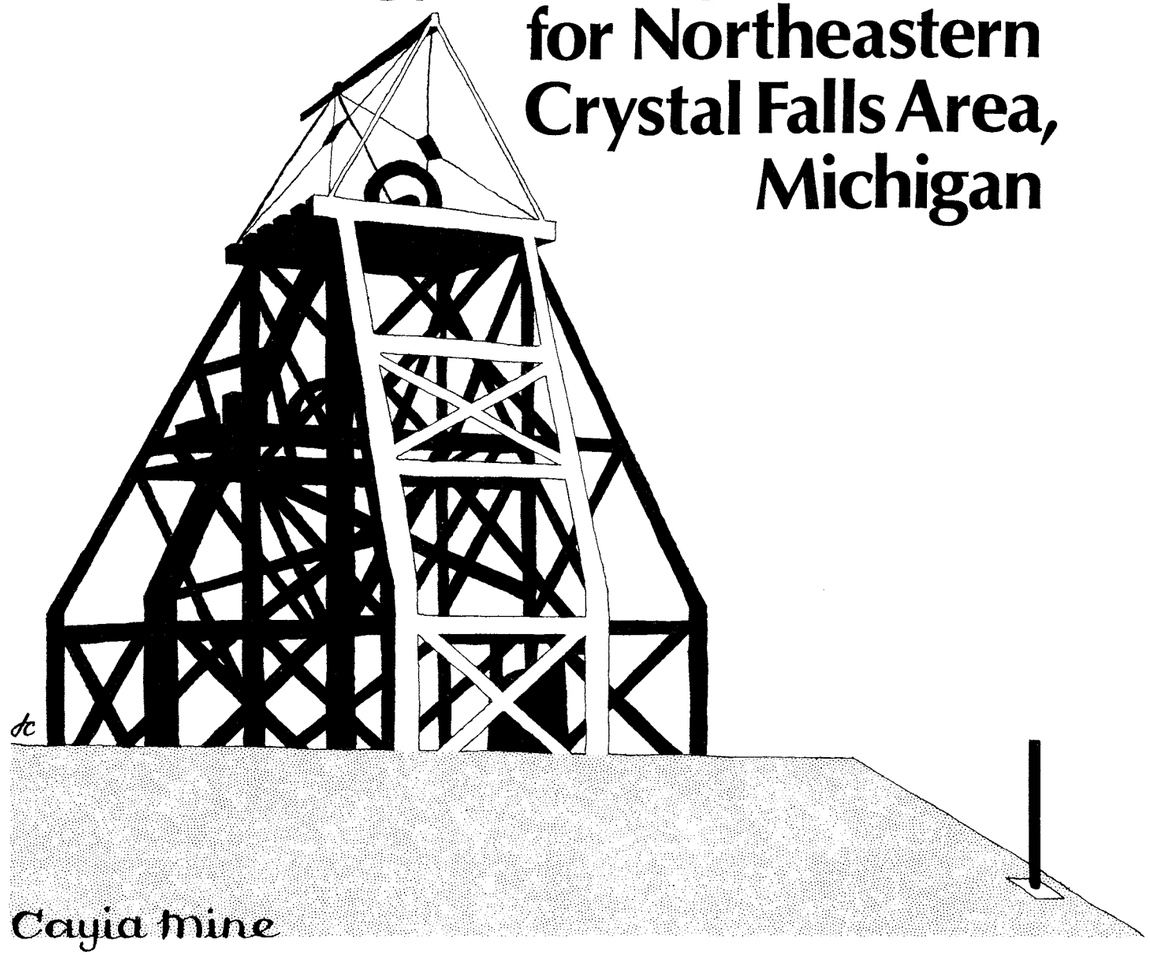
Geology and Magnetic Data for Northeastern Crystal Falls Area, Michigan



1971

Geological Survey Division
Department of Natural Resources

Front cover:

The Cayia mine, located two miles east of Crystal Falls, was opened on a small ore body by Inland Steel Company and operated during 1953 and 1954 but had to be abandoned prematurely because of caving to the surface.

(artwork by Jim Campbell)

State of Michigan
Department of Natural Resources

Geological Survey

Report of Investigation 11

GEOLOGY AND MAGNETIC DATA FOR NORTHEASTERN CRYSTAL FALLS AREA, MICHIGAN

by
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PREFACE

The purpose of this report, seventh 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 (1968), 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 Professional Paper 570.

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.

Denver, Colorado
July 1967

Kenneth L. Wier
Geologist
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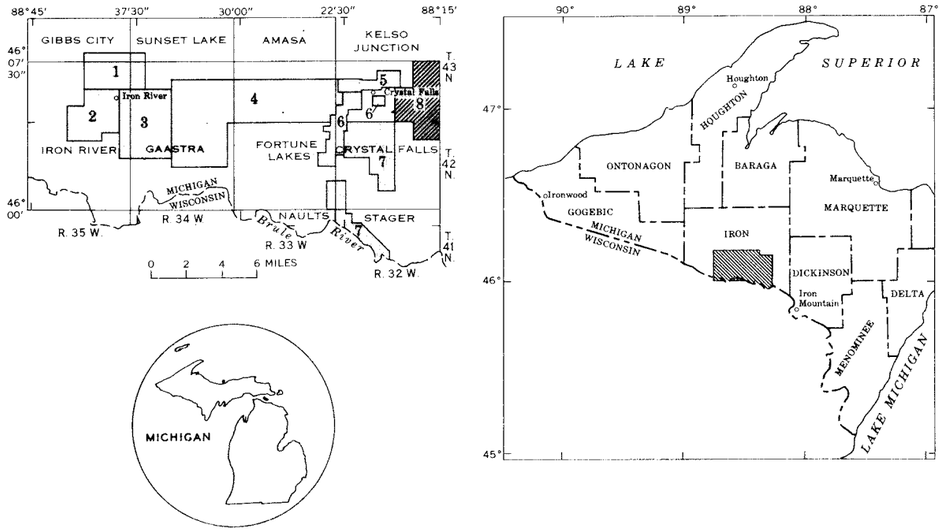

Figure 1 -- Location and index maps

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

1. Northern Iron River Area -- James, Dutton, Wier
2. Central Iron River Area -- Dutton
3. Southeastern Iron River Area -- James and Wier
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5. Northern Crystal Falls Area -- Pettijohn
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8. Hachuring delineates area of this report, *Northeastern Crystal Falls Area*--Wier

Right: Hachuring delineates Iron River-Crystal Falls District.

GEOLOGY AND MAGNETIC DATA
FOR
NORTHEASTERN CRYSTAL FALLS AREA, MICHIGAN

Abstract

The Northeastern Crystal Falls area, located a few miles east of the city of Crystal Falls, comprises an area of about 9 square miles adjacent to the Iron River-Crystal Falls synclinorium. Underlying the area are folded strata of the Animikie Series, which, from oldest to youngest, consists of the Hemlock Formation (with the interbedded Bird Iron-Bearing Member), the Amasa Formation, and the Michigamme Slate. The strata trend generally northwesterly to northerly, dip steeply, and are displaced horizontally as much as 3,000 feet by cross faults. Several mines in the Amasa Formation have shipped iron ore, but total shipments have been less than one million tons. Location of mines, partial extent of underground workings, exploration and drill-hole information, and magnetic survey data are shown on two geologic maps.

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 surveys and includes 23 detailed maps covering practically all areas of known iron-formation. The areas covered by the individual reports are outlined on fig. 1.

Information on early mining history was taken from the annual reports, 1879 to 1909, of the Commissioner of Mineral Statistics of the State of Michigan and from annual reports, 1912 to 1929, of the State Geological Survey. Additional mine history and production data were taken from "Lake Superior Iron Ores" (Lake Superior Iron Ore Assoc., 1938, 1952) and from "General Statistics Covering Costs and Production of Michigan Iron Mines" (Michigan Geological Survey, 1951-61).

The northeastern Crystal Falls area comprises about 9 square miles in the northeastern part of the Crystal Falls quadrangle. The report area is covered by two maps in this report: the Hope-Hollister area (plate 1 in pocket), comprising all or parts of secs. 13, 14, 23, 24, 25, 26, and 27, T43N, R32W; and the area southeast of the Hope mine (plate 2 in pocket), comprising secs. 34 and 35, and part of 36, T43N, R32W, and parts of secs. 1 and 2, T42N, R32W. Half a dozen inactive mines (Hollister, McDonald, Armenia, Lee Peck, Cayia, and Hope) are located within the area. The output from these properties has generally been tabulated with that from mines of the Crystal Falls or Iron River-Crystal Falls districts, but geologically this belt is distinct. The ores occur in the Amasa Formation, which is older than the Riverton Iron-formation.

Topographically, the northeastern Crystal Falls area is rather featureless. Broad low hills, for the most part lightly mantled with glacial till, are separated by low swampy ground. Total relief is about 200 feet. The most southeasterly part of the area is in part a pitted sandy outwash plain. The cover of glacial deposits is thickest to the west, where drill holes show more than 100 feet in several places.

Most of the area has been surveyed with Askania vertical magnetometers. In areas of economic interest or potential, measurements were made at 100-foot paced intervals along lines spaced 300 feet apart; elsewhere traverses were more widely spaced. Sundial compasses were used for traverse control in areas where the magnetic declination was not constant. Approximately 7,200 stations were occupied. Outcrops and test pits were located with respect to this survey on enlargements (1:12,000) of the 7 1/2-minute quadrangle map. Only test pits appearing to have reached bedrock are shown. The work was done at intervals from 1954 to 1956. The Cayia mine was examined briefly prior to its closing in 1954, at a time when much of the stoped ground was inaccessible because of sand runs caused by caving to the surface.

Approximately 85 exploration holes have been drilled in the area; but only the core of the I-C hole, drilled for the shaft location of the Cayia mine by the Inland Steel Co. in 1950, was obtained for examination. Company drill logs, which included sludge analyses

for iron, were available for the approximately 60 "J" holes drilled throughout the area from 1929 to 1931 by the Jones and Laughlin Ore Co., and for the 4 "series H-1300" holes in sec. 13, T43N, R32W, drilled by the M. A. Hanna Co. in 1930. The iron percentages mentioned below refer to these sludge analyses, made for about every 5-foot drill run. Drilling for which less complete records are available included 7 "CM" holes in the N 1/2 sec. 26, T43N, R32W, drilled by Corrigan, McKinney & Co. in 1912; 2 "H" holes in the SE 1/4 NE 1/4 sec. 27, T43N, R32W, drilled prior to 1918 by the M. A. Hanna Co.; 14 churn drill holes in the N 1/2 sec. 27, T43N, R32W, for which neither the date nor the name of the explorer is known; and scattered miscellaneous holes in the vicinity of the Hollister and McDonald mines.

GEOLOGY

Stratigraphy

From east to west, and stratigraphically from older to younger rocks, the entire area is underlain by the following units: Hemlock Formation (with the iron-bearing Bird Member), the Amasa Formation, and the Michigamme Slate. These formations are disposed in north-trending belts of nearly vertical strata, offset by a number of cross faults. The stratigraphic succession is shown in table 1.

Table 1.--Rock units in northeastern Crystal Falls area

Precambrian	Middle Precambrian	Animikie Series	Baraga Group	Michigamme Slate
				Amasa Formation
				Hemlock Formation

Hemlock Formation

Although only the upper part of the Hemlock Formation is present in the northeastern Crystal Falls area, probably 2,000 feet or more of strata is represented. The iron-bearing Bird Member is about 1,200-1,600 feet below the top of the formation.

The rocks consist mainly of interbedded basaltic flows and pyroclastics that have been metamorphosed to greenstones. The strata both above and below the Bird Member are well exposed, particularly in the Hollister-Hope map area (plate 1). Individual flows are difficult to distinguish; most can be traced for only short distances before they appear to lens out, end at cross faults, or grade into breccia or schistose greenstone.

Contacts between massive flows and beds of amygdaloidal and fragmental greenstone indicate a general north strike and a steep dip to the west. Distribution of amygdules in some of the flows indicates that top directions are toward the west. Most of the flows are massive, but ellipsoidal (pillow) structures occur in a few places, notably the SE 1/4 SW 1/4 sec. 13, and the NE 1/4 NW 1/4 sec. 24, T43N, R32W (plate 1). The most clearly defined structures are single elongated biscuit-shaped bodies ranging in size from about 4 by 12 inches to 1 by 3 feet. The flat base of the "biscuit" generally is on a flow contact. At one place, a flow contact is marked by a scallop pattern formed by a layer of small poorly-defined ellipsoids, each about 3 inches in diameter. The original "top" direction indicated by form of the ellipsoids is to the west.

Much of the greenstone originally was a pyroclastic. Angular to rounded fragments of either dense or amygdaloidal greenstone are contained in a finer grained matrix of similar material. Fragments are as much as several feet in diameter, but most are much smaller. In places, outcrop surfaces are broken and hackly in appearance without well-defined fragmental structure; the rock in which these rough surfaces develop may be flow breccia. The pyroclastic rocks are most abundant along the east margin of the area, stratigraphically below the Bird Member; but similar material is found interbedded with the flows throughout the area.

Much of the greenstone of the Hemlock Formation is magnetic, especially the pyroclastic parts, and magnetic anomalies can be related directly to outcrop in several places. The magnetic anomalies typically are erratic in tensity, trend, and continuity.

The contact between the Hemlock and the overlying Amasa Formation has been seen only in the workings of the Cayia mine, where it is a fault. Presumably, however, the two formations normally are conformable.

Bird Iron-Bearing Member The Bird Iron-Bearing Member is a discontinuous lenticular unit as much as 300 feet thick about 1,200-1,600 feet below the top of the Hemlock Formation. It is known only from test pits and drill holes and is mainly a slaty to cherty iron-formation commonly containing hematitic granules. Ferruginous quartzite and iron-formation conglomerate or breccia were found on several of the test pit dumps. In the vicinity of the Bird exploration in sec. 13, T43N, R32W, where the member is most thoroughly explored, the iron-formation is only slightly magnetic and does not cause a distinct magnetic anomaly; but elsewhere some of the slaty iron-bearing rocks are strongly magnetic, and in places can be related to sharp linear anomalies.

Amasa Formation

The Amasa Formation which overlies the Hemlock Formation, is about 1,600-1,800 feet thick. The formation is exposed at several scattered outcrop areas--at the Armenia mine cave, and in the Cayia mine, all in the Hope-Hollister map area (plate 1)--and is known from many test pits and drill holes.

The formation consists chiefly of ferruginous slate and interbedded cherty and slaty iron-formation. Little is known about the lithologic details of this unit, because only general information could be obtained from the dumps of most of the scattered test pits, and none of the drill core was available for examination. The slaty layers range from iron-poor gray and red slate to bedded iron-rich hematitic slate. Locally the slate contains much martite. Cherty iron-formation is interbedded with the ferruginous slate at several horizons. The chert is mainly gray to jasper-red, thin bedded, and generally not granular. Parts of the formation are strongly magnetic. Iron ore has been mined from this ferruginous unit at the Hollister, McDonald, Armenia, Lee Peck, Cayia, and Hope mines, but ore bodies were small and of low grade.

Michigamme Slate

The Michigamme Slate overlies the Amasa Formation and is inferred present throughout the entire western part of the two map areas. So far as known, it forms no natural exposures in the areas of plates 1 and 2. Except where observed in the workings of the Cayia mine, it is known mainly from material cast out on the dumps of test pits and from company drilling records. Some of the rock was briefly exposed during construction of a pipeline trench in the southern part of sec. 27, T43N, R32W; the material observed was oxidized red to gray slate and graywacke.

At the Cayia mine, the Michigamme was exposed for more than 1,000 feet along the two main haulage drifts at the 400 and 600 levels. The formation also was the only rock encountered in the 700-foot hole drilled for the shaft location. The drill core is mainly light-or dark-gray, thin-bedded to laminated, fine-grained, sericitic slate interbedded with fine-to medium-grained graywacke. Some of the core from the upper part of the hole is mottled red and gray because of irregular oxidation along seams mostly parallel to bedding. Graded bedding indicates that the strata are overturned in the upper part of the hole. In the mine, the formation is similar interbedded sericitic slate and graywacke. The slate is mainly thin bedded to finely laminated with a pronounced fissile cleavage, but in places it is massive with only poorly-developed cleavage. Many of the slate and graywacke beds appear to be graded, but top directions could not be determined with certainty. In places some of the slate is mottled green, red, and gray because of local oxidation. Small calcite metacrysts as large as one-quarter inch in diameter, but generally much smaller, are common; and locally crystals and bunches of pyrite up to about one-half inch in diameter are scattered throughout the slate.

Graywacke layers range in thickness from less than an inch to several feet, and the graywacke is very fine grained to medium coarse grained. Clastic quartz grains are numerous and in the coarser grained beds, are as much as one-eighth inch in diameter. Locally, feldspar fragments or grains are abundant and are conspicuous where altered to a lighter color in the partly oxidized zones.

Bedding is noticeable within the slate layers and as the contact between the slate and graywacke beds. Cleavage in the slates is generally about parallel to the bedding but in some places crosses the bedding at slight angles. In places, a slight crinkle foliation is subparallel to rude cleavage and the intersection of the two results in a steep plunging lineation. The strike of the beds is about east in the southern part of the drifts and gradually changes to about N. 20° E. at the north end of the drifts. Dips are steep, and in places the beds are overturned.

The contact between the Michigamme Slate and the underlying Amasa Formation, as seen in the mine, is abrupt but conformable.

Magnetic anomalies

Magnetic anomalies are caused by greenstone agglomerate in the Hemlock Formation (at stratigraphic positions both above and below the Bird Member), by the iron-bearing Bird Member itself, and by one or more zones in the Amasa Formation. The principal anomaly in the Amasa Formation appears to be related to a zone of magnetic slate stratigraphically in the lower part of the formation, below the productive iron-bearing horizon. The magnetic slate is exposed at several localities in the SW 1/4 NE 1/4 sec. 26, T43N, R32W.

Although much more complex in places, the general magnetic pattern shows two strong linear anomalies about half a mile apart, one

of which is associated with the Hemlock Formation and the other with the Amasa Formation. This pattern is particularly well shown in the anomalies south of Michigan Highway 69, in the area covered by plate 2. North of the highway, in the area of plate 1, the pattern is not as straightforward. The principal magnetic anomalies are more discontinuous partly because of faulting, partly because of facies changes (in the greenstone), and partly because of deep oxidation that has altered the magnetic rock (in the Amasa Formation). Furthermore, the pattern is complicated by other sporadic anomalies, such as that caused by the iron-rich rock of the Bird Member of the Hemlock.

With one exception, the anomalies can be related directly to the strata on the basis of exposed rock. The exception is the broad domelike anomaly near the center of sec. 27, T43N, R32W. This anomaly is within an area underlain by Michigamme Slate, but probably is not caused by that formation. Configuration of the anomaly indicates a minimum depth to the magnetic rock of about 500 feet; possibly the anomaly is caused by a magnetic part of the Amasa Formation brought relatively closer to the surface on a buried structure.

Structure

The northeastern Crystal Falls area, separated structurally from the Iron River-Crystal Falls basin, is located on the southwest flank of the "Amasa oval", the core of which is about 10 miles to the north. The general strike of the beds, which are vertical or nearly so, swings from northwest in the southern part of the area (plate 2) to north in the Hope-Hollister belt (plate 1).

The structural pattern of this north-northwest belt is broken by a half dozen faults, that, in general, cross the strike of the formations at a high angle. The principal break is the Cayia fault, which offsets the Amasa Formation from the area of the Hope mine to that of the Cayia mine. The fault, which trends about N. 70° W., is believed to continue for several miles west into the Crystal Falls area (U. S. Geol. Survey Prof. Paper 570, James, Dutton, Pettijohn, and Wier, 1968) and it has been traced for 2 miles or more to the east (Bayley, 1959, p. 96). The offset is right lateral, and the horizontal displacement in this area is about 3,000 feet. The fault, which is about vertical, was observed in the Cayia mine, where the Amasa Formation ends abruptly against sheared greenstone. Though not specifically recognized, the fault probably was encountered in drill holes J-11, J-14, J-19, J-21, and J-22, in the NE 1/4 SW 1/4 sec. 26, T43N, R32W.

The most southerly fault of the group offsets the Amasa Formation in the SW 1/4 sec. 35, T43N, R32W. The offset, also right lateral, is about 1,000 feet, and is well shown by the offset of the parallel anomalies of the Amasa and Hemlock formations.

The faults north of the Cayia fault are less clearly defined. The pattern shown represents a reasonable interpretation of the outcrop, test pit, and magnetic data; but many uncertainties remain. The positions of several of the postulated faults could be significantly in error. The least understood structure is in the northern part of sec. 24, T43N, R32W. The offset of the Bird Member is not great (about 500 feet) but the faulted ends of this unit as well as of the underlying and overlying greenstone are separated by a strip of Amasa (?) Formation 400-1,200 feet wide.

The movement on the faults seems to have been dominantly lateral, with the north side shifted progressively east. The aggregate displacement is somewhat more than a mile in a north-south distance of about 4 miles.

The west-northwest trend of the faults also is reflected in the dominant strike of a foliation in the greenstone. Throughout the belt of Hemlock Formation the usual trend of foliation is about west, with the dip either vertical or steep to the south. Evidently this foliation is not related to the folding in the area but to the later fault movements.

MINES

Except for local concentrations in the iron-bearing Bird Member of the Hemlock Formation, the ore deposits of the northeastern Crystal Falls area are confined to the Amasa Formation. Iron ore has been mined at the Hollister, McDonald, Armenia, Lee Peck, Cayia, and Hope mines. Total ore shipments from these mines was 962,667 tons, and with the exception of the Cayia, which operated from 1952 to 1954 and shipped a total of 44,492 tons, all production was prior to 1915. As noted previously, the Cayia mine was examined briefly in 1954, but the other mines have long been flooded or caved and only rather incomplete geologic records are available concerning them.

Hollister

The Hollister mine is in the NW 1/4 SW 1/4 sec. 13, T43N, R32W. The earliest reported exploration in the area was done about 1887 by a S. D. Hollister. Ore from the Hollister workings was first mined in 1889 and 4,098 tons of ore was shipped from 1890 to 1892. Later the property was controlled or worked by various companies including the Oglebay, Norton & Co., the Oliver Iron Mining Co., the M. A. Hanna Co., and the Hollister Mining Co. Ore shipments during 1907 to 1911, 1913, and 1914, increased the production from the Hollister mine to a total of 143,117 tons. Complete or detailed mining records are not available, but the ore zone apparently was from about 10 to 20 feet wide and was developed for a strike distance of about 600 feet, and in places to a depth of at least 8 levels. Records of two horizontal underground drill holes, one drilled 200 feet eastward and the other 700 feet westward, reveal almost 1,000 feet of ferruginous strata mainly interbedded quartz and jasper, martite slate and schist, and red and gray slate. Brief records for surface holes 1 and 3 in the vicinity of the mine list only short runs of "ore", and for holes 7 and 8 south of the mine list interbedded jasper, quartz, chert, martite slate, red slate, and gray slate.

Scattered test pits in the W 1/2 SW 1/4 sec. 13, are in ferruginous slate and chert, and some of the group of pits along the southeastern edge of the SW 1/4 SW 1/4 are deep, with large dumps of ferruginous slate and slaty and cherty iron-formation. The large waste-rock dump at the Hollister mine in the NW 1/4 SW 1/4 contains much gray to jasper-red layered chert and thin-bedded to laminated ferruginous slate. The chert or jasper layers range in thickness from about 1/2 to 2 inches and commonly are about 1/2 inch thick. Much of the layering in the chert seems to be coloration banding; but there is some interbedding of chert and ferruginous slate, and some specimens show replacement of chert by hematite. Some of the ferruginous slate is massive with a "silty" texture. A few large blocks of brecciated material, consisting mainly of fragments of chert and ferruginous slate in a finer ferruginous matrix, are present. Iron enrichment by hematite replacing both the cherty and slaty layers is apparent in many specimens. A few specimens are of massive "ore", composed chiefly of crystalline hematite in a finer hematitic matrix. Specimens of iron-bearing rocks from test pits and the mine dump are typically nonmagnetic to only slightly magnetic and the area underlain by the Amasa Formation in sec. 13 lacks well-defined anomalies.

McDonald

The McDonald mine is in the SE 1/4 NE 1/4 sec. 23, T43N, R32W. The first exploration in the vicinity of the mine was test pitting in the SE 1/4 NE 1/4 by a Thomas McCuster in 1887. Reference also is made to the "Maggie" as an old exploration in the SE 1/4 NE 1/4. In 1890 the McDonald Mining Co., opened the McDonald mine and from 1909 through 1913 shipped a total of 30,289 tons of ore. The mine was also known as the North Armenia. Detailed records of the mine are not available, but mine workings reached a depth of 418 feet and consisted of four levels developed for distances up to about 500 feet along the trend of the formation. Ore was mined from several small bodies and possibly from more than one horizon.

Most of the waste rock on the McDonald mine dump is cherty and slaty iron-formation. The chert is variegated light gray, buff, pink, or jasper-red and typically is marked by irregular iron-rich bands that apparently are hematitic replacement of the chert. Interbedded chert and thin-bedded ferruginous slate is common, with individual layers generally ranging in thickness from less than one inch to several inches. The ferruginous slate is commonly martitic.

Armenia

The Armenia mine is in the SE 1/4 sec. 23, T43N, R32W. It was first known as the Angus Smith when opened in 1887, at which time the workings consisted of a 60-foot shaft and an 80-foot crosscut reportedly all in "ore". Exploration by Paul Du Charme in the NW 1/4 SE 1/4, in the present area of test pits northwest of the mine, also was reported for that year. In 1888 the Smith property was taken over by the F. Schlesinger interests, and known thereafter as the Armenia mine. This company operated the mine only through 1890. The first year's production, in 1889, was either 44,670 or 47,775 tons of ore and shipments from this period of operation (including a small stockpile shipment in 1895) were 78,969 tons of ore. The mine remained idle until about 1901 when Corrigan, McKinney & Co. acquired the property, sank a new shaft, and renewed mining on a larger scale. Shipments from 1901 through 1914 (no shipments in 1905, 1908, and 1909) increased to a total of 713,395 tons of ore.

Available information about the mine workings is neither detailed nor complete, but the workings extended for distances of about 200 to 800 feet on nine levels and reached a depth of probably about 700 feet. Each level showed from one to three stoped areas ranging in diameter from about 100 to 200 feet. The stoped areas indicate that the main ore body plunged steeply northward from the surface to at least the 9th level, and smaller less continuous ore zones were adjacent to and, on some levels, probably connected with the main body. The ore from the first shipments reportedly was about 60 percent iron; but it is unlikely that much of

the ore mined was this high grade. Michigan Mineral Statistics for 1906-7, p. 62, notes that "The ore produced is low grade, about 52 percent iron, and high in silica."

Records of horizontal drilling from the lower levels of the mine give some indication of the extent of the iron-bearing formation in this area. From the southwesternmost mine workings on the seventh level, a 1,025-foot hole bearing about S. 30° W. was drilled in gray slate, with some iron-formation at about 700 feet. From about 200 feet west of the shaft on the 8th level, a 565-foot hole bearing N. 5° E. was in iron-bearing rocks ranging in iron content from about 30 to 40 percent (presumably sludge analyses) for the first 450 feet and from about 40 to slightly over 50 percent for the next 100 feet. A drift on the 8th level was driven into this possible ore zone, but apparently no major production came from this area. From about 150 feet north of the shaft on the 8th level, a 305-foot hole bearing N. 65° E. was in ferruginous chert and slates that ranged from about 30 to 40 percent iron.

Iron-bearing rocks of the Amasa Formation are exposed along the edge of the Armenia mine cave. On the north wall of the pit several tight folds are visible with fold axes bearing about N. 15° W. and plunging about 40°. Poorly-defined drag folds indicate the pit area may be in a synclinal structure. In general the bedding on the east side of the pit strikes N. 30° E. to N. 10° W. and dips steeply westward, whereas bedding on the west side of the pit strikes N. 10°-60° W. and dips steeply eastward, indicating a synclinal structure.

Most of the exposed rock is cherty iron-formation in which gray to jasper-red chert is interbedded with thin-bedded to laminated ferruginous slate. Individual layers range in thickness from generally less than 1 inch up to several inches. In places, irregular color banding in the chert, apparently caused by hematite replacing the chert, gives an appearance of wavy bedding. Some of the chert is granular. The east side of the pit is mainly thin-bedded ferruginous slate with only rare chert layers. One zone, about 2 feet wide, is fine-grained, thin-bedded, gray, "silty", sericitic quartzite with alternating dark and light layers up to about one-quarter of an inch thick. The darker layers are caused by a greater abundance of magnetite and martite, much of which is in small crystals. A 10-foot width of ferruginous slate has a pronounced fissile cleavage parallel to bedding and a wider spaced cross jointing, which results in a hackly exposed surface. In places this zone is slightly brecciated.

Lee Peck

The Lee Peck mine is in the SW 1/4, NE 1/4 sec. 26, T43N, R32W. The property was opened in about 1887 or 1888 by a Mr. H. B. Swain. In 1888 the shaft was reported to be 78 feet deep, with drifts from the bottom cutting ore. The mine was extended and operated by the Cherry Valley Furnace Co. in 1891, and in 1892 shipped 2,844 tons before closing.

The mine was briefly reopened by Corrigan, McKinney & Co. in 1900, but no further shipments were made. The extent of the mine workings is not known, but apparently the shaft was about 100 feet deep, with several short drifts or small stopes into the ore zones. The rock on the mine dump is mostly cherty and slaty iron-formation and ferruginous slate.

Cayia

The Cayia mine, in the SE 1/4 NW 1/4 and NE 1/4 SW 1/4 sec. 26, T43N, R32W, was developed in 1951 by the Inland Steel Co. to mine an ore body in the NE 1/4 SW 1/4 revealed in drilling done by Jones and Laughlin Ore Co. about 20 years earlier. A vertical shaft was sunk to a depth of 600 feet in the southeastern part of the SE 1/4 NW 1/4, and drifts on the 400 and 600 levels were driven S. 20° W. for slightly more than 1,000 feet through Michigamme Slate to the iron-formation. The ore zone was entered from several branching drifts and crosscuts and stoped to the surface from sublevels. In 1953, caving of the upper workings reached to the surface, and wet glacial silt and sand entered the mine. The cost of controlling the sand run, coupled with the high moisture content, relative low grade of the ore, and small size of the ore bodies, resulted in closing of the mine. Total production from the property was 44,492 tons of ore shipped in 1954.

The iron-formation in the Cayia workings is mainly interbedded chert and hematitic slate. Chert layers are as much as 3 inches thick but most are less than 1 inch. The chert is commonly gray or light red. In places irregular and partial replacement of the chert by hematite results in darker red, dense cherty zones. The hematite-bearing slaty layers are generally thicker, and some are thin bedded. Iron content varies from bed to bed; some of the layers contain little iron whereas others are almost entirely hematite. The ore is mainly earthy hematite mixed with considerable chert or quartz, and ore zones were rather low grade and small. Most of the iron-formation is slightly magnetic.

Hope

The Hope mine is in the SE 1/4 sec. 27, T43N, R32W. The earliest record of explorations in the vicinity of the mine is of test pits dug in the S 1/2 SW 1/4 in 1885 and 1886 by the Blaney Iron Co. The pits reportedly were mainly in two groups, one group considerably south of the other, and small amounts of "ore" were found in many of the pits, one or two of which were as deep as 90 feet. The only known test pits in the SW 1/4 are relatively shallow and in gray slate, so that the location given is probably in error, especially as later references place the Blaney exploration in the SE 1/4. Because both groups of pits apparently were in iron-formation, the northern group may refer to the pits in the southwestern part of the SE 1/4 NE 1/4 and the southern group to those in the northeastern part of the SE 1/4 SE 1/4. Some of the pits in the northeastern part of the SW 1/4 SE 1/4 are deep, but it is unlikely that these could be the southern group, because the dump material is chiefly red slate typical of the Michigamme Slate. In 1887 the Blaney exploration became known as the Wauneta, and in that year about 1,500 tons of ore was mined. In this reference the Wauneta is placed in the N 1/2 SE 1/4, but the mining probably was done at the present location of the Hope mine shaft, in the northern part of the SE 1/4 SE 1/4 (later references place it in that forty). In 1891 the property came under the control of the Hope Iron Mining Co. and was known thereafter as the Hope mine. The mine was active until 1893, during which time 17,818 tons of ore was shipped. An attempt to reopen the mine in 1899 was unsuccessful because part of the mine was discovered to be on lands not owned by the mining interests. In 1901 the property was optioned to the Oliver Iron Mining Co., and mining was resumed for a short time. The workings in the SE 1/4 SE 1/4 were known as the South Hope, and those in the NE 1/4 SE 1/4 as the North Hope. Production in 1902 and 1903 increased the ore shipments from the property to a total of 28,530 tons.

Little information is available about the Hope mine workings, but incomplete mine maps indicate that the ore zone strikes about N. 10°-15° W. and dips steeply to the west. The mine was developed to a depth of about 350 feet and on two levels for a distance of about 300 feet along the strike.

EXPLORATIONS

Town 43 North, Range 32 West

Section 13

Other than the exploration related to the Hollister mine, the principal exploration in sec. 13 is on the iron-formation of the Bird Member of the Hemlock Formation. The member is named after the Bird exploration in the SW 1/4 SE 1/4 of the section. The exploration was first known as the Voos, when opened in 1900. There is no record of production or shipments from the property. The iron-formation has a maximum thickness of about 300 feet, lies about 1,200 feet below the top of the Hemlock Formation, and trends N. 20° W. across the central part of the section. As revealed on numerous test pit dumps, the formation consists mainly of interbedded ferruginous slate, chert, and a few thinner layers of nearly pure hematite. Granular (oolitic) iron-formation, iron-formation conglomerate, and ferruginous quartzite were found on several dumps.

Drill holes H-1301, H-1302, H-1303, and H-1307 were drilled along the iron-bearing belt. Hole H-1301 encountered slaty and cherty iron-formation interbedded with some gray-green ferruginous slate to 440 feet and then amygdaloidal greenstone to the bottom of the hole at 457 feet; hole H-1302 was in greenstone to 350 feet and then in gray, banded to laminated iron-formation, with iron-formation conglomerate at the contact, to the bottom of the hole at 463 feet; hole H-1303 was in slaty to cherty iron-formation with some jasper, to the bottom of the hole at 263 feet; and hole H-1307 was in slaty and cherty iron-formation with some martitic and granular (oolitic?) zones and some thin layers of almost pure hematite to 460 feet, and greenstone to the bottom of the hole at 490 feet. Analyses ranged from about 20 to 40 percent iron and averaged about 30 percent for the entire iron-formation drilled.

Many of the iron-formation specimens from the test pits are slightly to moderately magnetic, and although some minor magnetic highs appear to be related to the iron-bearing rocks, the Bird Member in sec. 13 is not distinctively magnetic. The iron-formation is inferred to extend northward parallel to general magnetic trends to about the edge of the map area, but the formation has not been explored north of drill hole H-1303.

Section 14

The Amasa Formation underlies the eastern part of the section, and typical slaty and cherty iron-bearing rocks have been found in test pits at several places. Although direct geologic evidence is lacking, except for the absence of magnetic anomalies, the Michigamme Slate (the next younger stratigraphic unit) undoubtedly overlies the Amasa Formation to the west through sec. 14 and into sec. 15. A small outcrop of ferruginous cherty and quartzitic rock of the Amasa Formation is present in the northeastern part of the SW 1/4 SE 1/4.

Bedding is not apparent, but poorly-defined color banding strikes N. 25° W. and dips about vertically. Rock specimens from this outcrop and from the many scattered test pits are essentially nonmagnetic; but the northern end of a strong anomaly, apparently related to magnetic strata in the lower part of the formation, extends into the southeastern part of the section. A weak narrow magnetic trend continues northward and may reflect the northward extension of the magnetic rocks of the formation. Strong magnetic anomalies are characteristically associated with the Amasa Formation to the south. The cause for the general lack of similar anomalies in sections 13 and 14 is not known. Inferred faults project into this area and the magnetic rocks may be cut out or downfaulted. The lack of magnetics may possibly be related to deeper oxidation of the unit in this part of the area. The two inferred faults trending northwesterly in the general strike direction of the strata are believed to partly repeat the Amasa Formation and cause the apparent greater thickness of that unit in secs. 13 and 14.

The test pit explorations in sec. 14 date back to 1882. An early reference to a "Tobin's Mine" in the SE 1/4 probably refers to a group of deep pits in the western part of the SE 1/4 SE 1/4.

Section 23

A faulted belt of Amasa Formation underlies the eastern part of the section; and to the west, the Michigamme Slate is believed to underlie the rest of the section and that part of sec. 22 within the map area. Test pits, drill holes, and workings of the McDonald and Armenia mines reveal the extent of the iron-bearing Amasa Formation.

Part of a strong linear magnetic anomaly trends about N. 25° W. across the northeast corner of the section. It could not be correlated directly with magnetic rocks; but ferruginous slate typical of the Amasa Formation has been test pitted on both sides of the anomaly, and the magnetics apparently are related to the lower part of that formation. West of the Armenia mine, in the SE 1/4, a much weaker anomaly with the same general trend lies within the upper part of the formation. The anomaly is believed to be caused by rocks of the Amasa Formation, and the greater thickness of glacial overburden in the southern part of the section may be partly the reason for the apparent decrease in magnetic intensity.

NE 1/4 Test pits are confined mostly to two groups, one north of the McDonald mine in the northern part of the NE 1/4 NE 1/4, and another south of the mine in the southern part of the SE 1/4 NE 1/4. Ferruginous slate and slaty and cherty iron-formation are found on the pit dumps.

Holes J-2, J-3 and J-4 in the central part of the NE 1/4 NE 1/4 are shallow, and encountered interbedded varicolored slates, ferruginous chert, and slaty martitic iron-formation. Deeper holes, J-5 and J-6, a short distance to the north near the group of test pits, were mainly in ferruginous chert and slaty martitic iron-formation. Iron analyses ranged from about 15 to 35 percent for the more ferruginous chert and slaty iron-formation, and generally were less than 10 percent for the leaner chert and mottled slates. Angle hole J-1, drilled eastward from west of the McDonald mine for a total length of 840 feet, passed through the older mine workings at about 620 feet. The hole was in gray, green, and red slates to 270 feet, then in lean ferruginous chert to 490 feet, and finally in hematitic, limonitic, and martitic cherty iron-formation to the bottom of the hole. Percent of iron in the slate and lean chert to 490 feet was generally less than 10 percent, but ranged from 15 to 35 percent in the iron-formation from 490 to 840 feet and averaged about 30 percent in the lower part of the hole. The two McDonald holes, McD-2 north of the mine, and McD-3 south of the mine, were drilled in 1912. Company records show both holes only in ore formation. Iron analyses (presumably of the sludge at 5-foot intervals) run generally from 20 to 30 percent for McD-2, less than 10 percent for the upper 400 feet of McD-3, and 15 to 30 percent for the lower 200 feet. A southwest-trending 410 foot angle hole drilled from the shaft area at the 3rd level of the McDonald mine also was noted as being in ore formation, but iron analyses generally are higher, with some runs 40 to 50 percent. Information about the Woodward holes, W-2, W-3, and W-4 in the SE 1/4 NE 1/4, and the Mass Holes, M-1, M-2, and M-3 in the NE 1/4 NE 1/4, consists of an undated sketch map showing lotion of the holes and brief notes that ore formation, red slate, cherty material, jasper, and soapstone were drilled. "Greenstone" and "cherty material--900 feet" were listed for hole M-3. The greenstone almost certainly is not part of the Hemlock Formation, but may represent either green slate of the Amasa Formation or dike material.

SE 1/4 Test pits are confined to the N 1/2 SE 1/4, probably because of the thicker glacial cover to the south, and are in ferruginous slate and cherty and slaty iron-formation. The pits in iron-bearing rocks in the NW 1/4 SE 1/4, almost 2,000 feet northwest of the Armenia mine, show the extent of the Amasa Formation in this area and indicate either the amount of horizontal displacement along the inferred fault or the degree of folding. Angle drill hole J-7, along the north edge of the NE 1/4 SE 1/4, reportedly passed through

200 feet of lean cherty iron-formation and then into about 600 feet of martite-bearing slaty and cherty iron-formation having an iron content of about 20 to 40 percent. This hole shows that the iron-bearing strata at the McDonald mine continues southward into the Armenia mine area.

From about the same location in the southern part of the NW 1/4 SE 1/4, drill hole J-23 angles eastward in ferruginous slate having minor amounts of slaty and cherty iron-formation with iron content generally below 15 percent; and hole J-25 angles westward in chlorite schist and slightly ferruginous varicolored slates with iron content of about 10 percent. About 200 feet to the west, hole J-26 also is in green schistose rock with iron content of about 10 percent. The rocks encountered in hole J-23 are almost certainly of the Amasa Formation. The probable igneous rock in holes J-25 and J-26 may represent dike material. In the southern part of the SE 1/4, hole J-29 is in martitic red and gray slates having 20 percent to slightly more than 30 percent iron, characteristic for the Amasa Formation; whereas hole J-30, only 300 feet to the west, is in red and gray slates and graywacke with iron content below 10 percent, typical of the Michigamme Slate. The contact between the two formations almost certainly lies between the drill holes.

Section 24

Section 24 is underlain mostly by the Hemlock Formation, and the characteristic greenstone flows and pyroclastics are well exposed throughout much of that part of the section within the map area. Moderately strong magnetic anomalies are associated with the greenstones, and the general N. 15° W. trend of the magnetics reflects the geologic strike of the Hemlock Formation. The iron-bearing Bird Member trends about S. 15° E. to S. through the central part of the section. This unit has been found in test pits southward from the Bird exploration to a short distance south of the north edge of the section, and for a distance of about 1,000 feet along its strike in the east-central part of the NW 1/4. In the latter area of test pits, the formation is strongly magnetic; and the existence and position of the member across the southern part of the section is inferred from the magnetic data. The Amasa Formation overlies the Hemlock Formation along the western part of the section. Presumably, the Amasa occurs as a faulted wedge between outcrop areas of the Hemlock Formation in the northern part of the section.

In the southwestern part of the section, east and northeast of the Armenia mine area, many test pits in ferruginous slate and red and gray slate are apparently within the lower part of the Amasa Formation. A well-defined linear magnetic anomaly lies within the area of test pits; and is undoubtedly related to the Amasa Formation although most of the rocks on the test-pit dumps are not magnetic. The anomaly trends about N. 10° W. along the west edge of sec. 24 into the NE cor. sec. 23 and has been referred to earlier. About 200 feet south of the NW cor. sec. 24, hole J-241 lies east of the anomaly and was drilled at an angle eastward into 275 feet of mainly red and gray martitic slate containing from 15 to 30 percent iron. The hole bottomed in greenstone. The contact between the two formations and the relationship of the anomaly here, therefore, are well established. Several hundred feet east of the clearly-defined anomaly is a parallel weaker less continuous magnetic zone; and the inferred contact between the Amasa and Hemlock Formations has been placed along the eastern edge of the weaker zone under the assumption that these magnetics also are caused by the iron-bearing rocks. However, the eastern anomaly may be associated with the Hemlock Formation, in which possibly the geologic contact would lie between the two magnetic trends.

Two drill holes and many test pits in slaty and cherty iron-formation, ferruginous slate, and red and gray slate reveal the presence of the Amasa Formation between the greenstone exposures in the northern part of the section. Shallow drill holes J-242 and J-243 along the north edge of the section are in ferruginous red and gray slate having an iron content from 10 to 15 percent. Several core analyses for iron content from hole J-243 showed about 10-18 percent iron. The structural association of these iron-bearing rocks of the Amasa Formation within the area of Hemlock greenstone is not clearly understood; but the explanation offered is that the Amasa Formation here is a faulted segment that has shifted southeastward.

Section 25

With the exception of a small area of inferred Amasa Formation near the northwest corner, the entire section is underlain by the Hemlock Formation. Outcrops of the greenstone are numerous and are widely scattered throughout the part of the section within the map area. A broad strong magnetic zone trends southward through the western part of the section. It is caused partly by the Bird iron-bearing Member, and partly by other parts of the Hemlock Formation. The magnetics could be correlated with greenstone exposures in several places. The Bird Member has been found in test pits in the northeastern part of the SW 1/4 NW 1/4. Much of the iron-bearing rocks on the test-pit dumps is strongly magnetic, and the extent of the member is inferred mainly from the magnetic data. The

unit is shown trending southward through the western part of the section along or parallel to strong linear magnetic trends. The iron-bearing member is pinched out in the southern part of the section inasmuch as it seems unlikely that the unit could continue along the magnetic trends between the closely-spaced outcrops near the center of the SW 1/4 without being exposed.

Section 26

The Hemlock Formation is exposed in the eastern part of the SE 1/4 NE 1/4 sec. 26, and the contact between it and the Amasa Formation is assumed to lie between the outcrops and the large irregular magnetic anomaly to the southwest. The contact is inferred to roughly parallel the magnetic trends between the two faults.

The belt of Amasa Formation continues southward from west of the Armenia mine into the NE 1/4 NE 1/4 where it is inferred to be shifted southwestward along the southwest-trending fault. North of the fault, in the NE 1/4 NE 1/4, drill holes J-27, J-9, J-6, J-5, J-16 and J-34 are partly or entirely in cherty and slaty iron-formation with an iron content that commonly ranges from about 20 to 40 percent with an average of about 30 percent. The Amasa Formation is mainly nonmagnetic in this vicinity. Control for the fault and geologic contact with the Hemlock Formation in this immediate area is based mainly on hole J-34, which bottomed in 32 feet of sheared greenstone. The contact between the Amasa Formation and the Michigamme Slate is established by several other drill holes. The upper part of hole J-6 is in green and red carbonate slate that averaged only 5 to 6 percent iron, and the bottom 17 feet of hole J-16 is in green and red slate that averaged about 10 percent iron. About 200 feet westward, in the NW 1/4 NE 1/4, the upper parts of holes J-12 and J-20 are in red and green sandy slates with iron content generally below 10 percent, whereas the lower part of these holes are in slaty and cherty iron-formation with iron content much higher. The varicolored slates with low iron content are considered to be Michigamme Slate.

In the north-central part of the section, an inferred faulted wedge of the Amasa Formation lies between the southwest-trending fault and a shorter northwest-trending fault. The extent of this segment of the Amasa Formation and the location of the faults is based partly on the presence of the isolated but well-defined magnetic anomaly in this area. Slightly magnetic ferruginous slate and some red-gray mottled sericitic slate are exposed in the northeastern part of the SE 1/4 NW 1/4, within the area of the anomaly, along the railroad cut to the Cayia mine. Several hundred feet to the northwest, along the western edge of the anomaly, a group of test pits is in similar iron-poor slates and in more ferruginous slates and chert. From the same location within this area of test pits, hole J-15 was drilled eastward toward the anomaly, first through about 100 feet of red and gray sandy slate containing about 5 percent iron and then into slaty iron-formation that averaged about 30 percent iron; and hole J-13 was drilled westward away from the anomaly in green, gray and red slate containing less than 10 percent iron. From the drill-hole information the contact between the Amasa Formation and the Michigamme Slate probably should lie east of the start of the drill holes, but because of cherty material on most of the test-pit dumps, the contact has been placed west of the pits and drill holes. The drill-hole locations given on the company logs refer to the northwest corner of the section. Possibly that corner was not accurately established at the time of the drilling, therefore, the drill holes actually lie west of their location on the map; in which case, the drill-hole data would correlate better with the test-pit information.

The position of the northwest-trending fault is controlled by the magnetic and drill-hole data. Hole J-12 angles S. 45° E. through red and gray sandy slate (low in iron and probably part of the Michigamme Slate) then into slaty and cherty iron-formation of the Amasa Formation; a fault is inferred to separate the two formations. Available information about the "CM" drill holes consists only of location descriptions and brief notations showing where jasper iron-formation or slate were encountered. However, a possible location of the fault is indicated. Hole CM-2 is in the jasper to 280 feet, and then in slate to the bottom at 670 feet. Hole CM-3 starts in slate but goes through 200 feet of iron-formation and again into slate. Holes CM-4, CM-5 and CM-6 are in slate only, and the fault is inferred to pass between these three holes and CM-3. The fault is inferred to lie at the lower iron-formation-slate contact in CM-3, and at the jasper-slate contact in CM-2.

Hole CM-1 is in slate, but from its location the hole probably is in slaty parts of the Amasa Formation rather than in the Michigamme Slate. The bottom part of CM-7 also was noted as being in slate, although both the subparallel J-2 hole about 100 feet to the north, and the intersecting J-32 hole from the east, show iron-formation with high iron content in the vicinity of the reported slate in the CM-7 hole.

The belt of Amasa Formation continues southward from the southwest-trending fault to the major northwest-trending Cayia fault in the southern part of the section. Much of this segment of the formation is marked by a

strong magnetic anomaly, and at several places in the southeastern part of the SW 1/4 NE 1/4 magnetic gray slate is exposed. Similar magnetic slate probably is the main cause for anomalies within the Amasa Formation. The exposed slate is thin bedded to finely laminated and is mainly light to dark gray with a few more ferruginous layers, giving a slightly red streak. In places the slate has a strong fissile cleavage apparently parallel to bedding. The more magnetic parts of the slate contain scattered small visible crystals of magnetite. Iron-formation of the Amasa Formation is exposed in the SW 1/4 NE 1/4 about 200 feet west of the Lee Peck mine along an old railroad grade. The rock is layered ferruginous slate and chert in which the individual layers range in thickness from about 1/4 to 2 inches. The slate layers are commonly red, but some of the more iron-rich ones contain much martite and are blue-gray. Much of the chert is jasper-red and granular. The rocks on the Lee Peck mine dump, and on dumps of scattered test pits east of the mine and east of the magnetic slate outcrops, are mainly similar slaty and cherty iron-formation and ferruginous slate. In addition to the drill holes in this general area referred to earlier, holes J-18, J-28, J-31, J-32 and J-33 are in typical ferruginous slate and slaty and cherty iron-formation of the Amasa Formation.

The contact between the Amasa Formation and the Michigamme Slate between the two faults is accurately located in the vicinity of the Cayia mine. Hole J-35 in the southwestern part of the SW 1/4 NE 1/4 and hole J-1 in the northeastern part of the NE 1/4 SW 1/4 both start in slate and graywacke of the Michigamme Slate and end in the iron-bearing rocks of the Amasa Formation. In the group of drill holes in the vicinity of the Cayia mine workings, practically all the holes that were drilled northward ended in Michigamme Slate, and the contact was observed at several places in the mine. This group of drill holes revealed iron ore that resulted eventually in the development of the Cayia mine.

Some of this drilling established the position of the Cayia fault, which separates the Hemlock Formation and the Amasa Formation south of the Cayia mine. Holes J-11, J-19, J-21, and J-22 started in greenstone and then entered the Amasa Formation. Hole J-14, the southernmost hole and presumably lying the farthest into the Hemlock Formation, first entered 60 feet of jasper and martite iron-formation before going through 450 feet of greenstone with some interbedded ferruginous chert and then into 400 feet more of iron-formation. This hole is at about the stratigraphic position of the Bird Member. The iron-bearing rocks in the upper part of the hole may possibly be that unit. Another possibility is that the iron-formation in the upper part of J-14 is a fault sliver of the Amasa Formation.

Section 27

The Amasa Formation in the southeastern part of the section is part of the belt that continues southward from the Cayia fault. The associated linear magnetic anomalies indicate the trend of that formation through the E 1/2 SE 1/4. The western limit of the Amasa Formation is revealed northwest of the magnetic zone by a group of test pits in the southwestern part of the SE 1/4 NE 1/4 in cherty and slaty iron-formation, ferruginous slates, and martitic slate. The westernmost pit is in red and gray slate characteristic of the Michigamme Slate. Drill holes H-1 and H-2, drilled by the M. A. Hanna Company, angle east in the vicinity of the test pits but provide little information. Brief records list gray slate, lean ore formation, and martite slate for the 518-foot hole H-1, but only gray slate for the 663-foot hole H-2 that is less than 200 feet to the south. A test pit east of the magnetic crest in the east-central part of the NE 1/4 SE 1/4 is in very martitic schist. To the south, in the northern part of the SE 1/4 SE 1/4 on the west side of the anomaly, the Hope mine and another group of test pits are in the iron-bearing rocks of the Amasa Formation. Less than 300 feet west of the mine, two test pits are in gray slate believed to be part of the Michigamme Slate.

Michigamme Slate borders the Amasa Formation on the west and north and underlies the remaining larger part of the section. The contract between the two formations is controlled by the test pits referred to above and to some extent by the limit of the magnetic anomaly associated with the Amasa Formation. Michigamme Slate also has been test pitted in the SW 1/4 SE 1/4 and the NE 1/4 SW 1/4, and was encountered in the SW 1/4 SW 1/4, along a pipeline trench.

A group of 19 churn drill holes is reported to have been drilled in the northern part of the section. Neither the sponsorship nor the date of the exploration is known. All reportedly cut slate or soap rock. Eleven of the holes are north of the inferred position of the Cayia fault, and the stratigraphic assignment is uncertain; they may be in the upper part of the Michigamme Slate or the lower part of the Dunn Creek Slate. The holes south of the fault presumably are in the Michigamme Slate.

Section 34

On the basis of the magnetic data, test-pit information in the Hope mine area, and records of drilling in the SW 1/4 sec. 35, the Amasa Formation is inferred to be present

through the northeast corner of sec. 34 (plate 2). Michigamme Slate is assumed to underlie the remaining part of the section as the next younger stratigraphic unit, although known only from red and gray slates on the dumps of a group of shallow test pits in the NW 1/4 NW 1/4. The date of the test-pit exploration is not known, but the pits appear quite old and were probably dug during the period of most active exploration in this general area in the 1880's or 1890's. Several widely-spaced magnetometer traverses indicate the general absence of magnetic rocks in this section.

Section 35

All but the western part of sec. 35 is underlain by the Hemlock Formation. Metavolcanic rocks outcrop in widely separated places. The exposures are mostly massive greenstone flows, in part amygdaloidal, and minor amounts of agglomerate. At several places flow contacts strike S. 30°-40° E., about parallel to magnetic trends, and dip steeply or vertically. Shearing in the exposures strikes east to southeast, mainly subparallel to inferred faults and across the general geologic trends.

A strong linear magnetic anomaly trends S. 30° E. across the eastern part of the section between outcrops of greenstone, and specimens from exposures near the magnetic crest are moderately magnetic. The magnetics are caused, at least in part, by the metavolcanic rocks; but the anomaly is at about the stratigraphic position of the iron-bearing Bird Member and also may be caused to some extent by that unit when present.

The Amasa Formation is known from the drilling data in the SW 1/4, and is inferred to be present as a belt about 1,000 feet thick trending S. 25° E. across the western part of the section. Hole J-351, drilled eastward on the west side of the strong western anomaly assumed to be associated with Amasa Formation encountered ferruginous red and gray martitic slate. Hole J-352, drilled westward from the same location, was in similar ferruginous slate. To the northwest, holes J-353, J-357, J-354, J-355, and J-356 revealed several hundred feet of slaty and cherty iron-formation interbedded with ferruginous slate. Bands of conglomerate and breccia at about 370 feet, and possible fault gouge at 620 feet, were noted in hole J-355.

In hole J-356, the westernmost of this line of drill holes, the upper part was in a brecciated black cherty quartzite (?) to 270 feet; the central part was in ferruginous slate and cherty and slaty iron-formation to 650 feet; and the lower part was in greenstone or tuff, and amygdaloidal greenstone schist to the bottom of the hole at 723 feet. About 1,000 feet north of this main group of holes, hole J-358 encountered ferruginous quartzite and gray slate with sandy layers at ledge surface, and then gray and red chert and slaty and cherty iron-formation to the bottom of the hole.

The quartzite reported at ledge surface in the two western holes, J-356 and J-358, possibly is Michigamme Slate, which would place the contact between the Amasa Formation and Michigamme Slate a short distance east of the two drill holes. The conglomerate reported at depth in hole J-355 lies between substantial thicknesses of slaty and cherty iron-formation and apparently is intraformational.

A fault trending S. 65°-70° E. across the southern part of sec. 35, T43N, R32W and through the northeast corner of sec. 2 into the NW 1/4 sec. 1, T42N, R32W is inferred to explain the offset in the linear magnetic anomalies. The apparent horizontal movement is about a quarter of a mile with the south side shifted northwestward. Possible fault gouge reported in the bottom of hole J-355 and brecciated rock noted in holes J-355 and J-356 also indicate probably faulting in this vicinity.

The amygdaloidal greenstone schist noted in the lower part of hole J-356 is probably the Hemlock Formation and may be part of a fault sliver along the inferred fault. However, hole J-356 is drilled toward the southern segment of the western anomaly. Possibly these magnetics are associated with the Hemlock rather than the Amasa Formation, and the greenstone in the bottom of the hole is actually part of the main body of the Hemlock Formation. If so, the contact between the two formations would lie along the west side of the anomaly, from 400 to 600 feet west of their location on the map. Also the thickness of the Amasa Formation would be much less than shown.

Section 36

All of sec. 36 within the map area (plate 2) is believed underlain by the Hemlock Formation. Metabasaltic flows, in part amygdaloidal, are exposed in several places in the northern part of the section. The greenstone in this area is essentially nonmagnetic inasmuch as the magnetometer survey disclosed no magnetic anomalies. No explorations are known in the section.

Town 42 North, Range 32 West

Section 1

Most of sec. 1 within the map area (plate 2) is underlain by the Hemlock Formation. Massive greenstone flows and agglomerate are exposed in the west-central part of the section. Three large outcrops, only 100-200 feet apart, form a belt about 1,900 feet long in a S. 70° E. direction. Poorly-defined pillow structures in the eastern part of the easternmost outcrop indicate a S. 60° E. strike for the flows, which is subparallel to magnetic trends in that vicinity. The occurrence of agglomeratic greenstone along the southern parts of all three outcrops, which are mostly massive flows, also indicates a general S. 60°-70° E. trend for the formation.

The magnetic zone associated with the Hemlock Formation crosses the outcrop area, but is weaker and less sharply defined than to the north and apparently ends to the southeast at about the east edge of the map area. The exposed rock is not especially magnetic and the anomaly could not be related to the outcrops. Actually, the magnetics cross geologic trends at this place because fairly well-defined magnetic crests lie south of the southeastern outcrop and north of the center outcrop along the same general magnetic anomaly, with no apparent break in the geologic continuity between outcrops. The magnetic rocks causing the anomaly in the vicinity of the outcrops are at probable depths of 200-300 feet and may well be at different stratigraphic horizons.

In the southwestern part of the section the Hemlock Formation is inferred to be overlain in part by the Amasa Formation and in part by the Michigamme Slate, mainly on the basis of the magnetic data and of regional stratigraphic relationships. The Amasa Formation is shown as lensing out near the center of the SW 1/4, but is not verified by direct geologic evidence.

So far as known, no test pitting or drilling has been done in the section.

Section 2

The Hemlock Formation underlies the northeastern part of sec. 2; and massive greenstone flows, partly amygdaloidal, are exposed at several places. Agglomerate was noted in the large outcrop area in the NW 1/4 NE 1/4, and in the northern part of this exposure, flow contacts strike about N. 70° W., subparallel to magnetic trends. Schistosity in the exposures strikes in the same general direction and dips steeply.

The magnetic anomaly associated with the Hemlock Formation trends S. 50° E. across the northeastern part of the section between outcrops, but the magnetics could not be correlated with rock exposures.

The Amasa Formation is inferred to overlie the Hemlock Formation in a narrow belt that trends S. 50°-55° E. across the northern part of the section. The magnetic anomaly assumed to be associated with the formation ends in the NE 1/4, but the unit is inferred to continue to the southeast with a gradual decrease in thickness. In the discussion under section 35, the possibility of this magnetic anomaly being related to the Hemlock Formation was pointed out, in which case, the Amasa Formation here in sec. 2 would probably be much thinner and lens out before reaching sec. 1.

The Michigamme Slate is inferred to overlie the Amasa Formation and occupy the remaining part of the section. A very weak magnetic anomaly trends S. 50° E. through the central part of the section and is assumed to be within the area of Michigamme Slate.

No explorations are known in the section.

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