THE ORIGIN AND OCCURRENCE OF SPECULAR HEMATITE (SPECULARITE) IN THE LOWER HURONIAN OF THE MARQUETTE DISTRICT, MICHIGAN

Thesis for the Degree of M. S.

MICHIGAN STATE COLLEGE

William Holway

1952

THESIS

This is to certify that the

thesis entitled

"Origin and Occurrence of Specular Hematite in the Lower Huronian of the Marquette District Michigan"

presented by

William M. Holway

has been accepted towards fulfillment
of the requirements for

M.S. degree in Geology

B. T. Sandefur
Major professor

Date 6/17/52

O-169

THE ORIGIN AND OCCURRENCE OF SPECULAR HEMATITE (SPECULARITE) IN THE LOWER HURONIAN OF THE MARQUETTE DISTRICT MICHIGAN

by

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A THESIS

Submitted to the School of Graduate Studies of Michigan
State College of Agriculture and Applied Science
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Geology and Geography

1952

THESIS

10-14-52

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ORIGIN AND OCCURRENCE OF SPECULAR HEMATITE (SPECULARITE) IN THE LOWER HURONIAN OF THE MARQUETTE DISTRICT, MICHIGAN

William Holway

GENERAL DESCRIPTION OF THE MARQUETTE DISTRICT

General: This is a study of the occurrence of specular hematite in the lower Huronian formations confined to the eastern part of the Marquette Range. However, a brief summary of the geology of the entire district is presented to portray a better understanding of the geologic relationships that are involved.

Stratigraphy and Structure: The principal geologic feature of the district is a westward plunging abnormal synclinorium*

*Van Hise, C. R. and Leith, C. K., 1911, The Geology of the Lake Superior Region, U. S. Geol. Survey, Mon. 52, p. 253.

of Huronian sediments. The structure extends from Marquette, westward for a distance of approximately forty miles with a trough that varies in width from one to six miles. Intruded into the sediments are Keweenawan basic dikes and sills together with some acid dikes which may be of Killarney age.

The Huronian sediments of the trough are bounded on the north and south and are underlain by Keewatin and other pre-Huronian rocks which are for the most part igneous. Keewatin greenstone schists are prevalent north of the Marquette synclinorium, but most of the rocks south of the trough are granites and granite gneisses. There is some question as to the exact age of certain of these rocks. Lamey*

*Lamey, C. A., 1931, Granite Intrusions in the Huronian Formations of Northern Michigan, Jour. Geology, vol. 39.

INDEX MAP

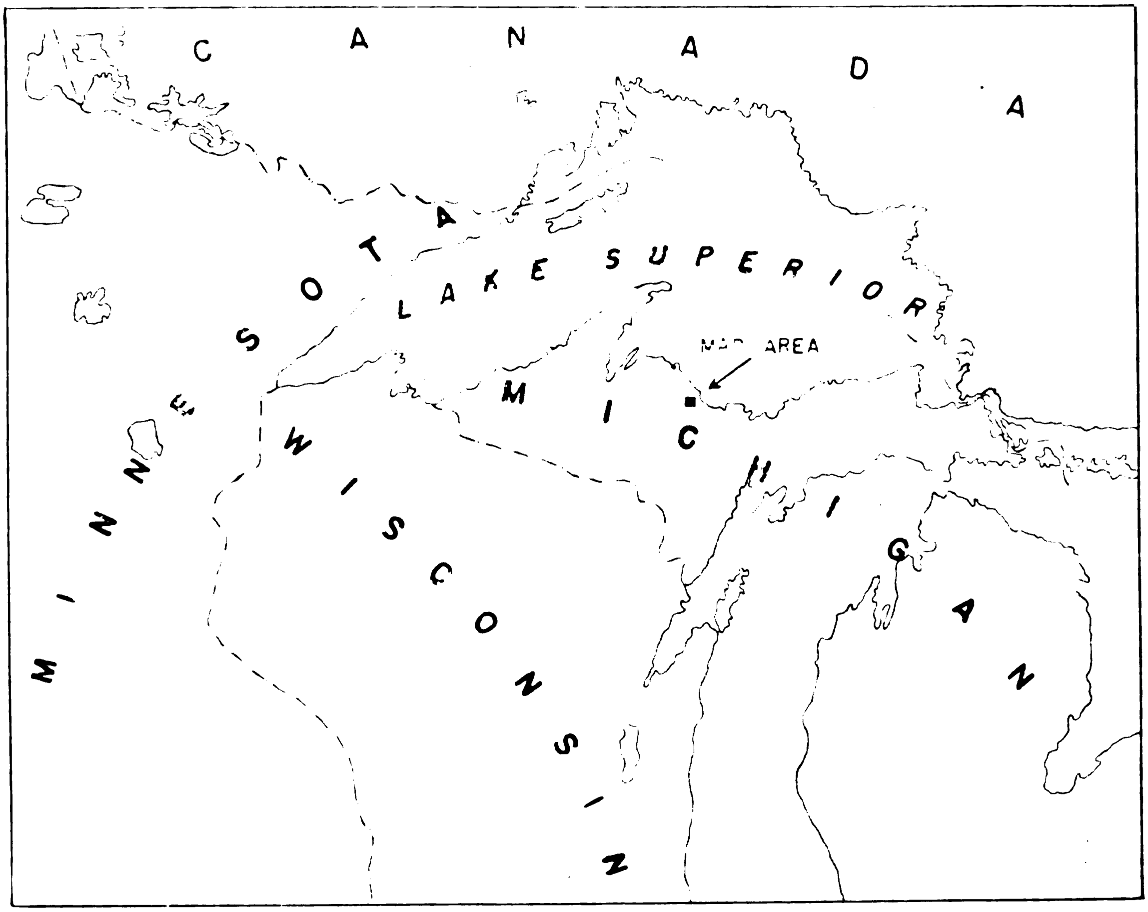


TABLE 1

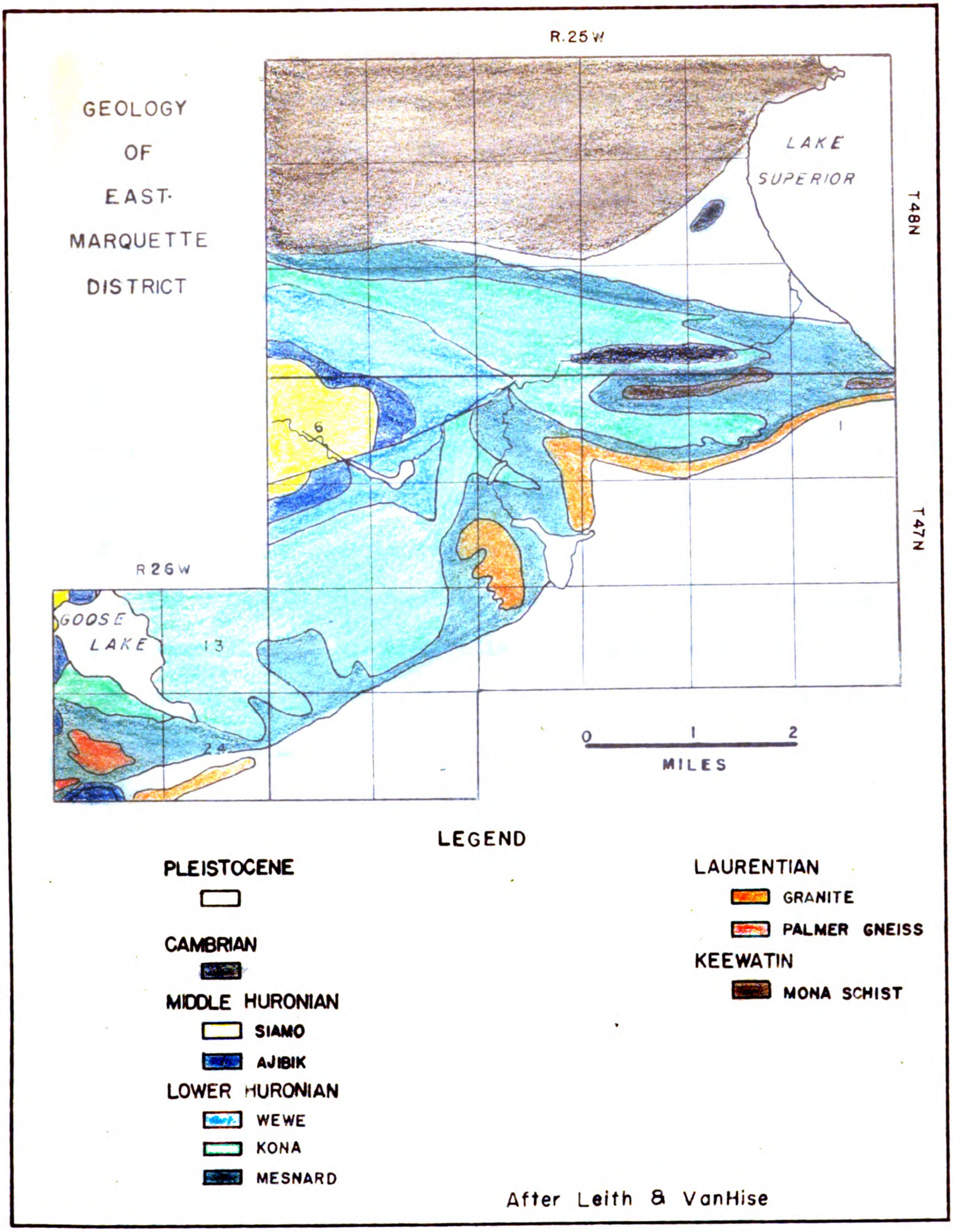
STRATIGRAPHIC COLUMN*

CENOZOIC	
Quaternary	
Pleistocene	sand, gravel, clay
PALEOZOIC	
Cambrian	sandstone
----------Unconformity----------	
PROTEROZOIC	
Keweenawan	basic dikes and sills
Killarney	acid dikes and intrusives
Upper Huronian	
Upper Michigamme	graywacke, slates, quartzites
Bijiki	iron bearing
Lower Michigamme	slates
Clarksburg	volcanic sediments
Greenwood	iron bearing
Goodrich	conglomerate, quartzite
----------Unconformity----------	
Middle Huronian	
Negaunee	iron bearing
Siamo	slates, graywacke
Ajibik	quartzites, slates
----------Unconformity----------	
Lower Huronian	
Wewe	slates, graywacke
Kona	dolomite, slates, quartzites
Mesnard	conglomerate, quartzite
----------Unconformity----------	
ARCHEOZOIC	
Laurentian	granite, gneiss, syenite
Keewatin	green schist

*Van Hise, C. R. and Leith, C. K., 1911, op. cit., pp. 251-252.

*Zinn, J., 1932, Correlation of the Upper Huronian of the Marquette and Crystal Falls Districts, <u>Papers of Academy of Science, Arts and Letters, vol. 18, p. 442.</u>

PLATE 2



GEOLOGY
OF
EAST
MARQUETTE
DISTRICT
R.25 W
R 26 W
T48N
T47N
LAKE
SUPERIOR
GOOSE
LAKE
6
13
1
24
0
1
2
MILES
LEGEND
PLEISTOCENE
CAMBRIAN
MIDDLE HURONIAN
SIAMO
AJIBIK
LOWER HURONIAN
WEWE
KONA
MESNARD
LAURENTIAN
GRANITE
PALMER GNEISS
KEEWATIN
MONA SCHIST
After Leith & VanHise

inferred that some of the granite south of the synclinorium is intrusive into the Huronian sediments.

The Huronian sediments form successive bands within the east-west synclinorium so that traversing the trough from north or south to the center, successively younger formations are crossed.

The entire district has been subjected to tectonic forces of great magnitude with the result that folding and faulting have produced complicated structures. This coupled with the variations in sedimentation of the original Huronian sediments, makes correlation of stratigraphic units very difficult. The strike of the prominent folds is east-west.

The principal iron bearing formations of the district occur in middle and upper Huronian sediments. They are mainly soft, red, earthy hematite. Massive hard, blue hematite and specular hematite occur in subordinate amounts.

Topography: The land surface of the district, when considered on a large regional scale, is rather level and regular. The average altitude for the district is around 1350 feet above sea level. However, the more resistant metamorphosed rocks of the synclinorium and the basic igneous rocks to the north stand much higher than and in marked relief against the jack pine covered sand plains to the south of the structure.

The terrain within the synclinorium is locally quite irregular; ridges and valleys are very common with a relief ranging between 200 and 400 feet. Usually the ridges are developed on the more competent quartzites and dolomites, while the valleys are formed in the less resistant slates.

The area has been thoroughly glaciated, many of the quartzite knobs showing striae quite plainly. Small lakes and swamps are common and the cover of glacial drift leaves only limited exposures of bedrock.

In the eastern part of the district the drainage is roughly east-west, parallel to the strike of the synclinorium, with streams that drain into Lake Superior. In the central and western parts of the district the streams flow south across the regional structure and discharge into Lake Michigan.

Vegetation: The vegetation consists mostly of second growth poplar, maple, birch, and various types of pine. The upland to the south of the synclinorium is covered mostly with jack pine, whereas cedar is prevalent in the swamps. Hardwood forests are seldom found along the south edge of the synclinorium.

THE OCCURRENCE AND ORIGIN OF SPECULAR HEMATITE IN THE MIDDLE HURONIAN

The hard specular hematite of the middle Huronian occurs mostly in the upper part of the Negaunee iron formation and in the lower part of the Goodrich quartzite. Although these ores are high grade they are secondary to the soft ores which provide by far the greater tonnage of the commercial ore in the district. According to Van Hise and Leith*

*Van Hise, C. R. and Leith, C. K., 1911, op. cit., pp. 274-278

the specular hematite ores were formed from soft ore or ferruginous chert by the metamorphic effects of igneous intrusions of post-Goodrich time and by folding and shattering along the contact plane between the quartzite and the underlying iron formation. The igneous intrusives which at times were unable to penetrate the competent quartzite, spread laterally along the contact, causing the iron formation to become indurated. Where both folding and movement occurred specular hematite developed from the softer hematite. Van Hise*

*(Van Hise, C. R., Bayley, W. S. and Smyth, H. L., 1897, The Marquette Iron Bearing District of Michigan, U. S. Geol. Survey, Mon. 28, p. 404.)

recognized that some of the specularite was deposited directly from cold, downward percolating, iron bearing solutions which moved freely along the contact plane.

The soft and hard ore differ in that the latter is crystalline and often associated with anhydrous silicates and magnetite.

PROBLEM

Statement: The Marquette District of Michigan has long been noted for its iron ore resources, the origin of which has been the subject of many papers and discussions. However, most of these papers deal primarily with the vast, soft iron ore bodies of great economic importance. Ore occurs for the most part in the Negaunee formation of the middle Huronian. Within the lower Huronian formations of the same district are some occurrences of specular hematite. While these have been prospected, their irregular disposition has caused them to be neglected in favor of the larger, soft ore bodies of the middle Huronian formations. Some of the deposits have been reported by Rominger*

*Rominger, C., 1881, Upper Peninsula, Geol. Survey of Mich. vol. 4.

and Van Hise.*

*Van Hise, C. R., Bayley, W. S. and Smyth, H. L., 1897, op. cit.

It is the purpose of the writer to describe the occurrence and origin of specular hematite from two localities within the lower Huronian formations of the district.

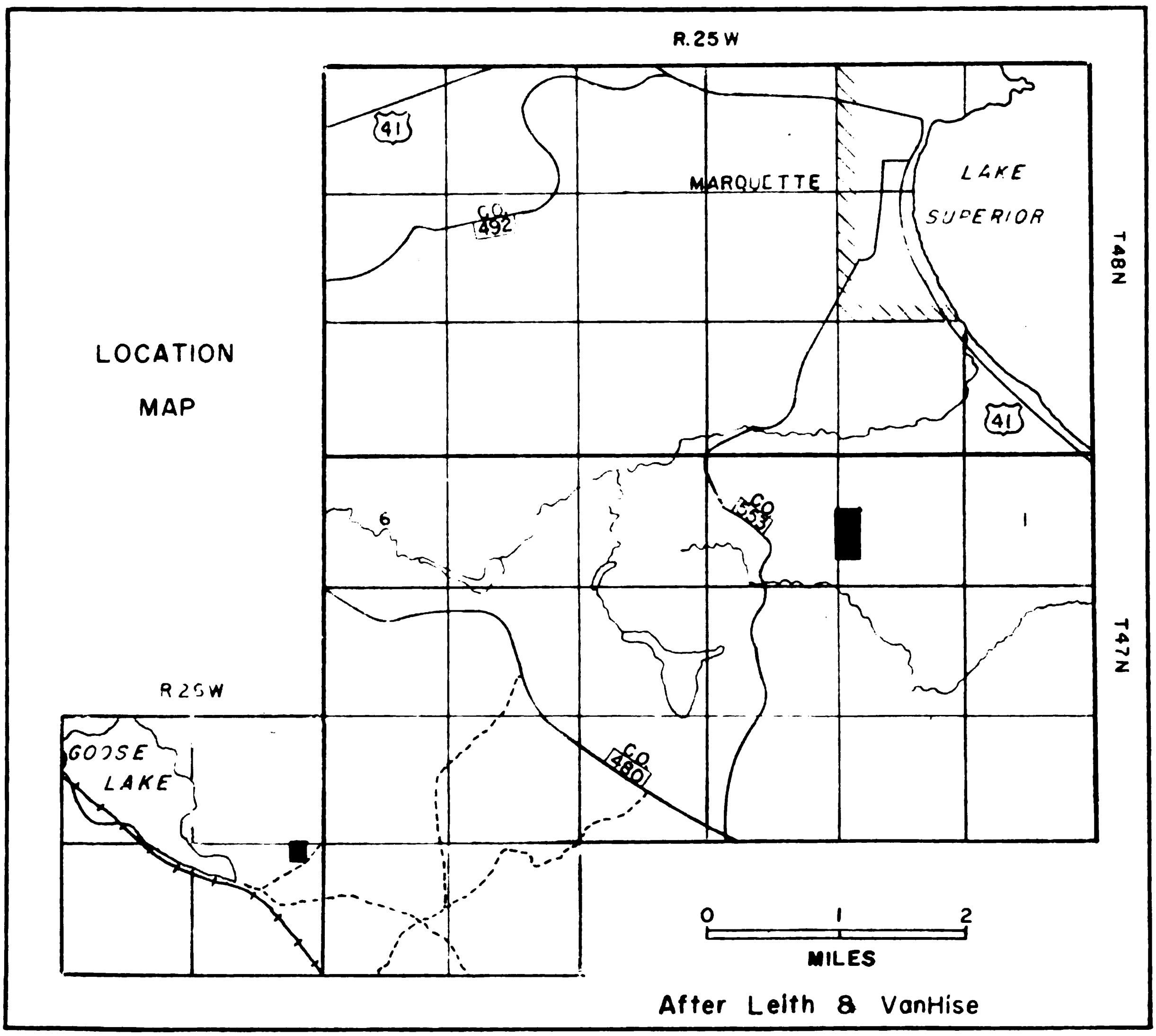
Location: The areas under consideration are located in the NW$\frac{1}{4}$, SW$\frac{1}{4}$, Section 2, T. 47 N., R. 25 W., and in the NE$\frac{1}{4}$, NE$\frac{1}{4}$, Section 24, T. 47 N., R. 26 W., County of Marquette, Michigan. The two sections will hereafter be referred to as section 2 and section 24 respectively, in this report.

Previous Investigations: Both areas have been prospected and in some places small mining operations were developed. These operations ceased many years ago.

No report of the occurrence of specular hematite in section 2 appears in any previous publications on the Marquette district. The deposit is small and for this reason probaly missed examination. However, a local landowner in the area informed the writer that some prospecting took place about 1900 but to his knowledge, no ore was ever shipped from this locality.

The specular hematite in section 24, on the other hand, has

PLATE 3


R.25 W
41
MARQUETTE
LAKE
SUPERIOR
CO.
492
T48N
LOCATION
MAP
41
CO.
553
6
1
T47N
R 25 W
GOOSE
LAKE
CO.
480
0
1
2
MILES
After Leith & VanHise

been reported in at least two previous reports. One by Rominger*

*Rominger, C., 1881, op. cit., p. 57.

gives a short description as follows:

> "In the N. E. quarter of Sect. 24, Town. 47, R. 26, a cluster of low quartzite knobs projects from the sand plains through which the Escanaba River flows after its outlet from Goose Lake. The plains generally seem to be underlaid by granite rocks, which come to the surface in some hillocks close to the Escanaba Railroad, in the centre of the south line of the above named quarter-section, while the quartzite hills are intersected by the north line of it. The latter are noteworthy on account of the interlamination of ferruginous hematitic schists and of tolerably fair seams of a schistose specular iron-ore with the quartzite beds, but the amount of good ore is too small to pay for its being mined."

Van Hise*

*Van Hise, C. R., Bayley, W. S. and Smyth, H. L., op. cit., p. 310.

described more completely the stratigraphy of this area but also makes reference to the iron present. He states:

> "These quartzites were shattered and cemented by quartz and iron oxides."

PROCEDURE

__Field__: The areas were mapped on a scale of 50 feet to the inch with the aid of a Brunton compass and steel tape. The field relationships between the ore and country rock were noted and samples of each were collected. Base lines were run from well marked section corners to designate the location of each area precisely. In order to secure samples that would

show the proper relationships of the ore and country rock in section 2, it was necessary to pump the water from the main prospect pit.

Laboratory: Thin sections of ore and country rock and polished sections of ores were made. Minerals of these sections were identified with the aid of the petrographic and metallographic microscopes. Textures and age relationships of the ore and gangue materials were noted.

The ores were identified by methods described by Short*

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*Short, M. N., 1940, Microscopic Determination of the Ore Minerals, U. S. Geol. Survey, Bull. 914.

---

and Cooke.*

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*Cooke, S. R. B., 1936, Microscopic Structure and Concentrability of the Important Iron Ores of the United States, U. S. Bur. Mines, Bull. 391.

The sedimentary rocks were classified according to Pettijohn*

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*Pettijohn, F. J., 1949, Sedimentary Rocks, Harper and Bros., p. 227.

---

and the igneous rocks according to the procedure outlined in Johannsen.*

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*Johannsen, A., 1939, A Descriptive Petrography of the Igneous Rocks, Univ. Chicago Press, pp. 141-161.

Stratigraphy and Structure: Although a study of the occurrence and origin of specular hematite in this area was the primary interest of the writer when this locality was under investigation, it was found that some interesting stratigraphy exists. Because of time and expense involved, a thorough examination of the stratigraphy was not undertaken. However, a few interesting facts present themselves (see map in pocket).

The white Mesnard quartzite is found in the southwest part of the area adjacent to a pink granite which is not shown on the map. About 300 fee north of this quartzite are some small outcrops of Keewatin green schist which at one place contain pebbles of chert and quartz. Immediately north of this schist are a number of outcrops of a massive, reddish quartzite in which the main prospect pit is located. On top of this quartzite at one place in the area a small outcrop of typical Kona dolomite appears to rest conformably.

North and adjacent to this massive reddish quartzite are some small areas of calcareous quartzite which weather out dark brown on the surface. Interbedded with the calcareous quartzites are a few thin beds of black slate. To the east, a rather thick bed of black purple slate underlies the calcareous quartzite conformably. In the northwest part of the area there is a buff colored banded sediment which the writer refers to as a laminated graywacke.

The sediments have been metamorphosed and bedding planes are often nonexistent or obscured. However, where it was possible to observe the bedding, the sediments had west or northwest strikes and dips which varied from south to north and southwest to northeast. The black purple slates which underlie the calcareous quartzites have a persistent dip to southwest of about 23°.

In the southeast portion of the area is a massive diorite dike, at least 50 feet wide, which intrudes these sediments. This east-west dike can be traced intermittently along its strike for at least a mile. The original magma that formed the dike may have entered along an east-west fault. This seems probable because an outcrop of pink granite occurs west of the area, and between green schist and white Mesnard quartzite. Since the green schist and the granite represent the basement complex upon which the Huronian sediments were deposited a fault could be present between this basement complex and the younger quartzites, slates, calcareous quartzites and graywackes to the north. The trend of this inferred fault is on line with the diorite dike and strikes into it. The displacement along the fault is such that the north side has moved down. The hanging wall is part of the Kona formation.

The stratigraphic relationships of the sediments north of the fault are not clear. The slates on the east side of the area underlie the calcareous quartzites and dip southwest. These same slates may be present between the calcareous quartzites and massive quartzites of the Kona formation in which case they overlie the latter, or the calcareous quartzites may represent merely a lateral facies of the massive reddish quartzites. If the latter were true then the slates underlie the quartzites north of the fault.

The laminated graywacke is probably a facies of the black slate. If so, it is probably that the slate and graywacke are one member while the red quartzite and calcareous quartzite form another member stratigraphically above them.

The more competent quartzites have been fractured in an east-west direction. The slates have well developed east-west cleavage, the joints in the diorite also have an east-west trend. In some of the east-west fractures of the massive reddish quartzite, specular hematite was deposited, while in similar trending fractures in the calcareous quartzite specularite bearing quartz veins are apparent.

PETROGRAPHY OF SEDIMENTARY ROCKS

General: The rock adjacent to the main prospect pit is a quartzite which probably grades northward into a calcareous quartzite. The strike of these rocks is essentially east-west or slightly north-west. The dips in these rocks vary from north to south within short distances indicating the occurrence of many small folds which gives the beds a corrugated appearance. North of the calcareous quartzites are the laminated graywackes. The presence of these rocks north of the quartzites would seem to indicate that the beds north of the fault are on the earth limb of an anticline which strikes about east-west.

Quartzite

Megascopic: The siliceous quartzite is a very compact, hard, rock, reddish in color due to iron oxide.

Microscopic: The rock is composed of quartz grains cemented with secondary silica in optical continuity with the original grains. Limonite forms a thin film around the edges of the original quartz grains and secondary silica has been deposited upon this film (Pl. 5, fig. 1). Calcium carbonate forms the cement in the rock in a few instances.. Sericite may be found

PLATE 4

MINERAL COMPOSITION AND TEXTURAL CHARACTERISTICS

OF DIORITE AND LAMINATED GRAYWACKE

Figure

1. Diorite

The minerals are oligo-andesine, diopside, and olivine (center bottom). Diorite dike which intrudes the sediments in section 2.

2. Laminated Graywacke

The small white splotches are quartz grains. The matrix consists of small clay particles. A small cavity in the dark band near the bottom of the fiture has been filled with quartz particles. The beds are right-side up.

PLATE 4

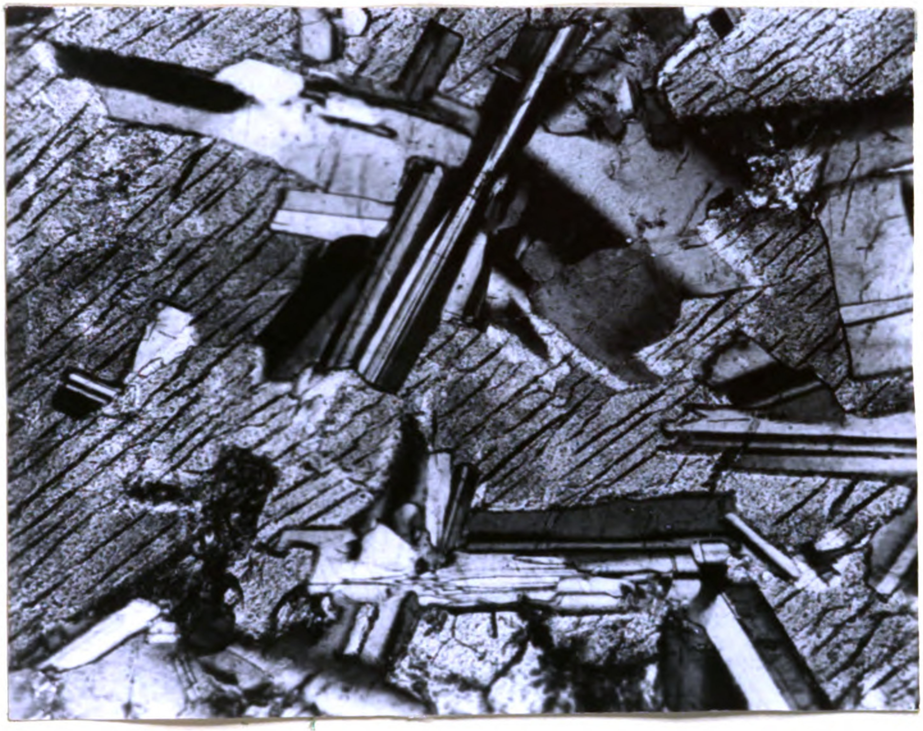

Figure 1

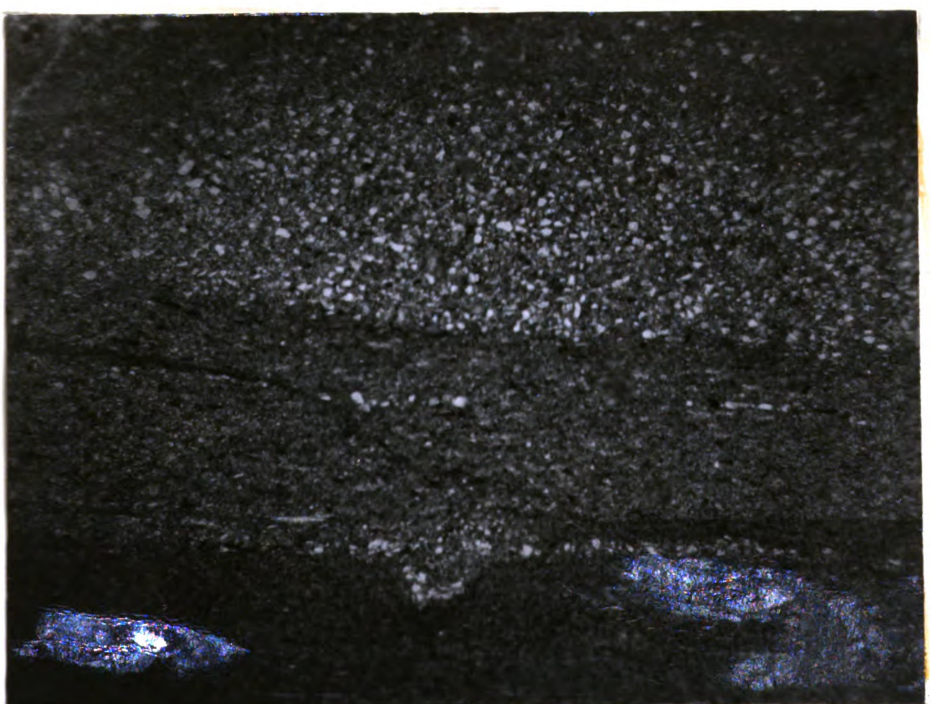

Figure 2

PLATE 5

MINERAL RELATIONSHIP OF QUARTZITE AND

CALCAREOUS QUARTZITE

Figure

1. Massive Red Quartzite

   A qaurtzite interbedded in the Kona formation. Secondary silica has been deposited around the original quartz grains which are outlined by a thin film of limonite. A few small calcite crystals are present between the grains.

2. Calcareous Quartzite

   By an increase in the carbonate cement the quartzite of fig. 1, grades into a calcareous quartzite. The large grains are quartz. This rock weathers to a dark brown on exposed surfaces.

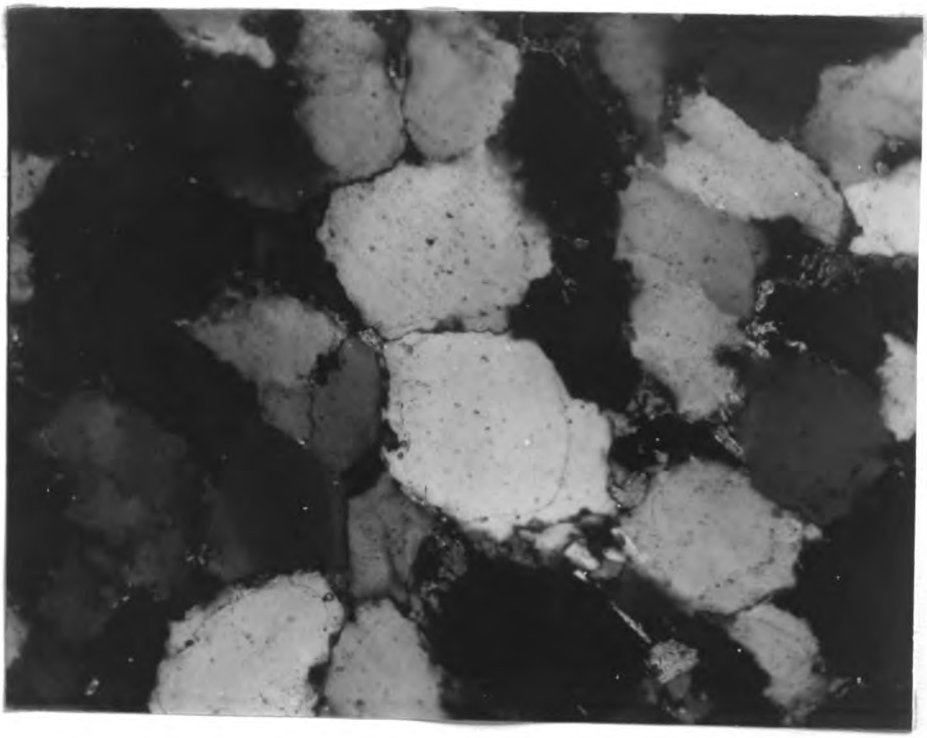

Figure 1

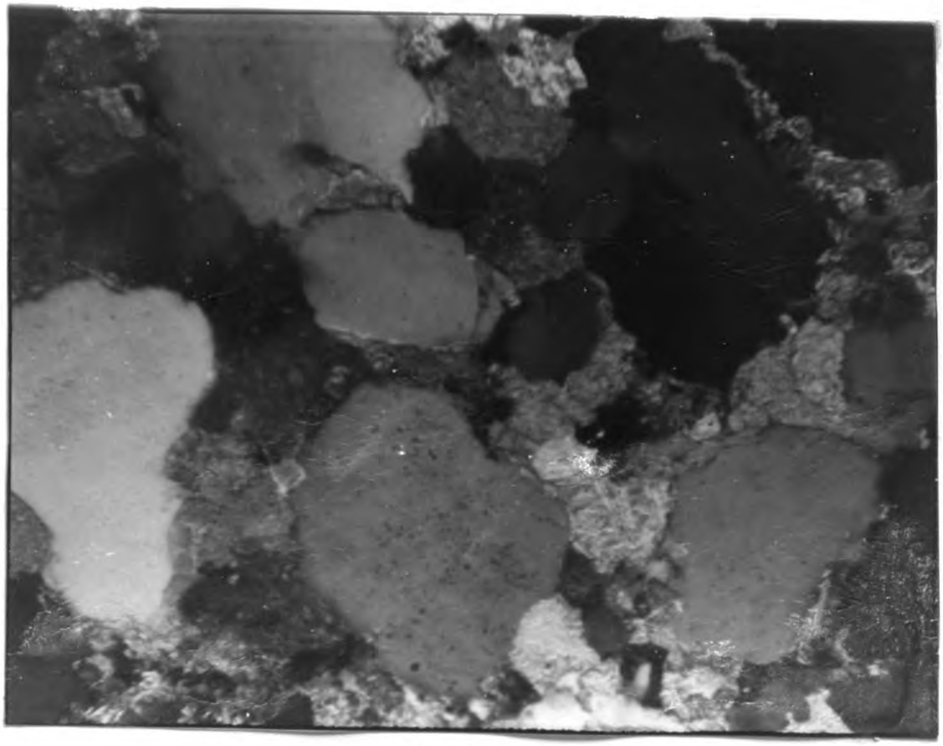

Figure 2

along some of the sutured contacts of the quartz. Finely disseminated amorphous hematite is deposited on some of the quartz grains and limonite occurs along some of the cleavages of the carbonate. Quartz is the principal mineral of the rock. Calcite, sericite, and iron oxide comprise less than eight percent of the total mineral constituents.

Calcareous Quartzite

Megascopic: The rock is massive, compact and dark red. A brown crust of limonite and silica formed on the weathered surfaces is probably due to the leching of the carbonate cement.
Microscopic: The rock is composed of quartz grains, calcite, limonite, and hematite. Secondary silica has been added to some of the quartz grains. Calcium carbonate cement makes up 35 percent and white quartz about 60 percent of the rock composition (Pl. 5, fig. 2).

Laminated Graywacke

Megascopic: The rock is composed of alternating dark and light red bands which give it a purple buff coloration. The material within the bands is easily scratched with a knife blade to produce a fine, whitish powder.
Microscopic: The rock is made up of alternating layers of clay material and small detrital quartz grains and has the appearance of a varved sediment (Pl. 4, fig. 2). Limonite and hematite are present as small particles throughout the rock. Limonite forms a thin film at the contact of the quartz and clay bands. The contacts are sharp at the bottom of the

quartz and at the top of the clay bands, but in the intermediate areas they are gradational. The clay material comprises about 60 percent, quartz about 32 percent and iron oxide approximately 8 percent of the rock composition.

PETROGRAPHY OF THE IGNEOUS ROCKS

Diorite

Megascopic: The rock is dark green, coarsely crystalline and contains plagioclase crystals that may be seen readily with the aid of a hand lens.

Microscopic: The texture of the rock is hypautomorphic granular (diabasic). The primary minerals are oligo-andesine diopside, olivine, hornblende, magnetite and pyrite. Secondary minerals include sericite, antigorite, chlorite and uralite. Some of the plagioclase crystals are zoned and most of them are strained. Euhedral crystals of olivine are altered to antigorite, chlorite and hornblende. Some of the pyroxene has altered to hornblende and a few of the plagioclase crystals to sericite. Magnetite and pyrite are very scarce.

PETROGRAPHY OF THE VEIN MATERIAL

General: The wallrock of the main prospect pit is quartzite and has been described previously. In the center of the pit fracturing has been severe resulting in some brecciation of the quartzite. A green schistose material containing small plates of specular hematite fills a few of the fractures. Clinging to the sides of some of the fractures are plates or blebs of the same iron mineral. The bottom of the pit has been stained a gun metal blue which is probably due to the action of iron bearing solutions. Rocks from the dump show specular hematite in forms similar to that in the pit.

In the calcareous quartzites to the north of the main pit are some east west, vertical dipping quartz veins which carry small amounts of specularite.

Fracture Fillings of the Main Pit

Megascopic: The vein material is light green, silky in luster with inclusions of plates of specular hematite.

Microscopic: It is composed of quartz, sericite, calcite, tourmaline and specular hematite. The quartz is brecciated in a matrix composed mainly of sericite. The sericite has replaced the quartz particles along their edges and in some places has resulted in complete replacement. Small euhedral crystals of tourmaline are present in the sericite matrix. Some crystals show a wormy, corroded texture. Hematite in the form of small micaceous laths and larger plates are also found in the rock. An occasional crystal of calcite is noted (Pl. 6, fig. 1, fig. 2).

Quartz Veins

The specularite bearing quartz veins which occur in the calcareous quartzites north of the main prospect pit are massive and milky in appearance and appear frozen to the wallrock. They range in width from one-half inch to about one foot with small vugs present in some cases. Platy hematite is plastered on the external surfaces and throughout the quartz.

PETROGRAPHY OF THE ORE

The ore, which is specular hematite, occurs as large plates and in smaller micaceous form. (Pl. 7, fig. 1, fig. 2.)

PLATE 6

MINERALS AND TEXTURES OF THE VEIN MATERIAL

Figure

1. Mineralized Zone

   The brecciated quartz grains (grey) are being replaced by sericite (white). A tourmaline crystal is shown at the top center. The last mineral to form was the black specular hematite.

2. Mineralized Zone

   A vein cutting specular hematite (black) and sericite. The upper part of the vein is calcite (dark grey), the lower part is quartz partially replaced by sericite. The sericite forms a comb structure along the edge of the vein and appears to replace the calcite in the upper part of the vein.

PLATE 6

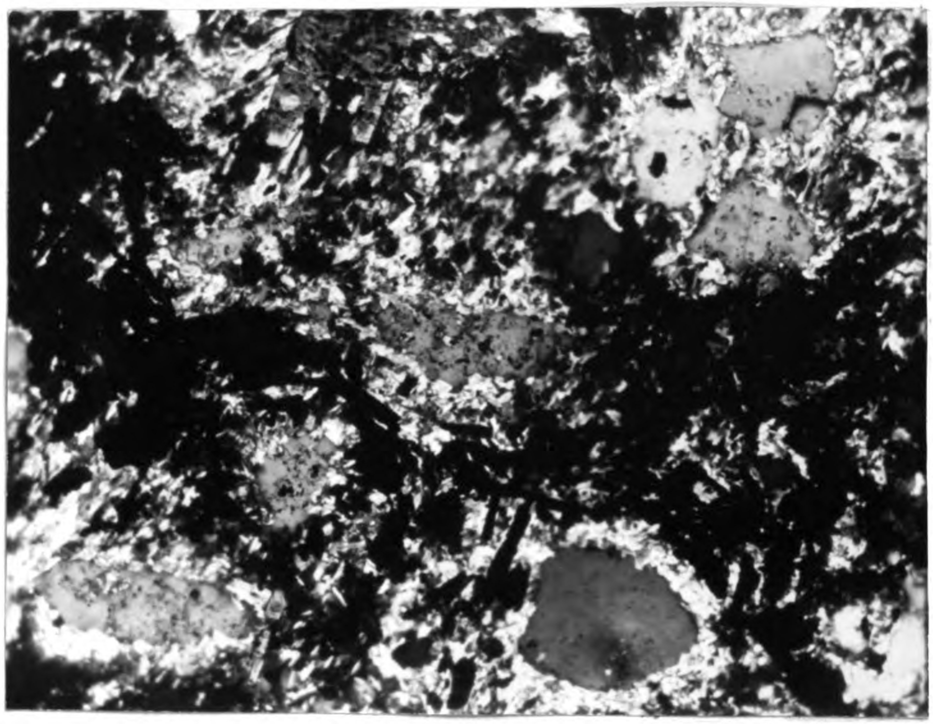

Figure 1

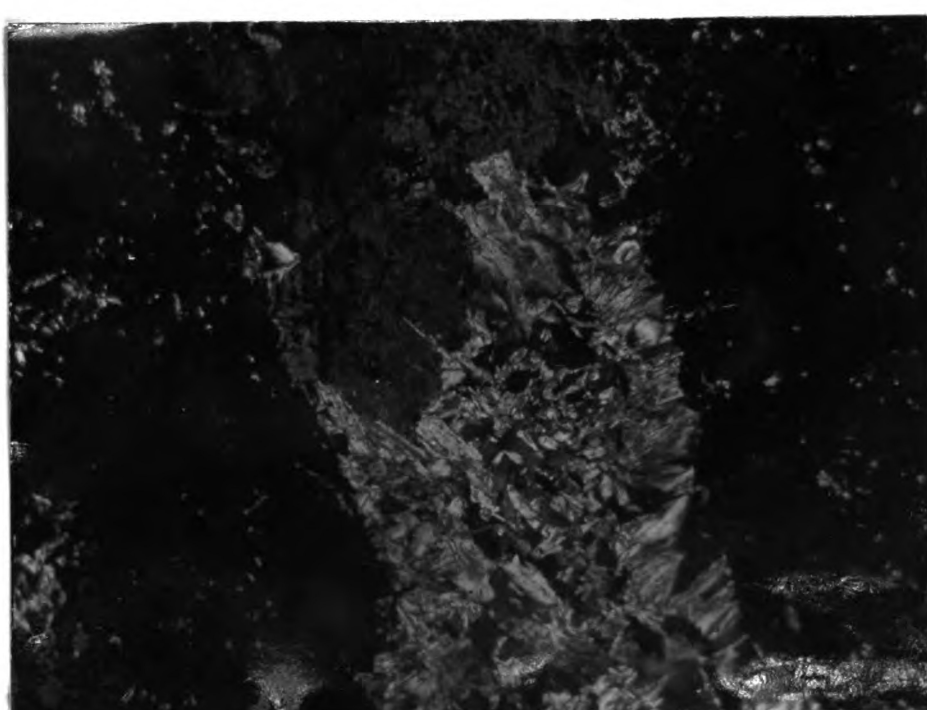

Figure 2

PLATE 7

MICACEOUS AND PLATY SPECULAR HEMATITE

FROM SECTION 2

Figure

1. Specular Hematite

   The white areas are small micaceous laths of specular hematite. The large grey areas are quartz grains. The quartzite was fractured and brecciated and the hematite was deposited in the openings.

2. Specular Hematite

   The white areas are large plates of specular hematite. The dark areas are pits in the mineral. Some of the dark areas are occupied by calcite which does not show.

PLATE 7

Figure 1

Figure 2

With the aid of the metallographic microscope the large platy variety, consisting of well developed lenticular plates, and the smaller micaceous flakes, forming a felt-like aggregate, may be noted. The mineral is strongly anisotropic and has a distinct bluish tinge when viewed between crossed nicols. The mineral is white in plain light and is negative to HNO_3, HCL, KOH, KCN, $FeCl_3$, and stannous chloride-hydrochloric acid solutions. The large platy form of the mineral is not magnetic but upon crushing some to the size of a pin head and smaller, the magnetism becomes quite noticeable.

Several of the large plates have a faintly developed Widmanstatten structure, in others a structure of alternating parallel light and dark bands is present which appear similar to albite twinning. The mineral is not scratched by a steel needle but does chip easily into small flakes. The streak of the mineral is dark red brown. Gilbert*,

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*Gilbert, G., 1925, Magnetite-Hematite Relations, Econ. Geology, vol. 20, no. 6, p. 588.

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in commenting on the characteristics of specular hematite, states that:

> "Hematite is pure white, or bluish white under the microscope, with hardness high, and is negative to all common reagents. While it can develop its own crystal outlines the form is characteristically platy and the majority of the plates, being inclined to the plane of the section, appear as laths."

GENESIS OF THE ORE

In the opinion of many authors the presence of specular hematite, tourmaline and the development of sericite indicates that high temperature solutions or vapors are the source of these minerals. That the deposit is not supergene due to weathering is indicated by these high temperature minerals. Gruner* makes the distinction between the effects of weathering and hydrothermal solutions by the presence of specular hematite. He states that:

> "There seems to be no single criterion for differentiating the effects of weathering from those of hydrothermal oxidation and leaching unless it be the presence of specular hematite and other minerals commonly ascribed to thermal action."

*Gruner, J. W., 1932, Additional Notes on Secondary Concentration of Lake Superior Iron Ores, Econ. Geology, vol. 27, p. 204.

Gilbert* seems to be of the same opinion and states:

> "To sum up, I do not believe that platy (micaceous) hematite is ever supergene."

That the above mentioned high temperature minerals could have been contributed by a magmatic source is indicated by the presence of specular hematite and tourmaline.

*Gilbert, G., 1925, op. cit., p. 596.

According to Grout*

*Grout, F. F., 1932, Petrography and Petrology, McGraw-Hill Book Company, Inc., 3rd. ed., p. 422.

these minerals indicate a magmatic source of the mineralizers, and he states:

> "The contact minerals that most conclusively indicate magmatic contributions are tourmaline, axinite, scapolite and the metallic ores."

The presence of the ferrous iron, detected by the magnet, indicates that the specular hematite may consist of zoned crystals similar to those described by Sosman and Hostetter.*

*Sosman, R. B., and Hostetter, J. C., 1918, Zonal Growth in Hematite and Its Bearing on the Origin of Certain Iron Ores, Am. Inst. Min. Eng., Trans, vol. 58, pp. 434-444.

They found that FeO and Fe_2O_3 form a solid solution from Fe_2O_3 toward Fe_3O_4. They also concluded that most all natural iron oxides are either homogeneous solid solutions or non-homogeneous, and that the latter type can be magnetically fractionated. This non-homogeneous type represents a zonal growth of the hematite, the zones being similar to the zoning of the plagioclase feldspars.

Regarding the deposition of such material they say:*

*Sosman, R. B., and Hostetter, J. C., 1918, op. cit. p. 444

> "Since Fe_3O_4 goes into solid solution in Fe_2O_3, forming a single solid phase of varying composition and properties, a zonal distribution of FeO is to be expected in an oxide of iron depositing from a vapor or solution. The occurrence of such zonal growth indicates continuously changing conditions of temperature, pressure and concentration during the formation of the crystals."

They give a temperature of between 100°C and 700°C and a pressure of 300 atmospheres as sufficient for the formation of the specular hematite from the island of Elba, from a vapor consisting of iron, chlorine, hydrogen and oxygen. Grout*

*Grout, F. F., 1932, op, cit., p. 441.

believes that specularite forms at a temperature above 358° C.

The faint Widmanstatten structure indicates that the specularite is a result of unmixing from a solid solution. Such textures are common in ores that result from exsolution. Bastin*

*Bastin, E. S., 1950, Interpretation of Ore Textures, Geol. Soc. America, Mem. 45, pp. 10-13.

comments on this type of texture as follows:

> "The commonest type of unmixing texture is the grating type in which the crystal structure of one constituent controls the distribution of the other."

he further states:

> "In magmatic ores, unmixing of solid solutions is a phenomenon of the post-magmatic stage when initially high temperatures have declined through a considerable range."

A pseudo-Widmanstatten texture sometimes arises from the oxidation of magnetite to martite. Cooke*

*Cooke, S. R. B., 1936, op. cit., p. 35.

describes such an occurrence:

> "Oxidation occurs along the octahedral cleavages of the magnetite. Polished sections show a triangular, square, or rhombic latticing, depending on the orientation of the section."

However, martite is pseudomorph after magnetite*

*Cook, S. R. B., 1936, op. cit., p. 35.

> "The process of oxidation of magnetite to hematite with retention of the gross crystal outlines of the primary mineral is referred to as martitization."

and as no magnetite crystals are present it seems doubtful that the Widmanstatten texture is false. The possibility that the texture may have been caused by the unmixing of the better known solid solution series of magnetite and ilmenite was dispelled when a chemical test for titanium proved negative. It seems, therefore, that specular hematite was formed as a result of the unmixing of a solid solution of ferric and ferrous iron, with the ferric iron predominating.

Since calcium carbonate is the matrix in some of the ore it may be that oxidation of the original solutions was accelerated by CO_2. This may account for the fact that the solid solution formed was more ferric than ferrous and consequently the prevalence of specular hematite.

The magmatic source of the solutions or vapors which deposited the specular hematite must have been the diorite dike. It is very close of the occurrence of the specular hematite and the only intrusive of any size in the vicinity capable of procuding such a deposit.

GEOLOGY OF SECTION 24

Stratigraphy and Structure: The most prominent feature of this area is a knob of ferruginous chert about 50 feet high which rises abruptly from the sand plains (see map in pocket). It slopes rather gently northward at an angle which varies from 15° to 30°. The chert ends more suddenly on the east, west, and south. Immediately below the chert is a bed of black siliceous slate with a contact that is sharp and conformable. This contact can be seen both on the north and west sides of the knob. Interbedded with the chert are some small bands of slate which have been well undurated by metamorphism. The thickness of the exposed black slate beneath the chert is about 12 feet. The thickness of the chert varies from one foot on the north to about forty feet on the south. A zone of ferruginous schist may have been present on the west side of the chert knob but has been entirely removed by an earlier mining operation. Evidence of this schist is found on the dumps at the west end of the knob. It may have represented a westward lateral thickening of some of the slate bands which are interbedded with the ferruginous chert.

The slates have a well developed northwest-southeast cleavage which ends abruptly at the contact with the chert. Small, similar trending folds with a plunge gently to the southeast have developed in the slates. The ferruginous chert has been fractured, shattered, and brecciated. Many of these openings are now recemented with silica. The re-cemented breccias resemble pseudo-conglomerates somewhat. The most prominent fractures in the ferruginous chert strike about N. 60° and dip vertically. A weaker fracture system strikes northwest and dips vertically. There are other fractures which vary in strike between these. The ferruginous chert strikes N. 50° W. and dips 30° to the northeast. This conforms very closely to the strike and dip of the slate on the west side of the knob. Vein quartz fills some of the fractured bedding planes within the chert.

Just where the ferruginous chert and the slate belong in the stratigraphic column is not precisely known. Rominger*

*Rominger, C., 1881, op. cit., p. 57.

refers to them as underlying the siliceous limestone beds which occur north of this area. This would place the chert and slate in the Mesnard formation. Van Hise*,

*Van Hise, C. R., 1897, op. cit., p. 273-274; 310.

on the other hand, refers to the slate as Wewe and the quartzite as Ajibik. Later, Van Hise and Leith*

*Van Hise, C. R., and Leith, C. R., 1911, op. cit., p. 258.

mapped the ferruginous chert as Mesnard, but make this statement:

> "On the knobs northeast of the southeast end of Goose Lake, quartzite mapped as Mesnard is found to lie directly upon the Kona dolomite. The quartzite with this relation may be an interstratified layer in the Kona dolomite similar to quartzite layers seen in this formation in the Mount Chocolay section. The boundary between the quartzite overlying the Kona dolomite in this locality and the true Mesnard quartzite is not known."

In this paper the writer has placed the slates and ferruginous chert in the Kona formation with the reservation that their true stratigraphic position is in doubt. It might be well to point out that the rock which the previous investigators have classified as quartzite is in the writer's opinion, a ferruginous chert. This distinction is important, the value of which will be discussed later.

PETROGRAPHY OF SEDIMENTARY ROCKS

General: There are two principal rock types in this area. One is a black siliceous slate and the other a ferruginous chert. Some massive specularite bearing quartz veins cut the ferruginous chert. This chert, has been fractured and brecciated in a number of places and secondary silica and iron oxide have been deposited within these openings.

Ferruginous Chert

Megascopic: The chert is a very hard, dense, dark red to black rock and has a smooth conchoidal fracture. Glittering reflections from many small scattered particles of a metallic mineral are seen. On the sides of small fractures, thin films of specular hematite have been deposited. Small crystals of martite are often embedded in the chert.

Microscopic: Three varieties of quartz are present. One is a fine grained microcrystalline variety covered by a thin film of red amorphous hematite and represents the chert rock (Pl. 8, fig. 1). Small veinlets of quartz which cut this chert in various directions do not have as much iron oxide on them as the chert itself. Where the chert has recrystallized the quartz is more granular and individual crystals are easily recognized. Where vein quartz has penetrated the chert the quartz is very coarse and exhibits a flamboyant structure. (Pl. 8, fig. 2). A few particles of sericite are scattered throughout the rock.

A few outlines of rhombic crystals are seen. Along the borders of these rhombs small crystals of red hematite have developed which tend to accentuate the rhombic outline. In places there is no break in the quartz matrix in which these rhombs occur. Some of the rhombs are filled with quartz and others with specular hematite. It was noted that the rhombs are more likely to occur where the quartz is more crystalline than where chert predominates. In places the crystalline hematite which forms the outline of the rhomb replaces the quartz toward the interior (Pl. 10, fig. 2).

PLATE 8

TEXTURAL RELATIONSHIP OF CHERT AND VEIN QUARTZ

Figure

1. Ferruginous Chert

   A fine grained mosaic of quartz. A fine film of red hematite is spread over the chert which accounts for the red to black appearance. Small laths of sericite are hardly recognizable because of their size.

2. Vein Quartz

   A quartz vein which cuts the fine grained chert. The vein quartz has a coarser texture than the chert. The dark area to the right of the vein is specular hematite.

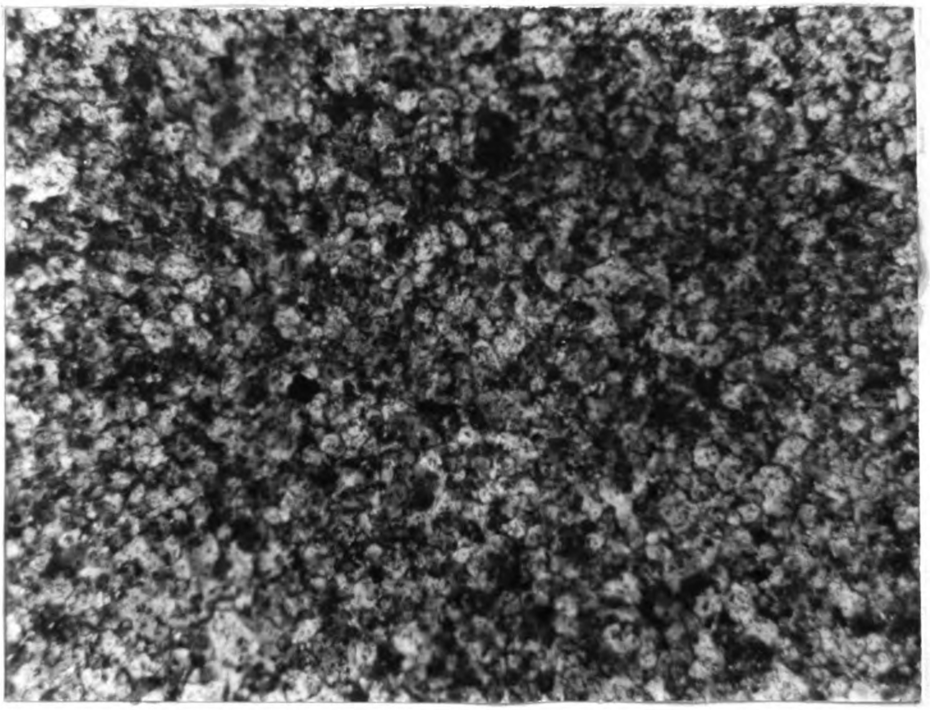

Figure 1

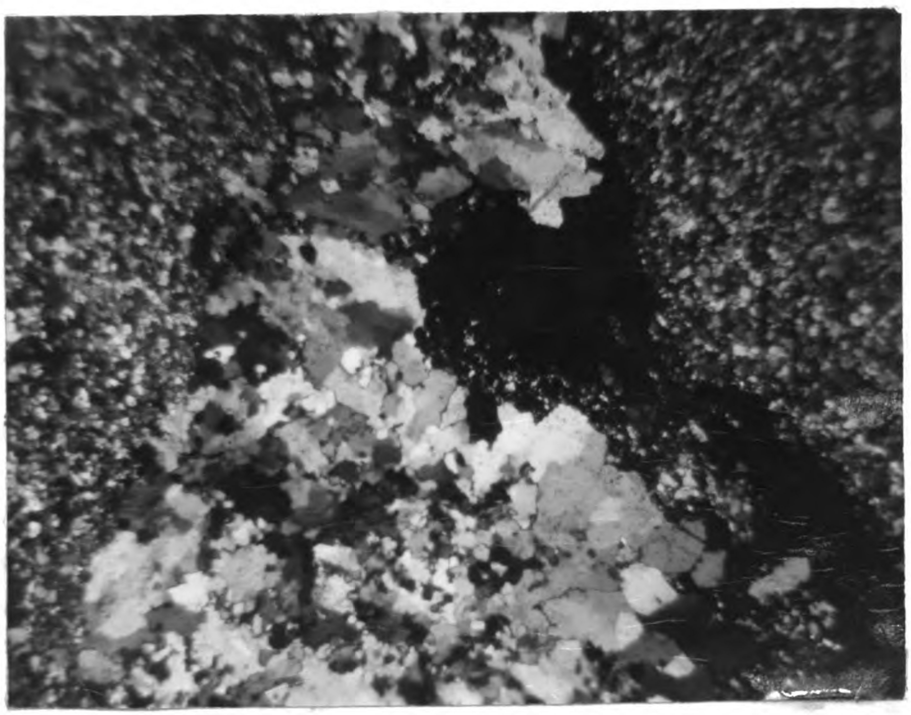

Figure 2

PLATE 9

REPLACEMENT OF MAGNETITE AND VEIN QUARTZ

BY SPECULAR HEMATITE

Figure

1. Martite (Specular Hematite)

   These crystals were probably magnetite which have been altered to specular hematite. The mineral formed by such a change is called martite. The white is martite, the grey is quartz and the black are pits in the section.

2. Specular Hematite

   Large platy crystals of specular hematite (white) replacing massive vein quartz (grey). The black is chipped out hematite.

PLATE 9

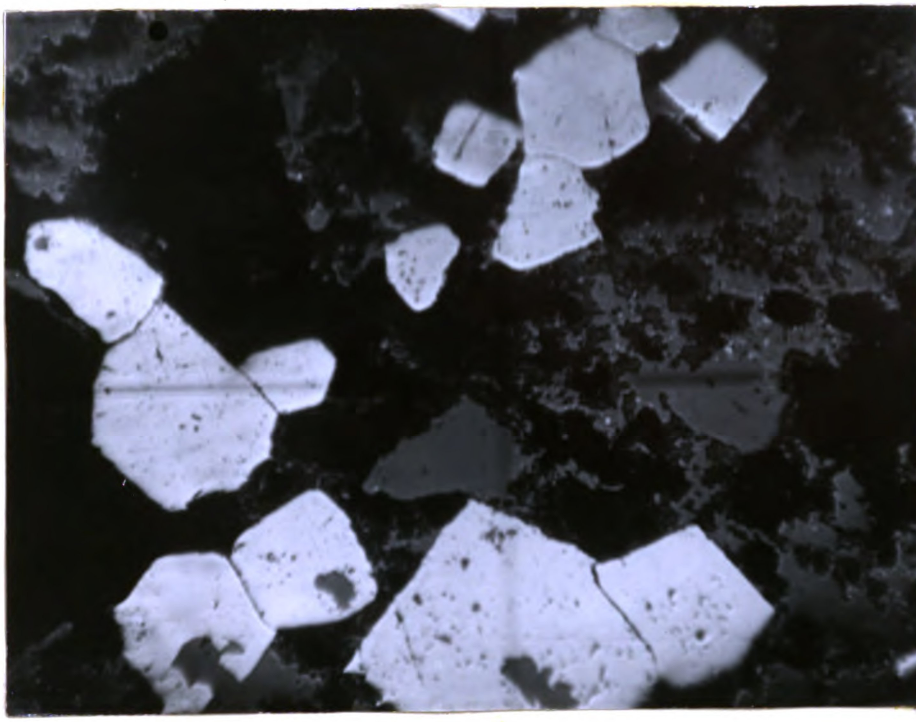

Figure 1

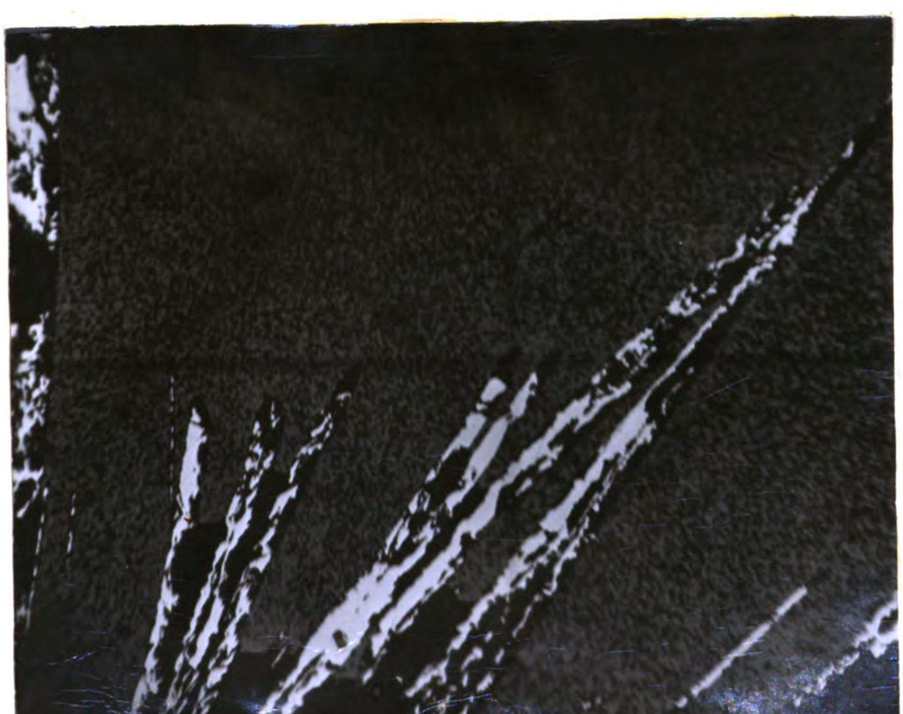

Figure 2

PLATE 10

REPLACEMENT OF QUARTZ BY SPECULAR HEMATITE

Figure

1. Specular Hematite

    Plates of specular hematite (black) replacing massive vein quartz (grey) along small submicroscopic fractures.

2. Rombic Pseudomorph

    A rhombic pseudomorph partially filled with quartz and being replaced by hematite. This might have been a carbonate mineral initially.

PLATE 10

Figure 1

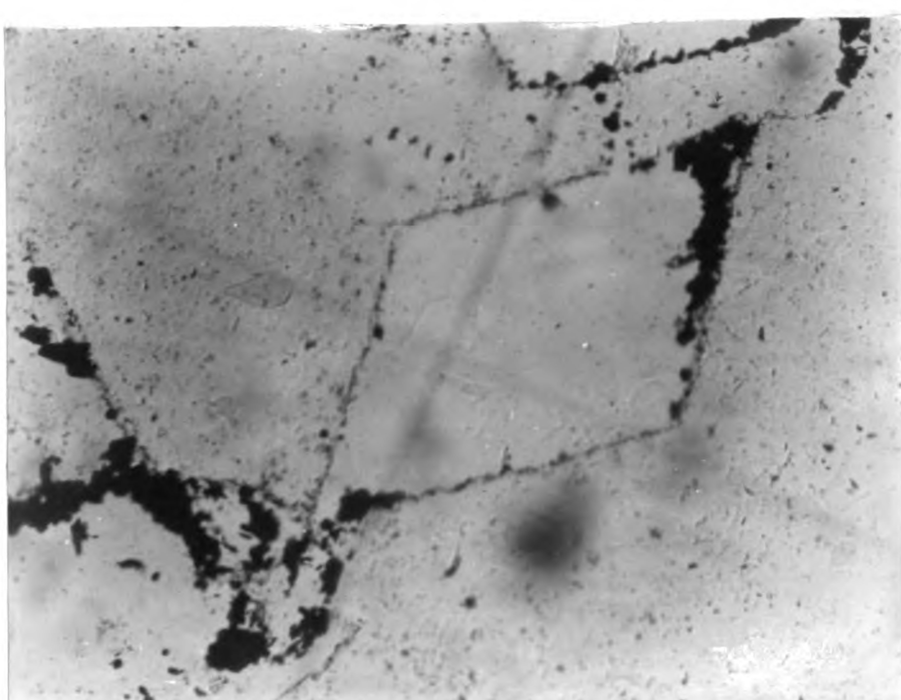

Figure 2

Black Siliceous Slate

Megascopic: The rock is black with stains of limonite and hematite occurring on the cleavage surface. It is easily scratched by a knife blade.

Microscopic: The rock is composed of muscovite and quartz. The quartz forms a fine grained matrix and may have been deposited as amorphous silica. It is not of detrital origin. The muscovite is scattered throughout the rock. Small bits of specular hematite and amorphous hematite are found throughout the rock.

Ferruginous Schist

General: This rock was not found in place but is present in great quantities on the ore dumps at the west end of the chert knob.

Megascopic: The rocks consists of finely foliated layers of specular hematite with many small crystals of martite present. The rock is heavy and has a shiny metallic appearance.

Microscopic: The rock is composed of hematite and quartz. The quartz forms a granular mosaic of small crystals whose texture would indicate that it is recrystallized. Crystalline hematite and martite comprise about 30 percent of the rock. The latter mineral forms small cubes and rhombs in a matrix of specular hematite.

PETROGRAPHY OF THE ORE

The ore present is specular hematite and martite. The former mineral occurs as large plates associated with quartz veins and as small micaceous laths scattered throughout the ferruginous chert. This crystalline hematite exhibits most of the characteristics of specular hematite described from section 2. The main difference is that no Widmanstatten structure was observed in these ores.

The martite forms almost perfect pseudomorphs after magnetite crystals (Pl. 9, fig. 1). The mineral is white in plain light and strongly anisotropic between crossed nicols. In the latter position the mineral is bluish white. The original magetite has been completely altered to martite for in no place was an isotropic mineral seen which resembled magnetite. The specular hematite associated with the quartz veins shows the same magnetic phenomenon as the specular hematite from section 2. The specular hematite is often replacing the quartz in the veins. (Pl. 10, fig. 1); (Pl. 9, fig. 2).

GENESIS OF THE ORE

The presence of the ferruginous chert type of rock in which specular hematite and martite occur, appears to be of major importance in deciphering the origin of the hematite. It has been stated by Van Hise and Leith*

*Van Hise, C. R. and Leith, C. K., 1911, op. cit.

and is generally assumed, that the soft iron ore bodies of the Negaunee formation were formed from ferruginous chert, similar in many respects to the chert in section 24. In fact most of the iron ores formed in the Lake Superior iron ranges have been derived from this type of rock. The original rocks from which these ferruginous cherts were developed consisted originally of chert and siderite or greenalite. The alteration of this original rock to a ferruginous chert has been described by Van Hise,*

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*Van Hise, C. R. and Irving, R. D., 1892, The Penokee Iron-Bearing Series of Michigan and Wisconsin, U. S. Geol. Survey, Mon. 19, pp. 201-202.

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who says:

> "The first alteration to which these rocks are subject is an oxidation of the carbonate producing brown hydrated hematite, red hematite or magnetite. Very frequently the decomposition of the iron carbonate has not changed the forms of the original crystals, and thus leaves the various oxides as perfect pseudomorphs after the iron carbonates."

Regarding the more crystalline form of the silica, Van Hise states:

> "Accompanying this oxidation of the siderite is generally a rearrangement, and apparently often an introduction of silica in these altered rocks, is frequently more coarsely crystalline and often in combination with the iron oxides has a concretionery and brecciated appearance."

That the ferruginous chert in section 24 may have been derived in a manner similar to that described by Van Hise is shown by the presence of iron oxides in some of the rhombic forms and the nature of the chert itself. Tyler*

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*Tyler, S. A., 1941, Development of Lake Superior Soft Iron Ores from Metamorphic Iron Formation, Geol. Soc. of America, Bull, vol. 60, pp. 1101-1124.

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while recognizing the fact that the original iron formation consisted of chert and siderite or greenalite is of the opinion that although ferruginous chert does develop from this original rock, it develops on a much larger scale by the oxidation of a metamorphic iron formation consisting of chert and secondary iron silicates. He is also of the opinion that if sufficient oxygen were present the original cherty iron carbonate rock would be changed to magnetite and chert, but if oxygen were deficient the iron silicates would form. He recognizes the intermediate situation and states:

> "The more normal situation seems to have been the development of some magnetite from the siderite and greenalite, with the remainder of the iron combining with chert to form iron silicates."

That the ferruginous chert was not derived from a metamorphic phase of iron formation consisting of secondary iron silicates seems evident from the fact that there are few iron silicates or relicts of them. It appears that the ferruginous chert in section 24 may have been derived from a cherty siderite and that conditions were not favorable for the formation of secondary iron silicates. This would mean then that sufficient oxygen was present to change the cherty siderite rock to magnetite and chert. The rhombs which are occasionally observed may indicate that a carbonate was once there, however, rhombs can be produced by slicing a magnetite octahedren lengthwise and by other means. It would seem also that if the original carbonate chert rock had been metamorphosed to the extent necessary to recrystallize the chert, the carbonate would be easily eliminated.

Gruner*

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*Gruner, J. W., 1926, Magnetite-Martite- Hematite, Econ. Geol., vol. 21.

---

has proved that martite, a pseudomorph after magnetite has the same crystal lattice as hematite. The formation of martite involves the oxidation of magnetite to form hematite.

He*

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*Gruner, J. W., 1930, Hydrothermal Oxidation and Leaching Experiments; Their Bearing on the Origin of the Lake Superior Hematite-Limonite Ores, Econ. Geol., vol. 25.

---

points out that magnetite is very stable under normal surface conditions but suggests that oxidation of magnetite to martite could be accomplished rather easily by hydrothermal alteration.

Tyler*

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*Tyler, S. A., 1949, op. cit. p. 1123.

---

is of the same opinion regarding the alteration of magnetite to martite.

Evidence that high temperature, oxidizing solutions were active in the area is indicated by massive specularite bearing quartz veins. The fact that magnetite has altered completely to martite also indicates the activity of such solutions.

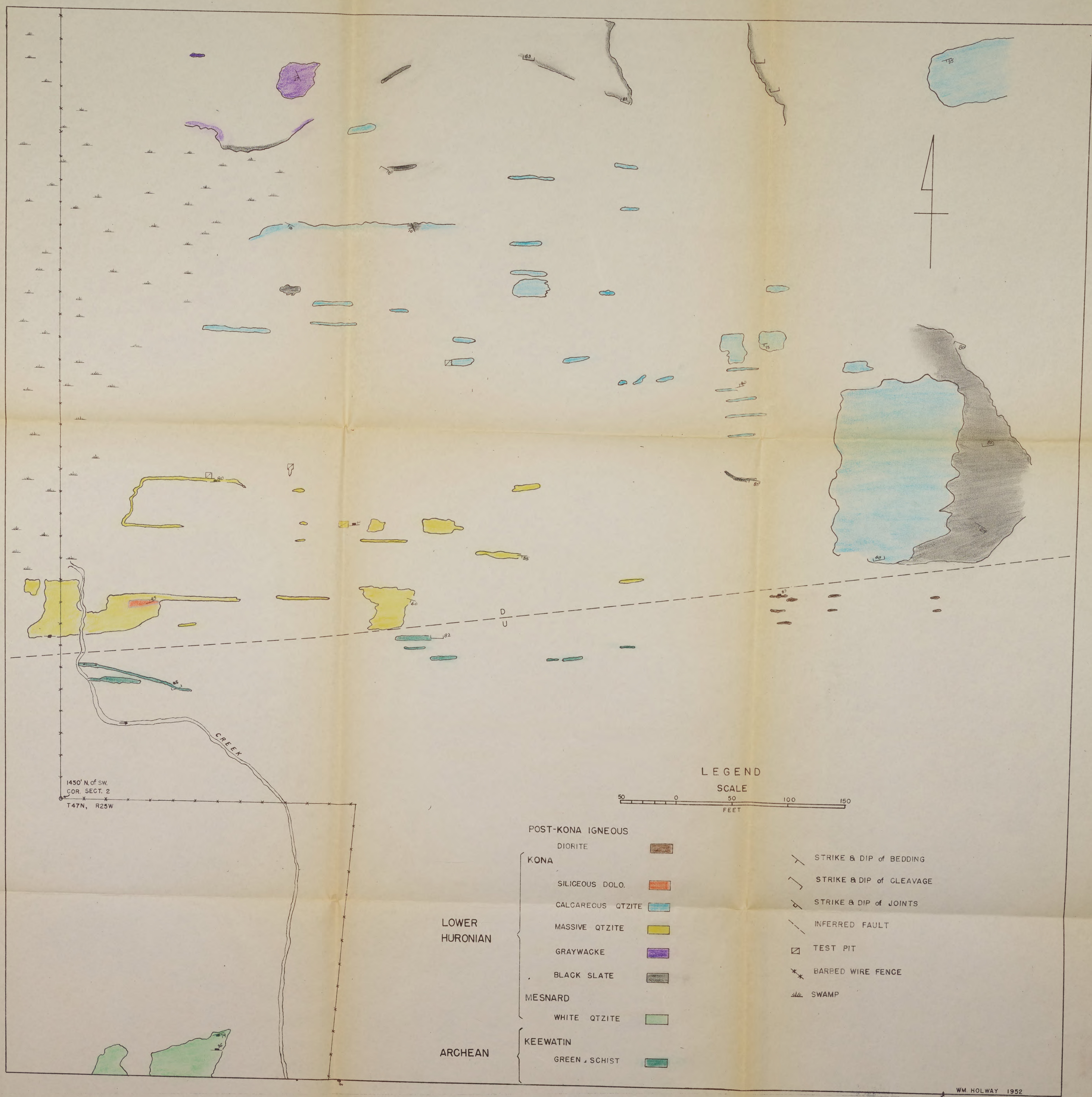
The micaceous specular hematite was probably formed by the crystallization of amorphous hematite when the chert was folded. This is similar to the micaceous hematite of the upper Negaunee formation, which has already been described.

CONCLUSIONS

In view of the facts presented the following conclusions seem justified.

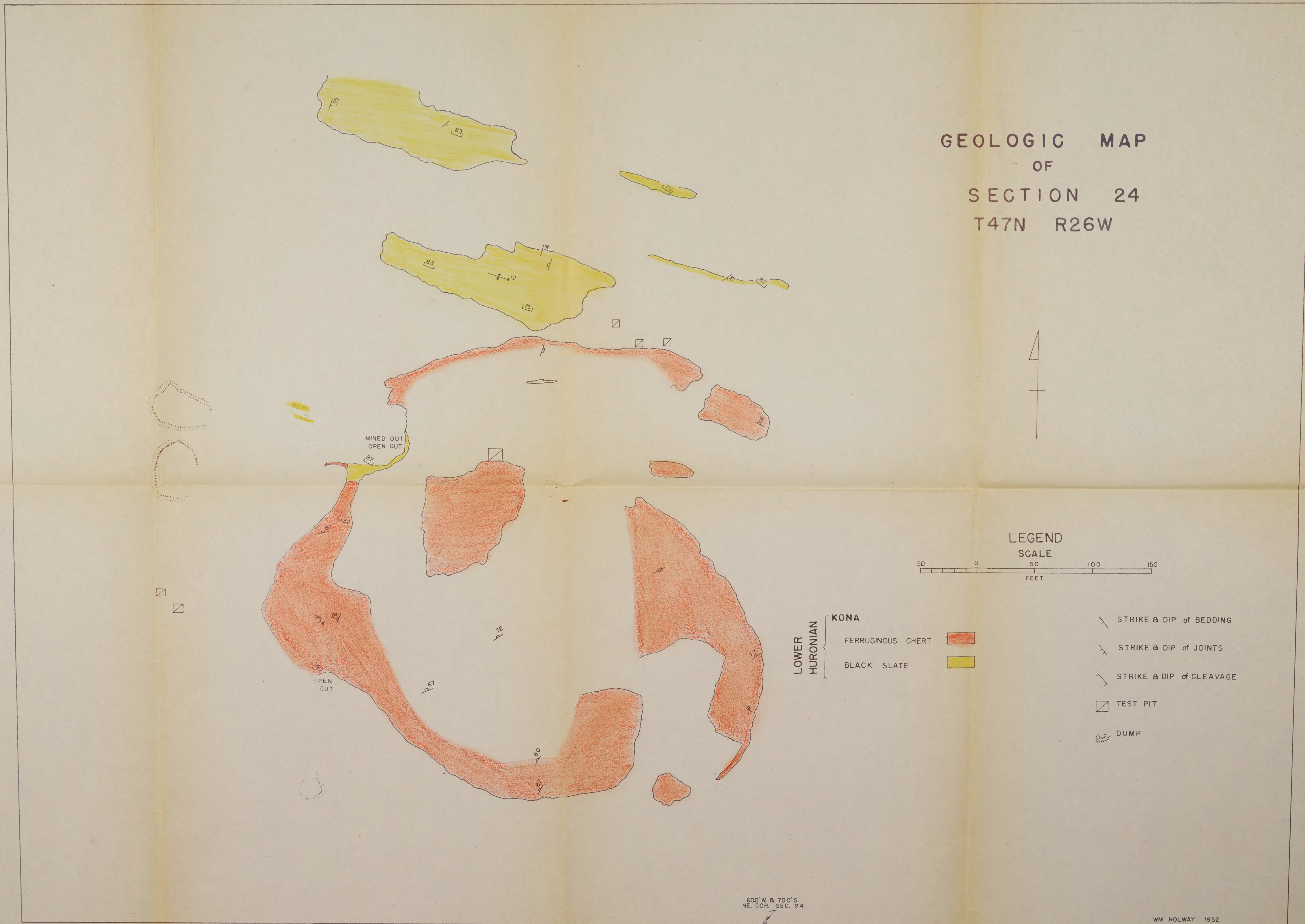
1. Specular hematite occurs in the Kona formation the the southeast side of the Marquette district.
2. Most of the specular hematite in this formation is hypogene in origin.
3. The source of the mineralizing solutions may have been magma associated with diorite intrusives.
4. Large plates of specular hematite associated with the mineralizing solutions seem to be composed of both ferric and ferrous iron.
5. Ferruginous chert, usually associated with the iron formations of the middle and upper Huronian is present also in the lower Huronian.
6. The stratigraphy of the lower Huronian formations varies considerably from one locality to another and correlation of beds cannot be attempted until further field work is undertaken.

GEOLOGIC MAP OF SECTION 2



SUPPLEMENTARY MATERIAL

PLATE 12



Pocket has:
Plate 11
&
Plate 12

SUPPLEMENTARY
MATERIAL