The relation of the remainder of the aeromagnetic pattern to geology is obscure. The relatively high gravity values present in this area appear to be the effect of Keweenawan mafic rocks north of the iron-formation.

Iron ore.—The Gogebic Range, or iron-bearing district, extends northeastward into Michigan, and iron ore was produced in both States until 1965. Total production in the district was 295,000,000 tons of ore, of which 71,000,000 tons were produced in Wisconsin.

The ore is in the Ironwood Iron-Formation, which is of Lake Superior type in that it is composed of interbedded iron-rich layers and silica-rich layers. Average grade is about 30 to 35 percent iron. The iron-rich layers consist mainly of siderite, hematite, and magnetite, in various amounts, and lesser amounts of chert and fine-grained silicate minerals. The silica-rich layers contain the same minerals, but the proportion of iron-rich minerals to chert and silicate minerals is reversed. The Ironwood Iron-Formation is divided into five members based on the relative abundance of thin evenly bedded chert layers versus thick irregularly bedded chert layers. Most ore bodies were in the members of the latter

TABLE 2.—Occurrences of mineral commodities exclusive of quarries.

Location number (refer to sheet 6) name of commodity	Township North	Range	Sections
1. Asbestos	36	21 E	24
2. Cerium	29	6 E	22
3. Chromite	37	21 E	21
2. Columbium	29	6 E	22
4. Copper	33	6 W	16
5. do	24	7 E	8
6. do	29	8 E	35
7. do	30	6 E	33
8. do	36	11 E	20
9. do	38	19 E	19
do	33	18 W	6, 16
do	33	19 W	11, 14
do	35	18 W	2, 4, 8, 9, 16
do	36	17 W	19
do	36	18 W	10, 21, 28, 33
do	37	16 W	7, 9, 10, 15, 18, 21, 23, 29, 35
do	37	17 W	13, 31
do	37	18 W	25
do	39	19 W	9
do	42	10 W	2, 4, 5, 18
do	42	11 W	13, 22, 28, 33
do	42	15 W	9
do	43	8 W	2, 4, 14, 18, 19
do	43	9 W	4, 5
do	43	10 W	1, 12, 14, 22, 28, 33
do	43	13 W	6
do	43	14 W	2, 6, 9, 23
do	44	5 W	6
do	44	6 W	1, 2, 11
do	44	7 W	4, 15, 20, 29
do	44	8 W	26, 29
do	44	9 W	15, 23
do	44	13 W	11, 14, 15, 21, 22, 23, 27, 28, 31
do	44	15 W	32, 33
do	46	2 E	9, 17
do	46	15 W	11
do	47	11 W	6
do	47	12 W	3, 6
do	47	13 W	1, 2, 8, 10, 11, 16, 17
do	47	14 W	14, 15, 21, 28, 31
do	48	10 W	21, 27, 29, 30
do	48	12 W	28, 29, 31, 32
do	48	13 W	36
10. Gold	26	7 E	8
11. do	27	7 E	32
12. do	27	8 E	13
13. Gold	28	7 E	24
14. do	36	20 E	8, 17
15. do	36	21 E	16
16. Graphite	25	6 E	34
Iron	21	3 W	4, 15, 17, 18, 19, 20, 25, 26
do	21	4 W	1, 11, 12
do	22	3 W	31, 32
do	24	2 W	22
do	40	17 E	25, 35
do	40	18 E	20, 21, 27, 31, 32, 33, 34
do	41	1 W	21, 28, 29
do	41	1 E	2, 4
do	42	1 E	22, 23, 24, 29
do	44	3 E	23, 26, 27, 28
do	44	1 W	6
do	44	2 W	1, 2, 8, 9, 10, 17 18
do	44	3 W	9, 13, 14, 15, 16, 17, 18, 19
do	44	4 W	13, 14, 19, 20, 21, 22, 28, 29, 30
do	44	5 W	23, 24, 25
do	44	6 W	24, 25, 26, 27
do	45	1 W	25, 26, 27, 32, 33, 34
do	45	1 E	1, 10, 11, 12, 15 16, 19, 20
do	45	2 E	6
do	46	2 E	24, 25,26, 27, 32, 33
3. Magnesite	37	21 E	21
17. Molybdenite	33	20 E	18
18. do	38	19 E	33
19. Nickel	38	19 E	30
Pegmatite	Many local occurences		
20. Pyrrhotite	31	16 E	11, 12, 13
21. do	31	17 E	6, 18
22. do	36	11 E	30
9, 19. do	38	19 E	19, 30
23. do	38	20 E	7
24. do	39	18 E	27
25. Pyrite	29	7 E	24
26. do	34	8 W	9
13. Silver	28	7 E	24
4. do	33	6 W	16
14. do	36	20 E	8, 17
15. do	36	21 E	16
27. do	43	7 W	20
28. do	44	6 W	2, 11
29. Talc	25	5 E	10, 11, 15
30. do	25	6 E	7
31. Zircon	29	6 E	15, 22, 23

type. Lithologic and structural features that controlled the direction and amount of leaching or replacement of chert determined the location and size of ore bodies.

The iron-formation in the eastern part of the Gogebic district in Wisconsin is not highly magnetic, and bodies of high-grade direct shipping ore were formed where silica had locally been much leached or replaced. Mining in the Gogebic area ceased because the proportion of very fine hematite particles in the direct-shipping ore made it difficult to handle and use in competition with direct-shipping ore from other areas. No successful methods of beneficiation or concentration have been developed for these ores.

The rocks in the western part of the Gogebic district in Wisconsin have been metamorphosed, and the grain size of the iron-bearing and silica-bearing minerals has been so enlarged that concentration by magnetic methods is possible. Studies are being made as to commercial feasibility of concentrating ores from this area.

Quarries.—Gabbro is quarried near Mellen for dimension stone that is commercially designated "Black granite."

The Bad River Dolomite, a dolomitic marble, is quarried southeast of Grandview and used to make terrazo chips.

BUTTERNUT-CONOVER AREA

The bedrock of the Butternut-Conover area (fig. 1) is inferred to be mainly northeasterly-trending metasedimentary rocks and greenstone (metabasalt) separated by granite (sheet 3). However, sparse outcrops, limited to a small part of the area (sheet 1), are metabasalt, garnet-kyanite-biotite schist, and granite. The eastern part of the area is possibly at the center of the Watersmeet node of regional metamorphism (sheet 6), described by James (1955).

Records of exploratory drilling for possible iron ore where magnetic surveying had indicated interesting anomalies (sheets 1 and 2) have been very helpful in the interpretation of the geology. The rocks most commonly penetrated in drill holes were several varieties of schist and a few associated occurrences of iron-formation. Locally metadiabase or metadiorite intrusives in the metasedimentary rocks were penetrated. Some small intrusive occurrences of granite were intersected , and some holes were reported to have been in granite only. Allen and Barrett (1915) discuss the geology in five exploratory areas referred to as Marenisco range, Turtle range, Manitowish range, Vieux Desert district, and Conover district. The stratigraphy and structure of the schists and iron-formations have not been determined. Relative ages of the metasedimentary rocks and metabasalt are not known. Ages of kyanite-biotite schist (1.72 b.y.) and of a granite (1.66 b.y.) have been reported by Goldich and others (1961, p. 105).

King (1882), Allen and Barrett (1915), and Hotchkiss and others (1915, 1929) present geologic data and interpretations concerning other parts of the Butternut-Conover area.

Magnetic anomalies in the Butternut-Conover area trend northeasterly in the northwestern part of the area where they are generally related to iron-formation, but locally may be related to magnetite-bearing mafic igneous rocks. Anomalies in the southeastern part of the area are generally of lower amplitude and trend easterly; geologic information is sparse, but no anomalies related to lean iron-formation are known.

Iron-formation is not exposed in this area, but was discovered at four places by explorations based on dip-needle surveys (sheet 1). Test pits dug before 1911 penetrated iron-formation in T. 41 N., R. 1 E. (Ford and Lucas-Whiteside explorations) and T. 42 N., R. 1 E. (Broomhandle and Michigan mine explorations), but ore-grade material was not found. During two later periods, exploratory drilling was done in these areas and in parts of an adjoining area 4 miles wide (T. 41 N. to T. 44 N.) and 14 miles long (R. 1 W. to R. 13 E.). Explorations from 1911 to 1914, when 48 drill holes were put down, are described by Allen and Barrett (1915). All holes but one were vertical; they passed through overburden ranging from 25 to 235 feet in thickness and penetrated bedrock to depths ranging from 6 to 160 feet. Three holes penetrated magnetic iron-formation for 9 to 26 feet; three other holes were in ferruginous slate for 40 to 90 feet; one hole passed through 20 feet of carbonate (sideritic) slate; and one hole was in oxidized iron-formation for 50 feet.

Exploratory drilling from 1955 to 1966 was based on magnetometer surveys, and the records of about 90 inclined drill holes in T.41 N., R.1 W.,T.41–42 N., R.1 E., and T.44 N., R. 3 E., were made available to the writers. Thickness of overburden commonly ranges from 20 to 40 feet but was 180 feet thick in one area. Bedrock was explored to depths ranging from about 300 to 600 feet. The approximate width of the iron-formation area cut by drills ranged from 40 to more than 8,000 feet and averaged from 550 to 2,300 feet, whereas the length of the area explored was from 5,800 to 12,000 feet.

These explorations were made to appraise the quality and quantity of ore suitable for concentration into a marketable product. Magnetite was found to be the principal iron-bearing mineral at each area of exploration, but considerable hematite and siderite occur at Pine Lake (T. 44 N., R. 3 E.), hematite at Butternut (T. 41 N., R. 1 W.) and the Michigan mine, and grunerite at Ford and Lucas-Whiteside. Chert is a common material in all the areas except the Lucas-Whiteside area. Magnetic iron in magnetitic iron-formations ranges from about 10 to 30 percent. Pits to obtain lean iron-formation for laboratory tests were excavated at the Butternut and Michigan mine areas. The present status of interest in development of any of the explored areas is not known.

The most common rocks associated with the iron-formations are schists that are composed chiefly of one or more of the micaceous minerals biotite, sericite, and chlorite; chlorite schists at Pine Lake have interbedded lenses of calcite or marble. Phyllite, black slate, quartzite, and greenstone elsewhere are present locally. Iron-formation at Butternut is cut by granite and that at Michigan mine and Pine Lake by diabase.

In the Butternut area and in the Agenda area (T. 41 N., R. 1 E.) the similarity of formations to the north and south of the iron-formation and the limited extent of the magnetic anomalies suggest possible synclinal structure. However, the iron-formation masses also could be lenses, fault segments, or locally magnetic parts of a more extensive lithologic unit.

Exploration in other parts of the Butternut-Conover area, as shown on sheet 1, found no iron-formation. Magnetic anomalies in these areas presumably are related to the reported occurrences of magnetic diabase, magnetic serpentine, and magnetic hornblende schist. The associated rocks are reported to be mainly granite and hornblende schist.

RHINELANDER AREA

The Rhinelander area (sheet 1) is characterized by much greenstone with associated diorite, sulphide-bearing rhyolite (for location see sheet 6, no. 8 and 22) and possibly considerable granite.

Prominent magnetic anomalies near Rhinelander are west of the main area of outcrops and are probably related to diorite or greenstone bodies.

FLORENCE AREA

The Florence area is part of the Menominee iron-bearing district, of which other parts are to the east and the northwest in Michigan.

The geology of this area is shown by Dutton and Linebaugh (1967) and is described mainly by Dutton (in press), also in part by Bayley and others (1966), and Lyons (1947).

The characteristic bedrock in most of this area is a thick middle Precambrian sequence of northwest-trending metasedimentary rocks and interbedded basalt (sheets 3; 4, part A) that has been folded and faulted. The southernmost part of the area is underlain by metarhyolite and metabasalt of early Precambrian age, and the latter has been intruded by metagabbro and granite of middle Precambrian age. Metamorphism of the rocks ranges from chlorite to garnet grade (James, 1955).

The aeromagnetic data indicate relatively high intensity related to mafic rocks and magnetite-bearing quartz pebble conglomerate in the southwestern part of the Florence area and to local iron-formation in the northern end of that area. Data by Patenaude (1964) for the northeastern part of this area are not detailed enough to allow correlation with the complex geology. Additional data on aeromagnetics (King, Henderson, and Vargo, 1966) and geology (Dutton, in press) give a better insight to the relation of geology and the pattern of magnetic anomalies.

A few mineralized occurrences have been reported in the area, the locations of which are shown on sheet 6. The Riverton Iron-Formation, which is in the Paint River Group of middle Precambrian age, is about 500 feet thick. It was mined until 1932 for direct-shipping ore from several open pits and underground mines near the communities of Florence and nearby Commonwealth. A small mining operation again was active from 1953 to 1960. Thin layers of iron-formation in and just below basalt that is older than the Riverton also have been explored, but the possibility of finding direct-shipping ore or lean ore suitable for beneficiation does not appear favorable in these layers. Core from a drill hole in sec. 27, T. 39 N., R. 18 E., contains veinlets and disseminated grains of pyrrhotite in the Michigamme Slate. Mafic rocks in sec. 30, T. 38 N., R. 19 E., were explored for nickel by drilling, but the results are not known. Pyrrhotite with associated fluorite is present locally in granite in sec. 7, T. 38 N., R. 20 E.

Molybdenite-bearing quartz veins occur near Aurora in southeastern Florence County where they are associated with pegmatites in mica schist. A few specimens contained from 1.12 to 2.18 percent molybdenum. The deposits are described by Fisher (1957) and by Kirkemo and others (1965).

MOUNTAIN-AMBERG AREA

The Mountain-Amberg area is underlain mostly by a complex of felsic and mafic intrusive igneous rocks but also has associated extrusive igneous rocks. The most abundant intrusive rock is pink or gray granite; the extrusive rock is mainly metabasalt. Some mafic pyroclastic rocks and rhyolite are near Mountain. Quartzite is present in two localities.

The geology of parts of the area is shown or described by Banks and Cain (1969), Borst (1958), Cain (1961, 1963, 1964, and unpub. data), Cain and Beckman (1964), Cain and Rebello (unpub. data), Mancuso (1957, 1960), Read (1962), and Wadsworth (unpub. data).

The aeromagnetic pattern in the Mountain-Amberg area (sheet 2) has a reasonably good correlation of high magnetic intensity to areas of mafic rock and low intensity to areas of felsic rock. The cause of the northwesterly extension of the high magnetic anomalies in the southern part of the area is not known.

Monumental and dimension stone are quarried from several areas of granite and granodiorite near Amberg in the central part of Marinette County (Buckley, 1898; Hanson, 1967).

Roofing granules are made from greenstone (metabasalt) quarried about 7 miles east of Pembine (T. 37 N., R. 20 E.). The exposures of greenstone in this part of the area and elsewhere are shown on sheet 1, and the inferred areal extent of these rock units is indicated on sheet 3.

Molybdenite-bearing quartz veins in the central part of Marinette County (sheet 6) are described in Fisher (1957) and by Kirkemo and others (1965). The veins pinch and swell, have indefinite irregular contacts, and are not associated with pegmatites as they are near Aurora. Fisher reported that operations in 1939–1940 produced 6,094 pounds of concentrates that contained 47.82 percent molybdenum and 50 parts per million of rhenium.

Short fiber crysotile asbestos occurs locally along fractures in small knobs of serpentine in SE¼ sec. 24, T. 36 N., R. 21 E., 11 miles east of Pembine.

Small occurrences of talc-magnesite with minor magnetite and chromite and quartz-magnesite with minor chromite are in sec. 21, T. 37 N., R. 21 E. The magnesitic material is associated with a metabasalt that, in nearby localities, is intruded by granite.

Exploration in the NE¼SW¼ sec. 16, T. 36 N., R. 21 E., is reported to have yielded a sample that contained 12.39 ounces of silver and 0.61 ounce of gold per ton. Five other samples were from 0.01 to 0.1 ounce of silver per ton.

BARRON AREA

The Barron area is underlain mainly by the Barron Quartzite, which as shown on sheet 3, is areally between older Precambrian crystalline rocks to the east and younger Paleozoic rocks to the west. The contacts with these bordering rocks are inferred to be unconformities. The quartzite is presumed to be of Precambrian age.

According to Hotchkiss (1915, p. 35–45), the quartzite is predominantly fine-grained quartz cemented by silica. Quartzitic siltstone and argillite (R. G. Schmidt, written comm.) and "pipestone," which is kaolinitic in contrast to sericitic-pyrophylitic pipestone or catlinite in southwestern Minnesota, are present. The quartzite is well bedded but pronounced color banding is at an angle to the bedding in some places. Beds dip 5° to 12° westward. The formation is locally folded and faulted and generally is much fractured and jointed. It is probably about 600 feet thick.

In the Barron area, the magnetic pattern and the extensive area of quartzite exposures trend at right angles to each other and appear to be unrelated. The quartzite continues westward beneath the Paleozoic rocks as indicated by the three inliers (sheet 3) and the elliptical pattern of relatively low magnetic intensity (sheet 2) may be due to a thickness of quartzite that masks the effect of magnetic rocks under it.

Iron-formation older than the Barron Quartzite is indicated by pebbles in sparse thin basal conglomerates, especially in the SE¼ sec. 8, T. 36 N., R. 7 W. (Hotchkiss and others, 1915, p. 37, 211). The only occurrence of ferruginous material known in the vicinity is a very small area of ferruginous rock exposed in the SW¼ sec. 10, T. 34 N., R. 8 W. This area was explored by test pits prior to 1915 and is described by Hotchkiss (1915, p. 179–180). Specimens collected in 1913 were examined in the present study and classified as probably quartzite but some may be recrystallized chert. Hematite is the principal ferruginous mineral commonly occuring in massive, layered, or irregular finely crystalline material. Martite is present in some specimens and pyrite in others where it is scattered through a rock consisting chiefly of very fine quartz or very slightly foliated quartz and sericite.

A magnetic anomaly based on dip needle data trends northeasterly through T. 34 N., R. 8 W., about a half mile south of the explored area in section 10 mentioned above, and possibly may be related to unexposed and unoxidized ferruginous rock that is otherwise similar to the material in the explored area.

An elongate S-shaped aeromagnetic anomaly at the south end of the Barron area (sheet 2) locally has the same location in and direction across the township as a dip-needle anomaly. It extends northeasterly into the Butternut-Conover area and southwesterly into the area where Paleozoic strata form the bedrock surface. No geologic feature to which this anomaly might possibly be related is known.

Small amounts of malachite are in irregular fragments of slightly foliated and probably brecciated rock composed of sericite and quartz that came from the bottom of a 30-foot well in the SE¼ sec. 16, T. 33 N., R. 6 W. The reported assays indicated 0.75 percent copper in one sample but none in the other; each sample contained one ounce of silver per ton. Malachite, in association with small quartz veins in schistose greenstone, occurs in the SE¼ sec. 35, T. 36 N., R. 8 W.

The rock exposed in a group of outcrops in T. 32 and 33 N., R. 6 and 7 W., is designated Flambeau Quartzite by Hotchkiss (1915, p. 50–53). It is presumed to be older than the Barron Quartzite because it is better cemented, more strongly folded, and less broken. Other differences between the Barron and Flambeau Quartzites, respectively, are reported to be (1) well marked versus obscure bedding, (2) shades of pink, purplish, and yellowish versus reddish brown to pale yellowish gray, and (3) conglomerate at base of the Barron, which contains few iron-formation fragments, versus conglomerate locally throughout the Flambeau as well as at the base, all containing moderate amounts of iron-formation fragments.

Exploration in T. 33 N., R. 8 W., an area between the Barron and Flambeau Quartzites, tested two magnetic anomalies. Six holes indicated that one anomaly was related to magnetite-bearing rhyolite. Two other holes penetrated granite, and one was in syenite so the cause of the second anomaly was not established.

BLACK RIVER FALLS-NEILLSVILLE AREA

The Black River Falls-Neillsville area, in Jackson and Clark Counties, just west of the center of the State, is largely covered by Cambrian sandstone. The Wisconsin River and its tributaries have exposed small scattered outcrops of Precambrian granite, granite gneiss and, locally, gabbro and other rocks.

Quartz-hematite-magnetiteiron-formationnearBlackRiver Falls is exposed at several places, has been explored by drilling, and is being mined at a locality about 6 miles east of the city. The iron-formation averages about 30–35 percent iron and is beneficiated at a ratio of three tons of lean ore to one ton of marketable concentrate of at least 65 percent iron. The operation has an expected 20-year annual production of 750,000 tons of pelletized concentrates. Exploratory drilling in an area about 1½ miles long and 1 mile wide just northeast of Black River Falls shows that overburden of sand and sandstone where present is 10 to 180 feet thick. The underlying Precambrian bedrock, testcd to depths of 170 to 400 feet, contains iron-formation masses from 30 to 200 feet thick but of undetermined length and relation to each other.

Schist associated with the iron-formation and known mainly from drilling consists of quartz, biotite, chlorite, and garnet in various proportions. The relationship and structure of the iron-formation and schist are not known.

The prominent circular anomaly at Black River Falls, shown on sheet 2, is due to the magnetic iron-formation and probably indicates that the iron-formation or the magnetic part of it has quite limited horizontal extent. Linear magnetic anomalies determined by ground surveys trend S. 45 to 60 E. for a distance of about 8 miles, from near the city of Black River Falls to about 3 miles beyond the prominent exposure of iron-formation that is being mined. One of the outcrops of iron-formation near the Black River is about ⅛ of a mile from an outcrop of massive medium-grained granite, but relations of the granite to iron-formation are not known. Nearby, however, an angular fragment collected by R. W. Patenaude, from the dewatered channel of the Black River and believed to have come from nearby bedrock, shows granite in intrusive contact with contorted iron-formation.

Metamorphic zones at Black River Falls are elliptical in shape, as shown on sheet 6, but data are scarce and other shapes are possible. The relation of metamorphism and exposed granite is not known.

A minor local magnetic anomaly, not shown on sheet 2, is about 2 miles south of Neillsville. It apparently is related to quartz-magnetite iron-formation which is exposed very sparingly in scattered small outcrops and is probably a thin discontinuous layer. The cause of another anomaly about 3½ miles south of Neillsville is not known.

Several other rather prominent magnetic anomalies are present in this area, but their relation to the unexposed underlying geology is not known. Two of these, the anomaly south of Eau Claire and the other near Necedah Mound (T. 18 N., R. 3 E.) have high values within a hook-shaped area of low values. The general pattern has some resemblance to that in the Tigerton area and perhaps indicates a similarity in the geology of the areas.

TIGERTON AREA

The Tigerton area has scattered exposures of anorthosite and younger granite (Weis, 1965). Although each kind of rock is only slightly magnetic, the borders of granite in contact with anorthosite, as observed in several outcrops and in loose fragments, are moderately to very magnetic. Magnetite crystals in clusters to one-half inch in maximum dimension were seen along the border of a granite dike in contact with anorthosite.

The magnetic character of these contact zones may give a clue to the cause of anomalies of high values in a distinctive concentric pattern in the Tigerton area inside a hook-shaped group of low values that are apparently related to granitic rock (sheet 1). In the absence of any other information concerning occurrences of magnetite in this part of the area, it is suggested that the groups of high magnetic values indicate the contact zone of the anorthosite mass and the granite that presumably partly surrounds it. The economic potential of this inferred contact zone has not been investigated.

WAUSAU-WISCONSIN RAPIDS AREA

The Wausau-Wisconsin Rapids area is in the southern part of the region underlain by Precambrian rocks. It comprises about half of the "North Central Wisconsin" area of Weidman (1907). The Wisconsin River and its tributaries have uncovered bedrock at many places, and exposures adjacent to stream channels are extensive; elsewhere, outcrops are small and scattered.

The overall geologic pattern of this area (sheet 3) has not been fully determined, owing to the variety of lithologic types and paucity of information as to their relative geologic ages. A careful and comprehensive study appears justified not only to appraise the mineral resource potential of this interesting area but also to help clarify the general Precambrian history of the State.

Intrusive igneous rocks, apparently the predominant rock type, include massive medium-grained felsic rocks mainly granite and syenite, and a somewhat gneissic aplite that is possibly an intrusive rock. On the basis of outcrop data indicated on sheet 1, syenite and nepheline syenite bodies are shown on sheet 3 northwest of Wausau; however, Emmons (1953) proposes that the syenites are in a system of parallel northwest trending dikes in an extensive mass of aplite. Some gabbro and anorthositic gabbro are exposed, and diorite is present locally as dikes and as scattered outcrops of unknown relation to adjacent rocks. Extrusive igneous rocks, also present, are greenstone (metabasalt), which locally contains ellipsoids, and rhyolite which is massive to banded, porphyritic or uniformly aphanitic, and locally has associated fragmental units that may be flow breccia, agglomerate, lappili tuff, or possibly volcanic conglomerate. An unknown amount of the rhyolite that has been reported and so indicated in the Wausau area on sheets 1 and 3 is rhyodacite; whether it is also present in other areas where rhyolite is indicated is not known. Migmatite and associated mica schist are present locally.

Metasedimentary rocks are in scattered occurrences in the area. Probably the most areally extensive metasedimentary rocks are micaceous and chloritic phyllite and schist with associated graywacke and minor quartzite. Some schists contain garnets and, locally, staurolite. The most prominently exposed metasedimentary rock is a massive quartzite in Rib Mountain near Wausau. An occurrence of this quartzite west of Wausau contains sillimanite. Elsewhere "quartzite," such as that at Powers Bluff, may be recrystallized chert. A partly tuffaceous siltstone and quartzitic-conglomerate unit is only gently inclined and probably is the youngest mappable formation in the area. It is intruded by a porphyritic rhyolite dike.

The complex pattern of metamorphic zones in the Wausau-Wisconsin Rapids area is shown on sheet 6. The pattern of metamorphism and the areal geology are so inadequately known that only a few features are mentioned. The zones of metamorphism appear to have a northeast trend somewhat similar to the general distribution of mafic masses in the area. The gravity contours are parallel to that trend, but the magnetic contours are nearly transverse to it.

One of the prominent magnetic features in the northern part of the State is an east-west trending area of low magnetic values and low gravity values north of the Wausau-Wisconsin Rapids area, especially in Lincoln County. These values suggest that a batholithic granite complex underlies the entire area. Southward continuation of low magnetic values from the east end of this area forms a hook-shaped extension that curves in a clockwise direction around the Tigerton area (sheet 2). The positive anomalies in southwest Langlade County and southeast Lincoln County may indicate contact zones like those inferred in the Tigerton area.

Another prominent magnetic feature is the east-west trending tract of magnetic highs in central Marathon County south and west of Wausau. The crest of the anomaly is related to magnetite in the contact zone of quartzite intruded by granite. The anomaly between the 400 and 800 gamma contours probably is due to syenite and nepheline syenite. The small circular anomaly on one of the eastern prongs is due to gabbro and diorite and that on the other prong is probably related to similar rocks. The effect of several other rock types is shown by a more detailed aeromagnetic survey (Henderson, Tyson, and Paige, 1963) and geologic field reconnaissance (Allingham and Bates, 1961).

Elsewhere in the Wausau-Wisconsin Rapids area (sheet 2) the magnetic pattern has low relief, has general east-west elongation, and appears to be unrelated to known or inferred areal geology.

The Wausau-Wisconsin Rapids area is on the northwest side of a gravity low, which has values to -90 milligals. No relation between geology and gravity pattern is evident.

Granite is being produced mainly for monumental stone from four quarries in the vicinity of Wausau and was previously produced from several other quarries (Hanson, 1967, p. 140-142).

Disintegrated granite that is widely distributed west of Wausau and Mosinee is dug by power shovels and is used for surfacing roads, patios, and other areas.

Rhyolite is quarried northwest of Wausau for making roofing granules. The distribution of rhyolite in this area and elsewhere is indicated on sheet 1.

Radioactive materials occur at twelve localities in T. 29 N., R. 6 W. in residium from syenite or greenstone. A description by Vickers (1956) shows that thorogummite was found at four localities, thorium-bearing zircon at four others, allanite at one, and unidentified thorium-bearing materials at three. Vickers (1956, p. 44) described these deposits as follows: "The commercial value of the occurrences is not known, because several factors, such as ease of recovery of the valuable minerals from the gangue minerals, depth and lateral extent of the radioactive minerals, grade of the rock, and salability of the ore or concentrates are not known."

A small amount of zircon, containing some hafnium, was mined in the 1940's from a small pit in pegmatite near he center of NW¼ sec. 22, T. 29 N., R. 6 E. The zircon is reported (Vickers, p. 37) to have occured ". . . as thin but continuous bands in highly sheared feldspar and quartz and also as rich lenses in quartz" in syenite within a quarter mile of its contact with greenstone. A resistivity survey in 1946 and subsequent drilling and digging by the U.S. Bureau of Mines did not indicate the presence of other minable occurrences of zircon.

Rare earths (mainly columbium and cerium) occur in the SW¼NW¼ sec. 22, T. 29 N., R. 6 E. (Weidman, 1907, p. 308-312), but material of economic value was not found in subsequent sampling by the U.S. Geological Survey.

A magnetic anomaly which forms a circle about one mile in diameter, mostly in sec. 1, T. 29 N., R. 6 E., but also in parts of sections 2, 11, and 12, may be due to an alkalic plug. The exposed bedrock is syenite that contains visible magnetite. Allingham and Bates, 1961, p. 296, stated that "the anomaly . . . is possibly an alkalic plug. If so, this area might be geologically favorable for exploration for niobium-bearing minerals, because this association of a circular zoned intrusion, hornblende diorite, and pyroxenitic rocks with syenite is similar to an occurrence in Ontario Province, Canada, that yields niobium (columbium) -bearing pyrochlore (Westrick and Parsons, 1957). Spectrographic analysis of samples from the syenite (Vickers, 1956) shows concentrations of niobium."

Fine-grained sulphide minerals, probably pyrite, are abundant in rhyolite in sec. 24, T. 29 N., R. 7 E.

Small amounts of chalcopyrite and malachite occur locally in the greenstone in sec. 33, T. 30 N., R. 6 E., and in sec. 35, T. 29 N., R. 8 E.

GEOPHYSICAL DATA IN OTHER AREAS

Several major anomalies shown on sheet 2 are in areas of sparse outcrops away from the areas described above.

Gravity values from -10 to -40 milligals in an area north and west of Wausau define a prominent southwesterly trend shown on sheet 2 which is about 160 miles long, from near the Rhinelander area in Oneida County to Buffalo County in the southwest. The only rocks exposed in this area are in Chippewa, Eau Claire, and Clark Counties, where predominantly granite and diorite-gabbro of Precambrian age are exposed by streams that have cut through the overlying Paleozoic rocks. The location of positive gravity and magnetic anomalies at the north end, near and west of Rhinelander, is strikingly similar and is probably related to unexposed mafic rock. An adjacent gravity anomaly in northeastern Oneida County has a northwesterly trend, values from -20 to -40 milligals, and is about 40 miles long. The only exposed rocks in the area of this anomaly are a few outcrops of granite in the southwestern part.

A prominent negative gravity anomaly, ranging from -60 to -90 milligals, trends southwesterly from the Florence area for 145 miles to Waushara County. It extends through part of the Mountain-Amberg area, the Tigerton area, and the eastern part of the Wausau-Wisconsin Rapids area. Granite is the most widely exposed rock within the area of the anomaly, but quartzite is exposed locally in the Mountain-Amberg area and anorthosite in the Tigerton area. There appears to be little relation between the gravity and magnetic anomalies, except possibly with part of the previously described magnetic high in the Tigerton area.

A pronounced gravity low in the western part of northern Wisconsin extends southwesterly from Washburn County through Pierce County. The minimum values are -80 milligals, from which the rise to the east is moderate but that to the west is steep. This sharp gradient is believed to reflect the edge of the adjacent raised block of mafic rock in the Keweenawan area. The gravity low is interpreted as caused by a thick mass of upper Keweenawan sediments (Thiel, 1956, p. 1088).

GEOLOGY, GEOPHYSICAL SURVEYS, AND MINERAL DEPOSITS OF SOUTHERN WISCONSIN

The data for outcrop areas of Precambrian rocks shown on sheet 5 were compiled from Leith (1897), Weidman (1898), Warner (1904), Weidman (1904), Van Hise and Leith (1911), Wanenmacher (unpub. map), and Asquith (1964). Information concerning wells that penetrated Precambrian rocks is from the files of the Wisconsin Geological and Natural History Survey and the Wisconsin Department of Natural Resources.

Glacial deposits cover the eastern two-thirds of southern Wisconsin (fig. 4) but are either only locally and sparingly present or are absent in the remaining third.

Stratified formations of Cambrian to Devonian age, predominant as the bedrock surface (sheet 5), are exposed widely in the western third but crop out only locally elsewhere.

Precambrian rocks generally are exposed in small scattered outcrops but in the Baraboo area outcrops of quartzite are numerous and some are extensive (Wanenmacher, unpub. map). The structure is an elongate asymmetrical syncline with very steep to locally overturned beds in the north limb and more gently dipping, upright beds, generally inclined 20 to 40 degrees north in the south limb (Weidman, 1904). The Baraboo Quartzite is underlain by rhyolite, granite, and diorite that crop out at only a few places as shown on sheet 5. Precambrian rocks younger than the quartzite are the Seely Slate and the Freedom Dolomite. The latter is predominantly dolomite but has interbedded slate and chert and is locally iron-bearing. It may be overlain by quartzite and then slate known only from reported but unverified descriptions of drill cores (Schmidt, 1951). The rocks younger than the Baraboo Quartzite are everywhere covered with Cambrian sandstone. The iron-bearing unit occurs in the basal part of the Freedom Dolomite. It is a mixture of widely varying proportions of hematite, chert, iron carbonate, and dolomite. It is about 200 feet thick and contained ore bodies 20 to 30 feet thick that consisted mainly of hematite and averaged about 53 percent Fe (Van Hise and Leith, 1911, p. 362–363). One mine that operated from 1904 to 1916 and another from 1916 to 1925 contributed about equally to a total production of 643,000 tons of ore (Lake Superior Iron Ore Association, 1952, p. 231).

Precambrian rocks exposed elsewhere in the southern part of Wisconsin are mainly scattered outcrops of quartzite and rhyolite that locally have associated granite and mafic intrusives (Asquith, 1964; Leith, 1897; Van Hise and Leith, 1911, p. 359–365; Weidman, 1898). Strikes and dips of the quartzite in the Waterloo-Portland area (T. 8 and 9 N., R. 13 and 14 E.) indicate the overall structure is an eastward plunging syncline (Warner, 1904).

About 120 wells drilled for water have gone through the Paleozoic strata and penetrated Precambrian rocks. The rock most commonly reported in drill records is quartzite, granite is second in abundance and diorite and rhyolite are third, having been reported in a few places only (Wisconsin Geol. and Nat. History Survey, unpub. data).

Gravity and magnetic contours show a southwest trend in southern Wisconsin (sheet 5), the axis being along a gravity low of about 20 milligals relief and a magnetic high of about 400 gammas relief. However, the relation of magnetic and gravity values to bedrock geology cannot be inferred satisfactorily because Precambrian rocks are either only sparingly exposed as inliers surrounded by Paleozoic strata or have been penetrated by too few wells.

The most prominent gravity anomaly in southern Wisconsin is north of the Baraboo area and has values as low as −80 milligals. It is the southwestward continuation and termination of the previously described anomaly that extends from the Florence area. The relation of this anomaly to geology is not known. Rocks similar to rhyolite, diorite, and granite exposed in the Baraboo area also are exposed in small inliers northeast of the Baraboo area and underlie part of the northeastern continuation of low gravity values. In contrast, rhyolite and granite, penetrated by wells in the vicinity of Madison, are associated with gravity values of −40 milligals.

Gravity values in the Waterloo-Portland-Lake Mills areas generally are about −40 to −50 milligals. This area is underlain, according to outcrops and well data, by quartzite extending mainly to the northeast but probably also to the south. Gravity values of approximately −30 milligals are in the southwestern part of the State, where granite, at least locally (T. 3 N., R. 1 W.), has been penetrated in a well. Comparable gravity values extend northward to LaCrosse and then decrease eastward.

The southern part of Wisconsin has three areas of high magnetic values and three of low values. The previously mentioned magnetic high of southwest trend is north of the Baraboo area. Another positive anomaly of southwest, but irregular, trend is in the eastern part of southern Wisconsin and has values mainly from 200 to 800 gammas. A third area of high values ranges mainly from 100 to 400 gammas and trends through Madison. Values in adjacent lows are from 0 to −500 gammas.

Relation of magnetic anomalies to the bedrock geology is only partly understood and is not consistent. Positive anomalies are underlain by rhyolite and granite such as are exposed northeast of the Baraboo area and exposed in wells in the vicinity of Madison. High values at and northwest of Milwaukee are, at least peripherally, underlain by quartzite that has been penetrated by wells; whether quartzite is the prevalent bedrock is not known. In contrast, quartzite in the Waterloo-Portland-Lake Mills areas appears to have associated low magnetic values. Other negative anomalies are possibly related to the granite areas previously mentioned in the western and southwestern part of southern Wisconsin.

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CONGDON AND CAREY
MINERAL EXPLORATION

April 15, 1971

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Re: Proposed Exploration Program For Portions of the Greenstone Belt in Wisconsin

Gentlemen:

This program was proposed by Jack Everett and Bradley Huedepohl to Congdon and Carey by telephone a few weeks ago. On Thursday, April 1, Huedepohl, Everett and myself conferred in Duluth for about five hours. The concepts presented are my understandings from this meeting. The necessity to reduce it to paper is self-evident.

Geology

A great amount of exploration attention has been given to the extension of the Canadian Greenstone belt into Northern Minnesota. A similar but much more productive Greenstone belt which includes Timmins and other famous districts can by geologic extension be presumed to underly parts of Northern Wisconsin.

Exploration in Wisconsin has been hindered by thick glacial cover with little outcrop. On the flanks of this covered area, some outcrops do occur and near one of these Bear Creek Mining Company has recently announced a "commercial" discovery.

Other indications of the presence of the Greenstone are indicated by the magnetic pattern, interception of favorable rock in water wells and the character of the drift itself. This information is shown on the accompanying maps and text of U.S.G.S. Map I-631.

An overlay has been prepared for Sheet 3 of this map series and is appended to this report. The information on the overlay is taken directly from that furnished by Everett and Huedepohl (E & H).

Fourteen areas, which are only roughly defined, appear to have promise. Most of these are removed from the outcrop areas of known Greenstone which have naturally attracted the attention of the early birds in this play.

The concept is therefore not unique and is but an extension of the search for metal in the Greenstones (volcanic piles) which has been on the scene across the border for many years. It is proposed that the conduct of the program follow the generally accepted routine of airborne EM (INPUT) followed by ground EM or IP. In addition to this, consideration might be given to comparatively cheap rotary drilling to bedrock for geochemical evidence before anomalies are finally checked by diamond drilling. (The latter is not part of the E & H proposal).

Land

Exploration on the extensions of the Greenstone belts into the United States has been and is still hampered by the fact the land is held in fee and for the most part in small acreages. In portions of Wisconsin, however, large land grants were issued to railroads and lumber companies approximately 100 years ago. These land holdings and their owners are known to Mr. Huedepohl and he has negotiated a contract on one such large parcel. The terms in this instance were an obligation for a work commitment of 10¢ per acre per annum for two years. Input would be acceptable for the work followed by a selection of acreage with a rental (preferably advanced royalty) of $2.50 per acre with a minimum selection of 800 acres ($2,000 minimum acceptable rental). Royalties were negotiated at 2½% of net smelter returns at a grade of $12 per ton graduated to 7% at $21 per ton. This is the type of deal we would seek using Mr. Huedepohl's expertise and contacts with the landowners.

Since the land holdings are in a checkerboard pattern, this does not complete the acquisition effort but does give a foothold in the area at no extra cost since the expenditure of 10¢ per acre by flying would have to be done in any event.

Managing the Program

The logical designation of operator for this program would appear to be that organization having the greatest experience in this type of exploration. Of the three parties now considering participation, SELCO would seem the logical nominee.

Budgeting the Program

A number of budgets were proposed by E & H. The minimum budget entails only that amount of money necessary to meet the work commitment for land acquisition. Since the land is already burdened with royalty, this does not appeal to Congdon and Carey. Our objective is the discovery of and the earning of an equitable interest in viable ore deposits. This tentative budget is modified from that which was present by E & H and, of course, subject to revision before an operating entity is formed.

The budget reflects the following interests: SELCO, Congdon and Carey and Dennison Mines - equal shares of 32%. A 4% carried interest is reserved for E & H in consideration for the initial presentation and for consulting work to be performed on the project at rates somewhat reduced from their normal fees. This latter point may be accomplished by a fixed retainer which would include ground follow-up work.

1st Year - 2,000 line miles Input flying, land acquisition, ground follow-up on promising anomalies and rotary drilling

INPUT cost @ $25 per line mile	$50,000
Management Fee	5,000
E & H consulting and ground follow-up (including travel expenses)	20,000
2,000' rotary drilling @ $3.00/ft.	6,000
Land acquisition (small acreages on anomalies)	5,000
Contingencies	4,000
	$90,000

Division of Budget

SELCO - Credit for reduced rate on INPUT	$20,000	
Management Fee	5,000	
Cash	5,000	
		$30,000
Congdon and Carey (cash)		30,000
Dennison Mines (U.S.) (cash)		30,000
		$90,000

2nd Year - 2,000 line miles Input flying, land acquisition, ground follow-up and 2,500' diamond drilling

INPUT cost @ $25 per line mile	$ 50,000
Management Fee	5,000
E & H consulting and ground follow-up (including travel expenses)	25,000
Land acquisition (additional small acreage)	5,000
2,500' diamond drilling @ $10/ft. (all up cost)	25,000
Contingencies	7,000
	$117,000

Division of Budget

SELCO - Credit for reduced rate on INPUT	$20,000	
Management Fee	5,000	
Cash	14,000	
		$ 39,000
Congdon and Carey (cash)		39,000
Dennison Mines (U.S.) (cash)		39,000
		$117,000

Concluding Statement

The Wisconsin Greenstone belt sequences are most probably limited in aerial extent yet they appear to have attractive exploration possibilities. A three-year program is the minimum in which conclusive results could be reasonably expected. In this regard, the final year's budget is left open as it depends to such a large degree upon the success of locating attractive targets and land acquisition.

To repeat, the budgets are flexible at this time. If the consensus is that a much larger budget is needed, another partner may be found to fill this need. A meeting of the interested parties is necessary to resolve a final syndicate agreement.

Very truly yours,

Dolf W. Fieldman

jw

Clam Lake
Eagle River
Iron River
Hazelhurst
Philips
Bradley
Argonne
Bear Creek
Goodman
Hollister
Antigo
Wausau
Stanley
Chippewa Falls
Overlay of USGS Map I-631 sheet 3
Northern Wisconsin
Commercial discovery
Greenstone outcrop
Rhyolite outcrop
Sulphide outcrop
Not previously described
Magnetic High
Gravity high
Areas already flown with INPUT
El Dorado
Proposed Areas for Exploration with identifying name
4/11/71
Congdon & Carey
Denver, Colo.