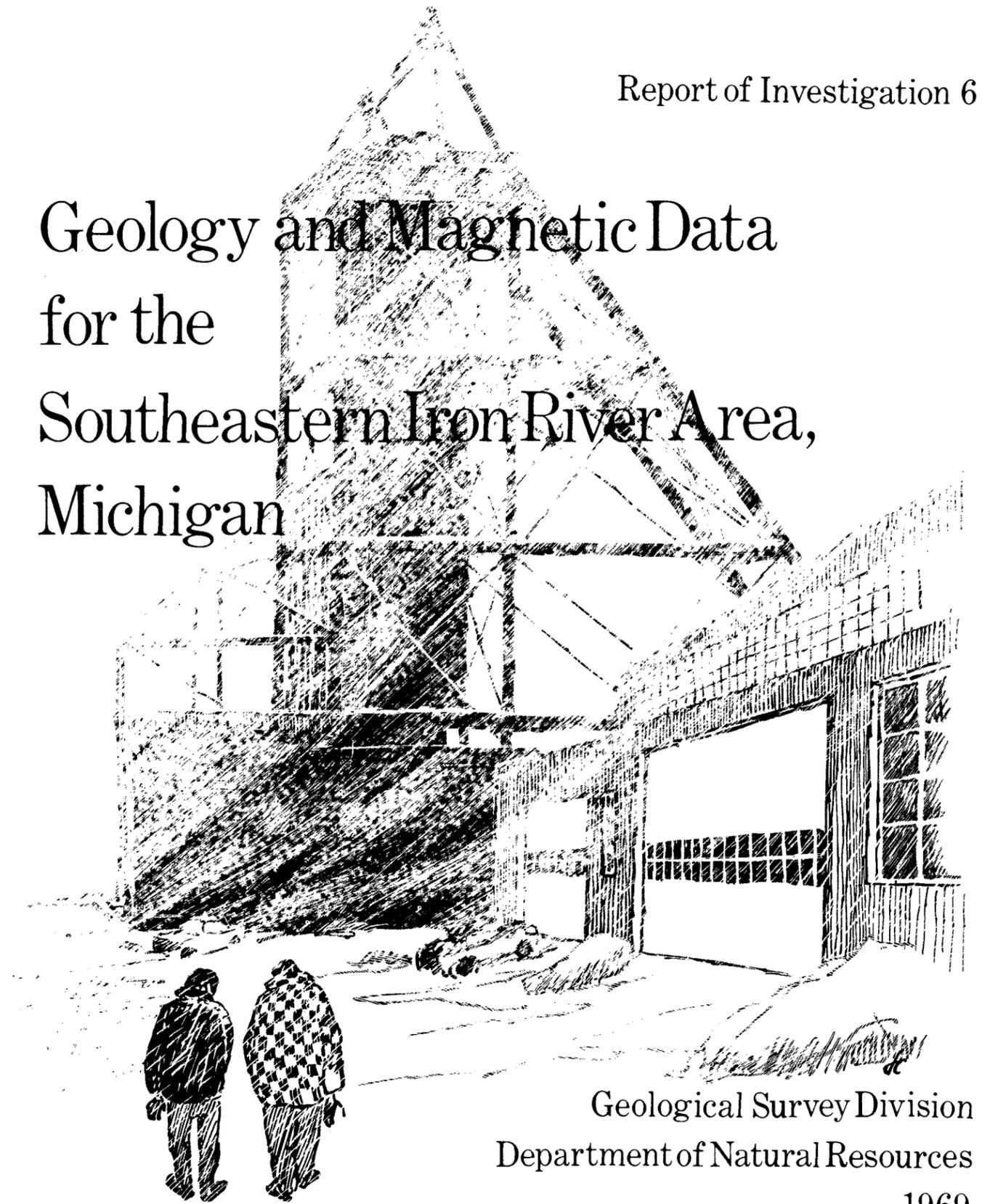


Report of Investigation 6

Geology and Magnetic Data  
for the  
Southeastern Iron River Area,  
Michigan



Geological Survey Division  
Department of Natural Resources

1969

State of Michigan  
Department of Natural Resources



Geological Survey

---

Report of Investigation 6

---

GEOLOGY AND MAGNETIC DATA FOR SOUTHEASTERN  
IRON RIVER AREA, MICHIGAN

by  
H. L. James and K. L. Wier

*Prepared in cooperation with the  
Geological Survey  
United States Department of the Interior*

Front cover:

*The Cannon mine, located just east of Stambaugh.  
Opened in 1955 to develop extensions of the Bangal and  
Tully ore bodies--part of which contained considerable  
manganese--the mine produced about 5 million tons of  
ore and then closed down in 1962.*

Lansing, 1969  
*Originally scheduled for publication in 1968*

STATE OF MICHIGAN  
William G. Milliken, *Governor*

DEPARTMENT OF NATURAL RESOURCES  
Ralph A. MacMullan, *Director*

GEOLOGICAL SURVEY DIVISION  
Gerald E. Eddy, *State Geologist and Chief*

COMMISSION OF NATURAL RESOURCES

August Scholle, *Chairman, Detroit*, 1961, 1966-70  
Carl T. Johnson, *Grand Rapids*, 1963-71  
E. M. Laitala, *Hancock*, 1961-70  
Robert C. McLaughlin, *Detroit*, 1963-72  
Harry H. Whiteley, *Rogers City*, 1961-69  
Samuel A. Milstein, *Executive Assistant*



Published by Authority of State of Michigan CL '48 s. 321.6  
Printed by Speaker-Hines & Thomas Inc., Lansing, December 1969

Available from Publications Room, Dept. of Natural Resources, Lansing, Michigan  
Also deposited in public libraries

48926  
\$2.00

PREFACE

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

Field investigations of the Iron River-Crystal Falls district were 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 provided maps and records and permitted 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.

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

H. L. James  
K. L. Wier  
*Geologists, U.S.G.S.*

| ILLUSTRATIONS     |  | <i>page</i> |                                 |
|-------------------|--|-------------|---------------------------------|
| <i>In Pocket:</i> |  | iii         | PREFACE 17                      |
|                   |  | 1           | ABSTRACT 17                     |
|                   |  | 1           | INTRODUCTION 17                 |
|                   |  | 2           | BAKER CREEK AREA 18             |
|                   |  | 2           | Geology 19                      |
|                   |  | 2           | Mines 19                        |
|                   |  | 2           | Rogers 20                       |
|                   |  | 3           | ,Baker 20                       |
|                   |  | 4           | Cannon 20                       |
|                   |  | 5           | Delta 22                        |
|                   |  | 5           | Riverton (Iron River) 22        |
|                   |  | 5           | Isabella 22                     |
|                   |  | 6           | Cyr 22                          |
|                   |  | 6           | Lennox 22                       |
|                   |  | 6           | Barras 23                       |
|                   |  | 7           | Bengal 23                       |
|                   |  | 8           | Tully 23                        |
|                   |  | 8           | Explorations 23                 |
|                   |  | 8           | Town 43 North, Range 34 West 24 |
|                   |  | 8           | Section 19 24                   |
|                   |  | 8           | SE $\frac{1}{4}$ 24             |
|                   |  | 8           | Section 20 25                   |
|                   |  | 8           | SW $\frac{1}{4}$ 25             |
|                   |  | 8           | SE $\frac{1}{4}$ 25             |
|                   |  | 9           | Section 29 25                   |
|                   |  | 9           | NW $\frac{1}{4}$ 26             |
|                   |  | 9           | NE $\frac{1}{4}$ 26             |
|                   |  | 10          | SW $\frac{1}{4}$ 28             |
|                   |  | 10          | SE $\frac{1}{4}$ 28             |
|                   |  | 10          | Section 30 28                   |
|                   |  | 11          | N $\frac{1}{2}$ 28              |
|                   |  | 11          | SE $\frac{1}{4}$ 28             |
|                   |  | 11          | SW $\frac{1}{4}$ 29             |
|                   |  | 11          | Section 31 29                   |
|                   |  | 12          | N $\frac{1}{2}$ 29              |
|                   |  | 12          | SW $\frac{1}{4}$ 29             |
|                   |  | 14          | Section 32 30                   |
|                   |  | 14          | NW $\frac{1}{4}$ 30             |
|                   |  | 14          | NE $\frac{1}{4}$ 30             |
|                   |  | 15          | SW $\frac{1}{4}$ 30             |
|                   |  | 15          | Town 43 North, Range 35 West 30 |
|                   |  | 15          | Section 25 30                   |
|                   |  | 15          | NW $\frac{1}{4}$ 30             |
|                   |  | 15          | NE $\frac{1}{4}$ 30             |
|                   |  | 15          | SW $\frac{1}{4}$ 30             |
|                   |  | 15          | SE $\frac{1}{4}$ 30             |
|                   |  | 16          | Section 36 30                   |
|                   |  | 16          | NW $\frac{1}{4}$ 30             |
|                   |  | 16          | NE $\frac{1}{4}$ 30             |
|                   |  | 16          | SW $\frac{1}{4}$ 30             |
|                   |  | 16          | SE $\frac{1}{4}$ 30             |
|                   |  |             | GAASTRA AREA 17                 |
|                   |  |             | Geology 17                      |
|                   |  |             | Mines 17                        |
|                   |  |             | Dober 17                        |
|                   |  |             | Caspian 17                      |
|                   |  |             | Cottrell 18                     |
|                   |  |             | Buck Group 18                   |
|                   |  |             | <i>Berkshire</i> 19             |
|                   |  |             | <i>Forgarty</i> 19              |
|                   |  |             | <i>Buck</i> 20                  |
|                   |  |             | <i>Youngs</i> 20                |
|                   |  |             | <i>Baltic</i> 20                |
|                   |  |             | <i>Zimmerman</i> 22             |
|                   |  |             | <i>DeGrasse</i> 22              |
|                   |  |             | Explorations 22                 |
|                   |  |             | Town 42 North, Range 34 West 22 |
|                   |  |             | Section 5 22                    |
|                   |  |             | Section 6 23                    |
|                   |  |             | NW $\frac{1}{4}$ 23             |
|                   |  |             | NE $\frac{1}{4}$ 23             |
|                   |  |             | SW $\frac{1}{4}$ 23             |
|                   |  |             | SE $\frac{1}{4}$ 24             |
|                   |  |             | Section 7 24                    |
|                   |  |             | NE $\frac{1}{4}$ 24             |
|                   |  |             | NW $\frac{1}{4}$ 25             |
|                   |  |             | SW $\frac{1}{4}$ 25             |
|                   |  |             | SE $\frac{1}{4}$ 25             |
|                   |  |             | Section 8 25                    |
|                   |  |             | N $\frac{1}{2}$ 26              |
|                   |  |             | S $\frac{1}{2}$ 26              |
|                   |  |             | Section 18 28                   |
|                   |  |             | Town 42 North, Range 35 West 28 |
|                   |  |             | Section 1 28                    |
|                   |  |             | NE $\frac{1}{4}$ 28             |
|                   |  |             | NW $\frac{1}{4}$ 28             |
|                   |  |             | SW $\frac{1}{4}$ 29             |
|                   |  |             | SE $\frac{1}{4}$ 29             |
|                   |  |             | Section 12 29                   |
|                   |  |             | REFERENCES CITED 30             |

GEOLOGY AND MAGNETIC DATA  
FOR  
SOUTHEASTERN IRON RIVER AREA, MICHIGAN

Abstract

The Southeastern Iron River Area comprises about 13 square miles immediately southeast of the city of Iron River and includes the towns of Stambaugh, Caspian, and Gaastra. Badwater Greenstone of the Baraga Group occupies the extreme southwest part of the area and is stratigraphically overlain by the Dunn Creek Slate, Riverton Iron-formation, Hiawatha Graywacke, and Stambaugh Slate of the Paint River Group. The area is within the western part of the Iron River-Crystal Falls synclinatorium and, as marked by the Riverton Iron-formation, both the north and south limbs of that structural feature are present. Regional geologic trends are easterly to southeasterly, but strong cross folds result in long anticlinal and synclinal projections of the geologic units. Isolated downfolds of the Stambaugh Formation, as reflected by strong magnetic anomalies, are common.

Areas of outcrop, partial extent of mine workings, drill-hole information, and magnetic survey data are shown on two geologic maps: one for the Baker Creek area to the north and the other for the Gaastra area to the south. A brief history, description of ore bodies, and production for each mine, and descriptions of known explorations are given.

Iron ore shipments from twenty some mines or properties in the Southeastern Iron River Area totaled about 50 million tons. All mines are currently inactive.

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 fig. 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 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 southeastern Iron River area have appeared as preliminary reports by James, Clark and Smith

(1947) and James and Wier (1948).

The southeastern Iron River area is covered by two map sheets; the Baker Creek area (plate 1) on the north, and the Gaastra area (plate 2) on the south. The stratigraphic sequence of rock units in the two areas is shown on table 1.

Table 1 -- Rock units in Southeastern Iron River area

|             |                    |                     |                   |                         |
|-------------|--------------------|---------------------|-------------------|-------------------------|
| Precambrian | Middle Precambrian | Animikie Series     | Paint River Group | Stambaugh Formation     |
|             |                    |                     |                   | Hiawatha Graywacke      |
|             |                    |                     |                   | Minor unconformity      |
|             |                    |                     |                   | Riverton Iron-formation |
|             |                    |                     | Dunn Creek Slate  |                         |
|             | Baraga Group       | Badwater Greenstone |                   |                         |

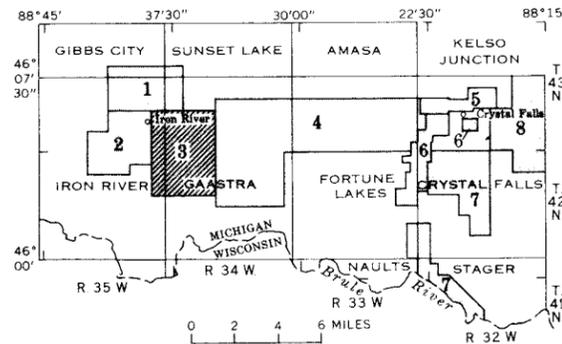


Figure 1 -- Location and index maps

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. Shading delineates area of this report, 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. 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

BAKER CREEK AREA

The Baker Creek map area (plate 1) occupies about 7 square miles in the western part of the Iron River-Crystal Falls district. It includes the town of Stambaugh. Several mines, all now inactive, have been developed in the area--the Delta, Riverton, Isabella, Cyr, Lennox, Barras, Bengal, Tully, Cannon, Baker, and Rogers--of which the Riverton, Bengal, Cannon, and Rogers were major producers. Only the Bengal mine was accessible for mapping during the period of field work. Brief inspection trips were made in the Cannon mine during its period of operation.

Most of the area has been surveyed magnetically, by use of a Superdip oriented in a E-W position, sigma 1 1/2°, or by use of a Schmidt-type vertical-component magnetometer. In general, measurements were made at 100-foot intervals along lines spaced 300 feet apart.

The only outcrops in the area are in the town of Stambaugh. Magnetic slate (Stambaugh Formation) is exposed in several outcrops in the SW 1/4 NW 1/4 and NW 1/4 SW 1/4 sec. 36, T43N, R35W. Graywacke and graywacke with chert fragments, assigned to the Hiawatha Graywacke, are exposed along the road extending down the hill in the SW 1/4 NW 1/4 sec. 36. Near the extreme west margin of the map area, an outcrop of Riverton Iron-formation represents the initial discovery of iron in the Iron River-Crystal Falls district. Iron-formation also is exposed at the margins of the old open pits of the Riverton and Isabella mines.

Geology

The map area is part of the west portion of the Iron River-Crystal Falls basin, as marked by the Stambaugh Formation. The Stambaugh, reflected by strong magnetic anomalies, forms long synclinal projections in the eastern part of the area. The entire area is marked by deep isolated downfolds of this magnetic unit. These separated basins, revealed by oval to irregular-shaped magnetic anomalies, are the most characteristic feature of the geology. The orientation of the magnetic anomalies shows folds of both northerly and westerly trend and of about equal importance; these comprise the "radial" (westerly) and "peripheral" (northerly) sets referred to in discussions of the structural habit of the district in U.S. Geological Survey Professional Paper 570 (James and others, 1968).

The rest of the area, so far as it is known, is underlain mostly by Hiawatha Graywacke and Riverton Iron-formation; Dunn Creek Slate occurs only locally in the western,

southwestern, and northeastern parts of the map area. The Hiawatha Graywacke and Riverton Iron-formation are deeply oxidized in the area of the Rogers mine, in the Cannon-Tully-Bengal area in the SE 1/4 sec. 36, and in the Isabella-Riverton belt along the western margin. Elsewhere, particularly in the belt of Riverton east, south, and west of Ice Lake, the iron-formation is unoxidized.

Mines

Rogers

The Rogers mine is in the NE 1/4 sec. 29, T43N, R34W. The shaft, a four-compartment structure about 500 feet deep, is in the SW 1/4 NE 1/4. It was opened in 1912 by the Munro Iron Mining Co., and the first ore was shipped in 1914. The property was later taken over by the M. A. Hanna Co., which shipped ore each season except 1921 and 1934 until the mine was closed in 1937. Further shipments were made from stockpile in 1940, 1941, 1942, and 1945. The ore consisted in part a firm red non-Bessemer hematite, and in part a hard red manganiferous hematite. Total shipments were 2,907,375 tons.

The mine was opened and operated under unusually difficult conditions. The overburden, which is about 150 feet thick, consists of water-soaked sand, necessitating the use of air-tight compression chambers in shaft sinking. Drainage sublevels were driven above the two main levels to reduce the flow of water into the ore bodies. The mine is now filled with water, information regarding the geology and occurrence of ore is from company records.

The ore was developed from two main levels, the deepest being about 450 feet below the surface. The 1st level is shown on fig. 2. The main ore body, which is about 800 feet long and about 300 feet wide at the 1st level, is located near the nose of a westward-plunging syncline. In a broader sense, however, the belt of iron-formation containing the ore body is the west flank of a north-trending anticlinal cross fold interrupting a west-trending syncline. The footwall Dunn Creek Slate bounding the ore body on the east side is along the axis of the cross fold, the nose of which appears to merge with a west-trending anticline in the northern part of the workings. The 1st level workings that enter the Schiebler property (NE 1/4 NE 1/4) cross this anticline and intersect iron-formation to the north. The nose of the north-trending anticline appears to have been crossed in the extreme northeast part of the workings.

The major ore body, as shown in part by the stoped areas, rested directly on the west-

dipping footwall, reaching its maximum development along the major synclinal axis. Little is known of the occurrence of manganese other than the ore appears to lie in the upper part of the iron-formation (fig. 2). The ore is high in sulfur, typically containing 0.250-0.330 percent. Water is also a problem. These are the reasons the mine was closed. The ore itself is likely to continue to considerable depth.

A belt of iron-formation is inferred a short distance east of the Rogers mine workings, between the footwall slate and the younger strata giving rise to the strong magnetic anomaly in the eastern part of sec. 29 (plate 1). To explain the westward extension of the anomaly into an area assumed to be underlain by either iron-formation or rocks stratigraphically immediately above the iron-formation, the north-trending structure is assumed to be overturned with magnetic rocks present at depth (see cross section on fig. 2). The relation could equally as well be explained on the basis of a north-trending fault.

A narrow dike, trending N60W is reported to have been crossed on the 1st level. It apparently cuts part of the ore body and seems to have exerted little or no influence in localization of the ore.

Baker

The Baker mine, in the SW 1/4 SW 1/4 sec. 31, T43N, R34W, was opened in 1909 by Corrigan, McKinney Steel Co. and shipped a total of 267,107 tons through 1915, except for 1912. After 1911, the ore was hoisted through the Tully Shaft, adjacent to the west. The ore is described as "soft, red, non-Bessemer hematite". The property is now held by the M. A. Hanna Co.

The mine was developed on four levels to a depth of about 550 feet below surface. The shaft is caved and the workings completely inaccessible and, except for the outlines of the workings, very little is known of the mine. No geologic maps are available, nor could any lithologic description be found of the material cut by the underground drill holes. The plan of the 3rd level workings is shown in small scale on plate 1.

Available records do not indicate footwall slate (Dunn Creek) was encountered in any part of the underground workings or drill holes. Most likely the rock is mainly the stratigraphically upper (slaty) part of the Riverton Iron-formation. In the southwestern part of the workings, the ore continued toward the southwest and was mined as part of the combined

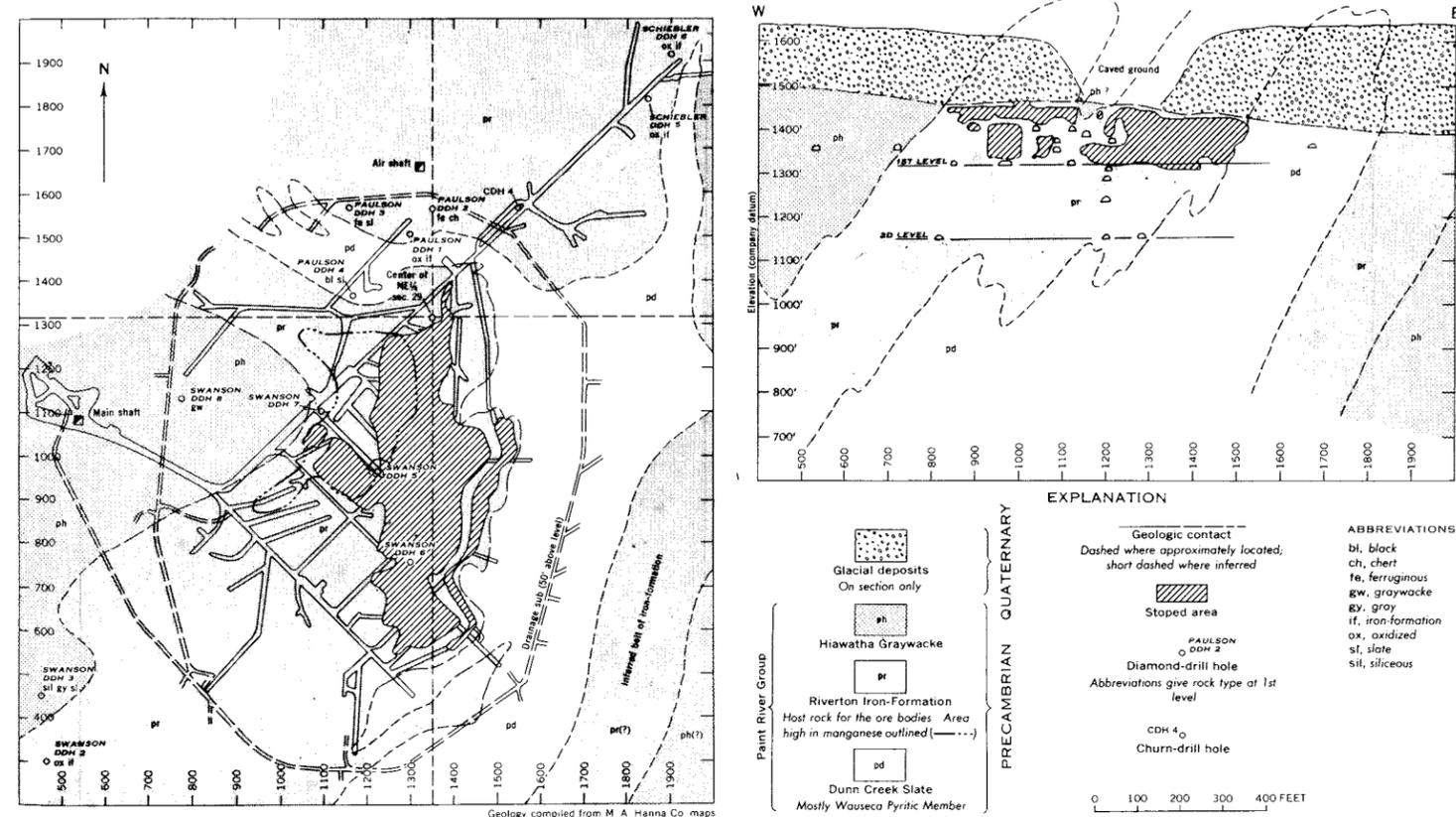


Figure 2--Rogers mine, sec. 29, T43N, R34W. Plan of 1st level and cross section along coordinate 900 N.

Tully-Baker operation.

### Cannon

The Cannon mine, with a shaft in the NW $\frac{1}{4}$  SW $\frac{1}{4}$  sec. 31, T43N, R34W., has its main workings in the SE $\frac{1}{4}$  sec. 36, T43N, R35W. The mine, opened in 1953 by the M. A. Hanna Co. to further develop the areas of the old Tully and Bengal mines in the SE $\frac{1}{4}$  sec. 36, operated on four main levels, the lowest of which, the 9th, is at a depth of about 1450 feet. The mine was opened after active field work in the area by the U.S. Geological Survey had ceased, so most of the information is from company records supplemented by observations made during a few inspection trips underground. The operation was shut down in 1962, and the workings are now flooded.

For the period 1953-63, a total of 4,894,517 tons of ore was shipped. A substantial part of this tonnage was high-manganese ore taken from the area of the old Bengal mine, which was an earlier producer of similar high-manganese ore.

The geology and occurrence of ore in the NE $\frac{1}{2}$  SE $\frac{1}{4}$  sec. 36 are discussed elsewhere in this report (see "Bengal mine"). In essence, the ore mined at lower levels in the northwestern part of the Cannon mine is the downward continuation of that in the Bengal mine; it is a manganese-rich ore at the nose of a north-plunging anticline.

A major part of the Cannon production has been from the old Tully properties, in the S $\frac{1}{2}$  SE $\frac{1}{4}$  sec. 36. The early workings in this area were from the three Tully shafts, which connected to the Baker shaft in sec. 31, the deepest level being at a depth of about 700 feet. The area was entered from the Cannon shaft with main levels at depths of about 860 feet (6th), 1060 feet (7th), 1260 feet (8th), and 1460 feet (9th). Despite the extensive workings through a vertical range of more than a quarter mile, the geology remains only poorly known. The bewildering complexity results partly from the fact that the lower part of the Riverton in this area is a thick mass of chaotic chert breccia, similar in most respects to the chert breccia at the base of the overlying Hiawatha Graywacke, and it is partly due to extremely tight folding along axes of strongly divergent trends. Furthermore, because of the lack of a clearcut footwall contact, the ore bodies do not as clearly outline structure as elsewhere in the district. The Cannon levels have been mapped carefully and in detail by geologists of the M. A. Hanna Co., but many aspects of the structural pattern will probably remain unsolved; the ultimate structural complexity of the Iron River-Crystal Falls district probably is reached in these two "forties".

The geology at bedrock surface in sec. 36 (plate 1) is highly generalized, but probably adequately depicts the general structure. Viewed broadly, the ore bodies occur in structures flanking a complex north-trending anticline, the nose of which is reflected in the form of the ore body in the Bengal mine. Even if the general structure is correct, the Dunn Creek Slate may have much less expression than indicated at the bedrock surface because the only positively identified "footwall" strata occurred on the 6th level, a few hundred feet southeast of the center of the SE $\frac{1}{4}$ . Much of the rock classed as Dunn Creek Slate may actually be the dark chert breccias and slaty iron-formation in the lower part of the Riverton.

The principal ore bodies mined in the old Tully mine were west of the No. 1 and No. 2 shafts, on the west flank of the inferred central anticline; these persist as relatively small bodies to depths in excess of 1400 feet. The main ore body mined from the Cannon shaft is a complex one in the SE $\frac{1}{4}$  SE $\frac{1}{4}$  sec. 36; most of the ore seems to lie in a doubly plunging north-trending syncline and in part on an adjacent anticline (fig. 3). Both assumed to be minor folds on the east flank of the central syncline.

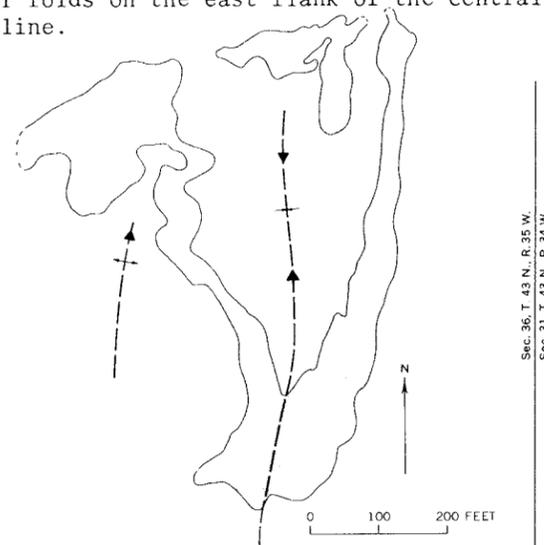


Figure 3--Cannon mine at approximately 8th level, showing mined ore bodies (shaded) and probably anticlinal and synclinal axes.

The Cannon shaft itself is in graywacke, graywacke-chert breccia, and slate of the Hiawatha Graywacke, but at the depth of the 8th level (about 1260 feet) it enters unoxidized Riverton Iron-formation, which in general trends north. At the 8th level a long drift has been driven to the northeast from the Cannon shaft, and prior to the closing of the Cannon in 1962 it was planned to continue this drift into the area of the Rogers mine about 2 miles distant. For several hundred feet northeast of the shaft, the drift is in unoxidized iron-formation with infolded slate, then passes into graywacke and slate of the Hiawatha.

The last inspection trip of the mine by the authors was made when the drift was a distance of about 2500 feet from the shaft. At that point the rock is laminated and is assigned to the Stambaugh Formation, previously inferred from the magnetic anomaly in the area. The rock formerly exposed was nonmagnetic, but specimens from an extension of the drift have since been examined; they include laminated magnetic rock typical of the Stambaugh.

### Delta

The Delta mine, chiefly in the SW $\frac{1}{4}$  SW $\frac{1}{4}$  sec. 25, T43N, R35W, was a small operation that yielded 95,759 tons of ore during the period 1920-25. Two shafts were sunk and three levels of workings developed; the deepest level, the 3rd is at a depth of about 360 feet.

The geology of the mine is inferred almost entirely from rather sketchy mining records. In general, the mine is located in the belt of Riverton Iron-formation continuing north from the Riverton mine. Younger strata lie to the east, and older strata to the west. The ore seems to have been located in the stratigraphically lower part of the Riverton Iron-formation, in the axial zone of a south-plunging minor syncline. A long drift to the north, into the NW $\frac{1}{4}$  SW $\frac{1}{4}$ , apparently encountered this structure again, presumably on a reversal of plunge.

### Riverton (Iron River)

The Riverton mine is in the W $\frac{1}{2}$  NW $\frac{1}{4}$  sec. 36, T43N, R35W, and in the adjoining parts of sec. 35. Known in its early years as the Iron River mine, it was one of the first producers of iron ore in the district; shipments began in 1882. The Commissioner of Mineral Statistics reported the ore had been stripped for a distance of 800 feet and was 30 to 80 feet wide, and that a second showing had been opened in the SW $\frac{1}{4}$  SW $\frac{1}{4}$  sec. 36. The latter was to become the Isabella mine.

The initial open-pit operations gave way to underground mining within a few years, and by 1890 four Riverton shafts had been sunk. In 1899 the property was taken over by the Oliver Iron Mining Co. and renamed the Riverton. The mine was closed in 1931, after nearly 50 years of operation, at which time 5,881,550 tons of ore had been mined; this total includes some ore from the Isabella, Duff, and Dober properties, and includes shipments made from stockpile from 1935 to 1937.

The area of the Riverton mine is one of the few in the western part of the district

where bedrock is at or near the surface. The open-pit mines, now filled with water, mark the position of the ore bodies as they were uncovered. The near-surface mined area, which trends north, is about a fourth of a mile long.

The ore occurred in a belt of complex structure bounded on the east by a steeply-dipping major fault separating the Riverton Iron-formation (and locally the Dunn Creek Slate) from the Hiawatha Graywacke. A considerable part of the Hiawatha must be cut out on this fault, as the Stambaugh Formation is within 200 feet of the Riverton in the NW $\frac{1}{4}$  NW $\frac{1}{4}$  sec. 36.

Near the surface the ore bodies occurred on both sides of a long narrow north-trending syncline in which the two limbs of Riverton are separated from each other by a width of 100 feet or less for a distance of more than a quarter of a mile. The east limb is in fault contact with Hiawatha Graywacke to the east. Down to the 4th level, at a depth of 410 feet, the ore bodies were entirely within the NW $\frac{1}{4}$  NW $\frac{1}{4}$  sec. 36, but at the 5th level (511 feet), the west limb had entered the NE $\frac{1}{4}$  NE $\frac{1}{4}$  sec. 35, and the ore-bearing east limb had continued to the south-southwest into the SE $\frac{1}{4}$  NE $\frac{1}{4}$  sec. 35 and broadened greatly on the synclinal axis, which at this level has an apparent northerly plunge. In general, therefore, it can be said that the main Riverton mine ore body occurred in the axial area and to some extent on the limbs of a tight synclinal fold.

### Isabella

The Isabella mine, in the SW $\frac{1}{4}$  SW $\frac{1}{4}$  sec. 36, T43N, R35W was opened in 1882, the same time as the Iron River (Riverton) mine a short distance to the north. Like the Riverton, the Isabella was first operated as an open pit, then underground from a shaft. No separate production records have been maintained for the Isabella. In fact, it existed only briefly as an independent operation. Until about 1935, it was operated as part of the Dober mine, which is the adjoining property to the south, and the production from both was merged in statistical records with that from the Riverton. After 1935, both the Dober and Isabella were incorporated with the Hiawatha No. 2 operation of the M. A. Hanna Co.

The ore bodies mined in the Isabella-Dober are the near-surface part of the huge ore body of the Hiawatha No. 2. In general, the ore occurs in the axial part of a west-plunging syncline; it widens greatly in the down-plunge direction and has now been mined to a depth exceeding 2000 feet in the Hiawatha No. 2.

## Cyr

The Cyr mine, in the NE $\frac{1}{4}$  SW $\frac{1}{4}$ , sec. 36, T43N, R35W, appears to have been opened in 1912 by the Michigan Mining Co. and closed shortly after. No production is reported. The shaft was sunk to a depth of 182 feet, with the first (and only) level being developed at 170 feet. The workings, shown in plate 1, consist of about 800 feet of drift extending both northwest and southeast of the shaft. The workings are caved and entirely inaccessible at the present time.

The available information concerning the mine workings is from a Michigan Mining Co. map by O. R. Hamilton; interpretation of the geology is based on Hamilton's map plus examination of the core from the later drilling in the area (see Cyr-Lennox exploration). The shaft apparently was in Hiawatha Graywacke (jasper formation, soap rock, etc.). Ore formation is shown on the map a short distance east of the shaft, and iron-formation, by analysis, is present in the southeastern part of the workings. So far as can be determined the footwall strata (Dunn Creek Slate) were not encountered; the iron-formation is on anticlinal folds partly or wholly surrounded by strata assigned to the Hiawatha Graywacke. Structural trends are not definite. The southeast occurrence of iron-formation seems to define a west-trending anticline. The iron-formation west of the shaft and cut by drill hole CL-9 may be part of a dome-like structure connecting at depth with the southeast anticline.

## Lennox

The Lennox (or Lenox) mine in the SE $\frac{1}{4}$  SW $\frac{1}{4}$  sec. 36, T43N, R35W, was opened by the Iron County Steel Co. in about 1910 and was operated for about two years. No ore shipments are recorded in the annals of the Lake Superior Iron Ore Association, although the developments indicate some ore was mined. The workings are now entirely inaccessible.

The shaft was sunk to a depth of 358 feet through glacial cover about 100 feet thick. The 1st level, at a depth of approximately 150 feet, consisted of about 1400 feet of drifting and crosscutting; the 2nd level, at a depth of 250 feet, consists of about 3700 feet of workings. As with the Cyr mine, previously described, most of the information regarding the workings is from a 1912 map by O. R. Hamilton.

The plan of the 2nd level workings is shown on plate 1, and a cross section through the workings and through drill holes CL4, CL11, and CL5 is shown on fig. 4. The geology is uncertain partly because of the use on the available map of terms as jasper, black jasper,

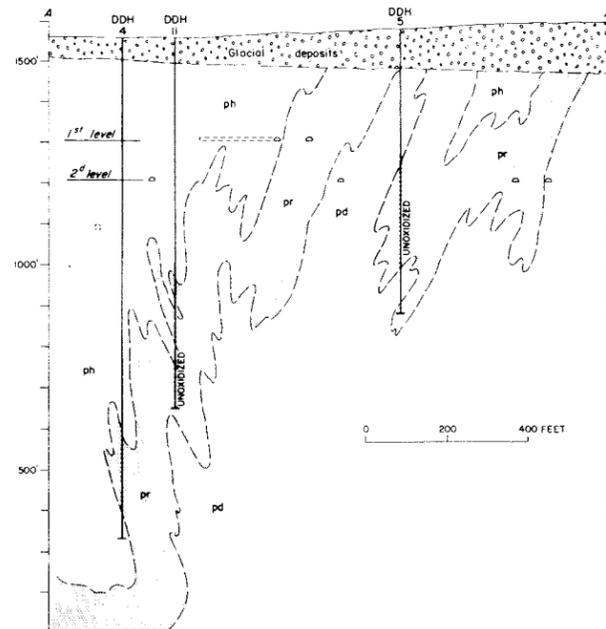


Figure 4--Cross section through workings of Lennox mine, SE $\frac{1}{4}$  SW $\frac{1}{4}$  sec. 36, T43N, R34W. Riverton Iron-formation (pr, stippled), oxidized except where otherwise indicated, overlain by Hiawatha Graywacke (ph), and underlain by Dunn Creek Slate (pd).

and lean formation. The drill core of a later exploration of the property has been helpful in interpreting the geology of the area.

As shown on the cross section, the western part of the property is underlain by Hiawatha Graywacke which has a generalized steep dip to the west. This rock is flanked to the east by a belt of Riverton Iron-formation infolded with footwall rocks. The shaft seems to have entered an anticlinal fold of footwall Dunn Creek Slate (black slate and black and gray slate on Hamilton's map). At the elevation of the 2nd level, whether the area of footwall rock surrounding the shaft connects with the one inferred to the northeast is uncertain. According to the company map the drift extending east from the shaft is in black slate almost to the first crosscut south, but underground drill hole No. 1, for which only analyses are available, shows material containing about 30 percent iron. Probably the drift is in iron-formation, possibly unoxidized or possibly with infolded footwall slate.

Several small "pockets" of ore were encountered, as indicated by raises in the western, eastern, and southernmost workings.

## Barras

The Barras mine, in the SW $\frac{1}{4}$  NE $\frac{1}{4}$  sec. 36,

T43N, R35W, was opened by a shaft to a depth of 244 feet in about 1907 by the Verona Mining Co. The workings at this level (plate 1) extended east and west across the "forty", and south into what later was to become the Bengal mine. The only ore encountered was in the south workings, a few hundred feet south of the center line of the section. This ore, mined later as part of the Bengal mine, was locally highly manganese; an analysis map shows the manganese part of the ore body to have been rudely circular in plan, to have been about 100 feet in diameter, and to have had an average manganese content of about 20 percent, and iron, 34 percent. Individual samples contained as much as 49.30 percent manganese.

The mine workings have long since been abandoned and caved. The information available from old mine maps and from drill holes in the area indicates that the main east-west drifts passed through a series of folds of northerly trend that involved the slaty upper part of the Riverton Iron-formation and the lower part of the Hiawatha Graywacke (see also "Bengal mine").

## Bengal

The Bengal mine, one of the major producers in the district, is in the N $\frac{1}{2}$  SE $\frac{1}{4}$  sec. 36, T43N, R35W. It was one of the few producers of manganese ore in the Iron River-Crystal Falls district. The mine was opened in 1913 by the Verona Mining Co., after having been entered from the Barras mine to the north. In 1949 the property was incorporated with adjoining properties into the Cannon mine by the M. A. Hanna Co. (see Cannon mine). Total shipments credited to the Bengal mine aggregate 5,987,744 tons.

Five major levels were developed by the Verona Mining Co. from two shafts. The lowest level, the 5th, is at a depth of about 670 feet. The outline of the 1st level, at a depth of 180 feet, is shown in small scale on plate 1; it indicates the form of the large ore body mined to bedrock surface. After the property was taken over by the M. A. Hanna Co., it was entered from the Cannon shaft by four new levels (6th - 9th), the lowest of which is at a depth of about 1460 feet. The upper levels were mapped by the authors in detail, but most of the information on the lower levels is from maps furnished through the courtesy of the M. A. Hanna Co.

Structural analysis of the Bengal and adjoining areas is made extraordinarily difficult by the fact that the stratigraphic succession normal for the district does not prevail. The lower part of the iron-formation, and perhaps the upper part of the underlying slate, consists of a thick chaotic chert breccia, similar to that commonly found at the

base of the Hiawatha Graywacke, plus much slaty iron-formation elsewhere characteristic of the upper part of the Riverton. The normal sharp break between Riverton and pre-Riverton slate does not exist. In many places little regularly bedded iron-formation appears. Nevertheless, inspection of the geologic map of the area (plate 1) shows clearly the Bengal is located in a general anticlinal area of Riverton projecting northward into younger strata.

The Bengal ore body is in the axial area of an anticline plunging steeply (65° or more) to the north-northwest. The pattern of the ore body at bedrock surface is approximately as shown by the outlines of the 1st level on plate 1. The ore body continues downward at least to the Cannon 9th level, a vertical range of more than 1400 feet, with progressive migration to the north; at the lower levels, plunge carries the north tip of the ore body into the Barras property to the north. A cross section of the ore body in the upper five levels, as indicated by stoped areas, is shown on figure 5. Unlike most other ore bodies in the district, the ore does not rest on a sharply-defined footwall of pyritic slate. Ore contacts are gradational on both hanging-wall and footwall sides, and in many places the contacts transgress structures.

Much of the ore in the Bengal mine was manganese. The manganese occurs mainly as hausmannite that veins limonitic ore. The hausmannite is black and well-crystallized; single crystals are as much as half an inch in

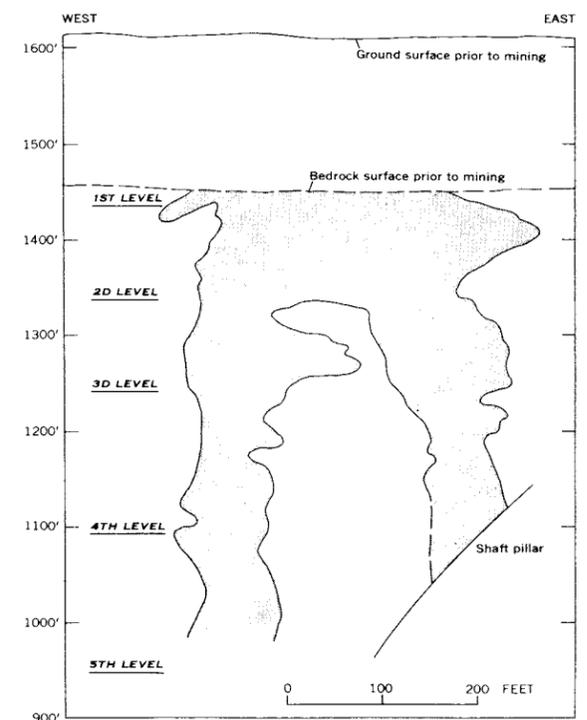


Figure 5--Generalized outlines of stoped ore (shaded) in the Bengal mine. East-west section along line approximately 900 feet south of center line of sec. 36, T43N, R35E. Looking north.

diameter, but most in crystalline aggregates with individual grains a few millimeters across. Braunite has been reported but not observed by the authors. In a few places, notably on the 6th level, thin veinlets of pink rhodochrosite and of sussexite cut the ore, and vuggy areas were marked by colloform goethite and a green clay mineral. The specific distribution of manganese in the Bengal iron ore body is not well known. As noted previously under "Barras mine", at the 1st level the manganiferous ore occurred in a rudely circular area about 100 feet across at the north tip of the main ore body. At the 6th level (Cannon), the manganiferous ore has similar dimensions and grades rapidly into nonmanganiferous ore.

#### Tully

The old Tully mine is in the S $\frac{1}{2}$  SE $\frac{1}{4}$  sec. 36, T43N, R35W. The original mine, opened in 1909, consisted of three shafts, each about 700 feet deep, from which four levels were developed by Corrigan, McKinney Steel Co. The workings were connected with those of the Baker mine to the east. During the period 1910-26, a total of 1,151,623 tons of ore was shipped. Later, the property was acquired by the M. A. Hanna Co. and was operated as part of the Cannon mine.

Geology is discussed under "Cannon mine".

#### Explorations

Town 43 North, Range 34 West

#### Section 19

SE 1/4: Nine holes have been drilled at various times in the SE $\frac{1}{4}$  sec. 19. Six of them (the 3100 series), known as the Winton Exploration, were drilled in 1913 by the Bates Iron Co. The core could not be located for examination. Data regarding the holes are from logs by O. W. Wheelwright, and are summarized as follows: hole #3101, drilled to a depth of 749 feet, cut cherty carbonate at bedrock surface and ended in the same material after having passed through an alternation of slate and unoxidized to partly oxidized iron-formation; hole #3102, drilled to 433 feet in cherty carbonate; hole #3103, drilled to 286 feet in brecciated cherty carbonate; hole #3104, drilled to 354 feet in gray slate; hole #3105, drilled to 393 feet in gray and red slate; and hole #3106, drilled to 282 feet in cherty iron carbonate. Two other holes, W-1 and W-2, had previously been drilled in the same area. The core for W-1 was stored by Pickands Mather &

Co. at Caspian; it consisted of fine-grained graywacke and graphitic slate with chert nodules from bedrock surface at 238 feet to the bottom at 253 feet. Hole W-2, which ledged at 253 feet, is reported to have cut black slate, ore, and ore and slate to the bottom at 368 feet. The most easterly hole, EM-4, was part of the 1949 "East Mineral Hills" exploration of Pickands Mather & Co.; it was drilled to a depth of 803 feet, the upper part being in slate and graywacke and the rest in similar material alternating with unoxidized slaty iron-formation.

#### Section 20

SW 1/4: Five shallow holes were drilled in 1913 by the E. J. Longyear Co. along a north-south line in the SW $\frac{1}{4}$  sec. 20. No core could be located, and the available records are as follows:

| Hole No. | Depth to bedrock (feet) | Total depth (feet) | Material  |
|----------|-------------------------|--------------------|---|
| L51      | 165                     | 205                | Cherty iron carbonate and slate.                                |
| L52      | 203                     | 227                | Cherty iron carbonate and mottled slate.                        |
| L53      | 200                     | 201                | Calcareous slate with bands of black slate.                     |
| L54      | 200                     | 244                | Quartzose ferruginous graywacke; gray slate and iron carbonate. |
| L55      | 206                     | 241                | Quartzose graywacke.  |

SE 1/4: A churn drill hole, NB4, was sunk to a depth of 230 feet in the NE $\frac{1}{4}$  SE $\frac{1}{4}$  by Inland Steel Co. in 1958 as part of the "North Bates" exploration. The choppings were examined; they consisted mostly of chert and gray slate.

The SE $\frac{1}{4}$  SE $\frac{1}{4}$  sec. 20, which adjoins the Rogers mine and has been explored by five deep holes, J1-J5, drilled by the M. A. Hanna Co. in 1951-52. The core was available for study at Iron River, and the results are summarized as follows: hole #J-1 entered gray slate containing chert fragments (Hiawatha Graywacke) at bedrock surface, then from about 240 feet to the bottom at 578 feet was in unoxidized slaty iron-formation (Riverton); hole #J-2 was mostly in slate and graywacke with chert fragments to the bottom at 793 feet; hole #J-3, which was wedged off J-2 at 340 feet to the south at an 80° angle, was in material similar to that in J-2 but with a greater percentage of graywacke to the bottom at 1249 feet; hole #J-4 was in slate, siltstone, and graywacke to about 725 feet, then in unoxidized slaty iron-formation to about 840 feet, and ended at 915 feet in highly-sheared graphitic slate with abundant vein quartz; hole #J-5, drilled at 70° to the north, was in graphitic pyritic slate at ledge to 330 feet, in cherty iron-formation (in part oxidized) to about 400 feet, then in an alter-

nation of unoxidized slaty iron-formation and dark slate containing chert fragments to the bottom at 748 feet.

#### Section 29

This section seems to be almost entirely underlain by rocks that may be assigned stratigraphically to the Riverton Iron-formation or to the Hiawatha Graywacke. Dunn Creek Slate forms a belt bounding the Rogers mine ore body on the east, and one or two small areas of Stambaugh Formation are present.

Structural trends are diverse. A dominant feature is a general anticlinal high, extending from the southwest corner of the section to the northeast corner, on which Riverton Iron-formation is brought to bedrock surface. Possibly this northeast trend is developed by a series of structures on which trends are more northerly than northeasterly. A magnetically well-defined syncline crosses the NW $\frac{1}{4}$  at an easterly trend, and its apparent continuation is in the easternmost part of the NE $\frac{1}{4}$  NE $\frac{1}{4}$ . A west-trending syncline containing magnetic Stambaugh Formation projects into the SE $\frac{1}{4}$ .

The only mine developed in the section is the Rogers, which is now inactive (see "Rogers mine"). Nevertheless, a considerable part of the area is underlain by iron-formation at bedrock surface, and oxidation is very extensive. Three diamond drill holes stopped in ore at depths of more than 1500 feet, and possibly a large tonnage could be developed.

NW 1/4: Exploration on the White property in the SE $\frac{1}{4}$  NW $\frac{1}{4}$  consists of 14 diamond drill holes (C1-C14) sunk by the Cole and McDonald Co. sometime during the period 1905-10, and 2 holes (M1, M2) sunk by the Munro Iron Mining Co. in 1908. None of the core could be located for examination, but the records seem reasonably adequate. The average depth of the holes is about 1000 feet, and one (C3) reached a depth of 1555 feet.

The holes were drilled either in oxidized iron-formation and ore or in oxidized rock of the Hiawatha Graywacke. Oxidation seems to have been so intense throughout the area, that quite likely some of the rock recorded as iron-formation actually belongs to stratigraphically younger strata. However, several of the holes, notably C8, C9, C10, C13, and C14, appear to have entered oxidized iron-formation at bedrock surface. Many of the others intersected paint rock, jasper, sandstone, quartzite, and ferruginous slate that may be assigned to the Hiawatha Graywacke. (The sandstone referred to is, in all probability, oxidized graywacke.)

Structurally, the area forms the south flank of an east-trending syncline. The iron-formation drilled at bedrock surface appears to form an anticlinal high between this syncline

and a shallower syncline of Hiawatha strata in the southern part of the property.

The general structure and the depth of oxidation makes the area one of considerable ore potential (drill hole C3 stopped in ore at a depth of 1555 feet). Probably none of the drill holes reached the contact with the Dunn Creek Slate, on which most of the ore bodies of the district are found.

Five holes L1-L5, were drilled by the Cole and McDonald Co. in the SW $\frac{1}{4}$  NW $\frac{1}{4}$ , known as the LeRoy exploration, probably during the period 1910-1915. The holes vary in depth from 405 feet (L4) to 1497 feet (L5). None of the core could be located for examination.

Most of the material cut was recorded as sandstone, chert, slate, jasper, and paint rock, although holes L1 and L5 appear to have intersected some iron-formation. Descriptions and the spacial relations to the drilling and magnetic anomaly in the area immediately to the east and northeast, indicate the holes were drilled mainly in the lower part of the Hiawatha Graywacke.

Structurally, the area seems to lie near the west end of a major syncline. The rock encountered is probably about in the same stratigraphic position as that in the vicinity of the shaft of the Rogers mine. Oxidation appears to be deep--the material in the lower part of the deepest hole (L5) is recorded as jasper, slate, ore, and quartz.

NE 1/4: Exploration on the Paulson property is limited to four holes, P1-P4, in the extreme southeastern part of the NW $\frac{1}{4}$  NE $\frac{1}{4}$ , an area subsequently entered by the workings of the Rogers mine covered under the description of the Rogers mine. The holes were drilled in 1909 by the Munro Iron Mining Co.

The Schiebler exploration, in the NE $\frac{1}{4}$  NE $\frac{1}{4}$  sec. 29, consists of 15 drill holes, C1-C4 and S5-S15, 4 of which were sunk by a churn drill and 11 by diamond drill. The holes were drilled vertically in 1907-1910 by the Munro Iron Mining Co. Depths range from 201 feet (S12) to 1019 feet (S10). The southwestern part of the property was entered by the workings of the Rogers mine (fig. 2), and the Schiebler drilling apparently was part of the exploration that led to the opening of that mine. None of the core could be located for examination, so descriptions are entirely from company records.

Overburden is thick, averaging about 200 feet. Nine of the holes entered iron-formation at bedrock surface. Of these, holes C4 and S5 continued into black slate of the footwall strata subsequently entered by the Rogers mine workings. Hole S7, after passing through 150 feet of iron-formation, reportedly cut "granular gray rock", which probably is graywacke of the hanging-wall strata here overturned and dipping

beneath the iron-formation (see fig. 2). Hole S9 was recorded as having cut "light green slate" and having stopped at a depth of 235 feet. Hole S10 was recorded as follows:

| Total depth | Material                  |
|-------------|---------------------------|
| 0-210       | Overburden                |
| 210-689     | Iron-formation and ore    |
| 689-794     | Gray slate                |
| 794-887     | Black slate               |
| 887-1010    | Graywacke and black slate |

On the basis of this description, and the location of the hole with respect to the low magnetic anomaly in the northern part of the property, the hole is assumed to have entered Hiawatha Graywacke. Hole S12 was drilled only 3 feet into bedrock; the material was recorded as "black slate". Hole S13, after cutting 150 feet of iron-formation, entered "black slate banded with chert", which in all probability is part of the uppermost part of the Riverton Iron-formation or the lowermost part of the Hiawatha Graywacke. Shallow hole S14 is recorded as being in "gray slate".

The Swanson property, now the site of the Rogers mine, was explored in 1907-8 by the Munro Iron Mining Co. Nine holes were drilled in the SW $\frac{1}{4}$  NE $\frac{1}{4}$ , several of them intersecting the ore to be mined later. Two holes (S1 and S2) encountered iron-formation and ore not entered by the mine workings. Three holes (S3, S8, and S9) are in the syncline of Hiawatha Graywacke immediately west of the ore body. Graywacke is the predominant rock cut. Hole S9 became the site of the shaft (see description of Rogers mine).

SW 1/4: Exploration on the Blair property consists of 14 drill holes sunk in 1908-09 by the Corrigan, McKinney Steel Co. Eight of these holes (B1-B8) are in the SW $\frac{1}{4}$  SW $\frac{1}{4}$  and 6 (B9-B14) are in the NE $\frac{1}{4}$  SW $\frac{1}{4}$ . All are vertical. None of the core could be located for examination. The records available are not entirely adequate but do show the iron content of the sludge.

The holes in the SW $\frac{1}{4}$  SW $\frac{1}{4}$  appear to have been drilled into an anticlinal arch on which iron-formation reaches bedrock surface in places. Hole B1, which was drilled only 9 feet into bedrock, encountered slate. Hole B5 also entered slate and was stopped after cutting 87 feet of bedrock. The remainder of the holes in this "forty" encountered what is described as ore and quartz, jasper, lean ore, and the like. These holes are relatively deep (B2, 985 feet; B3, 450 feet; B4, 1017 feet; B6, 555 feet; B7, 578 feet; and B8, 842 feet). The analyses indicate an iron content typically ranging from 20 to 40 percent. Possibly most of this rock is properly classed as oxidized rock of the Hiawatha Graywacke, rather than iron-formation. None of the holes appear to have intersected the Dunn Creek Slate.

Holes B9-B14 are in the NE $\frac{1}{4}$  SW $\frac{1}{4}$ . All ex-

cept B11, which reportedly encountered sandstone (probably oxidized graywacke) at bedrock surface, entered oxidized iron-formation and ore. Hole 9 was stopped in ore at a depth of 1525 feet; hole 13 stopped at 1279 feet in rock containing 35-45 percent iron, according to sludge analyses. Of all the holes in the Blair exploration, only in B14 does the foot-wall Dunn Creek Slate seem to have been reached. Below about 610 feet in this hole, the sludge analyses show less than 10 percent iron and the rock is described as black slate. In general, the iron-formation encountered at this locality is in a similar structural position to that drilled immediately to the north on the White property--that is, it forms an anticlinal high between areas of Hiawatha Graywacke.

SE 1/4: Exploration on the Michaels property consists of seven holes (M1-M7) drilled by the Corrigan, McKinney Steel Co. in 1909, and one hole (R1) drilled in 1950 by the Republic Steel Corp. The precise locations of several of the holes are doubtful, and in general, the records are inadequate. For two only generalized sludge analyses are available. None of the core of the older drilling could be located for examination. The description of hole R1 is from a report by W. A. Seaman.

The Corrigan, McKinney holes are located close to the west boundary of the property. Holes M3, M4, and M6 are in the SW $\frac{1}{4}$  SE $\frac{1}{4}$  sec. 29. (Another hole, M2, not shown on the map is reported to have been drilled a few hundred feet south of M3, but no other information is available.) Of these three holes, lithologic description is available only for M6, drilled in slate and sandstone to a depth of 873 feet. The only information concerning material cut in holes M3 and M4 is that the iron content was 7-36 percent and 9-26 percent, respectively. Presumably the rock cut in M3, M4, and M6 was slate and oxidized graywacke of the Hiawatha Graywacke. Holes M1, M5, and M7, all in the northwestern part of the NW $\frac{1}{4}$  SE $\frac{1}{4}$ , appear to have been drilled chiefly in oxidized Riverton Iron-formation. Hole M7 stopped in ore at a depth of 1712 feet. This property, like the adjacent Blair and White properties, has a large ore potential.

Hole R1, in the east part of the SW $\frac{1}{4}$  SE $\frac{1}{4}$ , is a vertical hole drilled to a depth of 1200 feet. The hole was located in an area of magnetic low. Oxidized iron-formation was encountered at bedrock surface. According to the report, the bedding was nearly vertical, and the hole passed into Hiawatha Graywacke (graywacke with chert fragments and oxidized slate).

#### Section 30

Sec. 30 is marked by two major magnetic anomalies, both of which are assumed to be related to deep synclinal folds containing

Stambaugh Formation. A major north-trending anomaly (and syncline) enters the section near the south quarter corner; it also extends southward to form a complex pattern in sec. 31. The oval-shaped magnetic anomaly in the northeastern part of sec. 30 presumably reflects a basin-like syncline of Stambaugh. The major trend is northwesterly. Doubtless much of the remainder of the area is underlain by beds of the Hiawatha Graywacke, but Riverton Iron-formation is known or at bedrock surface several places around the outer margins of the section. Although not shown on plate 1, iron-formation is possibly at bedrock surface in the NW $\frac{1}{4}$  SW $\frac{1}{4}$  of the section.

N 1/2: The East Mineral Hills exploration consists of 12 deep drill holes (201-207, EM1-3) drilled in 1948-49 by Pickands Mather & Co. The core, stored at Caspian, was available for inspection.

Holes EM1-3 are in the NE $\frac{1}{4}$ . Hole EM1, drilled to a depth of 890 feet, is in graywacke and graywacke with chert fragments its entire length. Hole EM2, 906 feet in total depth, is in unoxidized slaty iron-formation alternating with dark chert breccia and some graywacke. Hole EM3, drilled to 673 feet, is mainly in graywacke alternating with unoxidized iron-formation, apparently along the folded contact of the Riverton and Hiawatha formations.

Holes 201-207 are in the E $\frac{1}{2}$  NW $\frac{1}{4}$ . Hole 201 entered bedrock at 92 feet and was drilled to 258 feet in unoxidized slaty iron-formation (Riverton). Hole 202, the most northerly of the holes, entered bedrock at 212 feet and was drilled to a depth of 1475 feet; most of the hole is in graywacke and slate (Hiawatha), with a few short runs of unoxidized iron-formation. Hole 203 ledged at 164 feet in unoxidized iron-formation breccia (Riverton) and ended at 525 feet in black slate and graywacke. Hole 204 ledged at 79 feet in unoxidized slaty iron-formation (Riverton) and continued to 676 feet in this rock interspersed with gray and black slate. Hole 205 cut unoxidized slaty iron-formation at bedrock surface, and at about 295 feet passed into graphitic black slate and graywacke that graded into unoxidized iron-formation with interbedded graphitic slate; the hole stopped at 595 feet. Hole 206 was drilled at an angle of 57° north; to the bottom at 552 feet it cut partly oxidized cherty iron-formation (Riverton) that graded into dark slaty iron-formation with graphitic partings. Hole 207, drilled from the same location as 206, but to the south at 57°, cut similar material (Riverton) at ledge surface but passed into dark chert breccia at 890 feet and into graywacke with chert fragments (Hiawatha) that continued to the bottom of the hole at 955 feet. Of considerable interest in hole 207 is the iron-formation containing magnetite, doubtless accounting for the magnetic anomaly extending westward from this locality.

SE 1/4: Holes A1 and A2 are in the SE $\frac{1}{4}$ . Hole A1, ledged at 120 feet, is in unoxidized slaty iron-formation (Riverton) with some graywacke to the bottom at 355 feet. Hole A2 at 179 feet entered graywacke with abundant chert fragments (Hiawatha Graywacke) and except for short runs of infolded unoxidized iron-formation (Riverton) continued in this material to the end at 1024 feet.

Eight holes, C1-C8, of the Coe and Blair exploration, were drilled in the S $\frac{1}{2}$  SE $\frac{1}{4}$  about 1907-08. Most of the holes were shallow; the deepest is C8 drilled to 386 feet. All were vertical. Core could not be located for examination, and records are rather meager. Except for holes C4, C6, and C8, which reportedly cut ore and jasper, ore and quartz, slate and lean ore, the material intersected is recorded merely as slate or black slate.

Two shallow holes were drilled in 1909 by The Cleveland-Cliffs Iron Co. near the southeast corner of sec. 30. The material was examined in the Cleveland-Cliffs core storage house at Ishpeming. Hole CCl cut sideritic slate with some chert; CC2 cut dark gray slate with a little chert. The material in both holes can be assigned to either the uppermost part of the Riverton Iron-formation or the lower part of the Hiawatha Graywacke.

SW 1/4: Eight shallow holes were drilled in the SW $\frac{1}{4}$  by the Oliver Iron Mining Co. in 1907-08. One of these (No. 5, about midway between 03 and 04, and not shown on plate 1) was drilled 186 feet without reaching bedrock and some doubt is expressed as to whether 04 actually cut bedrock. None of the bedrock material from these holes could be located for examination, and descriptions are exceedingly brief. Most of the material is referred to as black rock and chlorite.

#### Section 31

The east two-thirds of sec. 31 is characterized by strong magnetic anomalies over synclinal folds of Stambaugh Formation. The major syncline extends southward from sec. 30 through the central part of sec. 31, and then appears to divide into two separate synclines, although possibly the two anomalies may be limbs of a syncline deep enough to include beds higher than the magnetic slate. A group of anomalies of high intensity but small area are present in the E $\frac{1}{2}$  SW $\frac{1}{4}$ . The magnetic slate causing the anomalies seems to be contained in a series of tight doubly-plunging synclines.

Exploration and mining have been extensive in the southwestern part of the section, especially in the W $\frac{1}{2}$  SW $\frac{1}{4}$  (see also "Baker mine" and "Cannon mine"). The W $\frac{1}{2}$  SW $\frac{1}{4}$  is underlain by complexly-folded rocks assigned mostly to the upper slaty part of the Riverton Iron-

formation and to the lower part of the Hiawatha Graywacke. The folding is such that almost any hole drilled in this area will encounter these two units. Doubtless the map pattern shown is not correct in detail, and certainly does not indicate the structural complexity present.

N 1/2: The "D & M" exploration is the drilling campaign conducted in about 1935 by the M. A. Hanna Co. Six holes (3111-3116) were drilled in the E $\frac{1}{2}$  NW $\frac{1}{4}$ , and four holes (3117-3120) were drilled in the N $\frac{1}{2}$  NE $\frac{1}{4}$ . Core was examined in company storage.

The six holes in the NW $\frac{1}{4}$  are all relatively shallow; the deepest, hole 3115, is 238 feet. All were drilled in graywacke or graywacke and slate of the Hiawatha Graywacke. Holes 3117 and 3118 in the NW $\frac{1}{4}$  NE $\frac{1}{4}$  also entered Hiawatha Graywacke to shallow depths. Holes 3119 and 3120, in the NE $\frac{1}{4}$  NE $\frac{1}{4}$ , however, cut unoxidized Riverton Iron-formation consisting of chert and siderite with a small amount of slate. The rock actually at bedrock surface in hole 3120 is graywacke with chert (Hiawatha Graywacke); the hole is located very close to the contact with the Riverton.

The Farley exploration in the SW $\frac{1}{4}$  NW $\frac{1}{4}$  consists of six drill holes, only three of which reached the bedrock surface. The material recovered from these three holes (F2, F4, F5) was examined in the Pickands Mather & Co. core storage house in Caspian, Michigan.

Hole F2, which entered bedrock for only 5 feet, encountered sideritic graywacke; hole F4, drilled 22 feet into bedrock, cut black slate, somewhat graphitic with some chert; and hole F5, drilled 39 feet into bedrock, cut graywacke, slate, and some chert breccia. All the rock can be assigned, with little question, to the lower part of the Hiawatha Graywacke.

A group of four holes was drilled by Pickands Mather & Co. in the eastern part of the NE $\frac{1}{4}$  NE $\frac{1}{4}$ , the D & M exploration. The core was located and examined at the company storage building in Caspian. All are relatively shallow, the deepest entered bedrock for 100 feet. Hole P2 cut oxidized graywacke at bedrock surface and then passed into unoxidized Riverton Iron-formation. Holes P3, P4, and P5 were drilled in graywacke, with a small amount of gray slate and chert. All this rock, except for the iron-formation cut in the lower part of P2, is stratigraphically part of the Hiawatha Graywacke.

SW 1/4: This area has been drilled rather extensively, except for the SE $\frac{1}{4}$  SW $\frac{1}{4}$ . Eight exploration programs are represented as follows:

| Holes       | Exploration                    |
|-------------|--------------------------------|
| A, B, C, E, | Original Baker exploration     |
| F, G, H, J. | (Corrigan, McKinney Steel Co.) |

|   |  |
|---|--|
| M1, M2, M3,<br>M4, M5, M6,<br>M7, M8, M9.                               | Corrigan, McKinney Steel Co.   |
| 01, 02.   | Oliver Iron Mining Co.   |
| C1, C2, C3,<br>C4, C5, C6,<br>C7, C8, C9,<br>C10, C11,<br>C12.          | Carlson (D. M. & M.) exploration<br>(Verona Mining Co.).   |
| T37   | Tully exploration (Corrigan,<br>McKinney Steel Co.).   |
| 3101, 3102,<br>3103, 3104,<br>3105, 3106,<br>3107, 3108,<br>3109, 3110. | D. M. & M. exploration (M. A.<br>Hanna Co.).   |
| TH4, TH5.   | M. A. Hanna Co. churn drill<br>holes.  |
| H1, H2, H3.   | Carlson exploration (M. A.<br>Hanna Co., 1950). These holes<br>drilled near site of Cannon<br>shaft. |

The Baker exploration, in the SW $\frac{1}{4}$  SW $\frac{1}{4}$ , presumably was carried out by the Corrigan, McKinney Steel Co. prior to the opening of the Baker mine in 1909. The exploration consisted of nine diamond drill holes (holes A-H, J, pl. 1), all of which were drilled at an angle of 60°. None of the core could be located for examination, and the records are meager, for some of the holes the only information is the analyses of the drilling sludge.

Most of the holes appear to have cut oxidized iron-formation (and ore), or oxidized slate and graywacke of the Hiawatha Graywacke. Holes A and B cut iron-formation; hole C was drilled in sandstone to a depth of 525 feet; hole D cut iron-formation (?) at bedrock surface, then cut sandstone from 385 feet to the end of the hole at 445 feet; hole E cut sandstone at bedrock surface, and passed into iron-formation (?); hole F cut material containing from 12 to 41 percent iron; hole G entered sandstone at bedrock surface and probably continued in similar material to the bottom of the hole at 821 feet; hole H also entered sandstone and continued in this material to the bottom at 761 feet; and hole J entered sandstone at bedrock surface, then at 153 feet entered quartz and ore that continued to the bottom at 416 feet. Presumably, graywacke has been referred to in these records as sandstone.

The Corrigan, McKinney exploration, in the SW $\frac{1}{4}$  SW $\frac{1}{4}$ , consists of nine drill holes. The date of the drilling is not known, nor could any of the core be located for examination.

From the very brief descriptions apparently all of the holes were drilled in either the slaty upper part of the Riverton Iron-formation or in the lower part of the Hiawatha Graywacke. Probably none of the holes entered the lower part of the iron-formation, despite the fact that several are deep (hole M2 was drilled to 1646 feet, and five others were drilled 1200 feet or more). Short runs of sandstone (graywacke) are recorded in almost every hole; presumably this rock is complexly infolded with the strata of the upper part of the iron-formation. Although not specifically stated in the records all of the rock probably is deeply oxidized.

Two holes were drilled in the SW $\frac{1}{4}$  SW $\frac{1}{4}$  by the Oliver Iron Mining Co. in 1903. The core could not be located for examination.

Hole 01 is located about 300 feet west of the shaft of the Baker mine. The hole appears to have been in oxidized Riverton Iron-formation for most or all of its depth. Paint rock, jasper, and green rock are reported for parts of the hole, suggesting the hole crossed several narrow synclinal folds containing the Hiawatha Graywacke strata.

Hole 02, which was drilled west at an angle of 60°, reportedly cut black slate, sandstone, and paint rock down to about 475 feet. From this point to the end at 751 feet, the hole appears to have been partly in oxidized Riverton Iron-formation and partly in rock of the overlying Hiawatha Graywacke.

The Carlson exploration, in the N $\frac{1}{2}$  SW $\frac{1}{4}$ , also known as the D. M. & M. exploration, consists of 12 holes drilled by the Verona Mining Co. The date of the drilling appears to have been sometime during the period 1920-30. The core, in abbreviated form, was located and examined at the Pickands Mather & Co. core storage house at Caspian, Michigan. The generalized logs are as follows:

|                          |  |
|--------------------------|--|
| <u>Hole C1</u><br>0-169' | Overburden.<br>169-210 Mostly hematite and limonite.<br>210-320 Oxidized dark slate and white chert. |
| 320-390                  | Oxidized graywacke, locally with chert fragments.  |
| 390-430                  | Dark, poorly bedded slate.   |
| <u>Hole C2</u><br>0-154  | Overburden.  |
| 154-175                  | Black slate.   |
| <u>Hole C3</u><br>0-155  | Overburden.  |
| 155-290                  | Graywacke, oxidized 155-240.   |
| 290-340                  | Graywacke and black chert.   |
| 340-366                  | Graywacke and soft greasy black slate.   |

|  |   |
|--|---|
| <u>Hole C4</u><br>0-145'                   | Overburden.   |
| 145-151                                    | Graywacke.  |
| <u>Hole C5</u><br>0-133                    | Overburden.   |
| 133-150                                    | Iron-formation (hematite and white chert).                              |
| 150-175                                    | Slate, mostly green. Much vein quartz, some hematite.                   |
| 175-245                                    | Graywacke.  |
| 245-295                                    | Black slate and gray chert. Locally oxidized.                           |
| <u>Hole C6</u> (drilled E. at 70°)         |   |
| 0-168                                      | Overburden.   |
| 168-185                                    | Oxidized iron-formation (hematite and gray chert). Slaty toward bottom. |
| 185-195                                    | Pyritic black slate.  |
| 195-275                                    | Unoxidized iron-formation (chert and carbonate).                        |
| 275-280                                    | Pyritic black slate.  |
| 280-290                                    | Unoxidized iron-formation.  |
| 290-315                                    | Contorted black slate.  |
| 315-380                                    | Gray sideritic slate, with some chert. Contorted.                       |
| 380-382                                    | Mostly quartz.  |
| <u>Hole C7</u><br>0-108                    | Overburden.   |
| 108-230                                    | Hematitic slate, sparse chert.  |
| 230-338                                    | Oxidized iron-formation (limonite and chert).                           |
| 338-450                                    | Hematite and minor chert, with layers of black, green, and red slate.   |
| <u>Hole C8</u> (drilled E. at 60°)         |   |
| 0-126                                      | Overburden  |
| 126-425                                    | Oxidized iron-formation (hematite and chert). Slaty 318-366, 410-425.   |
| 425-612                                    | Slate, greenish gray to black, and small amount of chert and graywacke. |
| <u>Hole C9</u><br>0-116                    | Overburden.   |
| 116-305                                    | Slate, thin-bedded, oxidized, with some chert.                          |
| 305-330                                    | Black and gray slate, with chert.                                       |
| 330-415                                    | Core mostly white chert, some hematite.                                 |
| 415-440                                    | Soft black slate.   |
| 440-550                                    | Oxidized slate, with some chert.  |
| 550-570                                    | Slate similar to 415-440.   |
| 570-635                                    | Graywacke, coarse-grained, massive.                                     |
| 635-695                                    | Oxidized iron-formation (chert and hematite).                           |
| 695-757                                    | Graywacke, with some interbedded chert and black slate.                 |
| <u>Hole C10</u> (drilled S. 24° E. at 70°) |   |
| 0-148                                      | Overburden.   |
| 148-480                                    | Iron-formation, partly oxidized, with some black slate.                 |

Hole C10 (con't.)  
480-527 Sideritic slate, with some chert.

Hole C11 (drilled S. 60° E. at 70°)  
0-140 Overburden  
140-378 Graywacke and gray slate, some chert.

Hole C12 (drilled S. 69° E. at 69°)  
0-117 Overburden  
117-287 Gray sideritic slate, with much gray chert.

These records indicate most of the holes were drilled in either the slaty upper part of the Riverton or in graywacke and slate of the Hiawatha Graywacke. However, holes C5, C6, C7, and C8 appear to have entered the lower part of the Riverton Iron-formation. None of the holes cut the footwall Dunn Creek Slate.

Tully hole 37 (T37), in the SW $\frac{1}{4}$  SW $\frac{1}{4}$ , is one of a series drilled mostly in the area immediately to the west, in sec. 36, T43N, R35W, by the Corrigan, McKinney Steel Co. Core and lithologic descriptions could not be located. Analyses of the sludge form the only basis for classification.

Hole T37 was drilled to a depth of 1840 feet, in material averaging about 30 percent iron, the lower values in general for the rock near the top of the hole, the highest values near the bottom.

The D. M. & M. exploration consists of 10 drill holes (the "31" series on plate 1), drilled by the M. A. Hanna Co. in the N $\frac{1}{2}$  SW $\frac{1}{4}$ . Core is stored and was examined at the Rogers mine.

The holes in the NW $\frac{1}{4}$  SW $\frac{1}{4}$  (holes 3101, 3107, 3108, 3109, and 3110) were drilled in similar material. The rock consists principally of black and sideritic gray slate with chert and locally graywacke, and is to be assigned to the upper slaty part of the Riverton Iron-formation or to the overlying Hiawatha Graywacke.

The drill holes in the southern part of the NE $\frac{1}{4}$  SW $\frac{1}{4}$  are of considerable interest because they are located on or adjacent to strong magnetic anomalies. Holes 3102, 3103, 3104, and 3105 were all drilled in finely banded, gray, hard, sideritic rock typical of the Stambaugh Formation. Much of the rock is strongly magnetic. Hole 3106 is in coarse graywacke.

Two churn holes (TH4 and TH5) were drilled in 1949 in the SW $\frac{1}{4}$  SW $\frac{1}{4}$  by the M. A. Hanna Co. to test the water level in the area. Both holes cut red, hematitic slate at bedrock surface. Three holes (H1, H2, and H3) were drilled by the M. A. Hanna Co. in 1950 in the NW $\frac{1}{4}$  SW $\frac{1}{4}$ , to test a possible shaft site. The three holes are closely spaced. H1 is vertical; H2 was drilled north at 60°; and H3 was drilled

south at 60°. H1 was drilled to 2000 feet.

Each of the holes was drilled mainly in slaty iron-formation (Riverton). Hole H1 cut infolded graywacke stratigraphically above the iron-formation from 780 to 1022 feet and ended in dike rock. None of the holes entered the footwall strata. Oxidation is general throughout.

#### Section 32

Sec. 32 is marked by strong magnetic anomalies caused by the Stambaugh Formation, which occupies much of the eastern half of the section and projects in two synclinal troughs into the NW $\frac{1}{4}$ . Most of the remaining area is almost certainly underlain by rocks stratigraphically assigned to the Hiawatha Graywacke.

NW 1/4: Three holes (G1-G3) were drilled on the Goodman property in the NW $\frac{1}{4}$  NW $\frac{1}{4}$  in 1907-08 by the Oliver Iron Mining Co. Bedrock was drilled only a few feet in each. None of the material has been preserved.

The holes are located on a strong magnetic anomaly caused by the Stambaugh Formation. The material is described on drill records as black rock with quartz, black rock, and gray black slate with pyrite.

Six holes (M321-M323, M326-M328) were drilled vertically in 1930-31 by the Jones and Laughlin Ore Co. on the Manley property in the E $\frac{1}{2}$  NW $\frac{1}{4}$ . The core from this drilling was examined at the Jones and Laughlin storage house in Negaunee. Two drill holes (M1-M2) are reported to have been drilled in 1909 in the northwestern part of the NE $\frac{1}{4}$  NW $\frac{1}{4}$ .

Except for hole M323, which encountered 65 feet of oxidized Riverton Iron-formation at bedrock surface before passing into stratigraphically younger graywacke, all the holes were drilled through material definitely assigned to the Hiawatha Graywacke. Graywacke, typically with interbedded slate and scattered chert fragments, is the dominant rock.

Four churn drill holes (H12-H15) were sunk by the M. A. Hanna Co. in 1950 to test the bedrock surface in the SW $\frac{1}{4}$  NW $\frac{1}{4}$ . The material recovered in H12, H13, and H15 consisted of unoxidized siderite and chert, and in hole H12 of some slaty material. Graywacke, containing some chert, was recovered from hole H14.

The unoxidized iron-formation drilled in holes H12, 13, and 15 apparently is exposed on the crest of an anticline, as inferred earlier from the magnetic data.

NE 1/4: Only two holes have been drilled in the NE $\frac{1}{4}$  sec. 32. These are holes G324, in

the NW $\frac{1}{4}$  NE $\frac{1}{4}$ , and G325 in the NE $\frac{1}{4}$  NE $\frac{1}{4}$ . Both were drilled as part of the 1930-31 exploration by the Jones & Laughlin Ore Co. in the area adjacent to the west. Graywacke and slate of the Hiawatha Graywacke were encountered in both.

SW 1/4: Drilling in the SW $\frac{1}{4}$  seems to consist entirely of four shallow holes (G4-G7) in the NW $\frac{1}{4}$  SW $\frac{1}{4}$  drilled by the Oliver Iron Mining Co. in 1907-8 as part of an exploration that included three holes in the NW $\frac{1}{4}$  NW $\frac{1}{4}$ . Bedrock was penetrated to depths of 24-81 feet. Core could not be located, and information is scarce.

According to the available records, G4 encountered black rock; G5, black slate; G6, quartz and slate; and G7, black slate. From the position of these drill holes with respect to the magnetic anomalies and to the Hanna drilling in the property adjacent to the north, the rock was probably graywacke and slate of the Hiawatha Graywacke.

Town 43 North, Range 35 West

#### Section 25

Except for the belt of Riverton Iron-formation adjacent to the Iron River at the west margin of the section, sec. 25 has not been extensively explored. In general (again excepting the west margin) the south half of the section is underlain by Hiawatha Graywacke bordered to the north by an anticlinal belt of iron-formation that, in the east part at least, is unoxidized. The SE $\frac{1}{4}$  NE $\frac{1}{4}$  also is marked by an extension of the magnetic anomaly shown in sec. 30, T43N, R34W to be caused by an unusual magnetite-bearing facies of the Riverton.

NW 1/4: The J & L exploration (Miller exploration) in the SW $\frac{1}{4}$  NW $\frac{1}{4}$  consisted of five deep holes (M1-M5) drilled by the Jones & Laughlin Ore Co. in 1914. Core could not be located, and the only information is from company records. The holes ranged in depth from 580 feet (M1) to 1512 feet (M5); all cut oxidized iron-formation after entering bedrock in graywacke or black slate.

The Hammer No. 2 exploration consists of three holes (1-3) drilled prior to 1910 in the E $\frac{1}{2}$  NW $\frac{1}{4}$ . Core was located and examined in Pickands Mather & Co. storage at Caspian. Hole No. 1, depth 155 feet, entered gray slate at ledge (the material has now crumbled to powder); hole No. 2, to a depth of 238 feet cut graywacke and interbedded black slate; hole No. 3 was stopped in overburden at 299

feet.

NE 1/4: The McDermott exploration consists of five deep holes (MD1-MD5) drilled in 1954 by the Cleveland-Cliffs Iron Co. in the W $\frac{1}{2}$  NE $\frac{1}{4}$ . Core is stored at Ishpeming, Michigan. Hole MD1, at 60° south, entered bedrock at 200 feet and to about 1220 feet is mostly in graywacke and slate (Hiawatha Graywacke); from 1200 to 1320 is in oxidized Riverton Iron-formation, and ends at 1350 feet in sheared graphitic slate. A second hole wedged off at 1076 feet and drilled to 1554 feet cuts a similar succession but with dike rock between 1389-1398 feet. Hole MD2, also drilled at 60° south, cuts a small amount of dark slate at bedrock surface, below which is a section of oxidized iron-formation to 403 feet. From 403 feet to the bottom at 550 feet the hole is mostly in graphitic pyritic slate, typical of the Wauseca Pyritic Member of the Dunn Creek Slate. Hole MD3, was drilled at 60° north and is in partly oxidized iron-formation to a depth of about 675 feet; from 675 feet to the bottom of the hole it is in black slate. Hole MD4, drilled from the same location as MD3 but to the south at 50°, cuts an alternation of slate and unoxidized iron-formation to the bottom at 946 feet. Hole MD5 at 50° (?) north, is in slate and siltstone to the end at 325 feet.

In all, these five holes define an anticline that brings Dunn Creek Slate to or near the bedrock surface. The anticline is flanked by Riverton Iron-formation and Hiawatha Graywacke. Oxidation of the Riverton seems to be confined mainly to the north flank (holes MD1, MD2) and to a probable minor syncline cut in MD3.

SW 1/4: The Miller exploration consists of 15 holes (D1-D15) drilled prior to 1909 in the belt of iron-formation in which the Delta mine was developed. The exploration is briefly noted by Allen (1910, p. 86), but the only specific data obtained are from Allen's notes, which were made available to us. The deepest hole, D8, was drilled to a depth of 650 feet. Holes D1 and D12 record chloritic schist and gray slate; these holes definitely are in the Hiawatha Graywacke. Hole D15 is recorded in black slate assumed to be part of the Dunn Creek Slate. The remainder of the holes apparently were in iron-formation.

The Hammer No. 1 exploration consists of a single drill hole, H1, drilled prior to 1909 in the SE $\frac{1}{4}$  SW $\frac{1}{4}$ . The hole cuts gray slate and graywacke.

SE 1/4: A single deep hole, C1, was drilled by the M. A. Hanna Co. in 1950 in the SE $\frac{1}{4}$  SE $\frac{1}{4}$ . The hole, started vertically but deviating strongly to the south, was drilled to a depth of about 1459 feet. The hole is mainly in graywacke and slate, the bedding generally within 10°-20° of the axis of the core.

Massive dark-green porphyritic metadiabase is cut at depths of 1216-1253 feet, 1270-1280 feet, and 1289-1297 feet.

#### Section 36

The major geologic feature of sec. 36 is a deep north-trending syncline centering in the western part of the section. The Stambaugh Formation, contained within the syncline, gives rise to a strong magnetic anomaly -- the largest known in western Iron County. The major trend of the syncline is N 20° W, and the structure is overturned to the west. The plunge of the fold changes along the strike to form three separate spoon-shaped bodies of Stambaugh Formation, reflected by more or less separated magnetic anomalies. A second syncline containing Stambaugh Formation is inferred from the magnetic anomaly in the north-eastern part of the section. The anomaly, and presumably the structure, trend about N 70° W.

Most explorations have been confined to the extreme western part and to the south half of the section; so far as is known, holes have not been drilled in three of the four "forties" of the most northern tier.

NW 1/4: Three holes are on record as having been drilled from the surface in the NW $\frac{1}{2}$  NW $\frac{1}{4}$ , which was the site of a main part of the Riverton mine. Holes 3601 and 3602 were drilled by the M. A. Hanna Co. in about 1928, and the core was located for examination at the company storage building at the Rogers mine. Hole 3601, drilled at 45° N 73° E, is interesting because it entered greenish-to reddish-banded slate at a depth of 105 feet after passing through graywacke; clearly it crosses the contact between the Hiawatha Graywacke and the Stambaugh Formation. Hole 3602, at 60° E, is in graywacke.

Hole NR1, in the same "forty" was drilled in 1949 by the North Range Mining Co. at 60° N 73° E. The hole was drilled to a depth of 295 feet, mostly in dark graywacke and graphitic argillite containing chert fragments.

NE 1/4: The Barras exploration, which preceded the development of the Barras mine, consisted of eight holes drilled by Cole & McDonald in 1907 in the S $\frac{1}{2}$  NE $\frac{1}{4}$ . Abbreviated core was located and examined at the Caspian offices of Pickands Mather & Co. Four of the holes (Nos. 3, 6, 7, and 8) are located directly above the mine workings, and are not shown on the map. Hole B1, the most easterly, was drilled to 132 feet in unoxidized massive graywacke, the others (B2, B4, B5) are in oxidized red and green slate and graywacke, of the Hiawatha Graywacke.

SW 1/4: The Cyr-Lennox exploration consists of 13 holes (CL4-16) drilled in 1929 by the Brule Mining Co. in the E $\frac{1}{2}$  SW $\frac{1}{4}$  and SE $\frac{1}{4}$

NW $\frac{1}{4}$ . Core was located and examined at the Pickands Mather & Co. offices at Caspian. The geologic boundaries of this area, as shown on plate 1, are based mainly on information gathered from the drill core. The holes range in depth from 58 feet (CL15) to 1224 feet (CL4).

Except for hole CL5, which entered Dunn Creek Slate (Wauseca Pyritic Member), and hole CL10, which entered bedrock in unoxidized iron-formation (Riverton), all the holes encountered graywacke and slate of the Hiawatha Graywacke. Except for the most northerly holes (CL14, CL15, CL16), all entered Riverton Iron-formation at depth; even CL5, which is in Dunn Creek Slate at bedrock surface, is in overturned Riverton Iron-formation (unoxidized) from 688 feet to the end of the hole at 702 feet. The most northwesterly hole, CL14, is in rock assigned to the Hiawatha Graywacke at ledge, but at 103 feet to the end of the hole at 161 feet is in magnetic slate of the Stambaugh Formation; either the contact here is overturned, or the hole deviates from vertical.

A single deep hole, 1-43, was drilled by the M. A. Hanna Co. in 1943 near the center of the SW $\frac{1}{4}$ . It is the only drill hole in the SW $\frac{1}{4}$  SW $\frac{1}{4}$ . The core, available for examination at the company storage sheds, is chiefly of graywacke with some slate; the bottom 18 feet of the hole (1175-1193) is in metadiabase.

SE 1/4: The Bengal exploration consists of seven holes (B1-B7) drilled by the Verona Mining Co. in 1906-7. Abbreviated core from the drilling was located and examined at the storehouse of Pickands Mather & Co. at Caspian. All the holes were in oxidized iron-formation with some infolded strata of the overlying Hiawatha Graywacke. The area of drilling has since been entered by underground workings (under "Barras mine", "Bengal mine", "Cannon mine").

The Tully exploration was carried out by Corrigan, McKinney Steel Co. at some time prior to the opening of the Tully mine in 1909. Thirty-seven holes (T1-T37) were drilled, several to a depth of more than a thousand feet. The core was not preserved, and the only record is sludge analyses from the drilling; apparently no lithologic descriptions were prepared. The area has since been the site of extensive underground workings (under "Tully mine", "Cannon mine", "Baker mine").

The Verona exploration consists of two drill holes (V1, V2) in the extreme southeastern part of sec. 36, immediately above the southwest extension of the Baker mine. The only record is from old maps of the Corrigan, McKinney Steel Co., and the drilling probably was done prior to the opening of the Baker mine in 1909. The lithologic descriptions for both holes suggest they entered Hiawatha Graywacke at ledge surface.

#### GAASTRA AREA

The Gaastra map area (plate 2), at the southwestern margin of the Iron River-Crystal Falls basin, covers 6 square miles, and includes the villages of Caspian and Gaastra. The Dober, Caspian, Berkshire, Fogarty, Buck, Youngs, Baltic, Zimmerman, and DeGrasse mines are within the map area. All are now inactive, but the Buck group (Fogarty, Berkshire, Baltic) were in operation until 1961 and were mapped in detail. The entire area was surveyed with a Schmidt-type vertical magnetometer; except for the southwestern part, determinations were made at 100-foot intervals along lines spaced 300 feet apart.

#### Geology

The geology of the area consists, in general, of a west-northwest-trending fold belt of Riverton Iron-formation bounded on the southwest successively by the older Dunn Creek Slate and Badwater Greenstone, and on the northeast by the younger Hiawatha Graywacke with infolded Stambaugh Formation. This belt is crossed, at approximately right angles, by strong cross folds resulting in northeast anticlinal projections of older strata and trough-like downfolds of younger strata of the Stambaugh Formation. In U.S. Geological Survey Professional Paper 570 the west-northwest-trending folds are referred to as the "peripheral" set, the northeast as the "radial" set. A fold of one set merges with that of another; the cross folds apparently were not superimposed but rather were developed at about the same time as the peripheral folds.

Dominant geologic features are the two northeast-trending anticlines interrupting the peripheral folds in the vicinities of the Caspian and Baltic mines, and the northeast-trending syncline resulting in the complex basin of Stambaugh Formation east of Gaastra. On a smaller scale, the results of the two fold trends are well shown in the northern part of sec. 6, T42N, R34W by the distribution of the Stambaugh Formation.

The only fault shown on the map is in the extreme northwest part of the area but certainly many others must be present even if they cannot be delineated with the data at hand. In particular, the "footwall" side of the productive iron-formation in the Caspian, Fogarty and Zimmerman mines is highly sheared; possibly the fault shown near the northwest corner of the map area may continue far to the southeast. Igneous rocks are sparse. The principal known body is an irregularly-shaped mass of chloritized metadiabase encountered in the shaft stations of the Fogarty No. 1 at the

9th, 10th, and 11th levels. Thin dikes of similar material have been cut by several drill holes elsewhere in the area.

The Badwater Greenstone about a mile to the south contains a strongly-magnetic horizon, and the effect of this underlying magnetic rock is noticeable in the Gaastra map area. Magnetic values rise progressively to the south in secs. 7 and 8, T42N, R34W. The reason for the general rise to the east, particularly noticeable in sec. 8, is not known.

#### Mines

#### Dober

The Dober mine, in the NW $\frac{1}{4}$  NW $\frac{1}{4}$  sec. 1, T42N, R35W, was operated together with the adjoining Isabella property to the north as part of the Riverton group by the Oliver Iron Mining Co. until about 1935. After that, it was incorporated into the Hiawatha No. 2 operation of the M. A. Hanna Co. In the general statistical records, the production from the Dober is included with either the Riverton or the Hiawatha No. 2, although in the report of the Commissioner of Mineral Statistics for 1900 (p. 109), the Dober produced 10,980 tons in 1889 and shipments were also made in 1888.

The Dober ore body, in its uppermost levels, extended westerly beneath the bed of the Iron River. To mine the ore body safely, the river was diverted by means of a canal dug in 1900--the 1893 disaster at the Mansfield mine in which 28 men were killed by a breakthrough of the Michigamme River, was still very fresh in mind.

The Dober-Isabella ore body, the form of which at the 5th level is indicated on plate 2, was the relatively modest near-surface portion of the great ore body mined to a depth of more than 2000 feet in the Hiawatha No. 2. The ore body is in the axial area of a west-plunging syncline, and widens progressively downward.

#### Caspian

The Caspian mine, in the NE $\frac{1}{4}$  sec. 1, T42N, R35W, was opened by the Verona Mining Co. in 1903, and operated until 1937, shipping a total of 6,623,320 tons. The ore was mined from three shafts, from which five major levels were driven. The deepest of the levels was at about 539 feet.

The main ore body, contained in a relatively shallow syncline which bottomed near the

5th level, was a large lens trending about N 30° W. The lens was about a fourth of a mile long and as much as 400 feet wide in maximum horizontal dimensions, and diminished progressively downward (fig. 6). The syncline is doubly-plunging and strongly overturned to the east, the amount of overturn increasing with depth.

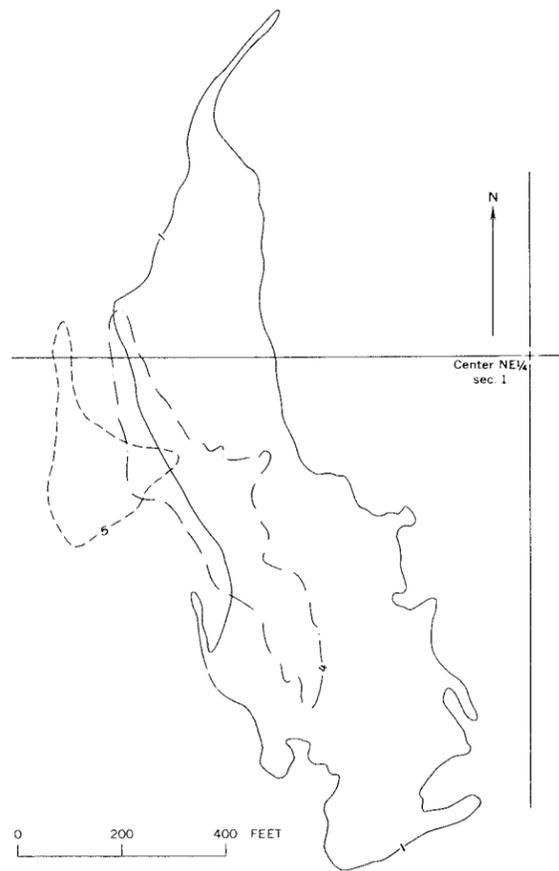


Figure 6--Plan of mined ore body in Caspian mine at levels 1, 4, and 5 (elevations 1,345, 1,115, and 965 feet), sec. 1, T42N, R35W.

Smaller ore bodies were mined north of No. 3 shaft up to the Tully property line; they seem also to have been contained in tight north-trending synclines.

At the 4th level, as shown in small scale on plate 2, long exploration drifts extend to the northeast, and a relatively small ore body was mined in the extreme northeastern part of sec. 1. This ore body trends northeast and

continues across the corner of the Tully property toward the old Baker mine. Excellent company maps show that the northeasterly structural trend is dominant throughout most of this area. The trend is nearly at right angles to the syncline containing the main ore body. On the basis of geologic data shown on the company maps, supplemented by examination of the core of numerous underground drill holes, evidently some hanging wall strata (Hiawatha Graywacke) are infolded with the Riverton Iron-formation, but the distribution is not sufficiently known to permit delineation on the map (plate 2). Nevertheless, the presence of these younger strata in an area of oxidized iron-formation and ore indicate deep synclinal folds which could contain substantial ore bodies.

#### Cottrell

The Cottrell mine in the NE 1/4 SE 1/4 sec. 1, T42N, R35W, was a small operation by the Oliver Iron Mining Co. Three levels, the deepest of which was 262 feet, were developed from a shaft; and 75,134 tons of ore were shipped during the period of operation, 1915-16. The main ore body was a small lens of easterly trend, apparently on the north limb of an east-plunging syncline. At lower levels the workings were merged with those of the Berkshire mine to the east.

#### Buck Group

The Buck group is a complex of mines in secs. 1 and 12, T42N, R35W, and secs. 6 and 7, T42N, R34W, gradually organized into a single operation by Pickands Mather & Co. The Fogarty, Buck, Berkshire, and Baltic were merged in 1944; the Zimmerman was included in 1948, and the DeGrasse in 1950. Production records of individual properties were not maintained after those dates. The major production in later years, however, was from the Buck property--in the SW 1/4 SW 1/4 sec. 6.

The form of the ore bodies in the area of the main Buck group, together with those of the adjoining Youngs and Cottrell mines, is shown on fig. 7.

The Buck group was closed in 1961; total shipments of ore, excluding those from the Zimmerman prior to 1948 and from the Berkshire prior to 1944, amounted to 15,368,486 tons through 1962.

The description of the Youngs mine is here included because, geologically, it is an integral part of the area. The mine however, was at no time part of the Buck group operations.

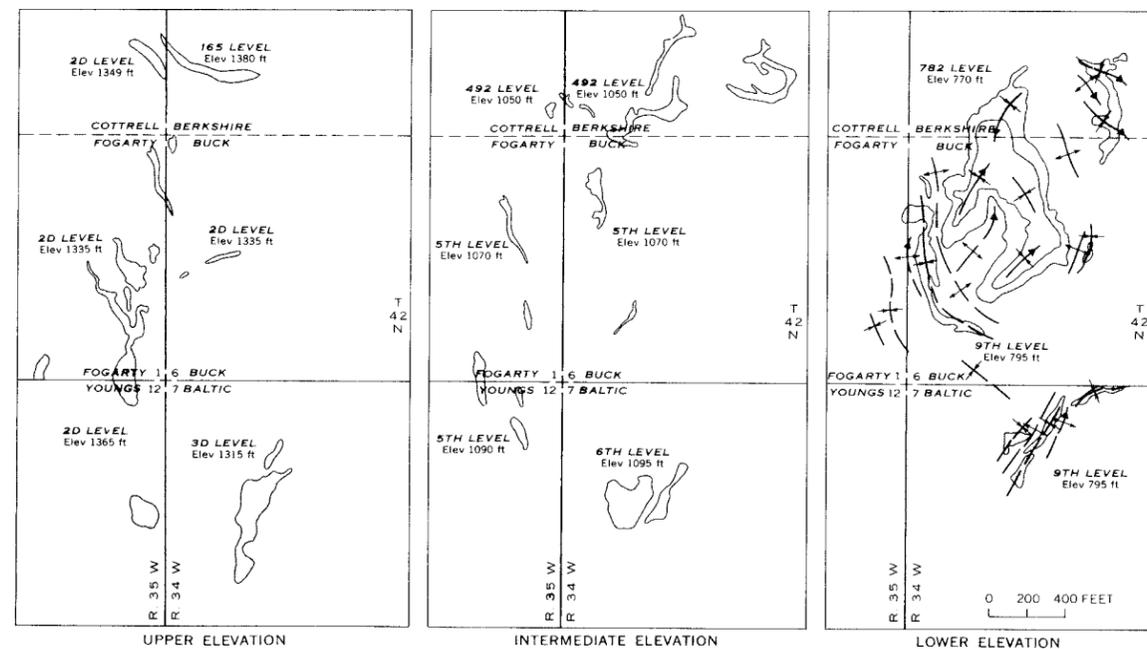


Figure 7--Generalized distribution of mined ore bodies in the Cottrell, Berkshire, Fogarty, Buck, Youngs, and Baltic mines at three elevations. Structural axes shown on lower level.

#### Berkshire

The Berkshire mine is in the N 1/2 SW 1/4 sec. 6, T42N, R34W. It was opened in 1908 by the Brule Mining Co. (Oglebay Norton & Co., Agents) from three shafts, and was developed by levels at depths of 165, 265, 365, 492, 692, and 782 feet. The mine was closed in 1930; production to that date (including the stockpile shipments of 1936-43) amounted to 2,963,657 tons. The mine was taken over by the Youngstown Mines Corp. and later by the Verona Mining Co. (Pickands Mather & Co., Agents); beginning in 1944 it became part of the Buck group operation and production figures are included in the Buck group total. As part of the Buck operation, the No. 2 shaft was rebuilt and ore was mined down to the Buck 12th level, at a depth of approximately 1280 feet.

The distribution of the ore bodies in the Berkshire mine is shown on fig. 7. At the upper levels, the mined ore had a trend nearly east. At moderate depth, the ore bodies, more complex in form, flanked a doubly-plunging anticline, still at a general easterly trend. At the deepest levels the trend of the ore bodies is dominantly south, with the principal ore body at those levels being in the axial zone of the south-plunging syncline containing

the major ore body of the Buck mine; to the east a second large ore body is on the crenulated western flank of a southeast-plunging syncline.

#### Fogarty

The Fogarty mine, in the SE 1/4 SE 1/4 sec. 1, T42N, R35W, was started as a separate operation in 1907 by the Verona Mining Co.; it became the base for operations on the adjoining Buck property in 1922, and after that time was operated as part of the Buck mine. Shipments credited to the Fogarty mine from 1907 through 1942 totaled 1,499,070 tons. Little or nothing is known of the history of the long-abandoned "Old Fogarty" shaft, shown on plate 2; all the development has been from two main shafts, the No. 1 and No. 2, from which 13 levels have been driven. The lowest level is at a depth of about 1420 feet, but most of the mining on the Fogarty property itself was at depths of 600 feet or less.

The principal ore bodies of the Fogarty occurred as tabular masses trending north-northwest and dipping 50°-75° to the northeast. The form in plan view is shown on fig. 7, and in cross section in the left part of plate 3 (cross section A-A'). The ore bodies occurred

on the flanks and axes of tightly-compressed overturned folds. This tight folding is characteristic of the Fogarty area; at the 9th level, within a distance of 300 feet east of the shaft, five isoclinal folds could be delineated on the basis of repetition of units in the upper part of the Dunn Creek Slate, mainly the Wauseca Pyritic Member, in a section of rocks of almost uniform dip. These folds in the footwall strata are the reflection of tight drag folds in the overlying iron-formation at upper levels, as shown on plate 3, A-A'. The folds are tightly compressed, but the great apparent vertical attenuation of the limbs of some of the folds is due to the fact that in places the folds plunge very steeply; locally the axes are vertical.

The shaft stations at the 10th and 11th levels are in a massive, soft, gray-green chloritized diabase dike (or sill) more than 200 feet thick. The diabase is approximately parallel to the axial planes of the folds, and may occupy a fault.

#### Buck

The Buck mine proper is in the SW $\frac{1}{4}$  SW $\frac{1}{4}$  sec. 6, T42N, R34W. The property was opened by the Verona Mining Co. in 1922 from the shafts in the Fogarty property to the west. The lowest level, the 13th, is at a depth of 1420 feet. As of 1943, shipments of 2,876,452 tons were credited to the Buck. Later production certainly would add considerably to this total.

At upper levels the ore bodies on the Buck property were small and scattered (fig. 7). At and below the 8th level (about 700 feet), however, very large ore bodies were developed; the generalized outlines at the 9th level are shown in fig. 7, and the form in cross section is indicated on plate 3, cross section A-A' and B-B'.

As shown on the map (plate 2), the Buck mine is situated in a generally northeast-plunging syncline that interrupts the regional northwest-trending folds characteristic of the Fogarty mine, just to the west. In detail the picture is highly complex: the area is marked by folds of both trends (fig. 7) resulting in extraordinary patterns. These interfering fold patterns make difficult the drawing of rational cross sections. In cross section A-A' (plate 3) drawn at right angles to the northwest trend, a huge bulbous mass of Hiawatha Graywacke appears in the central part of the cross section. In cross section B-B' (plate 3) drawn at right angles to the northeast trend, this same body is seen to be a relatively simple overturned syncline.

The great ore body completely outlining a complex syncline in the north-central part of the Buck mine at the 9th level (fig. 7) divides

at greater depth into two northeast-trending synclines. The keels of both structures, with respect to the ore-bearing Riverton Iron-formation, are between the 10th and 11th levels, and were entered by many crosscuts and drifts affording unparalleled opportunity to examine in detail the bottom of a major ore body. In all places, up to the contact with the underlying Wauseca Pyritic Member of the Dunn Creek Slate, the iron-formation had been converted to ore. The pyritic slate footwall itself is deeply oxidized to a dark red slate for a distance of several feet below the contact with the ore, but within a maximum distance of 10 feet the oxidized rock gives way to typical dense black pyritic rock of the Wauseca Pyritic Member.

At greater depth than the 9th level (fig. 7), the two most easterly ore bodies increase in dimension and continue at least to the lowest level of workings, the 13th, at a depth of about 1420 feet.

#### Youngs

The Youngs mine, in the NE $\frac{1}{4}$  NE $\frac{1}{4}$  sec. 12, T42N, R35W, was opened in 1905 by the Huron Iron Mining Co., and was operated intermittently under various managements until 1928. Total shipments aggregated 802,751 tons, most of which was mined in the period 1905-13. The mine was developed by five levels from a shaft reported to have been 518 feet deep; the deepest level for which records are available is at a depth of 418 feet. No part of the mine workings is accessible for examination.

Much of the ore mined was a direct continuation of ore bodies in the Fogarty mine to the north. The distribution at the 2nd and 5th levels is shown on fig. 7, and the inferred structure is shown in cross section C-C' (plate 3). The pod-shaped ore body in the southeastern part of the workings (fig. 7) is assumed to be in the axial area of a northwest-plunging syncline.

#### Baltic

The Baltic mine, in the NW $\frac{1}{4}$  NW $\frac{1}{4}$  sec. 7, T42N, R34W, was opened in 1901 by the Verona Mining Co. (Pickands Mather & Co., agents), and in 1922 was combined with the adjoining Fogarty and Buck mines into a single operation. In later statistical reports, shipments are included in the Buck group, but to 1943, shipments credited to the Baltic had amounted to 2,535,262 tons.

The initial mine development was from the two shafts in the NW $\frac{1}{4}$  NW $\frac{1}{4}$  sec. 7, but after incorporation with the Buck, only the No. 2 shaft was used. As part of the Buck group operation, the Baltic property was worked to the 12th level, at a depth of about 1220 feet.

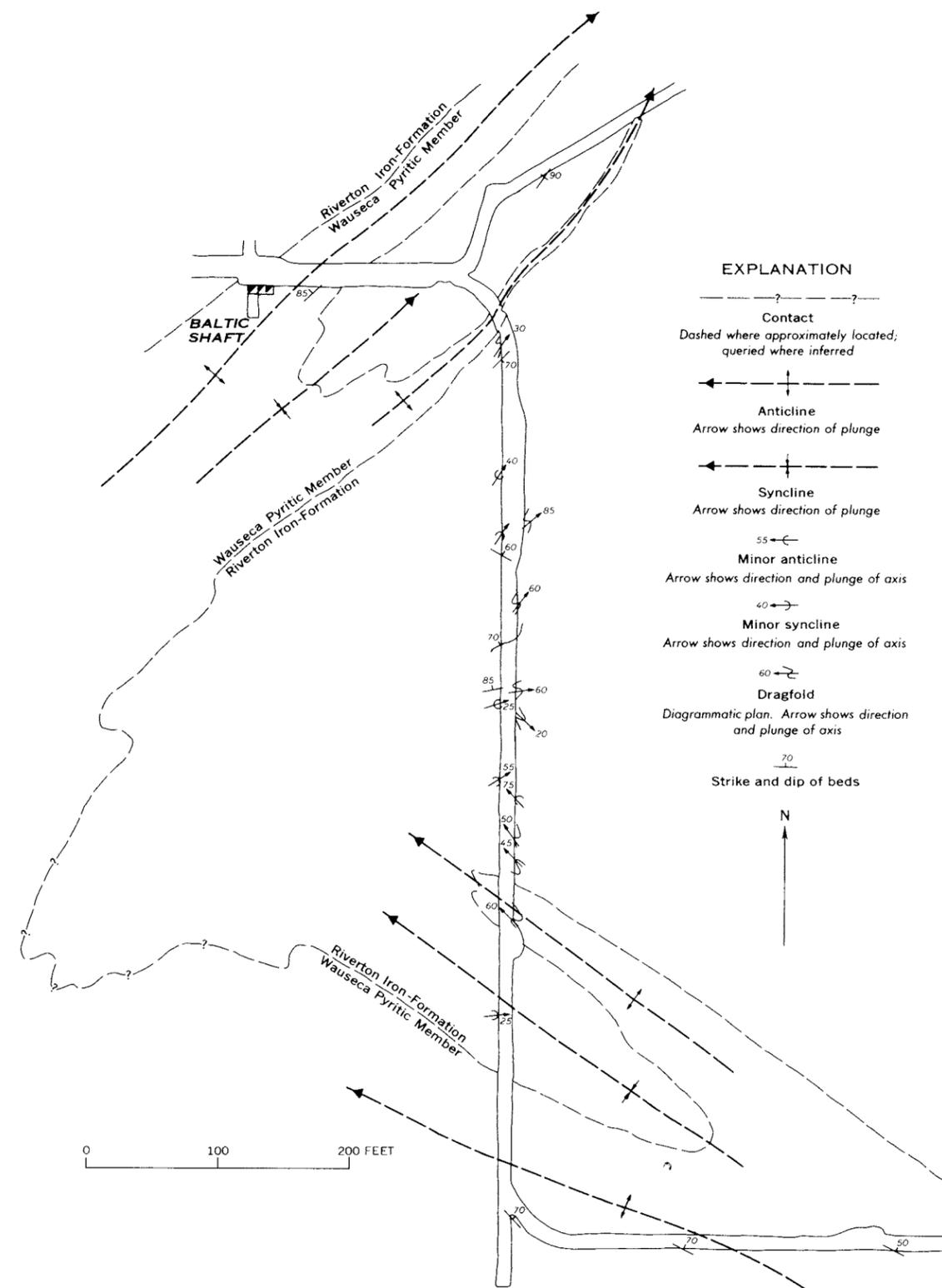


Figure 8--Attitudes of folds in transitional zone between northwest-trending peripheral folds and northeast-trending cross folds, 10th level in part of the Buck mine.

The Baltic ore bodies are nearly vertical pod-like to tabular masses extending from the surface to a depth of 1000 feet or more. They are shown in plan on fig. 7, and in cross section C-C' (plate 3). What was virtually a single mass at the uppermost levels separates into two or more bodies at depth, separated by a thin sheet of sheared graphitic slate. The structure is essentially an extraordinarily compressed anticline flanked by equally compressed synclines. The trends are northeast, and the folds abruptly terminate the regional northwesterly trends of the Zimmerman mine to the east and the Youngs mine to the west. The zone of transition as exposed on the 10th-level workings (plate 2) of the Buck mine is shown on fig. 8. This area is notable also in that the Riverton Iron-formation, deeply oxidized and in large part converted to ore in the northeast-trending structures, is entirely unoxidized in the northwest-trending folds at this level.

#### Zimmerman

The Zimmerman mine, occupying the E $\frac{1}{2}$  NW $\frac{1}{4}$  sec. 7, T42N, R34W, was opened in 1907 by the M. A. Hanna Co., which operated the mine until about 1944, when the mine was taken over by the Verona Mining Co. and incorporated with the Buck group. The recorded shipments from the mine to 1947 totalled 3,321,356 tons; later production, which was small, is included in the Buck group total.

The mine was opened from two shafts in the SE $\frac{1}{4}$  NW $\frac{1}{4}$  sec. 7, from which workings were developed at six main levels (not including the later entry of the Buck 10th level into the property at greater depth). The 6th level is at a depth of about 600 feet. The levels were extended into the DeGrasse property to the east, to exploit the eastern extension of the Zimmerman ore body.

The Zimmerman ore body is almost classic in form for the Iron River-Crystal Falls district. The Stope outlines at the 2nd level (plate 2), extending across almost the entire "forty" at a width of about 150 feet. The ore body is shown in cross section D-D' (plate 3); it occupied the crenulated south limb and axial area of a major dragfold deepening to the north.

The north part of the Zimmerman property, the NE $\frac{1}{4}$  NW $\frac{1}{4}$  sec. 7, is explored by the long 10th-level drift of the Buck mine, which passes across the entire width and into the DeGrasse property. At the west edge of the property, the drift (plate 2) is in unoxidized Riverton Iron-formation, then to the east crosses a narrow west-northwest-trending anticline of footwall slate, and reenters the iron-formation shown on cross section D-D' (plate 3). The iron-formation at the line of cross section is partly oxidized. At approximately

the point at which the drift swings to the southeast, the Riverton is in contact with graywacke (Hiawatha Graywacke) that continues to where the drift crosses the "forty" line into the DeGrasse property to the south. The south-heading drift again crosses partly oxidized iron-formation and enters the Wauseca Pyritic Member of the Dunn Creek Slate.

#### DeGrasse

The DeGrasse property, in the SW $\frac{1}{4}$  NE $\frac{1}{4}$  sec. 7, T42N, R34W, was tested from a shaft of shallow depth and unknown vintage. The only ore produced, however, was from an eastward extension of the Zimmerman ore body and was taken out from the Zimmerman shaft. The production, relatively small, is included in the Buck group total. The property was entered at the Buck 10th level, as previously described (see "Zimmerman mine").

The ore was restricted to the extreme west end of the property. The structure of the area and the distribution of ore (marked by stopes) is shown in cross section E-E' (plate 3).

#### Explorations

Town 42 North, Range 34 West

#### Section 5

Except for the inferred northeast projection of Riverton Iron-formation in its western part, sec. 5 is underlain chiefly by Hiawatha Graywacke with deep infolded complex basins of Stambaugh Formation marked by strong magnetic anomalies. Only ten holes are known to have been drilled in the entire section, and all are of shallow depth.

Three churn drill holes (H27-H29) were sunk in the N $\frac{1}{2}$  NW $\frac{1}{4}$  by the M. A. Hanna Co. in 1951, and the choppings were examined while the work was in progress. All three holes cut graywacke with chert fragments (Hiawatha Graywacke) at ledge surface and continued in this rock for a few feet to end of hole.

The "Greenhoot No. 2" exploration in the SW $\frac{1}{4}$  SW $\frac{1}{4}$  consisted of one hole (2-1), and the "Greenhoot No. 3" exploration consisted of one hole (3-1) in the NE $\frac{1}{4}$  SW $\frac{1}{4}$  and one hole (3-2) in the SW $\frac{1}{4}$  NW $\frac{1}{4}$ ; all were sunk with the churn drill and enter bedrock for less than five feet. Drill cuttings were located and examined in the Pickands Mather & Co. storage facilities at Caspian. Hole 2-1 cut coarse dark graywacke; hole 3-1 (on the east flank

of a strong magnetic anomaly) cut nonmagnetic dark gray slate and graywacke; hole 3-2 cut graywacke.

Four holes (01-04), known as the Oleson exploration, were drilled in the SE $\frac{1}{4}$  at some date prior to 1910. Each is recorded in R. C. Allen's notes as having encountered black slate at bedrock surface. The deepest enters bedrock for three feet.

#### Section 6

The southwestern part of sec. 6 is marked by two tight northeast-trending anticlines, between which is the synclinal area with some of the major ore bodies of the Iron River-Crystal Falls district. The northeast structural trend continues dominant in all but the extreme north-central part of the section. This trend is shown by the northeast elongation of magnetic anomalies caused by troughs of the Stambaugh Formation. In the north-central part, similar anomalies trend northwest, indicating synclines of that orientation. Most of the area, except for the fringes and projections of Riverton Iron-formation and Dunn Creek Slate and the basins of magnetic Stambaugh Formation, is underlain by Hiawatha Graywacke.

NW 1/4: The Borland exploration in the N $\frac{1}{2}$  NW $\frac{1}{4}$ , consisting of 13 diamond drill holes (B1-B13), actually represents two separate drilling campaigns: holes B1-B5 were sunk by the Brule Mining Co. in 1908, whereas holes B6-B13 were sunk by Pickands Mather & Co. in 1930-31. Only the core from the latter group of holes could be located; it was stored at the Caspian property of Pickands Mather & Co. The available information for holes B1-B5 is scanty; for hole B2, by far the deepest, the total record consists of the following: "0'-150', surface; 150'-665', iron-formation; 665'-730', quartz and slate".

Of the later drilling holes, B6-B10, all entered well-oxidized cherty iron-formation (Riverton) at bedrock surface, and all entered greenish to red ferruginous slate, graywacke, or breccia at depths ranging from 200 to 380 feet. The latter rocks probably are part of the complex chaotic material known to form the lower part of the Riverton in the area immediately to the northwest. Hole B11 is of much interest because it cuts, from 82 to 370 feet, an excellent section of the magnetic Stambaugh Formation (the hole is located on the southwest flank of a strong magnetic anomaly); below 370 feet to the bottom at 738 feet, the hole cuts Hiawatha Graywacke consisting of graywacke, graphitic slate, and chert-siderite breccia with graywacke as matrix and as separate layers. Hole B12 cuts unoxidized to partly oxidized iron-formation at bedrock surface, then at 180 feet it passes through iron-formation breccia grading into graywacke to

the bottom of the hole at 722 feet. Hole B13, except for infolded oxidized iron-formation at 640-835 feet, is in oxidized graywacke and slate for most of its length; it ends in massive coarse graywacke at 1045 feet.

The DM & M exploration consisted of six churn drill holes (D1-D4, D6, D8) and two test pits in the SE $\frac{1}{4}$  NW $\frac{1}{4}$ . Chip samples were found filed at the Pickands Mather & Co. storehouse in Caspian. None of the holes or test pits entered more than a few feet of bedrock. Similar material was cut in all: graywacke, some with abundant chert fragments, assigned stratigraphically to the Hiawatha Formation.

NE 1/4: Seven holes are known to have been drilled in the NE $\frac{1}{4}$ . Two (B1, B2), in the NW $\frac{1}{4}$  NE $\frac{1}{4}$ , comprise the "Brown exploration", and were put down prior to 1909; three, in the W $\frac{1}{2}$  NE $\frac{1}{4}$  (J61, J62, J63), were drilled by the Jones & Laughlin Steel Corp., and the core was located for examination at the company storehouse in Negaunee. One hole (1-52), in the NW $\frac{1}{4}$  NE $\frac{1}{4}$ , was drilled in 1952 by the M. A. Hanna Co., and the core was examined at the time of drilling; and one (G5) is a churn drill hole in the NE $\frac{1}{4}$  NE $\frac{1}{4}$  that was part of the "Glavin exploration" of unknown age (but pre-1909) and sponsorship.

Holes B1 and B2 are reported as having entered mainly black slate. Holes J61, J62, J63 cut material very similar to that encountered in the churn drill holes and test pits in the SE $\frac{1}{4}$  NW $\frac{1}{4}$  sec. 6--that is, graywacke, commonly with chert fragments; in each, the graywacke grades for short distances into an unoxidized chert-siderite breccia. Hole 1-52, drilled to 138 feet, cuts gray slate and sideritic slate. Chip samples from hole G5 indicate it cuts bedrock composed of dark graywacke and gray slate, with chert fragments.

SW 1/4: Only one surface hole is known to have been drilled in the NW $\frac{1}{4}$  SW $\frac{1}{4}$ , the Berkshire exploration. This hole, No. 13, entered iron-formation for a few feet. Of the many exploration holes drilled from the mine workings, No. 4 is worthy of specific note. This hole was drilled horizontally N 60° W from the 365 level and crosses the major anticline north of the mine workings. The hole is in Dunn Creek Slate for more than 1000 feet, then enters partly oxidized Riverton Iron-formation, here apparently in a minor syncline on the north flank of the main anticline, then ends in Dunn Creek Slate at 1544 feet.

The Corry exploration consists of 13 holes drilled by the Verona Mining Co. in the NE $\frac{1}{4}$  SW $\frac{1}{4}$  in about 1910. Of these, C1, C2, and C5 are churn drill holes; the remainder are diamond drill holes. Core from the holes was examined at the core storage facility of Pickands Mather & Co. at Caspian.

All the Corry holes entered Hiawatha

Graywacke at ledge surface, and holes C7, C8, C9, C10, C11, and C13 entered oxidized River Iron-formation at depth. One hole (C8) was continued into Dunn Creek Slate at a depth of about 500 feet.

The Corry shaft, in the western part of the "forty", was sunk to a relatively shallow depth by the Michigan Mining Co. shortly after the program of surface drilling was completed. Little is known of this development, but the shaft apparently was 255 feet deep. From the 255 level, Corry hole No. 14 was drilled at 80° south; the hole began in graywacke (Hiawatha), passed into oxidized Riverton Iron-formation at a depth of about 500 feet, and ended in pyritic slate (Dunn Creek) at 750 feet. The area of the drill hole and the Corry shaft later was entered by the easterly workings of the lower levels of the adjoining Berkshire mine.

The Buck (Youngs) exploration comprises 17 diamond drill holes (B7-B23) drilled at various times between 1914 and 1940 by Pickands Mather & Co. (Verona Mining Co.) in the SW $\frac{1}{4}$  SW $\frac{1}{4}$ . Abbreviated core from the drilling was examined at the Pickands Mather & Co. storehouse at Caspian. The area has been the site of extensive mining operations that extend through a vertical depth of 1420 feet (see "Buck mine"). Perhaps the only holes deserving specific mention are B22 and B23, in the southeastern part of the "forty", because they provide data on which the long northeastward anticline of Dunn Creek Slate is based (see plate 2). B22 entered sericitic slate and fine-grained graywacke at ledge surface and continued in similar material to the bottom at 1260 feet; B23 entered ledge in pyritic black slate, which alternated with sericitic slate and graywacke to the bottom at 1100 feet. In B23, the pyritic slate is identified certainly as Wauseca Pyritic Member (including the diagnostic slate breccia unit); B22 apparently is entirely in Dunn Creek Slate below the Wauseca Pyritic Member. In both holes, however, some of the rock encountered is graywacke with chert fragments--a rock type normally more characteristic of the Hiawatha Graywacke.

The only known exploration in the SE $\frac{1}{4}$  SW $\frac{1}{4}$  consists of churn drill holes (B1-B3) sunk by Pickands Mather & Co. in 1943 to test water levels. The holes enter bedrock only a few inches. B1 encountered iron-formation, B2 gray slate, and B3 black slate.

SE 1/4: The Glavin exploration, completed prior to 1910, consisted of six drill holes in the NW $\frac{1}{4}$  SE $\frac{1}{4}$ , of which G1, G2, G3, and G6 were sunk by churn drill and G4 and G7 by diamond drill. All are shallow; the deepest entered bedrock 12 feet. Choppings and core from the exploration were located and examined in Pickands Mather & Co. storage at Caspian. The rock cut at ledge surface in the holes

consists of graywacke or of graywacke and slate; chert, apparently as fragments, occurs with the graywacke in some holes.

Four holes (P1-P4) were drilled in the SE $\frac{1}{4}$  in 1950 by the Pacific Isles Mining Co. The core from the drilling was examined during the progress of the exploration. The holes range in total depth from 170 to 320 feet. All the holes are in unoxidized Riverton Iron-formation at ledge surface and for most of their length, except P2, which encountered short runs of graywacke (apparently infolded Hiawatha Graywacke) and ended in that rock.

#### Section 7

Except for the W $\frac{1}{2}$  SW $\frac{1}{4}$  and the N $\frac{1}{2}$  NE $\frac{1}{4}$ , sec. 7 has been extensively drilled, some of the earlier exploration resulting in development of the Baltic and Zimmerman mines in the NW $\frac{1}{4}$ .

Sec. 7 is crossed by a belt of Riverton Iron-formation trending ESE from the northwest corner. North of this belt is the younger Hiawatha Graywacke, and in the NE $\frac{1}{4}$  a deep infold of Stambaugh Formation is marked by a magnetic anomaly; south of the iron-formation the section seems to be underlain by Dunn Creek Slate.

NE 1/4: The Degrassee exploration consists of 13 holes (D1-D4, D7-D10, D12, D17, D21, and D26-D27) in the S $\frac{1}{2}$  NE $\frac{1}{4}$  drilled by Pickands Mather & Co. (Verona Mining Co.) at various times from 1906 to about 1950. Except for holes D1-D4, drilled in 1906, the core from the drilling has been located and studied at the Pickands Mather & Co. facilities at Caspian. As shown on cross section E-E' (plate 3), holes D7 and D8 cut the Riverton Iron-formation and extend into the footwall pyritic slate (Wauseca Pyritic Member), as does hole D9. Hole D10, however, located more centrally with respect to the principal synclinal axis of the area, ends in Hiawatha Graywacke at 490 feet. Hole D12 enters greenish slate of the Hiawatha Graywacke at bedrock surface, then passes through oxidized Riverton Iron-formation with locally infolded graywacke to 1440 feet, then cuts pyritic slate (Wauseca Pyritic Member) to the end of the hole at 1463 feet. Hole D17 is in pyritic black slate (Wauseca Pyritic Member) at bedrock surface, then continues to 335 feet in sericitic slate and fine-grained graywacke of the Dunn Creek Slate stratigraphically below the Wauseca Pyritic Member. Hole D21 is in Dunn Creek Slate to the bottom at 825 feet. Hole 26 cuts iron-formation at ledge, with pyritic slate (Wauseca Pyritic Member) from 365 feet to the bottom at 477 feet. Hole 27 is in Dunn Creek Slate to the end of the hole at 324 feet.

In the SW $\frac{1}{4}$  NE $\frac{1}{4}$ , two holes, V1 and V2, presumably were drilled by the Verona Mining Co. (also referred to as a Greenhoot exploration).

Both were drilled S 30° W at about 70°, and seem to have been entirely in Dunn Creek Slate.

Hole C3, the only one in the NW $\frac{1}{4}$  NE $\frac{1}{4}$ , was churn drilled in 1944 and reported to have cut black slate at ledge.

NW 1/4: Ten holes of the Zimmerman exploration, numbered A42, B42, C42, P42, W42, AA42, A-43, B-43, C-43, and D-43, were drilled in 1942-43 by the M. A. Hanna Co., mostly in the NE $\frac{1}{4}$  NW $\frac{1}{4}$ . The core was examined at the core storage maintained by that company at the Rogers mine.

The data obtained from holes W42, A43, B43, and C43 are summarized in cross section D-D' (plate 3). The other holes, except for A42 and B42, entered Hiawatha Graywacke at ledge, and most were continued into the underlying iron-formation. Hole W42 ended in pyritic slate (probably Wauseca Pyritic Member) at 535 feet. Holes A42 and B42 both cut iron-formation (Riverton) at bedrock surface, but the surface expression of the Riverton at hole B42 is not indicated on the map (plate 2); it is assumed to reach surface only locally on a minor anticline.

Two other groups of holes have been drilled in the E $\frac{1}{2}$  NW $\frac{1}{4}$ . In the extreme northwest part of the NE $\frac{1}{4}$  NW $\frac{1}{4}$ , hole M1 actually represents three relatively shallow holes drilled in different directions from the same location; the available records indicate each hole cut black slate and interlayers of black chert. In the southwestern part of the SE $\frac{1}{4}$  NW $\frac{1}{4}$  three holes (701-703) were drilled in 1928 by the M. A. Hanna Co. The holes are short; the deepest entering bedrock for 23 feet; all are recorded as cutting gray or dark gray slate.

Several holes were drilled in the NW $\frac{1}{4}$  NW $\frac{1}{4}$  in 1905 prior to the opening of the Baltic mine; the location of only one (B8) is known, and the area has since been extensively explored underground (see "Baltic mine").

A second group of holes (B11-B19, B22) was drilled by Pickands Mather & Co. in 1916 on the westward extension of the Zimmerman ore body. The core was not located, and the available descriptions are from logs made by W. L. Schofield in 1933. All except B22 cut oxidized iron-formation at bedrock surface, and holes B11, B18, and B19 (the latter an angle hole from the same location as B18) seem to have passed into the underlying Dunn Creek Slate. B22 cut about 65 feet of graywacke (Hiawatha) before entering iron-formation.

SW 1/4: The Kinney exploration consists of seven holes (K1-K7), the deepest of which, K1, was drilled 142 feet into bedrock. The only locations and descriptions are from a 1909 notebook of R. C. Allen. All are reported as cutting slate, except for black rock in K4.

The only other hole known to have been drilled in the E $\frac{1}{2}$  SW $\frac{1}{4}$  is A43, a shallow churn drill hole sunk by the M. A. Hanna Co. in 1942; chert and slate are reported to have been cut.

SE 1/4: Two groups of holes have been drilled in the N $\frac{1}{2}$  SE $\frac{1}{4}$ ; both are referred to as "Greenhoot" explorations. The earliest, known as the Greenhoot No. 1, was completed at some date prior to 1909. It consists of three short churn drill holes, G1-G3, one of which (G1) was drilled from a test pit 96 feet deep. G1 is reported to have cut gray slate. Choppings from holes G2 and G3 were located in the Pickands Mather & Co. core storage facility at Caspian; G2 cut pyritic black slate, and G3 cut probable graywacke.

A second drilling campaign, also prior to 1909, consists of six holes (M1-M6) sunk by the M. A. Hanna Co. (?) in the NW $\frac{1}{4}$  SE $\frac{1}{4}$ . Most of the holes were reported to have cut gray slate. M1, however, is described in 1909 notes by R. C. Allen as in ferruginous chert and ore, but this is not confirmed by another record which refers to the material as vein matter. M2, the deepest hole (675 feet) is of considerable interest, as both the company records and Allen's notes list dolomite from about 264 to 379 feet and from 486 to 576 feet. According to Allen's notes, the hole ends in dolomite and chert and slates, whereas the company record shows quartz and slates. The stratigraphic assignment of this "dolomite" is uncertain; possibly the material is from carbonate filling along a shear zone.

The Holmes exploration consists of four diamond drill holes (H1-H4) in the S $\frac{1}{2}$  SE $\frac{1}{4}$ . They were drilled prior to 1909 by the Munro Mining Co. and the only record located is from R. C. Allen's 1909 notes. All are reported as having cut gray slate.

#### Section 8

Few holes have been drilled in sec. 8, and most of these are in the southern and western parts of the section; holes are not known in the NE $\frac{1}{4}$ , or in the adjacent E $\frac{1}{2}$  NW $\frac{1}{4}$ . The geology of the section is marked by three principal troughs or basins, the northern two of which contain Stambaugh Formation (outlined on the basis of magnetic anomalies) and the southern one containing Hiawatha Graywacke enclosed in Riverton Iron-formation. This latter structure differs from that given on a previous map (James and others, 1959) and is based on reconsideration of drill hole data in the south-central part of the section. The simple pattern shown certainly will prove to be incorrect in detail and may be incorrect wholly, because scattered evidence indicates faults could provide a quite different map pattern. The evidence for faulting is in the occurrence of quartz vein and dikes, commonly

associated with faults elsewhere, in several of the drill holes.

**N 1/2:** A short churn drill hole (2-2'), part of the "Greenhoot No. 2" exploration dating back to the early 1900's, is located in the extreme northwest corner of sec. 8. Choppings were located and examined at the Pickands Mather & Co. storehouse; the material is black pyritic slate, presumably the Wauseca Pyritic Member of the Dunn Creek Slate. Three holes (W1-W3) comprise the Wakefield (or Girard) exploration in the SW 1/4 NW 1/4. The only record available is from the 1909 notes of R. C. Allen: Hole W1 was drilled to 614 feet, ending in slate after passing through 540 feet of iron-formation; W2 and W3 are shallow holes that cored black slate.

A second "Greenhoot" hole (G1) in sec. 8 is located in the NW 1/4 SE 1/4. The hole cuts iron-formation at bedrock surface, with slate from 314 feet to the bottom at 430 feet. R. C. Allen's notes also record a third hole, "L. & H. No. 3" cutting slate and quartz.

**S 1/2:** Ten holes were drilled in 1930-31 by the Jones & Laughlin Steel Corp. The core was examined at the Jones & Laughlin storage building in Negaunee. The holes are in two groups: one in the western part of the section (holes 87, 88, 89, 810), and one in the southern part (holes 81-86). Of the western group, hole 87 ends in graywacke (probably infolded and overturned Hiawatha Graywacke) at 609 feet; hole 88 cuts graywacke and slate (Hiawatha) with some infolded iron-formation to the bottom at 500 feet; hole 89, after cutting iron-formation at ledge surface, cuts black pyritic slate (Wauseca Pyritic Member) from 370 feet to the end of the hole at 470 feet; and hole 810 cuts a section consisting of Hiawatha Graywacke to about 430 feet, Riverton Iron-formation to about 800 feet, and Dunn Creek Slate to the end at 905 feet (Wauseca Pyritic Member to 895 feet).

Of the southern group, holes 81, 82, 83, 84, and 86 cut mostly an alternation of slate and graywacke, some of it with chert nodules and fragments, assigned to the Hiawatha Graywacke; holes 81, 83, and 84 cut also some infolded (?) iron-formation. Hole 83, itself an extension of Brule hole No. 4 (see below), later was continued as hole No. 1 of the North Range exploration (see also below). Hole 85, south of the main area of Riverton Iron-formation, for most of its length is in slate and fine graywacke tentatively assigned to Dunn Creek Slate; conceivably, however, the rock is Hiawatha Graywacke in yet another syncline.

The St. Claire exploration, of unknown sponsorship and date, consists of four diamond drill holes (SC1-SC4) in the northern part of the NW 1/4 SW 1/4; records are from old prints in company files. The holes are all deep (800-

1667 feet). SC1 and SC2 cut definite iron-formation (and ore) at ledge, and were continued into slate at considerable depth; SC3 cut possible iron-formation at ledge (jasper, slate, and quartz), passed into oxidized iron-formation and ore, and ended in slate at 837 feet. SC4 cut black slate at ledge surface but ended in lean ore at 800 feet.

The proper numbering and assignments of some of the drilling in the southern and western parts of sec. 8 is confusing. The holes here referred to as the Boorland exploration (B1-B4) in the S 1/2 SW 1/4 are listed in the 1909 notes of R. C. Allen as "Wakefield" holes 4-7.

The four Boorland holes are all shallow, the deepest entering bedrock for 20 feet. The two western holes are reported in greenstone and soapstone--both probably are in altered dikes. The two eastern holes, B3-B4, are recorded merely as in slate and gray slate.

The Brule (or McDonald) exploration consists of four holes drilled in 1907 by the Brule Mining Co. in the SW 1/4 SE 1/4. Only three (Br1-Br3) are shown on the map (plate 2); the fourth hole was reoccupied by hole 83 of the Jones & Laughlin exploration (and later by hole 1 of the North Range exploration). Br1, a vertical hole, cuts iron-formation (Riverton) to 332 feet, then is in slate (presumably Dunn Creek) to 535 feet. Br2 drilled at 75° S 45° E cuts iron-formation and slate to 540 feet, then slate to the bottom at 721 feet. Br3, drilled also at 75° but in the opposite direction seems to have been in Riverton Iron-formation to the bottom at 434 feet.

Three holes were drilled in the SW 1/4 SE 1/4 sec. 8 in 1950 by the North Range Mining Co. The core was examined at the time of drilling. The first hole, a continuation of J. & L. hole 83, which stopped at 440 feet, was drilled to 1180 feet. After cutting about 130 feet of Dunn Creek Slate, the hole penetrated two narrow dikes of metadiabase, probably along a fault, and then cut the Riverton Iron-formation to 742 feet. Below the iron-formation the hole passed through an alternation of dike rock and sheared quartz-veined slate, ending at 1180 feet in well-banded siltstone of the Dunn Creek Slate. Hole NR2 cut slate at ledge surface, then iron-formation from 161 to 460 feet, and slate (Dunn Creek) to the bottom at 575 feet. NR3, drilled north at 60°, also cut slate at ledge surface and then an alternation of infolded iron-formation and slate to the bottom at 980 feet.

The Saunders exploration consists of eight holes (S1-S8), drilled by the Cleveland-Cliffs Iron Co. in 1910-11 in the E 1/2 SE 1/4. The core was located and examined at the Cleveland-Cliffs offices at Ishpeming. Holes S1-S3 are in oxidized sericitic slate and fine-grained graywacke--probably that part of the Dunn Creek Slate below the Wauseca Pyritic Member, but

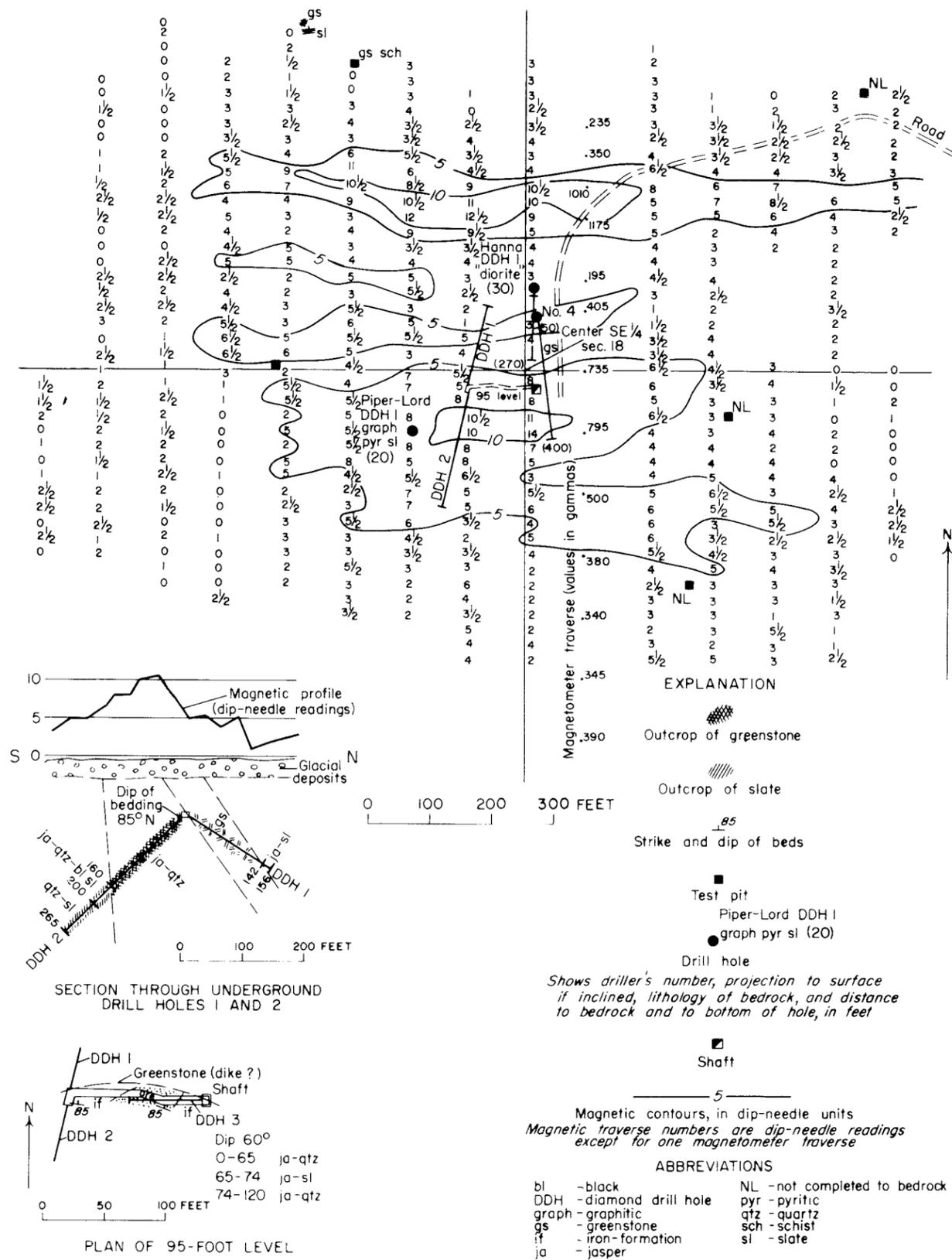


Figure 9--Geologic and magnetic data, vicinity of Wild Cat exploration, SE 1/4, sec. 18, T42N, R34W. Dip needle survey by T. Knutson. Geology from mining company records.

possibly Hiawatha Graywacke. Holes S4-S5 are in ferruginous slate and oxidized slaty iron-formation. Holes S6 and S8 are in ferruginous slate and graywacke. Hole S7 is particularly significant because it cuts banded to fissile magnetic slate of the Stambaugh Formation.

Section 18

The Wild Cat exploration, in the SE $\frac{1}{4}$  sec. 18, T42N, R34W, about a mile and a half south of Gaastra, is located within the south belt of Badwater Greenstone, outside the map area of plate 2.

The original development followed a test pit discovery of iron ore by Gaunce Gallup and Andrew Young in 1907. The property was taken over by the Huron Mining Co., which sank a shaft to a depth of less than 100 feet, with a short drift to the west at the 95-foot level. Three short holes were drilled from this level in 1908, as well as one hole from the surface, after which the property was abandoned. It was pumped out by K. D. Campbell and associates in 1939 for examination and sampling by the M. A. Hanna Co. A 270-foot hole was drilled on the property by the latter company in that year, but no further work was undertaken. A 335-foot hole sunk by the Piper-Lord Co. in 1946 represents the last exploration activity in the area. No ore was ever shipped.

The geologic and exploration data available are given on fig. 9. The only first-hand information available, other than the magnetic data, is from the mine dump and from the Piper-Lord drill hole, core which was examined. The mine dump shows a considerable amount of medium-grained greenstone (originally diabase), massive dark cherty material, and dense dark iron ore. The ore is magnetic, and apparently consists of fine-grained magnetite and hematite. The abbreviated log of the drill hole is as follows:

| (Feet)  | Material  |
|---------|---|
| 0-20    | Overburden.   |
| 20-140  | Dark gray slate and siltstone, with much pyrite as thin layers and crosscutting veinlets.           |
| 140-302 | Greenstone, fine-to medium grained. From 200-222 feet, greenstone is tuffaceous, strongly magnetic. |
| 302-335 | Tuff, banded, red and green. Parts magnetic, with visible magnetite octahedra.                      |

The interpretation of the data is not clear. However, the greenstone in this locality contains much interbedded slate, and is cut by at least one metadiabase dike. None of the material seen could be certainly classi-

fied as iron-formation. Possibly, if not probably, the cherty material and the magnetic ore are not strictly sedimentary in origin but are rather due to hydrothermal action related to volcanism during accumulation of the Badwater Greenstone.

Town 42 North, Range 35 West

Section 1

The northern and eastern parts of sec. 1 have been extensively explored by drilling. Ore has been produced from several mines; from northwest to southeast, the Dober, Caspian, Cottrell, and Fogarty. Geologically, the most striking feature (plate 2) is a major northeast-trending anticline interrupting the normal northwest-trending fold systems in which the Caspian and Fogarty mines are located. A few low exposures of slate (Dunn Creek) and Riverton Iron-formation occur along and adjacent to the Iron River in the southeastern part of the section.

NE 1/4: The Caspian exploration consists of 21 surface diamond drill holes sunk by the Verona Mining Co. at various times prior to and during operation of the Caspian mine in 1903-37. The holes are numbered C1-C5, C11, C17-C22, C25-C32, C53, and C55, of which several are immediately over the mine workings and are not shown on plate 2. The descriptions of holes through C29 are from company records; for numbers C30 and above, the core was located and studied at the storage facilities of Pickands Mather & Co. at the Caspian mine. Of these holes, only C31 and C32 warrant specific mention, because the others are in areas subsequently entered by mine workings. C32 enters oxidized iron-formation at ledge and passes into ferruginous slate (Hiawatha ?) below 230 feet. C31 also cuts iron-formation at bedrock surface, then ferruginous slate and graywacke at 280-300 feet, and from 300 feet to the end at 323 feet is in banded dark magnetic slate typical of the Stambaugh Formation. The hole is located on the flank of a magnetic anomaly, the crest of which is a short distance to the east. The data suggest that the syncline containing the Stambaugh Formation is overturned to the southeast (axial plane dips to northwest), and that the Hiawatha Graywacke is either extraordinarily thin in this locality or is in part cut out by an unmapped fault.

NW 1/4: The Dober explorations consist of two groups of holes, one (D1-D10) drilled prior to 1909 by the Oliver Iron Mining Co., and the second (1A, 1-44, 2-44, 4-44) drilled in 1941 and 1944 by the M. A. Hanna Co. The only records of the first group are from the 1909 notes of R. C. Allen, and virtually all (except D4 which was not ledged) cut rock described variously as black slate, black rock,

and similar rock; all are assumed to be in Dunn Creek Slate. The core from the second group of holes was examined at the Rogers mine storage of the M. A. Hanna Co. Hole 1A, drilled northeast at 55°, is in Dunn Creek Slate to approximately 400 feet, then is in unoxidized iron-formation grading into oxidized iron-formation to the bottom at 915 feet. Hole 1-44 cuts a small footage of unoxidized iron-formation at ledge and then is in slate to the bottom at 294 feet. Hole 2-44, drilled south at 60°, cuts sericitic gray slate and fine-grained graywacke to the bottom at 1050 feet. Hole 4-44 cuts unoxidized iron-formation breccia and unoxidized bedded iron-formation to the bottom at 996 feet. Presumably this material is to be assigned to the Riverton Iron-formation; if so, it must be contained either in a very tight deep syncline or a fault slice, neither of which are known from other data.

SW 1/4: The Longyear-Hodge exploration consists of four relatively shallow holes (L1-L4) drilled in 1907, and the only record located is from an old print in files of the Mineral Mining Co. L1 is reported as having cut quartz and slate at ledge surface, whereas the others cut green rock, presumably greenstone (Badwater).

SE 1/4: Sixteen holes (C1-C16) were drilled on the Cottrell property in 1913-14 by the Oliver Iron Mining Co. in the NE $\frac{1}{4}$  SE $\frac{1}{4}$ . Several of the holes (C4-C7) were in iron-formation subsequently entered by workings of the Cottrell mine. Most of the other holes, some long-angle holes, cut what is described merely as slate. Holes C13-C16, however, are reported to have entered iron-formation at bedrock surface, and from the analyses, hole C13 certainly is in Riverton. Each of these holes reportedly entered slate at relatively shallow depth after cutting iron-formation. Presumably the Riverton here occurs as a shallow doubly-plunging syncline. Hole C2 (same collar location as that of C1 and C3), a long hole drilled southwest at 45°, fails to intersect a southeasterly extension of iron-formation; and hole C11, drilled west at 45°, similarly fails to cut a northern extension.

The Morgan exploration consists of four closely-grouped holes in the northern part of the NW $\frac{1}{4}$  SE $\frac{1}{4}$ . The date and sponsorship of the drilling is not known, but the core was located at the storage facility of Pickands Mather & Co. at the Caspian mine. Unoxidized chert-siderite breccia, accompanied by graphitic slate and graywacke was encountered in each hole; presumably the holes are located stratigraphically in either the base of the Riverton (marked by chaotic breccia in this area) or the uppermost part of the Dunn Creek Slate, and that the alternation is due to interbedding and infolding.

The Winifred exploration consists of two holes (W1-W2), probably of about the same age

as the Morgan exploration (pre-1915 ?). Each was drilled at 45°, W1 to the southeast, W2 to the northeast. W1 is reported to have cut green rock assumed to be part of the Badwater Greenstone.

Several holes (F1-F3, F5, F10) were drilled from the surface in the SE $\frac{1}{4}$  SE $\frac{1}{4}$  during the period of early development of the Fogarty mine by the Verona Mining Co. (Pickands Mather & Co., agents). Only the core from F10 could be located at the Pickands Mather & Co. storage at Caspian. Except for F10, however, all the holes seem to have cut an alternation of iron-formation and infolded slate typical of the property (see "Fogarty mine"). F10 is mostly in slate and fine-grained graywacke, intensely sheared and quartz-veined; as previously mentioned, a northwest-trending fault may exist in this area.

Section 12

So far as can be discovered, except for the Youngs mine in the NE $\frac{1}{4}$  NE $\frac{1}{4}$ , sec. 12 has no explorations. The area is assumed to be underlain by Badwater Greenstone in the west and by Dunn Creek Slate in the east. The bedrock surface is exposed in the NW $\frac{1}{4}$  NE $\frac{1}{4}$ , and many low "grassroots" outcrops of a highly sheared sericitic slate are present.

# # #

REFERENCES CITED

- Allen, R. C., 1910, The Iron River iron-bearing district of Michigan: Michigan Geol. Survey, Pub. 3.
- \_\_\_\_\_, 1912-20, Mineral resources of Michigan: Michigan Geol. Survey, Pub. 8, 16, 19, 21, 24, 27, 29.
- Dutton, C. E., 1969, Geology and magnetic data for central Iron River area, Michigan: Michigan Geol. Survey, Report of Investigation 5.
- James, H. L., Clark, L. D., and Smith, L. E., 1947, Magnetic survey and geology of the Ice Lake-Chicagon Creek area, Iron County, Michigan: U.S. Geol. Survey Strategic Minerals Inv. Prelim. Rept. 3-213.
- James, H. L., Dutton, C. E., Pettijohn, F. J., and Wier, K. L., 1959, Geologic map of the Iron River-Crystal Falls district, Iron County, Michigan: U.S. Geol. Survey Mineral Inv. Map MF-225 (1960).
- \_\_\_\_\_, 1969, Geology and ore deposits of the Iron River-Crystal Falls district, Iron County, Michigan: U.S. Geol. Survey Prof. Paper 570, 133 p.
- James, H. L., Dutton, C. E., and Wier, K. L., 1967, Geology and magnetic data for northern Iron River area, Michigan: Michigan Geol. Survey, Report of Investigation 4.
- James, H. L., Pettijohn, F. J., and Clark, L. D., 1969 ?, Geology and magnetic data between Iron River and Crystal Falls, Michigan: Michigan Geol. Survey, Report of Investigation 7.
- James, H. L., and Wier, K. L., 1948, Magnetic survey and geology of the eastern and southeastern parts of the Iron River district, Iron County, Michigan: U. S. Geol. Survey Circ. 26, 18 p.
- Lake Superior Iron Ore Association, 1938, Lake Superior iron ores: Cleveland, Ohio, 364 p.
- \_\_\_\_\_, 1952, Lake Superior iron ores, 2nd ed.: Cleveland, Ohio, 334 p.
- Michigan Commissioner of Mineral Statistics, 1879-1909, Reports variously titled-- Annual reports, Mineral resources, Mines and mineral statistics. Volumes issued for 1877-78, 1880, 1881, 1882, 1883, 1885, 1886, 1887, 1888, 1889, 1890-91, 1895, 1897, 1900, 1901, 1901-2, 1906-7, 1907.
- Michigan Geological Survey, 1951-61, Mimeographed reports, variously titled, on general statistics covering costs and production of Michigan iron mines.
- Pettijohn, F. J., 1970 ?, Geology and magnetic data for northern Crystal Falls area, Michigan: Michigan Geol. Survey, Report of Investigation 8.
- \_\_\_\_\_, 1970 ?, Geology and magnetic data for southern Crystal Falls area, Michigan: Michigan Geol. Survey, Report of Investigation 9.
- Pettijohn, F. J., Gair, J. E., Wier, K. L., and Prinz, W. C., 1969, Geology and magnetic data for Alpha-Brule River and Panola Plains areas, Michigan: Michigan Geol. Survey, Report of Investigation 10.
- Smith, R. A., 1922, 1924-29, Mineral resources of Michigan: Michigan Geol. Survey, Pub. 32, 34, 35, 37.
- Smith, R. A., and Martin, Helen M., 1923, Mineral resources of Michigan: Michigan Geol. Survey, Pub. 33.
- Wier, K. L., 1970 ?, Geology and magnetic data, northeastern Crystal Falls area, Michigan: Michigan Geol. Survey, Report of Investigation 11.

# # #

Presswork: Offset lithography on Harris Single Color Offset  
 Binding: Signatures gathered and stitched on a Christenson Stitcher and trimmed on a Lawson 3 knife trimmer.  
 Paper: Body on 60# Carnival Offset  
 Cover on 65# Hammermill Antique Cover



