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Geological Survey

Report of Investigation 5

GEOLOGY AND MAGNETIC DATA FOR CENTRAL IRON RIVER AREA, MICHIGAN

by

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PREFACE

The purpose of this report, second in a series of eight reports being published by the State, is to preserve detailed 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 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 the Professional Paper 570 published in 1968.

The mining companies active in the district aided substantially by providing maps and records and permitting access to mine workings and drill core collections. The author gratefully acknowledges 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.

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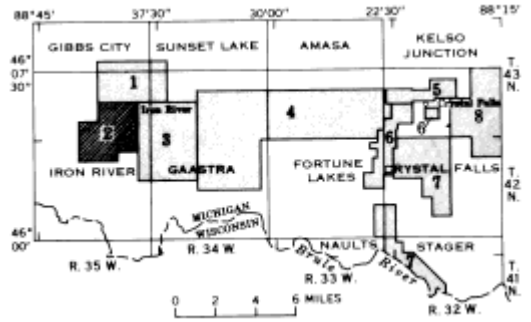

Index to work responsibility and topographic quadrangles in the Iron River-Crystal Falls District.

1. Northern Iron River Area—James, Dutton, Wier.
2. Shading delineates area of this report, Central Iron River Area—Dutton.
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Shading delineates Iron River-Crystal Falls District.

Figure 1. Location and index map

Abstract

The Central Iron River area lies south and west of the city of Iron River and is underlain by folded and faulted rocks of Animikie age, which from oldest to youngest are Badwater Greenstone, Dunn Creek Slate, Riverton Iron-Formation, and Stambaugh Formation. The structures in this area are part of the complicated western apex of the Iron River-Crystal Falls synclinorium; the major structure is a complex syncline in the southern part of the area and contained most of the iron ore produced from the Central Iron River area; other structures are folds and faults of northeast and southwest trend in the northern part and those of north and south trend in the eastern part.

Stratigraphic and structural data and interpretations based on outcrops, ground magnetic survey, exploration drilling, and mine mapping are presented.

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 shown in 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 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, 1951-67). Some of the results of U. S. Geological Survey work in the "Central Iron River area" have been presented as a preliminary report by Dutton (1949).

The central Iron River area, about 4 miles long and 2 miles wide, is just south and west of the towns of Iron River and Stambaugh. The geologic and magnetic data are shown on two map sheets—the Stanley Creek area (plate 1) on the west, and the Nanaimo-Sheridan and Hiawatha areas (plate 2) on the northeast and southeast. Mining in the area began in 1882 at the Nanaimo mine. Shipments through 1967 from all properties of the area totaled 22,865,342 tons of ore. Eight mines have produced ore. The most important, Hiawatha mine, operating from the No. 1 and No. 2 shafts, ceased operation in December 1966.

GEOLOGY

Outcrops, though small and far from abundant, are more

common in this area than elsewhere in the western part of the district. Most occur along the valley of the Iron River. Elsewhere the glacial deposits generally are a hundred feet or more thick.

Outcrops and test pits were mapped on enlargements of the topographic map of the Iron River quadrangle. Workings of the Hiawatha mine were mapped on base maps furnished by the M. A. Hanna Co. The area was surveyed magnetically by Schmidt-type vertical magnetometers, by K. L. Wier, R. B. Hall, and J. J. Hill. In general, determinations were made at 100-foot intervals along traverse lines spaced 300 feet apart. The magnetic relief is low in most parts of the area. The largest anomaly, with a relief of about 600 gammas is in the NE¼ SE¼ sec. 35, T. 43 N., R. 35 W. Anomalies are discussed later.

Stratigraphy

Bedrock of the central Iron River area consists of metasedimentary rocks of the Paint River Group. The sequence of units is shown in table 1. The Badwater Greenstone is known only from one outcrop in the SE¼ NW¼ sec. 33, T. 43 N., R. 35 W. (plate 1) and from a few drill holes. The Dunn Creek Slate, though rarely exposed at the surface, has been observed in workings of the Hiawatha mine and in drill core. As elsewhere in the district, the upper part, the one most commonly intersected, is a pyritic graphitic slate—the Wauseca Pyritic Member.

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

Table 1. Rock units in central Iron River area

The Riverton Iron-Formation, particularly the unoxidized facies, is exposed in many low outcrops and test pits in the eastern part of sec. 35, T. 43 N., R. 35 W. (plate 2). Drill holes and mine workings elsewhere disclose two variations from normal lithologic character. In the north-central part of sec. 35, in particular, the basal part of the formation is a breccia in a matrix of siderite and sideritic graphic slate, or their oxidized equivalents. In the Hiawatha mine, on the south flank of the Hiawatha syncline, the Riverton Iron-Formation is composed almost entirely of siderite, but does not contain the characteristic chert. One crosscut intersected a stratigraphic thickness of 100 feet of stylolitic siderite rock having an average iron content of about 30 percent.

The Hiawatha Graywacke, named for exposures at the surface and in workings of the Hiawatha mine, forms abundant outcrops in the SE¼ sec. 35, T. 43 N., R. 35 W. (plate 2). Most of the exposed rock is massive dark graywacke with scattered chert fragments, characteristic of the lower part of the formation.

The Stambaugh Formation has not been specifically identified at bedrock surface. Laminated flinty magnetic rock, typical of the formation, has been discovered at depth by the drilling north of the Hiawatha mine, and is responsible for the magnetic anomaly in the NE¼ SE¼ sec. 35 (plate 2). The buried block of Stambaugh Formation evidently is contained in an overturned doubly-plunging syncline cut off on the south by the North Hiawatha fault.

Structure

The central Iron River area is at the west apex of the Iron River-Crystal Falls basin and is characterized by a group of folds and faults of east-northeasterly trend and by another group alined almost at right angle to that trend. (See plate 1 of U.S.G.S. Professional Paper 570.)

Badwater Greenstone flanks the apex of the basin and rises in an eastward-plunging medial anticline near the center of the mapped area. Between the medial anticline and the south flank of the basin, the major geologic structure is a complex faulted syncline that trends eastward. North of the medial anticline are doubly plunging folds of west to southwesterly trend that in part are in a down-dropped fault block.

The principal geologic features in the Stanley Creek area are a centrally located eastward-plunging anticline of greenstone, and part of a complex synclinal structure to the south and part of another one to the north. Badwater Greenstone is exposed in a small outcrop in the SE¼ NW¼ sec. 33, and was penetrated by drill holes in the NW¼ sec. 34. Nearby explorations to the north and south are in Dunn Creek Slate.

Badwater Greenstone flanking the south side of the apex was penetrated by drilling in sections 3 and 4, T. 42 N., R. 35 W. Between the central and flank occurrences of greenstone are two synclines. The southernmost syncline is a westward continuation of a major synclinal basin from sec. 35, (plate 2); the south limb is absent because of faulting, and the north limb is modified by southward-plunging folds. The other syncline is a narrow fold of easterly trend known mainly from drill hole data from the SW¼ SW¼ sec. 33 and adjoining parts of sec. 4 to the south.

In the western part of the Nanaimo-Sheridan area (plate 2) westerly trending folds are in a block that has moved downward along the Buckholtz and Hilltop faults. The faults are inferred from the areal geology based on shearing and quartz veins observed in drill core. The direction and amount of dip of most faults are not known.

The general structural pattern of the Nanaimo-Sheridan area is that of two doubly-plunging faulted anticlines and associated synclines. Part of the south limb of the south anticline has been truncated by the Buckholtz fault. Data are insufficient to interpret the east end of the south anticline. The relative movement along the Buckholtz fault is indicated by uplift of Dunn Creek Slate on the south side into juxtaposition with formations as young as Hiawatha Graywacke on the north. The north anticline is cut by the Hilltop fault, which parallels the trend of the fold and dips northward. The inferred area of Dunn Creek Slate suggests that the south side of the normal fault moved relatively upward. Hiawatha Graywacke underlies the bedrock surface northward from the north anticline to the north limit of sec. 26.

The principal geologic feature in the Hiawatha area (plate 2) is a complex structure trending westward in the southern part of sec. 35 and involving the Riverton Iron-Formation, Dunn Creek Slate and Hiawatha Graywacke. The best documented and most economically important fold is the faulted steeply westward plunging Hiawatha syncline in the S½ SE¼ sec, 35 (fig. 2) and the NE¼ NE¼ sec. 2. The ore bodies of the Hiawatha mines are in this structure and its flanks, and the mine workings provide many intersections of the Riverton and associated formations. The Hiawatha syncline plunges westward at an angle of about 75°; the north and south limbs are nearly vertical and locally are overturned. The Stegmiller fault, marked by sheared and contorted rock on several mine levels, trends west-northwest across the northeast corner of the syncline and dips steeply southwestward; the south side is upthrown but the amount of displacement is unknown. The Hiawatha fault, marked by sheared rock and repetition of strata near Hiawatha No. 1 shaft, bounds the north side of the Riverton at the bedrock surface. This reverse fault dips southward at an average angle of 80° and has produced a repetition of strata in the workings of the Hiawatha No. 1 mine by vertical displacement of about 700 feet. The west half of the south limb of the Hiawatha syncline is apparently truncated by the westward-trending Duff fault that is inferred from areal pattern; this fault converges with the southwestward-trending Hiawatha fault, and a small fold near the junction in NE¼ NE¼ sec. 3 (plate 1) and is the west end of the Hiawatha syncline. The south side of the Duff fault has been relatively uplifted, but the amount of displacement and dip of the fault are not known.

The western extent of the Riverton in the north flank of the Hiawatha syncline is determined by a change in the strike of the formation toward the intersection with the Hiawatha fault. To the northeast, one segment of the Riverton is cut off by the North Hiawatha and Hiawatha faults and the other segment by a fault of approximate north trend at the east edge of the mapped area. The North Hiawatha fault, intersected by several crosscuts north of the Hiawatha No. 1 shaft, dips about 80° S.; the south side is upthrown, and the vertical displacement is about 3,000 feet.

North of the Hiawatha fault is a complex downfold of major proportions and probably the principal syncline to which the Hiawatha syncline is a second-order fold. It is a deep basin that centers in the N½ SW¼ sec. 35 and extends westward to the NE¼ NE¼ sec. 4 (plate 1). Sporadic low but distinct magnetic anomalies in the axial area of this structure suggest that local patches of the magnetic Stambaugh Formation are present. The discovery of Stambaugh Formation at depth in the NE¼ SE¼ sec. 35 has previously been mentioned; the rock must be present in an overturned syncline truncated by the North Hiawatha fault.

The south limb of the major basin is truncated by the Hiawatha fault. The north limb, as defined by the Riverton Iron-Formation, is complex and not well known, although it has been explored by drilling and by some underground workings. The map patterns suggest that the northeast end of the basin consists of several northeast-trending anticlines and synclines. The axial trends of these structures appear to swing progressively from northeast to north, with apices of synclines in the areas of the Wickwire mine and the Sheridan mine (plate 2).

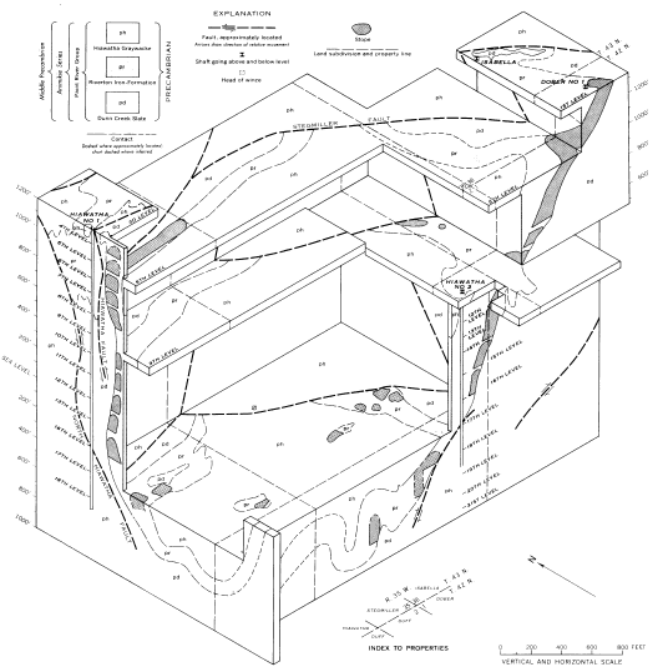

Figure 2. Isometric diagram showing geology of part of the Hiawatha mine.

MINES

Hiawatha

The Hiawatha mine of the M. A. Hanna Company began as two separate operations from the No. 1 and No. 2 shafts, but the workings are interconnected at the 9th, 16th and lower levels, and production records are

combined after 1943. The ore-bearing areas above the 18th level are not continuous, however, and the description here as separate mines follows local practice. The combined shipments from the operations through 1967 amounted to 20,781,730 tons.

Hiawatha No. 1

The Hiawatha No. 1 mine, the shaft in the SW¼ SE¼ sec. 35, T. 43 N., R. 35 W., was opened in 1893 by the Hiawatha Iron Co. under the supervision of W. H. Selden. The mine is 2,100 feet deep at the 18th level. Ore was obtained from parts of the Stegmiller property (SE¼ SE¼), Hiawatha (SW¼ SE¼), and West Hiawatha (SE¼ SW¼). Exploratory workings also extended into the North Hiawatha (NW¼ SE¼) and second West Hiawatha (SW¼ SW¼).

Ore in the Hiawatha No. 1 mine occurs in three separate areas: the north limb of the Hiawatha syncline (fig. 2), a block between the Hiawatha and North Hiawatha faults, and an undetermined structure north of the Stegmiller fault. The synclinal limb dips vertically to the 16th level and is structurally simple. The ore-bearing area, which is composed of at least two long narrow lenses along the strike, is about 1,100 feet long and 60 to 150 feet wide above the 11th level. The length of ore on the 12th through the 17th levels was 2,000-3,000 feet. Width averaged about 75 feet but reached a maximum of 300 feet locally. The dip is approximately 60° S. at the 17th level, and two small doubly-plunging anticlines have been penetrated by mine workings. At the 18th, the workings are in the complex of minor folds at the bottom of the Hiawatha syncline. At that level the ore bodies are continuous with those of the Hiawatha No. 2 mine and will be described more fully in the discussion of that mine.

The structure in the block between the Hiawatha and North Hiawatha faults is a series of westward-plunging folds of oxidized iron-formation first penetrated by mine workings at the 3rd and 5th levels. At greater depth, a syncline in this group of folds contains an ore body 500 feet long and 100 feet wide at the 9th level; 1,200 feet by 100 to 250 feet at the 12th level; and 400 feet by 100 feet on the 13th level. Apparently it does not reach the 16th level which is at a depth of almost 1,800 feet.

A small amount of ore is present north of the Stegmiller fault at most levels from the 3rd to the 21st, but geologic data are not sufficient to satisfactorily determine the structure, possibly a small southwestward-plunging syncline. Horizontal sections of ore from the 3rd through the 9th levels are about 150 feet in diameter or in form of a lens. The ore is isolated from the north limb of the Hiawatha syncline. The ore-bearing area increases to as much as 500 feet by 200 feet at the 10th through 13th levels and probably is a part of, or closely related to, the flank of the Hiawatha syncline. At the 16th and lower levels, the ore areas have decreased to 300 and 400 square feet and are again more isolated.

Hiawatha No. 2

The Hiawatha No. 2 shaft is in the NE¼ NE¼ sec. 2, T. 42 N., R. 35 W., and ore is mined from a body extending from the Isabella and Dober properties to the east. The mine was opened by the American-Boston Mining Company, with the first shipments being made in 1935, and later was taken over by the M. A. Hanna Co. Levels developed from the shaft are the 10th through the 21st and are interconnected with those of the Hiawatha No. 1 mine. The 21st level is at a depth of about 2,500 feet.

The ore body of the Hiawatha No. 2 mine is in the axial zone of the steeply-plunging Hiawatha syncline (fig. 2). From apices at surface outcrop in the Dober and Isabella mines just east of the area of plate 2, the ore body continued downward in expanding size to the irregular keel of the structure at a depth of nearly half a mile. Ore is generally in the lower part of the Riverton and is directly underlain by graphitic Dunn Creek Slate. Oxidized iron-formation overlies the ore except in the few places where the entire thickness of the Riverton has been converted to ore.

The iron-formation dips uniformly about 60° to the west. Folding is entirely absent or of little significance. Through the upper four levels, the ore trends approximately north-south for a length of several hundred feet and a width of 100 feet. With increasing depth, the length increases to 2,000 feet at the 16th level, and the plan becomes progressively more arcuate; both changes are in part a junction of the main ore with pods of ore beyond the northwest and southwest ends of the arc.

The ore body at the 18th level, like that of the No. 1 mine, has a very irregular pattern as a result of being near the complexly crumpled bottom of the Hiawatha syncline. The general trend of the main ore-bearing area is northwesterly, but ore bodies are separated by irregular strips of Dunn Creek Slate along anticlinal axes and by Hiawatha Graywacke along synclinal axes. The minor folds have trends that result in an over-all en echelon pattern. The explored and mined area at about the 18th level is approximately 1,600 feet long by 1,000 feet wide and is estimated to be 60 percent ore, 30 percent Hiawatha Graywacke, and 10 percent Dunn Creek Slate.

The ore-bearing area at the 19th level is an isosceles triangle that has 1,500-foot sides and is oriented with one apex at the northwest corner of the Stegmiller property. Ore north of the Stegmiller fault trends northward, but three other masses trend westerly.

The 20th and 21st levels have only small areas of ore, and no pattern is evident.

Chatham

The Chatham mine was opened in 1907 by the Brule Mining Company and was operated until 1920. Total ore shipments were 1,381,175 tons. Shaft No. 1 of the Chatham mine is in the northwestern part of the NE¼

SE¼ sec. 35 (plate 2). The mine has eleven levels at vertical intervals of approximately 100 feet, but the workings are not extensive because all of the ore occurred within 1,000 feet, horizontally, of the shaft, much within 500 feet. Final maps prepared in 1919 show stopes elongated parallel to the northeasterly strike of the iron-formation approximately 50 to 100 feet long, about half that wide, but extending vertically as much as 600 to 700 feet. Most of the mine workings are shown to be in iron-formation, presumably not oxidized inasmuch as associated materials are classified as sideritic slate (on maps) and cherty iron carbonate (in drill records). Graywacke, apparently part of the Hiawatha, is recorded along 4th level workings 500 feet south of the shaft. Iron-formation and iron ore are shown to be northwest and southeast of this area of graywacke. Thus, the presence of a synclinal structure seems to be well substantiated, and the plunge appears to be toward the south or southwest. The graywacke on the 4th level probably is similar to material at hole 3501, about 300 feet to the south.

Graywacke lies east of a belt of iron-formation from which ore was mined on the four lowest levels in the SE¼ NE¼ sec. 35. The general strike of the strata is to the north or northeast, and the progressive westward shift of stoped areas on successively lower levels indicates that the ore was along the upper stratigraphic limit of iron-formation, which had become the structural footwall as a result of overturned dip.

Geologic structure in the other parts of the mined area could not be determined from the information recorded on the mine maps.

Shaft No. 2 of the Chatham mine is in the southeastern part of the NE¼ SE¼ sec. 35. Only three levels, at approximately 100-foot intervals from the surface, were developed to mine two small ore bodies. One stope was 100 feet north of the No. 2 shaft at the 1st level but plunged southwest and ended 200 feet farther west on the 4th level from the Chatham No. 1 shaft. This occurrence of ore and iron-formation, which is just east of the area of graywacke mentioned previously in the description of the geology in the workings of the No. 1 shaft, is interpreted as being in the east limb of the synclinal structure. A second stope was at the south boundary of the tract, which is 400 feet south of the shaft. The ore at this locality is probably closely related to that at the 3rd level workings of the Hiawatha mine in the northeast corner of the SE¼ SE¼ sec. 35. Maps of the Chatham mine show an area of black slate north of this south stope. The rock is undoubtedly part of the Dunn Creek Slate because graphitic slate breccia of the Wauseca Pyritic Member is present in the dump of Chatham No. 2 shaft.

The crest line of a magnetic anomaly passes just north of the Chatham mine shaft No. 2 and near drill hole 3501. Inasmuch as the rock in the few outcrops and in drill core from hole 3501 is not magnetic, the cause of the anomaly was not determined until magnetic Stambaugh Formation at depth of 1,750 feet below the surface was revealed in 1947 by the drilling northward from the 16th level of the Hiawatha No. 1 mine. This mass of Stambaugh Formation, now enclosed in older strata, is interpreted as being the youngest bed in a syncline overturned to the south and truncated on the south by the North Hiawatha fault. The relation between the easterly trend of the anomaly and the apparent southward-plunging anticline near the No. 2 shaft of the Chatham mine remains undetermined. The magnetic strata probably are in several small synclinal masses parallel to the northward-trending fold axes, but the series of masses is alined parallel to the westward-trending magnetic anomaly.

Wickwire

The Wickwire mine, in the NW¼ NE¼ sec. 35, T. 43 N.5 R. 35 W. (plate 2) was opened in 1911 by the Wickwire Mining Company, and until closed in 1917, had shipped 128,869 tons of ore. The ore was east of the No. 1 shaft and extended about 200 feet north and 200 feet south, and had a width of about 40 feet. It dipped steeply to the west, and was bounded by Dunn Creek Slate in a tight overturned syncline. The three upper levels are at depths of approximately 100, 150, and 200 feet and were almost entirely limited to exploitation of the ore-bearing area. The 4th level is at a depth of about 300 feet and extends for more than 800 feet southwestward from the shaft and 100 feet northward. Abbreviated cores of five holes drilled from the 4th level are stored at the Rogers mine and were examined in 1949. Each hole penetrates some iron-formation, locally a chert breccia; most of the core is oxidized material. The record of hole C1 shows iron content of 25 to 53 percent in the interval between 30 and 140 feet. In hole C4 the iron content was mainly over 40 percent from 90 to 335 feet. The most common material associated with iron-formation was graphitic slate, some of which contained chert fragments. The slate is believed to be the material at the base of the iron-formation, but all these materials and the other graphitic slate possibly may be younger than the iron-formation. A small amount of graywacke is in the core from the two holes. Interpretation of the geology at the Wickwire mine is uncertain, but iron-formation in one or two synclinal folds of southerly or southwesterly plunge is inferred.

Sheridan

The shaft of the Sheridan mine is southwest of the center of the SE¼ SE¼ sec. 26, T. 43 N., R. 35 W. (plate 2). It was started as an open pit in 1886 by St. Clair Brothers, and underground work was begun in 1887 under Peter Sheridan. The property was taken over by the Sheridan Mining Co. in 1891, at which time the shaft was 180 feet deep and the 1st level was in operation. Ore was shipped from 1889 to 1900; shipments totaled 116,299 tons. The only known map of the Sheridan mine shows that four short levels were developed, but depths from the surface are not given. One stoped area 140 feet long and 20 feet wide at the

3rd level, is about 270 feet north of the shaft and has a general northeast elongation. Another stoped area about 75 feet long and as much as 30 feet wide at the 2nd level, is approximately 75 feet northwest of the shaft and is elongated north-northeast. No geological information is shown on the mine map.

Beta

The Beta mine is in the N^ SW¼ sec. 26, T. 43 N., R. 35 W. (plate 2). The mine, initially an open pit, was opened in 1886 by the Beta Mining Company and small shipments were made in 1886 and 1887. The property was taken over by McKinnon Brothers in 1889 and underground workings were extended southwestward into the Nanaimo property. A small tonnage was shipped in 1891, after which the mine was closed. In all, shipments totalled 27,156 tons, much of which was from stockpile in 1941 and 1942.

The mine had four levels at depths from 135 to 435 feet. Maps of the workings for 1,300 feet southwest of the shaft show the iron-formation to trend southwest and dip northwest. The belt of iron-formation is 350 feet or more wide and is shown bounded on both sides by slate. The largest ore-bearing area, on the 3rd level, was 600 feet long and averaged 50 feet wide.

Nanaimo

The Nanaimo mine, in the NW¼ SW¼ sec. 26, T. 43 N., R 35 W. (plate 2), was one of the first mines in the district. It was opened as an open pit by the Nanaimo Mining Company in 1881, and underground work was started in 1882 from an inclined shaft. In 1884, a second pit was opened several hundred feet to the south and was connected to the first by underground drifts. In 1889 the property was taken over, together with the Beta mine, by McKinnon Brothers, and still later by the Mineral Mining Company. Shipments aggregating 373,765 tons were made intermittently from 1882 to 1908. No geologic information is available.

Cortland

The Cortland mine, in the E½ SE¼ sec. 34, T. 43 N., R. 35 W. (plate 1), was operated from 1912 to 1914 by the Wickwire Mining Company, and 52,148 tons of ore were shipped. The mine had four levels at intervals of approximately 100 feet but most of the development was at the 2nd level. The only geology indicated on company mine maps consists of a few notations concerning the 3rd and 4th levels. The recorded strikes range from N. 45° to N. 90° W., and the respective dips from 50° SW to vertical.

Three holes drilled from the 4th level begin at locations about 250 feet south of the shaft and range in length from 183 to 266 feet. The abbreviated core is in storage at the Rogers mine and was examined. The first hole, drilled horizontally southward, and the third hole, drilled horizontally eastward, begin in iron-formation and then penetrate massive graywacke and graywacke with chert fragments. Thus, younger rocks lie to the south and southeast of the iron-formation at the Cortland mine. The amount of core from the second hole, which was vertical, is small and mostly gray slate, black slate, siltstone, and a little chert; these strata are probably interbedded in the upper part of the iron-formation.

Brule

The shaft of the Brule mine is in the SE¼ sec. 34, T. 43 N., R. 35 W. (plate 1), and workings from the shaft extend westward into the SW¼ and eastward to the area of the Cortland mine in the SE¼ SE¼. The mine was developed by the Brule Mining Company sometime prior to 1931, at which time it was taken over by the M. A. Hanna Company. A shipment of 4,200 tons of ore was made from stockpile in 1936; no other production is recorded.

The mine workings are principally main drifts that extend eastward and westward at two levels from the shaft. The 1st level is 340 feet below the surface and the workings extend 1,650 feet westward. The plan of the 2nd level, which is 490 feet below the surface, is shown on plate 1. Maps of the Brule Mining Company show that the shaft area at both levels is in cherty gray carbonate slate, which is undoubtedly unoxidized iron-formation. At the 1st level, oxidized iron-formation as much as 240 feet wide extends from 400 feet west of the shaft to the west end of the drift and is bounded on the north by underlying black slate. At the 2nd level, oxidized iron-formation as much as 350 feet wide extends from 950 feet west of the shaft to the west end of the drift; and to the north it is underlain by black slate. A crosscut that is 1,700 feet west of the shaft extends 920 feet southward into the SE¼ SW¼ and passes through folded cherty gray carbonate slate with some associated oxidized and unoxidized graywacke, gray slate and black graphitic slate. These associated strata are the materials generally present in the upper part of the iron-formation and the lower part of the Hiawatha Graywacke. The eastern part of the 2nd level of the Brule mine is along the north side of the SE¼ SE¼ and is thus beneath the Cortland mine. The drift is in unoxidized iron-formation for 250 feet, passes through oxidized iron-formation for 225 feet and partly oxidized graywacke for 170 feet, and ends in unoxidized iron-formation. The unoxidized iron-formation and partly oxidized graywacke are presumably the downward continuation of strata penetrated by the Cortland mine workings.

Geologic data on maps of the Brule mine show a general range in strike from N. 60° E. to S. 60° E., but the strike is due north near the shaft. The dips are predominantly southward about 800 but range from 60° S. to 60° N.

Five holes were drilled from the western part of the 2nd level. The holes are at distances of 1,200 to 2,000 feet west of the shaft, and all begin south of the main drift. The inclinations are 60° to 80° at bearings from N. 16° E.

to N. 16° W. The first four holes range in length from 206 to 285 feet and the 5th hole is 448 feet. The cores are stored by Pickands Mather & Co. at Caspian. Examination revealed normal features of lithology in the Hiawatha Graywacke, Riverton Iron-Formation, and upper part of the Dunn Creek Slate, but few important structural data.

EXPLORATIONS

Town 43 North, Range 35 West

Section 26

NE 1/4: Information concerning the NE¼ is from two explorations and is very sparse.

Diamond drill holes M1, M2, and M3 range in depth from 212 to 296 feet and were recorded as gray slate by R. C. Allen in 1909. The stratigraphic position of the slate is not known, but is presumed to be younger than iron-formation and probably part of the Hiawatha Graywacke.

The Sailor exploration, in the southwestern part of the SW¼ NE¼, is comprised of a test shaft and six diamond drill holes. The following information was obtained from records. One hole, inclined 70° SE from the 95-foot level of the shaft, is 136 feet long and in slate, jasper, and ore; the last 39 feet contained 44 to 50 percent iron. The other holes are from 207 to 359 feet long and were reported to be in various associations of slate, quartz, jasper, and ore. Iron content reported for 269 feet of bedrock at hole S6 ranged from 24 to 60 percent; 150 feet of material had more than 40 percent iron.

SE 1/4: Map records of numerous test pits in the SE¼ SE¼ indicate ore, jasper, chert, slate, and many occurrences of black slate-not only near outcrops of slate but also near outcrops of unoxidized iron-formation. Slates in the southeastern part of the SE¼ SE¼ are believed to be older than the iron-formation because of their proximity to diagnostic graphitic slate breccia of the Wauseca Pyritic Member of the Dunn Creek Slate, which is penetrated by drill hole 3504 in the northeastern part of sec. 35, T. 43 N., R. 35 W.

Diamond drill holes D8 and D10 at the east side of this tract were part of an exploration in the adjacent SW¼ SW¼ sec. 25. The holes were reported to be 570 and 650 feet deep and in ore-formation, quartz, jasper, and slate. Scattered outcrops and test pits elsewhere in the SE¼ sec. 26 define a synclinal area of Riverton Iron-Formation, largely unoxidized.

NW 1/4: Fourteen diamond drill holes in the NW¼ comprised the Hilltop exploration of the Cleveland-Cliffs Iron Company in 1950 and 1951. Six holes (H3, H8 and H11-H14) range from 320 to 740 feet deep, others from 1,049 to 1,510 feet. Core is stored in Ishpeming and was examined in 1950-51 and 1956.

Only drill hole H8, which is the minimum in depth, did not penetrate at least some part of the Riverton Iron-Formation, which is mainly in the north limb of an anticlinal structure and mainly across the S½ NW¼. As indicated on the map (plate 2), five holes enter oxidized cherty iron-formation at the bedrock surface. Five others, HI, H4, H5, H9 and H13 pass through the general sequence of Hiawatha Graywacke upper slaty part of the Riverton Iron-Formation in which chert nodules and fragments are present, and lower cherty part of the iron-formation. Holes H4, H9 and H13 end in dark gray to black slate that is generally not graphitic but which may be part of the Dunn Creek. Holes H2 and H6 penetrate graphitic slate at the bedrock surface; and the material may be part of the Hiawatha as indicated on the map, or the upper part of the Riverton. Both holes are in Riverton at greater depth; hole H2 passes into oxidized cherty iron-formation, and hole H6 cuts massive bedded siderite with almost no chert.

Six holes go through well-oxidized iron-formation that contains more than 45 percent iron. Drilled thicknesses of 10 to 20 feet of this material are commonly separated by equal or greater thicknesses of leaner material.

Sheared gray and graphitic slate and numerous small veins of quartz in six cores are the basis for the Hilltop fault designated by the Cleveland-Cliffs Iron Company. The sheared slate and vein quartz are at shallow depths in holes H6 (230 to 395 feet) and H14 (310 to 440 feet), at moderate depths in holes H3 (524 to 635 feet) and H13 (688 to 740 feet), and at greater depths in holes H7 (956 to 1,028 feet) and H10 (987 to 1,083 feet). Vein quartz is also at 887 to 900 feet in hole H4 and at 1,090 to 1,100 feet in hole H9. Data in the adjacent E½ sec. 27 indicate that the area south of the northward-dipping Hilltop fault moved relatively westward or upward, or both, and the geologic pattern shown in the NW¼ sec. 26 indicates the same relative upward displacement.

The Sipchen exploration was mostly in the southern part of the SW¼ NW¼ where holes P1 to P7 were by churn drill and holes P8 to P12 were by diamond drill; P13 is a churn drill hole in the northeastern part of the SE¼ NW¼. According to notes by R. C. Allen in 1909, the depths of holes PI to P6 range from 45 to 82 feet; hole P7 is 38 feet deep but did not reach bedrock and is not shown on the data sheet. Probably all these holes are in the Dunn Creek Slate.

Diamond drill holes P8 to P12 were explorations of undetermined date and origin. The top of hole P8 was beyond the south limit of the NW¼ but the hole is inclined northward and so most of the rock penetrated is in the area being considered. The core from this series of holes was stored by Pickands Mather & Company at Caspian. The depths of the holes range from 250 to 400 feet. Most of the rock penetrated by holes P8 to P11 is unoxidized cherty iron-formation, but some is oxidized iron-formation. Associated strata are graphitic slate, silty slate, and graywacke. Hole P11 goes through 140 feet of iron-formation and stops after penetrating 85 feet of feldspathic graywacke (Hiawatha). The core from hole P12 is mainly gray slate and black slate that is partly

graphitic; material in the bottom 300 to 400 feet is mostly vein quartz with some mashed and sheared gray to black slate. Drill hole P13, in the SE¼ NW¼, is in graphitic slate.

SW 1/4: Diamond drill holes B1 to B4 and B6 in the vicinity of the Beta-Nanaimo mine workings in the NW¼ SW¼ and hole B5 in the NE¼ SW¼ comprise the Beta exploration, drilled by the Mineral Mining Company in 1947-49. The depths of the holes range from 250 to 850 feet; four holes are more than 500 feet. The cores are stored at Iron River and were examined shortly after each hole was completed.

Each hole penetrates iron-formation, which is generally unoxidized but in holes B1 through B4 is partly oxidized. The material generally associated with the iron-formation is graphitic slate, locally laminated or massive, and chert breccia with graphitic slate matrix. Gray slate, silty slate, and graywacke are less commonly matrix material of chert breccias. The cores from parts of several of the holes are much sheared and contain much vein quartz; faults are probably present, but data are insufficient to evaluate their importance.

The breccias are believed to be the basal part of the Hiawatha Graywacke, and thus the areas of Riverton Iron-Formation are interpreted to be generally anticlinal. Repetition of iron-formation and chert breccia indicates either much interbedding of these lithologic units, complex folding, or combination of interbedding and folding. The preferred interpretation is folding.

Information concerning an unnamed and undated exploration in the eastern part of the NE¼ SW¼ was obtained from a print prepared by the Mineral Mining Company of the Beta-Nanaimo mine area. Diamond drill holes X1B through X3B range in length from 92 to 256 feet. Each is reported to have been in black slate, but so-called lean ore also is present in hole X1B. The slate is presumably older than the reported iron-formation.

Test pits in the north part of the SW¼ SW¼ are in black slate with associated iron-formation (three pits) and black slate with chert breccia (one pit). These materials probably represent the basal part of the Hiawatha Graywacke.

Section 27

NE 1/4: Insofar as known, the NE¼ has been explored only by diamond drill holes HI to H5 of the Hilltop exploration of the Cleveland-Cliffs Iron Company in 1950 to 1952. The depths of the holes range from 1,133 to 1,624 feet. The cores are stored at Ishpeming.

At the bedrock surface all holes are in coarse feldspathic, partly kaolinized graywacke and massive gray slate of the Hiawatha Graywacke. Holes H3 and H4 cut no other kinds of rock for their respective lengths of 1,471 and 1,624 feet. The other three holes also penetrate graphitic and sideritic slate containing chert nodules and fragments representing the upper part of the Riverton Iron-Formation; hole H2 ends in this material. Hole H1 is in unoxidized iron-formation from 830 to 890 feet and continues in slate with chert nodules and fragments to its total depth of 1,138 feet. Hole H5 goes through oxidized iron-formation from a depth of 700 to 850 feet and then is in bedded gray to black slate with small chert lenses to the end at 938 feet.

SE 1/4: The SE¼ is generally referred to as the Buckholtz property. The original exploration on the Buckholtz property, which was by Coe and Piper prior to 1910, comprised a shaft and less than 200 feet of workings from each of three levels at depths of 119 feet, 208 feet, and 367 feet. The geology represented on available maps shows oxidized iron-formation from 20 to 30 feet thick, overlain and underlain by black slate. The strata strike eastward and are inclined southward about 50° to 55° on the 1st and 2nd levels. The 3rd level was all in black slate. Iron-formation at this locality is probably in an anticline, inasmuch as the associated black slate is presumed to be the slaty upper part of the Riverton Iron-Formation or part of the Hiawatha Graywacke.

The Mineral Mining Company began its Buckholtz exploration of the SE¼ in 1948 with two holes near the Buckholtz shaft. Six additional holes in the NE¼ SE¼, three in the SE¼ SE¼, and ten in the NW¼ SE¼ were completed by August 1951. The core, now stored at the U.S. Bureau of Mines warehouse in Minneapolis, Minnesota, was examined at the time of drilling.

Hole B1 is inclined 60° at S. 10° E. and was drilled 475 feet, mainly in unoxidized and oxidized iron-formation with seams and partings of graphitic slate; graphitic pyritic slate with chert fragments is penetrated at 145-200 feet. Hole B2, at the same location as B1 but drilled N. 10° W. at 60°, is 292 feet in depth and alternately penetrates unoxidized iron-formation breccia and graphitic slate with nodules and lenses of chert. These holes are believed to be in the upper part of the Riverton Iron-Formation in the limbs of a small anticlinal fold.

Other holes in the NE¼ SE¼ range in depth from 130 to 600 feet and are mainly in graywacke, partly feldspathic, with some gray slate. Oxidized iron-formation was penetrated at drilled intervals as follows: B6 at 210-343 feet, B9 at 94-120 feet, and B10 at 407-532 feet. Unoxidized iron-formation is cut in hole B9 at 293-330 feet and from 339 feet to the end of the hole at 344 feet. Hole B11 is inclined 60° and was drilled 505 feet; unoxidized iron-formation is penetrated from the bedrock surface at 76 feet to 157 feet, and again from 333 to 345 feet and from 433 to 456 feet; associated materials are mainly graphitic slate, gray slate and some graywacke.

Holes B3, B7 and B8 comprise the exploration of the SE¼ SE¼; each is approximately 500 feet deep. The core from hole B3 is mostly medium- to coarse-grained feldspathic graywacke with associated gray slate (Hiawatha). The core from hole B7 is also predominantly feldspathic graywacke with minor gray sericitic slate and graphitic slate; five zones of quartz-filled tectonic breccia are between the depths of 243 and

457 feet. Below these brecciated zones the hole passes through chert and siderite fragments in graphitic slate, chert and siderite fragments in graywacke, and ends in 25 feet of unoxidized Riverton Iron-Formation. Hole B8 enters bedrock at a depth of 168 feet in a highly sheared unoxidized iron-formation with some graphitic slate and much vein quartz.

Holes B12 to B21 in the NW¼ SE¼ were drilled to depths of 580-960 feet. All except B19 enter feldspathic graywacke (Hiawatha) at the bedrock surface. All except B16 and B18 cut some iron-formation, generally at depths from 600 to 900 feet. In hole B19 unoxidized iron-formation was penetrated from 370 to 535 feet, and the uppermost bedrock was laminated pyritic slate with associated chert nodules and thin laminae of siderite and iron oxides. Five of the seven holes cutting iron-formation pass into sheared graphitic slate, commonly containing veinlets of quartz; these slates are presumably stratigraphically below the iron-formation and are part of the Dunn Creek Slate.

NW 1/4: Diamond drill holes F1-F3 in the E½ NW¼ were explorations in 1912 by the Florence Iron Company. The depths of the holes are 235, 225, and 160 feet. The reported bedrock at the several localities is gray tuffaceous slate, tuffaceous material and slate above graywacke, and ferruginous graywacke. Possibly the term "tuffaceous" may have been used because of the feldspathic character of the Hiawatha Graywacke as observed in recent drillings in adjacent parts of the area.

Hole WM4 was drilled to a depth of 500 feet by Pickands Mather & Company in 1948. The core, examined at the company storehouse at Caspian, Michigan, shows the hole to have cut altered dike rock at bedrock surface, sericitic slate and fine-grained graywacke in the middle 200 feet, and altered dike rock to the end of the hole.

SW 1/4: Diamond drill holes S1 to S4 near the north-south center line of the SW¼ comprise the Semer exploration. The depths of the holes range from 463 to 1,060 feet. The reported bedrock in the northernmost hole is red and gray slate, in the southernmost hole gray slate with chert, and in the other two holes gray slate and graywacke with chert. These materials are presumably part of the Hiawatha Graywacke, but information concerning structure is lacking.

Section 28

Explorations and geologic data concerning the bedrock in Section 28 are not known.

Section 33

N 1/2: The only data obtained for the NE¼ were records of 1909 indicating pipe driven in three test pits penetrated black slate at depths of 54 feet, 106 feet, and 135 feet. So far as is known, the NW¼ has not been explored by drilling or pitting, and an exposure of greenstone provides the only geologic information regarding the tract. Probably the N½ is underlain mostly by Dunn Creek Slate and Badwater Greenstone.

SE 1/4: The Gleason Ore Development Company drilled holes C1-C3 and C5-C11. The date of exploration is not known. Depths of seven holes range from 238 to 467 feet; two holes are 650 and 1,125 feet deep; C3 did not enter bedrock and is not shown on the map (plate 1). All holes except C11 are recorded as in iron-formation or in material described as lean iron. Hole C11 is reported as in gray to black slate, presumably Dunn Creek Slate. Holes G1 and W3 represent early drilling; no information is available other than that recorded on plate 1.

The Cambrian Mining Company drilled holes C12-C21 in 1926 and 1927. Four holes range in depth from 232 to 463 feet, and six from 640 to 742 feet. Cores from holes C13 to C21 were stored at Caspian by Pickands Mather & Company and were examined in 1947. The cores from holes C14 and C15 are especially significant in interpreting the geology of this part of the area. Hole C14 is inclined 70° NW and passes through graywacke from the drilled depth of 150 to 225 feet, graywacke with some siderite and chert from 225 to 475 feet, magnetic slate from 475 to 570 feet, graywacke with siderite and chert from 570 to 620 feet, and magnetic slate from 620 feet to the bottom of hole at 651 feet. The magnetic slate is believed to be stratigraphically part of the Stambaugh Formation, here preserved in a small but deep syncline and enclosed in Hiawatha Graywacke. Hole C15, parallel to and about 300 feet N. 45° W. of hole C14, is in graywacke and slate (Hiawatha Graywacke) from the drilled depth of 142 to 185 feet, in oxidized iron-formation and slate (Riverton) to 530 feet, and then in black graphitic slate (Dunn Creek Slate) to the bottom of the hole at 695 feet. The material from 630 to 642 feet is graphitic slate breccia that is a marker bed in the Wauseca Pyritic Member of the Dunn Creek Slate.

W1 and W2 are test shafts from which bedrock was drilled, probably for the Wickwire Mining Company. Along with a test shaft or third drill hole near the northeast corner, these explorations are the only ones known in the NE¼ SE¼. As shown on an undated blueprint of the Gleason Ore Development Company, the drill holes are 660 feet and 360 feet deep. The holes and test shaft probably are in Dunn Creek Slate.

SW 1/4: The earlier of two explorations in the SW¼ was in 1911 and 1912, when holes 11-15, 18, and 19 were drilled, probably for the Iron County Steel Company. Depths of the holes range from 67 to 229 feet, and the maximum amount of bedrock drilled was 184 feet. Analyses of material from 60 to 120 feet in hole 14 were recorded as 31-49 percent iron; and from 50 to 105 feet in hole 19 as 29-57 percent iron.

In 1928 holes 3301 to 3306 were drilled for the M. A. Hanna Company. Depths range from 70 to 400 feet; and the amount of bedrock penetrated was from 2 to 400 feet. Core is stored at the Rogers mine by the M. A. Hanna Co. and was examined in 1947. Most of it is

Riverton Iron-Formation, part of which is oxidized. Graphitic slate and gray slate from three holes is presumably Dunn Creek Slate. About half of the total core is unoxidized iron-formation breccia, similar to that at the Buckholts exploration in the SE¼ sec. 27.

Section 34

N 1/2: Holes H24-H26 in the SE¼ NW¼, drilled in 1951 for the M. A. Hanna Company range in depth from 151 to 176 feet and penetrate from 5 to 10 feet of greenstone, probably part of the Badwater Greenstone. The cuttings are stored at the M. A. Hanna Company office.

Holes R1-R5 on the east-west center line of the section comprise the Ross and Barras exploration of 1909 by the Cleveland-Cliffs Iron Company. Core is stored by the company at Ishpeming. The holes are shallow, and only a small amount of core is available for examination. Material is gray slate and graywacke classified as Dunn Creek Slate.

E 1/2 SE 1/4: A group of test pits and a shallow drill hole (C11), known as the Coe and Young exploration of the Cleveland-Cliffs Iron Company dates from 1909-10. The material encountered probably belongs to the Hiawatha Graywacke, as shown on the map. The Hiawatha fault shown across the southeast corner of this tract is based on subsurface information from mining and drilling at the 9th level of the Hiawatha mine workings in the adjacent part of sec. 35.

Diamond-drill holes R6 and R7 were also 1910 explorations of the Cleveland-Cliffs Iron Company. R6 is a vertical hole 517 feet deep and it penetrates 395 feet of bedrock. The uppermost 170 feet is in oxidized iron-formation with angular pieces of chert; the next 180 feet is black slate, probably the upper part of the Riverton Iron-Formation; and the last 45 feet is predominantly oxidized graywacke with chert (Hiawatha). The stratigraphic section cut in hole R6 evidently is overturned. Hole R7, 243 feet deep, cuts 119 feet of Hiawatha Graywacke partly oxidized and containing some chert.

Hole M12 is a shallow hole in the SE¼ SE¼, part of the Hamilton-Merryman exploration; it is reported to have cut black slate.

W 1/2 SE 1/4 and E 1/2 SW 1/4: Holes B1 to B13 drilled for the Palms-Book Land Company in 1922-23 penetrated ore that was the basis for initial development of the Brule mine. The depths of the holes range from 78 to 813 feet; the first three holes are not more than 80 feet deep, but the other ten holes are more than 400 feet deep. The core is stored at Caspian, Michigan by Pickands Mather & Company and was examined in 1947.

Core from the first three holes is entirely unoxidized cherty iron-formation with a small amount of associated pyritic graphitic slate. Core from each of the other ten holes is, in part, oxidized iron-formation; other materials are unoxidized iron-formation, unoxidized and oxidized graywacke, and varicolored slates.

The varicolored slates are probably from the upper part of the Riverton Iron-Formation and the graywacke from the lower part of the Hiawatha Graywacke, but graphitic slate in a few holes (B6, B8, B11, and B13) may be from the Dunn Creek Slate.

Holes B18 and B19 were drilled from the surface in the SW¼ SE¼, and five holes were drilled from the underground workings of the Brule mine in 1930 for the Brule Mining Company. The holes from the surface were 175 feet and 480 feet deep. Cores from these holes contain very little iron-formation. Most of the material is red, brown, gray, and black slate with chert; and some oxidized or partly oxidized graywacke is present.

Holes N2, N4, and N7 were drilled by V. Soderstrom, probably for the Northern Mining Company, but the date of the exploration is not known. The depths of the holes range from 98 to 464 feet. The various materials reported are paint rock and ore, paint rock and chert, chert and ore, lean ore, slate and quartz, and black slate. Probably all the holes are in partly oxidized strata of the upper part of the Riverton Iron-Formation.

Churn drill holes M9, M13, and M14 put down in 1910 as the Hamilton-Merryman exploration by the Cleveland-Cliffs Iron Company range in depth from 98 to 134 feet; a fourth hole was abandoned before entering bedrock. The reported samples from the holes, in numerical order, are slate, chert, and jasper; all the materials are probably from strata in the upper part of the Riverton Iron-Formation.

W 1/2 SW 1/4: As far as known, only hole X1 has been drilled in the NW¼ SW¼. I t is reported to end in 5 feet of gray slate, presumably the Dunn Creek Slate.

The SW¼ SW¼ has been explored by four drill holes along the west side, each reported to have penetrated iron-formation. Holes S1, S3, and S5 were drilled by V. Soderstrom and go only to the bedrock surface. Hole 12, a churn-drill exploration in 1912 by the Iron County Steel Company, is 262 feet deep and penetrated 105 feet of bedrock.

Section 35

NE 1/4 NE 1/4: The most geologically informative exploration in the NE¼ NE¼ is hole 3504, drilled by the M. A. Hanna Company. The hole, inclined 83° E., is 417 feet deep and passes through mostly graphitic slate; with graphitic slate breccia (the marker bed in the Wauseca Pyritic Member of the Dunn Creek Slate) from 248 to 267 feet. Hole 3505, drilled to the west, establishes the position of the boundary between the Dunn Creek Slate and younger partly oxidized Riverton Iron-Formation to the west. The core from these drill holes is stored at the Rogers mine, Iron River, Michigan.

An adjacent hole, designated B1, was presumably drilled

by the Brule Mining Company. The record states that black slate is present.

The Cleveland-Cliffs Iron Company explored the southern part of the NE¼ NE¼ by drill holes C14 to C17, which range in depth from 35 to 108 feet. These holes were drilled in 1909, and the abbreviated cores were examined at Ishpeming. The holes cut graphitic slate or iron-formation. Hole C18, in the northern part of this area, is 215 feet deep and penetrates oxidized iron-formation.

SE 1/4 NE 1/4: Eleven C-series holes were drilled in the SE¼ NE¼ by the Cleveland-Cliffs Iron Company in 1908-09. Nine are between 500 and 1,000 feet deep; two are 89 and 270 feet deep. Abbreviated cores and records examined at Ishpeming show mainly oxidized Riverton Iron-Formation with locally some ore. Two holes also show other types of rock present. Hole C24 was drilled vertically; it is in sideritic slate to a depth of 71 feet and then penetrates graywacke-chert breccia of the Hiawatha Graywacke, indicating the syncline of Hiawatha Graywacke to the east is overturned. The hole continues in oxidized iron-formation breccia to a total depth of 566 feet. Hole C27, inclined 57° E., passes through a little graywacke-chert breccia and then mostly oxidized iron-formation breccia to a drilled depth of 573 feet. Below this depth it is in oxidized graywacke with locally some chert breccia to the end at 780 feet; probably it intersects a small unmapped infold of Hiawatha Graywacke.

The M. A. Hanna Company drilled hole 3503 in 1928. The hole is inclined 60° E. and passes through oxidized iron-formation breccia to a drilled depth of 114 feet, through oxidized slate and graywacke (Hiawatha ?) to 270 feet, and ends in 15 feet of greenish-gray slate that probably is part of the Riverton Iron-Formation.

Holes B16 and B17 were drilled in 1918 by the Brule Mining Company and are inclined 60° E. Both holes enter oxidized iron-formation at the bedrock surface, pass through oxidized graywacke and partly oxidized slate, and end in graywacke at their respective drilled depths of 285 and 260 feet.

Holes 01 and 02 are old holes drilled by the Oliver Iron Mining Company and apparently are in iron-formation.

Eight holes were drilled in this area from the Chatham mine workings. The cores were not located, but the records appear to be reliable and contain some of the most detailed information available for old explorations. The data further substantiate the abundance of iron-formation and some iron-formation breccia in this area and the occurrence of graywacke east of the iron-formation. The drill records also apparently indicate that the ore passes downdip into unoxidized iron-formation.

NW 1/4 NE 1/4: Holes C6-C8 were drilled from the surface in the NW¼ NE¼ as part of the exploration of the Wickwire mine; abbreviated core stored at the Rogers mine was examined. Holes C6 and C8, inclined 70° SE., are 940 feet and 840 feet deep; C7 was drilled vertically to a depth of 650 feet. Much of the rock cut in the three holes consists of chert fragments in a hematitic matrix, but the material does not have the normal appearance of oxidized iron-formation and may originally have been a slate with chert fragments. As for similar material from holes drilled underground, the stratigraphic position is not certain but believed to be in the lower part of the Riverton Iron-Formation.

Two holes were drilled by the Cleveland-Cliffs Iron Company in 1909 in the northeastern part of the NW¼ NE¼; abbreviated core is stored at Ishpeming. Hole C26, inclined 53° E., was drilled 200 feet in oxidized iron-formation. Hole C28 was drilled vertically from the same location as C26 to a depth of 351 feet; the first 60 feet are in oxidized iron-formation and the rest is in ferruginous and black slate with some interbedded chert, probably part of the Dunn Creek Slate.

Another 28 vertical drill holes (C40-C128) and test pits in the NW¼ NE¼ were explorations by the Cleveland-Cliffs Iron Company at an undetermined date. Bedrock in the eastern and northern parts of the tract is penetrated for distances ranging mostly from 1 foot to 10 feet but to as much as 80 feet in a few places. Most of the available information is recorded on the map.

The M. A. Hanna Company drilled holes in 1925 and 1926 to explore the NW¼ NE¼. Core is stored at the Rogers mine. Holes A110-A113 are vertical and are not more than 60 feet deep. Holes A101, A102, A114, and A115 are angle holes drilled to depths of 755 to 1,140 feet. Graphitic slate, the uppermost bedrock, is penetrated by each of these holes for at least 235 feet and, except at hole A114, contains chert fragments. Beyond drilled depths of 360 feet the holes pass through 50 to 470 feet of oxidized iron-formation. Material below the iron-formation is graphitic slate, red and gray slate, or possibly some oxidized siltstone. Strata at the bedrock surface of this drilled area are probably the lower part of the Riverton Iron-Formation; and the local structure is interpreted as a southward-plunging syncline, possibly overturned to the east.

SW 1/4 NE 1/4: The M. A. Hanna Company explored the northern part of the SW¼ NE¼ in 1926 by seven shallow holes, H103 to H109. The materials in the cores, which are at the Rogers mine, are graphitic slate-chert breccia, gray slate, and unoxidized iron-formation. This association of lithologies is believed to establish the position of the lower part of the Riverton Iron-Formation in this area.

Two holes were drilled in the southeastern part of this tract during the explorations by the Cleveland-Cliffs Iron Company in 1908. Hole C7 is 74 feet deep and in sideritic slate that is probably from the unoxidized Riverton Iron-Formation . Hole C11 is in oxidized iron-formation to a depth of 555 feet and in slate to the bottom at 570 feet. Greatly abbreviated core is stored at Ishpeming.

Two holes drilled in 1903 are believed to have been explorations by the Verona Mining Company and have

been designated as V1 and V2. Most of the available information is recorded on the map.

NW 1/4: The NW¼ has been explored by only a few drill holes. Some iron-formation was penetrated and is mostly unoxidized.

Holes A1-A6 of undetermined date and origin were drilled in the northeastern part of the SE¼ NW¼. Hole A4 is 465 feet deep, hole A6 is 200 feet deep, but the others are each less than 75 feet. A small amount of core is stored at the Rogers mine. Presumably, the drilling was stratigraphically in rock near the upper contact of the Riverton Iron-Formation, as suggested by the presence of some massive graywacke, unoxidized iron-formation breccia, sideritic slate, and graphitic slate with a little chert as beds, nodules and fragments.

Two holes in the SW¼ NW¼ were drilled by the M. A. Hanna Company in 1949-50. Hole B1-49 is inclined 50°, is directed S. 20° E., and goes to 187 feet in gray slate and graphitic pyritic slate (Dunn Creek Slate). The rest of the total depth of 413 feet is unoxidized Riverton Iron-Formation. Hole B1-50 is directed N. 20° W. and is inclined 70°. The uppermost 20 feet of bedrock is graphitic and sideritic slates, with chert nodules and fragments, probably the uppermost part of the Riverton. The hole continues in unoxidized iron-formation to 440 feet, except for a zone of mixed slate, vein quartz, and pyrite at 245-300 feet. From 440 feet to the end at 478 feet is sheared laminated graphitic slate (Wauseca Pyritic Member). Hole B1-50 begins in strata in the upper part of the Riverton Iron-Formation and was drilled through the iron-formation into the Dunn Creek Slate.

Holes C2-C4 in the SW¼ NW¼ were drilled by the Cleveland-Cliffs Iron Company in 1908. The holes range in depth from 99 to 135 feet. Abbreviated core at Ishpeming consists of graywacke or fine siltstone and some sericitic gray slate. These materials are believed to be part of the Dunn Creek Slate, below the Wauseca Pyritic Member.

The Soderman exploration consists of holes N1-N5 near the center of the quarter-section. Date of drilling, depth to bedrock, and depths are not available. Holes N2 and N5, reported to be in soft ore jasper and jasper, presumably are in the northeasterly continuation of the Riverton Iron-Formation penetrated by holes to the southwest.

NE 1/4 SE 1/4: Hole 3501 was drilled 774 feet deep by the M. A. Hanna Company in 1928 and is the only hole known to have been drilled from the surface in the NE¼ SE¼. The core stored at the Rogers mine is mostly massive graywacke to 590 feet, and the rest is mostly gray-green slate and graphitic slate. These materials are part of the Hiawatha Graywacke, and exposures of similar rock are along the railroad and along a trench about 300 feet south of the hole.

NW 1/4 SE 1/4: Two holes were drilled from the surface in the NW¼ SE¼ by the Cleveland-Cliffs Iron Company in 1909. Hole C8 is 325 feet deep, and hole C10 is 50 feet deep; both are partly in graywacke-chert breccia of the Hiawatha and partly in gray to graphitic slate which probably is a local lithologic variation of the upper part of the Riverton.

The crestline of the prominent magnetic anomaly in the NE¼ SE¼ continues westward between drill holes C8 and C10 in the NW¼ SE¼. The bedrock is nonmagnetic Hiawatha Graywacke, but Stambaugh Formation has been cut 3,100 feet below the surface in a drill hole 550 feet north of Hiawatha No. 1 shaft.

SW 1/4: Holes S1-S8 drilled in 1913 comprise the Selden exploration. Hole S6 is 202 feet deep, and the other holes range in depth from 418 to 1,001 feet. Most of the drilling was in oxidized or partly oxidized graywacke, slate, and graywacke-chert breccia. These materials are characteristic of the Hiawatha Graywacke; no data, however, for further interpretation of geologic structure were recognized. A shaft (plate 2) in the NE¼ SW¼ is referred to as the Selden No. 3, or the Arlington on old mining company maps, but no other information is available.

Holes C21, C22, and C23, drilled in 1909 by the Cleveland-Cliffs Iron Company range in depth from 106 to 466 feet; abbreviated core is stored at Ishpeming. The holes cut sideritic and hematitic varieties of the Hiawatha Graywacke.

Hole 3502 was drilled by the M. A. Hanna Company in 1928, and core is stored at the Rogers mine. The hole was drilled southeastward at an inclination of 55° to a depth of 194 feet in oxidized Hiawatha Graywacke. Hole B2-49 was drilled by the same company in 1949. The hole is inclined 70° NW. and was drilled 420 feet. Unoxidized Riverton Iron-Formation extends from bedrock surface to drilled depth of 250 feet; the remainder of the hole is unoxidized iron-formation breccia.

The presence of low but distinct magnetic anomalies in the N½ SW¼ suggest possible shallow synclines containing magnetic Stambaugh Formation.

Town 42 North, Range 35 West

Section 2

NE 1/4: Drill holes D1-D9 are designated as the Duff exploration in this report; driller and date of drilling are not known. The holes range in depth from 650 feet to 1,228 feet; five are in excess of 1,000 feet. The material from most of them is recorded as slate or gray slate. Hole D4 in the NE¼ NE¼ was inclined 70° SE., and reportedly passed through iron-formation from the bedrock surface to a drilled depth of 840 feet, and then penetrated about 380 feet of footwall slate to the bottom of the hole. Analysis of the iron-formation showed 23-47 percent iron. Hole D6, 400 feet north of D4 and also inclined 70° SE., was reported in gray slate from bedrock surface to a drilled depth of 940 feet, in iron-bearing formation to 1,110 feet, and then in black slate to the

bottom of the hole at 1,154 feet. The iron-bearing formation from 1,035 to 1,110 feet was reported to contain from 24 to 54 percent iron.

Holes 01, 02, and 05, drilled about 1912 for the Oliver Iron Company, are reported only to have entered black slate.

Churn holes H1-H10 were drilled by the M. A. Hanna Company in 1949 along the west edge of the NE¼. The deepest hole went 110 feet below the surface, but five holes did not exceed 25 feet in depth. The drill cuttings were stored at the Rogers mine and were examined in July 1949. Hole H1 is in unoxidized iron-formation, and hole H3 is in graywacke that is probably part of the Hiawatha Graywacke as indicated by test pits in the adjacent corner of the NE¼ NW¼. The other holes are mainly in gray, green, or black slates, and some graywacke. These materials are probably from the Dunn Creek Slate.

NW 1/4: The NW¼ has been explored by two groups of test pits in the N½ NW¼ and three drill holes from the surface in the SW¼ NW¼.

The name and date of the explorations by test pits have not been determined. The material from three test pits in the northeast corner of the NE¼ NW¼ is interbedded siderite and chert believed to be unoxidized Riverton Iron-Formation; three pits reveal graywacke and chert fragments, and seven others are in graywacke in which no chert fragments were seen. These data determine the boundary between the Riverton Iron-Formation and Hiawatha Graywacke as shown on plate 2.

In the northwest corner of the NW¼ NW¼ one test pit was reported to have been in iron-formation and the other in slate, assumed to be a slaty part of the iron-formation.

The N½ NW¼ sec. 2 was explored to a depth of about 1,000 feet by five holes drilled southward from the 9th-level workings of the Hiawatha No. 1 mine in the southern part of sec. 35, T. 43 N., R. 35 W. In 1947, a hole drilled about horizontally southward through the W½ NE¼ NW¼ sec. 2, crossed a syncline containing Hiawatha Graywacke flanked on the south by iron-formation, beyond which are slate and graywacke of the Dunn Creek Slate. A hole drilled in 1948 about horizontally southward for 850 feet into the E½ NW¼ NW¼ penetrates Hiawatha Graywacke for 340 feet, unoxidized Riverton Iron-Formation for 170 feet, and Dunn Creek Slate to its end at 340 feet. A horizontal hole and two holes inclined 55° southward were drilled into the northwestern part of the NW¼ NW¼ and penetrate the Riverton Iron-Formation and some Dunn Creek Slate. The underground drilling, therefore, shows that at a depth of 1,000 feet the Riverton Iron-Formation continues across the northern part of this tract. At the surface, however, the iron-formation has been cut out by movement on the Duff fault.

The Hunter exploration consists of three holes (T1-T3) drilled in 1913 in the SW¼ NW¼ sec. 2. No core was located. One hole 50 feet deep and another of unknown depth are reported to have been in gray slate, which is probably part of the Dunn Creek Slate. The third one is reported to have been drilled 700 feet in greenrock probably part of the Badwater Greenstone.

Section 3

NE 1/4: The Edlund property in the NE¼ was explored in about 1907-8 by the Munro Iron Mining Company, and levels were opened from a shaft at depths of 157 feet and 253 feet. The area was further explored by two drill holes inclined northward from the 2nd level. According to a map and section, at the 2nd level, ore formation containing 27 to 37 percent iron extends from 20 feet south of the shaft northward for 290 feet; the north limit is, therefore, 80 feet within sec. 34. Dips are predominantly southward at 60°-80°. A smaller area of reported formation from 100 to 160 feet south of the shaft dips about 80° S. Both areas of iron-formation are reportedly underlain and overlain by black slate.

Hole E1, east of the Edlund shaft, which was drilled in 1949 for M. A. Hanna Company, is inclined 65° approximately northward and is 832 feet long. The unoxidized Riverton Iron-Formation penetrated from a drilled depth of 148-510 feet is overlain by Hiawatha Graywacke and is underlain by Dunn Creek Slate, including the diagnostic slate breccia of the Wauseca Pyrite Member. Drill holes from the west end of the 9th level of the Hiawatha mine workings entered the northeastern part of sec. 3 and also penetrated the Riverton Iron-Formation and Dunn Creek Slate; the structure is defined as the west end of the Hiawatha syncline.

Holes B1-B4 in the NW¼ NE¼ are the Borsback exploration and were drilled in 1909. The depths of the holes range from 148 to 253 feet. Two holes were recorded to have been in black slate, one in green slate, and one in chlorite slate. The stratigraphic position of these slates is not known; they are probably older, however, than the iron-formation.

The Holland and Jarchow exploration consists of short holes J1-J6 in the S½ NE¼. Drilling data is not known. The records describe only the material present at the bedrock surface; the type of material determined the depth of the holes. Two holes were reported to have been in green slate, two others in green and black slate, one in siderite, and one in cherty siderite. Stratigraphic interpretation is in doubt, but these materials are probably part of, or closely related to, the greenstone discussed next.

Holes H19 and H20 were explorations in 1950 for the M. A. Hanna Company. Diamond drill hole H19 is 325 feet deep; churn drill hole H20 is 180 feet deep. The core and chop-pings are stored at the Rogers mine. Hole H19 is in sheared and kaolinized greenstone containing veinlets of calcite and quartz. Some gray to black slate in the core is well bedded and nongraphitic. The choppings from hole H20 are mostly greenstone similar

to that in hole H19. The greenstone and associated slate are undoubtedly a part of the sequence in the Badwater Greenstone exposed to the south.

NW 1/4: Drill holes B14-B17 in the NW¼ NW¼ comprise the Holmes exploration done by the Brule Mining Company in 1927; core is stored at the Caspian mine. The holes range in depth from 170 to 207 feet and penetrate from 12 to 50 feet of bedrock that is gray slate and some red and brown slate.

The Erickson exploration in the W consisted of two drill holes by the M. A. Hanna Company; core is stored at the Rogers mine. Hole H1 is 780 feet deep and is in sericitic gray slate (Dunn Creek Slate), except for altered dike material at drilled depth of 715-735 feet. Hole H2, which is inclined 55° N. and is 841 feet deep is reported to have penetrated mainly greenstone (dike rock ?) and a small amount of associated slate.

Section 4

The Gleason exploration (possibly the same as the Wakefield exploration) was the series of diamond drill holes W7-W10 in the NW¼ NE¼ and G1-G6 in the E½ NW¼. The date and sponsor of the exploration have not been determined. Most of the holes are inclined 70° N.; their drilled depths range from 128 to 564 feet, and six are less than 300 feet. The holes penetrate from 103 to 539 feet of bedrock reported mostly as gray slate; but stratigraphic classification is in doubt. Holes G2 and G5, however, are believed to be in the Dunn Creek Slate. Iron-formation reported to be in holes W7 and W9 may be part of the Riverton, and the other holes reported in slate may be in slaty parts of the Riverton.

The earlier of two explorations in the northern part of the NW¼ NW¼ sec. 4 consisted of diamond drill holes 16, 17, I10-I13, part of the Blake exploration, which also included drill holes in the adjacent part of sec. 33. Hole I12 is not shown on the map because 402, a later hole from which core was examined, is at approximately the same location. The holes were drilled in 1912 and range in depth from 94 to 454 feet. The amount of bedrock penetrated ranges from 84 to 430 feet. Each hole is reported to have passed through ore or lean ore, and the associated material is predominantly gray slate, which contains some quartz, chert, or jasper. The iron content of much of the analyzed material is in excess of 30 percent, and in several samples is more than 50 percent.

Holes 401-403, drilled in 1928 by the M. A. Hanna Company in the NW¼ NW¼ constitute the Stanley Lake exploration, also known as the D & M exploration. The holes were drilled northerly at angles of 50°-55° and to depths of 640, 221, and 244 feet. Hole 401 is in unoxidized iron-formation (banded siderite and sideritic slate with interbedded gray chert and gray slate) for which the over-all average iron content was about 24 percent. Samples from the other holes are similar material, except where locally oxidized. The iron-formation near the bottom of hole 403 contains some chert fragments and consequently may be the upper part of the formation.

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