THE STRUCTURE AND STRATIGRAPHY OF A PORTION OF THE SOUTHERN EDGE OF THE DEAD RIVER BASIN MARQUETTE COUNTY, MICHIGAN

Thesis for the Degree of M. S.

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Richard J. Thompson

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ABSTRACT

THE STRUCTURE AND STRATIGRAPHY
OF A PORTION OF THE SOUTHERN
EDGE OF THE DEAD RIVER BASIN
MARQUETTE COUNTY, MICHIGAN

by Richard J. Thompson

Because of the uncertainty of the stratigraphic position of the sediments in sections 14 and 15, T48N, R27W it is the purpose of this report to attempt to analyze megascopically and microscopically the meta-sedimentary rocks in these sections in order to classify them and to describe or determine their mode of origin and deposition and to determine the stratigraphic position of these sediments in the geologic column. By determining the stratigraphic position, it will then be possible to correlate them with sediments in the Marquette Synclinorium.

The field work consisted of pace and compass mapping, collection of samples, and dip and strike readings wherever possible. The writer ground his own thin and polished sections for microscope studies. Mineral identification and textural relationships were determined by normal petrographic procedures. Structural relationships were determined by strike and dip readings and fracture densities.

From the writers field and laboratory studies the

following conclusions may be drawn:

1. The sediments in sections 14 and 15 are upper Huronian in age.

2. The sediments themselves are conformable but lie unconformably upon the greenstone.

3. The sediments are transgressive in nature and are onlapping to the northwest.

4. There have been at least three periods of intrusion by igneous rocks.

5. Folding and faulting occured post-upper Huronian and pre-Keweenawan.

6. The upper Huronian sediments of the Dead River Basin do correlate with those of the Marquette Synclinorium.

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By

Richard J. Thompson

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INTRODUCTION

The Precambrian rocks in the Upper Peninsula of Michigan have been the subject of much research and also of much controversy. However, most of the mapping done has been confined to the economically important trough areas; i.e., those areas that are directly or indirectly associated with the Precambrian iron formations.

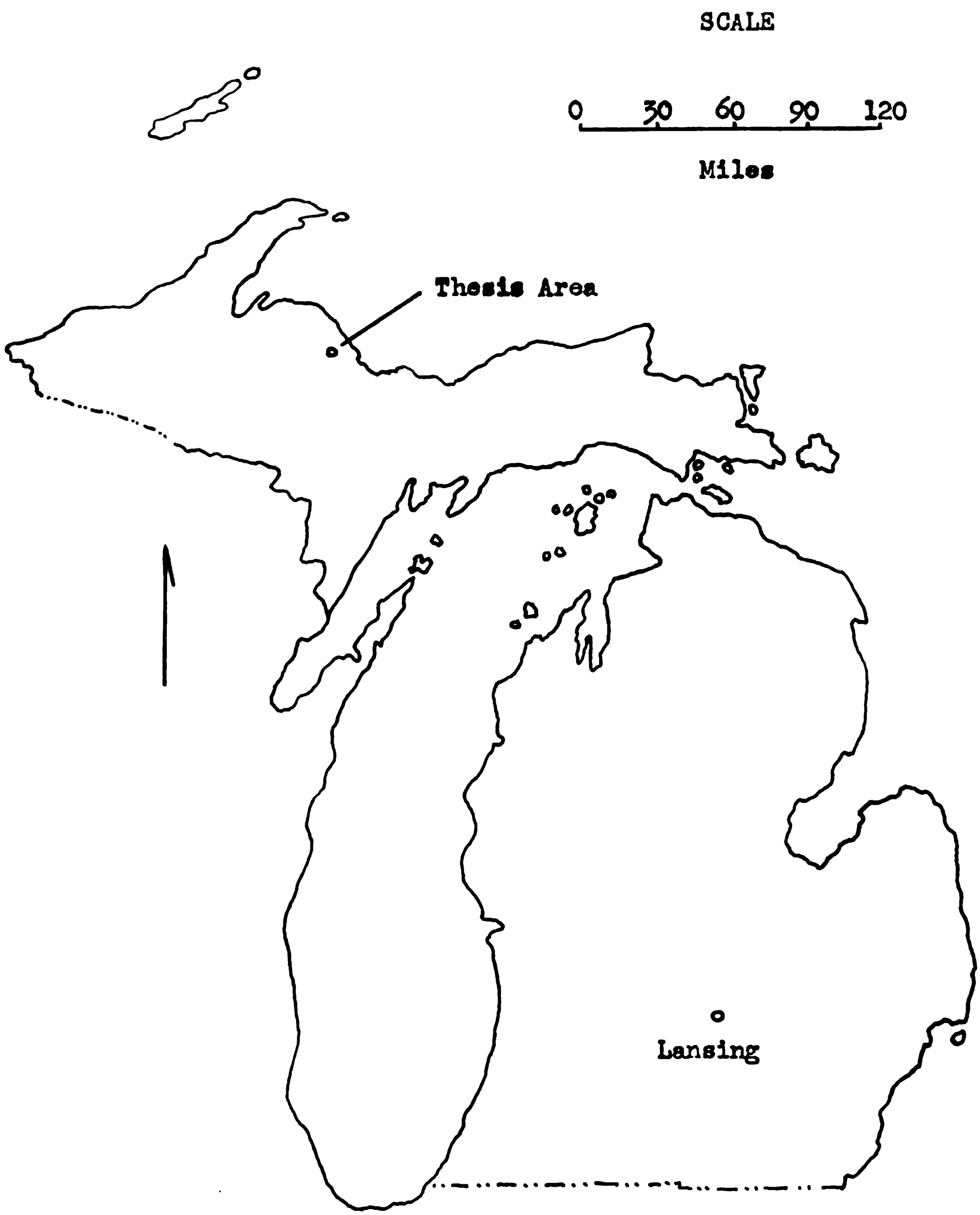
Various writers have correlated strata outside the major trough areas with the known sequence within throughs. This has been done, often, by rock types, sequential arrangement, and other accepted stratigraphic principles. However, correlation is quite difficult because of the lack of continous outdrops, lateral changes of rock types, the tectonics of the region, and the effects of several periods of differential metamorphism.

It is then, the purpose of this paper to describe the rock types and field position, the stratagraphic sequence, and the larger structures of a portion of the Dead River Basin. It is hoped that from the data a tentative correlation between the basin and the Marquette Synclinorium can be made.

Location and Topography

Township 48N, Range 27W lies in the northwestern part of Marquette County, Michigan. (See fig. 1, p 2) It covers a part of the structure known as the Dead River

Fig. 1. Index map.



Basin. This structural and topographic basin lies just north of and subparallel to the Marquette Synclinorium. It is approximately 18 miles long and 6 miles wide at its greatest dimensions and trends NW - SE.

Sections 14 and 15 T48N, R27W are on the southern rim of the basin. They are approximately 5 miles north of Negaunee, Michigan. The area is easily accessible by county road 480 which curves around the east end of Teal Lake and extends northward.

The southern rim area, in its present expression, is a rolling, low-lying, partially sand covered plain which supports some farming. The rim itself is composed for the most part of pre-Huronian rocks.

Field Procedure

The field work was completed during parts of two summers. The pace and compass method of mapping was deceided upon because of the local roughness of the terrain and the extensive brush cover.

A topographic map and aerial photographs of the area were consulted before beginning the field work. From the aerial photographs, the rough structural outline and rock strikes were determined. The traverses were then planned to run perpendicular to the prevailing strike.

It was deceided to run 8 traverses to the mile with one man walking the line and pacing while the other covered an area on both sides of the traverse. The writer feels that this provided adequate coverage of the area.

The sampling procedure was considered by the writer as very critical. It was suspected that lateral as well as vertical lithographic changes were present in the formations. Therefore, a great many samples were taken for later study in the laboratory. Each sample was given a number and its field position recorded in the field notes.

The dip needle was employed and found to be very useful in following and delineating the magnetic part of the iron formation of the area. Readings were taken by the man walking the traverse at his discretion.

Strike and dip readings were taken on outcrops using a Brunton compass. Care was taken that only bedding directions and not rock cleavage was measured. Jointing was noted but no systematic measurements were taken because the writer was interested in fracture density rather than attitude. The writer felt that density of jointing was a clue to nearby fault positions.

Laboratory Procedure

After the samples were brought in from the field and cataloged, various specimens were selected for thin section work. The writer tried to select a specimen which he felt was representative of the rock type. Some duplication occured when it was thought that lateral changes might occur within the rock type.

The writer hand ground his own thin sections. The results were not as satisfactory as could be desired because most of the slides were thicker than the ordinary, usually about forth order interference for quartz.

The slides were then studied paying particular attention to rock type, mineral composition, and associations and textures. All sedimentary rocks were classified according to Pettijohn (1957).

Identification of minerals was made by normal petrographic procedures.

Polished surfaces were made on representative specimens of iron formation in an effort to facilitate the study of textures and textural relationships.

As part of the research envolves the relative ages of the formations in the area, the writer kept a close check for zircons in an attempt to make use of a technique employed by Tyler, Marsden and others (1940).

Review of Literature

A discussion of the Marquette district first appeared in published literature in 1821 in a journal recorded by Henry Schoolcraft. For many years after that the district as a whole along with most of the remaining portions of the Upper Peninsula is mentioned in the reports of government surveyers and explorers. Various general discriptions appeared as a result of the surveys and explorations.

In 1845-46 Dr. Douglass Houghton began a more rigorous survey and investigation of the Upper Peninsula. He instructed his surveyors to keep note of the different types of rocks encountered and instructed that samples should be taken.

One William Burt, a member of the Houghton party, published a report in 1847 concerning the mines and minerals in the Upper Peninsula encountered while laying out township lines. In this report he makes mention of argillaceous slates occurring in T47 and 48N, R27 and 28W which encompasses the Dead River Basin as we know it today. Burt stated that these slates are westward extentions of those occurring near or at Marquette. He stated that the slates are dipping at high angles which "generally conform to the surrounding granites or flanking thee numerous protrusions of greenstones within their boundry". In J. W. Foster and J. D. Whitney's report of 1851 mention is made of the country between Teal Lake and the Dead River. They stated that the area is underlain by "chlorite-slates and talcose slates, intersected by three east - west belts of igneous rocks, many of which are thought to occur as sheets". They pointed out that the igneous rocks are greenstones which appear to be recrystallized volcanic ash beds.

In 1863, J. J. Bigsby made an attempt to correlate the "Azoic" rocks of the Upper Peninsula with Huronian formations found along the north side of Lake Huron.

In 1865, J. P. Kimball attempted to correlate the Marquette formations with the rocks of Canada so that the sucession of the Marquette District became more clear. This led to the naming of some of the rock as Laurentian. The sedimentary origin of the iron formations became clearer to the workers of this time, also.

In 1890 Van Hise in his paper "An Attempt to Harmonize Some Apparently Conflicting Views of Lake Superior Stratigraphy" pointed out the importance of the conglomerate which overlies the Negaunee Iron Formation. He thought that it represents a very large time break and proposed to break the Michigan Huronian into two series.

By this time a tentative workable stratigraphic column emerged. However, the east end of the Marquette District had not been properly tied in with the west end. Several columns had been published in which the Huronian was divided into two series and the Laurentian was included as the "basement complex".

In 1897, the first important and complete study of the whole Marquette District was published by the USGS in Monograph 28. In this monograph Van Hise and Bayley discussed the whole district as one stratigraphic and tectonic "province".

These authors believed that the area showed evidence of two transgressions of the sea represented by the lower and upper Marquette Series (Huronian). The lower Marquette includes the Mesnard quartzite through the Negaunee formation. The upper Marquette series begins with the Goodrich Quartzite and ends with the Michigamme Slates.

Only brief mention was made of the rocks in the Dead River Basin. This is included in the section on the Northern Complex (USGS Monomgraph 28, p 187). They described various masses of sideritic slate, ferruginous slate, ferruginous chert, and a grunerite-magnetite schist and recognized that these rock types resemble some in the adjacent Marquette Synclinorium. However, they believed that the strata were pre-Marquette (Huronian).

Van Hise and Leith (1911) sub-divided the Huronian into the lower, middle, and upper largely on the work of A. E, Seaman, Hotchkiss and others. A more complete picture of the geology in the district is here presented.

In their section on the Dead River Basin, these authors present a map drawn by A. E. Seaman which depicts the Ajibic Quartzite and Siamo Slate as bordering the southern rim of the pre-Huronian rocks. Seaman shows the wedging or feathering out of the Negaunee Iron Formation in section 15 T48N, R27W. The middle Huronian is then shown to be overlain by the upper slates, called Michigamme.

Since this time there has been little published on the Dead River Basin. From the writers' field work it was evident that there had been some work done in the intervening years because of marked survey lines.

However, to the writers knowledge the work has not been published.

There has been some thesis work done in the area in recent years.

Hagni (1954) discussed the origin and petrology of the Kitchi Conglomerite found in the southwest corner of T48N, R27W. He concluded that the Kitchi is older than the Huronian sediments but younger than the Keewatin. He tentatively assigns it to the Timiskaming.

Engel (1954) discussed the "Holyoke" sediments of the northeast corner of T48N, R27W. He describes them as a metamorphosed tillite and classifies them as sub-Huronian.

Since the writer is interested in source or origin of sediments and their relative ages, he attempted to use the technique described by Tyler and Marsden (1940).

In their studies, they were able to identefy three types of zircon as diagnostic of an age of igneous activity. The oldest was the "Hyacinth type" which they classified as pre-Huronian or Laurentian in age. It ranges in color from dark to light purple and is slightly pleochroic. These zircons occur as grains with definitely rounded crystal angles and are detrital appearing when found in igneous rocks. The grains may show a faint zoning.

Another type of zircon recognized, was the "Malacon type" whose age the authors stated as Late Pre-Huronian to middle-Huronian and was found to be abundant in the finer grained sediments. It is characterized by weak birefrigence, dull luster and a cloudy altered appearance. The grains usually have a rounded prismatic to spherical outline. Many grains have what appears to be etched and striated surfaces.

A third type, the "Normal type" has an age span from post-Huronian to Late Middle Kewwenawan (?). The "normal type" is found in lowest Keweenawan sediments. It is usually clear with a well developed crystal form with sharp crystal angles. The habit commonly consists of a combination of a unit prism (010) and pyramid (011). Many of the "Normal type" are zoned. It was suggested that the lack of "Normal type" zircon in the Huronian and older rocks could be indicative of an entirely different igneous epoch (Tyler, 1940).

Environmental conditions as reflected in the sediments are considered by the writer as a vital criteria upon which to base a correlation. James (1954) proposed a sequence of events for the Huronian based on his studies of Huronian iron formations. These iron formations are products of a combination of variable factors such as: source, manner of transportation and precipitation, environment of depositional site and post depositional alteration. One of the more important is environment.

White (1954) in his discussion of the Mesabi Range considers the "environmental boundry" as a major controlling factor on the type of sediment deposited. The boundry shifts with transgression and regression of the sea and in any one particular section such a shift could account for great variations in the sediments deposited there. White, then, is concerned with the facies concept which is defined by Moore (Krumbein and Sloss, 1958), who states that "Sedimentary facies is defined as any areally restricted part of a designated stratigraphic unit which exhibits characters significantly different from those of other parts of the unit."

DEFINITION OF PROBLEM

In previous work done in the Dead River Basin, the sediments in sections 14 and 15, T48N, R27W were classified as middle Huronian remmants from the Marquette Synclinorium (Van Hise and Bayley, 1897).

Later work (A. E. Seaman, Hotckkiss, and others, 1911) shows this area as basal middle Huronian overlain by upper Huronian slates. Seaman believed that the quartzite unconformably overlying the greenstone was Ajibik and was followed by the Siamo Slate. Overlying this, he showed undifferentiated Michigamme Slates. The map made by Seaman shows the wedging or feathering out of the iron formation thought to be Negaunee in section 15 T48N, R26W, at the east end of the Dead River Basin.

The writer examined section 15 T48N, R26W as a project during the summer field camp. The geology in this particular section was interpreted about the same as Seaman had done previously; the iron formation was recognized as Negaunee and the mapping indicated that it was truncated and progressively removed by erosions as it was traced eastward. Overlying the unconformity is a dirty or impure quartzite-conglomerate which is believed to be the Goodrich. It may also be that the base of the Goodrich cuts off the Ajibic Quartzite and the Siamo Slates as these are traced further to the west. Therefore, because of the uncertainty of the stratigraphic position of the sediments in sections 14 and 15, T48N, R27W, it is the purpose of this report to attempt:

1. To analyze megascopically and microscopically the metasedimentary rocks in these sections in order to classify them and to describe or determine their mode of origin and deposition.

2. To determine the stratigraphic position of these sediments in the geologic column.

3. To correlate these rocks with others of similar age occurring in the Marquette Synclinorium.

4. To describe the larger structures deforming the stratigraphic sucession in these sections.

Table 1. Modified Geologic Section of the Marquette Dostrict (After Leith, Lund, and Leith, 1934; Zinn, 1939; and Hagni, 1954)

Keweenawan	Diabases
--------------------Erosional	Break------------------------
Upper Huronian	
Upper Michigamme Fm	Graywacke, Quartzite, Slates
Bijiki Fm	Iron bearing
Lower Michigamme Fm	Graywacke, Slates
Clarksburg Fm	Volcanic lavas and tuffs
Greenwood Fm	Iron bearing [illegible] clastics
Goodrich Fm	Conglomerates, Quartzites, Slates
--------------------Unconformity------------------------	
Middle Huronian	
Negaunee Fm	Main iron formation
Siamo Fm	Slates, Quartz slates
Ajibik Fm	Conglomerates, Quartzites
--------------------Unconformity------------------------	
Lower Huronian	
Wewe Fm	Slates
Kona Fm	Dolomites, Quartzites, Slates
Mesnard Fm	Conglomerates, Quartzites, Slates
--------------------Unconformity------------------------	
Algoman	Granites, Syenites, Diorites
---------?---------------?	---------------?--------------
Timiskaming	
Kitchi Fm	Sediments, Volcanics
--------------------Unconformity------------------------	
Laurentian	Granite Gneiss
---------?---------------?	---------------?--------------
Keewatin	
Mona Schist	Altered Basic Igneous, Lavas
Greenstone	and Volcanic Sediments

Table 2. Geologic Column for Sections 14 & 15 T48N, R27W.

Age	Formation	Description	Thickness
Keweenawan		Diabase-Dikes, augite and labadorite, "normal type" zircon	Variable
	Lower	Slate-black, dense, graphitic, pyritic	?
	Michigamme	Slate-gray-green, with coarser clastics	?
	Greenwood	Iron fm.-red-brown, bedded hematite	55-60'
		Ferruginous Qtz. Sl. -gray-black	35-40'
	Iron	Banded Iron Fm.-gray to balck, magnitite	30-40'
		Ferruginous Quartzite-gray-black, magnetitic	20-30'
	Formation	Iron fm.-Bedded chert and hematite	25-30'
	(205-250')	Ferruginous Quartzite-red-brown, hematitic	40-50'
		Quartzite-gray, medium grained, vitrious	65-75'
		Quartz Slate-Green-black, bedded clastics	35-45'
	Goodrich	Quartzite-green-black, fine grained	40-50'
		Quartzite-gray-white, medium grained hematitic	55-65'
		Quartzite-red-brown, very fine grained	25-35'
Huronian	Formation	Graywacke-gray-black, tough	60-70'
		Quartzite-white, vitrious, medium grained	70-85'
		Pebble Quartzite-gray-red-brown, vitrious	25-35'
	(450-500')	Conglomerate-white-reddish brown, vitrious	10-30'
		Syenite-pink to gray-green, medium to coarse grained.	?
Algoman (?)	Algo	Granite-pink, fresh appearing, medium to coarse grained	?
		Diorite-gray-black, mottled, medium grained	?
Laurentian		Granite Gneiss-pink-green-black, porphyritic	?
Keewatin		Greenstone-green-black, altered basic igneous rocks	?

DESCRIPTION OF IGNEOUS ROCKS

The igneous rocks of the area are limited to an essentially east-west trending belt in the middle of section 14. Aside from this belt a few scattered outcrops of diabase occur as dikes intruding the sediments.

Specimen name: Greenstone

Specimen number: 17

Location: Approximately 1/8 mile west of east line and 1/3 mile north of south line, section 14

Megascopic description: It is a greenish black rock, commonly schistose and porphyroblastic. It varies within the area in both texture and composition. Some specimens are very fine grained schistose while others have a fine grained matrix with hornblende crystals and plagioclase laths visible to the unaided eye. This rock type is the main constituent of the high igneous belt within the thesis area.

Microscopic description: A good description of the greenstone is given by Van Hise (1897, p 155):

"...In thin section, the aphanitic schists are found to be nearly uniform in composition as they are in appearance. They consist of granular epidote, small flakes and needles of chlorite and hornblende, and altered plagioclase, with the addition usually of calcite, leucoxene, a little quartz and mosaic areas of albite and quartz. The plagioclase may sometimes be detected in small lath-shaped crystals, lying in all azimuths amidst the other components, but more frequently the mineral is so much decomposed that its original form can no longer be recognized"

Specimen name: Hornblende Gneiss

Specimen number: 63A

Location: Approximately 1/3 mile west of east line and 1/4 mile south of north line, section 14

Megascopic description: A greenish-black rock with pink porphyroblasts of feldspar. It shows a rough gneissic structure and is highly altered. It occurs as isolated knobs within the igneous belt.

Microscopic description:

C	Chlorite (Possibly altered hornblende)	60%
	Plagioclase	10%
	Quartz	15%
	Microcline	5%
	Sericite	8%
	Magnetite	2%

The feldspars appear to be partially to wholly sericitized. The quartz shows undulatooy extinction. Some of the plagioclase fragments show "hour glass" extinction. Questionable Laurentian (?) age.

Specimen name: Diorite

Specimen number: 137

Location: Approximately 45 paces west of east line and 1/2 mile south of north line, section 15

Megascopic description: It is a gray to black medium crystalline rock showing white plagioclase laths and what appear to be crystals of hornblende. It occurs as knobs within the igneous belt.

Microscopic description:

Plagioclase (Probably andesine ?)	40%
Hornblende-chlorite	39%
Quartz	10%
Biotite	11%

The chlorite is the alteration product of hornblende and biotite. Part of it appears to be the penninite variety showing the abnormal bluish-green color. The rock does not give any indication of having been altered to any great extent such as relic textures.

Specimen name: Syenite

Specimen not taken, rock was identified in the field.

Megascopic description: It is a pink to gray-green rock, medium to coarse crystalline. It occurs approximately in the center of the igneous belt and accounts for a large part of the area. It is composed of orthoclase, oligoclase and hornblende with little or no quartz.

Specimen name: Biotite Granite

Specimen number: 8

Location: Approximately 1/2 mile south of north line and 10 paces west of east line, section 14

Megascopic description: It is a flesh pink rock with green streaks, medium to coarse crystalline. The biotite appears to be "smeared" giving a foliated appearance to the rock. The granite occurs as knobs scattered throughout the igneous belts usually in or very near the syenite. It is a very fresh appearing rock.

Microscopic description:

Quartz	12%
Biotite	20%
Hornblende	7%
Plagioclase	12%
Orthoclase	40%
Microcline	5%
Sericite	3%
Leucoxene (?)	1%

The orthoclase has been partially sericitized. Both the hornblende and the biotite have been partially altered to chlorite. Zircons occur as inclusions within quartz grains. Both the "malacon" and hyacinth" types are present with "hyacinth" greater than "malacon."

Specimen name: Diabase
(See Fig. 2 and 3, p 19)

Specimen number: 3 and 27

Location: Approximately 1/4 mile south of north line and 5 paces west of east line, section 14 (sample 3). Also approximately 1/8 mile south of north line and 1/8 mile west of east line, section 14 (sample 27).

Megascopic description: It is greenish to black, medium crystalline, equigranular rock occurring throughout the area as dikes cutting both the sediments and the igneous belt. It occurs as dikes or sills (?). Most of these intrusives conform to the prevailing joint or fracture system.

There appears to be some difference in the magnetic qualitites of this rock. Some of these dikes produce high negative readings with a dip needle while others produce only a very slight anomaly. However, Trow (Personal communication,

Fig. 2. Specimen #3, Keweenawan Diabase (non-magnetic) showing ophitic texture; augite (dark) enclosing plagioclase (light) (x3; plane polarized light)

Fig. 3. Specimen #27, Keweenawan Diabase (magnetic) again showing ophitic texture (x3; plane polarized light)

1961) believes that the difference in the magnetic properties can be explained by the orientation of the diabase intrusion with respect to the magnetic field of the earth at the time of intrusion.

Microscopic description:

Augite	48%
Plagioclase (Labradorite)	40%
Magnetite	4-8%
Chlorite	4-8%

There are a few scattered "normal type" zircon occurring in the rock and this observation following the work of Tyler and Marsden (1940) would place the rock at least post-Huronian.

Origin and Relative Age of the Igneous Rocks

The oldest igneous rock in the area appears to be the greenstone. This rock was assigned to the Keewatin because of its' similarity to the Keewatin greenstones occurring in the Marquette Synclinorium and because its' relative position appears to be the same as that in the Synclinorium (Van Hise and Leith, 1911). This greenstone probably represents a highly altered basic lava and volcanics sequence.

The granite gneiss is next in the igneous sequence and appears to intrude the greenstone. Van Hise and Bayley (1897) describe the greenstone as "draping" upon the granite gneiss and this fact was considered to form an unconformable sequence. However, this "draping" maybe the result of intrusion. The writer did not see either the actual contact between the greenstone nor anything that appeared to be "draping." The writer did see the granite gneiss occurring as knobs or protrusions within the greenstone belt. Therefore, the writer concludes that the granite gneiss did intrude the greenstone and the rock is then assigned to the Laurentian.

Intruding the greenstone-gneiss mass is a series of more acid type rocks -- syenite, diorite, and biotite granite. These rock types appear to be related, both spatially and genetically. The inner zone might be represented by the syenite, followed by an intermediate zone of granite and then the outer zone of diorite. In other words the acidity of the rock types increases inward from the outside of the mass. In no place were these rocks seen in contact and the above sequence was deduced by the writer from his mapping. They are fresher appearing rocks then the greenstone or the gneiss and are thought to have been intruded subsequent to Laurentian orogeny which highly altered the earlier rocks. This sequence of syenite, diorite, and biotite granite is assigned to the Algoman.

The diabase appears to be the youngest igneous rock in the area. It intrudes both the greenstone belt and the sediments. The writer assigns this rock to the Keweenawan based on the "normal type" zircon, high negative anomaly, and relatively fresh and unaltered appearance. It probably occurs as dikes or sills and it is presently exposed as low lying, elongate knobs. The intrusions appear to conform to the regional joint or fracture pattern, NW - SE.

At the present time Warren Wood of this department is doing research on the younger or Keweenawan Diabase dikes in an attempt to trace them from the Precambrian of Canada into the Precambrian of Michigan. One of his criteria for tracing is the strong negative magnetic anomaly.

Description of Sedimentary Rocks

In the following discussions, the sediments will be described as sedimentary rocks. However, they have been metamorphosed and are, therefore, metasedimentary rocks in their present state. The metamorphism was minor, being of the greenschist rank, and the rocks themselves have not been altered to any great extent with the exception of the formation of chlorite and the fine granular state of some of the chert.

The oldest sediment in the sedimentary sequence in the map area is the "Goodrich" formation which lies unconformably on the pre-Huronian greenstone and other igneous rocks. The following are detailed descriptions of several phases of this formation.

Lying immediately upon the greenstone is a conglomerate:

Specimen name: Conglomerate
(See fig. 4, p 23)

Specimen number: 181

Location: Approximately 80 paces north of south line

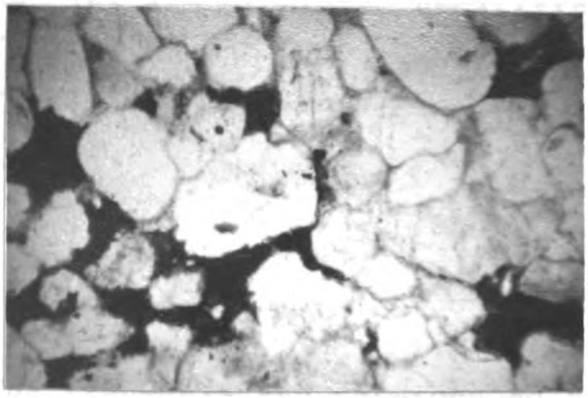


Fig. 4. Specimen #181, Conglomerate showing mixture of chert and quartz pebbles with interstitial hematite (x3; plane polarized)

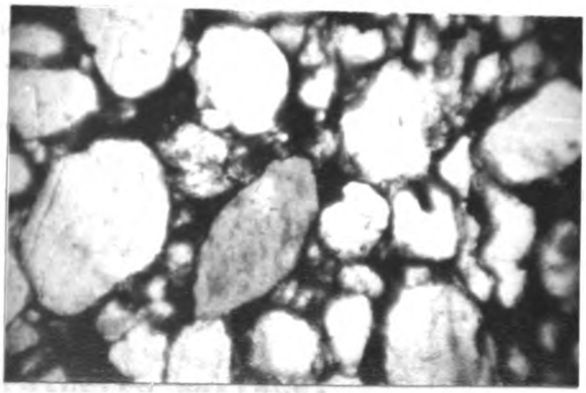


Fig. 5. Specimen #42, Pebble quartzite showing roundness of quartz pebbles and one detrital chert grain (gray-center) (x3; plane polarized)

and 1/4 mile east of west line, section 15

Megascopic description: This rock is white to reddish brown and vitreous, very coarse grained with pebbles up to a half inch in size. The pebbles are of slate, hematitic chert, feldspar and quartz. Limonite spots occur along certain horizons. Numerous exposures of this rock may be found.

Microscopic description:

Quartz	75%
Chert fragments	5%
Feldspar	2%
Chlorite	1%
Hematite-limonite fragments	6%
Chert cement	11%

The fragments are sub-rounded to rounded. There are a few chert fragments in the rock, some with hematite or hematite stain. The cement is chert with some of the chert being crystallized into cryptocrystalline quartz. The feldspar is mostly plagioclase. The section shows little in the way of bedding either cross or graded.

The conglomerate grades into a pebble quartzite which overlies it in most instances.

Specimen name: Pebble Quartzite
(See fig. 5, p 23)

Specimen number: 42

Location: Approximately 1/2 mile south of north line and 1/3 mile west of east line, section 14

Megascopic description: It is a gray to reddish brown, vitreous, medium grained rock. The rock is gray on a fresh surface and reddish on a weathered surface.

Microscopic description:

Quartz	85%
Chert	11%
Hematite	3%
Limonite	1%

The grains are sub-rounded and range in size from .4mm - 2mm. There are several questionable "hyacinth type" zircons occurring as inclusions in quartz grains. The cement is chert with the hematite occurring in the chert. Some of the chert is recrystallized to cryptocrystalline quartz.

The pebble conglomerate grades upward into a normal quartzite, a specimen of which is described as follows:

Specimen name: Quartzite

Specimen number: 167

Location: Approximately 5 paces east of west line and 1/4 mile north of south line, section 15

Megascopic description: This is a white, vitreous, medium grained rock which weathers to a chalky white with "rust spots" of iron oxide. Occassional pebble fragments of chert and some smaller fragments of weathered feldspar are seen. Also seen are a few amphibole or pyroxene fragments.

Microscopic description:

Quartz	82%
Chert	11%
Hematite	1%
Limonite	4%
Feldspar	2%

The clastics show a high degree of rounding and the grain size is fairly uniform. It is cemented by chert with some hematite and limonite.

The preceeding descriptions cover what the writer feels is a phase of deposition. The overlying rocks show an abrupt change in type of sediment and probably represent the beginning of a different phase. It begins with a graywacke which grades into a fine grained dirty or impure quartzite.

Specimen name: Lithic-Graywacke
(See fig. 6, p 26)

Specimen number: 112

Location: Approximately 1/4 mile east of west line and 1/2 mile north of south line, section 14

Megascopic description: This is a gray to black, fine grained rock which weathers chalky white. It is a tough rock and outcrops frequently.

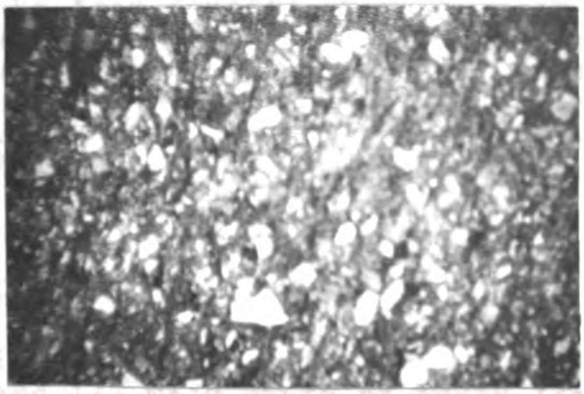


Fig. 6. Specimen #112, Graywacke showing angular to sub-angular plagioclase and quartz fragments in a silt or clay matrix (x3; plane polarized light)

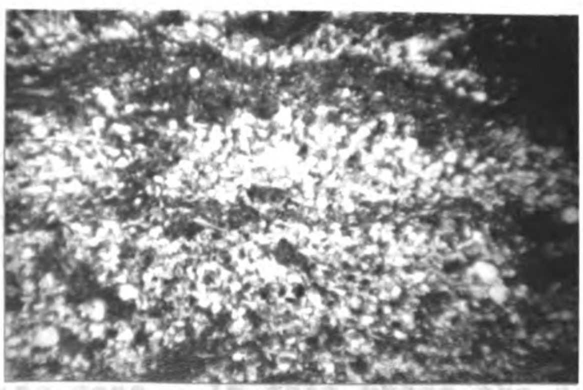


Fig. 7. Specimen #54, Quartz slate showing silt material with some chlorite (dark) and clastic quartz (light) (x3; plane polarized light)

Microscopic description:

Quartz fragments	45%
Plagioclase fragments	20%
Chert	5%
Slaty material	30%

The thin section shows a rough graded bedding with the grain sizes ranging from .1mm - .6mm. There are some patches of chert and a few scattered grains of pyrite. The clastic fragments are angular to sub-angular with no preferred orientation.

Specimen name: Quartzite

Specimen number: 40

Location: Approximately 1/4 mile west of east line and 1/3 mile south of north line, section 14

Megascopic description: This is a reddish brown, very fine grained rock which appears to be quite uniform throughout in the field. However, the unit is fairly thin and was not often found exposed.

Microscopic description:

Quartz fragments	72%
Plagioclase fragments	8%
Chert	10%
Carbonate (?)	1%
Hematite	4%
Limonite	1%
Chlorite	4%

Grain size ranges from .08mm - .5mm. Chert is the cementing material with some carbonate (?). The hematite is scattered throughout and some of the chert is stained with limonite.

Again there appears to be a rather abrupt change into the overlying zone. In this phase the sediments appear to have an increasing amount of coarser clastics than fine clastics (silt size). It begins with a gray quartzite.

Specimen name: Quartzite

Specimen number: 64

Location: Approximately 1/4 mile west of east line and 1/3 mile south of north line, section 14

Megascopic description: This rock is gray to white, medium grained sediment with "speckling" of weathered iron oxide. It weathers chalky white. It is a fairly consistant unit.

The sediments now appear to become dirtier; i.e. the silt or clay content has increased. The unit was classified as a Lithic Quartzite.

Specimen name: Lithic Quartzite

Specimen number: 170

Location: Approximately 20 paces east of west line and 1/4 mile north of south line, section 15

Megascopic description: This is a greenish black, fine grained, slightly argillaceous rock showing bands of "speckling" which is iron oxide. It is a tough rock and forms many good exposures.

Microscopic description:

Quartz fragments	65%
Plagioclase fragments	6%
Chert cement	12%
Chlorite	10%
Siderite	2%
Limonite	4%
Graphite (?)	1%

It appears to have a rather wide range in grain size .06mm - .8mm. Also it appears to have graded bedding. The chlorite appears to have been derived from clay material of which there is very little remaining. The iron oxide (Limonite ?) is confined to one layer within the thin section.

The ratio of coarse clastic to fine clastic material changes again and the rock becomes a quartz slate.

Specimen name: Quartz Slate
(See fig. 7, p 26)

Specimen number: 54

Location: Approximately 1/3 mile west of east line and 1/4 mile north of south line, section 14

Megascopic description: This slate is a grayish black, fine grained, thin bedded rock. The rock is frequently exposed and is quite consistant in appearance.

Microscopic description:

Silt material	45%
Quartz	27%
Plagioclase	4%
Chlorite	12%
Chert	7%
Hematite	4%
Graphite (?)	1%

The rock is thin bedded with alternating medium clastic layers and fine clastic layers. The medium clastic layers show a rough graded bedding. The quartz and plagioclase fragments are sub-angular to sub-rounded. Most of the hematite is confined to the medium clastic layers. However, it does occur in the fine clastic layers. Some of the fine clastic material has been altered to chlorite. Chert cements the medium clastic layers.

The quartz slate grades into the uppermost unit of the "Goodrich" which is represented in this area by a lithic quartzite.

Specimen name: Lithic Quartzite
(See fig. 8, p 30)

Specimen number: 98

Location: Approximately 1/5 mile south of north linee and 1/3 mile east of west line, section 14

Megascopic description: This is a gray, medium grained vitreous and massive rock. It is not continuous but where found it forms a bold outcrop. It appears to grade laterally into a pebble quartzite (Specimen number 24, see fig. 9, p 30) which is gray to reddish, vitreous, with feldspar and hematitic chert.

Microscopic description:

Quartz	75%
Chert	11%
Microcline	4%
Plagioclase	8%
Siderite (?)	2%

The fragments are sub-rounded to sub-angular and are cemented by chert. They range in size from .1mm - .7mm and appear to show graded bedding. There are a few grains of what appears to be "malacon type" zircon present.

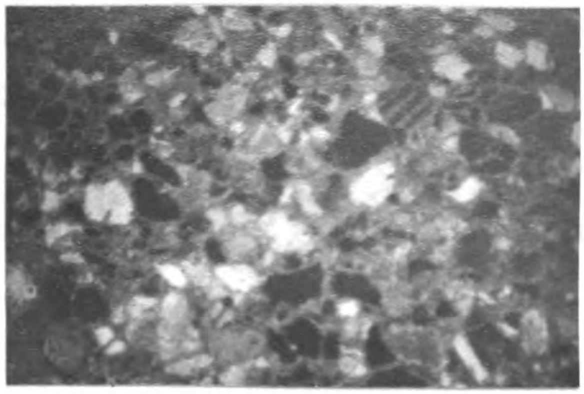


Fig. 8. Specimen #98, Lithic Quartzite showing sub-angular to sub-rounded grains of plagioclase (striped) and quartz (dark and light) in a chert cement (3x; crossed nicols)

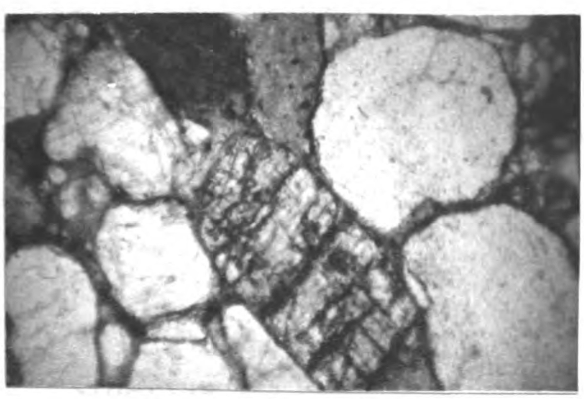


Fig. 9. Specimen #24, Pebble Quartzite showing quartz pebbles (light) feldspar pebble (lined) and a chert pebble (dark gray) (3x; plane polarized light)

No direct contact was seen between the upper most unit of the "Goodrich" and the lower most unit of the "Greenwood." However, the writer feels that the change in sediments and sedimentation is indicated in the unit which was assigned as "lowermost Greenwood." The depositional basin was still receiving clastics but they now consist mostly of fairly well rounded quartz. The "Greenwood" then represents a change from dominently clastic to dominantly chemical deposition. The lower most unit in the "Greenwood" is described as follows:

Specimen name: Ferruginous Quartzite
(See fig. 10, p 33)

Specimen number: 144

Location: Approximately 1/3 mile west of east line and 1/4 mile south of north line, section 15

Megascopic description: This is a red to black thin bedded, fine grained rock occurring at the base of the "Greenwood." It weathers red from the relatively high iron content. It is quite continuous and is seen often in outcrop.

Microscopic description:

Quartz	55%
Hematite	10%
Martite	5%
Chert	25%
Plagioclase	4%
Siderite	1%

The bedding is very fine as is the grain size. It appears to be layered; i.e., clastics and essentially chemically deposited minerals with clastics greater than the chemical. The chert is the cementing agent.

The unit grades into a cherty iron formation.

Specimen name: Cherty Iron Formation
(See fig. 11, p 33)

Specimen number: 6

Location: Approximately 1/4 mile south of north line and 1/3 mile west of east line, section 14

Megascopic description: This is a brownish red and white, fine grained rock showing chert lenses. It is fairly continuous in outcrop.

Microscopic description:

Quartz	45%
Chert	35%
Hematite	15%
Siderite	5%

The quartz is a fine grained mosaic, probably of recrystallized chert. The chert occurs in lenses and is closely associated with the siderite. The hematite occurs as bands alternating with the chert. Occassionally some of the hematite appears oolitic; i.e., it forms a ring or band around a chert or quartz spherule.

There appears to be a change of environment at this point as the character of the iron formation changes from oxidizing to reducing.

Specimen name: Ferruginous Quartzite
(See fig. 12, p 34)

Specimen number: 33

Location: Approximately 1/4 mile south of north line and 1/3 mile west of east line, section 14

Megascopic description: This is a gray to black, thin bedded very magnetic rock. It is easily traced by dip needle but is not found in many exposures.

Microscopic description:

Quartz	45%
Chert	20%
Magnetite	20%
Plagioclase	4%
Microcline	1%
Chlorite	3%
Siderite	2%
Fe-Silicate (Minnesotaite ?)	5%

The magnetite occurs in bands or beds with Fe-silicates and chlorite. It shows octanhedral crystalline form. There are some scattered magnetite crystals in the clastic layers. which appear to cut across clastic grains. The clastic

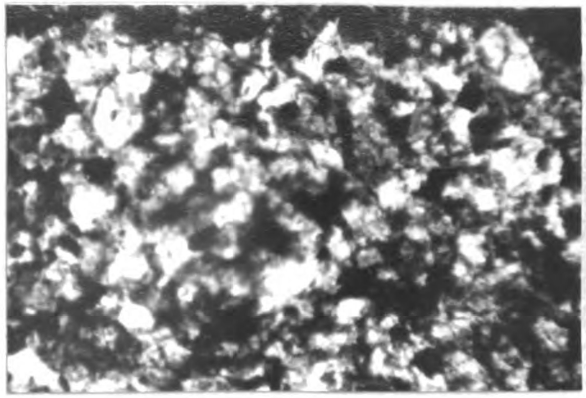


Fig. 10. Specimen #144, Ferruginous Quartzite showing hematite (dark, upper edge), clastic quartz (light, middle), and martite (dark, middle) psuedomorphous after magnetite and cutting clastic grains (x3; plane polarized)

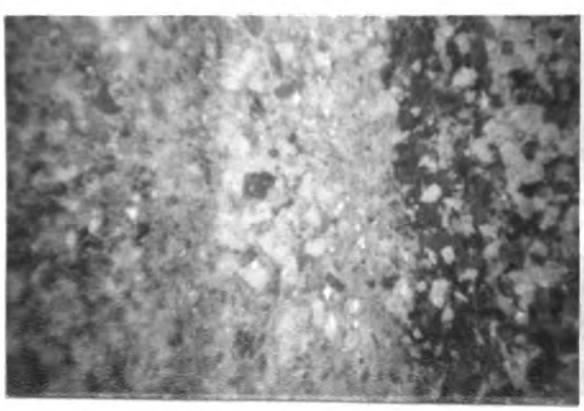


Fig. 11. Specimen #6, Cherty Iron Formation showing primary hematite with clastic quartz layer with scattered hematite (center) and a chert lense with very fine hematite particles (left) (x3; plane polarized light)

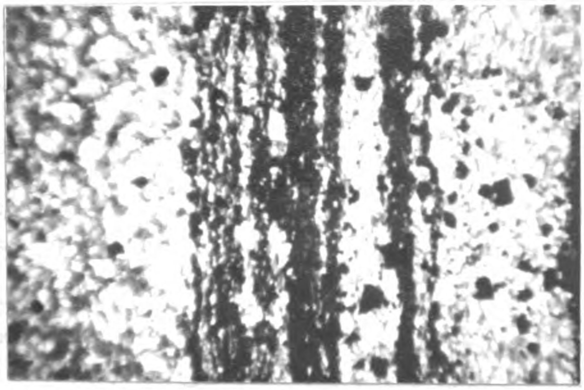


Fig. 12. Specimen #33, Ferruginous Quartzite showing magnetite band with chert and scattered euhedral magnetite crystals (black) cutting clastic quartz grains (x3; plane polarized light)

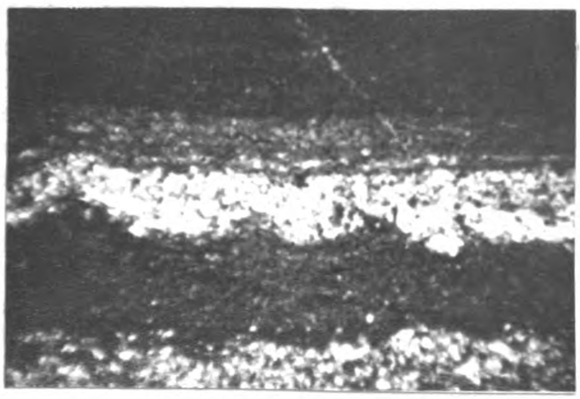


Fig. 13. Specimen #186, Iron Formation showihg very fine grained magnetite (black) and Fe-silicates (dark gray) and fine grained clastic quartz with chert (notice apparent "ripple marks" in magnetite band center) (x10; plane polarized light)

fragments are sub-angular to sub-rounded. The clastic material is cemented by chert.

This grades upward into a more pure form of iron formation and is described as follows:

Specimen name: Banded Iron Formation
(See fig. 13, p 34 and fig. 14, p 36)

Specimen number: 186

Location: Approximately 1/3 mile east of west line and 1/3 mile north of south line, section 15

Megascopic description: Gray and black alternating, very fine grained, and thin bedded rock which is very magnetic. It forms big but not conginuous outcrops.

Microscopic description:

Chert	40%
Quartz	11%
Magnetite	30%
Stilpnomelane	12%
Chlorite	3%
Graphite	1%
Siderite (?)	3%

The dark bands are compesed of magnetite and Fe-silicate with the Fe-silicates comprising the bulk. The light bands are composed of some clastic quartz, chert and chlorite and possibly some graphite and Fe-carbonate. There are also some scattered euhedral crystals of magnetite in the light fands. Much of the chert has been recrystallized to form an interlocking mosaic of quartz.

There appears to be a change in character into the overlying unit although no contact was seen. The overlying unit is a ferruginous quartz slate.

Specimen name: Ferruginous Quartz Slate

Specimen number: 160

Location: Approximately 1/3 mile west of east line and 1/4 mile north of south line, section 15

Megascopic description: This is a grayish black, thin bedded rock which weathers with a very noticeable limonitic stain. It is not very

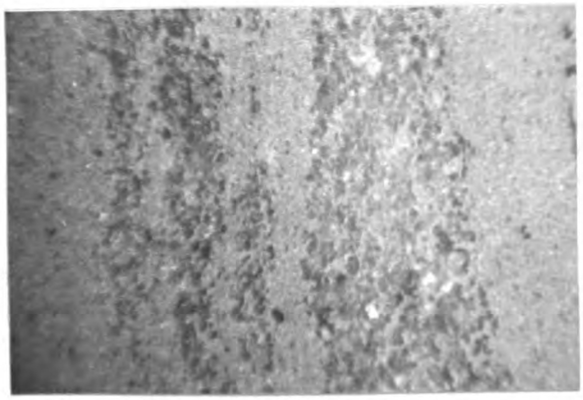


Fig. 14. Specimen #186, Iron Formation showing grainy nature of the bands of magnetite and Fe-silicate (dark) against the smooth nature of the quartz - chert band (light) (x10; reflected light)

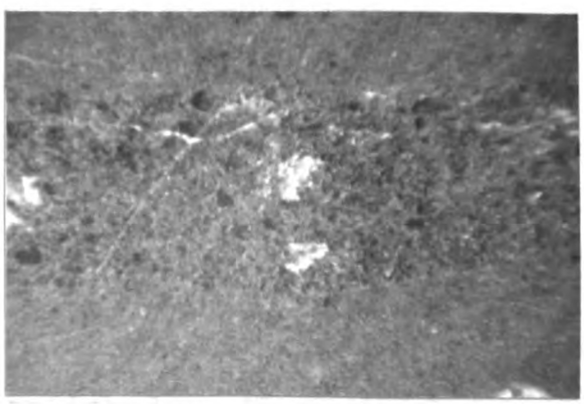


Fig. 15. Specimen #30, Iron Formation showing granule of martite in a chert layer (center) with very fine grain secondary hematite (x10; reflected light)

continuous and not exposed in large outcrops.

Microscopic description:

Quartz	25%
Silt material-chlorite	40%
Chert	30%
Hematite-limonite	5%

This rock consists of alternating beds of "silt material" with some hematite-limonite. The cherty beds contain most of the hematite and limonite; and clastic quartz beds have chlorite, hematite, and chert cement.

A poorer iron formation overlies the quartz slate.

Specimen name: Iron Formation
(See fig. 15, p 36)

Specimen number: 30

Location: Approximately 1/3 mile west of east line and 1/4 mile south of north line, section 14

Megascopic description: This is a reddish-brown, well bedded rock. It is fairly consistant, but forms only small outcrops.

Microscopic description:

Hematite	45%%
Martite	20%
Limonite	15%
Chert	15%
Quartz	5%
Siderite	5%

This slide shows interbedding of hematite-limonite with martite, chert and some siderite. The hematite-limonite layer is very fine grained with an occassional grain of clastic quartz. In the martite-chert layer, the martite appears to be in granule form (seen from a rough, polished section) and has a roughly oval or semioval shape, possibly oolitic. This unit is considered by the writer as being uppermost "Greenwood".

There is a rather abrupt change in the overlying formation (in this report called "Lower Michigamme") which reflects the change of environment and possibly of source. The lowest unit of the Michigamme is a gray to dark gray slates with interbedded coarser angular clastics as seen in an outcrop located approximately 60 paces south of the north line and 3/8's mile west of the east line of section 14. This unit is overlain by a black, dense, carbonaceous and pyritic slate which may be seen along the east section line of section 14. This slate was observed only in the northeast part of this section.

Origin and Environment of the Sediments

Pettijohn (1957) states that tectonics control sedimentation because such movements create the unbalance in relief which is the ultimate beginning of erosion and sedimentation. The physical and chemical factors of the local environment further modify the sediments. Interpretations based on local conditions as well as some interpretations of source area can be made from the sediments as seen in the laboratory and their field relationships.

The sediments in this area begin with the Goodrich formation. The basal unit of this formation is a conglomerate of varying thickness containing well rounded pebbles and lying unconformably upon greenstone or syenite. This conglomerate grades upward into a clean or pure, vitreous pebble quartzite. It appears, then, that this basal unit of the Goodrich represents well worked, near shore sediments.

The writer believes that this unit was laid down as a "sheet deposit" and is indicative of transgression or onlap. The grains are rounded and the sediments are quite pure which is indicative of textural maturity. It is, then, probably a near shore deposit or at least a shallow water deposit.

This unit appears to have been derived partly from igneous rocks in the immediate area and partly from pre-existing sedimentary or metasedimentary rocks to the southeast as indicated by the pebbles of slate and iron formation. The quartz and feldspar were probably derived from the immediate igneous area of acid rocks.

The basal unit of the Goodrich changes abruptly into a quartz slate-graywacke and an impure feldspathic quartzite sequence. The clastic particles range from angular in the quartz slate-graywacke, to sub-rounded, in the dirty feldspathic quartzite. There appears to be a pebble conglomerate which grades in and out of the upper-dirty, feldspathic quartzite. The cementing material for the clastic beds appears to be chert and in some cases carbonate. This sequence, then, may be considered to be composed of immature sediments because of lack of rounding of the clastic grains and the rather high feldspar content. The pebble conglomerate lenses might represent a stream or estuary deposit. This unit might fit Pettijohn's classification of a protoquartzite which he considers to be "a product of paralic sedimentation; i.e., one accumulated on a flood plain or in a delta..." As a whole, the Goodrich, then, appears to reflect tectonic instability with a combination of mature and immature sediments.

Overlying the lower clastic formation is the Greenwood iron-bearing formation. The first unit in the formation is a mixture of clastic sediment and chemically precipitated material and might be called a ferruginous quartzite. The iron compound is essentially hematite but some of the hematite is actually martite. Two explanations come to mind: The magnetite was primary and oxidized to hematite later, or the magnetite is diagenetic or metamorphic and altered to hematite at some later time. Fortunately the writer was able to find in thin section some martite crystals cutting across clastic grains. This would indicate a diagenetic origin for the magnetite and would seem to indicate that some of the hematite at least is the result of later oxidation of the initially deposited iron compound. The original environment therefore was probably mildly reducing. The presence of a relatively large amount of clastic material in this unit would indicate a near shore depositional site.

The next higher unit is more nearly a true iron formation. It consists mainly of hematite and chert with appreciable quantities of clastic quartz. Some of the chert occurs in lenses and some cements most of the clastic quartz. There is some clastic quartz in the hematite layers. The environment of deposition was probably oxidizing as the hematite appears to be primary. There are some grains of hematite which look like oolites, the presence of which would indicate some agitation of the sediment during shallow-water deposition.

Overlying this are units which might be assigned to the iron-silicate-magnetite facies. The iron silicates appear to be stilpnomelene and minnesotaite, however, they were not positively identified in all cases. The lower part consists of a high clastic - low chemical precipitate phase which grades into a low clastic - high chemical precipitate phase. In the high clastic phase the main iron mineral is magnetite but it appears to be diagenetic because it occurs as euhedral crystals; which cut across clastic grains of quartz. In the upper phase, the magnetite is very fine grained and the bands containing the magnetite - iron-silicates appear to show rather delicate bedding features such as sharp contact between the iron rich and iron poor layers or bands. If the magnetite was diagenetic or metamorphic, it would seem that delicate bedding would have been destroyed. The occurence of primary magnetite would indicate mildly reducing conditions during deposition.

James (1954) as a result of his work in the Lake Superior Precambrian believes that the Eh - pH relationships and weathering of the largely basic igneous terrain was responsible for the different facies of iron-formation as he classified them. He considered that vulcanism played a part in the sequence of deposition but only structrually and not chemically. From his work, he has derived a sequence of events for the deposition of iron-formation which was structurally based; i.e., the broad types of sediments being deposited were dependent on the relative stability or instability of the depositional site.

The uppermost unit of the iron-formation consists of a ferruginous quartz slate and bedded hematite. The clastic content is noticeably lower then the preceding units. The sediment is banded, with interlayered hematite and quartz or recrystallized chert. There occurs in this unit layers of what appears to be granules of martite. Granules, as defined by Pettijohn (1957) are structureless (no concentric banding or layering) oval or ovaloid shaped particles of a homogeneous material. If this is the case, the original material might have deposited in a zone of slight agitation which caused the formation of the granules. The originally deposited iron-bearing mineral may have been magnetite or Fe-silicate which oxidized to its present state.

Overlying the iron-formation is a sequence of inter-bedded silty slate and slate. The silt is largely fine grained angular clastic quartz. This unit grades upward into a black, dense, pyritic slate and is interpreted by the writer as an indication of the reactivation of uplift in the source area. This same reactivation may have deepened the depositional site which received carbonaceous material of organic origin that was deposited in a reducing environment so as to preserve the carbon content. This sequence is the highest or youngest sedimentary formation in the thesis area. These rock types outcrop as low lying hills in the northeast corner of section 14.

The sequence of sediments beginning with the Goodrich and ending with the Lower Michigamme appears to represent a deepening of the water or transgression as evidenced by the sediments themselves. The sediments appear to have been deposited in a more reducing environment as one goes up in the sequence and therefore indicates a deepening of the water at the site of deposition.

Several theories have been postulated to explain the origin and environment of deposition of the Huronian Iron Formations. Van Hise and Leith (1911) and some others before them argue for a volcanic origin for the iron and silica in these iron formations. This concept was proposed in part because they presumed that ordinary weathering could not supply the amount of iron solutions required for the deposition of an iron formation. Gruner and James (Pettijohn, 1957, p 458) im more recent work have stated that under tropical to subtropical conditions the iron and silica content of streams and rivers is high enough to account for iron-formation deposition.

Zinn (1961) believes that basic vulcanism and restricted embayments are necessary for the deposition of iron-formation. He points out that if weathering was the agent that supplied the iron and silica necessary for iron formation then what happened to the clay resulting from the breakdown of the source material? It is possible but not too probable that the slaty deposits are removed from the area in another direction or that they have been overlooked or not recognized.

White (1954) summarized some of the inadequacies of the theory of direct volcanic contribution:

1. Lack of association of iron-bearing sediments with contemporaneous volcanics in later geologic time.
2. The enormity of the volcanic source necessary.
3. The improbability that local magmatic sources could produce relatively uniform iron-formations of broad areal extent.

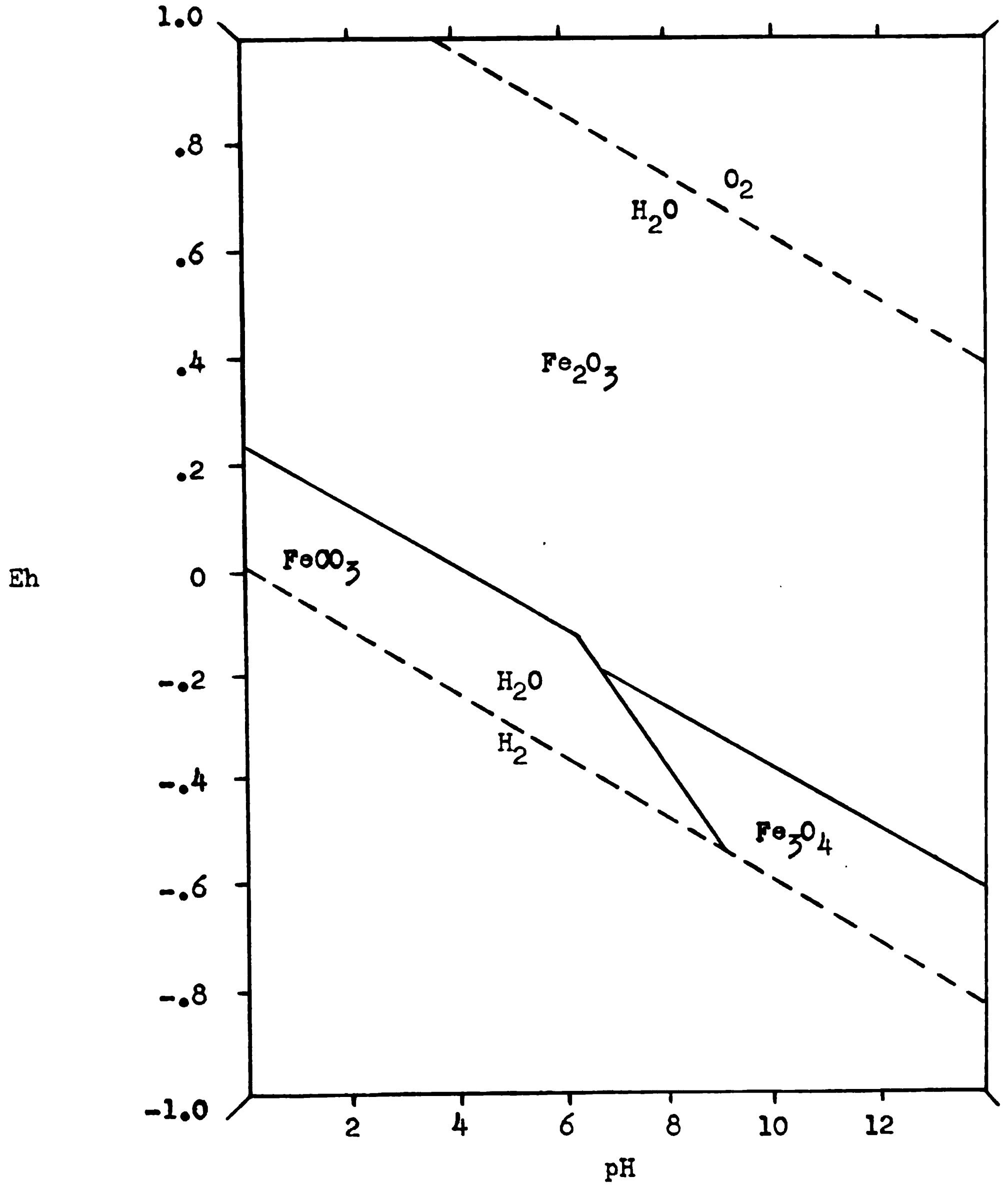
White goes on to say that he considers the "environmental boundry" as the major factor in determining the type iron-formation being deposited. By this he means that in a vertical section, the different types of iron-formation represented are the expression of the rising or falling of sea level which would change the deposits' nearness to shore and therefore change its environment and that horizontally, different rocks may be produced because of different environments.

Garrels and Huber (1953) and Garrels (1957) explain the derivation of the various types of iron formation as the result of certain physico-chemical relationships. One of the more important aspects of their theoretical considerations are their Eh-pH diagrams (See fig. 16, p 46).

Descriptions of the Greenwood Iron Formation as it exists in sections 14 and 15 has been given earlier. Perhaps some statements regarding the depositional environment and source of the ingredients may be tentatively offered. From field and laboratory work, the writer feels that however the iron was derived, either from sedimentary processes or from vulcanism, it was carried to the depositional site in a colloidal form. However, the iron could have been carried to the deposition site in a true solution and because of a change in chemical factors precipitated in the restricted area. Most ferric compounds are very insoluble and ferrous salts are quite unstable in the presence of oxygen. Then local Eh-pH conditions determined the form in which the iron was precipitated. In some cases the original material was altered either by diagenesis or metamorphism. The depositional site, which is a major factor in determining the local Eh-pH conditions, was probably a restricted basin of some sort.

In no way is this meant to be a working hypothesis covering all iron formations as the area under consideration is much too small to make broad generalizations

Fig. 16. Stability fields of Hematite, Magnetite, and Siderite in H_2O at 25°C, 1 Atm total pressure, and total dissolved CO_2 of 10^{-2}, $-6 = \log (Fe^{++})$. (Garrels, 1960).



meant to cover the wide areal distribution of the Lake Superior Iron Formation.

STRUCTURE

The broad structure of the Dead River Basin is that of a syncline. According to Zinn (1961) part of the north east rim of the basin appears to be an over thrust fault with thrusting toward the southwest. (See fig. 17, p 49) Though the basin itself is separated from the Marquette Synclinorium by a belt of pre-Huronian rocks, it is believed to be tied structurally to the synclinorium because sediments of the same age in the basin and synclinorium have been folded and faulted.

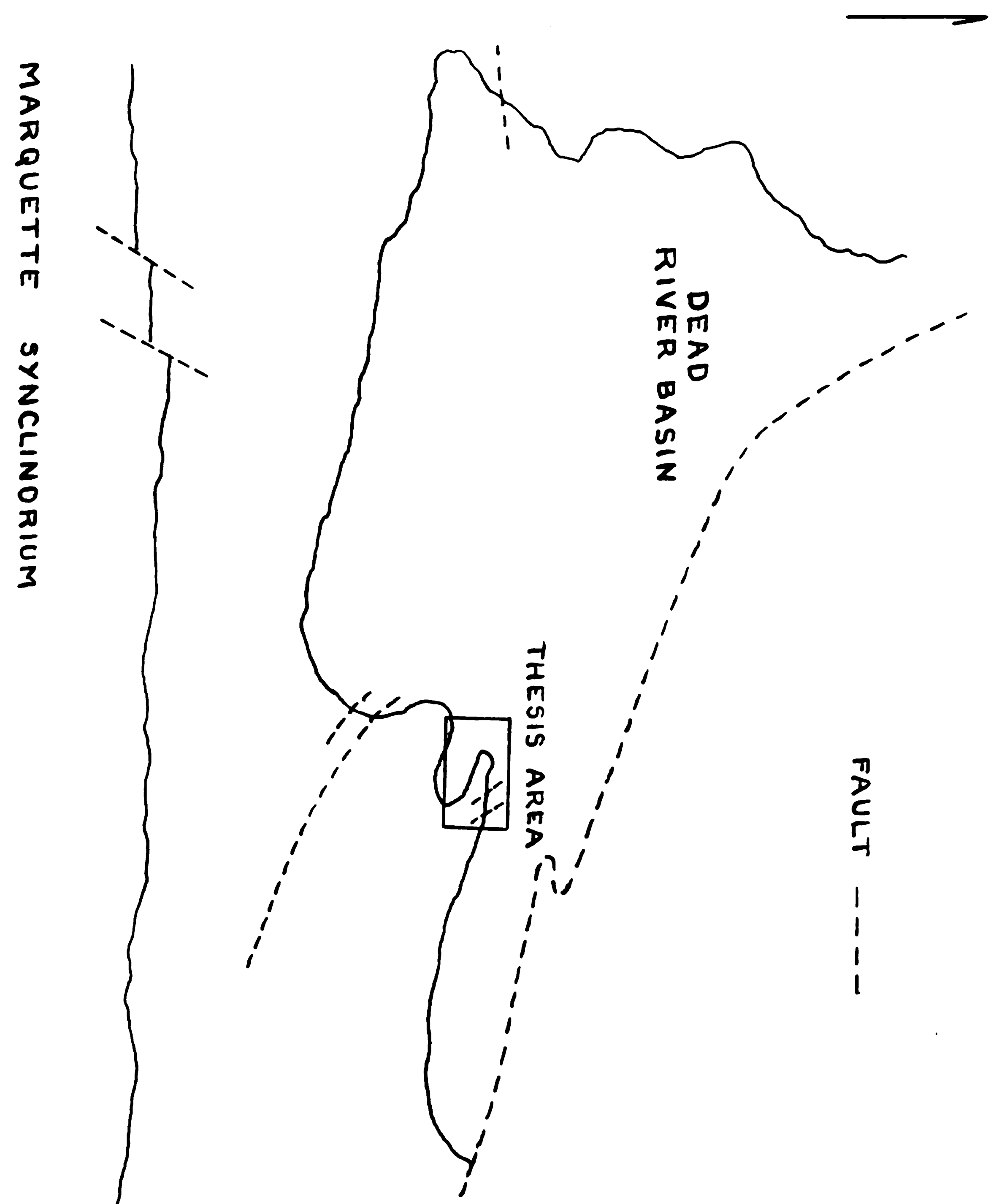
The area in this report shows en echelon folding; i. e., anticline, syncline, anticline all plunging to the N. W. as determined by field work (See map, fig. 18, p 52 and fig. 19, p 53). The folds appear to be the result of a horizontal compression from the north or northeast. From field work, the folds appear to be the similar type.

The faulting within the map area appears to have been the result of strike - slip or tear faults. Hill (1959) describes tear faults as "Unequal advances of adjacent

> sectors of moving nappes or of normally folded strata results in the development, concurrently with major structures, of strike - slip faults that trend tranverse to the strike of the deformed rocks."

Hill also states that tear or strike - slip faults are probably caused by shearing stresses developed as a component of compression in a horizontal plane. In the map area the dip of the faults appear to be almost vertical. This would indicate a horizontal compression with

Fig. 17. Generalized structure map of the Dead River Basin.



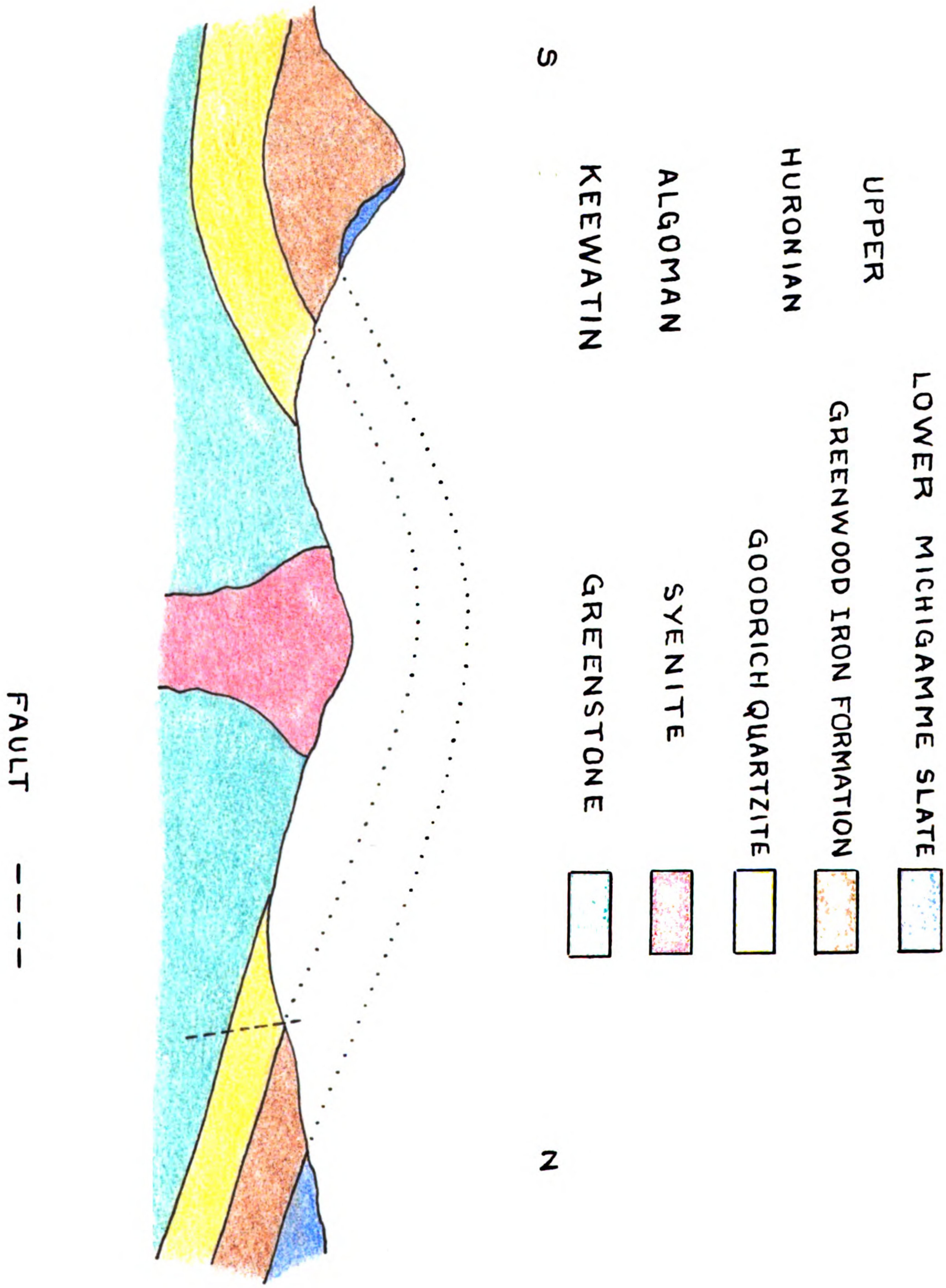
minimum stress also horizontal but at right angles to the maximum stress. However, the faults in this area are sinistral and theoretically the sinistral faults of a strike - slip fault system occur on the N. E. side of the main horizontal compression direction. Since the compression is thought to trend N. E. - S. W., this fact does not appear to conform to the direction of folding. There are two other possibilities which might explain the faults: The faults are the result of a horizontal compression which was directed N. W. - S. E. and occurred later than folding, or the faults are contemporaneous with the folding but were modified in some way to produce the observed results. The direction of faulting and the major fracture pattern appear to conform to a single pattern. Density of fractures or joints as noticed in the field and dislocation of beds are the writer's criteria for this conclusion.

The strike and dip of the formations were recorded wherever possible. The measurements were found to be very useful in the interpretation of the structure of the area. For example, in the northeast corner of section 14, the change in strike of the sediments as interpreted, was drawn on recorded measurements. Also, some changes in strike and dip were noticed and recorded in the immediate area of faulting. The dips were averaged for each formation and the average was used in figuring the approximate thicknesses of the formations.

There was more than one period of deformation in this area but the older ones were earlier than the upper Huronian sediments. In traversing the greenstone area, there appeared to be several different sets of fractures or joint patterns which might indicate earlier deformation as they were discordant to those found in the sediments. Also a basic dike, located 1/4 mile west of the east line and 1/4 mile north of the south line of section 14, has been altered to the same appearance as the surrounding greenstone and therefore, probably represents an earlier intrusion that was altered along with the greenstone, perhaps during Algoman activity.

The writer believes that the latest period of deformation was post-upper-Huronian and pre-Keweenawan. The sediments and the central igneous mass within the area have been affected by both folding and faulting but the Keweenawan Diabase Dikes have not. The folding and faulting might have been penecontemporaneous with the faults cutting the sediments in their folded position.

Fig. 18. Cross section along section line between sections 14 and 15, T48N, R27W.



T48N R27W
15
14
50° N35E
55° N80E
60° N60E
45° N75W
50° N68W
40° N67E
55° N75E
50° N60W
40° N50W
55° N50E
N30W 55°
70° N45W
65° N75W
50° N15E
40° N50W
LEGEND
SCALE
10" = 1 MILE
1 PACE = 6'
Keweenawan
Diabase
Upper Huronian
L. Michigamme Slate
Greenwood Iron Formation
Goodrich Quartzite
Algoman
Syenite
Granite
Diorite
Laurentian
Granite Gneiss
Keewatin
Greenstone

Fig. 19. Geologic map of sections 14 and 15, T48N, R27W.

Fig. 19. Geo
T48N, R27W.

T48N R27W
15
14
50° N35E
55° N80E
60° N60E
45° N75W
50° N68W
40° N67E
55° N75E
50° N60W
40° N50W
55° N30W
55° N50E
70° N45W
65° N75W
50° N15E
40° N50W
LEGEND
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10" = 1 MILE
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Keweenawan
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Goodrich Quartzite
Algoman
Syenite
Granite
Diorite
Laurentian
Granite Gneiss
Keewatin
Greenstone

Fig. 19. Geologic map of sections 14 and 15, T48N, R27W.

CORRELATIONS

Before beginning his work the writer considered the possibility that the sediments in this area represented an undivided Upper Huronian sequence. This was based on Zinn's reconnaissance survey in 1929-30. The mapping of section 15, T48N, R26W during the summer of 1958 had shown the Negaunee Iron-Formation as being truncated diagonally by erosion. The presence of an impure quartzite containing fragments of iron-formation overlying this rock seemed to indicate that this particular iron-formation was Negaunee because there is no other known iron-formation in the Huronian that is lower then the Negaunee or has a well marked unconformity at its top. On the basis of this, it was believed that further to the west the rest of the middle Huronian was also truncated by this same "dirty or impure quartzite." The writer also believed that by careful mapping and lithologic identification, and careful structural considerations, the sequence in sections 14 and 15, T48N, R27W could be identified and correlated with the known upper Huronian of the Marquette Synclinorium. (See Table 3, p 56)

The writer uses Zinn's (1932) description of the upper Huronian for correlation purposes. Zinn describes the Goodrich as a conglomerate, quartzite, and slate which overlies and truncates the Negaunee Iron Formation. The conglomerate unit is described as having a variable thickness and being "composed of pebbles of iron formation, quartzite, and granite, in a matrix of finer material of the same character." A thick, pure, vitreous quartzite overlies and grades down into the conglomerate unit. He also states that the formation as a whole vaires both in thickness and lithology within short distances.

The basal sediments, as the writer saw and described them, matches Zinn's descriptions very well. The basal formation lies unconformably upon the greenstone and contains pebbles of slate, hematitic chert, and quartz with a matrix of chert and hematite. This unit varies in thickness and grades upward into a rather pure, vitreous quartzite.

Zinn states that the Greenwood which overlies the Goodrich conformably is not a pure iron formation "but was deposited as an interlayered accumulation of clastic material and chemically deposited chert and siderite."

The writer describes the iron formation in his area as a high clastic iron formation. This formation as seen by the writer may be thicker than the comparable formation described by Zinn in the Marquette Synclinorium. Zinn assigns a minimum thickness of 50' while the writer assigns as his minimum thickness a value of 175'. The fact that this iron formation lies conformably upon sediments identified by the writer as Goodrich and it is a high clastic iron formation leads the writer to classiby this formation as Greenwood.

Table 3. Correlation between Marquette Synclinorium and Sections 14 and 15, T48N, R27W

Marquette	Age	Section 14 and 15
Diabase Dikes and Sills	Keweenawan	Diabase Dikes
U. Michigamme Sl		Not Present
Bijiki Iron Fm.	Upper	Not Present
L. Michigamme Sl.		L. Michigamme Sl.
Clarksburg Volcanics		Not Present
Greenwood Iron Fm.	Huronian	Greenwood Iron Fm.
Goodrich Quartzite		Goodrich Quartzite
Negaunee Iron Fm.	Middle	Not Present
Siamo Sl.		Not Present
Ajibik Quartzite	Huronian	Not Present
Wewe Sl.	Lower	Not Present
Kona Dolomite		Not Present
Mesnard Quartzite	Huronian	Not Present
Syenite		Syenite
Granite	Algoman (?)	Granite
Diorite		Diorite
Kitchi Conglomerate	Temiskaming	Not Recognized
Granite Gneiss	Laurentian	Granite Gneiss
Greenstone	Keewatin	Greenstone

The Clarksburg Volcanics of the Marquette District do not appear to be present in this area. However, Zinn states that the Clarksburg is a fairly local formation as it is restricted to the south side of the Marquette Synclinorium.

Overlying the Clarksburg or the Greenwood where the Clarksburg is absent is the Lower Michigamme Slates. Zinn describes this formation as a chloritic slate grading upward through a gray slate into a black carbonaceous or graphitic slate.

The writer reports a similar unit consisting of a basal quartz slate grading upward into a black, graphitic slate. The writer found that in his area, with exception of the basal conglomerate-quartzite formation, all relationships were conformable. Since there are no continuous outcrops between the Dead River Basin and the Marquette Synclinorium stratigraphic sequence and lithologic similarities are used for correlation.

There is a difference of metamorphic rank between the two areas. This could be ascribed, however, to the fact that the Dead River Basin was on the edge of the main orogenic belt and therefore further away from high temperature metamorphism.

The direction of onlap or transgression might be used in correlation. Since the Dead River Basin and the Marquette Synclinorium are sub-parallel, the same approximate direction of onlap for the same age of sediments would be expected. In the synclinorium proper, the direction of onlap is from the east to the west as the sediments become progressively younger in that direction while in the Dead River Basin it onlaps to the northwest as evidenced by truncation of middle Huronian sediments east of the thesis area.

The state of the Greenwood formation is also indicative of the direction of onlap. In the Marquette Synclinorium the Greenwood formation is unoxidized while in the Dead River Basin, the Greenwood formation is oxidized.

CONCLUSIONS

From the writer's field and laboratory studies of sections 14 and 15, T48N, R27w, the following conclusions may be drawn:

1. The sediments lie unconformably upon the Keewatin greenstones as shown by:
    a. A basal conglomerate which includes some fragments of greenstone.
    b. The definite lithologic change from greenstone to the sediments.
2. The sediments are transgressive in nature and are onlapping to the northwest shown by:
    a. Truncation and inclusion of fragments of uppermost middle Huronian further to the southeast (Section 15, T48N, R26W).
    b. The basal sediments are indicative of shalloww water deposits (sheet sands) and as the sediments become younger they also become more reducing in nature which is the result of a deepening of the water at the site of deposition.
    c. The Dead River Basin, lying subparallel to the Marquette Synclinorium, shows sediments of the same age onlapping in the same direction.
3. The sediments are conformable.

a. There is no angular discordance between any formation.

b. No good conglomerates occur other than that at the base of the Goodrich.

4. The Greenwood does exist as a separate and distinct formation as shown by:

a. Its high clastic content which distinctly belongs to Greenwood as described in other areas.

b. Its conformable position between the Goodrich and the lower Michigamme.

5. There have been at least three periods of intrusion by igneous rocks as shown by:

a. Granite gneiss classified as Laurentian cutting the Keewatin greenstones.

b. Granites, syenites, and diorites classified as Algoman cutting the greenstones but not the sediments.

c. Diabase cutting all rock types and showing a high negative magnetic anomaly.

6. Folding and faulting occured post-upper Huronian and pre-Keweenawan as shown by:

a. All sediments classified as upper Huronian have been folded and faulted.

b. Diabase dikes, classified as Keweenawan, cut all rock types but show no signs of folding or faulting.

7. The upper Huronian sediments of the Dead River Basin do correlate with those of the Marquette Synclinorium as indicated by:

   a. Lithologic similarity.

   b. Sequence of beds.

   c. Structural similarity.

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