MAP I–576

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# BEDROCK GEOLOGIC MAP OF THE MARENISCO-WATERSMEET AREA GOGEBIC AND ONTONAGON COUNTIES, MICHIGAN

By
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MISCELLANEOUS GEOLOGIC INVESTIGATIONS
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## INTRODUCTION

*Mapping method and bedrock outcrops.*———The recent mapping was done at scale 1:48,000. All fieldwork was planned with the aid of township plats compiled by the Michigan Geological Survey, which show the locations of bedrock outcrops found since 1910 on traverses along section lines, half-section lines, and, in some places, quarter-section lines. These data were transferred to modern topographic base maps. Attention then was focused on areas in which topography appeared to be controlled by bedrock, and in such places more outcrops commonly were found. Where numerous previously unmapped outcrops were found, small outcrops shown on the old maps may have been overlooked during the recent mapping, if not remapped as parts of larger outcrop areas. In a few places, "outcrops" shown on the old maps were not found or were reinterpreted as boulders in glacial drift. Nevertheless, it is likely that at least 90 percent of the outcrops in the area are shown on this geologic map.

*Surficial geology.*———The mapped area was glaciated in Pleistocene time. The trend of glacial striations on bedrock ranges from south-southwest in the Marenisco quadrangle to south-southeast in the Watersmeet quadrangle. Most of the area is blanketed by sand and gravel, the thickness of which reaches 280 feet at diamond-drill hole 42. Recognition of topographic features of Pleistocene age aided in the mapping of bedrock. Examples of such features are: (1) The hill at the 12-13 section line in T. 46 N., R. 43 W.--a drumlin; (2) the narrow ridge south of Blair Lake--an esker; (3) the irregular hill southeast of Bobcat Lake--a kame; (4) the broad ridge near the center of sec. 4, T. 46 N., R. 42 W.--part of a kame terrace, in which partly indurated gravel resembles conglomerate.

*Interpretation of bedrock geology.*———The placement of contacts and faults and the interpretation of stratigraphy and structure shown here were facilitated by aeromagnetic maps compiled by Philbin and Vargo (1963), Boynton and Vargo (1964), Balsley and Petrafeso (1965), and Philbin and McCaslin (1966), as well as by use of water-well logs and diamond-drill logs obtained from the Michigan and Wisconsin Geological Surveys. Drill cores have not been preserved, but bedrock cuttings from water wells recently drilled at Watersmeet have been saved by the Michigan Geological Survey at Escanaba.

## GEOLOGIC STRUCTURE

The principal geologic structures, in addition to faults, are (1) a large northeast-plunging anticline west of Lake Gogebic involving the Copps Formation of Allen and Barrett (1915) and underlying rocks; (2) a thick, northeast-trending, southeast-dipping monocline in the central part of the mapped area involving the Copps and younger Animikie strata; and (3) large domes near Watersmeet involving the Wolf Lake Granite of Allen and Barrett (1915) and overlying rocks. Synclines are inferred near the domes in order to account for known and probable reversals of dip of metasedimentary rocks adjacent to the Wolf Lake Granite.

The Marshall Creek fault was mapped to account for a 0.7-mile apparent right-lateral offset of the Copps-gneiss contact near Marshall Creek, which can be explained by a vertical displacement of about 2,000 feet along this fracture. The fault as mapped also accounts for the abrupt northeastward termination of a broad belt of magnetic anomalies caused by rocks mapped here as <u>strata of the Marenisco Range at Marenisco</u>. The Marshall Creek fault is in the approximate position of a major thrust fault inferred by Hendrix (1960, p. 74), but is interpreted here as normal.

The Barb Lake fault was mapped to account for a 5.6-mile apparent right-lateral offset of pillow lavas and associated fragmental rocks characteristic of the <u>strata near Blair Lake</u>, which display similar lithologies and trends on opposite sides of this fracture. North of the fault, pillow lavas are thinner, the overlying rocks of the same formation are more magnetic, and the underlying rocks mapped as <u>strata near Banner Lake</u> are less magnetic than their respective counterparts mapped south of the fault. These differences are accounted for by inferring a large vertical component of displacement along the fault as well as pinching and swelling of magnetic strata both laterally and along the dip of the magnetic rocks. A large lateral component of displacement along the fault also is inferred to account for the present positions of the displaced parts of the <u>strata near Blair Lake</u>.

The Barb Lake fault is believed to extend eastward along the north side of the main body of Wolf Lake Granite of Allen and Barrett (1915), but the position and extent of the fault east of U.S. Highway 45 are uncertain. This fault also accounts for the abrupt northeastward termination of magnetic anomalies at the Banner Exploration in sec. 1, T. 45 N., R. 43 W., but the extent and position of the fault farther west are uncertain.

Other faults are inferred northeast of Cup Lake to account for apparent offsets of the Keweenawan Series. Additional information concerning geologic structure is given in notes about the main map units.

## BEDROCK GEOLOGY

*Pre-Animikie gneiss and granite.*———Rocks mapped here as <u>gneiss near Mount Kimberly</u> and <u>granite near Nelson Creek</u> are parts of the Presque Isle Granite

(Allen and Barrett, 1915), the type area of which is near the Presque Isle River in sec. 33, T. 47 N., R. 43 W. Typical localities of the recently separated gneiss and granite are shown by letter symbol on the geologic map. The banded part of the gneiss consists of probable metasedimentary and (or) metavolcanic rocks of moderate to high metamorphic grade, which are overlain unconformably by the weakly metamorphosed Copps Formation of Allen and Barrett (1915). The banded gneiss is believed to have undergone strong metamorphism in pre-Copps (probably pre-Animikie) time and slight metamorphism in post-Animikie time. The gneiss and granite form the core of the large anticline near Lake Gogebic.

*Copps Formation of Allen and Barrett (1915).*——The basal conglomeratic quartzite of the Copps Formation of Allen and Barrett (1915) extends from the type locality near the old Copps mine in the SE¼ sec. 15, T. 47 N., R. 43 W., eastward into the map area and along the north limb of the main anticline. The conglomeratic quartzite there contains pebbles derived from the unconformably underlying gneiss. The quartzite is overlain conformably by interbedded graywacke and slate of the Copps characterized by thin lenses of impure crystalline limestone. The formation wraps around the nose of the main anticline and underlies a broad area south of Lake Gogebic. The Copps there consists mainly of nonmagnetic, slightly metamorphosed graywacke containing slaty partings and the characteristic limy lenses. These lenses commonly are parallel to the slaty partings, which represent original beds within the predominant graywacke. In most of the Copps south of Lake Gogebic, bedding and foliation are parallel; they commonly strike east-northeast and dip south-southeast. Dips are less regular in the lower part of the formation, especially in sec. 8, T. 46 N., R. 42 W., where the rocks are more slaty. Perhaps in that area foliation does not parallel bedding, and the formation is somewhat folded, as suggested on cross section B-B' nearby. In most places south of the lake, however, the formation is not appreciably folded. Its total thickness is at least 10,000 feet.

*Strata of the Marenisco Range at Marenisco.*——Rocks mapped here as strata of the Marenisco Range at Marenisco form only part of the Marenisco Range as mapped by Allen and Barrett (1915), which included lean magnetic iron-formation now placed in the lower part of the strata near Cup Lake. Rocks that Allen and Barrett mapped in the Marenisco Range are unexposed west of the Marenisco quadrangle, but have been traced by dip-needle surveys southwestward from Marenisco for at least 25 miles (Allen and Barrett, 1915, fig. 1). In the present map area, rocks mapped as strata of the Marenisco Range at Marenisco and strata near Cup Lake do not appear to be physically continuous. Where unexposed southwest of the map area, however, the Marenisco Range may include magnetic rocks of both map units brought into proximity by the Marshall Creek fault.

The stratigraphic position of the rocks exposed at Marenisco is uncertain. In general, they are more magnetic than the adjacent Copps Formation. Magnetic, chloritic rocks exposed at Marenisco were interpreted by Allen and Barrett (1915) as equivalent to the Ironwood Iron-Formation, which unconformably underlies their Copps Formation on the Gogebic Range. Many geologists currently working in the region, however, do not accept that interpretation.

The chloritic rocks exposed at Marenisco resemble the chlorite schist (mc) of probable pre-Animikie age mapped at Marshall Creek. This suggests that the strata at Marenisco might be pre-Animikie in age. If so, a displacement greater than 2,000 feet might be inferred along the Marshall Creek fault, assuming that the position of the fault as mapped is correct. On the other hand, the strata exposed at Marenisco, like the Copps exposed farther east, strike east-northeast and dip south-southeast away from the adjacent granite. The bedding attitudes suggest that the rocks at Marenisco, like the Copps, overlie the granite unconformably. Furthermore, the metasedimentary rock exposed in the SW¼ sec. 21, T. 46 N., R. 43 W., south of Marenisco is graywacke similar to rocks in the main part of the Copps Formation south of Lake Gogebic. The map suggests that the chloritic rocks beneath the graywacke at Marenisco occupy a stratigraphic position comparable to that of carbonaceous, pyritic slate beneath the predominant graywacke of the Copps near Marshall Creek. The strata of the Marenisco Range at Marenisco, therefore, are interpreted here as possibly equivalent to the Copps Formation of Allen and Barrett (1915).

*Strata near Cup Lake.*——The strata near Cup Lake are mainly metavolcanic in origin, but also contain interlayered metasedimentary rocks. The metavolcanic rocks include well-foliated amphibolite interpreted as metatuff and poorly foliated mafic rocks interpreted as probable metamorphosed lava. The metasedimentary rocks include metagraywacke, iron-formation, and conglomeratic quartzite. The strata are exposed mainly in T. 46 N., Rs. 41-42 W., but amphibolite and conglomeratic quartzite characteristic of the formation also are exposed near the West Branch of the Presque Isle River south of Marenisco.

Foliation in the metavolcanic rocks is approximately parallel to bedding in the interlayered metasedimentary rocks. Many of the foliation symbols shown on the map, especially in T. 46 N., R. 42 W., indicate the attitudes of crude layering or possible relict bedding in recrystallized, probably tuffaceous rocks. The layering and bedding in the strata near Cup Lake strike east-northeast and dip south-southeast, like the bedding in the adjacent Copps Formation.

Primary bedding features such as scour structures are well displayed in conglomeratic quartzite associated with amphibolite on the north side of an intrusive sheet of metadiabase in the NW¼ sec. 22, T. 46 N., R. 42 W. The scour structures consist of lenses of metasiltstone within quartzite. The lenses show plano-convex cross sections, with curved (lower) sides facing northwest and straight (upper) sides facing southeast. This evidence clearly indicates that the strata are right-side-up and overlie the Copps Formation.

The amphibolite at the base of the strata near Cup Lake is thinly layered in many places and locally grades downward into the predominant graywacke-slate of the Copps Formation, especially at the west edge of sec. 21, T. 46 N., R. 42 W. The strata near Cup Lake are not known to contain fragments derived from the underlying Copps. The apparent absence of such fragments and the similarity in bedding attitudes in both formations suggest that the strata near Cup Lake overlie the Copps conformably. Thus the basal amphibolite of the strata near Cup Lake is believed to reflect the outbreak of volcanic activity in post-Copps time.

In several outcrops, the strata near Cup Lake display tiny crenulations and small drag folds less than 1 foot in amplitude, which commonly plunge gently northeastward. Where such folds are anticlinal, they commonly exhibit short limbs on the northwest and long limbs on the southeast. This evidence indicates that the strata lie on the southeast limb of a major northeast-plunging anticline, presumably the major anticline mapped near Lake Gogebic. In general, however, the formation is not appreciably folded. Its thickness is probably at least 8,000 feet.

*Strata near Banner Lake.*——The strata near Banner Lake have been penetrated by 58 unmapped diamond-drill holes at the Banner Exploration. At least 20 of them penetrated graphitic slate and probable graywacke northeast of a belt of lean iron-formation. One of the northernmost holes entered "dolomitic schist." Allen and Barrett (1915, fig. 8, p. 103) interpreted the graywacke, slate, and dolomitic rock as stratigraphically beneath the iron-formation, which they thought occupied the trough of a tight southwest-plunging syncline. The recent mapping, however, has shown that the dolomitic rock and much of the slate and graywacke most likely are north of the Barb Lake fault. No indisputable evidence has been found to corroborate the syncline inferred by Allen and Barrett.

The strata near Banner Lake are best exposed in T. 46 N., R. 41 W., where the predominant rock is biotitic to garnetiferous metagraywacke. This rock resembles the graywacke of the Copps Formation, but lacks limy lenses where exposed. On the other hand, dolomite, slate, and lean magnetic iron-formation now thought to be part of this formation have been penetrated in diamond-drill holes in the southwestern corner of the mapped area.

In at least one outcrop in the northern part of the map unit, the strata near Banner Lake display tiny crenulations, but most of the rocks in this formation are not appreciably folded. They strike northeast and dip southeast. In some outcrops, beds are nearly vertical, and a few beds even dip northwest. Near U.S. Highway 2, however, excellent graded bedding indicates that the tops of beds face southeast. Beds as much as 1½ inches thick are quartz-rich on the northwest (lower) sides and biotite-rich on the southeast (upper) sides. Northwest-dipping beds, therefore, are believed to be slightly overturned rather than tightly folded. Bedding attitudes in the lower part of the formation suggest that these rocks conformably overlie the strata near Cup Lake. Near U.S. Highway 2, the strata near Banner Lake are approximately 11,500 feet thick.

*Strata near Blair Lake.*——The strata near Blair Lake constitute the most important "marker" unit in the mapped area, because pillow lavas and distinctive quartzite-bearing rocks (bq) characteristic of this formation are exposed on both sides of the Barb Lake fault. Pillow structures are displayed best in a roadcut near U.S. Highway 2 north of the fault, and in an outcrop near the east edge of sec. 5, T. 45 N., R. 42 W., south of the fault. Pillows in the lava of this formation commonly display pointed or irregular (lower) sides facing northwest and slightly convex (upper) sides facing southeast. This evidence clearly indicates that the strata near Blair Lake overlie the strata near Banner Lake.

The strata near Blair Lake are best exposed in T. 46 N., Rs. 40-41 W., although outcrops are not numerous. A belt of magnetic anomalies extending from Blair Lake to the east shore of Bond Falls Flowage is assumed to be caused by similar but unexposed magnetic rocks near the top of this formation. The thickness of the formation near Blair Lake is at least 8,000 feet.

South of the Barb Lake fault, the exposed rocks of this formation consist mainly of pillow lavas and fragmental rocks similar to those of the lower member mapped north of the fault. However, chloritic and garnetiferous schists and coarse-grained mafic metavolcanic rocks exposed in the SE¼ sec. 12, T. 45 N., R. 43 W., south of the Banner Exploration, appear to be continuous with rocks near the base of the formation mapped southeast of Barb Lake.

Foliation in the metavolcanic rocks of this formation is approximately parallel to bedding in the subordinate metasedimentary rocks such as iron-formation and quartzite within the formation. The foliation in the strata near Blair Lake, in general, strikes northeastward and dips southeastward, especially north of the Barb Lake fault. The attitudes are similar to those of bedding in the underlying strata near Banner Lake. The contact between the formations, therefore, is assumed to be conformable. The rocks of this formation are believed to reflect the second major outbreak of volcanic activity in this area in post-Copps time.

*Magnetic strata near Watersmeet.*——The unexposed magnetic strata near Watersmeet were mapped entirely by means of aeromagnetic anomalies. Two diamond-drill holes at the south edge of sec. 28, T. 45 N., R. 39 W., revealed that the anomalies are caused by lean magnetic iron-formation buried beneath 150–230 feet of sand and gravel. The holes plunged 50° toward each other. The northern hole intersected bedding at an angle 10°–15°; the southern hole intersected bedding at 65°–70°. These data indicate that the beds dip 60°–65° southward away from quartz monzonite gneiss penetrated in water wells at Watersmeet. The distribution of aeromagnetic anomalies suggests that the magnetic strata wrap around the southern and western sides of the main domelike body of the Wolf Lake Granite of Allen and Barrett (1915) and also delineate the north flank of a similar buried dome near Damon Lake, where the magnetic strata presumably dip northward.

*Strata near Paulding.*——Where least metamorphosed, the strata near Paulding are lithologically similar to the predominant graywacke-slate of the Copps Formation. During the recent mapping, the possibility that the strata near Paulding are part of the Copps Formation offset by a major northeast-trending fault was considered. However, no evidence was found for such a fault or for an unconformity at the base of the strata near Paulding, which now are assumed to overlie the strata near Blair Lake conformably.

In the northern part of the map unit, the strata near Paulding commonly dip southward, although they display small east-plunging drag folds like those in the underlying formations. Farther south, the rocks of this formation are highly folded and locally dip northward away from the Wolf Lake Granite of Allen and Barrett (1915). The stratigraphic thickness of the formation, therefore, is uncertain, but probably is at least several thousand feet where the rocks are least deformed near Bond Falls Flowage.

The strata near Paulding are inferred to underlie a broad area near Pomeroy and Langford Lakes, although bedrock is not exposed there. In view of the fact that metasedimentary rocks adjacent to the main body of Wolf Lake Granite dip away from the granite in the Watersmeet quadrangle, it is likely that field relations are similar in the Thayer quadrangle. Near Pomeroy and Langford Lakes, therefore, the strata of this formation are inferred to occupy the trough of a broad northeast-trending syncline.

*Stratigraphic position of local Animikie rocks.*———The Copps Formation of Allen and Barrett (1915) and overlying metavolcanic and metasedimentary rocks exposed in the central part of the mapped area are part of a northeast- to east-trending, monoclinal, conformable, stratigraphic sequence at least 40,000 feet thick. These rocks most likely were deposited in a eugeosynclinal environment. The stratigraphic sequence is placed above the Menominee Group within the Animikie Series (James, 1958) and is interpreted here as one of the least deformed parts of what Allen and Barrett (1915, p. 131) referred to as the "Michigamme slate series," which underlies many hundreds of square miles east and northeast of the mapped area. The thin conglomeratic quartzite at the base of the Copps Formation is lithologically similar to the Goodrich Quartzite of the Marquette district and has long been correlated with that formation. The predominant graywacke-slate of the Copps Formation and the strata near Paulding are lithologically similar to rocks of the Marquette and Iron River-Crystal Falls districts mapped as Michigamme Slate, which previously was thought to be only about 5,000 feet thick. In the Marenisco-Watersmeet area, however, the word Michigamme is not used as a formation name because of the presence of the Michigamme-type graywacke-slate in two widely separated stratigraphic positions within the monoclinal, conformable, stratigraphic sequence.

*Granite near Thayer.*———The granite near Thayer intrudes exposed parts of the strata near Cup Lake and the strata near Banner Lake now placed in the upper part of the Animikie Series. The granite near Thayer, therefore, is post-Animikie in age. The logs of diamond-drill holes 39 and 42 indicate that unexposed rocks mapped as part of the strata near Banner Lake also were intruded by small bodies of granite interpreted here as equivalent to the granite near Thayer.

*Wolf Lake Granite of Allen and Barrett (1915).*———The Wolf Lake Granite of Allen and Barrett (1915) forms the cores of domes similar in size and shape to domes near Amasa and Republic, Mich. James (1955) showed that the domes near Amasa and Republic consist of metamorphosed strata of early and middle Animikie ages surrounding granitic rocks of pre-Animikie age, which presumably could not have caused metamorphism of the overlying Animikie rocks. In contrast, no indisputable evidence has been found to indicate that metamorphosed strata adjacent to the Wolf Lake Granite are older than late Animikie. Allen and Barrett (1915) interpreted this granite as being intrusive into the adjacent Animikie strata and directly responsible for metamorphism of those Animikie rocks. The age and significance of the Wolf Lake Granite, therefore, are controversial.

Lithologic studies do not solve the problem, but tend to suggest a post-Animikie age for the Wolf Lake Granite. Inclusions of schists, metagraywacke, amphibolite, and metadiabase within the granite could be pre-Animikie in age, but many of them strongly resemble rocks characteristic of the Animikie Series. Subordinate dioritic parts of the granite exposed near Brush Lake resemble dioritic parts of the gneiss near Mount Kimberly, but the predominant quartz monzonite gneiss exposed near U.S. Highway 45 strongly resembles quartz monzonitic phases of the granite near Thayer exposed in the Marenisco quadrangle. Quartz monzonitic rocks of the Wolf Lake Granite and the granite near Thayer both are characterized by biotitic lenses ¼ inch to 6 inches long. In thin section, the rocks of both map units also display similar mortar structure, where large plagioclase crystals are surrounded by smaller crystals of quartz, feldspar, and mica. Furthermore, near the west end of the small metadiabase body mapped in the NE¼ sec. 5, T. 45 N., R. 39 W., part of the Wolf Lake Granite is slightly porphyritic and resembles the porphyritic felsite (gp) of probable post-Animikie age mapped east of Cup Lake.

The available structural data and evidence of metamorphism of the Animikie Series adjacent to the Wolf Lake Granite also tend to favor a post-Animikie age for this rock. West of the domes in the mapped area, pillow structures indicate that the tops of lava flows of late Animikie age face southeast toward the Wolf Lake Granite, and no evidence has been found for a fault or shear zone between the lava and granite exposed south of the Barb Lake fault. The strong deformation of the strata near Paulding shown on the map and on cross section E-E' north of the granite suggests that the strata were locally crumpled and forced upward as the Wolf Lake Granite was emplaced. Furthermore, the metamorphic grade of metasedimentary rocks north of the granite increases markedly toward this rock, suggesting that the metamorphism accompanied emplacement of the granite. The Wolf Lake Granite, therefore, is interpreted here as post-Animikie in age and most likely responsible for the doming near Watersmeet. This granite presumably is equivalent to the granite near Thayer.

*Metamorphism of local Animikie rocks.*———The granite near Thayer and the Wolf Lake Granite of Allen and Barrett (1915) are found only on the high-grade side of the garnet isograd. Progressive regional metamorphism of the Animikie Series in the mapped area is believed to have accompanied and perhaps followed emplacement of those granitic rocks. The metamorphosed Animikie Series is unconformably overlain by the unmetamorphosed Keweenawan Series. Metamorphism of the Animikie Series, therefore, is believed to have occurred during the Penokean orogeny in post-Animikie, pre-Keweenawan time.

*Keweenawan Series.*——The Keweenawan Series overlies the Animikie Series with marked angular unconformity, especially between Lake Gogebic and Paulding. In this area, the lowermost unit of the Keweenawan Series is a quartzitic sandstone as much as 100 feet thick. In the NW¼ sec. 13, T. 46 N., R. 41 W., this unit contains a basal conglomerate as much as 10 inches thick derived largely from the underlying Animikie Series. Most of the Keweenawan Series in the mapped area, however, consists of mafic lava flows. The local thickness of this series is at least 3,000 feet.

*Jacobsville Sandstone.*——The relatively undeformed Jacobsville Sandstone unconformably overlies the tilted, faulted, and partly eroded Keweenawan Series. Partly indurated gravel adjacent to gneiss in sec. 28, T. 47 N., R. 42 W., was interpreted by Irving and Van Hise (1890, p. 455-456, pl. 13) as a basal conglomerate of the Jacobsville, but the gravel now is known to be part of a kame terrace of Pleistocene age. On the other hand, in the SE¼ NW¼ sec. 13, T. 46 N., R. 41 W., typical Jacobsville Sandstone contains 4-inch cobbles of amygdaloidal basalt most likely derived from the Keweenawan Series. The Jacobsville is generally considered to be Precambrian in age, although the available field evidence merely indicates that its age is post-Keweenawan and pre-St. Croixan (Hamblin, 1961, p. 7). In the opinion of the author, therefore, the age of the Jacobsville probably should be considered Precambrian or Cambrian. In the northeastern part of the mapped area, the formation is at least 275 feet thick (Hamblin, 1958, p. 17).

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