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Economic Geology

of a part of the

Menominee Range

BY

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ECONOMIC GEOLOGY
of a portion of
THE MENOMINEE RANGE, DICKINSON COUNTY

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ABSTRACT

The investigations in 1942 revealed three areas in which there are possibilities of high grade iron ore, in the vicinity of Quinnesec, Norway, and Loretto. The geologic conditions in each area are described and presented by maps and cross-sections.

The geologic conditions of three other localities which possibly merit some exploration are also described. One area is between Quinnesec and Norway, and the other two areas are between Loretto and Waucedah.

Previous explorations in or near each described area have provided considerable information concerning the upper or Curry iron formation and have indicated the presence of faults. These explorations have, however, left a lower or Traders iron formation practically untouched, although most of the known ore bodies in this region have been in this formation and adjacent to fault zones. Thus the possibilities of ore bodies in the Traders iron formation at six different localities have not been tested.

Information concerning the possibilities of concentrating selected lean iron ores was obtained from five samples which were examined at the Michigan College of Mining and Technology. A brief description of the localities from which the samples were obtained and the results of the examination constitute the final portion of this report.

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INTRODUCTION

A restudy of the Menominee Iron Range in Dickinson County was initiated by the Michigan Geological Survey in 1937. Most of the investigation has been in an area which extends westward from the village of Waucedah to the Menominee River west of Iron Mountain. Three reports, prepared in collaboration with C. A. Lamey, contain discussions of the distribution and structure of the rock formations and the major problems of the area. The portion from Norway to Quinnesec is considered in Progress Report No. 5, published in 1939. Progress Report No. 6 presents the results of investigations during the following field season in the vicinity of Iron Mountain. Each of these reports is accompanied by a geologic map showing the general interpretations based on the data which were assembled for that portion. Progress Report No. 8 discusses the section from Norway to Waucedah and includes also some probabilities regarding the general geologic structure of the Menominee Range and the relation of ore bodies to geologic structure. The third report is accompanied by a geologic map of the entire restudied area, i. e. the south range.

Although the field work in 1942 was done in the same area, the objectives in this year were specifically directed toward the occurrences of iron ore. One part of the program involved the attempt to find localities in which drilling or other exploration might possibly reveal high grade iron ore masses. The other part of the work concerned the possibilities of concentrating selected lean iron ores to an acceptable product of higher grade.

In the compilation and interpretation of data for this 1942 report the writer was very capably assisted by Mr. B. J. Westman and his services are gratefully acknowledged. The geological work, both for the past summer and for previous field seasons, has been under the direction of Franklin G. Pardee, Mining Engineer, and Gerald E. Eddy, Mining Geologist, of the Geological Survey Staff.

GENERAL GEOLOGY OF THE AREA

The investigation was very directly dependent upon the information resulting from previous geologic and exploratory work in this area. A resume of the most important features will provide a foundation for some of the discussion in later portions of this report.

A normal succession of the strata has been recognized for some time. The Randville dolomite is the lowermost formation of the succession accompanying the iron-bearing layers. The dolomite is overlain by a series of slates and quartzites which were designated as "Traders" slates in Monograph 46 of the United States Geological Survey, and "Footwall" slates by L. M. Scofield, geologist for Pickands Mather & Company. The Traders iron formation is next in the succession and typically consists of an alternation of layers in which hematite is more abundant than silica, with layers in which the relative abundance is reversed. Above the Traders iron formation are the quartzose to quartzitic slates known as the Brier formation, and then the Curry iron formation, which is essentially similar to the Traders iron formation. Slates with some quartzite zones are commonly present in a position which suggests that they represent higher portions of the succession.

These have been called the Loretto slate and the Hanbury slate.

Although this succession has been repeatedly substantiated, uncertainties remain as regards the proper designation of the strata in some exposures. The Randville dolomite presents few problems of identification. The Traders and Curry iron can usually be distinguished from each other because the jasper in the Curry formation is conspicuously granular, whereas most of the jasper in the Traders formation is very fine grained. Those members of the succession in which slates are abundant cause the greatest difficulties of identification, and final decisions regarding all such strata do not seem possible at the present time. For example, some strata which have been thought to be Loretto slate or Hanbury slate may be reclassified when more work has been done on the problem.

An entirely different kind of rock in the area was formed by the solidification of molten material which was injected along fractures in the rock strata. These masses, known as diabase dikes, have been altered to a rock of reddish brown color and have cracked so extensively that there are very few fragments whose dimensions exceed one inch. The dikes are commonly one to two feet wide, but a dike in the east end of the Perkins pit at Norway has a width of about ten feet. Exposures of dikes are most abundant on the prominent hill north of the town of Norway, but dike material constitutes a very small proportion of the bedrock surface.

The general arrangement of the formation is indicated by their northwest-southeast trend, their steep downward inclination toward the south, and the occurrence of progressively younger formations southward from the Randville dolomite which normally occupies the northernmost position in the area. Locally, there are decided departures from these general conditions, i. e. strike may vary considerably because of folding and faulting; dip may be northward due to overturning; and formations may be repeated or missing as a result of faulting. A well defined fault pattern in the region consists of systems of faults parallel to one of four general directions: (1) northeast-Southwest, (2) northwest-southeast, (3) nearly north-south, and (4) approximately east-west. Some folds are present also, but faulting is much more prevalent in the area.

The three earlier Progress Reports on this area have shown that the occurrences of iron ore are apparently related to faults, although ore deposits are not present in some localities where faults exist. The soft blue ore of the Menominee Range is believed to have originated by a leaching action which removed the silica of the iron formations, and thus concentrated the residual hematite into masses of high grade iron ore. One important prerequisite for the operation of such a leaching process would be very active circulation of the ore-forming solutions. It is likely that the shattering of the formations adjacent to the fault zones provided passageways for the silica-dissolving solutions whose activity is little understood, but which was, nevertheless, localized and very effective. Furthermore the record of mining in this area shows that more iron ore has been produced from the Traders iron formation than from the Curry iron formation. In several localities the two iron formations are displaced by the same faults and ore bodies are present in the Traders formation, but similar enrichment has not occurred in the Curry formation. It is probable, therefore, that the minute differences in the lithology of these strata are sufficient to produce variation in the formation of ore bodies.

In addition to the soft blue ore, the production of some mines included a hard ore whose general appearance is somewhat like steel. The occurrences of this hard ore cannot be described because the writer has seen only fragments which were brought to the surface during mining operations. A comparison of the stratified structure of the hard ore with specimens of banded slates which are partially converted to hard ore suggests that this type of ore was produced by a replacement of the slates. This process of replacement is as little understood as the process of leaching, but it is hoped that proposed petrographic studies may help in the solving of these problems.

AREAS WITH POSSIBILITIES OF HIGH GRADE ORE

QUINNESEC AREA

Introduction

The Quinnesec area, northwest of the village of Quinnesec, includes portions of the southeastern quarter of section 34, T 40 N, R 30 W and the northeastern quarter of section 3, T 39 N, R 30 W. The southern margin is part of the extensive flood plain developed along the Menominee River but most of the area is part of a prominent hill whose crest, north of the area, rises about 300 feet above the plain.

Although some open pit mines were in the area, previous activity was essentially by underground operations. The Quinnesec mine had four shafts inclined northward from which ten levels were developed in the Traders iron formation. The Cundy mine operated two shafts and obtained ore from seven levels in the Curry formation. The Vivian mine, just west of the northwest part of the area, has two open pits and four underground levels developed in the Curry iron formation.

The accessibility of the Quinnesec area is shown by Plate 1 accompanying this report. The main line of the Chicago and Northwestern railroad and a spur to the Foote shaft of the Cundy mine are located along the south margin of the area, and several abandoned railroad grades cross the area. On the eastern side of the area, the county road which extends northward from Quinnesec and the road into the Quinnesec mine have good gravel surfaces, whereas a wood road, of rather steep grade, lies along the western edge of the area.

Geology of the Area

The materials covering the iron formations and associated strata in this region consist mainly of glacial debris but a sandstone caprock is also present in the northern part of the area. The overburden of glacial drift is normally less than eight feet thick and is the typical unsorted accumulation of boulders, sand, and clay. The caprock of Cambrian sandstone thickens to 400 feet as revealed by drilling near the northwest corner of the area and is characterized by a steep southern contact as if it had been deposited against a northward facing cliff of an ancient gorge, or a prehistoric seashore. The distribution of the sandstone is not shown on Plate 1, but that information can be obtained from Plate 30 of Monograph 46 of the United States Geological Survey.

The Pre-Cambrian rock formations exposed are those common to the Menominee Range. All are in normal facies as described in the previous part of this report. The Randville dolomite is present in ledges north of the Quinnesec mine. The slates and quartzites of the "Footwall" series are exposed only in the north wall at the Quinnesec mine. The Traders iron formation can be seen at the Quinnesec mine and in the small open pit to the east. The Curry iron formation is exposed in several trenches north of the quarter post between sections 34 and 3 and in numerous test pits southward in section 3 to the Foote shaft of the Cundy mine. The identification of the slates is very difficult because of the complex arrangement of all strata and the interpretation shown on the map is based mainly upon the character and relations of adjacent strata. The slates south of the iron formation at the Quinnesec mine are undoubtedly a part of the Brier formation and a similar distribution of formations exists at the small open pit which lies to the east. Slates were encountered in test pits or trenches between the Quinnesec mine and the Curry iron formation which extends across the southern part of section 34 and also between this occurrence of the Curry formation and one farther south in section 3. The map indicates that these slates were believed to belong to the Brier formation. The presence of slates and thin quartzite layers south of the Curry iron formation in section 3 was also revealed by test pits, but positive classification of these materials is lacking, although they have some resemblance to strata in the "Footwall" series.

The geologic map of the Quinnesec area shows that the iron formations and associated strata have a general northwest-southeast trend similar to most trends in the Menominee Range and the cross-sections show that their normal southward inclination exists in section 3. However, the strata in section 34 are not only inclined northward, as is so remarkably exhibited in the Quinnesec mine, but the original succession of formations is inverted--i.e., the Traders iron formation is overlain by the "Footwall" slates and is underlain by the Brier slates. The geologic map also shows two belts in which the Curry iron formation and Brier slates are present. This repetition and the inversion of the succession of strata might be the result of folding, faulting, or a combination of these deformations. The uniformity of the strikes and dips in the area, and the few folds found in exposures tend to support the probability of faults rather than folds. The faults shown on the map and sections are based upon: (1) interruptions in the trend of formations and of magnetic crests as determined by previous dip needle survey; (2) several diamond drill records; and (3) some mine maps. Perhaps, due to the lack of sufficient information, the details of this area have not been adequately determined, but the proposed interpretations indicate the type of arrangements which may be expected.

On the cross-sections, the fault which passes near the quarter post of sections 3 and 34 is shown in a vertical position. One interpretation of the geology indicates that the fault dips 75 degrees northward but insofar as is known no data concerning the inclination of the fault are available. Although the inclination of the fault and the actual movements of the faulted segments cannot be conjectured, the plan of displacements suggests that the northern side moved eastward and/or the southern side moved westward, but if this fault occurred earlier than the two faults to the north, its effects would undoubtedly have been modified during later deformation. The fault which passes south of the Quinnesec mine is presumed to be inclined northward inasmuch as such inclination offers a reasonable explanation for the limits of the Quinnesec ore body, and for unsuccessful exploration executed from the mine workings. The displacement along this fault appears to have been the result of a southward thrust of sufficient magnitude to overturn the succession of formations in the vicinity of the Quinnesec mine and carry the segments in the hanging wall south of their continuations across the fault, but erosion subsequent to faulting probably reduced the amount of gap which resulted from the original displacement. The most northerly fault in the area is also inclined northward as revealed by drill records and mine records in the area adjacent to the northern part of the western boundary. This fault apparently resulted from thrust directed southward and because of the incompetence of the "Footwall" slates the Traders iron formation was overridden by Randville dolomite.

Exploration of the Area

Suggestions as to the exploration of this area are specific applications of the general conclusions presented in the previous Progress Reports concerning the Menominee Range. Inasmuch as the history of mining here has shown that the Traders iron formation has been more productive of high grade ore than the Curry formation, and that the ore bodies of the Traders formation have been primarily associated with faults, the conditions in the Quinnesec area seem to warrant exploration at several localities.

Beginning at the northern part of the area, one project could involve the location of and evaluation of the segment of Traders iron formation which was previously joined to the segment in the Quinnesec mine. This exploration should be by drill holes which should begin north of the Quinnesec mine and be directed southward so as to pass north of and under the lower levels of the Quinnesec mine. These holes should be started between the points designated A' and B' at the northern ends of the lines of cross-section.

Both segments of the Traders iron formation produced by the fault whose trend carries it near the south quarter post of section 34 should be considered for exploration. This exploration should be by drill holes starting between the lines of cross-section. The cross-sections show that holes near A-A' section should be directed southward and those near B-B' section should be directed northward, but data from the first holes drilled in any new explorations might indicate some revisions of this plan for further operations.

It is unlikely that test pits or trenches will prove to be a satisfactory method of exploration in the Quinnesec area.

GREEN-CYCLOPS AREA

Introduction

The Green-Cyclops area is in the northern part of the town of Norway and is situated on the south slope of an elevation known as Norway Hill. This report concerns primarily an area 500 feet wide and

750 feet long in the central part of the southeast quarter of section 5, T 39 N, R 29 W. As indicated on Plate 2 accompanying this report, the area is readily accessible by road and although formerly served by the Chicago and Northwestern railroad it is now 2000 feet from the main line.

A number of abandoned mines are in the south half of section 5 as shown on the index map of Plate 2. The western part of the Green mine was developed as the usual type of open pit, but when operations were expanded eastward the method was changed to milling down the ore to a haulage level along which the ore was moved to a shaft for hoisting. The Cyclops mine was operated mainly as an open pit but some shallow underground operations extended westward under a sandstone caprock at pit No. 1. The Norway mine and the Perkins mine (also known as Saginaw or Stephenson mine) were underground developments, but now resemble abandoned open pit operations because of the extreme subsidence which has occurred.

Geology of the Area

The loose surface materials on Norway Hill are so extensive that there are few natural exposures of bedrock. The overburden consists principally of gravel, sand, and clay of glacial origin, at least 30 feet thick in places, but less than 10 feet thick over most of the area.

On the most easterly part of Norway Hill the iron formations and associated strata are immediately below the glacial drift, but elsewhere layers of Cambrian sandstone below the drift form a caprock on the underlying strata. Although this caprock is very thick in some parts of section 5, it is unlikely that it would interfere with the exploration of the area.

The rock layers below the caprock, or below the surface material where no sandstone is present, are similar to those found in many parts of the region, i. e. either iron formations or slates. In the Green-Cyclops area the Curry iron formation possesses its normal characteristics although much of it is fractured and contains cavities apparently developed by the removal of silica from jaspery portions. Locally, pockets of soft granular high grade ore seem to have developed by this process. The slates are essentially normal quartzose to quartzitic slates of the Brier formation, but in several places they are also fractured and sheared. So far as known, no other strata in the succession are exposed within the area, but several occurrences of dike material of normal characteristics may be noted.

The general trend and inclination of the strata have been complicated by folding and faulting of the rock layers, but the map and cross-sections show an interpretation of the available data. One prominent fault in the area has a northeast-southwest trend along the south sides of the Green and Cyclops pits. Another prominent fault brought the Curry and Brier formations adjacent to each other and is exposed in the northwestern corner of the Cyclops pit. The apparent trend of this fault is also northeast-southwest, and although it is possible that it is of greater magnitude than shown on the cross-section A-A', there is little evidence for any estimate of the amount of displacement. A third fault can be seen at the Curry-Brier contact in the western end of the Barbara pit. This fault may be an eastern continuation of the fault in the northwestern corner of the Cyclops pit as shown on the geologic map of Plate 2, or it may be an easterly branch from that fault. The fault in the western edge of the Barbara pit was not observed elsewhere in the pit, and consequently if it has a continuation eastward it may pass into the iron formation, or bend northward beyond the northeastern corner of Barbara pit, or be offset by a small adjustment fault of north-south trend as represented on the geologic map.

Except locally the rock layers in this area have a southward inclination as shown on the cross-sections of Plate 2, and consequently the Brier slates underlie the Curry iron formation. Then, inasmuch as no indications were observed that the normal succession of strata is not present in this locality, the Traders iron formation should be below the Brier slates, but so far as is known it has not been explored.

Exploration of the Area

As stated previously, the Traders iron formation has been more productive of high grade ore than the Curry formation, and the ore in both formations has been associated with fault structures. However, former mining and exploration in the Green-Cyclops area have been almost entirely in the Curry iron formation, including to some extent adjacent zones of the Brier slates. Inasmuch as the Traders iron formation should occur at depth and should be affected by the fault pattern described, it is possible that high grade ore may be present. The two conditions do not guarantee the presence of high grade ore, but undoubtedly warrant some exploration at this locality.

The ore in the western end of the Cyclops pit apparently developed in either the Brier slates or a slaty member at the base of the Curry formation, and because the overburden toward the east is commonly less than 4 feet, some exploration by trenching might be considered. Any such program ought to include several north-south trenches located north of the Green-Cyclops pits where faults occur in the Brier slates or at the Brier-Curry contact.

Exploration of the Traders iron formation in this area obviously requires a program of diamond drilling. The drilling should be done in a manner that will provide data concerning the Traders iron formation where it has been displaced by faults. On this basis four general situations should be investigated: (1) The area on the north side of the fault along the Green and Cyclops pits; (2) the area on both sides of the east-west fault north of the Green pit; (3) the areas adjacent to the fault through the northwestern corner of the Cyclops pit and the west end of the Barbara pit; and (4) the area under a zone of broken Brier slates located approximately 250 feet north of the Green pit.

The location and direction of drilling operations which would explore the possibilities in this area can be determined from the geologic map and cross-sections. Although data are insufficient to determine the arrangement of strata south of the fault along the Green and Cyclops pits, it seems advisable that exploratory drill holes should begin south of the fault and be directed northward at such an angle as to provide information concerning the strata between the surface and the point where the drill would pass through the fault to enter the iron formation north of the fault.

The fault which passes north of the Green pit and the fault from the Barbara pit to the northwestern corner of the Cyclops pit displaced the segments of the Traders iron formation in such a manner that separate drilling operations will be necessary to explore the possibilities of ore along these faults.

The cross-section B-B' shows that the Traders iron formation under the zone of broken slates along the northern edge of the area is likely to be so arranged that both segments could be explored by the same set of drill holes.

SOUTHWEST LORETTO AREA

Introduction

The southwestern part of the village of Loretto is included in the southwest Loretto area which extends westward to the Sturgeon River. The area consists of parts of the northeast quarter of section 13, T 39 N, R 29 W, and the northwest quarter of section 18, T 39 N, R 28 W. The dimensions of the area for which the formations are shown on the map, Plate 3, are approximately 2400 feet in length and 1400 feet in width.

The topography of the area has resulted primarily from the dissection of glacial deposits by surface run-off into the Sturgeon River. The glacial debris accumulated as floodplain or terrace deposits associated with streams which were carrying the discharge of outwash from melting ice.

No mines are in the area but some previous exploration was done by diamond drilling.

The accessibility of the area is well shown on Plate 3. U. S. Highway No. 2 crosses the length of the area and the Escanaba and Iron Mountain Railroad crosses the width of it.

Geology of the Area

The southwest Loretto area is extensively covered by surface deposits consisting of gravel, sand, and clay. Drill records show that these materials are at least 160 feet thick over some parts of the area, but a few outcrops of Randville dolomite are near the northern boundary.

Inasmuch as the iron formations and associated strata are not exposed, their identification must be inferred from the drill records which indicate that the strata are similar to those elsewhere in the Menominee Range. Absence of exposures also requires that the arrangement of formations be determined by the interpretation of drill records and of magnetic data obtained by previous dip needle survey. The general northwest-southeast trend and the southward inclination of strata seem to prevail in the area, but the duplication of iron formation in drill records and such notations as "soap rock," "mashed slates," and "sheared slates" show that complications evidently exist here.

The interpretations of the geologic structure in this area resulted from study of a series of cross-sections based upon drill records. The interpretations of the subsurface conditions were projected to the approximate bedrock surface and the geologic map was constructed. It should be readily apparent that in such a procedure informative data may be insufficient concerning the many complexities which actually exist at depth, but, nevertheless, the geologic map and cross-section present the probable structure of the area.

The principal complication in the arrangement of the strata seems to be the two faults indicated. The location of the northern fault is based upon explorations in the eastern part of section 18, and is extended toward the west because one record showed the Randville dolomite adjacent to an abnormally thin Traders iron formation near the iron pin at the sixteenth post. Insofar as known, no information concerning the inclination of this fault is available at the present time, but farther east the fault appears to have been the result of uplift on the northern side or a southward overthrusting of that area.

The southern fault is indicated in several records by such information concerning deformation as previously cited. In one place its probable position appeared to be vertical, but no other data concerning inclination are available. The distribution of formations along this fault as shown on Plate 3 reveals that the relative horizontal displacement of the northern segment was eastward and/or displacement of the southern segment was westward. The bulge of the Curry iron formation on the northern side of the fault may be the result of drag folding or of a branch fault associated with the fault indicated on the map. In the relative vertical displacement along the fault the northern block apparently moved downward and/or the southern block moved upward although the bend in the Curry iron formation complicated the relationships near the line of cross-section.

The highest dip needle readings and the upper limit of the Curry iron formation coincide throughout much of this area. In the southeastern corner, however, the crest of magnetic readings lies north of the upper limit of the Curry formation as projected from drill data. This relationship is probably indicative of further complexities, but sufficient information is not available at the present time to postulate concerning the arrangement of the strata.

Exploration of the Area

At the present time the best plan of exploration seems to be to test those localities in which the Traders iron formation has been displaced by faults and the southwest Loretto area apparently contains this combination of geologic conditions.

Most of the holes drilled during a previous exploration penetrated the Curry iron formation and associated strata, but did not enter the Traders formation. The other drill holes which provided information concerning the Trader formation encountered it at a considerable distance north of the fault which affected the Curry formation. Consequently the possibilities presented by the interpretation shown on the geologic map and cross-section have not been tested, although almost a dozen holes have been drilled in this area.

The position of the cross-section was selected especially to represent the minimum depth at which the Traders iron formation in the northern block is likely to be encountered adjacent to the fault. It would, therefore, seem advisable that exploration might begin at or near this part of the area, but similar geologic conditions should exist at greater depth both east and west of the line of cross-section. The segment of Traders iron formation in the southern block probably could be encountered adjacent to the fault at a minimum depth by explorations in the western part of section 18, but the trend of the magnetic crest suggests that complex relationships may exist there.

OTHER AREAS FOR EXPLORATION

Section 1, T 39 N, R 30 W

The area in section 1, T 39 N, R 30 W is located approximately two miles west of Norway and one mile east of Quinnesec. It is a portion of the general trend of iron formations which extends northwestward from Waucedah to beyond Iron Mountain, but, insofar as is known, it has not been explored thoroughly. The Bryngelson shaft is just west of the line between sections 1 and 2, and the Few mine is a short distance east of the boundary between section 1 and section 6.

The previous dip needle survey of the area between Norway and Quinnesec revealed that a magnetic belt extends through section 1. It was thought that the magnetic belt represented a westward continuation of the Traders iron formation which occurs at the Few mine and the Munro mine of section 6. However, no indications of a second magnetic belt to represent the Curry iron formation were obtained in this section, yet the formation is present in the sections adjacent to the east and west. The possibility that the magnetic zone represents the Curry iron formation rather than the Traders formation, or represents both formations, seemed untenable because the dip needle readings in this section are much lower than in nearby localities where the Curry formation is present.

The geologic maps accompanying Progress Reports No. 5 and No. 8 represent an interpretation of the conditions existing in section 1. The rock strata trend northwest-southeast and probably dip southward at high angles. If the magnetic crest through section 1 represents only one iron formation, the absence of the other iron formation would probably have resulted from faulting, apparently trending slightly north of west from the east quarter corner of section 1 to the Bryngelson shaft. Although this locality has no exposures of bedrock and the geologic conditions can be only inferred, it is possible that portions of the iron formations in the area have been converted to iron ore. Furthermore, as this area is one of the two localities in the southern belt of iron formations without record of any extensive explorations, it might, therefore, be very deserving of investigation.

LORETTO-WAUCEDAH AREA

The geology of the Loretto-Waucedah area is described in Progress Report No. 8 and is represented on the map accompanying that report. A belt of strata including iron formations extends southeastward from near the center of section 18, T 39 N, R 28 W, to the Breen and Emmett pits in the northern part of section 22, T 39 N, R 28 W. This part of the region is somewhat unusual because the Randville dolomite, which has been displaced upward and southward by faulting, seems to interrupt the continuity of the iron formations and associated strata through a distance of approximately 2½ miles. In this interval the Traders iron formation is apparently covered by overthrusted dolomite which locally covers the Brier slates and the Curry iron formation.

The determination of these general relationships was made possible by the study of drill records, which were, however, too incomplete to permit the deciphering of all the structural complications. Most of the holes in sections 17 and 18 encountered the Curry iron formation and the Brier slates, but then passed into the Randville dolomite. This relationship is part of the evidence of faulting in the area, and indicates that the relative displacement of the dolomite was upward. According to the proposed interpretation, these holes were not drilled at angles steep enough to encounter the Traders iron formation, which should be under the Brier slates and south of the fault. It is therefore likely that previous exploration did not test the possibilities in this area, and that further exploration should consider the advisability of drilling at steep angles in order to be more sure of obtaining information concerning the Traders iron formation.

Dip needle data in the southern part of section 16 indicates that the general northwest-southeast trend of the strata persists there, but no exposures of bedrock are present in or near the area. Drilling near the southeast corner of section 16 penetrated a succession of strata in which the Traders iron formation was at a depth of 500 feet and interpreting from projection it should constitute a part of the bedrock surface at the section corner. It is therefore reasonable to suspect that the Traders formation extends through the southern part of section 16, but it has not been investigated, and although data are insufficient to determine the location of arrangements of strata favorable for the concentration of iron ore, this area might possibly justify some exploratory drilling.

PRELIMINARY INVESTIGATION OF LEAN IRON ORES

Throughout most of the Menominee Range the Traders and the Curry iron formations are composed of layers having variable proportions of hematite and silica. Some layers are predominantly grains of the specularite variety of hematite with minor amounts of quartz grains. Other layers in which the ratio of the hematite and silica is reversed are known as jasper. The jaspers have a flint-like texture resulting from the variety of silica present, and usually have a maroon to purple color, because hematite is present as a finely divided pigment but may occur as specularite also. In addition to these extreme types of layers, many others of intermediate composition are present. Inasmuch as the iron formations consist of such layers in a variety of successions and thicknesses, the composition of the Traders formation differs from the Curry formation, and specimens from the same formation in different localities exhibit an equally wide range in composition.

In a few places the masses in which hematite was predominant have been sufficiently large so that they were bodies of high grade minable ore, but in other places the proportion of hematite is too low to be extracted profitably, although the total iron content may be very large. If, however, a mechanical technique of separating the hematite from silica could be devised, the iron formations in some places possibly could be concentrated to high grade iron ore. The remaining portion of this report deals with some preliminary investigations of these possibilities.

Five samples of iron formation were obtained from localities in which the overburden is thin; the volume of iron formation is large; the shipping facilities are good; and operation of an open pit would be possible. A further consideration in determining the localities to be sampled was the desire to obtain material in which a predominance of the silica appeared to be segregated into thick bands of jasper. This was advisable because it was hoped that concentration could be effected without fine grinding, as the cost of the fine grinding prohibits its use in recovery of most lean iron ores at the present time.

One sample (#201) of the Curry iron formation was obtained at Iron Mountain. The material was taken from exposures and from an abandoned pit mine at the west end of the prominent hill south of the caved ground of the Chapin mine. The hill is approximately 200 feet high and the iron formation underlies an area about 600 feet wide by 3600 feet long.

In the hill northwest of the village of Quinnesec the Curry iron formation is in two belts, and material from the southern belt comprised another sample (#205). The Curry iron formation at this locality rises about 80 feet on the south side of the hill, and an open pit mine could be approximately 300 feet wide and 1400 feet long.

A sample (#204) of the Traders iron formation was collected from test pits and dumps of abandoned pit mines in the northeast quarter of the southwest quarter of section 5, T 39 N, R 29 W. The area underlain by this iron formation is approximately 300 feet wide and 800 feet long. There is a rise of about 50 feet from the southern boundary to the northern limit of the formation.

The area of the Curry iron formation best suited to open pit operation in the same portion of section 5 is somewhat triangular in shape, contains approximately 300,000 square feet, and has a difference in elevation of about 40 feet. (Sample #203).

Another sample, (#202) of the Curry iron formation consisted of material from the east wall of Cyclops pit No. 1. The iron formation in this vicinity is approximately 250 feet wide, extends through a distance of 1000 feet, and the part of the southward slope which is underlain by it rises about 40 feet in elevation. The Green and Cyclops pits were operated within this area. Their dimensions are shown on Plate 2 of this report.

These samples were tested by the Ore Dressing Department at the Michigan College of Mining and Technology. The results of investigation are presented as an appendix to the present report.

APPENDIX

SAMPLE TESTS

The examination of the samples and their testing for concentration possibilities was done at the Michigan College of Mining and Technology under the direction of N. H. Manderfield. The samples were crushed and screened and then the possibilities of gravity separation were tested by the sink-float method described in a paper by Frank J. Tolonen at the New York meeting of the American Institute of Mining and Metallurgical Engineers in February 1933. The paper was listed as Contribution #46 and was entitled "Gravity Concentration tests on Michigan Iron Formation."

The complete report on the results of these tests is too voluminous to include here. The following summary gives the essential facts obtained. The samples were crushed to 3 mesh (¼"), a size which would be practical for gravity concentration. The information in the two following tables was taken from the graphs made up as a result of the tests.

Assuming that a 51.50% iron natural would be acceptable, and also that the moisture content of the concentrate would be approximately 8%, the dry analyses of the iron ore concentrates should be close to 56%. Table I then shows the amount of concentrate that could be obtained:

Table I

Sample No.	Percent Wt. Recovery	Percent Metal Recovery	Percent Fe (dry)	Percent SiO_2 (dry)
201	6	10	56	18
202	12	19.5	56	18
203	16	27	56	18
204	20	35	56	18.5
205	Nothing worthwhile			

If it is assumed that at least a 35 percent weight recovery is necessary, the following information is obtained from the graphs:

Table II

Sample No.	Weight Recovery	Metal Recovery	Percent Fe Dry	Percent SiO_2 Dry
201	35	49	49	29
202	35	50.5	49	27
203	35	55	52	25
204	35	56.5	51.5	25
205	35	50	49	27

The screen analysis of sample #204 also gives some information on the possibilities of concentrating these lean formations by gravity methods.

Table III

Screen Analysis of Sample number 204

Size	Weight	Percent weight	Percent Fe	Weight Fe	Percent Total Fe
+ 4	380	16.81	32.8	55.14	17.03
-4 + 6	448	19.82	31.4	62.23	19.22
-6 + 8	332	14.69	33.6	49.36	15.24
-8 + 10	264	11.68	31.4	36.68	11.33
-10 + 14	169	7.48	32.7	24.46	7.55
-14 + 20	138	6.11	32.7	19.98	6.17
-20 + 28	100	4.43	32.7	14.49	4.48
-28 + 35	75	3.32	32.8	10.89	3.36
-35 + 48	59	2.61	31.6	8.25	2.55
-48 + 65	50	2.21	29.8	6.59	2.04
-65 + 100	45	1.99	28.3	5.63	1.74
-100	200	8.85	34.0	30.09	9.29
	2260	100.00	32.38	323.79	100.00

Sample #204 Was further crushed to 10 mesh and the results obtained were closely parallel to those reported above.

This laboratory work shows clearly the intimate mixture of the hematite and the silica in the formations sampled.