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GEOLOGY OF THE CENTRAL PART OF THE IRON RIVER DISTRICT IRON COUNTY, MICHIGAN

By

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INTRODUCTION

Iron County is in the western part of the northern peninsula of Michigan (fig. 1), and in it there are two districts which produce iron ore at the present time. The Iron River district is in the western part of the county and has 11 active mines. The Crystal Falls district is about 15 miles east of the town of Iron River and has two mines in operation.

The central part of the Iron River district is an area approximately 2¼ miles from north to south and 3¼ miles from east to west. It includes most of the town of Iron River and also extends southward into the western part of the adjoining town of Stambaugh.

The only mines operating at the present time in this part of the district are the Hiawatha No. 1 and No. 2 mines, but at least ten mines formerly produced iron ore. Through 1947, the total production of ore from these mines was about 17,500,000 tons, and the present annual production of the Hiawatha mines is about 500,000 tons.1/

1/ Lake Superior iron ores, The Lake Superior Iron Ore Association, Cleveland, Ohio, 1938. General statistics covering cost and production of Michigan iron mines, Michigan Dept. of Cons., Geol. Survey Division, 1939-1947.

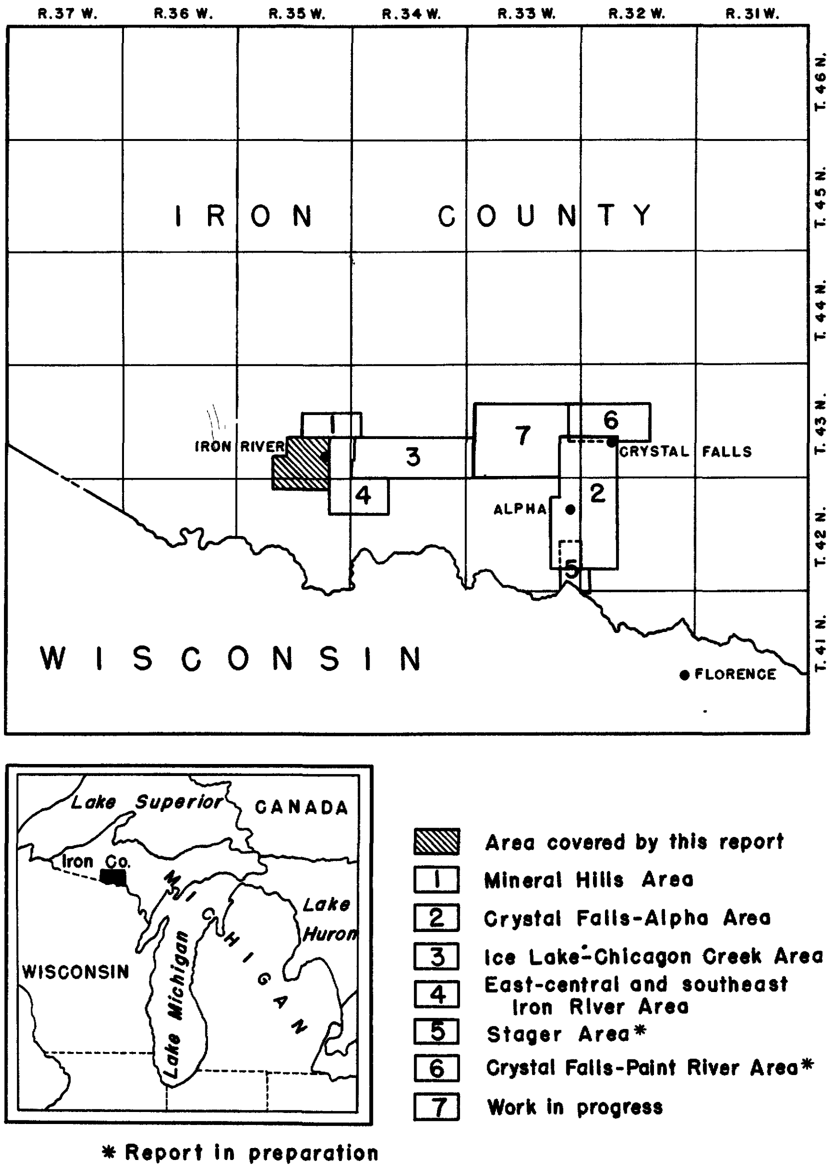

Figure 1.—Index map of Iron County, Michigan, showing areas covered by preliminary reports.

This report is one of several that have resulted from a continuing cooperative investigation of the geology in the iron-ore producing districts of Iron County by the Michigan Department of Conservation, Geological Survey Division, and the U. S. Geological Survey. Preliminary reports have been issued for the Mineral Hills area,2/ the Ice Lake-Chicagon Creek area,3/ the Crystal Falls-Alpha area (two reports),4/ and the eastern and southeastern parts of the Iron River District.5/ Reports are in preparation for the Stager area, the Crystal Falls-Paint River area, and the Fortune Lakes area.

The present report is based upon intermittent study and mapping of surface and underground data from June 1943 to October 1947. During the investigation the writer received wholehearted cooperation from the personnel of M. A. Hanna Co., Pickands, Mather and Co., Cleveland-Cliffs Iron Co., Jones and Laughlin Iron Co., and Mineral Mining Co. in obtaining many data from their files and in having access to drill cores. G. E. Eddy and F. G. Pardee of the Michigan Geological Survey aided by their advice and continued interest. The suggestions and discussions of H. L. James of the U. S. Geological Survey were especially significant and helpful. Acknowledgment is gratefully made also for the contributions of C. F. Park, Jr., J. R. Balsley, Jr., and Justin Zinn during plane-table mapping; of S. E. Good and L. D. Clark during underground mapping; and of R. E. Pagel for the final drafting. Special appreciation is expressed for the magnetometer survey made by K. L. Wier, R. B. Hall, and J. J. Hill.

GENERAL GEOLOGY

Principal features

Glacial materials form an extensive and generally thick cover over the bedrock in most parts of Iron County. Outcrops, although more numberous in the area covered by this report than elsewhere in the district, are scarce.

Bedrock in the district is usually called "ledge," and the stratified materials are graywackes, slates,6/ unoxidized or oxidized iron-formation, and locally some iron ore. These rocks are believed to be Upper Huronian.

2/ 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., pp. 1-4, 1945.

3/ 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. Invest. Prelim. Rept. 3-213, pp. 1-11, 1947.

4/ Pettijohn, F. J., Geology of the Crystal Falls-Alpha iron-bearing district, Iron County, Michigan: U. S. Geol. Survey Strategic Min. Invest. Prelim. Map No. 3-181, 1947. Pettijohn, F. J., Magnetic and geologic data of parts of the Crystal Falls-Alpha iron district, Iron County, Michigan: Michigan Dept. of Cons., Geol. Survey Division, pl. 1-9, 1948.

5/ 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 Cir. 26, pp. 1-18, 1948.

As shown on the geologic map of Iron County published in 1929,7/ masses of extrusive greenstone and possibly some related intrusive material extend along the northern and southern sides of the area occupied by sediments in southern Iron County. The geologic age of these igneous rocks is in doubt, but it is believed that they represent the underlying material on which the sediments of the basin rest.

One sill-like mass of basic rock is known in the northern part of the Iron River district and another one occurs in the southeastern part of the district. Igneous rock of diabasic character has been penetrated in diamond drill holes in two places in the central part of the district.

The general geologic structure of southern Iron County is apparently a triangular-shaped basin whose apices are at Iron River, at Crystal Falls, and at Florence, Wis., about 15 miles southeast of Crystal Falls. The strata of the basin are complexly folded and, except at the top or bottom of the folds, are characterized by steep or overturned dips. The central part of the Iron River district is immediately west of the western apex of the major basin and contains several faults as well as the complex folds that are typical of this district. Data are insufficient to determine satisfactorily the structure in much of the area.

Stratigraphy

The character and sequence of strata in the central part of the Iron River district are similar to that present in other parts of southern Iron County that have been examined during this restudy of the area. The concepts presented in this report are based on detailed mapping of the Hiawatha, Dober, and Isabella mines and on examination of all known outcrops and available drill cores.

The general designation of the strata and their relative stratigraphic sequence are shown in the following tabulation.

Magnetic slate Graywacke or graywacke-chert breccia	Hanging-wall strata
Iron-formation	
Laminated graphitic slate Slate breccia Sericitic slate	Footwall strata

Footwall strata.—The iron-formation is normally underlain by thinly bedded or laminated black graphitic slate. Pyrite is very abundant as a fine-grained disseminated material that is rarely visible megascopically. This unit ranges in thickness from 20 to 120 feet, but the latter figure represents some duplication by folding.

6/ Although most of the "slates" do not exhibit cleavage and evidences of recrystallization are slight, the use of the term for fine-grained rocks is well established in the district.

7/ Barrett, L. P., Pardee, F. G., and Osgood, W., Geologic map of Iron County, Michigan Dept. of Cons., Geol. Survey Division, 1929.

A distinctive slate breccia commonly underlies the bedded graphitic slate and ranges in thickness from 2 feet to perhaps 50 feet. This unit of the footwall strata is a massive layer in which fine-grained graphitic material constitutes the matrix around fragments of graphitic slate, which commonly range from minute particles to pieces whose maximum dimension is one-half inch. Locally fragments of chert are abundant, and some fragments of gray slate may be present also. The characteristics of this material suggest that it is intraformational breccia.

The next stratigraphic unit is the lowest one thus far determined in this part of the district. It is composed of gray, sericitic, nonsideritic slates with some fine-grained graywacke or siltstone normally present below the uppermost part.

Iron-formation.—The unoxidized iron-formation is composed of alternating layers in which either chert or siderite predominate, whereas in the oxidized iron-formation the siderite has altered to iron oxides (hematite and limonite), and ore is composed of iron oxides with little or no chert. The layers in the iron-formation commonly range in thickness from slightly less than half an inch to 2 inches and in a few places any one of them may be much thicker. The chert of the unoxidized iron-formation is generally dark gray to black but locally the prevailing color of the chert is a light grayish green. The chert in the oxidized iron-formation is almost invariably white, light buff, or very light gray, but in a few places dark-gray to black chert is interbedded with soft red hematite layers. The chert is rarely discolored by iron compounds and usually has a sharp boundary with the adjacent materials.

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 12 inches long and 2 inches thick to chips so small that a hand lens or microscope is necessary to identify the material. Where this facies is oxidized, the matrix is limonite or hematite.

The iron-bearing minerals most commonly present in the iron-formation are: hematite that is generally soft, red, and earthy but in some places is hard and massive, or an aggregate of small plates; hydrous yellow to brown iron oxides forming either soft and earthy materials, or very hard and massive material that generally has a well-developed conchoidal fracture; granular siderite that makes up a rock of light-gray color and fine-grained texture.

The unoxidized iron-formation commonly has partings or very thin layers of gray or greenish slate that become red where the formation is oxidized. Locally the upper part of the iron-formation contains interbedded graywacke, or graphitic slate somewhat similar to the laminated graphitic slate unit below the iron-formation but generally sideritic and much less pyritic.

Hanging-wall strata.—These materials are stratigraphically younger than the iron-formation, and in this part of the district the most common unit is a graywacke that normally contains fragments of chert.

The graywacke with chert fragments, if present, is immediately above the iron-formation. It is an important marker bed and occurs in the same stratigraphic position also in the Crystal Falls-Alpha area, the Ice Lake-Chicagon Creek area, the Mineral Hills area, and the eastern and southeastern part of the Iron River district.

The most conspicuous feature of these rocks as compared to other strata in the area is the larger grain size and poorly developed bedding of the materials. Although rounded grains of clear quartz and small rock fragments are characteristic features of these rocks, the most abundant material is a matrix which is too fine-grained for identification of its composition by use of hand lens. The fragments of chert are locally rimmed by pyrite, and in some places they are completely replaced by this material.

On the 16th to 18th levels at the Hiawatha No. 1 shaft, the graywacke with chert fragments is overlain by dark-gray, graphitic, coarse-grained graywacke containing small slate fragments and, in turn, is overlain by blocky, bedded graywacke without fragments. The latter type of material is, however, immediately above the iron-formation in some places.

Coarse graywacke containing abundant pink and light-gray feldspar grains was penetrated during drill explorations in the northern part of the area, but the relation of this material to other facies of graywacke in the hanging-wall sequence is not known.

Many of the graywackes are gray, but greenish and reddish varieties are present and probably the result of alteration related to the formation of ore. Most specimens of unoxidized graywacke contain disseminated siderite and yield sludge analyses of 15 to 20 percent iron. Oxidation produces red color and in several places reddish graywackes have been designated as "iron-formation" in records of drilling. One very peculiar color variation of the graywacke is the white or buff material that is usually associated with ore bodies and is indicative of geologic processes that bleached the rock and made it friable.

The next unit of the hanging-wall strata is the magnetic slate, the youngest unit recongnized thus far in this area. The rock is commonly mauve or purple and is highly magnetic, but it may be greenish gray and only locally magnetic, or light gray and essentially nonmagnetic. Although a number of variations in its appearance are encountered the material is usually sideritic, distinctly bedded, and exhibits a subconchoidal fracture. This stratigraphic unit is also present in other parts of southern Iron County and has been of considerable value in the determination of structure from magnetic data.

Stratigraphic relations.—With one possible exception the foregoing stratigraphic units constitute a conformable sequence of strata insofar as could be determined. The chert fragments in the graywacke immediately above the iron-formation were evidently derived from chert bands in the iron-formation inasmuch as no other source of the chert is readily available. The character of the graywacke unit therefore apparently records an unconformable relation between the graywacke and underlying iron-formation as has been proposed for other parts of the Crystal Falls-Iron River district. Graywacke with chert fragments occurs at many places adjacent to iron-formation, but in a few places graywacke without chert fragments is interbedded in the upper part of the iron-formation, and the relations are thus locally conformable. The interpretation of these conditions is that the iron-formation over most of the area was subjected to a slight disturbance—perhaps by gentle flexing and submarine slump—and contemporaneous or subsequent submarine erosion. The probable sequence and character of the processes can be shown by series of selected specimens that include (1) normal interbedded chert and siderite, (2) siderite with interbedded, segmented chert bands, (3) brecciated iron-formation, (4) brecciated iron-formation containing minor amounts of clastic material of sedimentary origin, (5) graywacke with chert fragments, and (6) graywacke without chert fragments.

Additional evidence possibly supporting an unconformable relation is present in a few places where the interval between the hanging-wall graywackes and the footwall slates is unusually small, suggesting that erosion reduced the iron-formation to much less than its normal thickness.

Structure

Structurally, the central part of the Iron River district is in what may be the western apex of a triangular-shaped basin that extends eastward to Crystal Falls, Mich., and southeastward to Florence, Wis. The strata in the mapped area are, in general, steeply inclined and in many places are in an overturned position. The general structural pattern in the area has been only partly determined, but many folds and a few faults are known to be present. The principal structural units that have been recognized are oriented approximately at right angles to each other.

North-trending folds are present in the eastern part of the area and include a major syncline with several second order anticlinal and synclinal folds to the west. Folds of this orientation plunge generally southward and most of them are overturned toward the east.

East-trending folds are present in the southern part of the area where the well-defined units are an anticline between two synclines which probably converge toward the west into one major synclinal structure. These folds have a plunge generally westward and are overturned toward the south in a few places. Several east-trending anticlines and synclines are present also in at least one locality in the northern part of the area. Some of these folds plunge to the west, but others are good examples of doubly plunging structures that are very common in the Iron River district. The doubly plunging folds are undulations along anticlinal and synclinal axes, and the pattern of the iron-formation on a horizontal surface is elliptical or is an S-shaped curve joined to a reversed S-shaped curve.

The strata are sheared and contorted in many parts of the area, but only a few specific faults are known to be present. The faults are in two systems that are approximately parallel to the orientation of the folds and undoubtedly are displacements resulting from the extreme thinning of the limb of an adjacent fold. North-trending faults are on the eastern side of the folds in the eastern part of the mapped area. Several east-trending faults are in or parallel to the prominent anticline in the southern part of the area. One of the faults in this latter group has an apparent vertical displacement of over 2,000 feet with the result that most of the iron-formation and the overlying graywacke are missing and footwall graphitic slate is adjacent to hanging-wall magnetic slate.

The description of geologic structures in a later part of the report presents additional information that would encumber the text at this point and thus detract from the emphasis on general features.

ECONOMIC GEOLOGY

Ore deposits

Hematite and limonite are the principal constituents of the iron ore. These minerals may be either soft and earthy or hard and compact, and consequently the physical character of the ore is largely determined by these variations. Although locally ore may be dense, the ore bodies normally are porous and contain a considerable volume of water. Much of the ore retains the layered structure of the iron-formation from which it was derived, but in some places this characteristic has been destroyed in the transformation.

The ore bodies are essentially tabular in form and parallel to the trend of the adjacent strata. In many instances, the graphitic slate underlies the lower side and the bottom of an ore body. A boundary of this type is very sharp and its shape is directly controlled by the structural pattern of the stratigraphic contact. In a few folds ore in the overturned limb rests on younger graywacke that has become a "structural footwall" as a result of the overturning. Although some interbedding of ore and graywacke may be present, the zone is a stratigraphic feature which can be used to map geologic structure. Elsewhere oxidized iron-formation is adjacent to ore. Boundaries of this third type are gradational, very irregular, and commonly result in fingerlike projections that extend upward from the main mass of ore.

The iron ore is the result of alterations of the iron-formation. The siderite of the unoxidized iron-formation has been changed to limonite and hematite. The chert that was interbedded with the siderite has been completely or almost entirely removed by either solution or replacement or perhaps a combination of the two. The oxidation produced some concentration of the iron by the formation of new minerals. The greater concentration, however, resulted from the removal of the valueless chert which constitutes about half of the volume of either oxidized or unoxidized iron-formation.

Ore was present at bedrock surfaces in several mines of the area, but some of these occurrences apparently stopped at depth because they rested in synclinal folds of slate or on a structural footwall that steepened. However, in one part of the Hiawatha mine, ore continues downward for more than 2,000 feet vertically below the surface without the lower limit of the ore being reached.

Principles of exploration

The ore bodies originated by the alteration and enrichment of iron-bearing strata which constitute only a small part of the succession of rock layers. It is evident therefore that exploration has been, and will continue to be guided by two primary considerations. The first factor that guides exploration is the location of the iron-formation and, in the absence of other information, this matter is usually settled either by test pitting (where the overburden is not too thick) or by diamond drilling. The maps indicate that considerable exploration is still necessary to provide sufficient information for the satisfactory determination of the distribution of the iron-formation. The second, and much more difficult factor in exploration, is the location of a structure that has been favorable for the conversion of the iron-formation to iron ore. The occurrence of many ore bodies in the district in synclinal structures is the logical basis for examining first the localities where the iron-formation occurs in these folds. It is well known, however, that some ore is not in synclines and that not all synclines contain ore; consequently, no occurrence of iron-formation should be excluded from consideration as a possible site of ore bodies.

Another feature with possibilities as a guide to exploration is that the strata in the vicinity of most ore bodies are oxidized. The members of the hanging-wall sequence may be thoroughly and extensively oxidized, but the footwall rocks are commonly affected to a lesser degree. Inasmuch as the oxidation is generally present at the surface of the bedrock above ore bodies, one approach to the problem of exploration would be simply to examine the bedrock surface to locate areas of oxidation and then search within that area for ore.

Three types of possibilities for exploration exist in the mapped area:

(1) The extension of iron-formation beyond known occurrences.

(2) Unexplored areas between explorations in which the rock has been tentatively classed as hanging-wall strata and those in which the material is believed to be footwall strata.

(3) Deeper exploration of areas in which oxidized iron-formation or oxidized hanging-wall graywacke has been found at the bedrock surface. Ore in such areas might be confined to the bottom of synclinal folds and not be encountered in shallow explorations.

Specific examples of the above types are discussed under the section, entitled Possibilities for exploration, in a later part of this report.

MAGNETIC SURVEY

A Wolfson vertical magnetometer was used for the determination of magnetic data. The instrument was compensated for temperature changes, and corrections for diurnal variations were made by check readings at a base station several times during each day. The base station for the survey was the same as that used in compiling magnetic data for the other parts of the Iron River district. It is in the NE¼NE¼ sec. 28, T. 43 N., R. 34 W.[8]

In general, traverse lines 300 feet apart were run by compass, and determinations along these lines were made at paced intervals of 100 feet. Determinations were not made where cultural features such as drill casings, railroad tracks, steel towers, and mine shafts would have produced valueless data; readings that were questionable have not been used in drawing magnetic contours.

The iron-formation is not magnetic except for rare and local areas of small extent. However, the iron-formation is overlain in normal stratigraphic order by graywacke, which may be slightly magnetic, and by the magnetic slate. Magnetic surveys reveal the location of this material, if present, in areas where outcrops are absent and thus aid in geologic mapping.

The magnetic survey determined several prominent anomalies, and at least three of them have been specifically correlated with the magnetic slate. A discussion of the geology in the area of each major anomaly is included in the section, entitled Geologic structures.

DESCRIPTION OF LOCAL FEATURES

Geologic structures

Southern part of the area.—The synclinal axis of a major structural unit trends approximately north through a prominent hill at Stambaugh in the northeastern part of the area shown on plate 1. Exposures of magnetic slate mark the center of this structure where an anomaly determined by the magnetometer survey (pl. 5) has the maximum range of values found thus far in the Iron River district. The graywacke exposed at a number of places on the western slope of Stambaugh Hill, and the iron-formation of the Chatham mine and Riverton mine (also Delta mine, pl. 4), form the western limb of this syncline. The eastern limb of the structure is east of the maps in this report and is represented by the iron-formation of properties on the eastern side of Stambaugh. Although not shown on the maps of this report, the iron-formation of the Cyr-Lennox exploration (E½SW¼ sec. 36, T. 43 N., R. 35 W.) at the south end of Stambaugh Hill possibly marks a partial closure of the structure on the south, but there are no data to indicate a comparable closure on the north.

Another major structure, in which the largest ore bodies of the mapped area occur, is the east-trending syncline whose axis lies between Hiawatha No. 1 shaft and Hiawatha No. 2 shaft (pl. 1). Locally, north of Hiawatha No. 2 shaft, the axis of this structure is probably marked by the outcrops of gray sideritic slates that are believed to be equivalent to the magnetic slates. From the surface to the present workings on the 18th level, most of the central part of this structure is composed of graywacke or graywacke with chert fragments (pl. 2), and the

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8/ James, H. L., Clark, L. D., and Smith, L. E., op. cit.

two belts of iron-formation remain approximately 1,500 feet apart. The limbs trend slightly north of east, but the southern one turns northwest in a series of folds near the Dober mine and is then terminated at the Isabella mine by a reverse fault that is parallel to the orientation of the adjacent folds. Although the change to a northwesterly trend in the southern limb suggests the possibility of this structure becoming closed at depth, the two belts of iron-formation have remained separated down at least as far as the 18th level. On and below the 13th level, the eastern part of the northern limb turns northeastward and is probably terminated by a fault (map of 16th level, pl. 2).

The anticlinal fold north of the Dober No. 1 shaft is a less prominent structure but is of special interest because of the volume of data substantiating it and because of the local effects on the areal map pattern (pls. 1 and 2). This fold trends northwest, is overturned to the east, and is truncated on the eastern side by a reverse fault of apparently considerable vertical displacement (section A-A', pl. 3).

An anticlinal fold trends east through the Hiawatha No. 1 shaft and is one of the major structures in this area as shown by maps on plates 1 and 2, and by cross-sections C-C', D-D' and E-E' on plate 3. Detailed data are available from the 3d to the 18th levels to give the most complete vertical section available in the district at the present time. The essential features of the structure include a tightly compressed footwall sequence in the central part of the fold, and a reverse fault displacement of the north limb that brings hanging-wall strata adjacent to the footwall strata.

Undoubtedly many more faults occur in the area than are shown on the maps and sections. Inasmuch as the complex folds are normally accompanied by considerable shear and contortion, the positive recognition of faults is difficult. The omission of members in the normal succession of strata as shown on the maps and sections is the essential feature for determining the faults that are indicated.

A deep synclinal structure lies between the Hiawatha No. 1 shaft and the Chatham No. 1 shaft. The bedrock surface in the area between the iron-formation at the two mines is apparently graywacke containing chert fragments (pl. 1), although a prominent magnetic anomaly is present there (pl. 5). Drilling has revealed that considerable magnetic slate occurs below the surface (section C-C', pl. 3) and that the syncline is not only overturned to the south but fault displacements have isolated a mass of magnetic slates among older members of the sequence. This synclinal structure appears to occupy a large area toward the west as shown by the prevalence of graywacke with chert fragments in the explorations northwest of the Hiawatha No. 1 shaft. The bedrock surface at that locality is thus composed of hanging-wall strata; but some iron-formation is present, probably along the axis of a doubly plunging anticline of general northeast trend.

One of the magnetic anomalies in the NW¼SW¼ sec. 35, T. 43 N., R. 35 W., is in an area where black slates were reported to be present in test pits (pl. 1), but the only bedrock material observed during this investigation was graywacke with chert fragments from one pit.

It appears, therefore, that the area is underlain by hanging-wall strata, and it is possible that these anomalies are related to another occurrence of the magnetic slates. The form and size of the anomalies suggest the presence of small masses of magnetic slates along synclinal axes.

The interpretation of the geology near the Chatham No. 1 shaft is based largely on information from records of the mining company although much drill core from adjacent explorations was examined during this investigation. Reported occurrences of "graywacke" and "black slate" in the mine workings are apparently hanging-wall and footwall materials and control the pattern of inferred geology at bedrock surface as shown on plate 1 and below the surface as shown in sections B-B' and C-C' on plate 3. In general, the structure in this part of the area is believed to consist of folds that trend north, are overturned to the east, and plunge southward.

A belt of iron-formation extends westward and northward, from the Chatham mine passing through the exploration in the SW¼NE¼ sec. 35, T. 43 N., R. 35 W.; then it probably turns to a southwestward trend and may continue across the northwestern part of sec. 35.

<u>Northern part of area</u>.—Another belt of iron-formation extends northward from the Chatham mine and passes through the Riverton mine (pl. 4), the Delta mine, and the SW¼NW¼ sec. 25, T. 43 N., R. 35 W. (Miller exploration). Rock exposures around the caved areas of the Riverton mine are the most extensive in this part of the district and, although several members of the sequence are present, determination of structural details is difficult. In the Riverton mine the iron-formation is complexly folded, is overturned toward the east (cross-section F-F', pl. 4), and is separated from a typical hanging-wall strata toward the east by a shear zone that is one of the few conspicuous structures in the area. The displacement along the fault is not clearly defined, but the mass east of the fault possibly moved relatively upward. The inclination of the fault could not be determined exactly, but is known to be steep. The graphitic slate in the caved area just south of Riverton No. 5 shaft (pl. 4) is represented as footwall material, but its true stratigraphic position could possibly be in the lower part of the hanging-wall sequence. The west side of the remainder of the caved area is partly oxidized material that includes slaty iron-formation, slate, and some graywacke, but very little typical iron-formation is exposed. Most of these rocks belong in the lower part of the hanging-wall strata and apparently form a long, narrow synclinal structure.

The interpretation proposed for the geology in the vicinity of the Delta mine is generalized and is based entirely on information obtained from records of mining and exploration. A map of the third level of the Delta mine (pl. 4)shows that a small body of ore and oxidized iron-formation at the north end of the workings was essentially encircled by "black slate". This arrangement probably indicates the bottom of a doubly plunging synclinal drag fold similar to one shown north of the shaft on the mine map. The areal geology at the bedrock surface has been drawn in accordance with this concept.

In the SW¼NW¼ sec. 25, T. 43 N., R. 35 W. (Miller exploration), drill holes are recorded as having first penetrated "slate and altered graywacke", and then passed into "oxidized iron-formation" that at least in part was at greater depth in the eastern holes than in the western ones. It is therefore likely that the iron-formation dips to the east, and the inferred geology is represented accordingly. The extension of the belt of iron-formation beyond this locality has not been determined.

A third belt of iron-formation extends northward from the Chatham mine to connect with that at the Sheridan shaft in the SE¼SE¼ sec. 26, T. 43 N., R. 35 W. (pl. 4). This northern part is probably a synclinal structure with associated anticlinal areas of footwall slates to the west and to the east where, as shown in cross-section F-F' on plate 4, drilling revealed the slate breccia of the footwall strata. Data are lacking concerning the continuation of the iron-formation more than a short distance northward from the Sheridan shaft.

The iron-formation at the inactive Wickwire mine (pl. 4) is probably isolated in a synclinal structure but is closely related to and at one time was continuous with the belt of iron-formation that extends northwestward from the Chatham mine. Breccia in which chert fragments are embedded in a graphitic matrix is present west of the mine and, as previously described, this material is a variety of the slate breccia unit of the footwall sequence. Drill holes, which were vertical or inclined eastward, passed through the breccia and entered the iron-formation; they thus establish the overturned position of the structure at this locality. Black slate reported to be present in test pits to the east of the mine are believed to be footwall strata also and, on sections prepared by a former mining company, black slate is shown to extend westward under the iron-formation. The structure at this mine is therefore interpreted as a synclinal fold that is overturned to the east, and the iron-formation is the youngest stratigraphic unit in the fold. The extent of the iron-formation northward and southward from the Wickwire mine is not known at the present time.

Exposures and explorations in the vicinity of the Beta-Nanaimo mine (pl. 4) show that the iron-formation, footwall strata, and probably hanging-wall strata are present in the western part of sec. 26, T. 43 N., R. 35 W. The occurrences of these materials suggest a folded structure trending east to northeast, possibly a general plunge westward, and one undulatory anticlinal axis. Although the true stratigraphic position of the "black slate" in the explorations north of the river is not known, it is assumed to be a part of the footwall strata, and an approximate contact with the iron-formation has been indicated.

Drilling in the SE¼ sec. 27, T. 43 N., R. 35 W. (pl. 6), penetrated coarse graywacke that contains many grains of light-gray and pink feldspar, and one hole entered oxidized iron-fromation below the graywacke. The graywacke is in the hanging-wall strata, and its occurrence at this locality signifies a continued westward plunge of the synclinal structure west of the Nanaimo shaft as shown on the map.

Southwestern part of area.—The trend of iron-formation in the S½ sec. 34, T. 43 N., R. 35 W. (pl. 6), in the vicinity of the Cortland and Brule mines, has been drawn in accordance with information at the bedrock surface and with information on maps prepared by the mining companies. Maps of the Cortland mine show "graywacke" north of southward-dipping iron-formation, and "black and gray slate" south of it. Several pieces of graywacke containing chert fragments were seen on the Cortland dump, and thus it is probable that the graywacke in the mine was normal hanging-wall material but that at this place the sequence of strata is overturned.

Maps of the Brule mine show some interesting geological data. The formations trend east in general, except for a deflection toward the north in the vicinity of the shaft, and the prevailing dip is south. Black slate is shown north of the iron-formation to the west of the shaft, and graywacke south of the iron-formation at the west end of the second level workings. Graywacke is also present at the east end of the second level (directly below the Cortland mine workings), but the structural relations at this locality are not clearly represented. Graywacke with chert fragments is present in the dump of the Brule mine and presumably came from one of these areas or possibly from the areas marked "brecciated cherty carbonate" and "graywacke" in a long exploratory cross-cut toward the south at about 1,700 feet west of the shaft. The end of this cross-cut to the south stopped in "graphitic black slate" that apparently belongs to the footwall strata and is in a secondary anticlinal fold on the northern flank of a major structure to the south. This concept of geologic structure is based on the interpretation that the magnetic anomaly in this part of the area (pls. 5 and 6) possibly indicates the presence of a syncline containing the magnetic slate and the immediately underlying slightly magnetic graywacke. If so, it is likely that the footwall slates and iron-formation would not come directly to the surface from the end of the long drift but would be south of the anomaly.

On the northern side of the Brule mine, the material from drill holes along the east-west center line of sec. 34, T. 43 N., R. 35 W., is similar to normal footwall strata, and the map has been drawn to show that interpretation.

The iron-formation at the Brule mine probably continues northeastward to join the belt of iron-formation that extends northwestward from the Chatham mine. The magnetic anomalies in the NW¼SW¼ sec. 35, T. 43 N., R. 35 W., tend to confirm this probability.

The indirect extension of the iron-formation westward from the Brule mine is based on the magnetic values in this vicinity, and the core from two of the drill holes in the $SE\frac{1}{4}$ sec. 33, T. 43 N., R. 35 W. (Greig-Jackson exploration), supplied valuable information concerning the geology of that part of the area (pl. 6, map and section I-I'). Drill hole no. 15, which was inclined to the northwest, penetrated iron-formation and then passed into a normal footwall sequence of graphitic slate and slate breccia. Drill hole no. 14, which also was inclined to the northwest and was 300 feet southeast of hole no. 15, penetrated graywacke at the bedrock surface and at greater depth went into the magnetic slate. The magnetic anomaly in the $SE\frac{1}{4}$ sec. 33 and the $SW\frac{1}{4}$ sec. 34, T. 43 N., R. 35 W., is related therefore to magnetic slate that is in a synclinal structure. Furthermore, the character and sequence of strata in this part of the area establish the correlation of these strata with those elsewhere in the district. In some places the inferred contacts of the iron-formation have been drawn to conform as closely as possible to the magnetic data rather than accepting the reported description of drill cores that were not available for examination. This choice was made because in many other cases the reported descriptions of cores that were examined were not adequate for determining the stratigraphic position of the strata.

The extension of the iron-formation from the Greig-Jackson exploration to iron-formation present in a small area of outcrops and in explorations in the $SW\frac{1}{4}$ sec. 33, T. 43 N., R. 35 W., and the $NW\frac{1}{4}$ sec. 4, T. 42 N., R. 35 W. (pl. 6), is hypothetical but is approximately parallel to the trend of small magnetic anomalies in that part of the area. The drill core that was available for examination was predominantly unoxidized iron-formation or iron-formation breccia. Very minor amounts of graywacke and graphitic slate were present also, and these associated materials probably indicate axes of a series of small folds. There is very little information however, concerning the probable limits of the iron-formation, its approximate trend, or the general structure at this locality. The stratigraphic position of the materials from drill holes north of the creek is uncertain, but the inference shown is that they are a part of the footwall strata.

The reported occurrence of iron-formation in a drill hole near the southwest corner of sec. 34, T. 43 N., R. 35 W., is the basis for the map pattern in that vicinity. Similarly, data on maps of the Edlund exploration in the northeast corner of sec. 3, T. 42 N., R. 35 W., and adjacent part of sec. 34, indicate the possibility of iron-formation as inferred.

Although the magnetometer survey covered the adjacent portions of the area and drill records of some explorations are available, the geologic structure remains indeterminate.

Western part of the area.—Magnetic values in the western part of the area in general higher than those in other parts of the Iron River district. The reason for these higher values is not known, but the magnetic attraction outside the mapped area continues to increase toward the south where there are exposures of greenstone that bound the southern side of Iron County. Therefore it is inferred that greenstone may be relatively near the surface in the western part of the mapped area.

POSSIBILITIES FOR EXPLORATION

The following brief descriptions are of several localities in which some exploration might be warranted.

The iron-formation in the southern limb of the major west-trending syncline between the Hiawatha shafts has not been located or explored west of the $NE\frac{1}{4}NE\frac{1}{4}$ sec. 2, T. 42 N., R. 35 W.

The well oxidized condition of the graywacke and the few occurrences of iron-formation in the $NE\frac{1}{4}SW\frac{1}{4}$ sec. 35, T. 43 N., R. 35 W., favor further examination of this general area.

The stratigraphic position of material in the drill holes in the $SW\frac{1}{4}NW\frac{1}{4}$ sec. 35, T. 43 N., R. 35 W., is undetermined thus far, but if it belongs to the footwall strata, a belt of iron-formation would normally pass between the drill holes and the magnetic anomaly in the $NW\frac{1}{4}SW\frac{1}{4}$ sec. 35, T. 43 N., R. 35 W.

Inasmuch as the large ore bodies of the Hiawatha No. 1 mine occur more than 1,000 feet below the surface, some deep exploration of the belt of iron-formation in the southern part of secs. 33 and 34, T. 43 N., R. 35 W., might be considered.

The probable presence of the iron-formation in several other localities between the Brule mine and the Beta-Nanaimo mine may warrant further investigation, but it is stressed that recent explorations in the $NW\frac{1}{4}SW\frac{1}{4}$ sec. 26 and $SE\frac{1}{4}$ sec. 27, T. 43 N., R. 35 W., have revealed the prevalence of unoxidized material in that vicinity, and a similar condition may extend widely into adjacent areas. (1) If the footwall strata are present along the east-west center line of sec. 34, T. 43 N., R. 35 W., as suggested previously, then one or more belts of iron-formation would normally be present between this locality and that of the graywacke with feldspar grains west of the Nanaimo explorations. So far as is known, explorations based on this possibility have not been made. (2) However, if the material in sec. 34 is a part of the hanging-wall strata, then the northern limb of an anticlinal structure near the Brule mine has not been located, and information concerning its possibilities for ore is lacking. (3) As stated previously and shown on the map, it has been assumed that the materials in the $SW\frac{1}{4}NW\frac{1}{4}$ sec. 35, T. 43 N., R. 35 W., and along the east-west center line of sec. 34, are part of the footwall strata. However, if they are hanging-wall strata, favorable exploratory conditions may exist over a large part of the area to the north and west of these localities.

The ore body at the Nanaimo shaft is located in a synclinal structure, and further exploration along the axis of the fold has been in progress. The westward-pitching syncline continues on the west side of the road and thus has warranted investigation in that direction especially. Except for the water hazard, another possibility for exploration could be the westward continuation of the iron-formation on the north side of the Iron River.

The foregoing examples do not exhaust the possibilities for exploration but will be sufficient perhaps to indicate some of the potentialities in the central part of the Iron River district.

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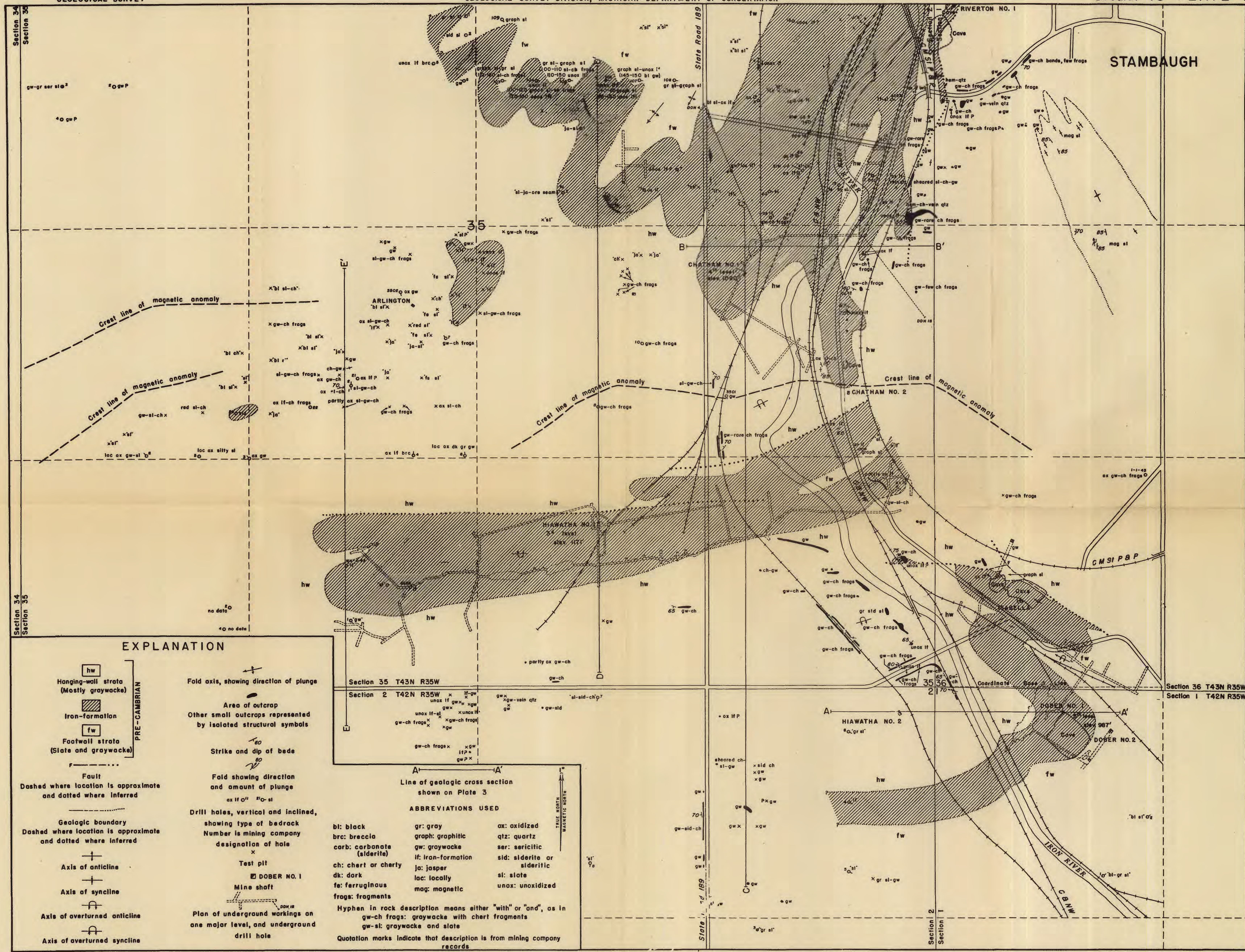

Geology by C. E. Dutton, 1948

MAP OF GEOLOGY AT BEDROCK SURFACE IN SOUTH-CENTRAL PART OF IRON RIVER DISTRICT, IRON COUNTY, MICHIGAN

200 0 200 400 600 800 Feet

SCALE

63748

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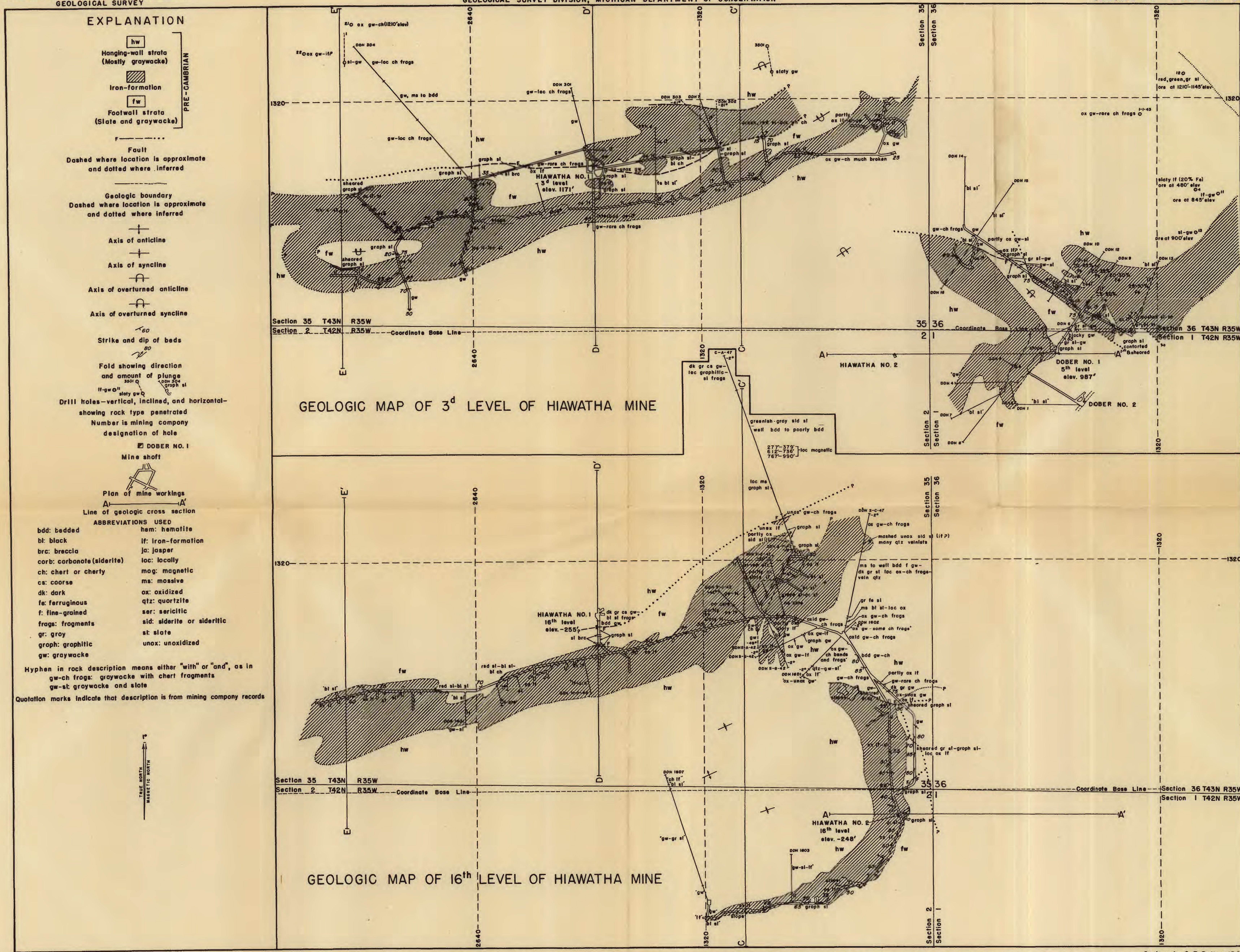

MAP SHOWING GEOLOGY AT TWO UNDERGROUND LEVELS IN SOUTH-CENTRAL PART OF THE IRON RIVER DISTRICT, IRON COUNTY, MICHIGAN

Geology by C. E. Dutton, 1948

200 0 200 400 600 800 Feet
SCALE

63745

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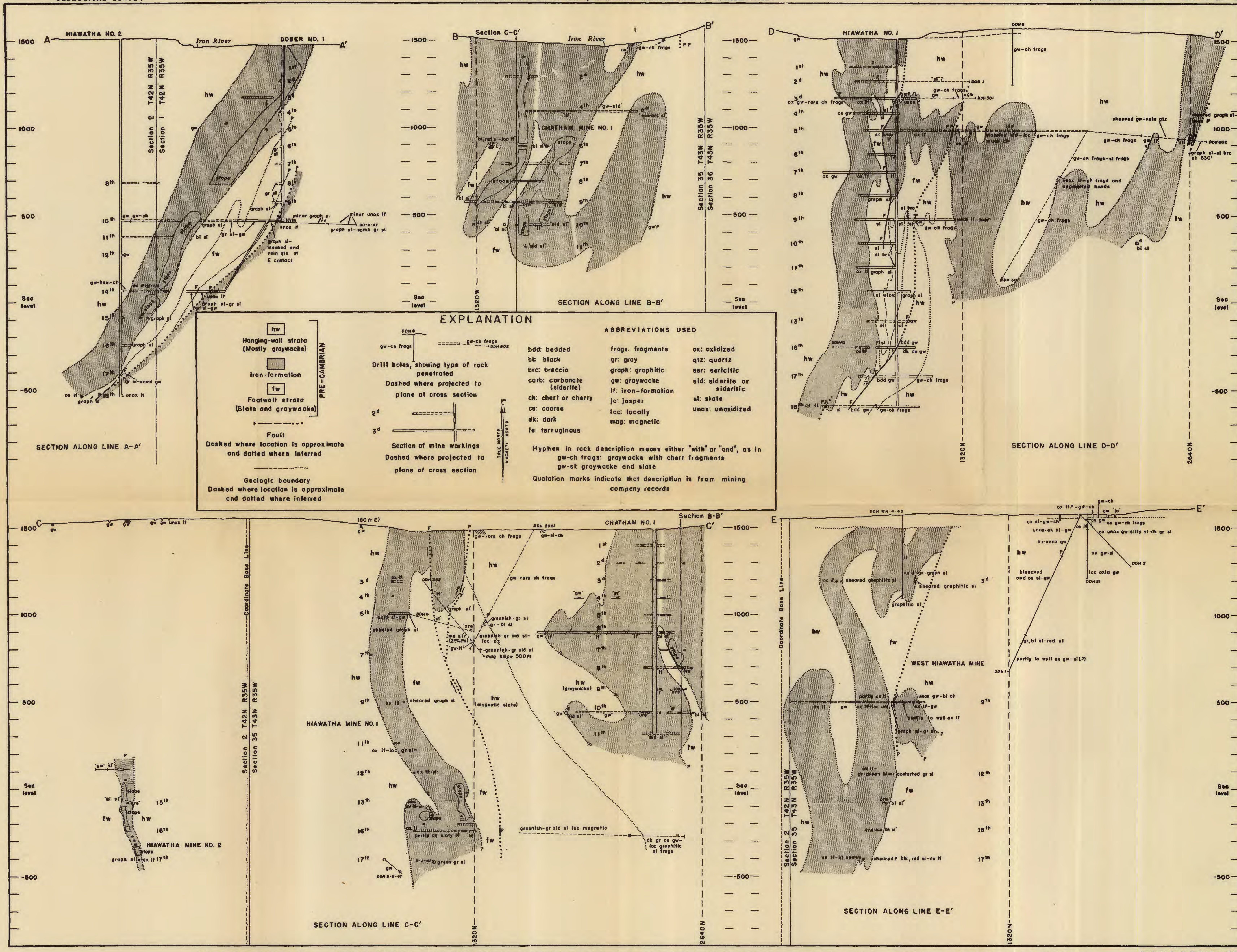


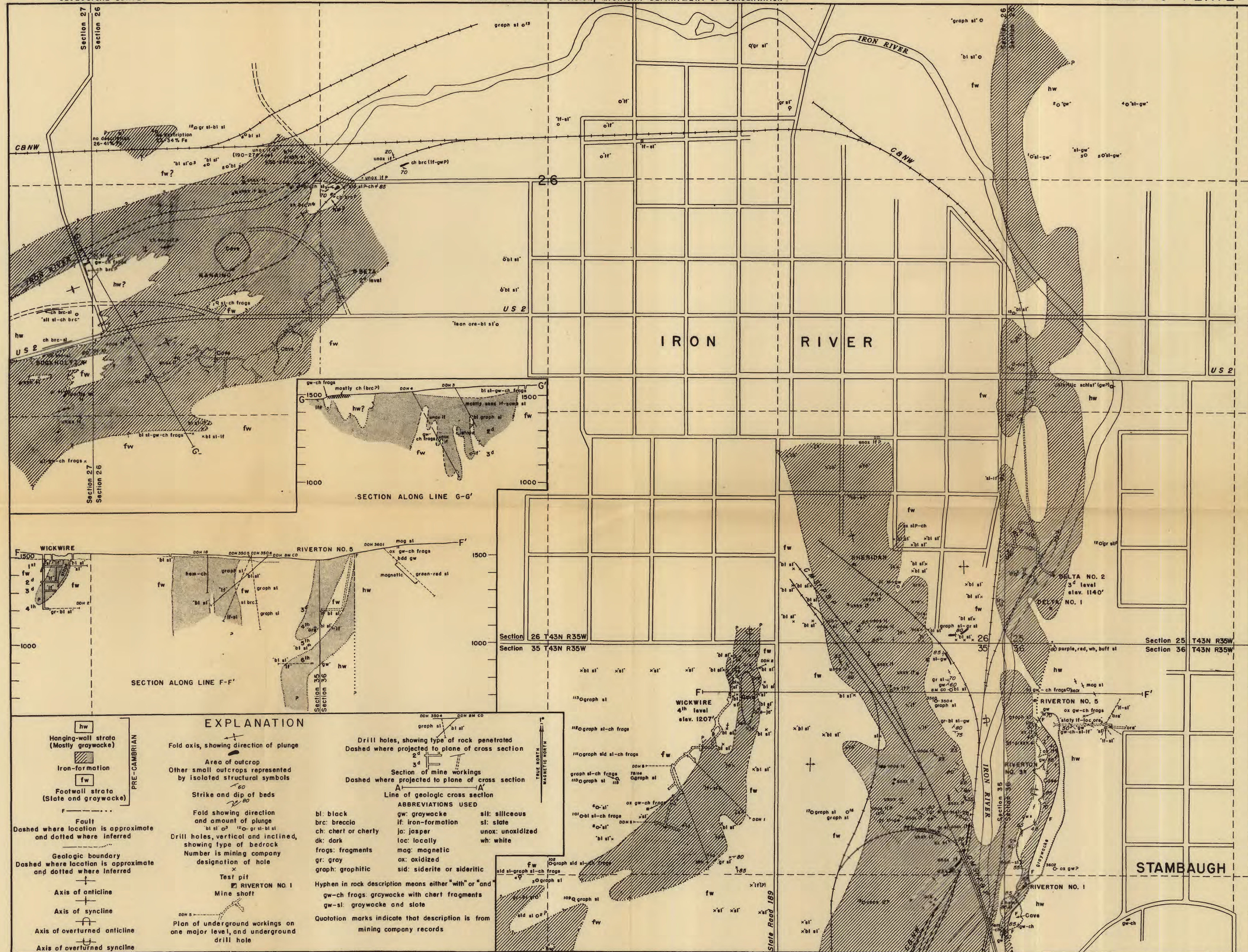
STRUCTURE SECTIONS SHOWING GEOLOGY IN SOUTH-CENTRAL PART OF IRON RIVER DISTRICT, IRON COUNTY, MICHIGAN

200 0 200 400 600 800 Feet

SCALE

Geology by C. E. Dutton, 1948

63943



MAP AND STRUCTURE SECTIONS SHOWING GEOLOGY IN NORTH-CENTRAL PART OF IRON RIVER DISTRICT, IRON COUNTY, MICHIGAN

Geology by C. E. Dutton, 1948

200 0 200 400 600 800 Feet
SCALE

63745

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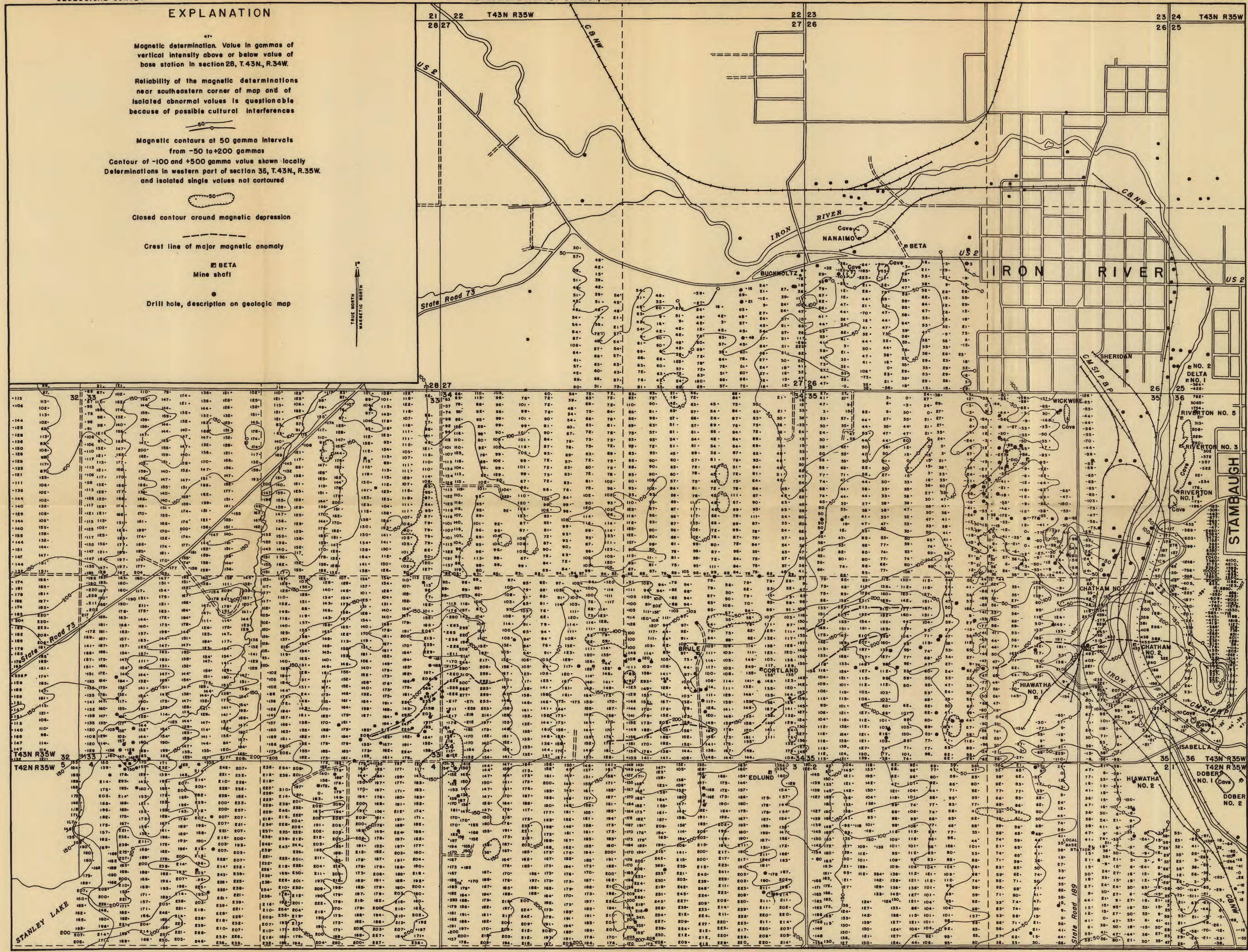
Circular 43 PLATE 5



Surveyed by K.L. Wier, R. B. Hall, and J.J. Hill, 1947-1948

MAP OF MAGNETIC DATA IN CENTRAL PART OF IRON RIVER DISTRICT, IRON COUNTY, MICHIGAN

500 0 500 1000 1500 2000 Feet
SCALE

63749

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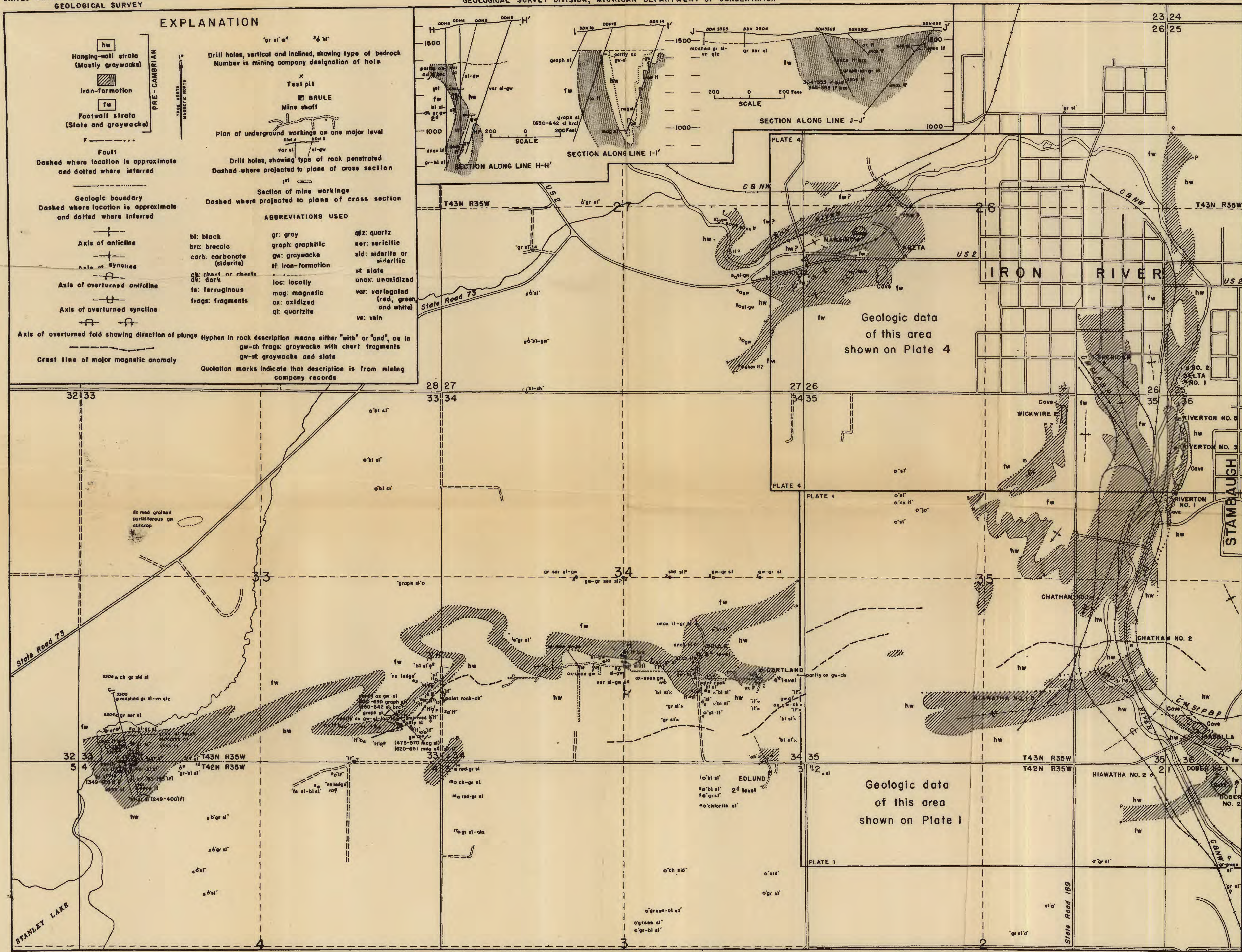

MAP AND STRUCTURE SECTIONS SHOWING GEOLOGY IN CENTRAL PART OF IRON RIVER DISTRICT, IRON COUNTY, MICHIGAN

500 0 500 1000 1500 2000 Feet

SCALE

Geology by C. E. Dutton, 1948

63745