PROGRESS REPORT NUMBER EIGHT

STATE OF MICHIGAN

DEPARTMENT OF CONSERVATION
P. J. HOFFMASTER, Director

GEOLOGICAL SURVEY DIVISION
R. A. SMITH, State Geologist

Geology of the Menominee Range Norway To Waucedah

By

Carl A. Lamey and Carl E. Dutton

April, 1942

A PRELIMINARY GEOLOGIC SURVEY OF PART OF THE MENOMINEE IRON RANGE FROM NORWAY TO WAUCEDAH, MICHIGAN

Carl E. Dutton[1] and Carl A. Lamey[2]

INTRODUCTION

The Michigan Geological Survey initiated a restudy of the Menominee Iron Range in 1937 and this is the third report resulting from that investigation. Progress Report No. 5, published in 1939, concerns the area from Norway to Quinnesec and Progress Report No. 6 deals with the investigations of the following season in the vicinity of Iron Mountain. These reports contain discussions of the distribution and structure of the rock formations and of the major problems of the areas. They are accompanied by geologic maps showing the general interpretations based upon the assembled data.

The area investigated in 1941 is a belt 7½ miles long and approximately 1 mile wide. The work was begun in Norway, at the eastern limit of the segment mapped in 1939, and continued eastward to Waucedah.

The general field procedure in 1941, similar to that of the previous seasons, consisted of: (1) stratigraphic studies; (2) mapping of outcrops and structural features; (3) taking dip needle readings at intervals of 40 feet along a grid of north-south and east-west traverse lines one-eighth mile apart; and (4) compiling data from such mine maps and drill records as were available. Control was established by taping distances between section corners and setting markers every eighth mile.

---

[1] Department of Geography and Geology, Wayne University

[2] Department of Geology, Ohio State University

The geologic map accompanying this report is only preliminary but represents those relations which seem to agree best with the assembled geologic and magnetic data. Due to the indefinite and incomplete character of the information available for other parts of the area, it is deemed advisable, at least for the present, to issue a map of only the narrow strip which includes the iron formations and associated strata.

The personnel of the field party in 1941 included, in addition to the writers, Mr. Irving Beckwith and Mr. Burton Westman as compassmen. Their services are gratefully acknowledged.

DISTRIBUTION AND STRUCTURE OF FORMATIONS

The area from Norway to Waucedah has many geologic features similar to those in the areas previously mapped. Thus the general strike of the formations is north of west, the general dip is southward at high angles, and the oldest formation of the immediate area, the Randville dolomite, occupies the northernmost position and is succeeded southward by progressively younger formations. Locally, there are decided departures from these general conditions; i.e., dip may be northward, due to overturning; strike may vary considerably because of folding and faulting; and formations may be repeated or may be missing as a result of faulting. Likewise, a well-defined fault pattern is apparent in the region consisting of systems of faults whose trends are parallel to one of four general directions: (1) northeast-southwest, (2) northwest-southeast, (3) nearly north-south, and (4) approximately east-west. Furthermore, faulting not only dominates the local distribution of the formations but apparently is also an important factor in their regional distribution.

The geologic map accompanying this report shows many of these characteristics and differs from the maps[3] in Monograph 46, United States Geological Survey, which indicate the belief that the general northwest-southeast trend of the rock layers from Norway to Waucedah was modified by a few folds and by one fault of small displacement. Less prominent differences in interpretation of the distribution and identity of some formations are shown on the accompanying map.

The geologic structure of the area shown on the map is considered more fully by a discussion of the essential features in each of three principal districts.

Norway-Vulcan District

This district, which includes parts of sections 9 and 10, T39N, R29W, extends eastward from the Old Brier Hill exploration shaft in Norway to north of the New Central shaft in Vulcan and includes that part of the Menominee Range in which iron mining by underground methods is most active at the present time. In the western portion of this district, the fault shown at the Old Brier Hill shaft is indicated by exposures of Randville dolomite only about 75 feet north of the conformable contact between the Traders and Brier formations at the shaft. These relationships are interpreted as being the result of a fault of east-west trend whose displacement brought about the omission of the "Footwall" slates, most of the Traders formation, and possibly some of the upper dolomite zones. This fault was recognized and mapped in earlier work to the west but its eastward continuation, apparently out into the dolomite, has not been determined.

The faults adjacent to the Curry shaft seem to have little effect upon the surface distribution of the formations at this locality.

3 W. S. Bayley: The Menominee Iron-bearing District of Michigan, U. S. Geological Survey (1904), plates 9 (in pocket), 33, 34, 35 and 36.

They were indicated by dip needle readings and have been plotted from mine data.

Exposures in the abandoned pits north of the Curry shaft show much brecciation, slickensides, and ore zones. These complexities were resolved into the fault pattern and distribution of formations as shown on the map. The principal features are an abrupt termination of the Traders formation in alignment with an abnormally wide belt of Brier slates and an offset in the trend of the Traders iron formation.

The geology of the Traders-Brier contact in the eastern part of Section 9 was rather easily determined because of the almost continuous exposures in the walls of the abandoned pit north of "C" shaft. The Traders iron formation and the Brier slates are sufficiently distinctive so that the faulting can be recognized readily. Faulting has produced extensive brecciation in both formations. The eastward extension of these relationships into the western part of section 10 has been based upon subsurface data in which one level connected with a shaft to the east and followed a brecciated contact between slates and iron formation. The dump from this shaft in section 10 is mainly Traders iron formation but pieces of slate and quartzite from the "Footwall" series are common also. The identity of these materials and the notations on the subsurface maps led to an interpretation of the geology proposed on the map.

Another fault is well shown by the exposures in the large pit east of "C" shaft in section 9. The Curry iron formation to the north of the fault has been thoroughly shattered adjacent to the surface of displacement and materials of uncertain age south of the fault have been sheared into sericitic and chloritic schists with quartzite pods or lenses. It is believed that two faults are present in the western end of the pit but exposures toward the east indicate that they probably merge into a zone of displacement in which individual faults are not recognizable. This faulting was also indicated by abrupt changes in the magnitude of the dip needle readings as north-south traverses were run across it, but the east-west continuation of the fault as shown on the geologic map is mainly based upon data from mine maps. The overlap of the formations along the fault reveals the relative movement in this displacement.

East Vulcan District

This unit of the area extends eastward from the New Central shaft in Vulcan to the Sturgeon River and includes a portion of the Menominee Range in which mining was once very active. The geologic structure of the district was determined from surface, subsurface, and magnetic data which were alike in their indications of complexity at the western end. The geologic map shows that faulting is common throughout most of this district, and that the relative displacement of the faulted segments controlled the distribution of both iron formations. In the eastern part of section 10, the Traders iron formation has been offset with overlap by two parallel faults of northwest-southeast orientation. The normal southeasterly trend of the Traders iron formation persists into the southern part of section 11 where the formation is apparently folded and displaced along two east-west faults. The relative movements in this locality were such that the formations in the block between the faults are east of their continuations along the strike in either direction.

The distribution of the Curry iron formation in the East Vulcan district is related primarily to displacement along several faults of northwest-southeast trend. These faults converge or intersect in an area which extends across the line between sections 10 and 11. This interpretation is based upon an apparently erratic distribution of iron formation and slate exposures in that area and the lack of agreement between surface and subsurface information. "Mixed slate and Curry iron formation" is placed on the geologic map for the same reason. At least two faults from this locality extend southeastward through section 11 and into the northern part of section 14, and two other faults, or branches of the easternmost fault in section 14, extend eastward through the southeastern part of section 11. Additional faults are suggested by the unusually wide belt of Curry iron formation in these sections. Still another fault of northwest-southeast trend forms the southern boundary of the Curry iron formation through section 10 and into section 11. Information on the course of this fault was obtained mainly from subsurface data, but in section 11 it was actually observed to pass through the Jones pit, south of No. 3 shaft, as plotted on the geologic map. The Curry iron formation in this pit is north of the fault and the bedding is almost parallel to the fault, but the slate layers on the south terminate abruptly at the zone of breccia and gouge.

The remainder of this district includes the northeastern part of section 14 and the northwestern part of section 13. So far as known at the present time, this part of the district is lacking in complexity, but the subsurface data are meager and the magnetic data were of little value for determining structure.

Loretto-Waucedah District

Interpretation of geologic structure just to the east of the Sturgeon River and south of Loretto was aided by drill records of exploration in that vicinity. These records indicate that more complexities undoubtedly exist there than have been shown. Folding of the strata in this locality has caused local changes in the trend of the two iron formations and faulting of eastnortheast-westsouthwest trend has also offset the Curry iron formation. The principal feature, however, is a fault of northwest-southeast orientation whose displacement brought the Randville dolomite adjacent to the iron formations and the Brier slates.

These relationships apparently continue from Loretto to Waucedah and constitute the characteristic and striking geologic structure of that section - the great thrust fault varying somewhat in direction throughout that distance, but in general maintaining a northwest-southeast trend. This interpretation of the geology and the map of this report are in striking contrast with the concepts of Monograph 46 which proposes that this district is without complexities in the succession and arrangement of the rock layers. The fault structure was first indicated by abnormally high dip needle readings on dolomite outcrops, and by noting that the trend of the magnetic crest was situated too close to exposures of dolomite to permit a normal succession of strata to be present. Interpretation of the relationships as an overthrust arrangement was substantiated by drill records since iron formation was encountered in some localities (sections 18 and 17) after the drill had passed through dolomite and a zone of sheared materials. Because of these data, the map has been drawn to show that the iron formations and associated slates probably extend from Loretto to Waucedah, but in at least two localities along this trend the continuity of the iron formations is apparently interrupted. The true relations, however, are believed to be that the displacement along a fault of northwest-southeast trend was of such character that, simply, the iron formations were covered by overthrust masses of dolomite. Additional faulting, not shown on the geologic map, is revealed by drill records of some holes which passed through more than two iron formations and also encountered formations whose identities are uncertain.

Southeastward from near the center of section 17, the map shows that the course of the fault trace is more easterly than the trend of the formations and consequently successively older strata reappear as they continue from beneath the overthrust dolomite. The interpretations in this section are likewise based upon magnetic data obtained from the dip needle survey and upon subsurface data in records of diamond drilling.

The distribution and structure of formations in the vicinity of Waucedah were determined from field observations on some natural outcrops as well as from exposures in test pits and in the abandoned pits of the Breen and Emmett mines. In general, the arrangement of the formations in this vicinity is not very complex but some revision of the interpretation reported in Monograph 46 seems advisable. The formations have a general east-west strike as shown on the map and are either in a vertical position or dip steeply southward. The mine pits are situated in a belt of Curry iron formation whose northern boundary is a fault contact with Brier slates, and from the observations which can be made at the present time it is apparent that the ore concentration was very closely associated with this fault contact or with adjacent sheared zones. Slate strata were encountered in a series of test pits between the Curry iron formation to the south and the outcrops of massive ferruginous chert to the north. This chert is believed to be the uppermost zone of the Traders iron formation, and the intervening slates are therefore classed as Brier formation. The small patch of "Footwall" slates is shown on the map in the north central part of section 22 because a record of drilling at this locality revealed "talc slate" adjacent to Traders iron formation and several test pits to the north of the massive ferruginous chert encountered slate strata. A fault contact was drawn at this locality because if the formations have been identified correctly, these slates and the outcrops of massive ferruginous chert are too close together to permit the normal thickness of Traders formation to be present.

The investigation did not extend east of Waucedah because the iron formations and associated strata are overlain by Cambrian sandstone in that direction and are not known to reappear from beneath the extensive cover of younger rock layers.

Magnetic data were assembled also for an area north of Waucedah in sections 15, 16, and 17. They revealed a trend of maximum dip needle readings as shown on the map by the "magnetic crest." The location and course of the crest are probably determined by one or more layers of iron formation, but no outcrops were found and no records of exploration are known. However, the magnitude of the magnetic readings in this region is comparable to the readings obtained along the south range and projection of the trend toward the northwest would carry the crest into an approximate alignment with occurrences of iron formations in the vicinity of the Loretto and Appleton mines north of Loretto village, in an area not yet remapped. These concepts are similar to those shown on the general geologic map[4] of Monograph 46.

If, north of Waucedah, another belt of iron formation is separated from the southern belt by an area probably underlain with dolomite, the arrangement would be similar to that which exists in the vicinity of Loretto, where dolomite is exposed in several large outcrops but iron formations are present both to the north and the south of the dolomite. As previously stated, the southern formations are known from

---

4 Op. Cit., Pl. 9, in pocket

magnetic and drill data whereas the northern formations were exploited by the Loretto and Appleton mines. Several exposures are present also. The strata exposed in the eastern end of a pit at the Loretto mine apparently belong to the Curry iron formation and are vertically inclined, but approximately 500 feet to the south in an outcrop of dolomite the layers are inclined only 45° southward. These relationships cannot be interpreted as simply an anticlinal fold with its axis situated between the Randville dolomite on the south limb and the Curry iron formation on the north limb because distance to accommodate all of the strata which should be present is insufficient. Consequently the proximity of these exposures and the anomalous inclinations of the strata in them seem to be sufficient evidence to preclude the possibility of a normal succession at this locality. Therefore it is proposed that one of the major faults of the region is indicated by these conditions near the Loretto mine. The occurrence of dolomite on the south side of such a fault would imply that it was in the block whose apparent motion had been upward. This type of displacement could have produced the existing recurrence of the iron formations to the south. This interpretation of the repetition of the iron formations at Loretto also suggests an explanation for the three "ranges" which constitute the major structural pattern of the Menominee Range.

STRATIGRAPHY

Although investigators in this region have differed as to the identity of strata in some exposures, they have been in general agreement concerning the normal succession of the formations. The lowest rock layers usually encountered in any range belong to the Randville formation. The predominant material in this formation is dolomite which crops out in numerous localities. The identification of the formation in this normal facie is unquestionable but information concerning the basal portions is lacking, or at least no strata have been recognized as representing the base of the succession. The layers above the Randville formation were designated "Footwall slates" by Scofield. This formation consists of a series of dolomitic and sericitic slates with some layers of quartzite, and others of massive, ferruginous chert. No surface exposures are known in which the nature of the contact between the dolomite and slates can be determined, but wherever they are adjacent underground they are separated by a fault zone. The Traders iron formation rests conformably upon the "Footwall" slates and is composed of interbedded jasper and hematite layers. Conformable relationships also exist between the Traders iron formation and the overlying quartzose slates of the Brier formation as well as between the Brier and the younger Curry iron formation which is generally similar to the Traders iron formation. An upper contact of the Curry iron formation and overlying slates is exposed in several places at the surface and occurs in many places underground. The relations at the surface clearly indicate the occurrence of faulting at such contacts, but Scofield proposed that the Curry formation is conformably overlain by the Loretto slates, which are ferruginous and become a chocolate brown when weathered. Others have proposed that strata called "Hanbury slates" rest unconformably upon the earlier formations and are the youngest part of the Huronian succession in this region, but the writers believe that the stratigraphy of such strata is uncertain.

Earlier reports of this investigation (Progress Reports 5 and 6) contain descriptions of the formations and present the characteristics which, if present, may serve to identify these strata but it is believed that several new phases of the stratigraphy were determined from field observations in the past season.

In numerous exposures, the Brier formation is a well bedded quartzose slate. Below such strata, however, similar slates were found which contain nodules, lenses, and occasionally bands of fine grained gray chert. Such beds occur along the south side of No. 4 pit, north of "C" shaft (section 9), and in slate exposures west of the Breen pit at Waucedah. This basal facie apparently represents a local variation because in other exposures slates without chert masses rest conformably upon the Traders iron formation.

A hitherto unnoted feature of the Curry iron formation was found. The cherty bands of this formation are normally of maroon color and possess a granular texture. The grains are usually of circular or elliptical cross-section, can be easily seen with a hand lens, and are imbedded in a much finer matrix. Most of the iron formation exposed in the pit east of "C" shaft has these characteristics, however higher layers at this locality consist of hematite interbedded with material of gray color and cherty to quartzitic texture. Exposures of similar strata occur along the south side of the Munro pit west of Norway, and at the Jones pit south of No. 3 shaft in East Vulcan, and perhaps also along the north wall of Emmott pit at Waucedah.

PROBABLE GEOLOGIC STRUCTURE OF THE MENOMINEE RANGE

The iron formations and associated strata of the Menominee Range occur in three separate units or "ranges." The southern range is a long narrow belt which extends southeastward 18 miles from the Menominee River west of Iron Mountain to Waucedah. It has contained the most important ore bodies of the region. Similarly, the middle range has a northwest-southeast trend but is divided into two long narrow belts according to the general geologic map[5] of Monograph 46. The western

[5] Op. Cit., Pl. 9, in pocket

portion extends southeastward from the Traders mine north of Iron Mountain to the abandoned Forest mine northeast of Lake Fumee and is about 5 miles in length. The eastern and western portions are separated by a distance of about 7 miles and the eastern portion occupies a belt 4 miles long from north of Loretto to north of Waucedah. The southern range, and some of the eastern part of the middle range as indicated by the "magnetic crest," are shown on the geologic map accompanying this report, which covers the areas mapped in 1939, 1940, and 1941. The geologic map of Monograph 46 shows that the northern range is about 5 miles northeast of Iron Mountain and 2½ miles north of Lake Fumee. It is only about 1½ miles long and very little is known about it. No outcrops of iron formation have been observed in this locality although a test shaft in section 15, T40N, R30W encountered the basal quartzite material of the Traders iron formation at a depth of approximately 35 feet, and Monograph 46 reports[6] that pits near the center of section 15, T40N, R30W have shown the presence of rocks believed to belong to the Curry formation.

The general successions of strata in the southern and middle ranges seem to be similar. From north to south, the normal sequence is (1) Randville dolomite, (2) "Footwall" slates, (3) Traders iron formation, (4) Brier slates, (5) Curry iron formation, and (6) slates of variable character and uncertain age (including the Hanbury slates if present). Monograph 46 refers[7] to dolomite exposures north of the possible iron formation in the north range, and thus the north range may have some resemblance to the other ranges but confirming data are lacking inasmuch as investigation has not yet extended to a restudy of that region.

The interpretation in Monograph 46 concerning the structural pattern of the entire Menominee Range emphasizes the presence of a major

---

6 Op. cit., p. 287

7 Op. cit., p. 200

unconformity at the base of the upper Huronian strata -- i.e., Hanbury (?) slates. That interpretation proposed that (1) folding occurred after the accumulation of the Curry iron formation, (2) a long interval of erosion truncated these folds, (3) renewal of accumulation produced the Hanbury layers which rested unconformably upon formations as low as the Randville dolomite, (4) a second deformation brought about the present inclination of all Huronian strata, (5) erosion removed the Hanbury slates from some areas, and (6) thus exposed the three "ranges" but left much of the region underlain by the Hanbury slates. According to this interpretation, the regional structure consisted of three synclinal folds, and in each of them only the northern limb was visible, whereas the southern limbs were unknown because overlain unconformably by a great thickness of deformed Hanbury slates.

The present investigation, however, has led to different interpretations of the major structures. As stated in a previous report[8], the "Hanbury slates" of the type locality at Hanbury Lake are dolomite, dolomitic slates, and dolomitic quartzites, yet these materials seem identical to some exposures in areas mapped as Randville dolomite. Also, other exposures which have been called "Hanbury slates" by previous investigators are similar to lower strata in the general succession and consequently it has seemed advisable simply to recognize "slates of variable character and uncertain age." Furthermore, wherever strata are in the normal position of the "Hanbury slates" -- i.e., adjacent to the upper contact of the Curry formation, evidences of faulting are conspicuously present. Occurrences of this relationship have been observed along the south side of the Munro pit west of Norway, through the pit east of "C" shaft in Norway, and in the Jones pit south of No. 3

---

8 Lamey, C.A., and Dutton, C.E., A Preliminary Geologic Survey of Part of the Menominee Iron Range in the vicinity of Iron Mountain, Michigan, Michigan Geological Survey, Progress Report No. 6, 1941, p. 10.

shaft in East Vulcan. Data also have been presented to show that a fault undoubtedly separated the Curry iron formation of the Loretto mine from dolomite exposures a short distance toward the south. Somewhat similar relationships are present in the vicinity of Lake Antoine where dolomitic strata were encountered in a trench south of the Curry (?) iron formation of the Globe-Cornell pit. Consequently the nature of the materials on the south side of the southern and middle ranges, the relation of these strata to the adjacent iron formations, and the numerous displacements in the south range are believed to be indications that faulting has been more important than folding or unconformities in producing the present structural pattern of the entire region.

According to the writers' interpretation, major fault zones divide the rocks of the region into a series of large fault blocks, which in turn are split into numerous smaller blocks. The major fault zones, primarily, produced the individual "ranges", and it is probable that each "range" is one of the large fault blocks. The south range may be taken as an example of the probable structure of the individual ranges and of the Menominee Range as a whole. The general structure of the south range is now depicted throughout its entire length by the second map accompanying this report. Three phases of the general structure deserve amplification: (1) the structural relationship of the south and middle ranges; (2) the structural relations existing between the south range and the adjoining area to the south; and (3) the structures within the major block composing the south range.

The structural relations existing between the south and middle ranges are indicated toward the eastern end of the south range in the area between Loretto and Waucedah where these two ranges are closest to each other. The "magnetic crest" indicates the position of the middle range. The Curry iron formation shows the position of the south range.

If the suggested interpretation is correct, a fault block is between the middle and south ranges and has as its northern boundary a major fault occupying some unknown position south of the "magnetic crest", and as its southern boundary the great overthrust fault which brought Randville dolomite over the younger formations. At the eastern end of the Menominee Range, therefore, the south and middle ranges are separated by an upthrust fault block composed apparently chiefly of Randville dolomite. Westward the distance between the south and middle ranges becomes progressively greater. The exact conditions to the west are not known, but it seems reasonable to assume that the same general type of faulting persists, as indicated by the great overthrust fault west and north of Quinnesec, and consequently, that the south and middle ranges probably are separated from each other by major fault zones throughout their entire length. Obviously there may be and probably is variation in complexity and character of faulting throughout the entire zone of separation.

Along the south side of the south range is much evidence of faulting, although doubt as to the exact age of formations to the southward makes interpretation difficult. However, there is reason to believe that to the south is a series of fault blocks, and that in a number of places older material to the south is in fault contact with younger material to the north. These relations have been cited in this and in previous reports.[9]

The structures within the major block composing the south range are complex. As a rule the rocks strike north of west and dip rather steeply southward or are nearly vertical, but locally they may dip northward due to overturning. Folding has been important, but the

---

9 Dutton, C.E., and Lamey, C.A., Op. Cit., 1939, pp. 3-4, 8; 1940, p. 10.

dominant structural feature apparently has been faulting of several types and probably of different ages. One group of important faults has a northeast-southwest trend; displacement along these faults produced most of the local structures in the south range. These faults cross the formations diagonally and have caused offset of formations with an overlapping arrangement. A second group of faults - those through the Chapin mine at Iron Mountain, through the Norway mine at Norway, and in the western part of the East Vulcan district - has a northwest-southeast trend. The general effect of the faults has been to produce repetition of the normal succession. Along some of these faults relatively great apparent displacement has occurred. Other faults trend approximately east-west. In general, displacements along such faults produced overlaps of the formations as if the northern segment moved eastward, but some of the faults in the vicinity of Norway have the apparent displacement in the opposite direction. A fourth group of faults includes the few which trend approximately in a north-south direction. Apparent displacement along these faults has been small, and all of the offsets have not been in the same direction. In addition to the four systems are the overthrust faults, whose trends are irregular - locally northwest-southeast, northeast-southwest, or east-west. Great displacement has occurred along these faults and they may, indeed, be extensions of major regional faults into the south range, tending to narrow the range or entirely obliterate it locally, as indicated to the south and east of Loretto and to the west and north of Quinnesec.

RELATION OF GEOLOGIC STRUCTURE AND ORE BODIES IN THE SOUTH RANGE

The restudy of the Menominee district has been largely confined to the southernmost belt of iron formation because of the important mines located in it and the availability of geologic information. Data have been compiled from observations of rock exposures, from dip needle surveys, from mine maps, and from diamond drill records. These sources have provided abundant evidence that although some folding of strata has occurred, the present distribution and arrangement of rock layers are primarily the result of displacements along four systems of faults which differ in direction and importance.

The sources of information concerning the geologic structure of the Menominee Range have provided abundant evidence also that the ore bodies are situated along the four zones of faulting but are not equally developed along each system. The principal concentrations of ore have been found along faults of northwest-southeast trend in the Chapin mine at Iron Mountain, in the Curry mine and Norway mine at Norway, and in some of the mines in the East Vulcan district. Other concentrations are along faults of northeast-southwest trend as possibly in the Walpole mine and Pewabic mine at Iron Mountain, in the Vivian mine at Quinnesec, and in the Aragon mine and Cyclops mine at Norway. Some of the faults of east-west trend are present in the Munro pit west of Norway, in the Aragon mine at Norway, in some mines of the East Vulcan district, and in the Breen mine and Emmett mine at Waucedah. A few examples of ore concentration along faults of north-south trend have been seen also but no extensive ore bodies of this type are known. These examples show the prevalence of faulting in regions of ore concentration. In fact, the Keel Ridge mine east of Iron Mountain is the only locality which has produced iron ore and has no apparent evidences of faulting. Dip needle readings in this vicinity, however, give no indication of the Curry iron formation. If the formation is absent, then faulting has occurred here also.

The prevalent concept of relations between ore bodies and geologic structure in the Menominee Range, presented in Monograph 46, is that the ore concentrations were located in pitching synclines where the downward circulation of subsurface water was directed through the iron formations because of the imperviousness of the underlying slate strata. The data assembled during this investigation indicate, however, that all geologic features in this region are much more complex than has been generally known, and that the proposed revisions concerning geologic structure are probably important considerations not only in accounting for the occurrence of ore bodies but are also of value in exploratory operations.

All the ore bodies, except possibly at the Keel Ridge mine, are not only in local areas of much faulting but have faults through or alongside them. This relationship is interpreted as a result of circulation of subsurface water along fault zones, with subsequent concentration of ore against impervious rock barriers. Therefore, it seems probable that if additional ore is found it is likely to be situated along faults rather than to be in folds or undeformed strata. Furthermore, the amount of ore concentration seems to be related to the trend of the faults, and although reasons for this condition are undetermined, it seems advisable that exploration be especially directed toward areas in which faults of northwest-southeast or northeast-southwest trends are known, or are likely to be present.

Faulting of the iron formations, however, is not the only condition necessary for the formation of ore bodies in the south range, as faults without known ore bodies are in such localities as west of Iron Mountain, Quinnesec to Norway, and Loretto to Waucedah. It is likely that a combination of factors such as the sequence of faulting, the permeability of the formations, the temperature and volume of the oxidizing solutions, or some other relationships also aided in the formation of the ore bodies.

Although the combinations of circumstances which caused the conversion of iron formation into iron ore are not clearly indicated, the foregoing suggestions are made in order that they may be considered by persons interested in the relation of geologic structures to ore bodies in the Menominee Range.