GEOLOGICAL SURVEY CIRCULAR 84

September 1950

PROGRESS OF GEOLOGIC WORK IN IRON AND DICKINSON COUNTIES, MICHIGAN

By

Carl E. Dutton

PREPARED IN COOPERATION WITH THE GEOLOGICAL SURVEY DIVISION
MICHIGAN DEPARTMENT OF CONSERVATION

UNITED STATES DEPARTMENT OF THE INTERIOR
Oscar L. Chapman, Secretary
GEOLOGICAL SURVEY
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WASHINGTON, D. C.

Free on application to the Geological Survey, Washington 25, D. C.

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CONTENTS

ILLUSTRATIONS

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INTRODUCTION

Location and extent

The areas considered in this report (fig. 1) are in the southeastern part of the Lake Superior region--along the base of the northern peninsula of Michigan.

The Iron River-Crystal Falls district is in the central part of southern Iron County; the district is 15 miles long and from 4 to 9 miles wide.

The Menominee district is in the southern part of Dickinson County; the length is approximately 20 miles, and the width ranges from 6 to 12 miles.

The Felch Mountain district is in the central part of Dickinson County, is about 15 miles in length, and ranges from 1 to 2 miles in width.

Objectives of program

The geologic work done in the Lake Superior region over a period of many years by individuals, mining companies, State Geological Surveys, and the U. S. Geological Survey is well known, and many valuable reports have been published. Nevertheless, much additional information from exploration, mining, and geologic studies has continued to become available, and the recent investigations in Iron and Dickinson Counties by the Geological Survey have sought to bring together as much of this information as can be obtained. The objective in the work has been a better understanding of the lithology, stratigraphy, and structure in each of the districts by means of detailed geologic mapping and a compilation of all available basic data. An essential part of the program is that much information becomes recorded and, if not confidential, may be used by other geologists interested in clarifying the concepts for the districts and for the region.

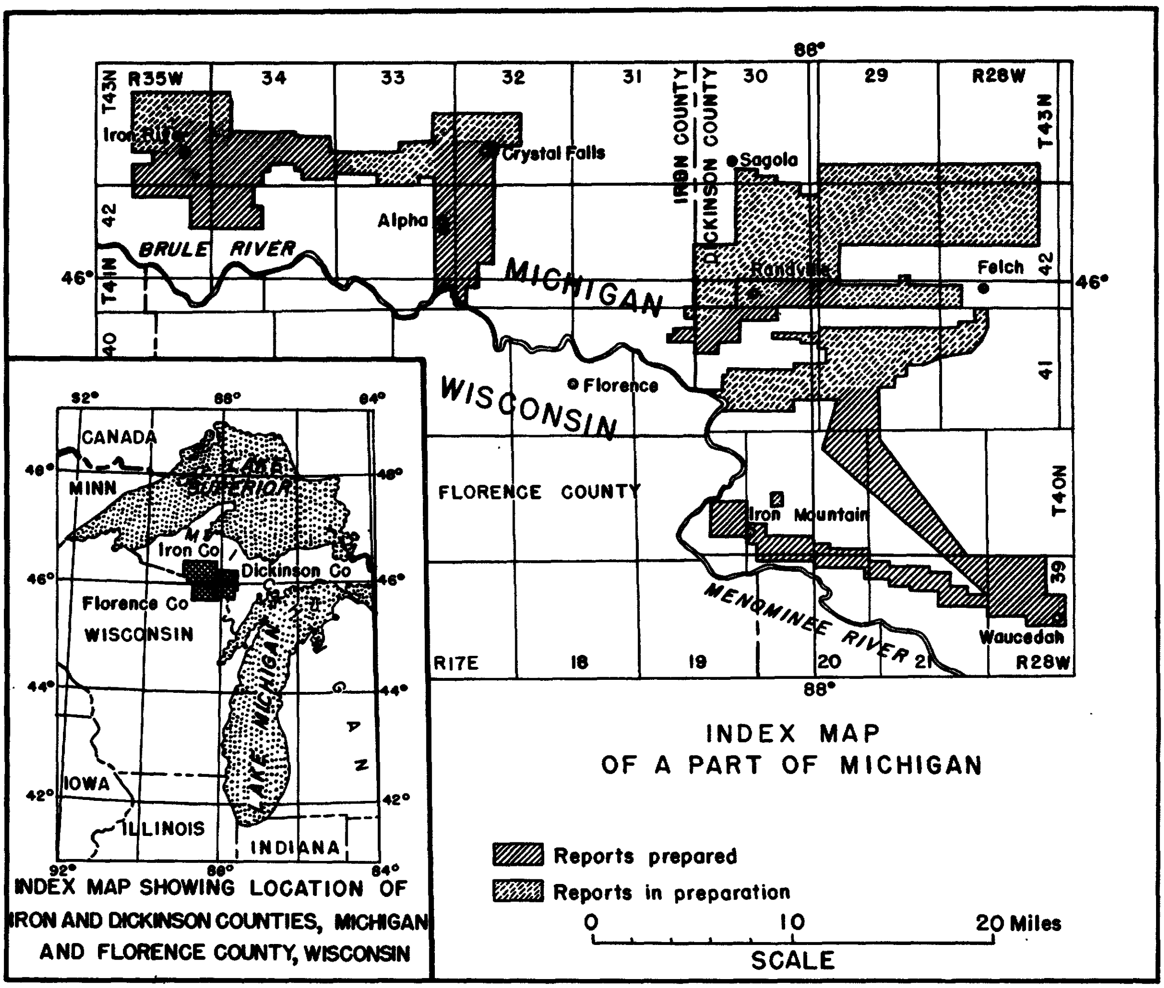

Figure 1. ---Index maps showing location of areas studied.

This report presents only the progress of investigations and summarizes the recent publications that have resulted from the work, but an ultimate objective of the program will be the preparation of comprehensive geologic reports concerning each district.

A restudy of the geology of the areas was begun in southern Dickinson County in 1937 by the Geological Survey Division, Michigan Department of Conservation, and was continued for five consecutive field seasons. A cooperative investigation by the U. S. Geological Survey and the Michigan Geological Survey started in 1943 with work in Iron County and was extended to central Dickinson County when reexamination of the geology of the Felch Mountain district began in 1945. Work in the adjacent parts of central Dickinson County began in 1947.

In addition to geologic field work, the preparation of new topographic maps and an aeromagnetic survey of the two counties have been included in the cooperative program.

Acknowledgments

The officials of mining companies have contributed to the work by granting admittance to mines for geologic mapping and to storehouses for examining drill cores, by furnishing information and innumerable prints of mine and exploration data, and particularly by providing many pleasant personal relationships. Grateful recognition of this cooperation is expressed to the Cleveland-Cliffs Iron Co., the former Davidson Ore Mining Co., Globe Iron Co., M. A. Hanna Co., Inland Steel Co., Jackson Iron and Steel Co., Jones and Laughlin Ore Co., Mineral Mining Co., North Range Mining Co., Pickands, Mather and Co., and Republic Steel Corporation.

The cooperation of the Geological Survey Division, Michigan Department of Conservation, in the investigation is especially acknowledged, and the work has benefited greatly from the discussions and counsel of G. E. Eddy and F. G. Pardee. B. E. Kennedy of the Michigan Geological Survey assisted in a part of the field work of 1948.

Acknowledgment is made also for the contributions of the U. S. Geological Survey personnel who have participated directly in the program. The summaries presented here have been prepared from field data, manuscripts, and preliminary reports of the following geologists: J. R. Balsley, Jr., L. D. Clark, Jacob Freedman, S. E. Good, J. J. Hill, H. L. James, C. A. Lamey, C. F. Park, Jr., F. J. Pettijohn, L. E. Smith, J. H. Trow, K. L. Wier, and the writer.

General geology

Much of the bedrock in Iron and Dickinson Counties is covered, locally to a depth of 500 feet, by a mantle of materials that is largely till, outwash, or alluvium.

The principal sedimentary rocks of the areas are of Huronian age and are quartzite, dolomite, iron-formation, graywacke, and a variety of slates.

These sedimentary rocks overlie unconformably granite gneiss, schist, or greenstone.

The strata of Huronian age and the older crystalline rocks are intruded by granite that was later than one set of diabase dikes and earlier than another set.

The strata of Huronian age are highly deformed in each of the districts, and some of the structural patterns have not been fully determined.

PROGRAM IN IRON COUNTY

Iron River-Crystal Falls district

General information.--The Iron River-Crystal Falls district is in southern Iron County (pl. 1). The Iron River area is at the western end of the district and is 15 miles from the Crystal Falls area at the eastern end. The limits of the areas are indefinite and the shapes irregular, but the Iron River area includes about 25 square miles and the Crystal Falls area about 15 square miles.

Iron ore was first shipped from the district in 1882. Approximately $3\frac{1}{2}$ million tons of iron ore was produced in 1948 from 11 mines in the Iron River area. A little more than one-half million tons of iron ore was produced from two mines in the Crystal Falls area in 1948. Total shipments from these areas through 1948 have exceeded 125 million tons.

A small amount of iron ore was formerly produced from a few mines several miles east of Crystal Falls, but the geology of the area has not been studied sufficiently to be included in this discussion.

The methods of investigation in this work have been adapted to the variety of conditions present. Exposures of bedrock in the western half of the district are small in area and few in number, but the geology in the extensive mine workings in the Iron River area has been mapped, and many thousands of feet of drill core have been examined. Outcrops are moderately abundant in the Crystal Falls area, and much drill core has been examined, but few mine workings have been accessible. The geologic work in the district has been supplemented and supported by magnetic surveys with magnetometers and superdips along traverse lines that were generally 300 feet apart. Maps that show geologic and magnetic data, and also interpretations of stratigraphy and structure have been compiled at scales of from 200 feet per inch for some maps to 1,000 feet per inch for others.

Character and succession of strata.--The recent geologic investigations in the Iron River-Crystal Falls district have provided much information concerning the character and succession of the strata associated with the ore-bearing formation. The similarity of general features is well established, although some local differences exist in each area.

Strata older than the iron-formation are predominantly "slates", the youngest unit of which is a laminated graphitic rock that contains abundant pyrite that is commonly so fine grained as not to be seen with the unaided eye. The next older unit is a massive graphitic slate breccia composed of fragments of graphitic slate embedded in fine-grained graphitic matrix. Locally some fragments of gray slate are present. This unit is an important marker bed and can be recognized easily because of its distinctive lithology. The breccia is underlain by sericitic slate, nonsideritic slate, and some fine-grained graywacke. These materials constitute the lowest stratigraphic unit identified thus far in the area.

The unoxidized iron-formation consists of interbedded, gray fine-grained siderite, and dark gray to black chert. The siderite and chert are in about equal quantities and are in layers from half an inch to 2 inches in thickness, but variations in composition and thickness are common. Where the iron-formation has been oxidized, the siderite has been converted to iron oxides (hematite and "limonite"); and where these oxides are present, the color of the chert generally is white or light buff. The iron ore is composed of iron oxides with little or no chert.

In some places the upper part of the iron-formation is a breccia composed of conspicuous, angular chert fragments and indistinct siderite fragments in a matrix of siderite. The fragments range in size from chips so small that a hand lens or microscope is necessary to identify the material to slabs 12 inches in length and 2 inches in thickness. Where this breccia is oxidized, the same changes have taken place as in the unbrecciated iron-formation.

Most of the strata younger than the iron-formation are graywacke, but some are slate. In many parts of southern Iron County the iron-formation is overlain stratigraphically by a breccia, in which chert fragments are few and scattered in a graywacke matrix, or chert fragments are practically the only material present. This breccia unit is also a marker bed for the determination of relative position in the succession of strata. At some places in the vicinity of Iron River the strata immediately younger than the iron-formation are local stratigraphic units of graphitic slate or sideritic slate that are absent elsewhere. The breccia and any local strata are succeeded stratigraphically by massive, thick-bedded graywacke.

The next younger stratigraphic unit, and the youngest one thus far recognized in the Iron River area, is a magnetic slate. It is a third marker bed and is especially important in geologic mapping because magnetic surveys can generally determine the distribution of this unit, where present, in areas without outcrops. The magnetic slate has pronounced variations of color, texture, structure, and composition, but one common variety is distinctly banded and cherty, and breaks along curved surfaces; whereas another is massive and finely micaceous, and breaks along parallel cleavage surfaces.

Structure. --The iron-formation and associated strata have been traced for a little more than half the distance from Iron River to Crystal Falls and form the northern limb of an inferred structural basin of triangular plan. The strata in the eastern limb of the basin trend southeastward from Crystal Falls to and beyond the village of Alpha, and seemingly extend to Florence, Wisconsin. Few data concerning the southern limb of the basin are available, but presumably the strata trend southeastward from the Iron River area and extend to Florence, Wisconsin, also.

The structure in the vicinity of Iron River is characterized by steeply dipping strata in normal or overturned limbs of numerous folds of several orders of magnitude. The trends of the fold axes are commonly in two directions at right angles to each other, but the two directions are not the same in all parts of the area. Furthermore, plunges in opposite directions along the axes of folds produce many undulations, and the resulting map pattern resembles the grain in sheets of plywood. Rotation of the fold axes slightly beyond vertical locally has reversed or overturned the plunge of a few folds, and thus an anticlinal arrangement of strata (oldest unit in the center) has a synclinal form (strata dip toward axis) or vice versa. Mining operations have reached the iron-formation in the bottom of many shallow folds, but some of the major structures extend below present workings, which are approximately 2,000 feet under the surface. Some faults are parallel to the trend of the axis of adjacent folds and have considerable displacement, as is shown by one in which the magnetic slate in the sequence that is younger than the iron-formation is in contact with the graphitic slate that underlies the iron-formation.

Similar structural features also extend eastward for half the distance to Crystal Falls, but mapping the geology in the intervening area will be difficult because outcrops, available drill data, and distinctive magnetic data are sparse.

The geologic structure in the vicinity of Crystal Falls has not been determined fully, but its general form is that of a syncline. The strata on the north trend eastward for a distance of about 4 miles, then turn toward the northeast, and appear to be terminated abruptly; the belt of strata that extends northward toward Crystal Falls also is terminated abruptly. This interruption in the continuity of the iron-formation undoubtedly has been produced by faults or by an unconformity, but thus far the cause of the interruption has not been determined definitely. An unusual feature of the northern side of the structure is the southeastward plunge of the secondary folds, where-as the general plunge of the major structure normally would be westward.

From Crystal Falls the belt of iron-formation and associated strata trends generally southward in a great arc that is convex toward the west. In detail this belt consists of a series of northwesterly plunging folds in which the width of outcrop of the iron-formation has been greatly increased by repetition in folds.

The geology along the southern side of the supposed basin has not been examined as a part of the present work in the area. Drilling explorations are few and outcrops are virtually absent for about 10 miles along the inferred extension of the iron-formation southeastward from the southeastern part of the Iron River area. Earlier magnetic surveys made with a dip needle give practically no indication that the magnetic slate extends through this part of the area, but a reconnaissance survey with the magnetometer may be made to appraise the possible value of the data for geologic mapping.

Masses of greenstone composed of extrusive and some intrusive material are north, south, and east of the Iron River-Crystal Falls district. This greenstone probably is older than the strata described above and may be the foundation on which the beds rest. The original contact of the greenstone with the strata may be an unconformity of major importance, but at some places the materials probably are now adjacent to each other along faults.

Status of program.--The investigations in the Iron River-Crystal Falls district have led to clarification and revision of the concepts of the local stratigraphy and geologic structure. A series of preliminary reports has been issued to make information available for use in mining and exploration, and so that the preliminary concepts might be tested, discussed, and revised prior to formal publication.

Four reports 1/ have been issued for areas in the western part of the district, and two other reports 2/ are in preparation.

Three reports 3/ have been published for areas in the eastern part of the district, and two reports 4/ are in preparation.

Most of the field work for the present investigation has been completed, and further work will be principally the preparation of a comprehensive report on the district.

Aeromagnetic survey of Iron County

Surveys by an airborne magnetometer have been made for several parts of the Lake Superior region, and one area surveyed was Iron County. In general, the flight lines or traverses were along north- or south-trending lines at intervals of approximately a quarter of a mile and at an altitude of about 500 feet above the surface of the earth. The variations in magnetic intensity were measured by the magnetometer, which was towed below and in back of the plane. By means of electrical circuits the variations in magnetic intensity controlled the movement of a pivoted arm on the free end of which a pen was mounted. The results of each traverse flight were thus recorded as a graph line on the surface of a roll of coordinate paper that moved at uniform speed under the activated pen.

A report on the aeromagnetic survey 5/ has been prepared for a part of Iron County that is 13 miles wide, with Iron River near the middle, and extends 72 miles northward from the south edge of Iron County into Baraga and Houghton Counties. No important anomalies are related to the iron-formation of the Iron River-Crystal Falls district inasmuch as this stratigraphic unit is magnetic in only a few places. Some anomalies in the southern part of Iron County are produced by the magnetic slate in the sequence above the iron-formation, and although magnetometer surveys on the ground have been indispensable in geologic mapping of the district, the folding of the magnetic slate is too complex in many places to be satisfactorily determined by data from the airborne surveys. Other anomalies are produced by some parts of the masses of greenstone on the flanks of the district. A pronounced, positive anomaly near the northern limit of Iron County appears to be related to abundant fine-grained magnetite in a dark laminated slate; others to the south possibly are also related to this slate; but for some the cause has not been determined. Negative anomalies are caused by diabase dikes that are negatively polarized.

Eastern Iron County has been surveyed magnetically along two sets of flight lines that form a rectangular grid pattern. The first flights were along north- or south-trending lines, but these traverses were parallel to the trend of the strata in so much of the area that additional traverses along east- or west-trending lines were flown in 1949. Much geologic field work will probably be necessary before a report on the results can be prepared.

PROGRAM IN DICKINSON COUNTY

Menominee district

General information.--The Menominee district in southern Dickinson County (pl. 2) is approximately 20 miles long, 10 miles wide on the west, and 6 miles wide on the east. Iron Mountain, the principal town, is near the western end of the district; the town of Norway is approximately in the center; and the village of Waucedah is at the eastern end.

Two mines were in operation in 1948 and produced approximately 85,000 tons of siliceous iron ore, but previously a mine at Iron Mountain had produced 27½ million tons of high grade ore up to 1934; one mine at Norway produced more than 11 million tons of ore through 1931, and another produced about 20 million tons of ore to the close of operations in 1945. No high grade ore has been shipped recently, but the total shipments through 1945 were approximately 81 million tons.

A variety of field methods has been used in the different parts of the district. Exposures of bedrock

[1] Dutton, C. E., Park, C. F., Jr., and Balsley, J. R., Jr., General character and succession of tentative divisions in the stratigraphy of Mineral Hills district, Iron River, Iron County, Michigan: U. S. Geol. Survey Prelim. Rept., 4 pp., 1945.
James, H. L., Clark, L. D., and Smith, L. E., Magnetic survey and geology of the Ice Lake-Chicagon Creek area, Iron County, Michigan: U. S. Geol. Survey Strategic Min. Inv. Prelim. Rept. 3-213, 11 pp., 1947.
James, H. L., and Wier, K. L., Magnetic survey and geology of the eastern and southeastern parts of the Iron River district, Iron County, Michigan: U. S. Geol. Survey Circ. 26, 18 pp., 1948.
Dutton, C. E., Geology of the central part of the Iron River district, Iron County, Michigan: U. S. Geol. Survey Circ. 43, 9 pp., 1949.

[2] James, H. L., and Dutton, C. E., Geology of the northern part of the Iron River district, Iron County, Michigan, in preparation.
James, H. L., Iron-formation and associated rocks of Iron River district, Michigan, in preparation.

[3] Pettijohn, F. J., Geology of the Crystal Falls-Alpha iron-bearing district, Iron County, Michigan: U. S. Geol. Survey Strategic Min. Inv. Prelim. Map No. 3-181, 1947.
________, Magnetic and geologic data of parts of the Crystal Falls-Alpha iron district, Iron County, Michigan: Michigan Dept. Conserv., Geol. Survey Div., 9 pl., 1948.
Good, S. E., and Pettijohn, F. J., Magnetic survey and geology of the Stager area, Iron County, Michigan: U. S. Geol. Survey Circ. 55, 4 pp., 1949.

[4] Pettijohn, F. J., Geology of the northern Crystal Falls area, Iron County, Michigan, in preparation.
James, H. L., and Hill, J. J., Magnetics and geology of the Fortune Lakes area, Iron County, Michigan, in preparation.

[5] Balsley, J. R., Jr., James, H. L., and Wier, K. L., Aeromagnetic survey of parts of Baraga, Iron, and Houghton Counties, Michigan, with preliminary geologic interpretations: U. S. Geol. Survey Geophys. Inv. Prelim. Map, 1949.

on the "iron range" in the southern part are moderately abundant in localities near mines and explorations but are scarce or absent in much of the area. The location of outcrop data and of magnetic data obtained by use of Lake Superior type dip needles was determined by a rectangular grid of traverses made with sun-dial compasses and pacing between points at taped intervals of one-eight mile along the section lines. Data concerning abundant outcrops in the northern part were compiled on aerial photos and in notebooks, and a geologic map was prepared by use of a Sketchmaster. A small area in the central part, where much bedrock is exposed around surface mine workings, was mapped with plane table and alidade.

Character and succession of strata. --In ascending order the stratigraphic units that are generally recognized in this district are (1) conglomerates, slates, and graywackes of pre-Sturgeon age, (2) Sturgeon quartzite, (3) Randville dolomite, (4) a series of slates, graywackes, and quartzites, (5) the ore-bearing part of the succession--the Vulcan iron-formation--composed of the Traders iron-formation member, the Brier slate member, and the Curry iron-formation member, (6) the Loretto slate of R. C. Allen and (7) the Michigamme slate, at one time called the Hanbury.

Difficulties in geologic mapping arise in trying to distinguish between the two iron-formation members of the Vulcan and to determine the correct stratigraphic position of the different slates. One very good marker bed in the succession is a coarse-grained ferruginous quartzite at the base of the Traders iron-formation member. This bed is a persistent unit; it occurs at practically every place where the base of the Traders is exposed or explored, and much of the structural interpretation in the district is based on the distribution of this unit.

The iron-formation members are composed of alternate layers of jasper, and micaceous hematite with some magnetite. The principal distinguishing feature of the two units is that the jasper in the Curry iron-formation member is invariably granular (best seen when the surface is moistened) or looks somewhat like a quartzite because of the recrystallization of the silica, whereas the jasper in the Traders iron-formation member generally is of much less conspicuously granular texture except in thin sections.

Distinguishing the three slate units is generally difficult, but sericitic slate with quartzite or graywacke bends is rather generally and definitely considered to be stratigraphically below the Traders iron-formation member.

In addition to the above lithologic features that aid in geologic mapping, the Vulcan iron-formation generally can be traced by magnetic surveys made with dip needles. Along traverses at right angles to the strike of the strata the magnetic intensity is higher for the Curry iron-formation member than for the Traders iron-formation member, and the magnitude of the magnetic intensity varies greatly along the strike of both iron-formation members. A feature of special significance in exploration is the great decrease of magnetic intensity in the vicinity of several abandoned mines.

Structure. --The general trend of strata in the Menominee district is west-northwest, and the dip to the south-southwest is generally steep. The Vulcan iron-formation is exposed in a southern belt or "range" that extends 25 miles from Waucedah to beyond Iron Mountain. Many exposures of dolomite occur on the northern side of the iron-formation. A second belt of Vulcan iron-formation is in two segments that are separated by a distance of 5 miles; it is north of, and parallel to, the southern belt. Dolomite is exposed in a number of places on the northern side of the second iron-formation belt. Because the succession is repeated in the same order in these two belts, it is probable that the belts are separated by a fault that parallels them and produces the repetition. Results of recent drilling indicate that, probably, there are one or more longitudinal faults between the second belt of iron-formation and the Sturgeon quartzite to the north and the northeast. This system of faults with a general northwesterly trend is indicated also by some displacements where units of the succession have been repeated or omitted in the southern range.

A second system of faults has a general northeasterly trend and is very well represented in the southern range and in the belt of Sturgeon quartzite. The intervening belt of the Vulcan iron-formation and associated strata has not been restudied in detail as yet, but presumably both systems of faults are also there.

From the eastern edge of the district the Sturgeon quartzite extends in an arc that is convex to the southwest. Investigations in this part of the district by Pettijohn 6/, Higgins 7/, and Trow 8/ have revealed that the quartzite belt is terminated abruptly about 6 miles southeast of Randville, and exposures of Sturgeon quartzite approximately 6 miles to the west probably the extension of the belt that has been displaced by a fault of westerly trend.

Status of program. -- The investigations by the Michigan Geological Survey dealt primarily with the southern belt of iron-formation and associated rocks. A series of four reports 9/ has been issued, but much work remains to be done.

During the field season of 1948 the western end of a belt of iron-formation about 2 miles northeast of the town of Iron Mountain was mapped by R. B. Hall and assistant.

An over-all restudy of the Menominee district is planned, and work will be resumed in the near future.

[6] Pettijohn, F. J., Basal Huronian conglomerates of Menominee and Calumet districts, Michigan: Jour. Geology, vol. 51, pp. 387-397, 1943.

[7] Higgins, J. W., Structural petrology of the Pine Creek area, Dickinson County, Michigan: Jour. Geology, vol. 55, pp. 476-489, 1947.

[8] Trow, J. W., The Sturgeon quartzite of the Menominee district, Michigan: A thesis at the University of Chicago, 60 pp., 1948.

[9] Dutton, C. E., and Lamey, C. A., Geology of Menominee range, Dickinson County: Michigan Dept. Conserv., Geol. Survey Div. Prog. Rept. 5, 10 pp., 1939.

Lamey, C. A., and Dutton, C. E., Geology of Menominee range in the vicinity of Iron Mountain, Michigan: Michigan Dept. Conserv., Geol. Survey Div. Prog. Rept. 6, 14 pp., 1941.

____________________, Geology of Menominee range Norway to Waucedah: Michigan Dept. Conserv., Geol. Survey Div. Prog. Rept. 8, 20, pp., 1942.

Dutton, C. E., Economic geology of a part of the Menominee range: Michigan Dept. Conserv., Geol. Survey Div. Prog. Rept. 9, 22 pp., 1942.

Felch Mountain district

General information.--The Felch Mountain district in central Dickinson County (pl. 2) is about 1 to 2 miles wide and 15 miles long. The village of Felch is at the eastern end of the district, and the way station of Randville in the western part of the district is about 14 miles north of Iron Mountain on the Chicago, Milwaukee,St. Paul and Pacific Railroad. Slightly more than 250,000 tons of iron ore that was mainly of siliceous grade was produced by two mining operations.

The geologic data for this district have been obtained from exposures that range in number from scarce to moderately abundant in a few places. The location of the outcrops and the magnetic data with respect to section corners was determined by traverses with compass and pacing, using methods previously described for the Menominee district. The few drill cores from the district have been examined. No underground mine workings have been accessible during the investigation.

Character and succession of rocks.--The rocks in this district are somewhat similar in lithology and stratigraphic sequence to those of the Menominee district. The Sturgeon quartzite is overlain by the Randville dolomite. The next units in ascending order are (1) quartzite, (2) mica schist, and (3) Vulcan iron-formation that has alternate bands of hematite-magnetite, and granular quartz produced from recrystallized chert. No strata younger than the iron-formation have been recognized.

Outcrops are generally not abundant in the area, and much of the interpretation of geologic structure is based on the distribution of the iron-formation as determined by magnetic surveys.

Structure.--The strata of the district have an approximate north-easterly to easterly trend. The areal pattern of formations in the vicinity of Randville suggests that the general structure is probably a tightly folded and faulted syncline in which the iron-formation is the youngest bed of the sequence and therefore occupies a central position in the pattern. Further evidences of the synclinal structure occur about 6 miles east of Randville, where the belt of iron-formation apparently terminates without indications of faulting, and a little farther east, where the dolomite exposures are flanked by quartzite to the north and to the south. The structure in the vicinity of the village of Felch has not been deciphered yet, and the general scarcity of rock exposures throughout this district prevents an over-all verification of the tentative interpretation.

Magnetic data in the district indicate the presence of some faults that have produced offsets in the iron-formation and in the quartzite, and one fault that trends northeastward from Randville has thrust dolomite over the iron-formation. It is probable that faults have a very important part in the structural pattern of the district, but probably most of them will remain undiscovered.

The western part of the district has been mapped as far as the boundary between Dickinson County and Iron County and has revealed an interesting structural problem. The belt of iron-formation extends southwestward from Randville to the western side of Dickinson County where its trend changes to westward and then apparently to northwestward. The belt of quartzite on the south changes trend also but turns from southwestward to more southward. Although mapping in this part of the district has not been completed, some exposures of the quartzite have been discovered about $1\frac{1}{2}$ miles southeast of the southernmost outcrops in the belt described above. The relationships described above suggest that the limbs of the syncline diverge at the county line, but because of faulting the sequence of formations is not complete in either limb. No outcrops have been found on this part of the northern limb, but apparently the iron-formation can be traced into Iron County by magnetic surveys. The southern limb is represented by the belt of quartzite, but exposures of other formations have not been found, and earlier magnetic surveys do not indicate that the iron-formation lies below the surficial cover.

The iron-formation in the southeastern part of T. 42 N., R. 31 W., and in the adjacent part of T. 41 N., R. 31 W., deserves some further investigation of possibilities for iron ore. The areas of low magnetic readings may be of particular interest because of the probability that magnetite has been converted to hematite by thorough oxidation. The southern part of T. 41 N., R. 30 W., and adjacent parts of T. 40 N., R. 30 W., and T. 41 N., R. 29 W., may have some potentialities for producing iron ore because the distribution of the iron-formation should normally be closely related to the distribution of the quartzite. Nevertheless, the determination of a fully satisfactory geologic basis for exploration in these areas will be difficult, if not practically impossible, because exposures are so few.

Status of program.--Some of the results of investigations in the Felch Mountain district during the field seasons of 1946 and 1947 are included in two reports by Lamey. 10/

The study was extended eastward during the field seasons of 1948 and 1949. The field work for this unit may be completed next field season and will be followed by the preparation of material to be included with information concerning adjacent areas in a report on the central part of Dickinson County.

Other parts of central Dickinson County

Four field parties were in other parts of central Dickinson County in 1948. The mass of gneiss north of Randville and an area on the northern side of the mass were mapped by F. J. Pettijohn of the U. S. Geological Survey and B. E. Kennedy of the Michigan Geological Survey. The study in the Sturgeon River area, which is a little over 20 miles northeast of Iron Mountain, was continued by L. D. Clark. The southern part of the gneiss mass south of the village of Felch was studied by J. Freedman. J. W. Trow worked about 6 miles southeast of Randville and mapped in the eastern part of an area between segments of Sturgeon quartzite that are separated by a distance of approximately 6 miles.

[10] Lamey, C. A., Geology of an area near Randville, Michigan: U. S. Geol. Survey unpublished manuscript, open file report, 1947.

———, Geology of a part of the Felch Mountain iron range, Michigan: U. S. Geol. Survey unpublished manuscript, open file report, 1949.

During the field season of 1949 the area in the vicinity of the Calumet mine, which is about 2 miles south of Felch, was mapped by J. Freedman. The distribution of the Sturgeon quartzite to the southwest of Randville was mapped and studied by J. W. Trow.

It is expected that geologic work will be continued in areas adjacent to those mentioned above until the regional problems related to the gneisses and granites as well as those of the stratified rocks are investigated fully. Then the program will be largely the preparation of a report on central Dickinson County.

Aeromagnetic survey of Dickinson County

Traverses with an airborne magnetometer have been made over all of Dickinson County except the extreme eastern edge. The profiles have been rectified, and data will be compiled and released as soon as they become available.

REGIONAL PROBLEMS

The regional pattern of geologic structure in central and southern Dickinson County consists of several elongate masses of gneiss of pre-Huronian age between which are synclinal structures or down-faulted blocks containing iron-formation and associated strata of Huronian age. Although the areas of stratified rocks are of prime interest in the investigations, the study of the borders of the crystalline masses probably will furnish structural data about folds and the faults that would not otherwise be available.

The principal regional structures of central and southern Dickinson County, in addition to the repetition of the Vulcan iron-formation and associated strata mentioned above, are the longitudinal faults that parallel the trends of these units. Several faults in the southern part of the Menominee district trend northwestward, and a fault in the northern part trends westward. A fault at Randville has a southwesterly trend, and recent work by Pettijohn indicates that possibly one of similar orientation is about 3 miles to the northwest. The regional pattern thus appears to be a general convergence of structural trends toward the west in the direction of the northeastern part of Florence County, Wisconsin--an area that from 1880 to 1932 produced about 7¼ million tons of iron ore.

The existence and possible importance of these structural trends in Florence County have not been determined thus far, but if they are not present, then some major structural feature that interrupts the trends is yet to be recognized. Another matter for investigation in Florence County is the similarity of the strata, except for a higher grade of metamorphism, to those in Iron County to the northwest, and the marked dissimilarity to the iron-formation and associated strata in Dickinson County to the southeast. The restudy of northeastern Florence County is essential to the solution of some regional problems and may reveal new potentialities for exploration.

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