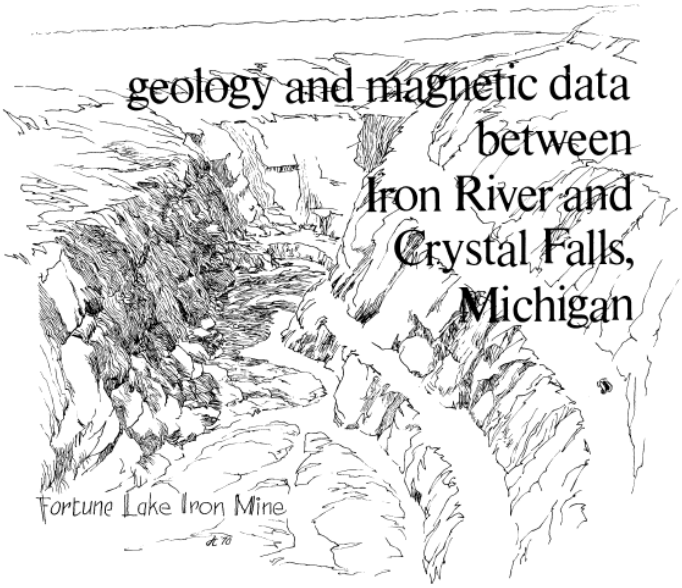

Front cover illustration:

Fortune Lake iron mine west of Crystal Falls. Operated between 1953 and 1958, it produced about 1,300,000 tons of ore. The pit was 1800 feet long, 800 feet wide, and 300 feet deep. (sketched by Jim Campbell from a photo by R. C. Reed)

STATE OF MICHIGAN DEPARTMENT OF NATURAL RESOURCES GEOLOGICAL SURVEY DIVISION

Report of Investigation 7

GEOLOGY AND MAGNETIC DATA BETWEEN IRON RIVER AND CRYSTAL FALLS, MICHIGAN

by

H. L. James, F. J. Pettijohn, and L. D. Clark

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

Lansing, 1970

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PREFACE

The purpose of this report, fifth 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 investigation 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 Professional Paper 570, published in 1968 by the U.S. Geological Survey.

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 authors gratefully acknowledge the friendly cooperation of officials and employees of The Cleveland-Cliffs Iron Co., the M. A. Hanna Co., Pickands Mather & Co., the Republic Steel Corp., the Mineral Mining Co., the Inland Steel Co., the North Range Mining Co., the Jones & Laughlin Steel Corp., and the Pittsburgh Coke and Iron Co.

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

And drill-hole and magnetic-survey data are shown on four geologic maps. A brief history of the mines and a description of known explorations are given.

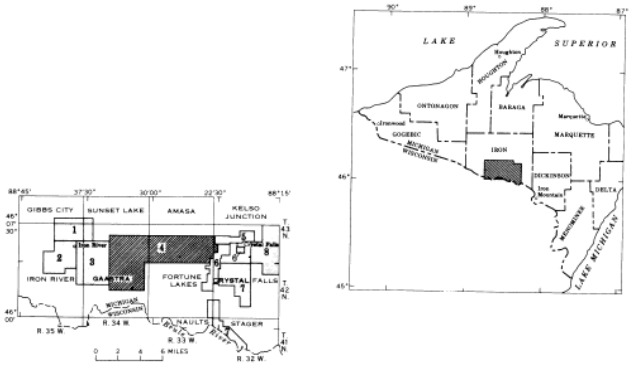

Figure 1. Location and index maps

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

1. Northern Iron River Area -- James, Dutton, and Wier

2. Central Iron River Area -- Dutton

3. Southeastern Iron River Area -- James and Wier

4. Shading delineates area of this report, 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.

Washington, D.C. Baltimore, Maryland Menlo Park, California July, 1967

ABSTRACT

H. L. James F. J. Pettijohn L. D. Clark *Geologists, U.S.G.S.*

INTRODUCTION

This report is one of the 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 The area between Iron River and Crystal Falls covers about 42 square miles and lies mainly along the northern part of the Iron River-Crystal Falls basin. The area is underlain by folded strata of the Animikie Series which, from oldest to youngest, include the Badwater Greenstone of the Baraga Group and the Dunn Creek Slate, Riverton Iron-formation, Hiawatha Graywacke, Stambaugh Formation, and Fortune Lakes Slate of the Paint River Group. Minor stocklike masses and dikes of metagabbro and metadiabase are locally present.

Glacial cover is extensive; and structural elements, especially toward the deeper part of the basin, are inferred chiefly from the magnetic anomalies caused by the magnetic Stambaugh Formation. Several faults, subparallel to the regional eastward trend of the rock units, occur along the north margin of the basin. Much of the Riverton Iron-formation is unoxidized, and iron ore shipments, from only two mines, totaled about 2,500,000 tons. Areas of outcrop, partial extent of mine workings, 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 area have been presented as a preliminary report by James, Clark, and Smith (1947).

The study area is covered by four geologic and magnetic data sheets: Round Lake (plate 1), Wagner Creek (plate 2), Chicagon Creek (plate 3), and Fortune Lakes (plate 4). The stratigraphic succession of rock units is shown in table 1.

Precambrian	Middle Precambrian	metagabbro and metadiabase ----------Intrusive contact----------		
		Animikie Series	Paint River Group	Fortune Lakes Slate
				Stambaugh Formation
				Hiawatha Graywacke
				---minor unconformity--- Riverton Iron-formation
				Dunn Creek Slate
			Baraga Group	Badwater Greenstone

Table 1. Rock units in area between Iron River and Crystal Falls

ROUND LAKE AREA

The Round Lake area (plate 1), located about 5 miles east of Iron River, comprises 7½ square miles near the west end and on the north flank of the Iron River-Crystal Falls basin. The map area includes parts of secs. 21, 22, and 23, and all of secs. 26, 27, 28, 33, 34, and 35 in T43N, R34W. Like most of the western part of the district, bedrock is deeply mantled; one drill hole in the NE¼ SE¼ sec. 21, penetrated 488 feet of glacial cover before

reaching bedrock. Only one outcrop, in the NE¼ NE¼ sec. 35, is known, although in many places along the east margin of the area, bedrock is within 20 feet of the surface and explored by test pits.

About two-thirds of the Round Lake area was surveyed magnetically at 100-foot intervals along lines 200-400 feet apart; and except for sec. 34, reconnaissance traverses were made over the remainder. The west half of sec. 33 and the S½ SW¼ sec. 28 were surveyed with a Hotchkiss Superdip oriented E-W with a sigma setting of 1½°. The SE¼ sec. 23, the east tier of "forties" in sec. 26, and most of sec. 35 were surveyed with a Superdip oriented N-S with a sigma setting 3½°. The remaining and largest part of the area was surveyed with an Askania vertical-component magnetometer. The instrument readings obtained with the N-S oriented Superdip cannot be converted accurately to gamma values, so the magnetic contours in the eastern part of the mapped area are based on instrument units rather than gammas.

Geology

The main structural elements of the area are established on the basis of the magnetic anomalies caused by the Stambaugh Formation. In general, the area is underlain by strata progressively younger to the south, giving rise to a belt-like pattern. In the western part of the map area, the Stambaugh Formation (and adjacent units) swings in an arcuate belt convex to the northwest. A short distance north of this arc is a persistent syncline along whose axis the Stambaugh Formation occurs as canoe-shaped bodies due to plunge reversals. This structure is illustrated in figure 2.

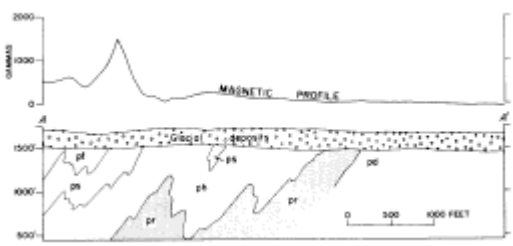

Figure 2. Magnetic profile and inferred geologic structure along west side of sec. 27, T43N, R34W, cross section A-A' (plate 1). Riverton Iron-formation (pr), underlain by Dunn Creek Slate (pd), and overlain successively by Hiawatha Graywacke (ph), Stambaugh Formation (ps), and Fortune Lakes Slate (pf).

The eastern third of the map area, which includes the Chicagon mine, is structurally most complex because of the westward-jutting elbow of Badwater Greenstone half a mile to the east. The Stambaugh Formation, forming a limb on the north flank of the Iron River-Crystal Falls basin, enters the mapped area from the east and trends northwest. In the south part of sec. 26, it is tightly folded in. a pair of southeast-plunging anticlines and synclines clearly outlined by magnetic contours. To the north, in the NE¼ sec. 26, the Stambaugh is contained in a faulted outlying syncline generally trending subparallel to the greenstone elbow to the east.

The Riverton Iron-formation crosses the map area in a fold belt about half a mile wide and has been fairly extensively explored by drilling. The Chicagon mine in the extreme eastern part of the area, however, is the only place where ore has been mined.

In the Round Lake area - or at least its eastern part - the thickness of the Hiawatha Graywacke changes markedly. East of the Chicagon mine, the formation is thin, commonly 50 feet or less; west of the mine it thickens rapidly to 200 feet or more.

Mines

The Chicagon mine is in sec. 26, T43N, R34W, about halfway between Crystal Falls and Iron River. The shaft is in the NW¼ NE¼. The mine was opened in 1909 by the Munro Iron Mining Co., and in the period 1911-22,

1,234,339 tons of ore were shipped. The ore was a red, non-bessemer hematite, some of which was manganiferous. The mine closed in 1922. At the time of our investigation it was held by the M. A. Hanna Co. Although the workings were inaccessible at that time, a study of the company maps and an investigation of rock on the mine dump gave a fair idea of the geology and occurrence of ore.

The mine, initially an open pit, was developed to a depth of 1,080 feet. Six main levels (2, 3, 5, 7, 9, and 10) were driven along a northwest-trending tract (about 2,400 feet long and 600 feet wide) centering approximately on the shaft. The plan of the 5th level, the most extensive of those driven, is shown on figure 3, together with a cross section showing the inferred structure.

The ore, located in a belt of iron-formation striking northwest and dipping steeply southwest, formed an irregular blanket on or near the footwall contact. Individual shoots, (fig. 3A) are lenslike in horizontal section but coalesce or diverge irregularly downdip.

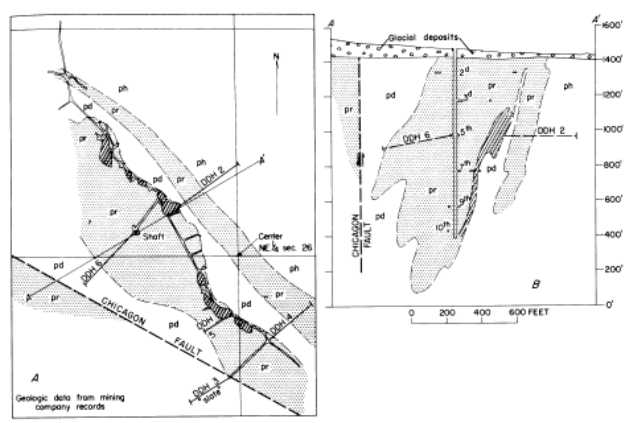

Figure 3. Chicagon mine. Riverton Iron-formation (pr), overlain by Hiawatha Graywacke (ph), and underlain by Dunn Creek

Slate (pd). Diamond drill holes (DDH), dashed where projected. Mined ore bodies shown by diagonal pattern.

Very little development or drilling was done except in the ore-bearing belt, therefore, the structure is incompletely known. Furthermore, all material encountered other than iron-formation is described as black slate on the mine maps. Careful examination of the mine dump shows the following rock types, in order of abundance:

1) oxidized iron-formation (banded chert and red hematite), 2) graphitic, pyritic slate, 3) graywacke and reddish slate (some of the graywacke contains chert fragments) and, 4) magnetic slate (very rare).

The graphitic slate is almost certainly the same as that which underlies the Riverton Iron-formation elsewhere in the district. The abundance of this slate would appear to indicate it forms the structural footwall in the Chicagon mine. The graywacke is assigned to the strata stratigraphically above the iron-formation - that is, to the Hiawatha Graywacke. So far as could be determined from examination of the mine maps, this amount of graywacke could have come only from the most northwestern workings on the 5th level. The magnetic slate (Stambaugh Formation) lies stratigraphically above the graywacke. The only workings entering an area of magnetic anomaly is the most southern crosscut on the 5th level.

On the basis of other evidence, a fault had been inferred to separate the Riverton Iron-formation from the area of magnetic slate south of the mine. The authors believe that the southern crosscut passed through the fault and that the magnetic slate found on the mine dump came from the most southwestern part of the crosscut.

As shown in cross section of figure 3, a drill hole to the northeast passed successively through black slate, iron-formation, and black slate. The last part of the drill hole is virtually beneath an area known from surface data to be underlain by rocks stratigraphically above the iron-formation. The authors assume, therefore, that the structure crossed by the drill hole is a northwest-trending anticline overturned to the northeast. The width of the northeastern belt of iron-formation drilled is less than that normal for this unit, as is the width encountered in the northern part of the 5th-level workings across the apparent projection of the belt. However, the contact with the overlying graywacke is an unconformity. The thinning of the unit, therefore, is assumed to be caused by erosion after deposition of iron-formation.

The structure southwest of the shaft can only be surmised. The thickness of the belt of iron-formation in the shaft area seems much too great to represent a true stratigraphic section. We assume, therefore, the slate encountered in drill hole 6 (drilled southwest from the shaft station on the 5th level) is stratigraphically below the iron-formation and that the iron-formation forms a tight, overturned syncline.

Some of the ore shipped from the Chicagon mine was manganiferous. Elsewhere in the Iron River-Crystal Falls district, the economically important manganese mineral is hausmannite, but this mineral was not located on the Chicagon mine dump. Two rare manganese minerals have been described from materials collected on the dump, seamanite, a hydrated borophosphate of manganese, is known only from this locality (Kraus, Seaman, and Slawson, 1930), and sussexite, an iron-manganese borate, was reported later (Slawson, 1934) as associated with the seamanite. Sussexite since has been found in the Bengal-Cannon mine in the western part of the district. Neotocite, an amorphous hydrated manganese silicate, has been observed in drill core immediately west of the mine area.

Explorations

Town 43 North, Range 34 West

PIECE 21

Despite a rather considerable amount of drilling in this section, the geology is very poorly known except in its southwestern part. A broad, domelike magnetic anomaly of slightly more than 1,000 gammas has been mapped in the southeastern part of the section and adjoining parts

of sec. 28 to the south. A number of holes on the west flank of this anomaly in sec. 21 are in fine- to medium-grained nonmagnetic greenstone not significantly different from known extrusive greenstone in the district. Nevertheless, several drill holes in the adjoining parts of sec. 28 cut similar material, clearly dikes or sills (see fig. 4).

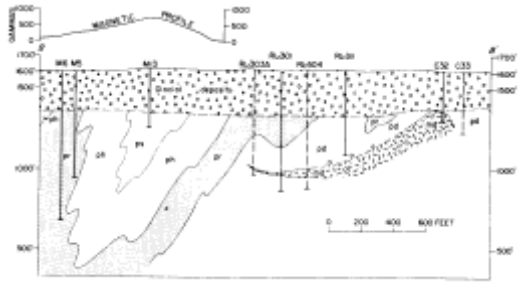

Figure 4. Inferred geologic structure and partial magnetic profile along cross section B-B' (pl. 1) through northwestern part of sec. 28 and adjoining parts of sec. 21, T43N, R34W. Riverton Iron-formation (pr), underlain by Dunn Creek Slate (pd) that is cut by metadiabase (md), and overlain successively by Hiawatha Graywacke (ph) and Stambaugh Formation (ps). Drill holes more than 50 feet from line of section shown as projected (dashed in section).

Elsewhere in the district, metadiabase is known to yield moderate positive anomalies. The authors conclude, therefore, that the anomaly is caused by a stocklike mass of metadiabase or metagabbro, that the drilled greenstone in the SE¼ SW¼ sec. 21 is at or near the west margin of the intrusive, and that the intrusive rock shown in the central part of figure 4 is an apophysis from the larger mass.

Except for two holes in the SE¼ SE¼, K1 and K2, and reported merely as encountering rock (hardly an illuminating bit of information), the only drilling in sec. 21 is

the "Bates exploration" done by The Cleveland-Cliffs Iron Co. in 1909-1913. During this period of time about 40 holes (C-series) were drilled, of which holes C5, C7, C11, and C13 are in the northern part of the section, outside the area of plate 1. Samples from some of the core were examined at the Cleveland-Cliffs offices in Ishpeming, Mich., but most of the descriptions are from company records. A few of the holes in the S½ SW¼ were drilled to considerable depth (C36 was drilled to 1,609 feet), but most are shallow and enter bedrock less than one hundred feet. The "overburden" is remarkably thick in places; near the center of the SE¼, hole C27 cut 488 feet before being ledged.

The only holes of economic interest are those in the SW¼ SW¼, known as the Erickson lease and now held by the M. A. Hanna Co. These holes (C1, C2, C3, C10, C17, C19, C22, C24, C25) are drilled in oxidized iron- formation and ore situated in a west-plunging syncline of moderate depth. The east edge of this syncline is projected on the northeast part of cross section B-B' (fig. 4), between holes R311 and C32. Most of the holes were drilled to depths in excess of 500 feet and at depth were in slate or graywacke (Dunn Creek Slate). In cooperation with the U.S. Geological Survey and the M. A. Hanna Co., a detailed gravity survey was made of this area (Bacon and Wyble, 1952) to determine the effect of a known, near-surface body of ore. Bouguer gravity shows a strong consistent regional increase south.

Subtracting this regional gradient, the residual gravity shows a slight positive gravity anomaly in the vicinity of drill hole C3, but the pattern is inconclusive; certainly the presence of an ore body would not have been inferred without prior knowledge from drilling.

Of the holes in the SE¼ SW¼, most either entered "greenstone" at ledge or cut greenstone after ledging in slate. The most southwesterly, C36, was drilled to a depth of 1,609 feet, mostly in an alternating gray, ferruginous, and graphitic slate, with greenstone reported from 350 feet to 440 feet. In cross section (fig. 4) this hole would be structurally a short distance southwest of hole C32; apparently the metadiabase body shown is a 90-foot thick sill at C36.

Little can be added to the map descriptions of the holes in the northern part of the S½ sec. 21. Most holes penetrate bedrock only a few tens of feet. The bedrock in the area is designated Paint River Group undivided, but probably most or all of the rock is part of the Dunn Creek Slate.

SECTION 22

Data are entirely insufficient to permit satisfactory geologic analysis in this section. Eleven drill holes (including 5 on the bounding section lines) are known, showing an average depth of nearly 300 feet. The area lies on the north flank of the district, well north of the belts containing the magnetic Stambaugh Formation. As a result, the magnetic anomalies that elsewhere provide a means of geologic interpretation are completely absent.

The only exploration entirely within sec. 22 is the Peterson exploration consisting of 7 holes drilled in 1910 by Cleveland-Cliffs. Some were drilled from the bottoms of test pits sunk to or near the bedrock surface (a common practice because at that time day labor cost less than drilling). Some of these "test pits" were 200 feet deep!

The drill holes are shallow; the deepest entered bedrock only 61 feet. A few small pieces of core from each hole preserved by Cleveland-Cliffs at Ishpeming were examined. They serve to confirm the original lithologic descriptions but are inadequate for stratigraphic classification.

Holes P1 and P2 are in the NW¼ of the section, outside the area of plate 1. Hole P1 is 1,120 feet north, 1,320 feet east, of the W¼ cor. sec. 22; it cut chert, gray slate, and unoxidized carbonate. P2, 620 feet south of P1, was drilled 46 feet into bleached graywacke. The other holes, P3-P7, cut mostly graywacke, with some ferruginous slate.

SECTION 23

Seven shallow holes (C1-C7), the Krans-Gustafson exploration, penetrating bedrock to depths of 27 to 51 feet, were drilled in the SW¼ in 1911 by Cleveland- Cliffs. A small amount of core from holes C1, C2, and C4 was located and examined. Only one of the holes,

C2, encountered iron-formation (verified). In core the rock was entirely unoxidized. Three others, C3, C5, and C7, cut what was reported as chert conglomerate. This presumably is the chert breccia typical of the lowermost part of the hanging-wall series. The material from hole C6 was described as coarse gray slate, but most likely is graywacke of the Hiawatha Graywacke. Hole C4 cut graphitic slate, perhaps the Dunn Creek Slate. Hole C1 encountered strongly sheared black slate. The North Chicagon fault would, if projected, cut close to this hole.

A group of 10 holes (K1-K10), the Krans exploration, were drilled in the SE¼ SW¼ and the SW¼ SE¼ sec. 23 by the Munro Iron Mining Co. in 1909-1910. None of the drill core could be located. The overburden is thick, ranging from 195 feet in hole K2, to 335 in hole K6. The depth of the holes ranges from 220 feet (hole K2) to 1,083 feet (hole K10).

According to the company records, holes K2, K5, K6, K7, and K9 and K10 encountered iron-formation, although the descriptions indicate more slate than normally present in this unit. The iron-formation seems to be fairly well oxidized, and one or two short runs of ore were noted. Holes K3 and K4 are in black slate, but the position of K4 with respect to the known area of magnetic slate to the southeast, as well as its relation to the inferred structure of the Chicagon mine (fig. 3), indicate it should be assigned to the Hiawatha Graywacke. Hole K1 reportedly cut black slate and quartzite. The rock probably is dark graywacke (Hiawatha). Hole K8 is reported in black slate north of the North Chicagon fault; stratigraphic position is unknown.

SECTION 26

As shown on plate 1, several test pits have been sunk in the SE¼ NE¼ sec. 26 (and adjacent parts of sec. 25). The date of the test pitting is uncertain but believed to be about 1910. These test pits define an almost complete

stratigraphic section for the district. From east to west the pits are in 1) graphitic pyritic slate (Wauseca Pyritic Member of the Dunn Creek Slate), 2) iron-formation (Riverton) consisting of banded chert and siderite partly altered to limonite, 3) graywacke and chert breccia (Hiawatha), and 4) magnetic sideritic slate (Stambaugh). A hole drilled at the east edge of the SE¼ NE¼ encountered black slate at a depth of 20 feet.

A major exploration in section 26 was carried out by Inland Steel Co. in 1952-53. The Campbell-Sherwood exploration, in the NW¼, consists of 31 holes (CS1-CS31), many of which were drilled to great depth. The Schriber and Wakefield explorations in the N½ SW¼ consist of 7 deep holes (S1-S4, W1-W3). The drill core was available for examination at the Sherwood mine, Iron River.

The drill holes have yielded much geologic information regarding the pattern and character of the stratigraphic units. The Riverton Iron-formation attains a thickness of nearly 400 feet -- considerably more than in the western end of the district. The lower hundred feet, however, contains much interbedded slate and chert breccia. The Hiawatha Graywacke, insofar as it has been cut by drill holes, consists mainly of green and red slate. The Riverton in most parts of the section is oxidized to a remarkable depth -- hole CS25 ends in well-oxidized iron-formation at 2,830 feet -- yet one hole (CS3) is in unoxidized rock at ledge surface.

A considerable number of holes are located at the westward extension of the iron-formation developed in the Chicagon mine. Hole CS14 is in oxidized iron- formation to the bottom at 1,103 feet, CS19 to 1,217 feet, CS21 to 753 feet, and CS24 to 672 feet. Hole CS 25, previously noted, is in oxidized iron-formation to the bottom at 2,830 feet. Veinlets of rhodochrosite were noted in CS25 at around 2,315 feet, and neotocite fillings at about 2,440 feet. Hole CS23 is in Riverton to 675 feet, then enters pyritic slate (Wauseca Pyritic Member of the Dunn Creek Slate); the hole probably is near the anticlinal axis immediately north of the ore bodies in the Chicagon mine (fig. 3).

Most of the remaining holes explore a syncline and associated structures centered in the S½ NW¼ sec. 26 (figure 5). A faulted anticline brings Dunn Creek Slate to bedrock surface between holes CS3 and CS7 -- the rock is cut in a drill hole a short distance west. The southward-dipping reverse fault is intersected in hole CS5. CS5 is in oxidized Riverton (slate and chert breccia near the base) to 562 feet, then passes into pyritic slate (Wauseca Pyritic Member) continuing to 723 feet. For several feet the hole is then in highly-sheared rock and vein quartz (fault zone), below which it cuts unoxidized Riverton Iron-formation on the underside of the reverse fault. Southeast of the intensively explored syncline is an inferred anticline (center of fig. 5) which results in an abnormally wide map pattern for the River- ton. Situated farther southeast are the steeply-dipping beds of the Hiawatha Graywacke, Stambaugh Slate (based on magnetic anomaly), and Fortune Lakes Slate.

The southeast-plunging anticline in the north and east part of the SW¼ sec. 26 is explored by holes S2, S3, S4, W1, W2, and W3. Hole W3, drilled to the east at 50°, begins in graywacke, slate, and chert (Hiawatha Graywacke) then enters oxidized Riverton Iron- formation. Holes S3 and S4, both drilled to the northeast at 50°, start in Riverton Iron-formation, as does hole W2 on the opposite flank of the anticline. Holes S3 and W2 both cut Dunn Creek Slate at depth, but S4 remains in iron-formation; apparently the fold is overturned to the southwest. The anticlinal axis appears to swing into a more westerly direction in the NW¼ SW¼, the evidence from hole S1 indicating the direction of overturn still having a strong southerly component. Hole S1, in oxidized slaty iron-formation for most of its length, passes into unoxidized cherty sideritic slate with some graywacke at about 1,000-foot depth; presumably this rock can be assigned to the Hiawatha Graywacke, here oveturned.

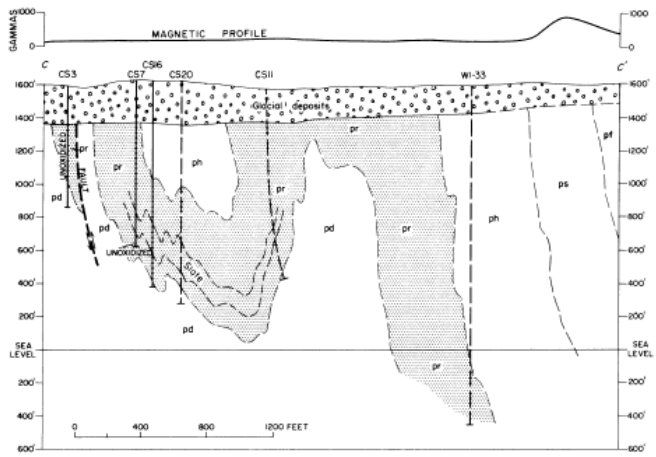

Figure 5. Magnetic profile and cross section C-C1 (plate 1), through drill holes in sec. 26, T43N, R34W. Riverton Iron-formation (pr) with slate unit indicated locally, underlain by Dunn Creek Slate (pd), and overlain successively by Hiawatha Graywacke (ph), Stambaugh Formation (ps), and Fortune Lakes Slate (pf). Iron-formation oxidized except where noted. Drill holes projected into section are shown dashed.

SECTION 27

The general structural trends in this section are easterly. The strong magnetic anomaly mapped in the southwestern part is assumed to reflect the presence of the Stambaugh Formation. This belt of Stambaugh is part of the north margin of the main basin and the anomaly produced can be traced, with some breaks, a- round much of the Iron River-Crystal Falls district. In the SE¼, the magnetic values rise steadily southward but the crest of the anomaly is not clearly defined. The absence of the typical sharp crest is unexplained. Perhaps it may be related to strong oxidation. Possibly the crest passes into the N½ NE¼ sec. 34, for which no magnetic data were obtained. The crest line is well defined again a short distance to the east in section 26.

A belt of low to moderate magnetic anomaly of west to southwest trend is situated in the N½ SW¼ sec. 27. The

anomaly dies out approximately in the center of the section. To the west it continues through sec. 28 into the area of the Rogers mine in sec. 29, and almost certainly, is caused by Stambaugh Formation contained in a narrow synclinal fold, the plunge of which varies thus increasing and decreasing the amount of magnetic rock and consequent anomalies. Between this syncline and the belt of Stambaugh Formation to the south the structure is anticlinal, and may locally expose the iron- formation at bedrock surface (plate 1).

The Holland (or Helgemo) exploration in the SE¼ NE¼ sec. 27 consists of 12 holes (D1-D3, H4-H12) drilled by the Cole 5 McDonald Exploration Co. from 1912-1914. Most of the holes are clustered in the eastern part of the "forty" and cut iron-formation and ore at the west end of the syncline noted earlier (fig. 5). None of the drill core was located and the available information from company records has largely been superseded by more recent and extensive exploration by Inland Steel Co. Inland Steel Co., in 1954 and 1955, drilled 25 holes in sec. 27. Most of them (I1-I23) are in the NE¼ on the Helgemo property; two (K1-K2) are in the S½ NW¼ on the Kapusta property. The drilling was done after the U.S. Geological Survey ceased its active work in the district. Some of the core, stored at the Sherwood mine, was examined later with Mr. John M. Ohlson, company geologist. Most of the following discussion is based on Ohlson's descriptions, with critical points verified by brief study of selected cores.

Four of the holes (I7, I21-I23) are in the N½ NE¼. All four holes cut rock assigned to the Dunn Creek Slate, although possibly the graphitic and sideritic slate containing chert nodules at ledge in hole I23 actually belongs to the basal part of the Riverton. Hole I21 also cuts metadiabase from 420 feet to 460 feet – possibly the metadiabase in an offshoot sill from the main body to the west.

A line of holes (I1-5) in the SE¼ NE¼, near the east margin of the section very clearly marks a synclinal fold, the keel of which is about 800 feet deep with respect to the Riverton Iron-formation. The same structure is cut at an angle by cross section D-D' (fig. 6) illustrating the geology disclosed by drilling to the west. Hole I17 (SW¼ NE¼) is of particular interest because it is in graywacke and slate with chert fragments in the upper part of the hole, and then cuts a full section of Riverton Iron-formation (oxidized) before passing into pyritic slate (Wauseca Pyritic Member, including the diagnostic slate breccia). The latter rock also is cut at ledge surface by holes I10 and I18 (SE¼ NE¼) on the crest of the anticline separating the two areas of Riverton.

Holes K1 and K2 in the S½ NW¼ were drilled to depths of more than 1,000 feet in Hiawatha Graywacke. K1, the more southerly of the two, is in graywacke containing fragments of chert and siderite to the bottom at 1,102 feet. K2 is in similar material in the upper part of the hole, then is in oxidized slate with a small amount of graywacke to 1,110 feet. From there to the bottom at 1,210 feet, the hole cuts varicolored slate with layers of hematite and fragments of chert -- possibly the uppermost part of the Riverton.

The Longyear exploration in the S½ NW¼ sec, 27 consists of 7 holes (L100-107) were drilled in 1914. None of the core could be located for examination.

Hole L101 (and L101-B, a deflection hole from the same location in SE¼ NW¼) reportedly entered ferruginous slate and chert after passing through 385 feet of overburden. Except for short runs characterized by graywacke, most of the rock is described as ferruginous slate. From the description the hole was probably drilled into either the lower part of the Hiawatha Graywacke or into an upper slaty part of the Riverton Iron-formation.

Among the holes near the west edge of the section, holes L102, L103, L104, and L107 are reported to have entered oxidized iron-formation at bedrock surface. Hole L105 reportedly cut graywacke and iron-formation, slate and graywacke and cherty graywacke and black slate to the bottom at 928 feet. Hole L106 cut graywacke. The rock in both holes is Hiawatha Graywacke. Therefore, the contact between the Hiawatha and the Riverton formations passes between holes L104 and L106. Hole L103, the most northerly of the group, probably entered the Wauseca Pyritic Member of the Dunn Creek Slate. Its simplified record is: of the core could be located for examination. Hole L101 (and L101-B, a deflection hole from the same location in SE¼ NW¼) reportedly entered ferruginous slate and chert after passing through 385 feet of overburden. Except for short runs characterized by graywacke, most of the rock is described as ferruginous slate. From the description the hole was probably drilled into either the lower part of the Hiawatha Graywacke or into an upper slaty part of the Riverton Iron-formation.

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Depth in feet	
0-246	Overburden
243-465	Oxidized iron-formation, lean ore and ore
465-505	Graphitic and ferruginous slate
505-535	Graphitic and gray slate

L104 is the deepest hole drilled, terminating in oxidized iron-formation at a depth of 1,220 feet.

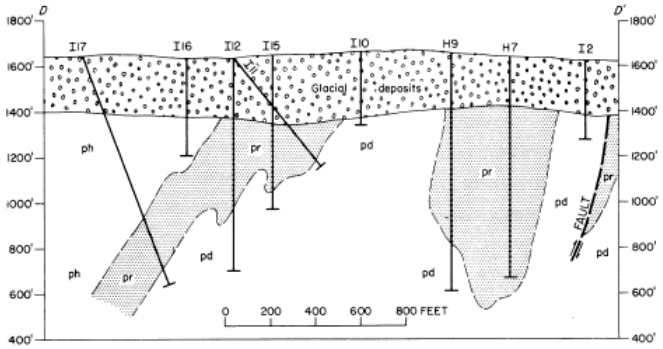

Figure 6. Cross section D-D' (plate 1), through drill holes in sec. 27, T43N, R34W. Riverton Iron-formation (pr), underlain by Dunn Creek Slate (pd), and overlain by Hiawatha Graywacke (ph).

SECTION 28

All drilling in this section is confined to the north half crossed by a northwest-trending belt of iron-formation. The southern part is marked by a magnetic anomaly related to the Stambaugh Formation. The Stambaugh occurs also in patches along the axis of a major syncline trending northwest through about the center of the section. The magnetic anomaly in the northeast part of the section is believed to be caused by a mass of metadiabase or metagabbro.

The Longyear exploration consists of six holes (L152, L154-L157, and L159) penetrating bedrock in the SE¼ NE¼, plus one hole (L151) in the SW¼ NW¼. Two other holes were stopped in the overburden. All these holes were drilled in 1910. None of the core could be located for examination, but the descriptions available seem reasonably satisfactory.

Two of the holes (L155 and L156) entered oxidized iron-formation at bedrock surface, but both passed into graywacke and slate that seem to belong to the hanging-wall series. The bedrock in the most northerly holes (L152-L154) is slate assigned to the Dunn Creek. The two most southerly drill holes (L157 and L159) cut cherty graywacke and cherty black slate. Almost certainly the rock is Hiawatha Graywacke. Hole L151 was drilled to a depth of 1,100 feet in ferruginous slate and black slate.

Thirteen holes (M1-M12, M14) were drilled by the Munro Iron Mining Co. in the NW¼ sec. 28. The date of drilling is not known, but probably it was in about 1912. None of the core could be located for examination, and the available descriptions are rather meager. Except for holes M3, M5, and M6, the holes penetrated less than 200 feet of bedrock. The overburden is fairly thick, drilled thicknesses ranging from 218 to 302 feet.

Holes M3, M5, M6, and M8 entered ore formation at bedrock surface and, except for hole M8 which was stopped at 294 feet, continue in the same material for several hundred feet. The other holes encountered “black slate" and "gray and black slate". Because of the proximity of these holes to the magnetic anomaly in the area, the material is assumed to belong stratigraphically to the Hiawatha Graywacke or to the Stambaugh Formation (holes M13, M14). The inferred stratigraphic positions of several of the holes in relation to the magnetic anomaly are indicated in cross section in figure 4.

The most extensive drilling in sec. 28 is the "Round Lake exploration" conducted by Pickands Mather & Co. in 1949-50. Thirteen holes, RL301, RL302A, RL303A, RL304-RL309, and RL311-RL314, were drilled to depths of several hundred feet or more. The core was available for examination at the company warehouse at the Caspian mine.

Most of the holes are in the north part of the NW¼ NW¼ testing the extension of the known ore body in the "forty" to the north. The rock and structure encountered in four of the holes are shown in the central part of figure 4. Most of the holes pass through the Riverton Iron- formation into the Dunn Creek Slate at no great depth; one hole (RL311) cut pyritic slate of the Dunn Creek (Wauseca Pyritic Member) at bedrock surface; and two (RL305 and RL307) are in metadiabase. The metadiabase, from 160 feet to 288 feet in RL307, is fine- grained at the top and bottom and medium-grained porphyritic in the central part. Hole RL302A cuts graywacke and gray slate (Hiawatha) to 365

feet, then from that depth to the bottom at 448 feet is in porphyritic metadiabase similar to holes RL305 and RL307 to the north. A line of three holes (RL308, RL309, and RL312) was drilled starting at the south shore of Round Lake (holes 308 and 309 were drilled through the lake ice). The most southerly hole, RL312, drilled north at 45°, cuts a few feet of graywacke (Hiawatha) at ledge, then passes into iron-formation (Riverton) that continues to the bottom at 1,066 feet. The iron-formation is oxidized except in the last 100 feet. RL308 cuts oxidized iron-formation at ledge and continues to 305 feet in the characteristic units of the Wauseca Pyritic Member of the Dunn Creek Slate (laminated pyritic slate, pyritic slate breccia). The most northerly hole, RL309, is in gray sericitic slate and siltstone definitely assigned to that part of the Dunn Creek Slate below the Wauseca Pyritic Member.

SECTION 33

Most of the western part of this section is believed to be underlain by the Stambaugh Formation; and most of the eastern part, the Fortune Lakes Slate. The magnetic anomalies defining the Stambaugh distribution are rather broad and nondistinctive -- much different from the sharply defined anomalies in the eastern and central part of the mapped area -- but they are continuous with anomalies to the northeast definitely related to known Stambaugh Formation.

No outcrops are present in the section, and only two holes are known to have been drilled. These holes, 1B and 2B, are shallow and were drilled in 1915 by the E. J. Longyear Co. The available records show that 2B cut slate, and 1B cut banded $FeCO_3$ slate. The latter hole is located on a broad magnetic anomaly and the material cut probably is the laminated cherty siderite-magnetite rock of the Stambaugh Formation.

SECTION 34

So far as known, this section is without outcrops and drill holes. The Fortune Lakes Slate probably underlies the entire section.

SECTION 35

Old records indicate that five or six holes were drilled in 1914 on the Soderman property in the NW¼, an area assumed to be underlain by Fortune Lakes Slate. Very little information beyond that shown on the map (plate 1) is available. Hole 1, ledged in slate, is reported to have then entered iron-formation. Hole 2, with jasper at ledge also is reported to have cut iron-formation. Elsewhere in the district, beds of iron-formation are known to occur in the Fortune Lakes Slate, and presumably the iron-formation reported in the drill holes is interbedded with more typical strata.

In the NE¼, 18 test pits were sunk through shallow cover to explore a magnetic anomaly caused by a long southeast-trending anticline of Stambaugh Formation. The rock uncovered is not typical of the Stambaugh Formation elsewhere; it includes chert breccia, graywacke with magnetite-bearing green chert, and cherty siderite. Some of these rocks are assigned to the Stambaugh Formation, and some are doubtfully assigned to the overlying Fortune Lakes Slate.

WAGNER CREEK AREA

The Wagner Creek area (plate 2) constitutes 8 square miles on the south flank of the Iron River-Crystal Falls basin. It includes sections 2, 3, 4, 9, 10, and 11 and parts of sections 14, 15, and 16, T42N, R34W. On the basis of magnetic anomalies and a few scattered drill holes, reasonable geologic inferences can be made for the western third of the map area. The geology of the greater part of the area, however, is virtually unknown.

Geology

A strong fairly well-defined anomaly enters the area near the northwest corner and continues to about the center of sec. 10. This anomaly, caused by the Stambaugh Formation, reveals a complexly-folded bed trending southeast. In the southern part of section 9, a low but persistent anomaly can be traced for one mile; as in the area to the west, it marks local preservation of Stambaugh Formation along a synclinal axis.

A broad domelike magnetic anomaly centers on the southeastern part of section 10. Analysis of magnetic data indicates the anomaly is caused by a magnetic body at a depth of about 1,000 feet. The anomaly is similar to one in sec. 25, T43N, R33W, and somewhat like that near Round Lake in sec. 21, T43N, R34W. The Round Lake anomaly has considerably steeper gradients, but is similar in size and form; it can reasonably be related to metadiabase known from nearby drill holes. Probably the anomaly in the Wagner Creek area is due to a body of metadiabase at depth, and is entirely unrelated to the linear anomaly caused by the Stambaugh Formation.

The linear anomaly caused by the Stambaugh Formation cannot be traced beyond the northwestern part of section 10. The reason for its gradual termination is not known. It may simply be due to a facies change of the formation to nonmagnetic material, but as noted in Professional Paper 570 (James, Dutton, and others, 1968), the general high gravity field related to the Iron River-Crystal Falls basin is broken by a great northwest reentrant of low gravity value in the vicinity of Chicagon Lake, in the eastern part of the Wagner Creek map area.

Possibly some relation may exist between termination of the magnetic anomaly related to the Stambaugh and the break in the gravity pattern.

Bedrock is not exposed at any place within the area, and drilling is confined entirely to the southwestern part.

Explorations

Town 42 North, Range 34 West

SECTION 9

The only exploration in this section is a line of seven holes (H1-H7) drilled in 1910 by The Cleveland-Cliffs Iron Co. Known as the Holmes exploration, the holes are all of shallow depth, the deepest entry into bedrock 39 feet. Samples of the core were located and examined at the Ishpeming offices of the company.

Holes H1, H3, and H4 all cut a laminated graphitic slate similar to typical "footwall" rock of the Wauseca Pyritic Member. Because of their position, however, H3 and H4 probably are not in this unit but in Hiawatha Graywacke, which in many places contains a considerable amount of interbedded graphitic slate. Hole H2 cut 17 feet of well-banded unoxidized iron-formation (Riverton). Hole H5, located at the crest of a modest magnetic anomaly, is interesting because it cuts a laminated cherty siderite closely resembling some of the Stambaugh Formation elsewhere. Although nonmagnetic (nonmagnetic portions are not uncommon in the formation) there seems little reason to doubt the assignment to the Stambaugh Formation. The formation is assumed to be contained in a tight synclinal fold, so that the graywacke cut in holes H6 and H7 to the north is considered part of the Hiawatha Graywacke.

SECTION 10

Five shallow holes drilled in 1910 along the north-south center line by Cleveland-Cliffs represent the only exploration in this section. Samples of the core were examined at the company offices in Ishpeming.

Hole 10-1 cuts oxidized slaty iron-formation to 135 feet, then ends at 150 feet in gray carbonate slate; hole 10-2 is in gray carbonate slate; and hole 10-3 is in banded chert-siderite iron-formation. All probably can be assigned to the Riverton Iron-formation. The most southerly hole, 15-1, is in chert and fine-grained dark graywacke to 142 feet; the most northerly hole, 10-4, is in finely-banded fine-grained graywacke to 165 feet.

SECTION 15

Three test pits along the west margin comprise all the known exploration in sec. 15. The pits were put down in 1910 by Cleveland-Cliffs and virtually all the information concerning them is given on the map (plate 2).

SECTION 16

Seven holes were drilled in 1910 by Cleveland-Cliffs in sec. 16, six (S2-S6, 16-1) in the N½. All are shallow holes penetrating bedrock for less than 40 feet. Samples of the core were located and examined at the company offices at Ishpeming.

Hole 16-1, at the northeast corner of the section, cuts 26 feet of unoxidized slaty iron-formation (Riverton). Hole S2 cuts pyritic black slate, probably the Wauseca Pyritic Member of Dunn Creek Slate. Hole S6 is in a green chloritic rock, which may be either a sheared dike or Badwater Greenstone. Holes S3, S4, and S6 cut nondescript cherty carbonate slate, gray slate, and black slate.

Two drill holes, 101 and 102, are recorded in the 1909 notes of R. C. Allen as having been drilled in the NW¼ NW¼. Both are shallow and both cut gray slate.

SECTION 24

The Brule River exploration, southeast of the map area of plate 2, consists of two groups of holes drilled in 1954-1955 by the M. A. Hanna Co. along the south flank of the Iron River-Crystal Falls basin. The location of the holes is shown on the geologic map of Professional Paper 570 (James, Dutton, and others, 1968). One group consists of two holes (BR-3-54 and BR-2-55) in the NE¼ sec. 24, T42N, R34W. The second group (BR-1-54, BR-1-55, BR-2-54) is several miles to the east, in sec. 34, T42N, R33W. The core from the drilling was examined at the storage facilities of the M. A. Hanna Co. at the Rogers mine.

The two holes drilled in the NE¼ sec. 24 were directed to the south at 60°. The easterly hole, BR-3-54, penetrated sericitic gray slate at ledge and ended at 705 feet in oxidized massive fine-grained greenstone. From 151 feet to 333 feet the hole is in porphyritic metadiabase, apparently a sill or dike cutting the slate. Probable dike rock also occurs at the contact of the slate with the greenstone. The westerly hole, BR-2-55, enters metadiabase at bedrock surface at 155 feet. From 206 feet to 270 feet it is in banded oxidized slate, below which it is first in oxidized porphyritic metadiabase (270- 309 feet) then in massive fine-grained greenstone to the end of the hole at 590 feet.

Both holes are interpreted as cutting the Dunn Creek Slate-Badwater Greenstone contact, with dikes of metadiabase in the slate and at the contact.

Town 42 North, Range 33 West

SECTION 34

The drilling in this section was on the south slope of a prominent northwest-trending ridge that crosses just south of the center of the section. The ridge is a bedrock high lightly covered with glacial debris. Rock is exposed at several places. The most westerly exposures are partly fissile sideritic slate, with irregular layers of white chert, and partly olive-green slate with layers of chert and siderite. The more easterly exposures are gray to green slate, with an outcrop of sheared graywacke on the extreme southeast end of the hill in adjoining section 35.

The most southerly of the three holes, BR-2-54, was drilled south at 45° to a depth of 339 feet. To 323 feet (ledge at 183 feet) the hole is in a thin-banded gray sericitic slate, then to the end of the hole is in soft decomposed greenstone. The greenstone could be a dike rock, but is interpreted as the uppermost part of the Badwater Greenstone, overlain by Dunn Creek Slate.

The center hole, BR-1-54, was drilled vertically to 285 feet. It cut slate, siltstone, and fine-grained graywacke, probably Dunn Creek Slate.

The most northerly hole, BR-1-55, was drilled N 20° E at 35° to a depth of 886 feet. The hole flattens to 6° at the end. It provides an excellent cross section of the ridge.

The bedding makes an angle of about 50° with the axis of the core in the upper part; in the lower part the drilling cut bedding at almost 90°. The log of the hole follows:

183 feet) the hole is in a thin-banded gray sericitic slate, then to the end of the hole is in soft decomposed greenstone. The greenstone could be a dike rock, but is interpreted as the uppermost part of the Badwater Greenstone, overlain by Dunn Creek Slate.

The center hole, BR-1-54, was drilled vertically to 285 feet. It cut slate, siltstone, and fine-grained graywacke, probably Dunn Creek Slate.

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The center hole, BR-1- 54, was drilled vertically to 285 feet. It cut slate, siltstone, and fine-grained graywacke, probably Dunn Creek Slate.

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Depth in feet	
0-92	Overburden
92-119	Thin-bedded chert and siderite, with seams of black slate.
119-185	Slate, black to dark-gray, locally pyritic and graphitic.
185-542	Thin-bedded chert and siderite, interlayered with black slate in beds of a fraction of an inch to a foot or so thick. Chert in irregular layers, in part nodular.
542-695	Black slate, graphitic, with seams of pyrite and chert. Massive light-gray rock, probably metadiabase, from 620- 650 feet. Some siderite layers in lower part.
695-835	Interbedded chert, siderite, and black slate.
835-886	Slate, black and graphitic. Seams of pyrite and black chert.

Most of the hole, perhaps all of it, is in rock that can be stratigraphically placed in the Riverton Iron-formation. The rock as seen in drill core has a notably smaller component of slaty material than would be estimated from surface exposures; prior to the drilling, classification as iron-formation was uncertain.

The crest of a moderate to low magnetic anomaly passes approximately through the center of the section, possibly indicating Stambaugh Formation. The anomaly has a maximum relief of about three instrument units as mapped with a dip needle; as measured with a vertical magnetometer, the relief is about 600 gammas.

CHICAGON CREEK AREA

The Chicagon Creek area (plate 3), covering 7½ square miles, is located on the north flank of the Iron River-Crystal Falls basin midway between the towns of Iron River and Crystal Falls. No mines are located within the area. It includes parts of sections 19 and 20 and all of sections 29, 30, 31, and 32, T43N, R33W; and sections 25 and 36 and part of section 24, T43N, R34W.

Geology

Outcrops, though scarce, are far more numerous than in most of the district to the east and west. All stratigraphic units except the Fortune Lakes Slate are exposed in at least one place. The Badwater Greenstone, which here forms a great southwest-jutting elbow into the main basin, is exposed at several places in section 25, and in sections 19, 20 and 30. The rock is massive porphyritic greenstone, considerably less altered than most greenstone in the district; most of it is structureless, but ellipsoidal structures are present as a layer in the southwestern part of sec. 20. A single outcrop of graywacke in the NE¼ NW¼ sec. 25, represents the only exposure of Dunn Creek Slate; more typical slate has been thrown out at a test pit in the SW¼ NW¼ of the same section. Riverton Iron-formation is present in a very poor exposure on the south side of U.S. Highway 2 in the southern part of sec. 24. The rock is slaty and nly superficially oxidized. A pipeline trench a few hundred feet to the northeast exposed a massive breccia consisting of fragments of chert and siderite in a siderite matrix. Oxidized iron-formation of the River-ton has been thrown up from test pits in the NE¼ NE¼ sec. 36. Rocks assigned to the Hiawatha Graywacke are exposed in a roadcut along U.S. Highway 2 in the SW¼ SW¼ sec. 24. Basal chert breccia lies immediately above the iron-formation in the roadcut. A continuation of the cut to the northwest exposes gray slate. Typical graywacke and slate of the Hiawatha are present in half a dozen test pits about 1,000 feet southwest.

The Stambaugh Formation is exposed in several small but excellent outcrops in and adjacent to railroad cuts in the

SW¼ SE¼ sec. 25 and the NE¼ sec. 36. Most of the typical lithologies of this unit -- laminated magnetic sideritic rock, banded pyrite-porcelanite, magnetic graywacke -- are well shown on these outcrops. Similar material also is present in rock thrown out of test pits in the NW¼ NW¼ sec. 25.

The southern and western parts of the area have been surveyed magnetically, mostly along lines 200 to 400 feet apart and with readings at 100-foot intervals. Different instruments were used for different parts of the area: the western portion was surveyed with a Superdip oriented in the north-south position, sigma angle of 3½°; the central part with a Superdip oriented east-west with a sigma angle of 1½°; and the eastern part with a Wolfson vertical-component magnetometer. On plate 3, the magnetic data are contoured in instrument units in areas of Superdip survey, and gammas elsewhere.

The structure of the area, particularly that of the western part, is complex. The Stambaugh Formation, revealed by the distribution of magnetic anomalies, occurs in tight folds around the "elbow" of greenstone -- north-west-trending in the area south of the Chicagon fault, and northeast-trending north of the fault. In many places, whether an anomaly is over a "limb" of Stambaugh or whether it is over a fold, is highly uncertain, and several alternative map patterns could be drawn. East of Chicagon Creek and the head of Chicagon Lake, the structure is more straight forward and the units forming the north flank of the Iron River-Crystal Falls basin appear only mildly flexed.

The Chicagon fault is an inferred steeply-dipping break coinciding with the south margin of the greenstone for at least 2 miles, then continuing with westerly strike beyond the turn in the greenstone "elbow". The fault is cut in hole P4, in the SE¼ SE¼ sec. 30. The hole, drilled at 42½° N starts in pyritic slate of the Wauseca Pyritic Member (uppermost part of the Dunn Creek Slate) and ends at 325 feet in a mixture of sheared, quartz-veined slate and greenstone; most of the Dunn Creek Slate has been cut out. The direction of displacement on the fault is not known. In the Chicagon mine area to the west, the south side appears to be downthrown, and this type of offset would explain the distribution in the area under discussion. Most likely the break is a north-dipping high-angle reverse fault. The North Chicagon fault seems to be one of dominant lateral movement, with the south side moved west. The magnetic anomaly in the northwestern part of sec. 25 is offset a distance comparable to that of the greenstone contact – about 500 feet.

Explorations

Town 43 North, Range 34 West

SECTION 24

The McCullum exploration in the S½ SW¼, consists of two holes believed to have been drilled by the M. A. Hanna Co. in about 1939. The core was not located. Descriptions are by A. E. Walker, company geologist. The holes are located one on each side of U.S. Highway

2. Hole M1 was drilled south at 45° for a distance of 155 feet in gray to black unaltered brecciated iron-formation (probably similar to the breccia exposed 500 feet east).

Hole M2, drilled at 45O N 74° W, penetrated "diorite" (probably metadiabase) from ledge at 17 feet to 60 feet, and again from 78 feet to 88 feet and from 90 feet to 105 feet. From 60 feet to 78 feet the hole is in greywacke and slate. From 105 feet to the bottom at 171 feet, the hole reportedly is in banded unaltered iron-formation. The relatively low content of iron recorded (12-15 percent), together with the position of the hole with respect to the nearby magnetic anomaly, suggests the rock may be a cherty siderite of the Stambaugh Formation rather than Riverton Iron-formation.

SECTION 25

The Wakefield exploration consists of many shallow test pits and 13 drill holes (1-13) that were sunk by the Munro Mining Co. in the west half of sec, 25 in about 1910 as part of the exploration related to the Chicagon mine. None of the core has been located for study and available descriptions are exceedingly meager. The average length of hole is about 300 feet, with one hole, number 4, having a length of 641 feet. The test pits are all slumped but sufficient angular material was found on some dumps to identify bedrock.

The overburden penetrated in this exploration is thin except in the southwestern part of the NW¼ SW¼, where it is locally as much as 150 feet thick. The rock encountered in holes 10 and 12 in this area is reported as iron-formation. Hole 13 cut 67 feet of iron-bearing formation after passing through a short run of quartz and slate. Hole 1, near the W¼ corner penetrated iron-bearing formation at the bedrock surface. The rock in most of the remaining holes is reported merely as quartz and slate, or black slate.

The material encountered in the test pits in the SW¼ is reported merely as slate. Identification could not be checked. Material thrown out of pits in the NW¼ NW¼, however, can be classified stratigraphically. Three of these pits were in magnetic sideritic slate of the Stambaugh Formation, and the test pits near the north line of the section show mostly deeply oxidized graywacke and slate of the Hiawatha Graywacke.

These test pits are important because they permit a structural interpretation of the anomaly in that part of the section: the anomaly clearly caused by the Stambaugh Formation contained within a northeast-trending syncline. The syncline is truncated on the south by the North Chicagon fault.

The most significant exploration data for the Chicagon Creek area were from a group of seven holes (P1-P7) in sec. 25, T43N, R34W, and sec. 30, T43N, R33W, the East Chicagon exploration. The holes were drilled in about 1933 by Pickands Mather & Co. The core was studied at the company storage building at the Caspian mine.

The position and nature of the contact between the Badwater Greenstone and the Dunn Creek Slate in the southeastern part of sec. 30, are established by holes P3 and P4. Hole P3, drilled north at 51½°, cuts massive porphyritic greenstone from bedrock surface to the end of the hole at 300 feet. Hole P4, drilled north at 42½°, is in pyritic graphitic slate (Wauseca Pyritic Member of the Dunn Creek Slate) at bedrock surface and ends at 325 feet in a mixture of dark-gray slate, vein quartz, and fine-grained greenstone; clearly the hole has cut the Chicagon fault, and most of the Dunn Creek Slate is missing.

Holes P1, P2, P5, P6, and P7 are in the southern part of sec. 25. Hole P1, drilled north at 50°, appears to cut a normal sequence of Hiawatha Graywacke to 230 feet, Riverton Iron-formation to 330 feet, and Dunn Creek Slate to the end of the hole at 395 feet. The iron- formation is much thinner than normal for the area, but the core showed no indications of a fault. Hole P2, in the southeastern part of sec. 25, also was drilled north at 50°. The hole ledges in graywacke (with chert fragments) and slate that can definitely be assigned to the Hiawatha Graywacke, and ends at 695 feet in porphyritic greenstone (Badwater). Between the Hiawatha and the Badwater, from 350 feet to 645 feet, is mostly oxidized iron-formation (Riverton) with some infolded (?) graywacke and slate. The upper 5 feet of Badwater Greenstone contains much vein quartz, and evidently this hole, like P4 a mile to the east, has cut the Chicagon fault. The entire Dunn Creek Slate has been cut out in this locality.

Holes P5 and P6, drilled north at 50°, both apparently cut a south split of the Chicagon fault. Hole P5 is in oxidized iron-formation to 410 feet, then from 410 feet to 500 feet cuts graywacke and slate (Hiawatha), and considerable vein quartz below 485 feet. The final 50 feet of the hole is pyritic graphitic slate (Wauseca Pyritic Member) and sericitic siltstone. Hole P6 is in Hiawatha Graywacke, with some chert fragments from ledge surface to 355 feet, with much vein quartz in the lower 5 feet. No core was obtained from 355 to 365 feet. Below 365 feet and to the end at 443 feet, the hole is in sericitic slate and silt-stone of the Dunn Creek Slate, stratigraphically below the Wauseca Pyritic Member. At this place, the fault cuts out all of the Riverton Iron- formation and the upper part of the Dunn Creek.

Hole P7 cuts a normal contact of Hiawatha Graywacke with Riverton Iron-formation. From ledge surface at 237 feet to 330 feet, it is in graywacke and graywacke-chert breccia, then ends at 333 feet in unoxidized siderite and chert.

Town 43 North, Range 33 West

SECTIONS 29 AND 32

A group of five shallow holes (1-5) was drilled by the Nevada Land Co. in the NE¼ NW¼ sec. 32 and adjoining part of sec. 29 in 1910. The only records are from company files, and the entire description is given on plate 3. From the position of the holes with respect to magnetic anomalies, probably all the holes cut the laminated sideritic rock of the Stambaugh Formation.

SECTION 20

Company records indicate a line of shallow holes were drilled in the W½ SE¼ sec. 20. No information is available as to date, sponsorship or depth; the entire record is as shown on plate 3.

FORTUNE LAKES AREA

Geology

The Fortune Lakes area (plate 4) covers 9½ square miles, mostly on the north flank of the Iron River-Crystal Falls basin. It includes parts of sections 21, 22, 23, 24, and 36, and all of sections 25, 26, 27, 28, 33, 34, and 35, T45N, R33W. Except at the east margin of the map area, where anticlinal projections from the Crystal Falls- Alpha belt extend to the northwest into the basin, the geology consists of a regular southward progression of older to younger rocks. The Badwater Greenstone on the north is succeeded by Dunn Creek Slate, Riverton Iron-formation, Hiawatha Graywacke, Stambaugh Formation, and Fortune Lakes Slate. The units of the Paint River Group form belts, modified by only slight folding, that extend from the west edge to the east edge of the map area, a distance of 4 miles. The iron- formation is unoxidized in the western half; only in the eastern part, where the structure is modified by an east- trending fault, is the iron-formation oxidized.

Outcrops are absent in the western part of the Fortune Lakes area, where the known depth of overburden is as much as 324 feet, but are fairly abundant in the east part, especially in secs. 23, 24, and 25. A large percentage of the known exposures of the Fortune Lakes Slate are in this area. Most of them consist of interbedded graywacke and gray slate. In the N½ sec. 25, a distinctive striped slate is exposed. Typically crossed by a steeply-dipping slaty cleavage at a high angle to bedding. The most westerly exposures of the Fortune Lakes Slate are in the SE¼ sec. 34, more than a mile away from other exposures of this unit. The rock in these western exposures, presumably in the upper part of the formation, is a banded chert-siderite (iron- formation) the extent of which is not known. The lowest strata of the Fortune Lakes Slate -- mostly carbonate slate and gray slate -- are exposed in the SW¼ sec. 36, where the formation borders the anticlinal belt of Stambaugh Formation. Several exposures of the latter formation, including blocky green mudstone, are in the same area. Highly magnetic mauve-colored laminated rock typical of much of the Stambaugh is well exposed adjacent to the road along the north margin of sec. 36. A major part of the geologic information concerning the "north belt" of Riverton Iron-formation and adjacent units is from an extensive drilling campaign carried out by Pick-ands Mather & Co. in 1948-1950. The holes in secs. 26 and 27 establish the main elements of the geologic pattern and also provide most significant information on the stratigraphy. The two lines of holes, P16, P21, P13A, and P23; P22, P18, and P20, in the

NW¼ of sec. 26 indicate: a) the Stambaugh Formation is present despite the absence of a magnetic anomaly; b) the Hiawatha Graywacke is about 40 feet thick in this area and consists wholly of a graywacke-chert breccia; c) the Riverton Iron-formation probably is about 800 feet thick; and d) pyritic graphitic slate, including the diagnostic slate breccia ("speckled gray"), forms the upper part (Wauseca Pyritic Member) of the Dunn Creek Slate and is as well developed here as in the type area in the western part of the district.

In general, however, the Fortune Lakes area evidentially has much closer stratigraphic affinity with the eastern (Crystal Falls) end of the main basin than with the western end, particularly with respect to the Hiawatha Graywacke and the Riverton Iron-formation.

Magnetic Anomalies

The southern two-thirds of the Fortune Lakes area has been surveyed magnetically, mostly with a Schmidt-type vertical component magnetometer, with readings taken at 100-foot intervals along lines about 600 feet apart. The SW¼ sec. 36 and adjacent part of sec. 35, was surveyed with a Superdip oriented E-W with a sigma angle of 1½°; the instrument readings have been converted to gammas and contoured to the same base as the magnetometer data.

The major unit traced with the magnetic survey, as elsewhere in the district, is the Stambaugh Formation. Characteristic anomalies caused by this unit are present on the northwest-plunging anticlines of Stambaugh along the east margin of the area. The main belt of the formation trending easterly across the entire map area, however, is represented only by patchy anomalies.

From the central part of sec. 27 to the northeastern part of sec. 25 -- a distance of more than two miles -- no anomaly is present. Prior to the drilling of hole 23 in the SE¼ NW¼ sec. 26, the margin of the basin seemed to be interrupted by some unknown structural complexity. Hole 23, however, ledges in a laminated sideritic rock interbedded with porcelanite -- rock reasonably typical of the Stambaugh Formation. Except this and an occasional thin layer, it is nonmagnetic. The absence of a magnetic anomaly is concluded to be due to a facies change in the Stambaugh -- that is, to the lack of magnetite rather than to the absence of the formation. Presumably other gaps in the magnetic pattern, as in sec. 28 and 33, are for the same reason.

In addition to the linear anomalies caused by the Stambaugh Formation, the survey also reveals two broad domelike highs in the east part of the map area. The more notable of the two, in sec. 25, is almost circular in plan. Analysis of the profiles indicates the magnetic body is at considerable depth, the top probably buried at least a quarter of a mile. Conceivably the anomaly is due to an otherwise undefined anticlinal uplift that brings the underlying Stambaugh Formation relatively near the surface. Considering its symmetry, the anomaly is probably due to a buried stock-like intrusive body, possibly of metagabbro -- rock elsewhere in the district known to yield moderate magnetic anomalies. The broad anomaly in the SE¼ sec. 26 and adjoining areas lies directly northwest of a certain Stambaugh anomaly, and, indeed, may be a continuation of that anomaly. It could be interpreted simply as being due to a local reversal of plunge in the buried anticline of Stambaugh Formation plunging northwesterly from near the W¼ corner of sec. 36; possibly it is combined with a buried intrusive as seems most likely for the sec. 25 anomaly.

Locally, magnetite-bearing rock occurs in the Riverton Iron-formation. An anomaly and exposure of the magnetite-rich iron-formation is found near the center of the SW¼ sec. 36.

Faults

The iron-formation at the Fortune Lake mine is bounded on the north by a nearly vertical fault assumed to be continuous with the fault north of the Ravenna-Prickett mine to the east. The fault was exposed in the mine workings, prior to flooding of the open pit; in part, it separates Riverton from Dunn Creek Slate, and, the Riverton from metagabbro. The fault zone is either entered, or closely approached, at the bottoms of holes P7 and P8 in the NW¼ NE¼sec. 26; in both, about 15 feet of metadiabase separates the iron-formation from the footwall slate. The fault probably continues beyond the limit shown on plate 4 to connect with the Chicagon fault several miles to the west. As with the Chicagon fault, the direction of movement is not readily apparent, because the fault is either parallel to bedding or nearly so in most places.

Intrusive Igneous Rocks

The major known intrusive body is a mass of metagabbro mostly in the SW¼ sec. 24. The rock is massive and appears green and medium-grained (the apparent grain size reflects the original pyrogenic pyroxene and plagioclase, now mostly altered to much finer-grained secondary products with retention of the gabbroic texture). The contact of the metagabbro with Riverton Iron-formation and Dunn Creek Slate is exposed in the north side of the Fortune Lake open pit.

This contact is partly a steeply-dipping fault, and partly, a tight contact, irregular in detail.

West of the Fortune Lake pit, a large percentage of the holes drilled intersect one or more metadiabase dikes; most are near the contact of the Riverton Iron-formation and the Dunn Creek Slate, but some are well within these units. In general, the dikes do not seem to have been intruded along the fault, which developed later than the emplacement of the main mass of metagabbro.

Mines

The Fortune Lake mine, located in the NW¼ NW¼ sec. 25 and the NE¼ NE¼ sec. 26, T43N, R33W, is one of the few open-pit operations of recent years. It was opened by

Pickands Mather & Co. in 1953 on an ore body that had been outlined by extensive drilling nearly 40 years earlier. The mine was operated through 1958 and the total shipments during 1953-58 amounted to 1,316,905 tons.

The open pit, filled with water since the mine closed in 1957, is about 1,800 feet long, 800 feet wide, and 300 feet deep. The glacial cover in the area is generally less than 100 feet thick, but operation was made difficult by the fact that beneath a thin surface veneer of sand the bedrock was mantled with 50 feet or less of a plastic varved glacial clay. The operation required diversion of Briar Hill Creek, but a large volume of water still entered the pit. This water was partly removed by pumping a shaft north of the pit. From this shaft a drift was driven at an elevation of 1,060 feet, one hundred feet below the bottom of the main workings.

No structural control for the ore other than the bounding fault on the north is evident. The ore body occurred simply as a lens resting on the footwall along an almost straight, nearly vertical limb of iron-formation. To the west and east, oxidized iron-formation and ore within the Riverton becomes progressively thinner; about 3/4 mile to the west, only the basal 100 feet of the formation is oxidized.

The ore is mostly soft and hematitic. In places it is high in sulfur content -- locally 3 percent or more. The sulfur occurs both as pyrite and as clear gypsum.

Explorations

Town 43 North, Range 33 West

SECTION 21

Four holes have been drilled in sec. 21, three of which (1-3) are known only from brief notes in company records. All information available is noted on plate 4. The fourth hole (M1) was drilled in 1949 by the Mineral Mining Co. Examination of the core at that time, revealed it consisted entirely of massive fine-grained greenstone from ledge surface at 324 feet to the bottom of the hole, at 373 feet.

SECTIONS 24, 25, AND 26

More than 100 holes were drilled by the Fortune Lake Mining Co. in 1914-1915 in and adjacent to a mile-long belt of iron-formation within which the Fortune Lake mine was later developed. As seen on the map the Unnumbered holes are closely spaced along lines 200-500 feet apart, seven in the area of the open pit. Most of the holes were sunk by churn drill; none penetrated bedrock more than about 20 feet. The drilling served to establish the position of the Riverton-Dunn Creek contact and to outline the ore body that subsequently was exploited. The high-sulfur content of much of the ore discouraged earlier development.

As previously mentioned, a large part of the geologic information concerning the north part of the Fortune Lakes map area is from an extensive drilling campaign conducted by Pick-ands Mather & Co. in 1948-50, preliminary to the opening of the Fortune Lake mine in 1953. In all, 24 holes (P1-P16, P18-P25) were drilled, 23 in sec. 26. The core was available for study at the company storage building at the Caspian mine.

The drilling clearly defines a belt of east-striking formations with vertical or nearly vertical dip. Many of the holes are directed north at about 60° and the bedding generally crosses the axis of the core at about 30°. P24 and P25 are vertical holes in the Fortune Lakes Slate. P24 was drilled to 420 feet in a massive clay slate with minor graywacke, but cuts very little section; bedding is within 10° of the axis of the core. P25 is also vertical, but cuts the bedding at a larger angle. It begins in light-gray clay slate similar to P24, but from 275 feet to the end at 363 feet, is in a dark-gray thin-bedded to laminated slate with occasional layers of chert and siderite.

SECTION 23

The West Lake exploration consists of eight holes (1-8) in the SE¼ SW¼ sec. 28 drilled in 1953 by the North Range Mining Co.; three additional holes were reported drilled later in the SE¼ sec. 28 but not verified. The core from these holes was examined at the Book mine. They were drilled on the assumption that the pattern of magnetic anomalies in this area indicated a fold with possible oxidation lessening the magnetic effects. The fold structure is verified by drilling, but the iron-formation is not sufficiently oxidized and leached to warrant serious economic interest.

The two most southerly holes (1 and 6) enter a graywacke-chert breccia (typical Hiawatha Graywacke) at ledge surface. Hole 1, which is vertical, continued in slate and graywacke to the bottom at 607 feet. Hole 6, drilled N 25° W at 70°, cut the graywacke-chert breccia and massive graywacke to 213 feet, and from 213 feet to the end of the hole at 259 feet, is in sheared graphitic slate with siderite layers (possibly the uppermost part of the Riverton Iron-formation). Hole 2 is in unoxidized slaty iron-formation, whereas hole 3 is in oxidized iron-formation with some unoxidized siderite near the bottom at 497 feet. Hole 5 mainly cuts oxidized slaty iron- formation. Hole 4 begins in an oxidized slate with some chert, then is in oxidized iron-formation from 366 feet to 429 feet; these strata probably are part of the Riverton. From 429 feet to the bottom at 560 feet the hole is in graywacke and graywacke-chert breccia (Hiawatha Graywacke), indicating the Riverton-Hiawatha contact here is overturned. Hole 7 drilled at 60° to the northwest, is in footwall graphitic pyritic slate (Wauseca Pyritic Member) from ledge surface to the bottom at 153 feet. Hole 8 was drilled from the same station but at 60° to the southeast; it is in banded unoxidized iron- formation to the end at 193 feet.

SECTION 35

Four holes are reported to have been drilled in the NW¼ NE¼ sec. 35, and another four in the NE¼ SW¼. The locations and total available information concerning these holes are given on plate 4.

Six holes (1-6) in the SE¼ comprise the "Michigan Iron and Land" exploration conducted by the Oliver Iron Mining

Co. in 1912. Information is from the company files. All holes are located stratigraphically in the

Fortune Lakes Slate and provide considerable information on this little-known formation. Holes 1, 2, and 3 cut similar material: graywacke and gray slate with interbedded slaty chert-siderite rock. From the footages given, it would appear that the chert-siderite rock makes up about half of the total section cut in each hole. Holes 4, 5, and 6, in contrast, are reported to be entirely in dark-gray slate and graywacke. These latter holes, particularly 4 and 6, are drilled almost parallel to the inferred strike of the formation, and probably cut only a small stratigraphic thickness. Nevertheless, the three holes seem to define a belt of gray slate and graywacke not less than 500 feet wide that surely separates the chert- and siderite-rich rock of holes 1 and 2 from that of hole 6; in other words, despite the fact that the rock cut in hole 6 is similar to that of holes 1 and 2, it is stratigraphically much lower in the section.

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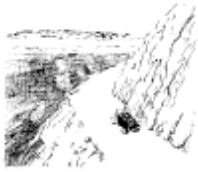

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