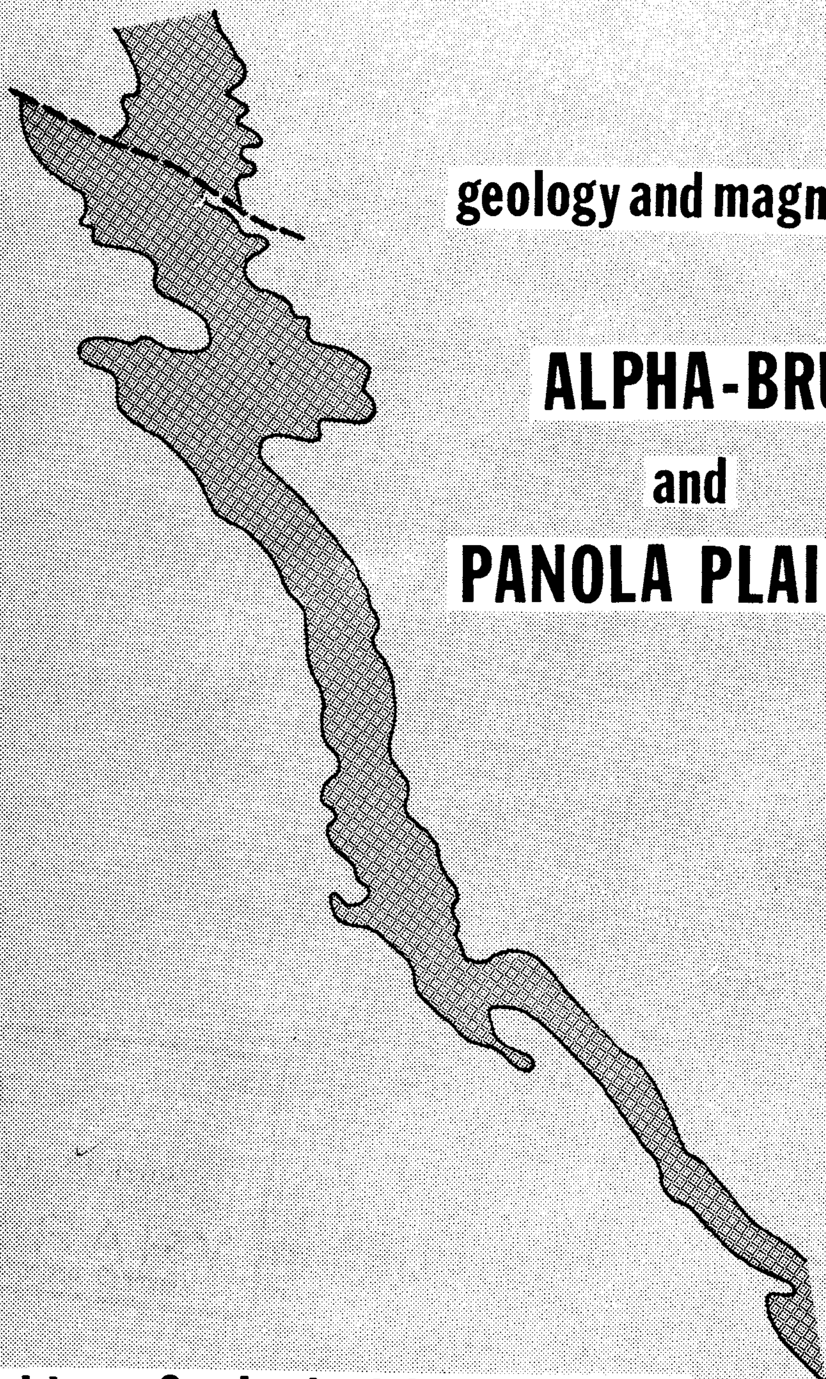
Report of Investigation 10



geology and magnetic data for ALPHA-BRULE RIVER and PANOLA PLAINS AREAS

Michigan Geological Survey 1969

Front cover:

Outline of Riverton Iron-Formation illustrating decreased intensity of folding to the southeast.

STATE OF MICHIGAN
Department of Natural Resources

Geological Survey

Report of Investigation 10

GEOLOGY AND MAGNETIC DATA FOR ALPHA-BRULE RIVER AND PANOLA PLAINS AREAS, MICHIGAN

by
F.J. Pettijohn, J.E. Gair, K.L. Wier, and W.C. Prinz

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PREFACE

The purpose of this report, second of a series of eight reports being published by the State, is to preserve information on explorations, mines and magnetic surveys and to provide more detailed bedrock geology not included in U.S. Geological Survey Professional Paper 570 but invaluable for future development.

This report is a product of field investigations of the Iron River-Crystal Falls district carried out by the U.S. Geological Survey in cooperation with the Geological Survey Division of the Michigan Department of Natural Resources during the period 1943-1955. Some of the results of the work were published as preliminary reports during the course of the field study. The broader conclusions on the geology and ore deposits of the district are presented in U.S. Geological Survey Professional Paper 570, published in 1968.

The mining companies active in the district have materially aided by providing maps and records and permitting access to mine workings and drill core collections. The authors gratefully acknowledge the friendly cooperation of officials and employees of the Cleveland-Cliffs Iron Co., the M. A. Hanna Co., Pickands Mather & Co., the Republic Steel Corp., the Mineral Mining Co., the Inland Steel Co., the North Range Mining Co., the Jones & Laughlin Steel Corp., and the Pittsburgh Coke and Iron Co.

The advice, encouragement, and stimulating interest of various members of the Geological Survey Division, Michigan Department of Natural Resources is gratefully acknowledged.

Baltimore, Maryland
Washington, D. C.
Denver, Colorado
Washington, D. C.
July, 1967

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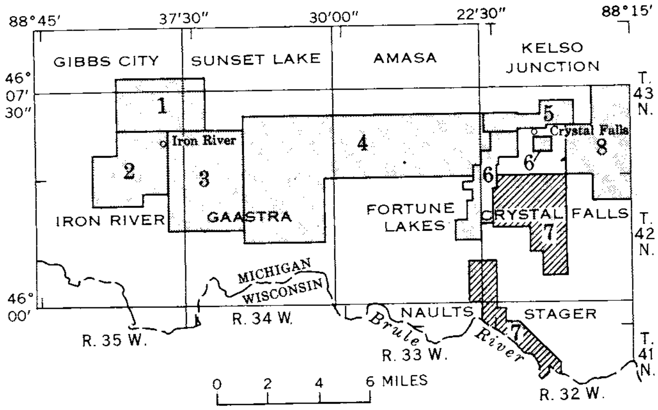

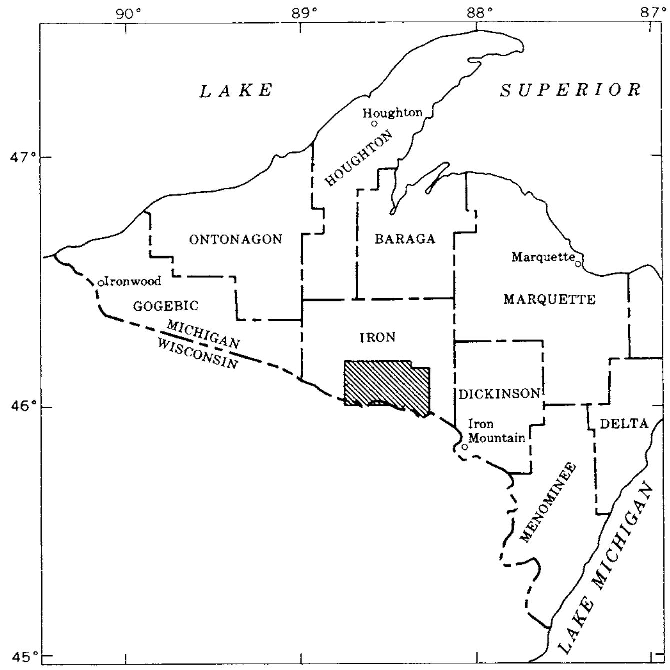

Figure 1 -- Location and index maps

Left: Index to work responsibility and topographic quadrangles in the Iron River-Crystal Falls District.

1. Northern Iron River Area--James, Dutton, Wier
2. Central Iron River Area--Dutton
3. Southeastern Iron River Area--James and Wier
4. Area between Iron River and Crystal Falls--James, Pettijohn, and Clark
5. Northern Crystal Falls Area--Pettijohn
6. Southern Crystal Falls Area--Pettijohn
7. Shading delineates area of this report, Alpha-Brule River and Panola Plains Areas--Pettijohn, Gair, Wier and Prinz
8. Northeastern Crystal Falls Area--Wier

Right: Shading delineates Iron River-Crystal Falls District.

GEOLOGY AND MAGNETIC DATA
FOR
ALPHA-BRULE RIVER AND PANOLA PLAINS AREAS, MICHIGAN

Abstract

The Alpha-Brule River area is bounded on the north by the town of Alpha and on the south by the Brule River, and lies along the southeastern flank of the Iron River-Crystal Falls synclinorium. Folded strata of the Animikie series trend south to southeasterly. From north to south the major folds decrease in magnitude and frequency, and some of the stratigraphic units change considerably in thickness and in lithologic character. A northwest-trending fault, which seems to cause a horizontal displacement of about 1,500 feet, is inferred in the northern part of the area. Except locally, the iron-formation is virtually unoxidized and iron ore, of minor tonnage, has been shipped from only one mine. Outcrop areas, ground magnetic survey data, and drill hole exploration information are shown on two geologic maps for the Alpha-Brule area and on one map for the Panola Plains.

The Panola Plains area lies northeast of the Alpha-Brule River area and mainly east of the belt of Riverton Iron-Formation that outlines the eastern margin of the Iron River-Crystal Falls basin. Two dike-like granitic bodies intrude the Animikie strata. The principal structure is a northwesterly plunging anticline, which is cored by the Badwater Greenstone. The apparent absence of greenstone from its normal stratigraphic position at the present erosional surface in the northeastern part of the map area is explained by rapid thinning and nondeposition along an inferred complementary syncline. An alternate interpretation would be that the greenstone is cut out along a major north-trending fault.

INTRODUCTION

This report is one of a series of eight reports supplementing U. S. Geological Survey Professional Paper 570, "Geology and Ore Deposits of the Iron River-Crystal Falls District Iron County, Michigan" (James, Dutton, Pettijohn, and Wier, 1968). This series presents data on the geology, mines, explorations, and magnetic surveys, and includes 23 detailed maps covering practically all areas of known iron formation. The areas covered by the individual reports are outlined on figure 1.

Information on early mining history was taken from the annual reports, 1879 to 1909, of the Commissioner of Mineral Statistics of the State of Michigan and from the annual reports, 1912 to 1929, of the State Geological Survey. Additional mine history and production data were taken from "Lake Superior Iron Ores" (Lake Superior Iron Ore Assoc., 1938, 1952) and from "General Statistics Covering Costs and Production of Michigan Iron Mines" (Michigan Geological Survey, 1951-61). Some of the results of U. S. Geological Survey work in the Alpha-Brule River and Panola Plains areas have appeared as preliminary reports by Good and Pettijohn (1949) and Pettijohn and Clark (1946).

The Alpha-Brule River and Panola Plains areas are two physically separated map areas. The Alpha-Brule River area is covered by two maps, Geologic and magnetic data in the Delphic-Stager area (pl. 1) and Geologic and magnetic data in the Stager Lake area (pl. 2); and the Panola Plains area is covered by one map, Geologic and magnetic data in the Panola Plains area (pl. 3). The stratigraphic sequence of rock units in the area of this report is shown in Table 1.

# # #

ALPHA-BRULE RIVER AREA

The Alpha-Brule River belt of iron-formation extends from the town of Alpha to the south edge of the Iron River-Crystal Falls district along the Brule River. It is the southeastward continuation of the southern Crystal Falls area (Pettijohn, 1970b?). Most of the Alpha-Brule River area is covered by two map sheets, the Delphic-Stager (pl. 1) and the Stager Lake (pl. 2). The 5-mile belt of iron-formation on these two areas is one of the least productive stretches in the district; it is matched in that respect only by the north belt between the Chicagon and Fortune Lakes mines.

Bedrock is at or close to the surface in much of the area. Outcrops are particularly abundant near the Brule River. Most of the test pits and drill holes that have been sunk encounter ledge surface within 10 feet, although doubtless the cover is thicker in parts of the area. In contrast to most of the Iron River-Crystal Falls district, the topography is to a considerable extent controlled by bedrock structure. The course of McGovern Creek (pl. 1) clearly reflects a major fold in the strata, and the Brule River along the south boundary is parallel to the strike of the beds.

Only one mine--the Delphic--has been developed in the belt of iron-formation, and it was of minor importance. The shipments, all made before 1900, aggregated some 33,770 tons.

Both map areas (pls. 1 and 2) were surveyed with Schmidt-type vertical magnetometers. Measurements were made at paced 100-foot intervals along lines spaced 200-300 feet apart and tied to established land-survey lines. The values were corrected for temperature and diurnal changes and reduced to an arbitrary zero base established for the Iron River area in sec. 28, T. 43 N., R. 34 W. Outcrops and test pits were located during the survey and plotted with respect to the instrument stations. The field work in the Delphic-Stager area was done in 1947 by S. E. Good, assisted by J. J. Hill; that in the Stager Lake area was done in 1953-54 by J. E. Gair.

Geology

The Geology of the Alpha-Brule River belt consists mainly of a north- to northwest-trending belt of iron-formation, flanked on the east successively by Dunn Creek Slate and Badwater Greenstone, and on the west by the Hiawatha, Stambaugh, and Fortune Lakes Formations.

Table 1.--Rock units in the Alpha-Brule River and Panola Plains areas

Precambrian	Middle Precambrian		Granitic rock	
			Instrusive contact	
		Animikie Series	Paint River Group	Fortune Lakes Slate
				Stambaugh Formation
				Hiawatha Graywacke
				Minor unconformity
				Riverton Iron-Formation
				Dunn Creek Slate
			Baraga Group	Badwater Greenstone
				Michigamme Slate

The structure and stratigraphy of the north end of the belt are entirely similar to those of the southern Crystal Falls area described in the southern Crystal Falls area (Pettijohn, 1970b?). At the north boundary of sec. 6, T. 41 N., R 32 W., however, the geology undergoes pronounced change. The Hiawatha Graywacke pinches out entirely and the Stambaugh Formation becomes almost indistinguishable from the overlying Fortune Lakes Slate. The Dunn Creek Slate seems to thin rapidly, and in the adjoining part of the Florence area in Wisconsin it is very thin or absent. The Riverton Iron-Formation also seems to thin to the southeast, and adjacent to U. S. Highway 2 on the south side of the Brule River the combined thickness of the Dunn Creek Slate and Riverton Iron-Formation may be a little as 400 feet. As a result of these rapid changes, the individual stratigraphic units of the Iron River-Crystal Falls district--at least those of post-Riverton age--cannot be distinguished with certainty in the Florence area of Wisconsin.

Structurally, the "zigzag" pattern of the southern Crystal Falls belt continues for a mile south of the Delphic mine, then gives way to a more regular trend. Folds are present, but they are of smaller magnitude and not spaced at regular intervals as they tend to be in the southern Crystal Falls area. Furthermore, a reversal of plunge is noted for at least one fold (the one crossing the south edge of T. 42 N., which is the join line between pls. 1 and 2).

Badwater Greenstone

The Badwater Greenstone is exposed in only two areas, one about 1 mile south of Alpha, and the other near the Brule River. The latter exposure, in sec. 9, T. 41 N., R. 32 W. (pl. 2), is part of the main "East belt" underlying the Dunn Creek Slate. The greenstone of the northern exposures, in sec. 19, T. 42 N., R. 32 W., and sec. 24, T. 42 N., R. 33 W. (pl. 1), is believed to reach the surface on an anticlinal structure--the southern extension of the Judson anticline--and is bounded on all sides by Dunn Creek Slate.

The greenstone of both areas is a nondescript dark-gray to greenish-gray, fine-grained, and generally massive rock. No primary structures were recognized.

The contact between the greenstone of the northern area and the overlying Dunn Creek Slate is exposed in the SW¼NW¼ sec. 19, T. 42 N., R. 32 W. The contact seems to be sharp and there is no evidence of interbedding. Neither is there any evidence to indicate a fault or unconformity between the two formations. No sandy or conglomeratic material was observed in the lowest slate bed.

Dunn Creek Slate

The Dunn Creek Slate, overlying the Badwater Greenstone, is exposed only in the northern part of the area (pl. 1 and environs). Exposures are too few to permit subdivision even in this northern area. The beds immediately below the iron-formation, however, are the typical graphitic pyritic slates of the district. Black and gray slates make up most of the exposures. The footwall Dunn Creek Slate was intersected in drill holes in sec. 24, T. 42 N., R 33 W. In holes 204 (SE¼SE¼ sec. 24) and 207 (NE¼NW¼ sec. 24), the diagnostic pyritic slate breccia of the Wauseca Pyritic Member of the Dunn Creek was encountered.

The thickness of the Dunn Creek Slate is uncertain. At the north end of the Alpha-Brule River belt it is no less than several hundred feet and could be as much as 1,000 feet. The thickness at the southeast end of the belt may be very much less, depending on the stratigraphic classification of the outcrops near U. S. Highway 2 on the south side of the Brule River. (See discussion under "Pain River Group, undivided.")

Riverton Iron-Formation

The Riverton Iron-Formation is believed to be present in a belt 500-1,500 feet wide and 5 miles or more long. It is represented by relatively few exposures, and these are small and scattered. The typical exposure, as along the railroad grades in the NW¼ sec. 31, T. 42 N., R. 32 W. (pl. 1), is of thin-bedded dark siderite and black chert, with slaty partings. Oxidation, except for superficial alteration, appears to be restricted to the area of the Delphic mine, and even there it is not extensive. Spotty magnetic anomalies in the belt of iron-formation are revealed by the magnetic survey of the Delphic-Stager area (pl. 1). These probably reflect local magnetite-bearing facies of the iron-formation, but such material has not been specifically located in outcrop.

The most southeasterly exposures of the Riverton Iron-Formation are two small inconspicuous outcrops in the western part of sec. 5, T. 41 N., R. 32 W. (pl. 2). Possibly, however, some of the rock exposed adjacent to U. S. Highway 2 on the south side of the Brule River is of this formation.

The thickness of iron-formation probably is 600-800 feet at the north end of the belt. It apparently diminishes to the southeast.

Hiawatha Graywacke

The Hiawatha Graywacke, which is several hundred feet thick in the Iron River area and which forms a thin but persistent marker bed in the Crystal Falls area, apparently pinches out in the Alpha-Brule River belt. This rock unit was encountered in drill holes in the NW¼ sec. 24, in drill hole 110 in NE¼ SW¼ sec. 24, T. 42 N., R. 33 W., and in a test pit in the SE¼SW¼ of the same section, but the only exposures are in the SW¼SW¼ sec. 31, T. 42 N., R 32 W., and the adjoining part of sec. 6, T. 41 N., R. 32 W. The breccia facies, which is a distinctive part of the formation elsewhere in the district, has not been recognized.

A short distance south of the exposures referred to above, the Riverton Iron-Formation is overlain by slate that is assigned to the Stambaugh Formation. Outcrops in this locality are closely spaced, and it is almost certain that the Hiawatha Graywacke is not present.

Stambaugh Formation

The Stambaugh Formation, although well located in most places by the magnetic anomaly it gives rise to, is not exposed for several miles south of Alpha. The main area of exposure is in the southern part of sec. 31, T. 42 N., R. 32 W., and the adjoining sec. 6, T. 41 N., R. 32 W. (southernmost part of pl. 1 and northernmost part of pl. 2). Most of the rock assigned to the formation is a greenish, fissile, carbonate-bearing slate, with some beds containing appreciable quantities of magnetite. Some graywacke is included, and in a very few places thin beds of porcelanite have been observed. In general, except for their magnetite-bearing parts and their lesser content of graywacke, the rocks are very similar to those of the overlying Fortune Lakes Slate. The flinty gray to mauve slate that characterizes the formation throughout most of the district is not present.

Coinciding with the physical change in the Stambaugh Formation is a change in the character of the magnetic anomaly it produces. The anomaly becomes lower in intensity and much less clearly defined.

A gap of little more than a mile separates the most southeasterly outcrops that can with some certainty be assigned to the Stambaugh from the outcrops on the south side of the Brule River, west of U. S. Highway 2. Some of the strata at the latter locality may belong to the Stambaugh Formation. (See under discussion of "Paint River Group, undivided.")

Fortune Lakes Slate

The Fortune Lakes Slate is exposed in many places along the Alpha-Brule River belt, and outcrops are particularly abundant near the Brule River. The bulk of the rock is nondescript gray slate and fine- to medium- grained graywacke. Porcelanite layers, such as are common in the lower part of the formation farther north, are exposed near the center of the SE¼ sec. 25, T. 42 N., R. 33 W.

The zone of very massive medium- to coarse-grained graywacke, which occurs several hundred feet above the base of the formation in the southern Crystal Falls area, persists in the Alpha-Brule River belt. Throughout the outcrop area adjoining the Brule River, these beds, marked with characteristic quartz veins, are located about 600 feet laterally west or southwest of the Fortune Lakes-Stambaugh contact. As the beds are vertical or practically so, this distance can be considered to define approximately the stratigraphic position of the main zone of massive graywacke in this area.

Paint River Group, undivided

Because of rapid facies changes in several of the formations, stratigraphic assignments in the extreme southeast part of the Alpha-Brule River belt are uncertain and the rocks are shown on the maps as "Paint River Group, undivided". The problem is particularly acute with respect to the rocks exposed immediately south of the Brule River, both east and west of U. S. Highway 2.

Fissile greenish to black slate makes up most of the outcrops. The rock is thinly bedded and locally contains layers of dark chert and siderite. Graywacke is scarce except on the southwest side of the outcrop belt. Much of the slate is weakly magnetic; small chips can be picked up by an Alnico hand magnet. Structurally the beds are nearly vertical. Some tight crumpling is evident, with the axes of minor folds plunging at various angles to the southeast.

The area of slate outcrop is separated from large exposures of Badwater Greenstone to the northeast by only 600 feet of cross-strike distance. Along the strike, to the southeast, is the iron-formation that continues into the Florence area of Wisconsin.

The rocks bear some degree of similarity to those at three widely separated stratigraphic positions in the Paint River Group as it is known to the north. Correlations can possibly be made with the Stambaugh Formation, with certain facies of the Riverton Iron-Formation, and with the iron-rich strata deep in the Dunn Creek Slate east of Alpha.

If the strata are Stambaugh equivalent, then the Riverton Iron-Formation and the Dunn Creek Slate would, unless faulted out, occupy the 600 feet between the outcrops of slate and the nearest outcrop of Badwater Greenstone. No independent evidence exists for a fault. The magnetic anomaly that can be definitely attributed to the Stambaugh Formation several miles to the northwest is continuous into the outcrop area, but it changes greatly in character. To the northwest, where present, it is narrow and sharply defined, whereas in the outcrop area and for about 2 miles to the northwest it is broad and without a sharp crest. A possible interpretation is that only a part of the anomaly is caused by the exposed magnetic slate (Stambaugh? Formation) and the greater part is due to deeply buried Riverton Iron-Formation, which would dip beneath the Stambaugh from a covered outcrop area to the east. This interpretation is not inconsistent with known facts, but it does require that the magnetic facies of the Riverton be confined to the more deeply buried part of that formation.

Iron-formation is known to be present along the strike about 1 mile southeast of the outcrop area, and it is possible the exposed strata are equivalent to some part of the Riverton itself. Again, this would require that more deeply buried parts of the formation be more strongly magnetic.

The possibility of the strata being equivalent to iron-rich rocks in the Dunn Creek Slate, which they do indeed resemble except for magnetite content, seems remote, as such an equivalence would provide no explanation for the magnetic pattern.

Structure

In general, the Alpha-Brule River belt of iron-formation and associated rocks is on the nearly vertical eastern flank of the southeast apex of the Iron River-Crystal Falls basin. The axis of this major structure is perhaps a mile southwest of the belt. Outcrops and drill holes in Riverton Iron-Formation in sec. 34, T. 42 N., R. 33 W., west of the report area, define, at least locally, the position of the southwest flank.

In the northern part of the belt--approximately the Delphic-Stager map area (pl. 1)--the nearly vertical formations are flexed at fairly regular intervals by large-scale drag folds. These folds plunge to the northwest. The general trend of the formations is nearly north. In most places because of the folds, the strike of bedding is about N. 45° W. In the southern part of the area--the Stager Lake area--however, the trend of the formations and the strike of the individual beds are parallel, about N. 45° W. Furthermore, the minor folds generally plunge southeastward, rather than northwestward. It is apparent, therefore, that a structural saddle exists and is located near the south boundary of T. 42 N. North of this line the structural plunge is to the northwest and the basin opens up to encompass the Iron River-Crystal Falls district. South of this line the plunge is to the southeast and the basin opens up into the Florence area of Wisconsin.

Folds and faults

The southernmost of the major northwest-plunging dragfolds is a rather gentle flexure that is reflected neatly by the course of McGovern Creek in sec. 36, T. 42 N., R. 33 W. (pl. 1). A much sharper anticline-syncline couple is present in the northern part of sec. 25, T. 42 N., R. 33 W., although the structure cannot be delineated with much accuracy. The marked magnetic anomaly associated with the Stambaugh Formation, which can be traced northwestward across most of sec. 25, ends in the NW¼ of the section. The magnetic anomaly in the NW¼NE¼ sec. 25, is assumed to be due to the same bed, as is the anomaly in the NW¼SW¼ sec. 24, T. 42 N., R. 33 W. The strike of the beds exposed is consistent with this interpretation. The structure is confirmed to some degree by marked angular divergence between cleavage and bedding in the NW¼ sec. 30, T. 42 N., R. 32 W., which indicates these beds to be near a fold axis.

The abrupt displacement of the formations in the vicinity of the Delphic mine is believed to be due to fault offset rather than to a fold couple. The magnetic anomaly caused by the northwest-trending Stambaugh Formation abruptly terminates in the NW¼SW¼ sec. 24, T. 42 N., R. 33 W., and apparently is displaced into the NE¼SW¼ sec. 24. The offset on the postulated fault--the Delphic fault--is 1,500 feet, with the north side being shifted east.

Slightly more than 1/2 mile north of the Delphic mine, just north of the map area of plate 1, another fault is inferred, with the same direction of offset. Bedrock is not exposed and the area has not been mapped magnetically in this study, but the results of old dip-needle surveys were available from the Michigan Geological Survey. The dip-needle results, coupled with the data from drilling, particularly the data from near the north edge of sec. 24, T. 42 N., R. 33 W., permit a reasonable reconstruction of the geologic pattern. The structure is interpreted as an anticline-syncline couple with a small fault offset along the common limb.

Mines and explorations

As previously mentioned, the Alpha-Brule River belt is one of the longest stretches of nearly nonproductive iron-formation known in the district. The Alpha-Brule River belt is also one of relatively little folding, which is a characteristic of probably significance. Doubtless folds are a prime localizing factor for the deep oxidation and leaching required for the production of ore. Except for relatively small areas around the Delphic mine and at the Wakefield exploration in the center W½NE¼ sec. 25, T. 42 N., R. 33 W., the iron-formation is virtually unoxidized for a linear distance of 5 miles or more.

Should techniques be developed for the economic utilization of low-grade chertsiderite rock (iron content about 25 percent), the area could be of importance. The relatively high ground, thin drift cover, and proximity of the Brule River and of the railroad are all favorable factors (described in more detail on page 126 in Professional Paper 570).

Delphic mine

The Delphic mine, situated on high ground in the NW¼SE¼ sec. 24, T. 42 N., R. 33 W., is one of the older properties in the district. Early exploration prior to the building of the railroad in 1882 consisted of a shaft, some 50 feet deep by 1882, and numerous test pits. Ore was reported in both the shaft and in a crosscut driven from the shaft and in test pits along the strike. Mining began in 1883, and shipments were made each year from 1883 through 1887. A small shipment of 52 tons in 1896 brought the total to 33,770 tons. The mine was operated by W. W. Whittlesey Brothers and Co. of Florence, Wis., lessees of the Delphic Iron Co.

The Nevada Land Co. drilled the Delphic area in about 1911 or 1912. The iron-formation was traced northward from the old Delphic pit into the swamp in the northeastern part of sec. 24. Apparently no ore was found.

The strike of the iron-formation at the Delphic mine is about N. 30° W., as shown by elongation of the caved area and the general distribution of test pits in the vicinity of the mine. The same trend is shown by outcrops of unoxidized iron-formation that occur in the rock cut of the old railroad grade just south of the mine, and, north of the mine, by outcrops along the same grade in the SW¼NE¼ sec. 24. The footwall (Riverton-Dunn Creek) contact is indefinitely located. Test pits reached the graphitic slate (Wauseca Pyritic Member) of the Dunn Creek a short distance southeast of the mine, in the northeastern part of the SW¼SE¼ sec. 24.

Although the iron-formation is traceable northward from the Delphic, it is believed cut off on the south by the Delphic fault, as noted in the previous section. The strike of the fault is about N. 60° W.

The ore at the Delphic is apparently in a bed located somewhere near the middle of the formation. There seems to be no significant structural control of the ore unless it be local crumpling associated with the drag on the nearby Delphic fault. The generally unoxidized character of the iron-formation found in this area and lack of favorable structure, as well as negative results of most of the drilling, lead to the conclusion that no major ore body is present.

Wakefield exploration

The Wakefield exploration lies in the W½NE¼ sec. 25, T. 42 N., R. 33 W. It consists mainly of a group of test pits in which both unoxidized and oxidized iron-formation were encountered. Some drilling is reported to have been done in this area, but no records have been found to indicate when and for whom. Results apparently were unsatisfactory.

# # #

PANOLA PLAINS AREA

The Panola Plains area (pl. 3) comprises about 9 square miles, in T. 42 N., R. 32 W. in the west-central part of the Crystal Falls quadrangle. It lies just east of the main belt of Riverton Iron-Formation that outlines the east margin of the Iron River-Crystal Falls basin. Topographically, the area consists of a low but prominent northerly trending dissected ridge in the central and western parts, west of U.S. Highway 2, and a flat sandy plain--the Panola Plains--on the east. The high ground is mainly bedrock lightly mantled with glacial deposits.

The area has been surveyed by means of a magnetometer in order to delineate several large magnetic anomalies known to exist from prior dip-needle surveys. Outcrops and test pits have been located relative to this survey.

Geology

The rocks underlying the area consist of the Michigamme Slate and Badwater Greenstone of the Baraga Group and the overlying Dunn Creek Slate and Riverton Iron-Formation of the Paint River Group. Two dikelike masses of intrusive granite of post-Paint River age are present in the eastern part of the area.

The Michigamme Slate occurs in the eastern part of the map area and the Riverton Iron-Formation occurs as a fringe in the western part. Neither is well exposed, and for further information on these units and on the granite the reader is referred to U.S. Geological Survey Professional Paper 570 (James, Dutton, Pettijohn, and Wier, 1968). The discussion in this section will be concerned primarily with the Dunn Creek Slate and the structure and magnetic anomalies of the area.

Dunn Creek Slate

In contrast to the few exposures in most parts of the Iron River-Crystal Falls district, the Dunn Creek Slate is exposed in many places in the Panola Plains map area. Probably at least half the known outcrops of the formation are within this area. In part this is due to a greater thickness of the formation and a more varied assemblage of rock types.

Although outcrops of the Dunn Creek are numerous, many of them are small and inconspicuous. Even where abundant, they are too scattered, isolated, and structurally complex to permit accurate subdivision or delineation of structure. Only for the top 200-300 feet, where drilling has provided an unbroken record, is the succession well established.

The rock is slate and lesser amounts of graywacke, siltstone, chert, and siderite, and possibly tuff. The general succession and salient features of the chief subdivisions are given in table 2 (following page). The subdivisions described in detail below are not distinct, sharply defined beds. They appear to grade into one another, and differ from each other only in the proportions of components common to all. It is difficult, therefore, to assign any small isolated outcrop to a stratigraphic position.

Lower cherty black slate: The lowest unit of the Dunn Creek Slate is cherty black slate. This unit is the most extensively exposed and thickest subdivision of the Dunn Creek Slate. The cherty black slate consists principally of dark-gray to black slate, interbedded with which are a few thin layers of chert. The chert rarely forms 5 percent of the rock. The slates are mostly nongraphitic, well laminated, and they show a good slaty cleavage. Outcrops, though numberous, are generally small and unimpressive. Owing to bedding-plane fissility or slaty cleavage and close-spaced jointing, the outcrops are readily reduced by frost action to a jumble of small angular fragments of slate. The chert layers yield white, sugary. and somewhat friable fragments. The chert beds rarely exceed 3 inches in thickness.

The relations between these slates and the underlying Badwater Greenstone are obscure. The contact is exposed in the SW¼NW¼ sec. 19, T. 42 N., R. 32 W., outside the mapped area; and in the SW¼SW¼ of the same section, the cherty black slates are separated from the greenstones by a covered interval less than 50 feet wide.

The highest part of the lower cherty black slate contains more and thicker chert beds, and is characterized by numerous, relatively thick beds (2-10 inches) of iron carbonate and many interbeds of black (and locally graphitic) slate. The chert, like that in the underlying slates, is black and fine grained; it forms both flat nodules and thin continuous layers. It makes up about one-tenth to one-fifth of the rock. The iron carbonate occurs in thicker beds which are nonfissile though conspicuously laminated. The carbonate is gray to nearly black on the fresh surface. It has a hackly to conchoidal fracture and is traversed by thin hairlike veins of white quartz. An analyzed specimen collected from a quarried outcrop near the center of the NW¼SE¼ sec. 7 contained more than 8 percent manganese. The carbonate forms about two-thirds of this unit. Fissile black slate is interbedded with the chert and iron carbonate.

Table 2.--Stratigraphic succession of Dunn Creek Slate, Panola Plains area and vicinity

Unit	Description	Thickness (feet)	Best exposures	Remarks
Wauseca Pyritic Member	Fissile, pyritic, graphitic slate and slate breccia at top.	20-30	Part of outcrop in NW¼NW¼ sec. 7, T. 42 N., R. 32 W.	Very rare exposures. Rapidly deteriorates on exposure; rarely oxidized.
Sericitic slate siltstone	Silty gray slate interbedded with graphitic, pyritic slate; locally contains chert disks.	45	Old railroad grade, SW¼NE¼ sec. 13, T. 42 N., R. 33 W.	Localities outside Panola Plains map area; known mainly from drilling.
	Mainly silty, gray, sericitic slates and fine-grained silty graywacke; locally heavy beds, coarse massive graywacke.	100-250	Massive graywackes exposed NE¼ sec. 32, T. 43 N., R. 32 W.; NW¼ sec. 31, same township.	
Upper cherty black slate	Crumpled, interbedded thin layers of chert, siderite, and black slate.	100-500	Old railroad grade SW¼SW¼ sec. 6, T. 42 N., R. 32 W.	A lean nonproductive iron-formation
Laminated slate	Laminated to "striped" slates, rarely cherty; pronounced bedding commonly at high angle to slaty cleavage.		NE¼SW¼ sec. 7, T. 42 N., R. 32 W.; N½N½ sec. 18, same township.	Locally outcrops are conspicuous; a distinctive slate.
Lower cherty black	Crumpled, interbedded thin layers of chert, siderite, and black slate.	100-200	Road "Y", NW¼SE¼ sec. 7, T. 42 N., R.32 W.	A lean nonproductive iron-formation; carbonate beds rich in manganese (up to 8 percent).
	Fissile, nongraphitic black slate with a few thin chert beds.	700-800	Sec. 6, T. 42 N., R. 32 W.; along County Highway 424 in sec. 7, same township.	Most common outcropping phase of footwall slates; chert makes up less than 5 percent of rock.

Much of it appears to be graphitic and pyritic.

Owing to the iron-rich characteristic of some of the beds, the weathered fragments tend to be limonite coated. The rusty-brown to mustard-yellow fragments resemble rather closely those produced by surficial oxidation of the productive iron-formation of the area. This iron-rich member of the footwall series has been, therefore, locally test pitted and recorded in field notes as "iron-formation". It is, in fact, a lean iron-formation which so far as known is nonproductive. It is generally closely folded and crumpled and, although neither its top nor its bottom is well defined, the bed is not more than 200 feet thick and may not exceed half this amount.

In the southern part of sec. 16, and adjacent parts of sec. 21 to the south, dozens of test pits have been sunk in rock that presumably is part of the lower cherty black slate unit. The material thrown out of most of the pits is cherty black slate or its oxidized equivalent. Several of the pits, however, were sunk in a tuffaceous-appearing rock that probably is from near the inferred base of the formation. In some of the pits located higher stratigraphically--that is, more westward--some oxidized iron-formation as well as the black slate was penetrated. This rock probably is about equivalent to that in the outcrops near the center of the NW¼SE¼ sec. 7

The lower cherty black slates, including the cherty and iron-rich beds, are approximately 1,000 feet thick. They constitute fully half the entire Dunn Creek Slate.

Laminated slate overlying the cherty black slate is a strikingly banded or striped slate. The weathered surface of outcrops show contrasting light-to dark-coffee-brown bands, which alternate with light-grayish-green to buff-colored bands of like or greater width. The latter show very delicate paper-thin laminations. The freshly broken rock is dark gray to black, and it is, therefore, unique in that it is the only part of the formation that weathers to a color lighter than that of the fresh rock. Apparently the coffee-brown layers contain a little siderite which upon oxidation becomes dark. Little or no chert is associated with this member.

The bedding is very commonly obliquely cut by well-developed slaty cleavage. These two directions of parting plus close-set joints yield rhomb-shaped fragments. These banded rhombohedral blocks, and the absence of chert, make the laminated slate one of the most distinctive units in the Dunn Creek Slate.

This unit is probably several hundred feet thick. As shown on plate 3, it has been traced from the northern part of sec. 18 northward through secs. 6 and 7 to Dunn Creek. From this point it apparently can be traced southeastward back into sec. 6, across the southwestern part of sec. 5 and into sec. 8. In a test pit near the southwest corner of sec. 9--possibly near the axis of a major syncline--similar rock was encountered.

Upper cherty black slate: Overlying the laminated slate unit is cherty black slate similar in almost all respects to the lower cherty black slate. It consists mainly of black slate, iron-rich slate, and chert. In places it contains enough chert and siderite to be virtually iron-formation, and is similarly crumpled. The rock is well exposed along the old railroad grade in the SW¼SW¼ sec. 6. The thickness is difficult to estimate, as the rock is exposed in only a few places; it may be as much as 500 feet, but probably is much less.

Sericitic slate-siltstone and Wauseca Pyritic Member: Most of the information concerning the two uppermost units of the Dunn Creek Slate--the sericitic slate-siltstone sequence and the pyritic slate of the Wauseca Pyritic Member--comes from drilling adjoining areas of active mining to the west. The sericitic slate and siltstone are light- to dark-gray rocks, commonly thinly bedded or laminated. In places the sequence contains beds of coarse-grained dark graywacke. The sequence is several hundred feet thick. Drilling shows the thickness of the graphitic and pyritic slate, the Wauseca Pyritic Member, to be about 20-30 feet. This Wauseca grades downward into a laminated slate consisting of thin seams of black graphitic slate that alternate with a fissile gray slate which contains small disk-shaped chert nodules. These beds in turn grade downward into gray sericitic slate and silty graywacke. Because of its high content of fine-grained pyrite the Wauseca Pyritic Member deteriorates rapidly when exposed to air and rarely is seen in outcrop.

Within the map area, two drill holes (3 and 52) in the SW¼SW¼ sec. 7 cut pyritic black slate that probably is part of the Wauseca Pyritic Member. Hole 3 was part of the Cheney exploration of the Hollister Mining Co. and was drilled in 1919. Hole 52 was drilled by E. J. Longyear in 1913. None of the core could be located for examination. Hole 53 of the Longyear exploration is recorded as having entered pyritic carbonate slate at ledge surface and as having ended at 100 feet in cherty carbonate slate and pyritic black slate. Very likely it was in the upper cherty black slate unit, stratigraphically below the sericitic slate and siltstone. The two most southerly exposures in the NW¼NW¼ sec. 7 probably are mainly in the sericitic slate and siltstone sequence, with some infolded or interbedded pyritic slate of the Wauseca Pyritic Member.

The contact of the Wauseca Pyritic Member with the overlying iron-formation is abrupt and shows very little interbedding.

Magnetic anomalies

The Panola Plains area was surveyed magnetically by W. C. Prinz and K. L. Wier during the winter of 1955-56. Approximately 4,600 determinations were made by Schmidt-type vertical magnetometers. In general, readings were taken at 100-foot paced intervals along traverse lines 300 feet apart. The values were reduced to an arbitrary zero datum, with a value of approximately 57,700 gammas of vertical intensity. (A station established by the U.S. Bureau of Mines in the SE¼SW¼ sec. 9. T. 42 N., R. 32 W., has an absolute value of 58,380 gammas.)

The survey reveals a large magnetic anomaly that crosses the area from the southeast to the northwest. It diminishes to very small values at the south end, but the north end is known from dip-needle surveys to continue for about one mile beyond the limit of the map area of pl. 3. The total length, therefore, is about 5 miles, along which there are five principal nodes, having peak intensities of from several hundred to nearly 3,000 gammas.

The breadth of the anomaly--about 1 mile in most places--and the smoothness of the contours are in striking contrast to the narrow sharply defined linear anomalies produced by the Stambaugh Formation and by parts of the Riverton Iron-Formation elsewhere in the district. Estimates based on the magnetic data indicate probable depths of the magnetic rocks to be from 1,000 to possibly 2,000 feet in the northeastern part of sec. 17, about 500 feet in the vicinity of the steep magnetic gradient in the northeastern part of sec. 7, and from about 1,000 to 1,500 feet along the magnetic highs through sec. 6.

No entirely satisfactory interpretation of the magnetic anomaly can be given. On first consideration it might seem that some degree of concordance exists between the anomaly and the distribution of the lower part of the Dunn Creek Slate. Closer inspection shows, however, that the anomaly crosses structural and stratigraphic trends. A relationship to the Dunn Creek Slate is further negated by the probable depth to the magnetic unit and by the fact that none of the rather extensive exposures of the Dunn Creek Slate are noticeably magnetic.

Two possible explanations are suggested:

First explanation: The anomaly could be caused by a buried magnetic part of the Badwater Greenstone.The body would necessarily have to be a lens that would begin at depth on the west flank of the Mastodon anticline, continue around the north-plunging nose of that structure, and terminate approximately at the axis of the Tim Bowers Creek snyncline. The lens thus would be at least 3 miles in horizontal extent, with the "updip" edge reaching locally to within 500 feet of the present surface. The dimension in the downdip direction would be indicated only by the northward extension of the anomaly on the plunge of the Mastodon anticline; in that particular cross section it would be a minimum of about 3 miles. The presence of such a bed at depth, folded with the other units, would explain the peculiar local coincidence of the anomaly with surface structure that can be observed in a number of places.

In support of this explanation, it can be noted that elsewhere in the district the Badwater Greenstone contains lenses of magnetic rock that yield strong local magnetic anomalies. Against this cause is the considerable degree of coincidence required between original form and later structure. Also, such a lens would not account for the fact that the anomaly does continue to the south, though in modified intensity.

Second explanation: The anomaly could be due to an intrusive mass that does not reach the present surface. Clearly the granite does not give rise to magnetic anomalies--as can be seen from the map, the large dikelike body near Little Tobin Lake is entirely without magnetic expression. Metadiabase, however, is known to yeild somewhat comparable anomalies in the northern part of the Iron River area (James, Dutton, and Wier, 1967) and in the Round Lake area (James, Pettijohn, and Clark, 1969?).

At the present time, there seems little basis for choice between the two alternative explanations, although the first seems somewhat more reasonable. It is possible, of course, that the anomaly is due to other unknown bodies of rock--the uppermost part of the Michigamme Slate, for example, locally contains magnetic rock. Perhaps the anomaly does not have a single explanation, but results from a combination of causes.

Structure

The two principal structures in the area have already been mentioned--the Mastodon anticline and the Tim Bowers Creek syncline.

The Mastodon anticline, constituted of a core of Badwater Greenstone outlined by the laminated slate unit of Dunn Creek Slate, is reasonable well defined. It plunges north or northwesterly at what, on the average, must be a relatively low angle. Rocks tightly crumpled along northwest-trending axes in the general axial zone of the anticline are well displayed in outcrops along County Road 424, in the eastern part of sec. 7 and western part of sec. 8. In outcrops 100 feet or more long, measured strikes in the lower cherty black slate of the Dunn Creek are northwest, but the trend of bedding is northeast. The general pattern of dragfolds, indicated by the approximate boundaries of the laminated slate unit of the Dunn Creek (pl. 3), is consistent with a northerly plunging anticline.

The Tim Bowers Creek syncline, however, is almost entirely inferred, and its possible existence is supported by very little direct evidence. The argument for this structure is wholly one of regional geology. In U.S. Geological Survey Professional Paper 570 (James, Dutton, Pettijohn, and Wier, 1968), it has been shown that the greenstone in the Mastodon anticline is continuous to the southeast with greenstone that has been demonstrated to overlie the Michigamme Slate. The stratigraphic position of the greenstone (Badwater) is established, therefore, as being between the Michigamme Slate and the Dunn Creek Slate. The northern termination of greenstone in sec. 17, T. 42 N., R. 32 W., as reviewed above, is the nose of a principal anticline, on which Badwater Greenstone is flanked on the west, north, and east by Dunn Creek Slate. The stratigraphic horizon allocated to the Badwater must necessarily turn and swing to the north if it is to separate the Michigamme and Dunn Creek Slates. The complete absence of exposed greenstone on the east flank of the inferred syncline--and the rock is prone to outcrop if present--is interpreted as being due to a rapid pinchout of the formation. In what is believed to be a comparable situation, the mile-wide belt of Badwater Greenstone north of Crystal Falls pinches out to the east in a distance of about 2 miles. The map patterns of these bodies of greenstone, with bedding now vertical or nearly so, are cross sections of the original volcanic piles. The 6-mile gap between the eastern termination of the greenstone north of Crystal Falls and that of the Mastodon belt is believed simply to reflect lack of coalescence, at the present erosion surface, of contemporaneous volcanic accumulations.

Exposures are few within the synclinal area, and the many test pits that have been sunk are slumped, making structural data impossible to obtain. Some degree of confirmation that a major structural axis is present is gained from the outcrop of cherty black slate along the railroad grade in the NE¼SE¼ sec. 17, T. 42 N., R. 32 W. Although individual beds of the outcrop strike northwest and are nearly vertical, a single thin layer of chert can be traced over innumerable minor folds for almost the whole length of the outcrop. The general trend of bedding, therefore, is northeast.

As has been mentioned in U.S. Geological Survey Professional Paper 570 (James, Dutton, Pettijohn, and Wier, 1968), it is the opinion of one of us (FJP) that a wholly different, and more likely, interpretation can be made of the structure in the eastern part of the Panola Plains area. The main postulate of this alternate interpretation is that the granitic bodies near Little Tobin Lake and Railroad Lake, together with two dikelike bodies farther north, would be aligned along a major north-trending fault. This fault would terminate in the north at the Cayia fault and to the south would pass between Badwater Greenstone and strata of the Paint River Group near the center of sec. 9, T. 41 N., R. 32 W. The area east of the postulated fault would be underlain wholly by Michigamme Slate, structurally discordant with younger rocks west of the fault. The Badwater Greenstone, instead of being mostly a continuous body as now shown on the maps, could well reach bedrock surface on a series of anticlines comparable to that of sec. 19, T. 42 N., R. 32 W., and adjoining areas. The Mastodon anticline would remain as the principal structure in this series, but the almost wholly inferred Tim Bowers Creek syncline would be eliminated. Instead, the broad magnetic anomaly that in the present map interpretation centers near the axis of the inferred syncline, could be interpreted as reflecting a buried anticline of Badwater. This interpretation also would eliminate the inferred and unlikely-appearing northward extension of Badwater on the east flank of the Tim Bowers Creek "syncline"; the fault would separate Michigamme Slate on the east from Dunn Creek Slate on the west.

The concept of a major structural break with attendant alternative possibilities for distribution of the various map units, though not accepted by a majority of the authors of this report and of U.S. Geological Survey Professional Paper 570 (James, Dutton, Pettijohn, and Wier, 1968) as the most probable interpretation, assuredly cannot be dismissed without further consideration. It does not conflict with the available geologic facts, and in some ways it provides a more reasonable explanation for some of them. It deserves consideration, therefore, as a recognized and satisfactory alternative to the interpretation now shown on the geologic maps.

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