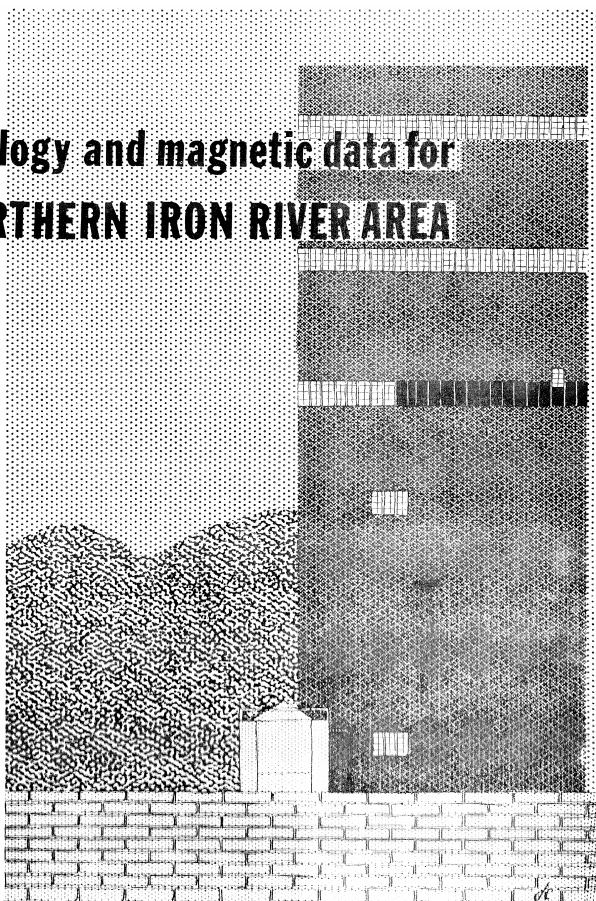


geology and magnetic data for NORTHERN IRON RIVER AREA



Front cover: New Homer-Wauseca, shaft at M. A. Ilanna Company's operation northeast of Iron River. This shaft contains Michigan's second Koepe hoist.

STATE OF MICHIGAN
DEPARTMENT OF NATURAL RESOURCES
GEOLOGICAL SURVEY DIVISION

Report of Investigation 4 GEOLOGY AND MAGNETIC DATA FOR NORTHERN IRON RIVER AREA, MICHIGAN

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ABSTRACT

The Northern Iron River areas commonly known as Mineral Hills, comprises about 7 square miles near the northwest margin of the Iron River-Crystal Falls synclinorium. Because of thick glacial deposits, bedrock geology is known mainly from mine workings and drill exploration. Rock units, from oldest to youngest, are: (1) tightly folded strata of the Animikie Series, which includes Badwater Greenstone, Dunn Creek Slate, Riverton Iron Formation, and Hiawatha Graywacke; (2) metadiabase dikes and sills, and; (3) at least one diabase dike of Keweenawau age.

Faults dominate the structure, particularly the North Mineral Hills fault and the South Mineral Hills fault, both east-northeast reverse faults of large displacement. The general distribution of iron ore bodies in relation to synclinal structures is shown in cross sections, maps and sketches. A brief history, description, and production for each mine, and descriptions of all known explorations are given. Partial extent of mine workings, drill-hole information, and magnetic survey data are shown on a geologic map.

PREFACE

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

This report is a product of field investigations of the Iron River-Crystal Falls district carried out by the U. S. Geological Survey in cooperation with the Geological Survey Division of the Michigan Department of Conservation 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.G. S. Professional Paper 570 to be published in 1968.

The mining companies active in the district during the period of field work helped importantly by providing

maps and records and permitting access to mine workings and drill core collections. The authors are particularly grateful for the friendly cooperation of the 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.

Also, advice, encouragement, and stimulating interest of various members of the Geological Survey Division of the Michigan Department of Conservation is gratefully acknowledged.

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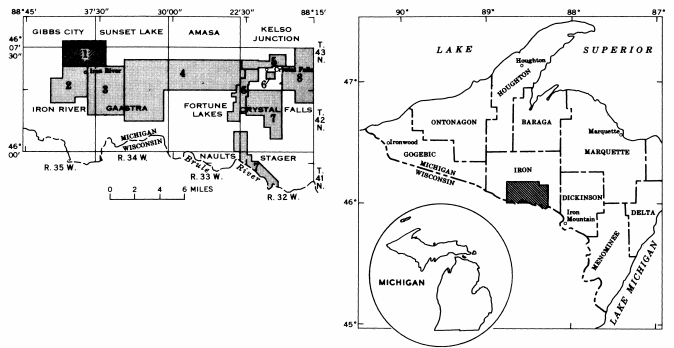


Figure 1 -- Location and index maps

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

- 1. Shading delineates area of this report. Northern Iron River Area--James, Dutton, Wier
- 2. Central Iron River Area--Dutton
- 3. Southeastern Iron River Area--James and Wier
- 4. Area between Iron River and Crystal Falls--James, Pettijohn and Clark
- 5. Northern Crystal Falls Area--Pettijohn
- 6. Southern Crystal Falls Area--Pettijohn
- 7. 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

INTRODUCTION

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

Information on early mining history was taken from the annual reports, 1879 to 1909, of the Commissioner of

Mineral Statistics of the State of Michigan and from the annual reports, 1912 to 1929, of the State Geological Survey. Additional mine history and production data were taken from "Lake Superior Iron Ores" (Lake Superior Iron Ore Assoc., 1938, 1952) and from "General Statistics Covering Costs and Production of Michigan Iron Mines" (Michigan Geological Survey, 1951-61). Some of the results of U. S. Geological Survey work in the northern Iron River area have appeared as preliminary reports by Dutton, Park, and Balsley (1945) and James and Dutton (1951).

The area designated "Northern Iron River" (plate 1) comprises about 7 square miles and includes secs. 13, 14, 15, 22, 23, and 24, T. 43 N., R. 35 W., and parts of secs. 18 and 19, T. 43 N., R. 34 W. It is located about 1 mile north of the town of Iron River and centers in "Mineral Hills", within which are located some of the major mines and ore deposits of the district. Substantial tonnages have been shipped from 12 mines: Bates, James, Forbes, Davidson No. 1, Davidson No. 2, Davidson No. 3, Davidson No. 4, Homer, Wauseca, Sherwood, Spies, and Virgil, of which the Homer-Wauseca, operated by the M. A. Hanna Co., and the Sherwood, operated by Inland Steel Co., were active in 1963.

Precambrian	Upper Precambrian	Keweenawan Series	Unconformity		Diabase
			Intrusive contact		
	Middle Precambrian	Animikie Series	Paint River Group	Metadiabase	
				Intrusive contact	
				Hiawatha Graywacke	
			Minor unconformity		
			Riverton Iron-Formation		
Dunn Creek Slate					
		Baraga Group	Badwater Greenstone		

Table 1. -- Rock units in Northern Iron River area

GEOLOGY

Except for exposures rimming caved ground over mine workings, bedrock is exposed in but a single outcrop in the entire area; elsewhere it is covered by glacial deposits to depths of as much as 360 feet.

The northern part of the Iron River area is on the northern margin of the Iron River-Crystal Falls synclinorium. The sequence of rock units is shown in table 1. The bedrock in the northwest corner of the map area is assigned to the Badwater Greenstone, which is exposed a short distance beyond the limits of the map area. The rock penetrated by drill holes has been recorded generally as slate, but much of it probably is sheared greenstone. The Badwater is separated from

the overlying Dunn Creek Slate by a sill of metadiabase that seems to be 100-200 feet thick. This sill (penetrated by drill hole NR2, in the NW 1/4 NE 1/4 sec. 14, T. 43 N., R. 35 W.) is marked by a low but distinct magnetic anomaly traced westward from the drill hole a distance of about one mile.

The belt of Dunn Creek Slate south of the sill is at least 1, 500 feet wide, as shown by drill holes NR1 and NR2 in the NW 1/4 NE 1/4 sec. 14. All of hole NR1 and most of NR2 revealed a siltstone and slate pseudoconglomerate formed by slumping prior to consolidation. The Riverton Iron-Formation, stratigraphically above the pseudoconglomerate, is intersected in the inclined drill holes M5 and M6, in the NW 1/4 sec. 14, T. 43 N., R. 35 W. The contact between the Dunn Creek and the iron-formation, here wholly unoxidized, is strongly sheared. The outcrop width of the Riverton, projected to the surface, is about 500 feet, but extrapolation to the east and west is uncertain; drilling information in the S 1/2 sec. 15, T. 43 N., R. 35 W., indicates the Riverton is missing, either because of pre-Hiawatha erosion or because of faulting.

Faults

The structure in the central part of the map area in Mineral Hills is dominated by two major faults: the North Mineral Hills fault and the South Mineral Hills fault. Both trend east-northeast, and are reverse faults of moderate to steep dip with displacements of thousands of feet.

North Mineral Hills Fault

The North Mineral Hills Fault zone is crossed at one or more levels of the Cardiff, Homer, Davidson No. 1, Forbes, Davidson No. 2, and Davidson No. 3 mines. See isometric sections on plate 2. On the west, where exposed in the Cardiff workings, the fault zone consists of 10 to 50 feet of intensely sheared and crushed rock cut by irregular quartz veins. The fault here dips steeply to the south. In the Forbes and Davidson No. 1 mines, two or three distinct faults can be mapped within a zone about 200 feet wide. One or more chloritized basic dikes lie within the fault zone in most places. In general, the dikes follow the fault zone, but locally (as in the Homer mine) they diverge.

The North Mineral Hills is a reverse fault, the south side having been thrust over the north side. Dip averages about 60° S. Displacement, totalling about 2, 000 feet, is difficult to determine exactly. Movement seems to have been virtually parallel to the dip. The fault truncates the fold structures at a low angle.

South Mineral Hills Fault

The South Mineral Hills fault is shown on isometric sections on plate 2. It trends about N. 60° E. and, in general, dips steeply to the northwest. On the 4th and 6th levels of the Spies mine, it is a well-defined shear zone marked by quartz veins. Deeply oxidized iron-

formation and ore are present on both sides of the fault in parts of the lower levels of the Sherwood mine where it is crossed by the 1200 level, and the direct evidence of faulting has been largely obliterated. The fault steepens to the east becoming at least 80° in the Spies mine. Its probable eastward extension, the Bates mine fault zone, is about vertical.

Chloritized basic dikes are numerous in and adjacent to the fault, some no more than 4 inches thick, with most continuing for only short distances along the strike. A large irregularly-shaped mass of dike rock is present at depth in the area adjacent to the Homer-Wauseca shaft, a short distance north of the fault.

Movement on the South Mineral Hills fault was high-angle reverse, with the north side upthrown. Displacement appears to be about 1,500 - 2,000 feet, comparable to the North Mineral Hills fault. The direction of throw, however, is reversed, so the two faults define a structural unit that is raised with respect to the areas adjacent on both the north and the south.

Others

A fault of considerable displacement, north side upthrown, extends in a S. 80° E. direction and bounds the ore bodies of the Spies mine on the north. This fault is about vertical. In the southern parts of the Davidson and James mines an easterly-trending break separates oxidized iron-formation from unoxidized iron-formation. The north side appears to be raised with respect to the south side.

An important easterly-trending fault, in about the south-central part of the map area, apparently branches off the South Mineral Hills fault in the SW 1/4 sec. 23, T. 43 N., R. 35 W. In the SE 1/4 of sec. 23, drill holes T8 and T9 both entered Dunn Creek Slate at bedrock surface, then passed through a shear zone into stratigraphically younger strata at depth. The displacement is north side up. Branching from this fault at about the line between secs. 23 and 24 is a steeply dipping shear zone that trends ENE, into the southeastern workings of the Sherwood mine at the 1200-foot level. The fault separates Dunn Creek Slate from Riverton Iron-formation, and the south side appears to be upthrown.

At least two east-trending faults of large displacement occur in the Bates mine area (See plate 2.) The faults are nearly vertical and are everywhere marked by intensely sheared rock veined with quartz. Apparently the south side of the northern fault was downthrown at least 1,000 feet. Inasmuch as its direction and general magnitude of displacement is similar to the South Mineral Hills fault, a connection is probable. The displacement on the southern fault has not been determined satisfactorily, but the areal pattern on the 14th and 16th levels of the Bates mine indicates that the south side probably is downthrown as on the northern fault. If this is true, the fault is vertical from the 6th level and passes along the south side of the truncated anticline. The alternate, but less likely, interpretation of

relative displacement requires the upward extension of the fault from the 6th level be inclined northward and pass along the north side of the anticline. In either interpretation, determination of the amount of displacement is questionable because the fault is generally parallel to the stratification. The two faults merge in the eastern part of the mine area.

Other Structures

Between North and South Mineral Hills Faults

The block between the North and South Mineral Hills faults has been extensively drilled and entered by mine workings. The principal elements of the structure, therefore, are known and are depicted graphically in mine level maps (figs. 2, 3) and isometric sections (plate 2).

The structures within the block consist chiefly of folds trending nearly east, and generally overturned to the north. The major structures are named: the North trough; the Spies anticline and its western analog, the Cardiff anticline; the Central syncline; the Shaft anticline; the South trough; and the South Homer trough. Each of these structures is modified by other folds of lesser magnitude. Crossfolds, some of which are tightly compressed, are common, and greatly complicate the structural pattern.

The dominant structure is the Central syncline, a deep fold locally placing the iron-formation at depths of more than half a mile. However, the subsidiary synclines flanking it on both the north and the south contained most of the ore.

The North trough, consisting mostly of two or more folds, has been one of the most productive structures in the Iron River district. The trough (details on plate 2) contained most of the ore bodies of the Cardiff, North Homer, Davidson, Forbes, and James mines, from which approximately 23 million tons of ore has been mined. The trough is separated from the Central syncline by the Spies and Cardiff anticlines which appear correlative though separated by intervening crossfolds. In general, the North trough is a shallow structure, which accounts for the thorough oxidation. The maximum depth of the iron-formation, for much of the length of the structure, is less than 1,000 feet. The trough widens and deepens eastward, forming the Spies-Barnett Basin in the northern part of sec. 24 and in the southern part of sec. 13 (cross section G-G¹ on plate 2). The trough, partly truncated by the North Mineral Hills fault, closes off at the west end by easterly plunge in the vicinity of the Cardiff mine.

The South trough, from which most of the ore of the Virgil, Sherwood, and Wauseca mines has been taken, is separated from the Central syncline by the Shaft anticline. This trough reaches its greatest depths at the Sherwood mine and in the southern part of the Homer mine, where the keel of the fold of iron-formation lies 1,

500 to 2,000 feet below surface. The South Homer trough, another downfold, is a complex structure in the N 1/2 SW 1/4 sec. 23, containing the ore bodies of the southern part of the Homer mine.

The deep synclinal folds of the Homer and Homer-Wauseca mines shallow rapidly westward, but the evidence for complete closure at bedrock surface is inconclusive. Data from drill holes and mine workings show the Riverton Iron-Formation is very thin in the E 1/2 sec. 22, T. 43N., R. 35 W. (25 feet or less in many intersections), presumably because of erosion preceding deposition of the Hiawatha Graywacke. This pinchout of the Riverton coincides with an increase in feldspar content of the Hiawatha Graywacke. No iron-formation has been located in the SW 1/4 sec. 22, despite the fact that holes WM7 and WM10 are in Dunn Creek Slate, and holes WM2, WM4, WM6, WM8, and WM9 are in Hiawatha Graywacke. Whether the apparent absence of iron-formation from the southwestern part of sec. 22 is due to pinchout or to inadequate exploration is not known, but pinchout seems more likely.

The Central syncline, with respect to the Riverton Iron-formation, closes off in the SE 1/4 NW 1/4 sec. 24 and is partly cut off by the South Mineral Hills fault. The North trough, however, progressively deepens and broadens east of the James mine. Actual identity cannot be established, but the structure may be reflected in the closure of the Hiawatha Graywacke in the Bates mine area.

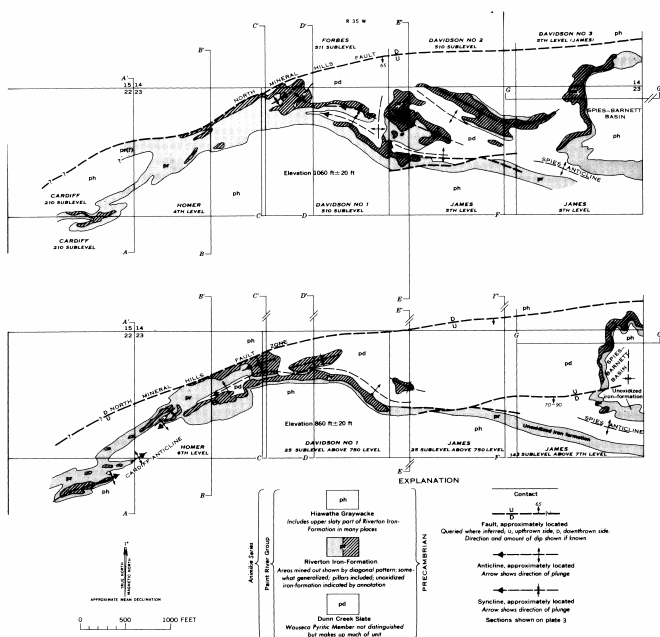


Figure 2 -- Distribution of ore bodies in relation to structure in northern part of Mineral Hills area.

In all of this area, but particularly in the areas of the James and Davidson mines, and in the "South Homer" (N 1/2 SW 1/4 sec. 23), the dominant easterly trending folds are interrupted by equally strong cross- folds at approximately right angle. (See fig. 2 for example.) These interruptions prevent the use of consistent

nomenclature for the individual folds in the east-trending set.

Between Sunset Creek and Mineral Hills

Most of the drill holes in this area encountered the Hiawatha Graywacke or the upper slaty part of the Riverton Iron-Formation. In the NW 1/4 sec. 13, T. 43 N., R. 35 W., a series of inclined holes drilled by the Cleveland-Cliffs Iron Co. in 1955 provides excellent information along two lines of cross sections. Abbreviated logs of these holes are as follows (distances in feet):

Drill hole M5 (60° N.)

0	-	136	Overburden
136	-	515	Slate, siltstone, graywacke, some chert
515	-	1,230	Iron-formation, unoxidized
1,230	-	1,328	Sheared rock, vein quartz
1,328	-	1,358	Iron-formation, unoxidized

Drill hole M6 (62 1/2° N. 2° E.)

0	-	124	Overburden
124	-	505	Iron-formation, unoxidized
505	-	559	Sheared black slate, vein quartz
559	-	1,216	Slate and siltstone; heavily sheared in 1,070 - 1,140

Drill hole M7 (54° N. 1° E.)

0	-	193	Overburden
193	-	962	Slate and fine-grained graywacke, some chert

Drill hole M8 (54° N.)

0	-	163	Overburden
163	-	985	Siltstone, slate, and graywacke
985	-	1,090	Iron-formation, slaty, unoxidized
1,090	-	1,267	Slate and graywacke

Drill hole M9 (59° N. 2° W.)

0	-	147	Overburden
147	-	513	Graywacke and slate
513	-	618	Iron-formation, slaty, unoxidized

Southeast of the South Mineral Hills Fault

Despite extensive drilling, the structure south of the South Mineral Hills fault and its probable continuation in the Bates mine area is poorly defined. A faulted anticline seems to bring the Dunn Creek Slate and Riverton Iron-formation to the surface in the SW 1/4 sec. 24. The dominantly east-trending structure is interrupted by a northerly-trending anticlinal belt in the SE 1/4 SE 1/4 sec. 24 and adjoining parts of sec. 19. This anticlinal belt is intersected by the 4th and 6th levels of the Spies mine. (See also description of Spies mine.)

This drilling defines a belt of unoxidized Riverton Iron-Formation between Dunn Creek Slate on the north and Hiawatha Graywacke on the south. Thick runs of

sheared rock and vein quartz indicate strong faulting in the area, which may account for the apparent absence of Riverton to the west.

Iron-formation, presumably the Riverton Iron-Formation on an anticlinal fold, is reported at bedrock surface in the SE 1/4 SE 1/4 sec. 15.

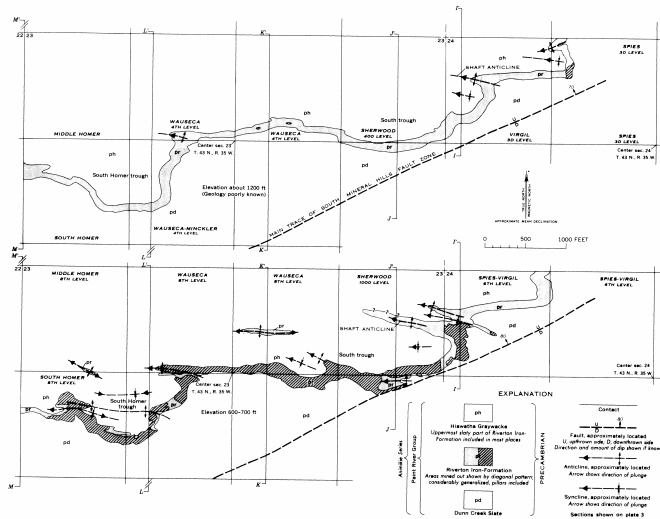


Figure 3 -- Distribution of ore bodies in relation to structure in the southern part of Mineral Hills area.

MINES

Homer - Wauseca Group

The Homer-Wauseca group is a mine complex in the western part of the Mineral Hills area. In general, each mine began as a separate operation, later merged with adjoining mines and ultimately the group was integrated by the M. A. Hanna Company.

The combined shipments through 1961 from the Homer and Cardiff mines totaled 12,319,034 tons, and from the Wauseca, 9,752,578.

Homer

The Homer mine, as used in this report, is in the W 1/2 NW 1/4 sec. 23, T. 43 N., R. 35 W., the mined ore bodies being confined almost entirely to the NW 1/4 NW 1/4. The "South Homer" property, immediately to the south, is described with the Homer-Wauseca operation.

The Homer was opened in 1914 from a shaft in the NW 1/4 NW 1/4 sec. 23. Ten major levels were developed. The workings on each level were more extensive than on the one above. The 3rd level, and each succeeding level, entered the Cardiff property to the west, and the 8th, 9th, and 10th levels were extended far to the south, to connect with the workings of the Wauseca mine. The lowest level, the 10th, is about 1,310 feet below the surface at the shaft.

The structure in the mine, depicted in figure 2 and on plate 2, section B-B', is extraordinarily complex. Many

aspects remain unsolved. The major ore body, occupying the north flank and axial zone of the North trough, is much more tightly compressed than farther east. Compare, for example, section B-B' with section E-E' on plate 2, adjacent to the North Mineral Hills fault. In part, the complexity is due to the progressive westward encroachment of the fault into the north flank of the North trough; at the 9th level, the north flank, with respect to the Riverton Iron-Formation, is entirely cut out.

A second major ore body occurred to the south on the south-dipping flank of an overturned anticline, and was continuous with that in the adjoining Davidson No. 1 mine. The ore extends for an unknown distance below the 9th level.

The extensive deeper levels of the mine provide much geologic information, both north and south of the ore-bearing areas. The North Mineral Hills fault zone is well exposed, particularly on the 8th level, where at least three distinct faults are present within a horizontal distance of a few hundred feet. The strikes of the faults are parallel, but the dips range from 50° to 80°. A narrow dike, with a strike parallel to the faults, occurs within the zone on the 8th and 9th levels. In the east workings of the 8th level, the fault separates Hiawatha Graywacke from the lower part of the Riverton Iron-Formation. In the west workings the iron-formation is missing and the Hiawatha is in contact with Dunn Creek Slate. In the shaft area at both the 8th and 9th levels, Riverton Iron-Formation is infolded with the Hiawatha Graywacke in the overridden block below the North Mineral Hills fault. Most of the iron-formation is unoxidized, as in the lower levels of the Davidson shaft to the east where the Riverton is exposed in a similar structural position. Drilling to the west at the 10th level discloses a belt of iron-formation at about 400 feet.

Main drifts at the 8th, 9th, and 10th levels extend to the south to the Wauseca mine, thus crosscutting the deep Central syncline of Mineral Hills. The rock consists of slate and fine-grained graywacke, very similar to the pre-Riverton Dunn Creek Slate, and in some areas partly of much oxidized chert breccia and slaty iron-formation. The amount of infolded iron-formation increases with depth.

In 1961 the Homer mine was closed and the main drifts were bulk-headed off from the Wauseca mine.

Cardiff

The Cardiff, adjoining the Homer mine to the west, is in the E 1/2 NE 1/4 sec. 22, T. 43 N., R. 35 W. The shaft, in the NE 1/4 NE 1/4, was sunk by the Wickwire Mining Co. to a depth of about 530 feet, from which the "first" level was driven. Most of the development, however, was from the Homer mine of the M. A. Hanna Co.; the Homer 3rd level entered the property at a depth of about 350 feet, the Homer 6th at 660 feet, the Homer 7th at 760 feet, the 8th at 930 feet, and the 9th at 1,130 feet.

Very little is known of the uppermost workings of the mine above the Homer 6th level, but apparently some ore was stoped, at least as high as the Horner 3rd level. At the Cardiff 1st level (equivalent to about the 90-foot sub above the Homer 6th level) three ore bodies were mined. One is a tight V-shaped mass about 500 feet on each side of the "V" and about 30 feet wide, the second a lens-like body to the south, 400 feet long and about 50 feet wide, and the third a small lens a little more than 100 feet long and 50 feet wide. The V-shaped body also is present on the Cardiff "210" sublevel above, as shown on figure 2, but at lower levels it seems to be absent. It apparently is at the crest of an easterly plunging anticline, as is the next ore lens to the south. At the 8th level, three subparallel ore bodies are arranged en echelon toward the southwest. The northern two are at the axes of easterly-plunging minor synclines, whereas the most southern ore body—long and narrow—is on the north flank of a major syncline. These ore bodies, smaller in dimension than those above, were intersected by the 9th-level workings. At both the 8th and 9th levels the ore has a high sulfur content.

The most western workings of the Cardiff, together with the drilling in the area, reveal the Riverton thins rapidly to the west in places to less than 25 feet thick.

Wauseca

The Wauseca mine in sec. 23, T. 43 N., R. 35 W., originally restricted to the SE 1/4 NW 1/4 and the SW 1/4 NE 1/4 was opened in 1926 by the Mineral Mining Co. The property was taken over by the M. A. Hanna Co. in 1941, and the operation was expanded to include the Aronson property (E 1/2 NW 1/4 SE 1/4) and the Minckler property (W 1/2 NW 1/4 SE 1/4 and the NE 1/4 SW 1/4). As mining progressed, the workings were connected to, and merged with, those of the Homer properties to the west and northwest. In 1963, the operation was served by three shafts: the Minckler, in the NW 1/4 SE 1/4; the Wauseca, in the SW 1/4 NE 1/4; and the Homer-Wauseca, in the SE 1/4 SW 1/4, a 4-compartment circular shaft sunk in 1959.

Ten major levels have been developed, the deepest of which is the 11th at 1,510 feet. Above the 4th level the ore bodies were modest in size and separated, but at depth they merged into a great continuous body of ore about three-fourths of a mile long and extending through a vertical distance of more than 1,000 feet. (See fig. 3.) The general width is about 100 feet. To the east the ore body is continuous with that of the Sherwood mine.

The ore body occupies much of the south flank of the Mineral Hills area structure. Most of the ore developed thus far has been on the south flanks and in the axial areas of synclinal troughs on the south margin of the Central syncline. The details of the dragfolds are gradually disclosed at depth. The syncline containing the great ore body of the Sherwood and Virgil mines has not "reached" the Wauseca at the present level of operation, the westerly plunge carrying it below the

lowest working level. Other minor synclinal troughs have been revealed, however, notably the trough in the South Homer property. This trough is outlined clearly near the 8th and 9th levels (fig. 3). Deeper, as at the 10th, the patterns are highly complex, typical of the bottom of folds in the district.

The Wauseca mine is the type locality for the Wauseca Pyritic Member of the Dunn Creek Slate. The rock is well exposed in hundreds of feet of workings, particularly on the 8th level south of the ore body and in a long exploration drift to the west, in the NE 1/4 SE 1/4 sec. 22.

The South Mineral Hills fault is, in general, a considerable distance south of the workings. The fault was encountered in holes drilled south from the 8th level; hole 883 (horizontal) and hole 889 (inclined) pass from Dunn Creek Slate through the fault into unoxidized Riverton Iron-Formation. Zones of strong shearing also were encountered in the Homer-Wauseca shaft within the Dunn Creek Slate, and at lower levels an irregularly-shaped body of altered diabase was penetrated. Probably the shear zones are branches from the South Mineral Hills fault.

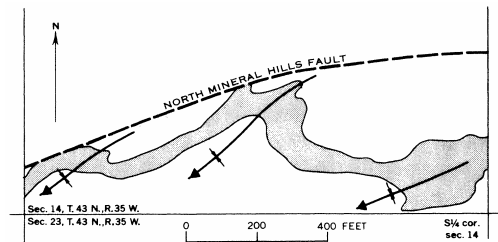


Figure 4 -- Mined ore (shaded) and synclinal axes at 275 level in Forbes mine.

Forbes

The Forbes mine, in the SE 1/4 SW 1/4 sec. 14, T. 43 N., R. 35 W., was opened in 1912 from two shafts in the southern part of the "forty". Until 1946, when it was mined out, it was operated at various times by the Jones & Laughlin Ore Co., the North Range Mining Co., and the Pittsburgh Coke and Iron Co. Up to that time, 2,283,822 tons of ore had been shipped. The property was taken over in 1947 by Pickands Mather & Co., which sank a new shaft, the Davidson, as part of its integrated development of the Davidson and James mines.

The workings prior to 1947 consisted of four major levels, at depths of 175, 275, 385, and 475 feet. Below 135 feet the ore body extended generally eastward, entirely across the "forty", and had a width of 50-200 feet. The general southerly dip carried the ore across the property line at a depth of about 530 feet.

The ore body, a westward continuation of the Davidson No. 2 and Davidson No. 3 ore body, occupies the north flank of the North trough, which centers in the Davidson No. 1 property to the south. (See plate 2, sections C-C', D-D'.) The North Mineral Hills fault in this area is just

below the north flank of the syncline. In part it is occupied by a dike, which formed the footwall to the western part of the ore body. The ore occupies the lower part of the Riverton Iron-Formation, here flexed into several folds plunging west-southwest (fig. 4).

The two Forbes shafts, as well as the Davidson shaft of Pickands Mather & Co., are on the downthrown side of the North Mineral Hills fault, and the horizontal distance from the shafts to the fault increases with depth. The deeper workings, therefore, cut long reaches of the Hiawatha Graywacke, here mostly graywacke with scattered chert fragments. At the 950 level of the Davidson shaft, the shaft station is in sheared and kaolinized graywacke, with the south margin of an altered diabase dike exposed in the north end of the shaft station. A fault parallel to the North Mineral Hills fault is indicated. A short distance south of the shaft station, the drift cuts unoxidized slaty iron-formation, the upper part of the Riverton, presumably on an anticlinal fold.

Davidson Group

The Davidson group consisted of four properties on the north flank of the Mineral Hills syncline. The Davidson No. 1 is in the NE 1/4 NW 1/4 sec. 23, T. 43 N., R. 35 W., between the James mine and the Homer mine. The Davidson No. 2 and No. 3 mines are adjoining properties in the SW 1/4 and SE 1/4, respectively, of the SE 1/4 sec. 14, just north of the James mine. The Davidson No. 4, known in its earlier years as the Purcell or Wapama, is in the SW 1/4 SW 1/4 sec. 14, north of the Homer mine.

Shafts were sunk on each property in about 1911, and although statistics on the shipments are grouped, the actual operations seem to have been largely independent. The combined operation was in the hands of the Davidson Ore Mining Co. until 1940, and the Pittsburgh Coke and Iron Co. from 1941 to 1947. In 1947, the mines, largely worked out except for the Davidson No. 1, were integrated by Pickands Mather & Co. with the James mine. A new shaft, the Davidson, was sunk on the old Forbes property, in the SE 1/4 SW 1/4 sec. 14.

The aggregate production from the four Davidson properties from 1911 to 1947, when operations ceased, was 8,325,613 tons. Stockpile shipments, however, continued until 1952.

No. 1

The Davidson No. 1 shaft in the NE 1/4 NW 1/4 sec. 23 was sunk to a depth of 950 feet. Five major levels were developed at 450, 550, 650, 750, and 950 feet. The structure is similar to the James mine adjacent to the east, with most of the mined ore coming from the North trough. (See cross sections C-C', D-D', on plate 2, also fig. 2.) The ore continued updip on the north side of this fold into the Forbes mine in sec. 14. The ore-bearing folds of the North trough were bottomed at a depth of

about 800 feet--slightly deeper than in the James mine. The ore body on the south-dipping flank of the anticline south of, and complementary to, the North trough is well developed down to the 950 level and for an unknown distance below, again greater than the James mine (See fig. 2.) As shown on section D-D' (pl. 2), however, unoxidized iron-formation is present at greater depth.

Important structural data were obtained from the long drifts from the Davidson shaft in the SE 1/4 SW 1/4 sec. 14 at the 650, 750, and 950 levels, which cut across the structure for more than a quarter of a mile. The 750 and 950 levels cross the North Mineral Hills fault, which separates Hiawatha Graywacke on the north from the Riverton Iron-Formation. The fault zone is more than 200 feet wide on both levels and contains one or more altered diabase dikes. The fault dips south at a moderate angle and strikes about N. 80° E. Displacement is reverse. On both the 650 and 950 levels, long drifts were driven to the south, about to the south boundary of the "forty." At both levels, a belt of ore is overlain to the south by oxidized cherty iron-formation, which gives way to the slaty, carbonate-rich upper part of the Riverton. The Riverton is then overlain by Hiawatha Graywacke, much of which is dark slate and graywacke containing scattered chert fragments. The southern part of both drifts is in dark slate and fine-grained graywacke. Possibly this slate and graywacke are part of the Dunn Creek Slate, upthrown against the Hiawatha Graywacke on an unrecognized major fault, though this seems unlikely.

No. 2

The Davidson No. 2 property, occupying the SW 1/4 SE 1/4 sec. 14, was entered by a shaft inclined to the south. It was developed from four main levels at 152, 240, 340, and 440 feet.

The ore was mined from a single tabular body extending easterly across the entire "forty." The ore dipped south at a moderate angle, passing across the south boundary of the property into the adjacent James mine at a depth of about 500 feet. The width of the ore, in horizontal section, was generally 50-150 feet. The ore body was mined to the property boundary.

The ore body occurred in the lower 100 feet of the Riverton Iron-Formation on the north flank of the North trough, 50-400 feet above the subparallel North Mineral Hills fault. (See plate 2, section E-E'.)

No. 3.

The Davidson No. 3 mine is in the SE 1/4 SE 1/4 sec. 14. Levels were established at depths of 350, 400, and 535 feet from a shaft in the south-central part of the property. Ore was mined from a continuation of the Davidson No. 2 ore body, which extended into the No. 3 property for about 400 feet or so on the uppermost levels. At the 350 level, a small ore body was located in the eastern part of the "forty." At the 460 sublevel this

ore body was connected with that in the western part to form a tabular mass 1,100 feet or more long and 50-100 feet wide.

Below the 535 level, the property was operated by Pickands Mather & Co. as part of a consolidated operation involving the Forbes, Davidson No. 1, Davidson No. 2, and James mines. The Davidson No. 3 ore was further developed by levels at depths of 650, 750, and 950 feet. At the 650 level a long ventilation drift was driven eastward from the "Davidson" shaft in the SE 1/4 SW 1/4 sec. 14 across the Davidson No. 2 and No. 3 mines, to connect by an incline with the 7th-level workings of the James mine.

As in the Davidson No. 2, the ore occurs on the north flank of the North trough (plate 2, section E-E'), updip from the central part of the trough in the James mine. In the southeastern part of the "forty," this flank merges with that of the Spies-Barnett basin, and the ore occurs in an arcuate belt concave to the southeast. (See fig. 2.) At the 7th level of the James mine, at about 850 feet, the general southeasterly dip of the structure carries the ore-bearing part of the Riverton across the south line of the property.

No. 4 (Purcell, Wapama)

The Davidson No. 4, known earlier as the Purcell or Wapama mine, is in the SW 1/4 SW 1/4 sec. 14. Ore was mined and shipped in 1913, 1917, and 1918 as from the Wapama mine, after which the operation was part of the Davidson group and was listed as the Davidson No. 4. The property was considered mined out in 1922, and total shipments from 1913 to 1921 amounted to 128, 599 tons.

The mine was opened from a shaft in the southeastern part of the "forty," and the lowest level of operation on record is that at a depth of 220 feet. The ore body, a westward extension of adjoining Forbes mine ore body, cuts across the southeast corner of the property. At the 173 level it was mined for a distance of 400 feet with an average width of about 50 feet.

James (Osana)

The James mine, once known as the Osana, occupies the N 1/2 NE 1/4 sec. 23, T. 43 N., R. 35 W. It adjoins the Davidson No. 2 and No. 3 properties on the north, the Davidson No. 1 on the west, and the Wauseca and Sherwood on the south. The mine was opened in 1906 and was operated by the Mineral Mining Co. until taken over by the James Mining Co. in 1925 and operated by Pickands Mather & Co. The operation consisted of two shafts: the main haulage shaft in the NW 1/4 NE 1/4 and an air shaft in the NE 1/4 NE 1/4, from which five main levels were developed. The deepest of these, the 7th level, is approximately 860 feet below the surface. At the lower levels the workings were interconnected with those of the adjacent Davidson mine, also operated by

Pickands Mather & Co. The mine was closed in 1954 after shipping 8,326,342 tons of ore.

The structural position of the ore bodies is well shown on plate 2 and figure 2. The major structure is a complex dragfold faulted near the anticlinal axis. The chief ore bodies were in the synclinal trough (the North trough described previously) of the dragfold, and the ore continued updip to the surface on the adjoining Davidson properties to the north. At the 5th level (about 500 feet), the bottom of the North trough was divided into several subsidiary folds with many reversals of plunge, so that some of the ore bodies are canoe-shaped. At the 7th level, the bottom of the trough was reached. Except at the east end, most of the drifts are in the footwall Dunn Creek Slate. The remaining ore bodies occurred in an arcuate belt at the west end of a broad complex syncline, the Spies-Barnett basin. The nose, or flank, of this structure dips to the east. The dominantly eastward trend of the North trough is strongly modified by northerly-trending crossfolds.

All of the Riverton Iron-Formation in the North trough is completely oxidized. A large part of it, probably 50 percent or more, has been converted to ore. The iron-formation occurring on the south-dipping limb of the complementary anticline to the south, however, is oxidized only near the surface, about the steeply-dipping fault that cuts the anticline. (See cross section E-E', pl. 2.) Below (south of) the fault, the iron formation, exposed in the shaft stations (cross section E-E', pl. 2), is wholly unoxidized. A second area of unoxidized iron-formation is in the extreme eastern part of the property, on the south flank of the Spies-Barnett basin. In that area, within 200 feet, oxidized iron-formation and ore pass laterally along the strike into unoxidized iron-formation (fig. 2).

Bates

The Bates mine, the mine farthest east in the Mineral Hills area, is chiefly in the NW 1/4 sec. 19, T. 43 N., R. 34 W. It was opened in 1910. Eight major levels--the 4th, 6th, 8th, 10th, 12th, 14th, 16th, and 18th--were developed through a vertical depth of about 1,850 feet from two main shafts: the No. 2, in the NW 1/4 NW 1/4 sec. 19, and the No. 3, in the NE 1/4 NW 1/4 sec. 19. The 18th level is approximately 220 feet below sea level. Ore was shipped continuously from the mine from 1915 until its closure in 1947; shipments totaled 4,054,666 tons.

The structure of the Bates mine area is one of the most complex in the district. In general it consists of several westerly-plunging folds cut by two nearly vertical east-trending faults. (See pl. 2, cross section H-H'.) Several ore bodies were mined, but the principal one occurs on the north limb and within the axial area of a syncline bounded on the north by one of the major faults. This ore body, approximately 600 feet long and 100 feet wide in maximum development, extends from above the 4th level to an unknown distance below the 18th level, or

through a minimum vertical distance of 1,500 feet. The outlines of the body from the 8th to the 16th levels are shown on figure 5. From a focal point immediately south of the fault and about 250 feet east of the center of the NW 1/4 sec. 19, the ore body swings more than 90°, from nearly east at the 8th and higher levels to southwesterly on the 16th level. At the 4th, 5th, and 6th levels, the ore body was relatively small and entirely on the north limb. It did not extend around into the axial area of the fold until reaching the 8th level.

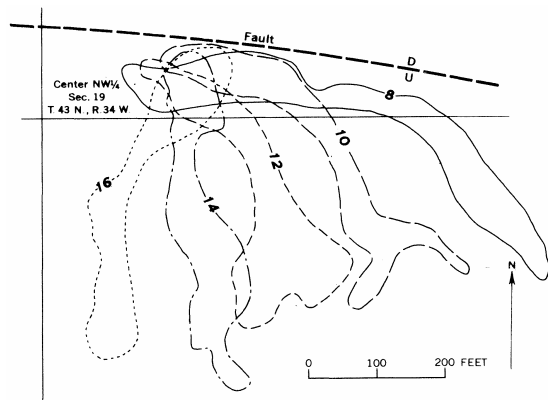


Figure 5 -- Outline of the main ore body in the Bates mine at 8th, 10th, 12th, 14th, and 16th levels.

Spies Group

The Spies group is in sec. 24, T. 43 N., R. 35 W. The early operations consisted of the Virgil mine, opened in 1912 in the SW 1/4 NW 1/4 sec. 24, and the Spies mine, opened in 1916 in the SE 1/4 NW 1/4 sec. 24. Later, the operations were consolidated by the Cleveland-Cliffs Iron Co. and ore was extracted by way of the Spies shaft from two ore bodies distinct from those of the old Virgil and Spies. These two are the Spies-Virgil in the SW 1/4 NW 1/4 sec. 24, (deeper than the old Virgil ore body) and the Spies-Johnson in the NE 1/4 SE 1/4 sec. 24. The workings of the Spies-Virgil and the Spies-Johnson were mapped in the course of the present study, but the old Spies and Virgil were inaccessible. The entire operation was closed in 1955, after 4,195,111 tons of ore were shipped.

Virgil

The Virgil mine, in the SW 1/4 NW 1/4 sec. 24, consisted initially of a shaft 281 feet deep and two levels of workings at approximate elevations of 1,445 and 1,345 feet. Ore was taken from a small, northerly-trending, steeply-dipping ore body about 400 feet long and about 100 feet in maximum width. Later, the ore body was entered by a 3rd level, at 1,230 feet elevation, from the adjoining Spies shaft, and was mined to or near to bedrock surface through a vertical distance of about 250 feet. A total of 134,482 tons of ore was reported shipped in the years 1912-14, 1916, and 1918. The mine was inactive from 1918 to 1925, and any later production from this ore body would be included with the deeper Spies-Virgil operation.

The ore body was located approximately on the axis of the generally west-plunging "south trough" of Mineral Hills, but in these upper levels the plunge seems to be nearly vertical. The ore, apparently too narrow to be mined, continued below the 3rd level of workings to connect with the much larger body of ore exploited by the deeper Spies-Virgil operations. The structural relations are not clear, as the available maps provide almost no geological data. The general form suggests that the ore body may have been in the upper part of the iron-formation rather than in the more usual lower part.

Spies

The Spies shaft, in the SE 1/4 NW 1/4 sec. 24, was sunk in 1916 to a depth of about 400 feet, and three levels developed at elevations of about 1,435, 1,335, and 1,235 feet. The ore body trending N. 10° W., was about 600 feet long and 30-140 feet wide, and had an overall dip of 50-60° W. It was mined from the 3rd level to or near to bedrock surface, a total dip length of about 500 feet. From 1917 to 1927, when mining ceased, 505,089 tons of ore were shipped.

The ore body on which the original Spies operation was based was located at the emergent axis of the major west-plunging Central syncline of Mineral Hills. The shaft is in Dunn Creek Slate in the upper levels, and the Dunn Creek likely is separated from the ore-bearing Riverton Iron-Formation by a steep fault that trends about N. 80° W. The ore body is not known to continue below the 3rd level of workings, but exploration probably was inadequate to test for its down-plunge extension to the west. Later developments from the shaft, at the 4th, 6th, and 8th levels, were all located in the footwall, east and southeast of the possible continuation of the ore body.

After consolidation of the Virgil and Spies properties in the late 1920's, the Spies shaft was deepened from 400 to 1,200 feet, and three major levels were developed to exploit the Spies-Virgil and Spies-Johnson ore bodies.

Spies-Virgil

The Spies-Virgil ore body, which probably was continuous to some degree with that of the old Virgil mine at higher levels, was entered by three main levels from the Spies shaft at elevations of about 1,075, 700, and 450 feet. The minable ore extended about 100 feet above the highest of these levels, the 4th, making the total vertical extent of the ore body about 700 feet.

The ore mined from the Spies-Virgil property formed the most eastern part of the largest ore body in the Iron River-Crystal Falls district. The general form of the ore body is well shown on figure 3. It occupies the entire lower 100 feet of the Riverton Iron-Formation at the nose of a syncline that plunges about 45° W. carrying the ore body into the adjacent Sherwood property below the 8th level.

Spies-Johnson

The Spies-Johnson ore body, in the NE 1/4 SE 1/4 sec. 24, was located by surface drilling. It was entered by long drifts from the Spies shaft at the Spies 6th and 8th levels. These drifts provided a large amount of geologic data. At both levels unoxidized Riverton Iron-Formation in the shaft area is in contact with Dunn Creek Slate to the south. Approximately 400 feet southeast of the shaft, both levels pass through the nearly vertical South Mineral Hills fault, separating the Dunn Creek from the Hiawatha Graywacke. Beyond the fault, and continuing for about half a mile to the east, is graywacke and slate of the Hiawatha Graywacke, with some complexly interfolded unoxidized iron-formation. The iron-formation is the upper part of the Riverton Iron-Formation (on plate 1, this part of the iron-formation is included with the Hiawatha.) At approximately the east line of sec. 24, the drifts pass from slate of the Hiawatha Graywacke into a north-trending belt of oxidized iron-formation and into the Spies-Johnson ore body.

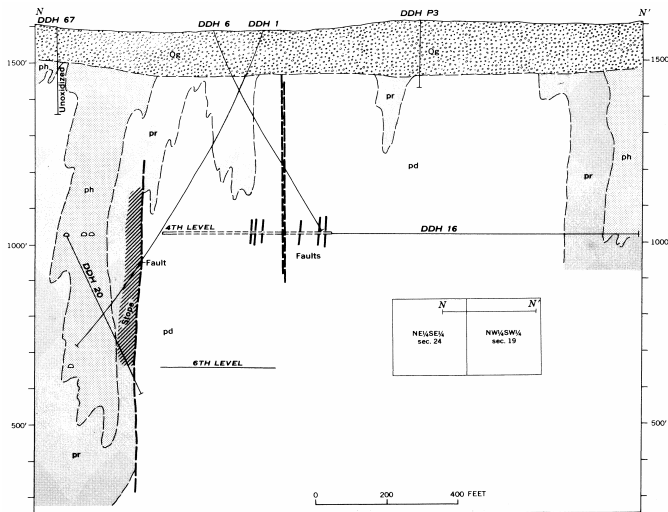


Figure 6 -- Cross section showing stope in the Spies Johnson ore body. Riverton Iron-Formation (pr), overlain by Hiawatha Graywacke (ph), and underlain by Dunn Creek Slate (pd); glacial deposits (Qd). Mined orebody shown by diagonal pattern. The ore was lifted through the Spies shaft, about three-fourths mile northwest.

The Spies-Johnson ore body was about 1,000 feet long and had an average width of about 50 feet. As shown on figure 6, the ore body was nearly vertical. It extended about 500 feet above and an unknown distance below the 6th level. The east limit of the ore body is a nearly-vertical fault, which in most places cuts out the Wauseca Pyritic Member of the Dunn Creek Slate. The 4th level was continued to the east several hundred feet into the footwall in sec. 19. The rock is intensely sheared toward the east end of the drift, but no stratigraphic displacement can be defined. A number of holes drilled eastward from the 4th level intersected Dunn Creek Slate.

Sherwood

The Sherwood mine, one of the most productive mines of the district, is mainly in the SE 1/4 NE 1/4 and the NE 1/4 SE 1/4 sec. 23, T. 43 N., R. 35 W. Its operations were extended in the late 1950's to include the SE 1/4 sec. 24.

The property was first entered from the adjoining Virgil mine. In the period 1931-36, a small tonnage was shipped from a minor pod of ore in the eastern part of the property. In 1943, the mine was taken over by the Inland Steel Co., and a shaft sunk near the center of the SE 1/4 NE 1/4 sec. 23. Six main levels had been developed as of 1963—the 400, 800, 1000, 1200, 1425, and 1625 levels, and all but the lower two have been mapped in detail in the course of this study. Through 1961, ore shipments totalled 7,410,785 tons.

The major structure is a west-plunging syncline immediately north of the South Mineral Hills fault (fig. 3; also section J-J', plate 2). The south limb of the fold, which brings Riverton Iron-Formation to the surface, consisted largely of ore below a depth of about 800 feet. At the 1200 level virtually all the iron-formation contained in the fold was ore. With depth the great ore body "migrates" progressively across the property into the adjoining Wauseca property to the west (fig. 7).

North of the productive syncline is a complementary anticline, the axis of which is a few hundred feet north of the shaft at the 1200 level. Other minor ore-bearing synclines, not fully explored, are also present.

The South Mineral Hills fault crosses the south part of the workings, near the base of the iron-formation. For a short distance, iron-formation is present both north and south of the fault, and the ore body continues across the fault, direct evidence for which has largely been destroyed by intense oxidation.

The area south of the South Mineral Hills fault has been explored mainly by an extension of the 1200 level. Most of the rock encountered is the upper part of the Riverton Iron-Formation, here mostly graphitic slate, and slate of the Hiawatha Graywacke. In the southern part of the NE 1/4 SE 1/4 sec. 23 the drift cuts an anticline that brings the main part of the Riverton to the level. The Riverton is oxidized, and has in part been converted to ore. The area is of some interest because of the local occurrence of uranium mineralization. (See U.S. Geol. Survey Prof. Paper 570, 1968.)

The 1200 level was extended eastward in 1956-57 to exploit an ore body in what is known as the MacDonald Annex, in the SW 1/4 sec. 24. The mined ore body, rather irregular in shape, about 1,000 feet long and 10 to 200 feet wide, trends ENE, from approximately the center of the SW 1/4 sec. 24. It is paralleled, and in part bounded on the south, by a steeply-dipping fault zone. The ore body was stoped for a short distance above the 1200 level.

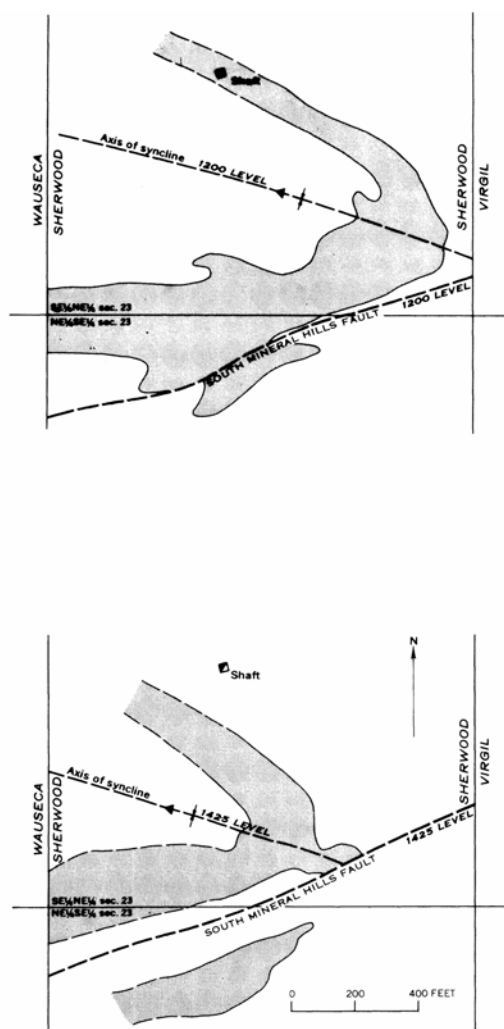


Figure 7 -- The Sherwood ore body migrates progressively westward at depth. The upper map is 1200 level, the lower, 1425 level.

EXPLORATIONS

Town 43 North, Range 34 West

Section 16-22

The Bates exploration refers to 18 holes drilled in the central part of T. 43 N., R. 34 W. by the Inland Steel Co. in 1958-59. All but two of the holes are east of the area of plate 1 (locations and numbers on figure 8.) Holes NB1, NB2, NB3, NB4, and NB6 are churn drill holes known as the "North Bates" exploration; holes SL1-SL13 are diamond drill holes comprising the "Sunset Lake" exploration of mining company designation.

The choppings and core from this drilling have not been examined, as the drilling was done subsequent to active field investigations in the area. Excellent descriptions of the holes are available from logs by J. M. Ohlson, Inland Steel Co. geologist. Significant data concerning the holes are given in the following tabulation:

Hole	Location	Depth to bedrock (feet)	Total depth (feet)	Material
NB1	NW 1/4 SE 1/4 sec. 18	244	250	Dark-gray slate.
NB2	SW 1/4 SE 1/4 sec. 18	249	255	Dark-gray slate, vein quartz.
NB3	SE 1/4 NE 1/4 sec. 20	132	135	Chert fragments in graywacke matrix.
NB4	NE 1/4 SE 1/4 sec. 20	199	230	Do.
NB6	NE 1/4 NE 1/4 sec. 22	215	225	Sheared gray slate.
SL1	NW 1/4 NW 1/4 sec. 16	330	339	Oxidized greenstone.
SL2	SW 1/4 NW 1/4 sec. 16	230	266	Gray and black slate.
SL3	NE 1/4 SE 1/4 sec. 17	203	252	Pyritic graphitic slate; slate breccia at 245 feet.
SL4	SE 1/4 SE 1/4 sec. 17	210	335	Black slate, beds of siderite, nodular chert.
SL5	NE 1/4 NE 1/4 sec. 20	196	249	Graywacke with chert fragments.
SL6	SW 1/4 SW 1/4 sec. 16	234	295	Pseudoconglomerate : slate fragments in slaty matrix.
SL7	SE 1/4 SE 1/4 sec. 16	290	341	Dark-gray slate.
SL8	SE 1/4 NE 1/4 sec. 16	375	585	Graywacke and slate.
SL9	SW 1/4 NE 1/4 sec. 16	345	366	Graywacke and gray slate.
SL10	NE 1/4 NE 1/4 sec. 16	405	425	Do.
SL11	NW 1/4 SE 1/4 sec. 17	280	300	Feldspathic graywacke and slate.
SL12	NW 1/4 SW 1/4 sec. 18	140	206	Gray slate.
SL13	NW 1/4 SW 1/4 sec. 18	110	126	Gray slate, with beds of siderite, beds and nodules of chert.

Very few holes can be stratigraphically located with any degree of accuracy. Exceptions are hole SL4 which cuts pyritic slate definitely assigned to the Wauseca Pyritic Member of the Dunn Creek Slate; and hole SL13 which cuts slate interbedded with siderite and chert assigned to either the lower part of the Hiawatha Graywacke or the upper part of the Riverton Iron-Formation. Holes NB3

and NB4 cut graywacke with chert fragments that probably is Hiawatha Graywacke.

The exploration was designed to test for an eastward extension of the highly productive Mineral Hills structure. Though widely spaced, the holes virtually eliminate the possibility of such an extension. Iron-formation certainly is not a dominant rock type at the bedrock surface, and the rocks are not deeply oxidized.

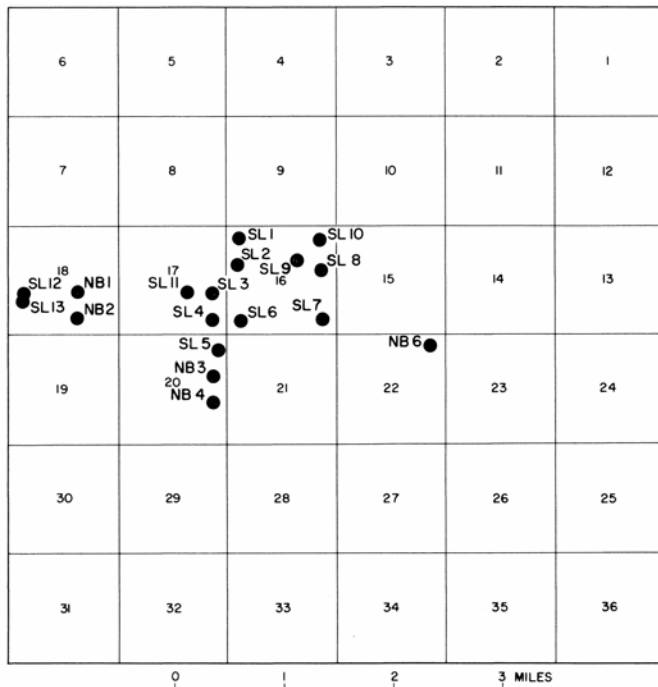


Figure 8 -- Distribution of drill holes of the Bates exploration in T. 43 N., R. 34 W. NB series are churn drill. SL series are diamond drill.

Section 18

Three shallow churn holes (B3, B4, B5) were drilled in the west half by the Verona Mining Co. (Pickands Mather & Co., agents) prior to 1909. Choppings were examined at the Pickands Mather & Co. storehouse at Caspian. B3 cuts a few feet of gray slate, B4 cuts well-banded unoxidized iron-formation (Riverton) and zones of slaty carbonate and chert nodules characteristic of the upper part of the formation, and B5 cuts dark slate and graywacke containing some chert nodules. Holes SL12 and SL13, drilled in 1959 by the Inland Steel Co., are included within the Bates exploration mentioned on p. 29.

The SW 1/4 SW 1/4 sec. 18 is crossed by a long exploration drift at the 4th level of the Bates mine.

Section 19

The west half of sec. 19, the site of the Bates mine and the Johnson workings of the Spies mine, has been extensively drilled and other- wise explored. (See also "Bates mine" and "Spies mine.")

NW 1/4: The Phyllis exploration consists of 30 holes drilled in 1908-10 by the Bates Iron Co. Holes 17, 20, 28, and 29 are in the E 1/2 of the section (the latter two are beyond the area of plate 2). Samples of the core, stored in capsules, were examined at the Rogers mine of the M. A. Hanna Co. The area of drilling has since been extensively developed by underground workings. Hiawatha Graywacke, intersected by holes 7, 8, 9, 15, and 19, contains much graphitic slate commonly interbedded with sideritic slate. Hole 20 cuts unoxidized iron-formation at bedrock surface within 1,000 feet laterally of areas in which thorough oxidation extends to depths of more than 1,800 feet.

The Bates exploration consists of four holes (1-44, 3-45, 4-45, and 5-45) drilled in 1944-45 by the M. A. Hanna Co. All were drilled at angles of 65° - 70°. The core was examined at the Rogers mine. Hole 1-44 starts in oxidized iron-formation (Riverton) with some infolded slate and graywacke (Hiawatha) in the upper part, and ends in pyritic black slate (Wauseca Pyritic Member of Dunn Creek Slate) at 1,020 feet. Hole 3-45 cuts slate interbedded with siderite and chert (Hiawatha?) at bedrock surface and continues to 455 feet in similar rock grading into banded chert-siderite rock (Riverton). Hole 4-45 is mainly in oxidized iron-formation to the bottom at 500 feet. Hole 5-45 begins well down in the Dunn Creek Slate then passes through pyritic slate of the Wauseca into oxidized iron-formation (Riverton) and ends in massive gray and black slate (Hiawatha Graywacke) at 917 feet.

The Bates exploration also includes hole 2 (or 2-44, a joint hole with the Cleveland-Cliffs Iron Co.) drilled west at 45°. The hole is mostly in Riverton Iron-Formation to the bottom, at 1,230 feet. The core, examined at Ishpeming, starts in oxidized rock that grades, below 595 feet, into unoxidized slaty iron-formation characteristic of the upper part of the Riverton.

SW 1/4: Four groups of holes were drilled in the SW 1/4 sec. 19, mostly in the NW 1/4 SW 1/4 which is also entered by the Johnson workings of the Spies mine.

The oldest group (3001-3009) was drilled in 1912-13, and, except for 3006 (labeled S6 on pl. 1) and 3009 (S10 on pl. 2), descriptions are from the files of the Cleveland-Cliffs Iron Co. Core from holes 3006 and 3009 was examined at Ishpeming. Hole 3001 is reported to have cut iron-formation from bedrock surface to 822 feet; from 822 feet to the bottom, at 902 feet, it is in black slate. All the remaining holes apparently cut Hiawatha Graywacke at bedrock surface and for some depth. Holes 3002, 3003, 3004, and 3006 (S6) were continued into iron-formation.

A second group of holes, C1-C8, was drilled in 1915. Except for C3, C7, and C8, these holes enter oxidized iron-formation at ledge surface and help define an anticlinal area of Riverton. Holes C3, C7, and C8 all appear to be in rock (noted as cherty black slate, black slate, and gray slate with chert) assigned to the lower part of the Hiawatha Graywacke.

Records of four holes (P1-P4) were found in the files of Pickands Mather & Co. Descriptions are meager. Date and sponsorship of drilling are not known. Each hole enters bedrock for some tens of feet in what is referred to as gray slate, black slate, or graywacke.

The most recent surface drilling within the area consists of six deep holes (1, 3-7) sunk by the Cleveland-Cliffs Iron Co. in 1943-44. Core was examined in the company office at Ishpeming. Holes 1 and 6, 3 and 5, and 4 and 7 were drilled in pairs in opposing directions at 65° - 70°. The geology encountered can be understood by reference to figure 6. Hole 3, drilled to the west, begins in Dunn Creek Slate, cuts a narrow minor syncline of Riverton Iron-Formation between 420 and 455 feet, and reenters Dunn Creek Slate, which continues to 708 feet. From 708 feet to the bottom of the hole, at 969 feet, the hole passes through oxidized Riverton Iron-Formation, and ends in black slate containing chert nodules (Hiawatha Graywacke). Hole 5, drilled toward the east, is entirely in Dunn Creek Slate to the bottom, at 1,050 feet. Holes 3 and 5 would correspond to holes 1 and 6 if those holes were to be shifted a hundred feet to the east. The plunge of the syncline of Riverton Iron-formation indicated in the central part of the cross section (fig. 6) is steeply to the south. Holes 4 and 7 cut this syncline. Hole 4, drilled westward, starts in Hiawatha Graywacke (here black slate containing chert nodules), passes through Riverton Iron-Formation, and ends in Dunn Creek Slate at 1,080 feet. Hole 7, drilled in the opposite direction, also starts in Hiawatha Graywacke, cuts Riverton Iron-Formation between 235 and 1,360 feet, and ends in Dunn Creek Slate at 1,435 feet.

Town 43 North, Range 35 West

Section 13

The C. C. I. exploration consists of eleven holes (B1-B4, M5-M9, G11-G12) drilled by the Cleveland-Cliffs Iron Co. during the period 1950- 53. Core from the drilling was examined at the Cleveland-Cliffs Office in Ishpeming. All the holes except B4 were drilled north at about 60 to depths of 500-1,300 feet. The holes provide excellent cross sections of the geology. Holes M5-M9, in the NW 1/4, have been discussed previously (see "Structure between Sunset Creek and Mineral Hills".)

SE 1/4: Holes B1-B4 and G11 were drilled along a north line in the W 1/2 SE 1/4. B4 vertical at the south end, starts in unoxidized Riverton Iron-Formation, and to the bottom, at 1,358 feet, passes through an alternation of unoxidized iron-formation (Riverton) infolded with breccia, slate, and graywacke representing the lower part of the Hiawatha Graywacke. B1 is dominantly in graphitic to sideritic and cherty slate containing some graywacke (Hiawatha) to the bottom, at 655 feet, with short runs of infolded unoxidized Riverton Iron-Formation. B2 is entirely similar, and ends in graywacke at 555 feet. Hole B3 also cuts a similar section, ending

in graywacke and gray slate at 1,000 feet. Hole G11 differs only in that the infolded iron-formation is well oxidized to a depth of 735 feet. It also ends at 1,021 feet in graywacke and slate (Hiawatha).

Evidence from all the holes indicates that the Hiawatha Graywacke is generally at bedrock surface but that at relatively shallow depths it is tightly infolded with Riverton Iron-Formation. Hole G12, a quarter of a mile east of G11, cuts slate and ledge surface, and ends in unoxidized slaty iron-formation (Riverton) at 1,130 feet.

The Hill exploration consists of ten shallow holes (H1-H10) drilled in 1913 by the C. M. Hill Lumber Co. Only brief descriptions are available consisting of little more than given on pl. 1. Holes H9 and H10 are shown on the map as being in Riverton Iron-Formation mostly on the information from adjoining hole B4, although H10 is reported to have cut a few feet of lean ore at bedrock surface.

The Grossbusch exploration consists of two holes (G1 and G2) straddling the quarterline 400 feet east of the center of section 13. The drilling was done in approximately 1915 by the McGillis Exploration Co. G1 is reported to have been in ore formation to 280 feet, in ferruginous slate from 280 to 500 feet, and then in gray slate to the bottom, at 770 feet. Hole G2 is reported to have cut lean ore formation, black slate, and ferruginous slate to the end, at 479 feet. The analyses given for hole G1 indicate probable iron-formation (25-35 percent iron.) The Riverton Iron-Formation likely reaches bedrock surface on the axis of an anticlinal fold in this area.

The Hanna exploration consists of five holes (2-44, 3-44, 4-44, 1-45, 2-45) drilled by the M. A. Hanna Co. in the S 1/2 SE 1/4 in 1944- 45. All were drilled north at angles of 60° - 70°. The core was examined at the Rogers mine warehouse of the M. A. Hanna Co.

Holes 2-44, 3-44, 4-44, and 1-45 were drilled along a general east-west line, and all cut dominantly graywacke interbedded with gray and black slate containing chert nodules and fragments—readily assigned to the Hiawatha Graywacke. Some infolded unoxidized banded iron-formation and iron-formation breccia (Riverton) are cut in each. Holes 2-44 and 1-45 also intersect the dike of unaltered diabase crossing the area. The rock on each side of the dike is similar, indicating the dike does not occupy a fault. Hole 2-45, north of hole 1-45, cuts the dike at bedrock surface, then enters medium- to coarse-grained graywacke interbedded with slate. Unoxidized iron-formation (Riverton), most of which is a breccia, is present from 290 feet to the end of the hole at 576 feet. In all these holes, the coarser facies of the graywacke contains bleached feldspar grains which a mile or two west become a dominant characteristic of the Hiawatha Graywacke.

NW 1/4: A shaft known as the Hector exploration, from which two short holes were drilled, is located in the western part of the SW 1/4 NW 1/4. Now caved, it was sunk 212 feet by the Munro Mining Co. sometime prior to

1909. The material on the dump is mostly oxidized slate and graywacke.

The Cronin exploration consists of two holes (C1-C2) drilled in 1948. Core was examined at the time of drilling. Hole C1, drilled south at 60° to a depth of 400 feet, cut deeply-oxidized slate and graywacke assigned to the Hiawatha Graywacke and a very small amount of interfolded (?) oxidized iron-formation. Hole C2, drilled vertically to 210 feet, is in slate interbedded with fine- to coarse-grained graywacke.

The McFarland exploration consists of two holes (1 and 2) shown in the southeastern part of the SW 1/4 NW 1/4. These shallow churn holes were drilled prior to 1909. No lithologic descriptions are available, but the relatively high iron content (52 percent) indicates they cut oxidized iron-formation, probably at ledge surface on an anticlinal fold.

SW 1/4: The Barnett exploration consists of five holes (108, 109, 111, 112, and 113) in the SW 1/4 SW 1/4, and two holes (114 and 115) in the NW 1/4 SW 1/4, all drilled by the Odgers Exploration Co. The Core was examined at the Odgers warehouse in Iron River. Hole 108, drilled north at 75°, passes through Riverton Iron-Formation to cut Dunn Creek Slate to a depth of 950 feet. Hole 109, drilled in the same direction and at the same angle, begins in black slate, sideritic slate, and chert of the lower part of the Hiawatha Graywacke, then from 135 to 315 feet cuts unoxidized iron-formation (Riverton), and passes into Dunn Creek Slate. Hole 111, originally drilled to 128 feet at 75° south, cuts Dunn Creek Slate (Wauseca Pyritic Member) at bedrock surface. From 128 to 1,010 feet the hole remains in Dunn Creek Slate, then cuts oxidized Riverton Iron-Formation that grades into unoxidized iron-formation at the bottom, at 1,173 feet. Holes 112 and 113 were drilled from the same location, 112 vertically and 113 to the north at 45°. Both cut black slate at ledge surface, and continue to 123 and 960 feet, respectively, in slate and fine-grained graywacke. Hole 114, at 60° to the north, begins in black slate and chert, but passes, within less than 150 feet, into dominantly graywacke that continues to the bottom, at 1,004 feet. Hole 115, drilled vertically to 337 feet, is in massive graywacke. The graywacke in holes 114 and 115 is assigned to the Hiawatha Graywacke.

Under the auspices of the Bureau of Mines, four holes (BM1-BM4) were drilled in the W 1/2 SW 1/4 sec. 13 in 1945. Core was logged at the time of drilling.

Holes BM1 and BM2, drilled to 235 and 295 feet, respectively, cut oxidized graywacke, some with chert fragments, definitely assigned to the Hiawatha. Holes BM3 and BM4 are located south of the North Mineral Hills fault. BM3 cuts a few feet of metadiabase, then a hundred feet of fresh diabase, and reenters metadiabase below which it cuts Hiawatha Graywacke. The intersected dikes are continuations of those found in mine openings in and adjacent to the North Mineral Hills fault farther west. Hole BM4 cuts graywacke containing

chert fragments (Hiawatha) at ledge surface, then cuts unoxidized iron-formation containing some slate from about 74 feet to 205 feet, and passes into pyritic slate, sericitic slate, and fine-grained graywacke of the Dunn Creek Slate. The hole ends in a dark breccia crowded with fragments of chert and pyritic slate.

The J & L. exploration consists of a line of five holes (131, 132, 133, 134, and 135) drilled in the E 1/2 SW 1/4 by the Jones & Laughlin Ore Co. in 1931. The core was examined at the company warehouse at Negaunee. The southernmost hole, No. 135, at ledge surface cuts sideritic and graphitic slate with chert layers, nodules, and fragments (lowermost part of Hiawatha Graywacke), then to 651 feet intersects mainly iron-formation (Riverton), partly oxidized and cut by fresh diabase from 305 to 358 feet. Below the iron-formation, the hole is in Dunn Creek Slate to the end, at 780 feet. The diabase, which in the Davidson properties to the west is along the North Mineral Hills fault, apparently has here diverged from the fault and crosses a normal Hiawatha, Riverton, and Dunn Creek section. Hole 134, next north, cuts oxidized to unoxidized iron-formation to the bottom, at 463 feet. Hole 131, entering bedrock in sideritic slate (presumably Hiawatha), cuts oxidized iron-formation from 310 to 361 feet, then enters black graphitic slate, much of it a breccia. The black slate resembles the Wauseca Pyritic Member of the Dunn Creek Slate. If so, the Riverton Iron-Formation is here very thin. Hole 132 passes through gray chert into gray slate and fine-grained graywacke. Hole 133 cuts medium- to coarse-grained graywacke interbedded with some dark slate, sideritic slate, and chert as layers, nodules, and fragments--a typical assemblage for the Hiawatha Graywacke.

Others: Three shallow holes (B1-B3) located in the W 1/2 SW 1/4 are recorded in the 1909 notes of R. C. Allen. Virtually all the information available is given on pl. 1; each is recorded as having cut lean ore. Allen also notes the "Boyington well, n a shaft or deep test pit in the SW 1/4 SE 1/4 as having intersected banded ore and chert. Six holes are reported to have been drilled many years ago in the S 1/2 SE 1/4 by the Verona Mining Co. No data could be found except for hole VI, reported to have cut iron-formation. Two shallow churn holes (C1, C2) also were drilled by the Verona Mining Co. prior to 1909 in the SE 1/4 SE 1/4. Choppings were located and examined at the Caspian mine warehouse of Pickands Mather & Co. Both holes cut gray slate.

Section 14

Most of the drilling in sec. 14 has been done in the southern tier of "forties," the site of several mines. The geology of the mines has been described previously (see "Purcell mine," "Forbes mine," "Davidson No. 2 mine," "Davidson No. 3 mine"). Other explorations are few and information sparse. In fact, except for holes NR1 and NR2, almost all available information is presented on plate 1. Holes NR1 and NR2 were drilled in 1949 by the North Range Mining Co. and the core was

examined at the time of drilling. Hole NR1, drilled northerly at approximately 30°, is in siltstone pseudoconglomerate typical of the Dunn Creek Slate to the bottom. Hole NR2, drilled north at about 45°, is in similar rock to 612 feet. From 612 feet to the bottom, at 678 feet, the hole is in the metadiabase dike that gives rise to the west-trending magnetic anomaly in the area. The rock is slightly magnetic in hand specimen.

Section 15

The geology of sec. 15 is poorly known, but the contact of Dunn Creek Slate with the Badwater Greenstone presumably crosses the northern part, separated at least in part by the metadiabase sill cut by drill hole NR2 in sec. 14 and marked by a magnetic anomaly.

McGoffin exploration consists of a group of 10 shallow holes (M1- M10) predating 1913 in the NE 1/4 sec. 15. Another group of 7 (S1-S7), known as the Sipchen exploration, is recorded in the 1909 notes of R. C. Allen as being in the NW 1/4. No information other than recorded on plate 1 is available.

Johnson and Keweenaw explorations consist of twenty-four holes drilled in the S 1/2 sec. 15 by the Jones & Laughlin Ore Co. in 1909-10. These comprise the Johnson exploration (holes J1, J2, J3, J4, J7, J10, J13, J16, J21) and the Keweenaw exploration (holes K6, K9, K11, K14, K15, K17, K20, K22-K24, K27, K28, K30, K32, K34). Descriptions are from company records.

Information on the Johnson holes is given on plate 1. Most of them penetrated bedrock at 25-100 feet. Of the Keweenaw exploration, only hole K14 seems to have entered definite iron-formation (iron content of 20-44 percent) at bedrock surface. The hole passes into gray slate at 403 feet. Nearby holes K11, K15, K23, and K24 all enter slate at ledge, then pass into iron-formation, suggesting that the iron-formation (Riverton) cut in K14 is a ledge surface on the crest of an anticline, and that it is flanked by Hiawatha Graywacke. Hole K34 similarly cuts iron-formation at depth.

Section 22

E 1/2: The easternmost tier of "forties" in sec. 22 has been entered in many places by the workings of the Cardiff, Homer, and Homer-Wauseca mines. Explorations predating or directly related to the development of these mines include: a group of 13 holes (N1-N13) in the E 1/2 NE 1/4 by the Niagara, Iron Mining Co.; the "Keweenaw exploration" of the Jones & Laughlin Ore Co. (K series), mostly in the NE 1/4 SE 1/4; the "Hunter exploration" (H1-H4) in the SE 1/4 SE 1/4; and two holes near the center of the NE 1/4, IR1 and SC1, drilled by the Iron Range Iron Ore Co. and the St. Clair Mining Co., respectively. The geology is described previously in the section on Mines.

NE 1/4: Hanna exploration consists of six holes drilled in the S 1/2 NE 1/4 by the M. A. Hanna Co. in 1950-51. Holes 1-50 and 2-50 were drilled north; 3-50 was drilled

northwest at 55°; holes 1-51, 2-51, and 3-51 northwest at 70°. The core was examined at the time of drilling.

Hole 1-50 enters Dunn Creek Slate at ledge surface and continues in this unit (except for a short run of infolded or unfaulted unoxidized iron-formation) to the bottom, at 657 feet. The rock in the lower part of the hole is intensely sheared and probably is close to the south-dipping North Mineral Hills fault zone. Hole 2-50, 3-50, 1-51, 2-51, and 3-51 all cut the Riverton Iron-Formation on the generally south-dipping limb of the Mineral Hills syncline. Each hole starts in either feldspathic graywacke or in a mixture of gray slate, graphitic slate, and graywacke, then cuts 50 feet or less of ferruginous slate and oxidized iron-formation representing the Riverton, and ends in Dunn Creek Slate. Clearly, the Riverton in this locality is much reduced from its normal thickness. In hole 3-50 it is not more than 30 feet thick.

Hole 1-52 in the NE 1/4 SE 1/4 was drilled as part of the same program by the M. A. Hanna Co. It tests the Riverton on the south flank of the Mineral Hills syncline, starting from the stratigraphically lower side. The hole is in Dunn Creek Slate to 565 feet, then cuts the Riverton Iron-Formation which in this area is about 10 feet thick, enters a mixture of gray and graphitic slate with chert fragments, and ends in feldspathic graywacke at 860 feet.

J. & L. exploration located in the SW 1/4 NE 1/4 was drilled by the Jones & Laughlin Ore Co. in two separate campaigns, one (the "K" series) in about 1909-11 and the second (holes J1-J4) in 1925. The scant information regarding the earlier holes is superseded by data from the later drilling.

As in the Hanna exploration, the "J" holes cut a much-thinned Riverton Iron-Formation on the south-dipping limb of the Mineral Hills syncline. The overlapping sequence of holes J2, J1, and J3, each drilled to the north at about 70°, cuts the iron-formation at progressively greater depths to the south. Each hole starts in Hiawatha Graywacke, penetrates 50 feet or so of Riverton, and ends in Dunn Creek Slate. Hole J4, offset to the west, cuts the same sequence.

W 1/2: West Mineral Hills exploration consists of eight holes (WM series) drilled in the W 1/2 by Pickands Mather & Co. in 1948. The core was examined at the Pickands Mather & Co. storehouse at Caspian. Holes WM7, WM10, and WM11 are all in Dunn Creek Slate, with WM7 cutting the pyritic graphitic slate of the Wauseca Pyritic Member at ledge surface. South of these three holes in "footwall" slate, holes WM6, WM8, and WM9 cut graywacke and interbedded slate. The graywacke generally is medium- to coarse-grained, and contains abundant feldspar characteristic of the Hiawatha Graywacke in this area. Both graywacke and slate are heavily altered to clay minerals. The Riverton Iron-Formation should occur between the two groups of holes but the drilling to the northeast indicates this formation may be very thin or possibly entirely absent. Hole WM1, north of the projected position of the North

Mineral Hills fault, cuts slate similar to that interbedded with graywacke in holes WM8 and WM9, and is assumed to be in Hiawatha Graywacke. Hole WM2, in the extreme southwestern part of the section, cuts feldspathic graywacke and slate (now Kaolinized) typical of the Hiawatha.

Section 23

Sec. 23 contains some of the principal mines in the Iron River-Crystal Falls district, and hundreds of holes have been drilled from the surface and from underground workings. The geology of the area has been discussed previously under the James, Davidson, Homer, Homer-Wauseca, Wauseca, Minckler, and Sherwood mines. The surface drilling is summarized as follows:

Holes (pl. 1)	Exploration	Area, sec. 23	Company	Date
12, 26, 27	James	N 1/2 NE 1/4	Pickands Mather & Co.	1945-46
K1, K2, K3, K5	Konwinski	SW 1/4 NE 1/4		pre-1909
W1-W10	Wauseca	SW 1/4 NE 1/4 SE 1/4 NW 1/4	The M. A. Hanna Co.	1939
1-3	Davidson	NE 1/4 NW 1/4	Pittsburgh Coke & Iron Co.	
D1	Davidson #1	NE 1/4 NW 1/4	do	1944
D1-D17 (except 7 and 8)	Donahue	NW 1/4 NW 1/4	Niagara Iron Mining Co.	pre-1909
9-10	Homer mine	NW 1/4 SW 1/4	Buffalo Iron Mining Co.	1931-32
D1-D2, D7-D8	So. Donahue	NW 1/4 SW 1/4	Niagara Iron Mining Co.	
M1-M18 (except 6)	Minckler	NE 1/4 SW 1/4 NW 1/4 SE 1/4		pre-1920
01-03	Olson	SW 1/4 SW 1/4		pre-1909
1-44, 6-44	Minckler	SE 1/4 SW 1/4	The M. A. Hanna Co.	1944
A1-A4	Aronson	NW 1/4 SE 1/4		pre-1909
93-99	do	NW 1/4 SE 1/4		
T1-T13	Turosky	SE 1/4	Inland Steel Co.	1949-50
S1-S12, S18	Sherwood	SE 1/4 NE 1/4 NE 1/4 SE 1/4	Republic Steel Corp.	1933
01-05	Olson	SE 1/4 SE 1/4	McPherson Explor. Co.	1912-13
S1-S4	Sturgul	S 1/2 SE 1/4	Republic Iron & Steel Co.	1913-14
SH1, SH3, SH4	Sherwood	SE 1/4 NE 1/4 NE 1/4 SE 1/4		

The only explorations warranting further specific attention are in the southeastern part of the section. The main elements of the geology can be discussed by referring to the map (plate 1) and the cross section through significant drill holes (fig. 9). Holes T8 and T9 of the Turosky exploration (core from which was examined at the Sherwood mine) are in Dunn Creek Slate, intruded by several thin metadiabase dikes, to depths of about 500 feet, then pass through a fault into graywacke and chert breccia (Hiawatha Graywacke) and into Riverton Iron-Formation. Hole T8 was continued in Riverton (largely unoxidized) to 1,044 feet, then to 1,115 feet, crossing, in order, the three units--chert breccia, laminated graphitic slate, and graphitic slate breccia--of the Wauseca Pyritic Member of the Dunn Creek Slate. The fault dips north at 70° and the movement is reverse, the north side upthrown. To the west of the fault, hole T12 ends in highly sheared Dunn Creek Slate at about 750 feet, and clearly enters the north-dipping shear zone. Hole T13, to the east, is on the south side of the fault. It begins in a graphitic slate-chert-graywacke mixture, then passes into oxidized iron-formation to a depth of more than 1,100 feet. The northermost holes, T3 and T4, both cut black slate at ledge surface. T3,

however, continues to 760 feet, mostly in a siltstone-sericitic slate sequence typical of the Dunn Creek Slate. T4 passes into graphitic slate containing chert nodules, and then into Riverton Iron-Formation, and ends in unoxidized iron-formation at 1,335 feet.

Section 24

The Spies and Virgil mines are located within sec. 24. Workings of the James mine extend into the NW 1/4 NW 1/4. The "Macdonald" workings of the Sherwood mine enter the SW 1/4. Most of the mine development is confined to the western and extreme eastern parts of the section. (See descriptions of individual mines.) Many holes have been drilled elsewhere in the section, mostly by the Cleveland-Cliffs Iron Co. (holes S1-S91) The most recent hole for which records are available is S91, drilled in 1954. Abbreviated core from all these holes has been examined at the Cleveland-Cliffs office in Ishpeming. In the NW 1/4 NW 1/4, in addition to the holes drilled by the Cleveland-Cliffs Iron Co., nine holes (100-107, 110) were drilled by the McPherson Exploration Co., two holes (241, 242) were drilled by the Jones and Laughlin Ore Co., and six holes (V1-V6) were drilled prior to 1909 by the Verona Mining Co. Four holes (V1-V4) in the NE 1/4 SE 1/4 also were drilled by the Verona Mining Co., and 13 holes (4001, etc.) were drilled in the S 1/2 SW 1/4 by the Inland Steel Co. in 1954. The core from most of these explorations and drilling adjacent to and in the mines has been located and examined, but the amount of information is so great (more than 20 miles of core) that it can only be summarized here.

NE 1/4: Most of the drill holes in the NE 1/4 cut surprisingly similar rock--sideritic and graphitic slate interbedded with some unoxidized iron-formation. The alternations cut by the drill holes (and exposed in the long drifts at the 4th and 6th levels of the Spies mine) are due to a combination of interbedding and tight folding of the uppermost part of the Riverton Iron-Formation with the lower part of the overlying Hiawatha Graywacke. On plate 1, the rock is shown as the Hiawatha Graywacke. Holes S61 and S62 cut long reaches of such material. For example, S61 begins in sideritic slate and banded chert-siderite, and ends at a depth of 1,559 feet in similar rock; S62 starts in the same lithologic assemblage which persists to the end at 1,518 feet.

Two holes were drilled out from an old shaft or test pit in the NW 1/4 NE 1/4. According to old notes, the pit itself bottomed at 94 feet in black graphitic slate striking S. 60° W. and dipping 60°- 65° SE. The drill hole to the northwest was reported to have cut oxidized iron-formation from 87 to 162 feet, then to have entered siliceous gray slate. The hole to the southeast was drilled to 516 feet, and was reported to be mostly in black and gray slate, the last 6 feet gray slate, jasper, and quartz.

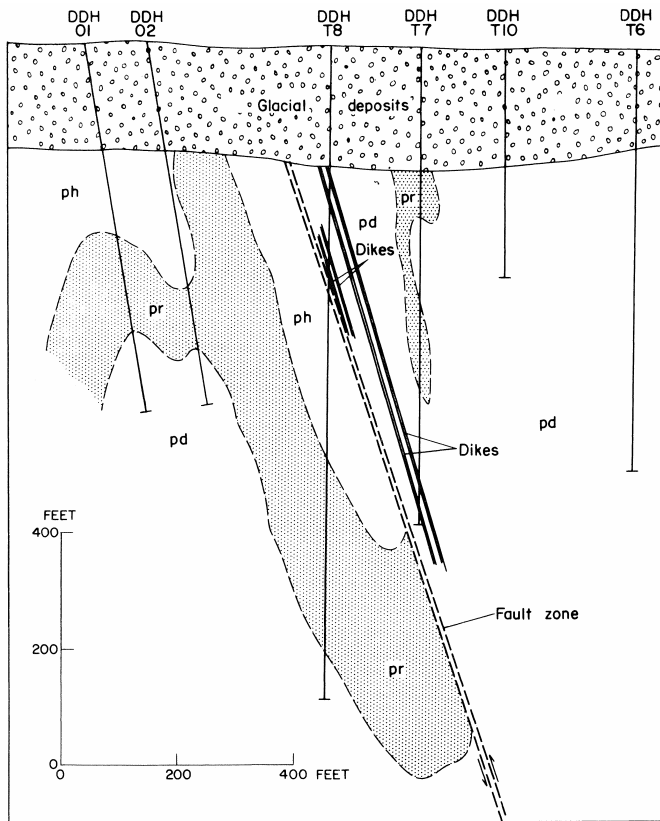


Figure 9 -- Cross section through drill holes in SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 23, T. 43 N., R. 35 W. Stipled area is Riverton Iron-Formation (pr), underlain by Dunn Creek Slate (pd), and overlain by Hiawatha Graywacke (ph).

NW 1/4: The S 1/2 NW 1/4 is the site of the Virgil and Spies mines for which dozens of holes were drilled prior to and during operation. (See individual mine descriptions.) Other holes are along the west edge of the NW 1/4 NW 1/4, as is the Verona air shaft of the James mine. Of the cluster of holes just south of the shaft, core from only holes 105 and S2 has been examined. S2 is in definite Dunn Creek Slate (including the characteristic "speckled gray" of the Wauseca Pyritic Member.) Hole 105 starts in graphitic slate (Wauseca) and passes into iron-formation (Riverton). Of the holes north of the shaft, S76 is typical: drilled north at 65°, beginning in graphitic slate, successively cutting unoxidized iron-formation breccia (Riverton (?)) from 101 to 325 feet, graywacke and slate containing chert and siderite fragments to 422 feet (basal Hiawatha), graphitic slate containing chert nodules to 461 feet, graywacke and slate containing chert fragments (repetition of basal Hiawatha) to 478 feet, unoxidized iron-formation (Riverton) to 636 feet, and graphitic to sideritic slate containing chert fragments and nodules (another repetition of basal Hiawatha) to the end at 865 feet. As in the area to the east, the northern part of the NW 1/4 sec. 24 clearly is underlain by Hiawatha Graywacke and tightly infolded Riverton Iron-Formation.

SW 1/4: As shown on plate 1, the S 1/2 SW 1/4 is entered by workings at the 1200 level of the Sherwood mine ("MacDonald option"). Prior to this development, 13 holes (4001, 4009, etc.) were drilled in 1954 by the

Inland Steel Co. The core was examined at the time of drilling. The southernmost holes (4809, 4825, 5213, and 5221) cut material typical of the lower part of the Hiawatha Graywacke of this area--mostly graphitic to sideritic slate containing beds, nodules, and fragments of black chert. Hole 4817, to the bottom at 435 feet, is mostly in Riverton Iron-Formation oxidized only in the upper part. Hole 4413 starts in Riverton Iron-Formation, then passes into a section of iron-formation and highly sheared slate, with a thin metadiabase dike at about 240 feet, and ends in quartz-veined graphitic slate at 523 feet. For a considerable distance the hole apparently is in the north-dipping reverse fault defined on the basis of drilling to the west. (See fig. 8.) Hole 4405, also located just north of the projected fault, is mostly in Dunn Creek Slate containing much vein quartz to the bottom, at 425 feet. The hole cuts dike rock at 270-279 feet and 422-425 feet. Doubtless the fault cut in this hole and in hole 4413 extends farther east than shown on plate 1. The geologic contacts shown, therefore, will need considerable modification when and if the area is explored further.

SE 1/4: Except for a strip of Riverton along the east side and a central anticlinal area of Riverton, the SE 1/4 is underlain chiefly by Hiawatha Graywacke. Much of the exploration is concentrated in the eastern part of the NE 1/4 SE 1/4, near the Johnson workings of the Spies mine. (See "Spies mine"; also fig. 6.) South of the mine workings, hole S71 cuts a few feet of slate at ledge surface, and then is in mostly unoxidized Riverton Iron-Formation to 564 feet, where it is in contact with Dunn Creek Slate that continues to 635 feet (Wauseca Pyritic Member 564-605 feet). From 635 to 675 feet, the hole cuts sheared slate, gouge, and vein quartz--apparently the southwestward projection of one of the main faults shown on figure 6. From 675 feet to the bottom at 1,216 feet, the hole is in Dunn Creek Slate with infolded Riverton Iron-Formation (oxidized) from 892 to 1,049 feet. Hole S79, to the southwest, illustrates relationships in that area. The hole cuts an alternation of sideritic slate, graywacke, and chert breccia (Hiawatha), and some infolded (interbedded (?)) iron formation to 943 feet, then is in iron-formation (Riverton) to 1,484 feet, with the lower part oxidized, and finally ends in graphitic slate (Dunn Creek Slate, Wauseca Pyritic Member) at 1,497 feet.

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