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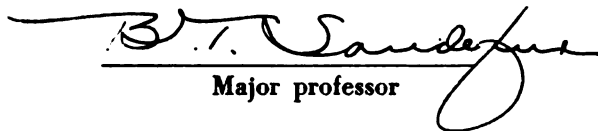
SUB-HURONIAN (TIMISKAMING?) SEDIMENTS OF THE
LAKE ENCHANTMENT AREA, MARQUETTE COUNTY, MICHIGAN

presented by

Gerald L. Brooke

has been accepted towards fulfillment
of the requirements for

M. S. degree in GEOLOGY


Major professor

Date May 11, 1951

SUB-HURONIAN (TIMISKAMING?) SEDIMENTS OF THE LAKE
ENCHANTMENT AREA, MARQUETTE COUNTY, 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

1951

INESIS

ACKNOWLEDGEMENTS

To Dr. Justin Zinn, the writer wishes to express his appreciation for suggesting the problem and for advice used in the field and laboratory.

The writer wishes also to thank Dr. B. T. Sandefur for critically editing the manuscript and for many helpful suggestions in laboratory procedure; Dr. J. W. Trow, for his interest and many timely suggestions; and Dr. W. A. Kelly, for his time and help in preparing the topographic map from the aerial photographs.

The writer is indebted to Mr. P. G. Phillips for the photomicrographs, and to Mr. R. E. Sanem for the structural diagram.

6/29/51
Gift

CONTENTS

	Page
List of illustrations	i
Introduction	1
Location	1
Culture	1
Topography	3
Lakes and Drainage	3
Previous investigations	3
General geology	5
Definition of the problem	7
Procedure	10
Field procedure	10
Laboratory procedure	11
Geology	12
Stratigraphy	12
Petrography	15
Keewatin	15
Sub-Huronian	16
Lower Huronian	19
Late diabase	19
Thin section study	20
Petrographic analysis	20
Summary of petrographic study	34
Structure	37

	Page
Conclusions	40
General	40
Correlation	41
General	41
Possible correlations	42

ILLUSTRATIONS

Plate	Page
1. Index map of the Lake Enchantment area	2
2. Topographic map of the Lake Enchantment area and vicinity	4
3. Summary of exposed rock formations in the Lake Enchantment area	13
4. Photomicrographs of rock specimens	25
5. Photomicrographs of rock specimens	30
6. Photomicrographs of rock specimens	33
7. Classification of arenites	36
8. Structural diagram	38
9. Face poles of schistosity, cleavage, and joints.	39
10. Geologic map of the Lake Enchantment area - in pocket	

SUB-HURONIAN (TIMISKAMING?) SEDIMENTS OF THE
LAKE ENCHANTMENT AREA, MARQUETTE COUNTY, MICHIGAN

Gerald L. Brooke

INTRODUCTION

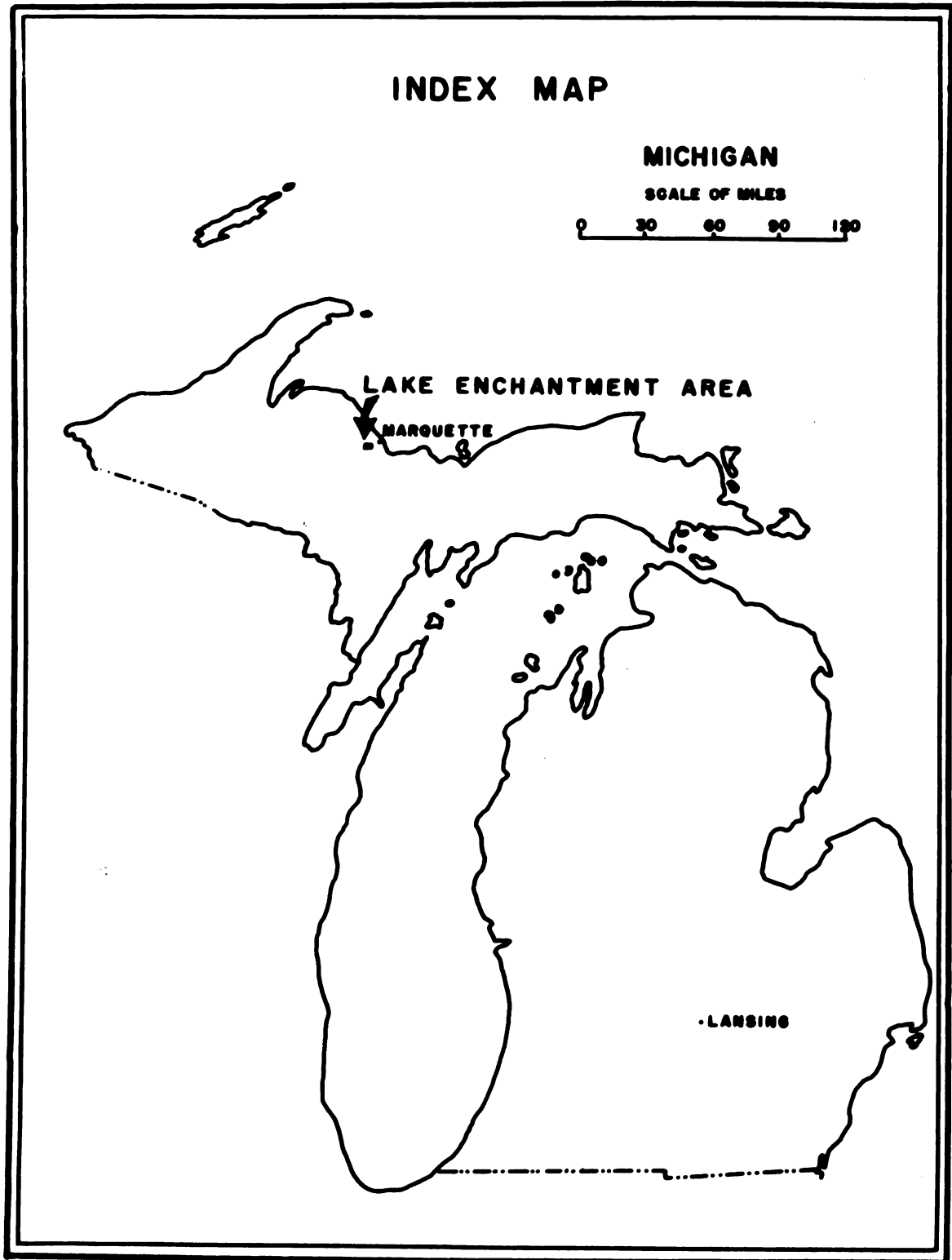
Location: The Lake Enchantment area is in the south $\frac{1}{2}$ of section 29, T.48N., R.25W., Marquette County, Michigan. The area derives its name from Lake Enchantment, referred to as Mud Lake in earlier literature and on old maps.

Culture: The area is made readily accessible by a hard surfaced road, known as the old Marquette-Ishpeming road, or Michigan State highway M-492. To enter the area it is necessary to drive approximately five miles west from Marquette on M-492, and then follow a dirt road approximately one mile to the southeast.

Two small lakes are in the area; Lake Enchantment in the south central part of the area and Marl Lake several hundred feet to the west. These lakes are nestled in a small east-west valley. Prominent ridges lie to the north and south of this valley. The area provides an easily accessible resort for residents of Marquette, and there are several lake-front cottages around the lakes.

Second growth timber covers the area. The most prominent species are birch, aspen, maple, and pine. Most of these trees have little value as timber. They range from small shrubs to trees 50 to 60 feet in height, and form an effectual bar to extended vision, except from high, rocky points. Where the second growth timber is thick it

PLATE I



is more difficult to penetrate than the virgin forest.

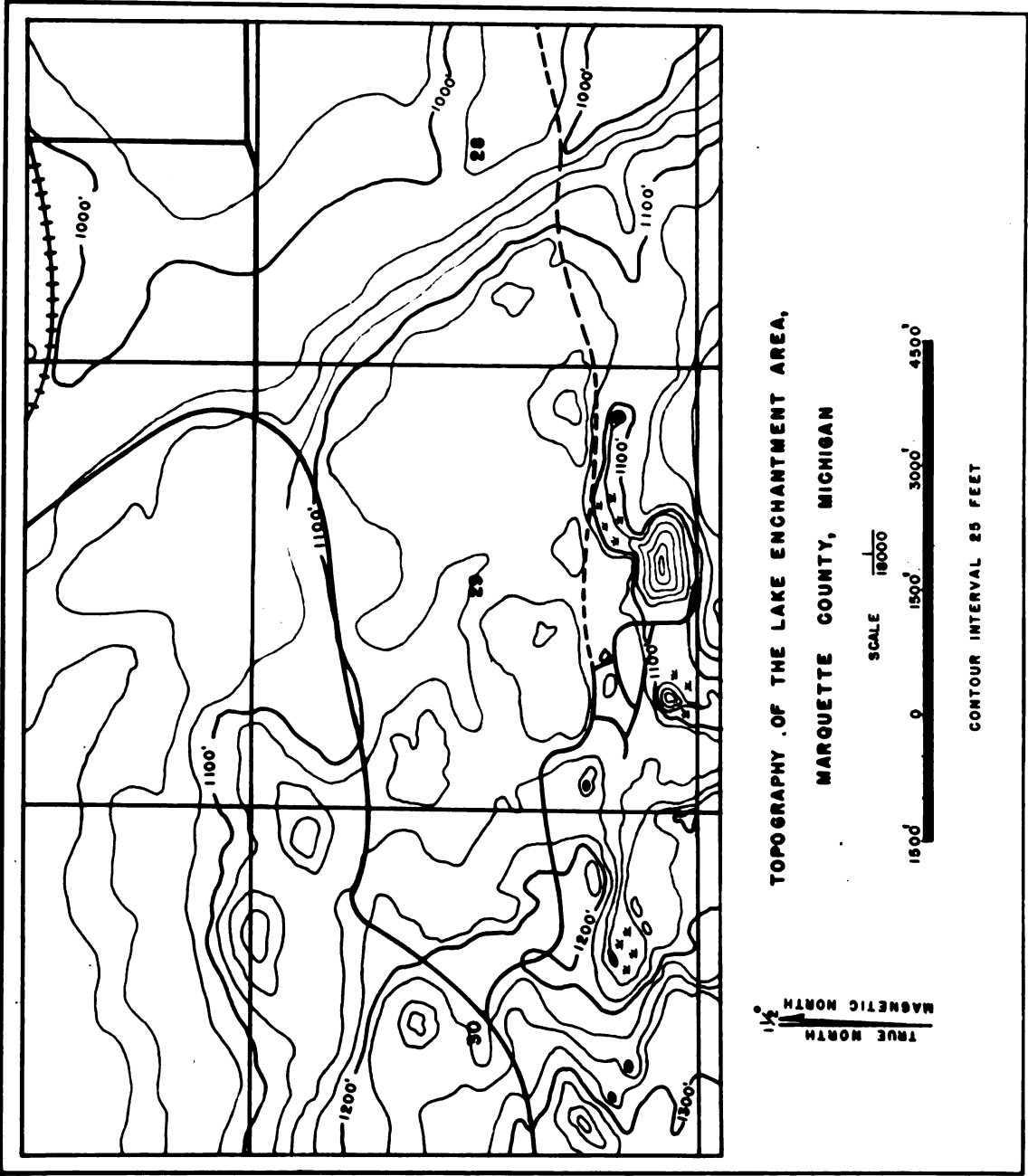
Topography: The topography, in general, is typical of pre-Cambrian glaciated regions. The surface of the area is broken and hilly; the larger hills were nearly leveled by glacial erosion and the eroded material used to fill the valleys. Northeast of Lake Enchantment the Mona Hills, type locality for the Mona Schist, rise in smooth, round knolls. These knolls are typical of the regional topography.

The outcrops form low, smooth hills or knobs in most places, but some have rough, precipitous faces 20 to 50 feet above the surrounding drift. Several east-west ridges, give prominence to the area. These ridges are rarely continuous for any great distance, but usually are broken into isolated, rounded knobs, clustered together in rows. They are rarely more than 100 to 200 feet above the adjacent valley.

Lakes and Drainage: The valleys contain marshes or small lakes connected by creeks. At some places two or three lakes are found in close proximity and all connected by creek channels. An excellent example of this type of valley drainage is provided by Lake Enchantment and Marl Lake.

Previous Investigations: The Marquette district is the oldest important iron-producing area of the Lake Superior region. For this reason many geologists have examined parts of the district and have written a large number of reports. However, most of these investigations

PLATE 2



covered the sections of economic value and many of the more interesting localities, from a theoretical standpoint, escaped detailed study.

Reports written by Maj. T. B. Brooks in 1873, Raphael Pumpelly in 1876, M. E. Wadsworth in 1880, Dr. Carl Rominger in 1881, R. D. Irving in 1883, and many others, covered all, or part of the Marquette district. However, none of these men mention the Lake Enchantment area.

U. S. Geological Survey Monograph 28, a classic by C. R. Van Hise, W. S. Bayley, and H. L. Smyth, was the first report to mention this area. Another less extensive description is given in Monograph 52, 1911, by C. R. Van Hise, and C. K. Leith.

The report "Pre-Cambrian Rocks of the Lake Superior Region", by C. K. Leith, Richard J. Lund, and Andrew Leith, in the U. S. Geological Survey Professional Paper 184, 1935, covered some parts of the Marquette district, but contains nothing about the Lake Enchantment area.

There is a brief description of the Lake Enchantment area in the report "Summary of the Geology of the Marquette Iron Range", by W. A. Seaman. This report was published in the State Progress Report of 1944, and is the last known report on the Marquette district.

GENERAL GEOLOGY

The Lake Enchantment area is on the northern edge of the Marquette syncline. Within the area a group of

sediments stratigraphically above the Keewatin Mona schist and below the Lower Huronian Mesnard quartzite are exposed.

The Marquette syncline extends from the city of Marquette on Lake Superior, west for a distance of nearly forty miles, to Lake Michigamme. Folded within the syncline are Huronian sediments. The syncline varies in width from one to six miles and is bounded on the north and south by areas of the "Basement Complex". The term "Basement Complex", first proposed by Irving,*

*Williams, G. H., The Greenstone Schist Areas of the Menominee and Marquette Regions of Michigan, U. S. Geological Survey Bulletin, no. 62, p. 21, 1890.

has been used to designate the Laurentian granites and Keewatin schists beneath the Huronian sediments. This indicates that these formations constitute the basement upon which the Huronian sediments were deposited. The northern area is called the "Northern Complex" and the southern area, the "Southern Complex".

The contact between the Mona schist and the sediments of the Lake Enchantment area is a few feet north of an old dirt road, which crosses the southern part of section 29 (see map in pocket). The contact between these sub-Mesnard sediments and the Mesnard quartzite is approximately 200 feet north of Lake Enchantment.

The northern complex, directly north of the area, is composed of greenstone cut by a small diabase dike. Masses of granite and granite dikes are found farther to the north.

The sediments of the area consist of, 1) a basal conglomerate, 2) a slate, in which are found scattered pebbles and boulders of graywacke, and 3) three thin beds of graywacke. These sediments are overlain by the Mesnard quartzite.

The Mesnard quartzite is reported to have a basal quartz conglomerate exposed near the U. S. Route 41 road-cut north of Negaunee. This quartz conglomerate is very thin and appears to be plastered against the quartzite according to W. A. Seaman.*

*Seaman, W. A., personal communication.

A quartz conglomerate with the above characteristics has been reported at the base of a quartzite near Silver Lake in the northwestern part of Marquette County, by Dr. W. A. Kelly.*

*Kelly, W. A., personal communication.

The quartzite at Silver Lake is not known to be Mesnard.

The basal quartz conglomerate was not exposed in the Lake Enchantment area.

DEFINITION OF THE PROBLEM

Van Hise*

*Van Hise, C. R., Bayley, W. S., and Smyth, H. L., The Marquette Iron-Bearing District of Michigan, U. S. Geological Survey Monograph XXVIII, p. 232, 1897.

includes the Mud Lake (Lake Enchantment) area in a page of

"Interesting localities" of the Marquette district. In an earlier section of the report he describes the sediments of this area as a basal member of the Mesnard quartzite. In his description of the Mesnard quartzite Van Hise* states:

*Op. cit., Van Hise, C. R., Bayley, W. S., and Smyth, H. L., p. 223, 1897.

"On the north side of the trough north of Mud Lake, in sec. 29, T.48N., R.25W., the lowest horizon is again a basal conglomerate, the numerous fragments being derived mainly from the granites and schist of the Northern Complex, the latter being more abundant because immediately adjacent."

In this monograph Van Hise includes the group of sediments, mapped by the author, as a minor, basal member of the Mesnard quartzite. He considers the Kitchi schist, west of Lake Enchantment, contemporaneous with the Mona schist. In other words, he regards the Kitchi schist as Keewatin, and the Lake Enchantment sediments as basal Huronian.

In Monograph 52, Van Hise*

*Van Hise, C. R., and Leith, C. K., The Geology of the Lake Superior Region, U. S. Geological Survey Monograph LII, p. 254, 1911.

appears to have revised his opinion, and states:

"Near Mud Lake a series of green schists, graywackes, and slates intervenes between the typical Mona schist on the north and the Huronian beds on the south. The intervening series is conglomeratic near its contact with the Mona schist and in turn is overlain unconformably by the Huronian series, with basal conglomerate. These green schists and slates look not unlike some of the phases of the Kitchi schist farther west, suggesting the

possibility that the Kitchi schist may be partly younger than the Mona schist and may be locally more largely sedimentary than is apparent in the typical Mona schist area. Indeed, if mapped independently of other parts of the district, the green schists and slates between the Mona schist and Mesnard quartzite of the Mud Lake area would be mapped as sedimentary, probably lying unconformably below the Huronian and unconformably upon the Mona schist."

Mr. W. A. Seaman and others share in the opinion voiced by Van Hise. Mr. Seaman*

*Seaman, W. A., Snelgrove, A. K., and Ayres, V. L., Strategic Minerals Investigations in Marquette and Baraga Counties, Progress Report no. 10, State of Michigan, p. 11, 1944.

states:

"The oldest known sediment on the range is a conglomerate having well rounded pebbles of the Keewatin schist and vein quartz and various phases of the Laurentian granite. The basal conglomerate is well exposed close along the north side of a dirt road across the southern part of Sec. 29, T48N, R25W, north of Enchantment Lake (called Mud Lake on the older maps). Intermittent exposures of this same conglomerate are found for several miles westward past Negaunee and for two or three miles eastward. South of the conglomerate is the thick overlying graywacke and considerable slate, both of which, being derived largely from the underlying Keewatin, are often mistaken for it."

There is one more possibility, which must not be overlooked, namely; that this so-called conglomerate may be a tillite. F. J. Pettijohn describes a tillite among a group of sediments he calls basal Huronian in the Fern Creek area of the Menominee district. Pettijohn*

*Pettijohn, F. J., Basal Huronian Conglomerates of the Menominee and Calumet Districts, Michigan, Journal of Geology, vol. LI, p. 391, 1943.

says:

"The sporadic nature of the fragments, the discrepancy between their size and the fine-grained graywack matrix, the lack of bedding of the latter-all remind one of a tillite. The obviously rafted nature of some of the large cobbles in the laminated phyllites further suggest ice action."

This Fern Creek "tillite" lies in a stratigraphic position similar to the sediments of the Lake Enchantment area.

The early opinions on the geology of the Lake Enchantment area were voiced without the aid of a detailed map for reference. The early maps of the area were done on a regional scale.

The problem related to this study was to map the area in as much detail as time would allow; collect samples for reference and thin section study; classify all rocks megascopically and check them microscopically; determine the structure, the mode of deposition, the relationship of the sediments to the Mona schist below and the Mesnard quartzite above; and lastly to draw a conclusion in support of one of the opinions stated above.

PROCEDURE

Field Procedure: The field work was done during the fall of 1950, and consisted of studying the outcrops,

preparing a map, and collecting samples. At this time of year most of the leaves had fallen from the deciduous trees and vision was increased.

The mapping was done with the aid of a plane table and open-sight alidade, using a scale of 1" = 100'. The southwest section corner could not be located and it was necessary to rely on two surveyor property stakes for reference.

Rock samples collected in the field were labeled for location and orientation, so that any evidence of microscopically graded bedding could be used to determine the top of the beds.

Laboratory Procedure: Thin sections were prepared from the rock samples collected. From these the different stratigraphic units were examined microscopically, minerals identified, and the various units classified. The igneous rocks were classified according to Johannsen,*

*Johannsen, A., A Descriptive Petrography of the Igneous Rocks, (Univ. Chicago Press, 1939), vol. I, p. 141.

and the sediments according to Pettijohn.*

*Pettijohn, F. J., Sedimentary Rocks, (Harper and Brothers, New York, 1949), p. 227.

Pettijohn's classification is based upon the mineral composition of the detrital fraction of the beds. The percentages of quartz, feldspar, and clay minerals were calculated by using the method proposed by F. Chayes.*

*Chayes, F., A Simple Point Counter for Thin-Section Analysis, The American Mineralogist, vol. 34, pp. 1-11, January-February, 1949.

The topographic map of the area was drawn from aerial photographs, with the aid of an Abrams contour finder. A tilt graph was prepared and traced on the photographs. Corrections were made for tilt during contouring, thereby eliminating tilt distortion. Twenty-five foot contour intervals were used.

For the purpose of this paper the word "Timiskaming" is spelled as indicated. It has had numerous spellings in the past, including 1) Timiskaming by Collins, W. H., 1922, 2) Temiskaming by Miller, W. G., 1911, 3) Temiscaming by Coleman, A. P., 1915.*

*Wilmarth, Grace M., The Geologic Time Classification of the United States Geological Survey Compared with Other Classifications, U. S. Geological Survey Bulletin no. 769, p. 121-126, 1925.

GEOLOGY

STRATIGRAPHY

The rocks mapped in the Lake Enchantment area rest unconformably upon the Mona schist, and are believed to lie unconformably below the Mesnard quartzite.

The unconformable relationship between the Lake Enchantment sediments and the Mona schist is clearly visible. The contact is covered by talus in places; where

PLATE 3

Summary of exposed rock formations in the Lake Enchantment Area, Marquette County, Michigan

	Age	Formation	Character	Thick- ness (feet)	Sample Number
Proterozoic	Pleistocene		Glacial drift	0-30	
	Lower-Furonian	Unconformity— Mesnard quartzite	(Killarney)— Predominantly a pure vitreous quartzite, sericitic at the base.	150- 170	47e & 47e
		Unconformity?—	(Algomen)—(Late Diabase?)		
Archeozoic	Sub-Furonian (Timiskaming?)	Graywacke	A pinkish-gray, medium to fine- grained graywacke.	± 75	50b
		Graywacke	A smoky-gray, fine- grained, laminated graywacke.	44	43d & 49c
		Graywacke	A pinkish-gray, medium to fine- grained graywacke	19	43c & 48e
		Slate	A greenish, medium to fine-grained slate, containing scattered boulders of graywacke	284	15a, 15b, 16c, 43a, 46b, & 46d
		Conglomerate	Conglomerate, com- posed of pink granite, greenstone, and an occasional chert boulder. The matrix is com- posed of finer particles of the same material	31	11a, 11b, 11c, 11d, 12c, 12b, 12e, & 14a
	Keewatin	Unconformity— Mona Schist	(Laurentian)— Predominantly highly schistose greenstones.	?	39e & 41e

it is exposed, it is very irregular. The criteria used to establish this unconformity consists of:

1. A great lithologic change. The unquestionable change in environment at the time the Lake Enchantment sediments were deposited, in contrast to the environment at the time the Keewatin lavas were extruded is responsible for this great lithologic change.

2. The inclusion of underlying rocks in the basal conglomerate of the Lake Enchantment sediments.

A second unconformity is indicated between the Mesnard quartzite and the underlying Lake Enchantment sediments. The existence of this unconformity is not as clear as the one between the Mona schist and the overlying Lake Enchantment sediments. The contact is not exposed in the area. Nor is the basal quartz conglomerate of the Mesnard formation, reported by W. A. Seaman, exposed here. However supporting, if not diagnostic evidence for this unconformity consist of:

1. Truncation of the Lake Enchantment sediments - the strike of the beds near the contact of the Lake Enchantment sediments and the Mesnard quartzite indicate an angular unconformity.

2. A lithologic change - the difference in environment that existed at the time of deposition of the Lake Enchantment sediments in contrast to that during Mesnard deposition, was brought out in the thin section study. A definite change is indicated. The Lake Enchantment sediments

contain as much as 45 percent feldspar, whereas, the Mesnard quartzite is nonfeldspathic. The Lake Enchantment sediments were formed during a period of rapid deposition, or under glacial conditions, and the Mesnard quartzite during a period of mature weathering.

The existence of an unconformity between the Lake Enchantment sediments and the Mesnard quartzite is suggested, but cannot be proven from work done in this area. More detailed work must be carried on in other areas, where similar conditions exist and the contact is exposed, or where the basal quartz conglomerate of the Mesnard quartzite is exposed, to prove this unconformity. The presence of a fault contact, instead of an unconformity cannot be ruled out.

PETROGRAPHY

The rocks are divided into three series, namely;
1) Keewatin, 2) sub-Huronian (Timiskaming?), and 3) Huronian.

KEEWATIN

Mona schists: The Mona schists of the basement complex are the oldest known rocks of the area. The intruding granites, diabase dikes and other intrusives, along with thin beds of chert and iron formation, make up the remainder of the basement complex as known today.

G. H. Williams*

*Op. cit., Williams, G. H., p. 158, 1890.

believes that the Mona schists are recrystallized basic tuffs or altered lavas. He states:

"The banded greenstone schists of the northern Marquette area are to be regarded as consolidated and highly metamorphosed diabase tuffs. These are intimately associated with numerous contemporaneous flows of diabase and quartz porphyry, together with tuffs of the latter rock, while all have been broken through by much younger dikes, both basic and acidic."

As these rocks were original flows, it is evident that there must have been a foundation upon which they were deposited, but this foundation has not been determined.

The character of the schists varies widely. In some places they are fine-grained and highly schistose; at other places they are coarser-grained, fibrous or dense to massive. In all cases they are green and as a general rule, the more massive types are darker than the highly schistose varieties.

In many places these greenstone schists are highly altered and should be classed as chlorite, or hornblende (uralite) schists. However these varieties are not common in the immediate Lake Enchantment area.

SUB-HURONIAN

Conglomerate: This basal member of the sub-Huronian sediments, which lies unconformably above the Mona schists, is thin and limited in lateral extent. The few outcrops are within several feet of an old dirt road, which traverses the southern part of section 29. The outcrops literally

cling to the face of the greenstone ridge (see map in pocket).

The particles of this conglomerate range from minute size to boulders one to two feet in diameter. They consist of well rounded pink granite, or more angular greenstone. This textural condition seems natural enough, as the granite boulders were probably transported a greater distance. Occasional chert fragments are also found. All of these materials are represented in the basement complex, the source beds.

The matrix appears to be finer particles of granite and greenstone. In places where the matrix is the most abundant constituent of the conglomerate, planes of schistosity are apparent.

The only banding observed in the outcrop was due to the concentration of the larger boulders in the basal portion of the formation. However, the outcrops are rather narrow and this banding is not too apparent.

The greenstones, below and in contact with the conglomerate, rise in a nearly vertical cliff 20 to 30 feet high. This cliff extends beyond either end of the conglomerate outcrops.

Slate: This member is a dark green, fine-grained rock containing boulders of graywacke scattered throughout. The boulders appear to have been dropped aimlessly during the deposition of the original sediment. Their presence is easily explained by ice rafting, although

their occurrence may be due to other causes.

The slates are thicker and cover a greater area than the underlying conglomerate. At the eastern end of the area, the slates are found in near contact with the greenstones, suggesting a definite pinch-out of the conglomerate. This conglomerate is absent at the western end of the area also, but the position of this pinch-out is not as definite (see map in pocket). A slaty cleavage, always present in the slate, strikes east and dips nearly 90 degrees.

The slate is not unlike some of the more schistose greenstones. It has the same green color and was probably derived from the greenstones.

There is no visible contact between the slate and the older conglomerate.

Graywacke: This member of the sub-Huronian sediments exhibits shades of gray. In places it is reddish-gray and appears much like arkose, or feldspathic quartzite. In others it is smoky, or yellowish-gray, the more common colors for graywacke. The graywacke also exhibits a variety of textures, fine to medium-grained, and massive in certain places and laminated in others. Scattered, small, vitreous, detrital quartz grains are seen by the unaided eye.

Cleavage, which occurs in the more laminated varieties, strikes east and dips nearly vertical.

The graywacke deposits are divided into three beds, the lower-most of which is medium-grained, massive and

reddish-gray. The intermediate bed is finer, laminated and dirty or smoky-gray, while the upper bed is medium-grained, massive, and reddish-gray like the lower one. Although contacts between these beds are gradational, the differences in lithology are readily observed in traversing the up-turned beds.

LOWER-HURONIAN

Mesnard Quartzite: This formation is given the name Mesnard, because it constitutes the mass of Mount Mesnard south of Marquette.*

*Op. cit., Van Hise, C. R., Bayley, W. S., and Smyth, H. L., p. 221, 1897.

The Mesnard quartzite, as stated previously, is believed to lie unconformably above the sub-Huronian sediments just described.

The lowermost Mesnard in the area is a sericitic quartzite which grades upward into a clear, vitreous variety. Bedding is apparent in the sericitic phase, whereas in places the original ripple-marked surfaces are found in the vitreous phase.

LATE DIABASE

A fine-grained, greenish-black, diabase dike with discernible crystals of feldspar cuts the Mona schist in the northern part of the area.

THIN SECTION STUDY

Thin sections were prepared from the specimens collected in the field. Where the specimens exhibited any megascopic lineations, the thin sections were cut perpendicular to these planes.

The results of the microscopic study are presented below. The minerals, classed as primary, secondary, and accessory, are arranged in each group in approximate order of abundance. In some cases the approximate percentages are given.

The igneous rocks were classified according to A. Johannsen, and the sedimentary rocks according to F. J. Pettijohn, in the manner described under laboratory procedure.

PETROGRAPHIC ANALYSIS

Rock Name	Sample Number	Description								
Mona schist (greenstone)	39a and 41e	Megascopic description. A medium to fine-grained, dark green, schistose greenstone. Microscopic description. Spherulitic texture, uniform composition, consisting of granular epidote, small flakes and needles of chlorite and hornblende, microlitic plagioclase, often clouded with whitish opaque leucoxene. Mineralogy <table><tr><th>Primary minerals</th><th>Percent</th></tr><tr><td>Hornblende</td><td>33</td></tr><tr><td>Microlites (oligoclase)</td><td>23</td></tr><tr><td>Quartz</td><td>3</td></tr></table>	Primary minerals	Percent	Hornblende	33	Microlites (oligoclase)	23	Quartz	3
Primary minerals	Percent									
Hornblende	33									
Microlites (oligoclase)	23									
Quartz	3									

Secondary minerals

Chlorite	11
Calcite	9
Epidote	9
Leucoxene	7

Accessory minerals

Pyrite	3.5
Ilmenite	1
Magnetite	0.5

Name: Mela-andesite, 3212E (Johannsen)

Conglomerate
(granite
boulders)

11c,
12a,
12b,
and
12c.

Megascopic description. Reddish,
rounded granitic boulders, con-
sisting largely of feldspar and
quartz.

Microscopic description. Hypauto-
morphic granular texture, highly
altered, feldspar altered to
sericite, kaolinite, and chal-
cedony, the pyroxene or amphibole
altered to chlorite and calcite.

Mineralogy

Primary minerals	Percent
Plagioclase (oligo-andesine) .	26
Quartz	18
Microcline ,.....	13
Muscovite	7
Secondary minerals	
Sericite	12
Calcite	11
Chlorite	6
Kaolinite	2
Limonite	2
Chalcedony	1
Accessory minerals	
Pyrite	1
Magnetite	0.5
Apatite	0.5

Name: Granodiorite, 227P (Johannsen)

Conglomerate
(greenstone
pebble)

14a

Megascopic description. A fine-
grained, dark green, schistose
greenstone.

Microscopic description. A spherulitic
rock, composed of microlitic plagio-
clase, granular epidote, small
particles of hornblende and chlorite,
opaque leucoxene, and a few small
crystals of quartz.

Mineralogy

Primary minerals	Percent
Hornblende	31
Microclites (oligoclase) ...	21
Secondary minerals	
Chlorite	13
Sericite	12
Kaolinite	9
Leucocoxene	9
Accessory minerals	
Pyrite	5

Name: Mela-andesite, 3212E (Johannsen)

Conglomerate 11d
(chert pebble)

Megascopic description. A well rounded, fine-grained, grayish pebble.

Microscopic description. The specimen is composed mainly of coarse-grained, saccharoidal, chalcedonic quartz. Shear planes with chlorite and calcite deposited along them, are very evident.

Mineralogy

Primary minerals	Percent
Chalcedony	85
Secondary minerals	
Calcite	8
Chlorite	7

Name: Chert

Conglomerate 11a
matrix and
11b

Megascopic description. A dark green, schistose rock, consisting of sub-angular to rounded pebbles of quartz, feldspar, and greenstone fragments.

Microscopic description. Sub-angular to rounded grains of quartz, microcline, plagioclase (oligo-andesine), greenstone, and chert embedded in sericite, kaolinite, chlorite, and chalcedony.

Mineralogy

Primary minerals
Quartz
Microcline
Microclites (oligo-andesine)
Muscovite

Secondary minerals
 Sericite
 Chlorite
 Kaolinite
 Chalcedony
 Accessory minerals
 Pyrite

Name: Conglomerate

Slate 15b Megascope description. A dark green,
 and fine-grained rock.
 46b

Microscopic description. A fine elastic texture and uniform composition; composed largely of grains of quartz, microcline, and plagioclase. Abundant shreds of sericite, flaky chlorite and muscovite, small grains of pyrite and magnetite are noted.

Mineralogy

Primary minerals	Percent
Quartz	15
Microcline	3
Plagioclase (oligo-andesine)	2
Secondary minerals	
Sericite	46
Chlorite	30
Leucoxene	1
Accessory minerals	
Muscovite	1
Magnetite	1
Pyrite	0.5
Ilmenite	0.5

Name: Pelite (Pettijohn)

Slate 15a, Megascope description. Dark-gray
 (graywacke 16c, massive boulders, with grains of
 inclusions) 43a, quartz and feldspar apparent on
 46b, fresh fracture.
 and
 46d Microscopic description. Clastic texture. The specimen consists of sub-angular grains of quartz, orthoclase, plagioclase, and microcline together with a few flakes of muscovite, small grains of magnetite, pyrite, and ilmenite. Calcite, sericite, chlorite, chalcedony, and leucoxene are secondary.

INTERPRETATION OF PLATE 4

1. Monaschist, Sample no. 14a. Nicols crossed. X16

A fine-grained, schistose greenstone, consisting of granular epidote, small flakes or needles of chlorite, hornblende, microlite plagioclase, and clouded with leucoxene.

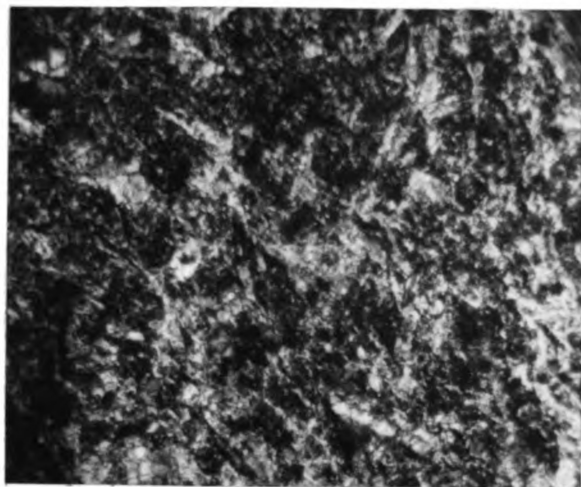
2. Granodiorite, Sample no. 12b. Nicols crossed. X16

A granodiorite boulder from the conglomerate; microcline, quartz, and calcite (black) are apparent.

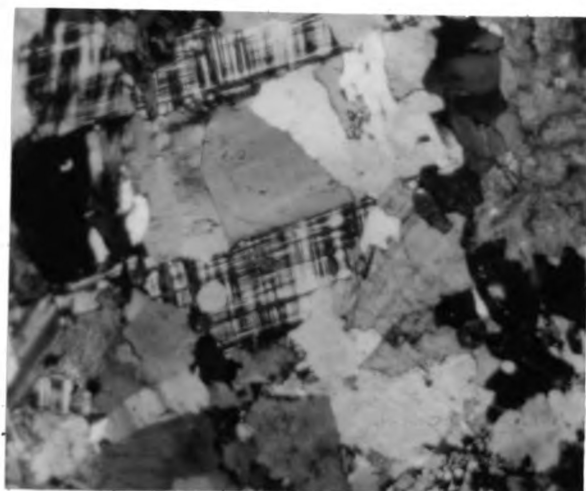
3. Conglomerate, Sample no. 11b. Nicols crossed. X16

The sub-angular to rounded grains consist of quartz, feldspar, greenstone, and chert, embedded in sericite, kaolinite, chlorite, and chalcedony.

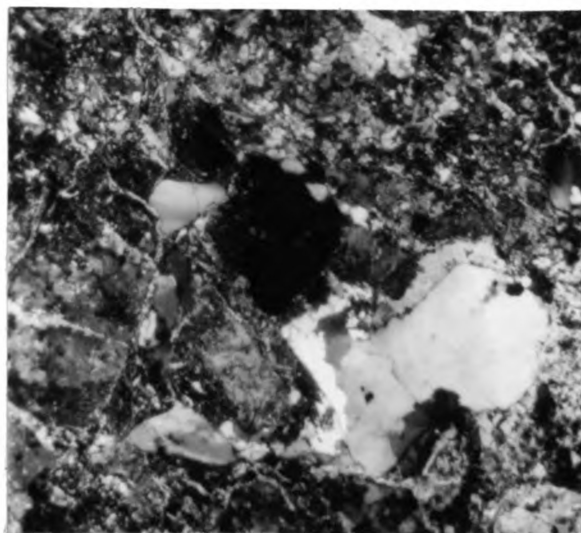
PLATE 4



1



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3

Mineralogy

Primary minerals	Percent
Quartz	46
Orthoclase	13
Plagioclase (oligo-andesine)	8
Microcline	7
Secondary minerals	
Sericite	13
Chlorite	6
Calcite	2
Chalcedony	1
Leucoxene	1
Accessory minerals	
Pyrite	1
Muscovite	1
Magnetite	0.5
Ilmenite	0.5

Name: Graywacke (Pettijohn)

Graywacke

43e
and
48e

Megascopic description. Reddish-gray, medium-grained, graywacke.

Microscopic description. Clastic texture. The specimen is composed of sub-angular grains of quartz, orthoclase, plagioclase, and microcline, small flakes of muscovite, and fragments of chert. Many feldspars altered to sericite and chalcedony. A few pyrite and magnetite grains may be noted. Minor amounts of chlorite and epidote are also present.

Mineralogy

Primary minerals	Percent
Quartz	38
Orthoclase	9
Plagioclase (oligo-andesine)..	6
Microcline	6
Secondary minerals	
Sericite	19
Chlorite	16
Chalcedony	3
Epidote	1
Accessory minerals	
Pyrite	1
Magnetite	0.5
Muscovite	0.5

Name: Graywacke (Pettijohn)

Graywacke 43d
and
49e

Megascopic description. A dark gray, fine-grained, laminated rock.

Microscopic description. Clastic texture. The rock consists of small grains of quartz, orthoclase, microcline, and plagioclase, euhedral crystals of magnetite and pyrite, embedded in shreds of sericite, chlorite, and kaolinite. A few flakes of muscovite are also present.

Mineralogy

Primary minerals	Percent
Quartz	42
Orthoclase	4
Microcline	3
Plagioclase (oligo-andesine)	1
Secondary minerals	
Sericite	22
Chlorite	21
Kaolinite	3
Leucoxene	2
Accessory minerals	
Magnetite	1
Pyrite	0.5
Muscovite	0.5

Name: Subgraywacke (Pettijohn)

Graywacke 50b

Megascopic description. Reddish-gray, medium-grained graywacke.

Microscopic description. Clastic texture. The rock consists of sub-angular grains of quartz, microcline, orthoclase, and plagioclase together with a few flakes of muscovite, embedded in calcite, and shreds of sericite. A few small grains of magnetite are also present. Many of the grains are covered by a layer of iron oxide.

Mineralogy

Primary minerals	Percent
Quartz	32
Microcline	8
Orthoclase	6
Plagioclase (oligo-andesine).	2

1. The first part of the document discusses the importance of maintaining accurate records of all transactions. It emphasizes that proper record-keeping is essential for the integrity of the financial system and for the ability to detect and prevent fraud.

2. The second part of the document outlines the specific requirements for record-keeping, including the need to maintain separate accounts for each transaction and to ensure that all records are properly indexed and filed.

3. The third part of the document discusses the importance of regular audits and the need to ensure that all records are subject to independent review.

4. The fourth part of the document outlines the consequences of failing to comply with the record-keeping requirements, including the potential for fines and penalties.

5. The fifth part of the document discusses the importance of training and the need to ensure that all personnel involved in the financial system are properly trained in record-keeping procedures.

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Secondary minerals	
Sericite	40
Chlorite	9
Calcite	1
Leucoxene	0.5
Accessory minerals	
Magnetite	0.5
Muscovite	0.5
Limonite	0.5

Name: Graywacke (Pettijohn)

Mesnard
Quartzite

47a

Megascopic description. A clear,
vitreous, quartz rock.

Microscopic description. The rock
is composed of rounded quartz grains
with siliceous cement, which is in
part granular and in part in optical
continuity with the original quartz
grains. An occasional grain of
cryptocrystalline quartz is also
present.

Mineralogy

Primary minerals	Percent
Quartz	98
Secondary minerals	
Chalcedony	2

Name: Quartzite (Pettijohn)

Sericitic-
Mesnard
quartzite

47e

Megascopic description. A dull,
sericitic quartz rock. Bedding
planes are readily apparent.

Microscopic description. The rock is
composed of small rounded quartz
grains, which are surrounded by
dense sericite. Cloudy leucoxene
is scattered throughout the rock.
Feldspar is absent.

Mineralogy

Primary minerals	Percent
Quartz	20
Secondary minerals ..	
Sericite	70
Leucoxene	10

Name: Subgraywacke (Pettijohn)

INTERPRETATION OF PLATE 5

1. Graywacke, Sample no. 15a. Nicols crossed. X16

One of the graywacke boulders from the slates, consisting of sub-angular grains of quartz, microcline, and plagioclase, embedded in sericite, calcite, and chlorite. Some of the feldspar has altered to sericite.

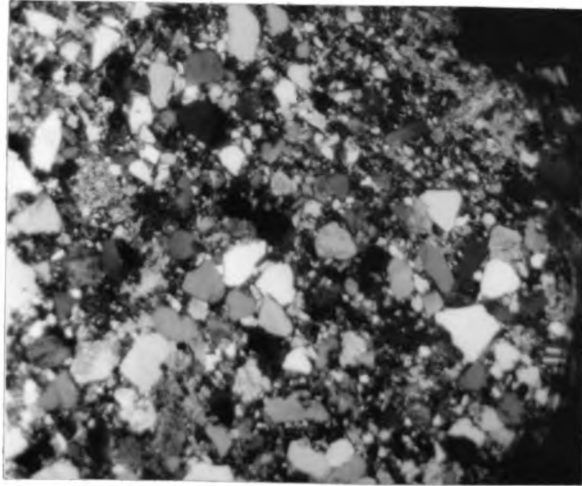
2. Graywacke, Sample no. 48e. Nicols crossed. X16

A sample of the upper graywacke bed. It is similar to the rock described above, except it contains somewhat less feldspar.

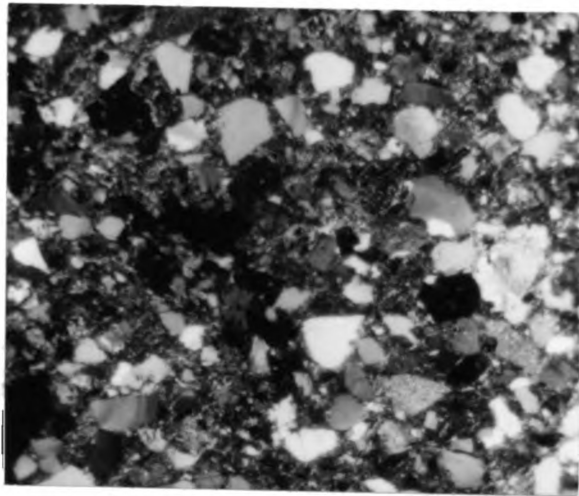
3. Subgraywacke, Sample no. 49c. Nicols crossed. X16

This bed is composed of sub-angular grains of quartz, and very little feldspar, embedded in sericite, calcite and chlorite.

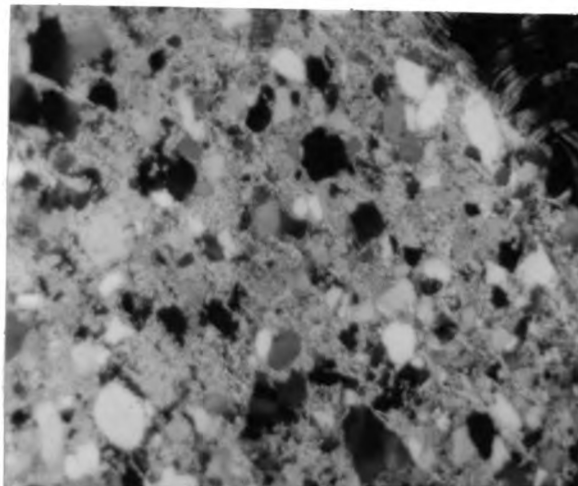
PLATE 5



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Diabase
(gabbro)

3a Megascope description. A fine-grained, greenish-black rock. Small laths of plagioclase and grains of amphibole are recognizable.

Microscopic description. Ophitic ("Diabasic") texture, highly altered, the pyroxenes altered to ura-
lite and chlorite, and much of the feldspars to calcite, zoisite, and zeolites.

Mineralogy

Primary minerals	Percent
Plagioclase (labradorite) ..	45
Magnetite	12.5
Secondary minerals	
Uralite	28
Chlorite	4
Epidote	4
Saussurite	2.5
Calcite	2
Accessory minerals	
Leucoxene	2

Name: Gabbro, 2312P (Johannsen)

INTERPRETATION OF PLATE 6

1. Mesnard quartzite, Sample no. 47a. Nicols crossed. X16

The vitreous Mesnard quartzite, 98 percent quartz, with an occasional crystal of chalcedony.

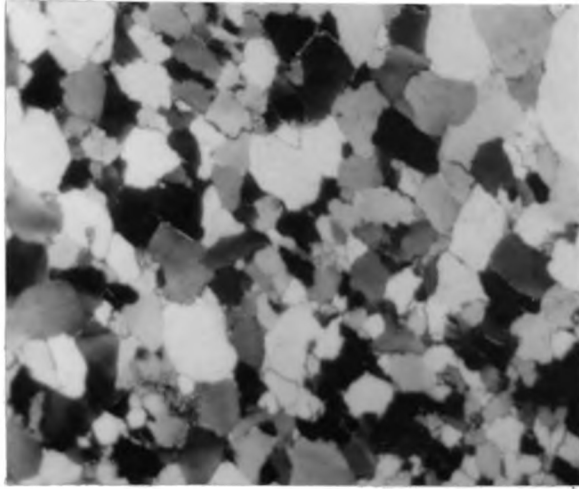
2. Mesnard quartzite, Sample no. 47e. Nicols crossed. X16

The sericitic phase of the Mesnard quartzite, consisting of fine quartz grains embedded in dense sericite. Note bedding plane separating two layers of distinctly different size grades. Apparently a mud crack in the lower bed was filled with the coarser material.

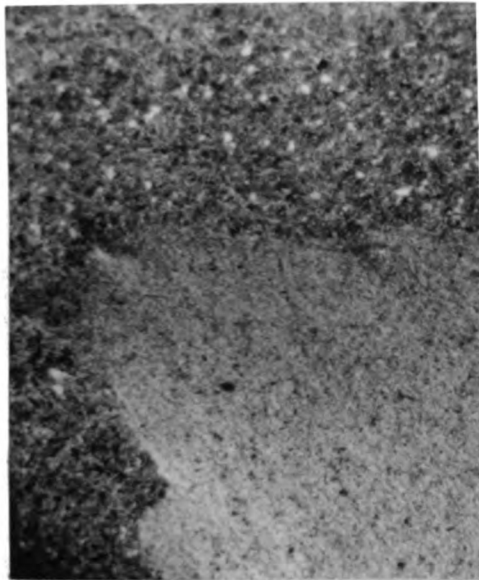
3. Gabbro, Sample no. 3a. Nicols crossed. X16

The dike-rock cutting the greenstone schists. It is composed of hornblende (uralite), plagioclase (labradorite) laths, granular epidote, chlorite, and magnetite.

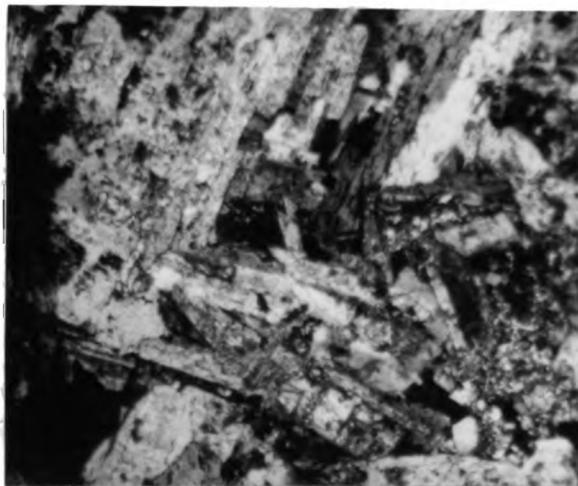
PLATE 6



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Summary of the Petrographic Study: The study of the rocks in the field and the later studies of the thin sections in the laboratory indicate a great change in the environment from the time the Keewatin greenstones, and the sub-Huronian (Timiskaming?) sediments were deposited. Another great change in environment is evident from the time the sub-Huronian sediments and the Mesnard quartzite were deposited.

The Keewatin greenstones in the immediate area indicate a period of great volcanic and pyroclastic activity. They are metamorphic equivalents of original lavas and tuffs.

The sub-Huronian sediments were formed either by rapid deposition, or by slow deposition under glacial conditions. This is confirmed by the great abundance of unaltered feldspars (see plate 7) and the sub-angular nature of the detrital grains.

The Mesnard quartzite was deposited during a period of mature weathering. This is indicated by the absence of feldspar, and the rounded character of the quartz grains.

These changes in environment give further ~~indirect~~ evidence to the existence of unconformities above and below the sub-Huronian sediments.

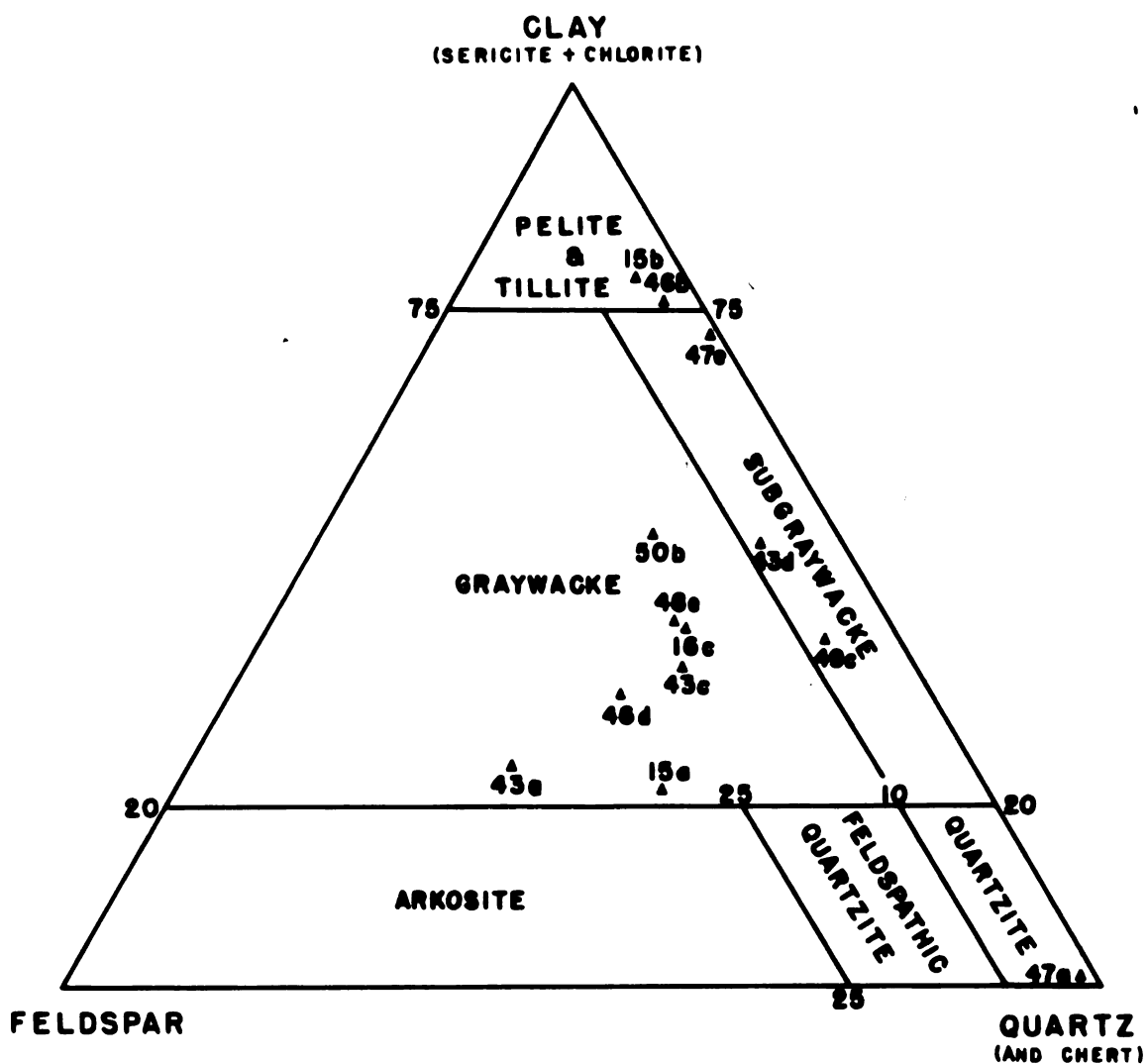
The sediments of the Lake Enchantment area are probably terrestrial; deposited by stream action or in a fresh water lake. They contain scattered flakes of mica.

INTERPRETATION OF PLATE 7

Sample Number	Rock Name
15b, and 46b	Slates
15a, 16e, 43a, and 46d..	Graywacke boulders in slates
43e, and 48e	Upper graywacke bed
43d, and 49c	Intermediate graywacke bed
50b	Lower graywacke bed
47e	Sericitic Mesnard quartzite
47a	Vitreous Mesnard quartzite

Generally speaking, the northern-most sediments in the area contain the most feldspar. The bed of sub-graywacke, and the pelites are the exceptions.

PLATE 7



CLASSIFICATION OF THE ARENITES BASED UPON THE
MINERAL COMPOSITION OF THE DETRITAL FRACTION
AFTER F. J. PETTIJOHN

F. H. Lahee*

*Lahee, F. H., Field Geology (McGraw-Hill Book Company, Inc., New York, 1941), p. 36.

suggests that such mica is typical of continental sediments.

STRUCTURE

The main structural feature of the area was brought-out by mapping (see map in pocket). This is the trough, which was eroded in the greenstones, and later filled with the deposits of sub-Huronian.

The rocks of this area have a general east-west strike and a nearly vertical dip. Actual bedding planes were found only in the Mesnard quartzite. Here the top of the bedding is indicated by ripple marks. Not enough bedding planes are present to give a very clear picture of the structure.

The strike and dip of the unconformity between the greenstone schist and the conglomerate was observed in several places. In all cases, a slight northerly dip was recorded, which would indicate a slight overturning of the beds. This contact is so irregular that the true strike and dip is difficult to determine.

A high degree of schistosity is exhibited in all the well-foliated varieties of the greenstone schists. This schistosity dips at high angles and strikes east-west approximately parallel to the trend of the Marquette syncline. Schistosity is also apparent in the finer-grained portions of the conglomerate.

BLOCK DIAGRAM, SHOWING CROSS-SECTION AND IMPRESSIONISTIC VIEW OF
TOPOGRAPHY AS RELATED TO SUBSURFACE STRUCTURE

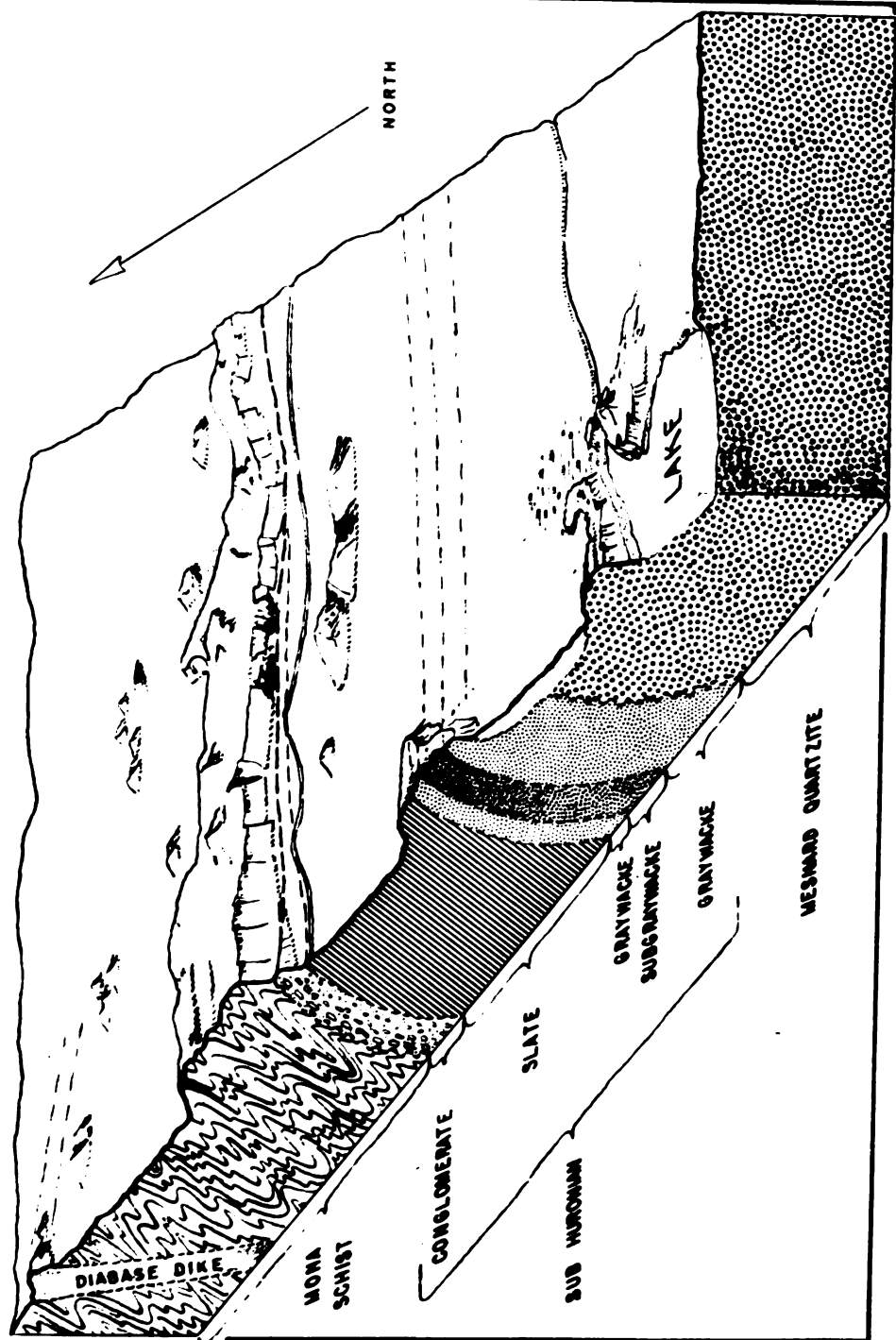
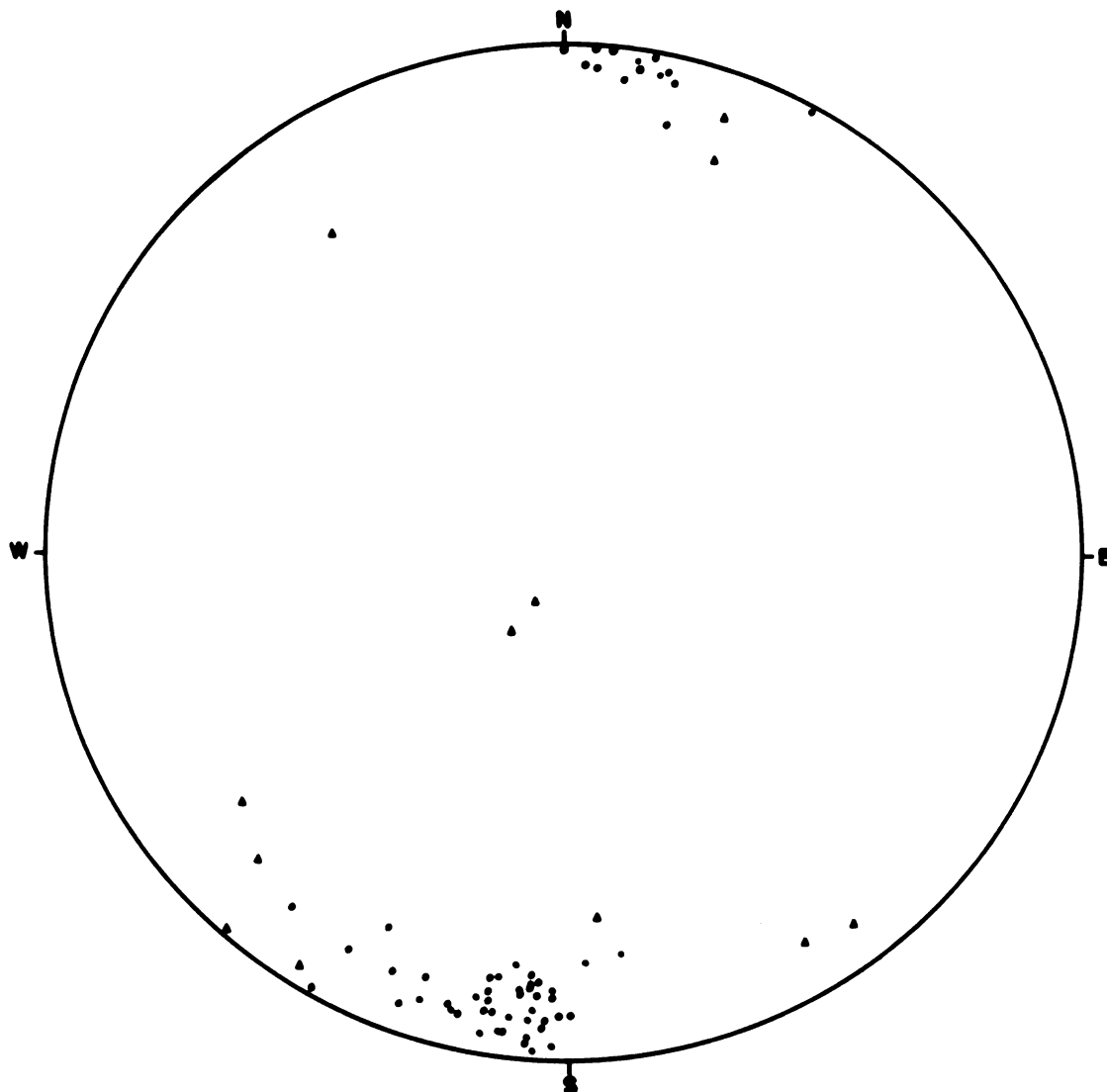


PLATE 9

FACE POLES OF SCHISTOSITY, CLEAVAGE, AND JOINTS
IN THE LAKE ENCHANTMENT AREA



SCHMIDT NET, POLAR CASE PLOTTED ON LOWER HEMISPHERE

BEARINGS MAGNETIC

- PLANES OF SCHISTOSITY
- PLANES OF CLEAVAGE
- JOINT PLANES

Cleavage is abundant in the slates, and graywackes. These cleavage planes also dip at high angles and strike generally east-west.

Jointing is apparent in many of the outcrops throughout the area.

CONCLUSIONS

General: On the basis of the evidence acquired in this investigation, the following conclusions are justified:

1. The major feature is a trough cut in the Keewatin greenstones.
2. The sub-Huronian sediments are believed to have been deposited under continental conditions, either by stream action, or in a fresh water lake.
3. The graywacke boulders found in the much finer-grained slates were probably emplaced by ice rafting.
4. A definite change of environment is indicated between the Keewatin and the sub-Huronian deposition. Another change is indicated between sub-Huronian and Mesnard deposition.
5. An erosional period between sub-Huronian and Mesnard is indicated by the truncation of sub-Huronian beds.
6. The sediments exposed in the Lake Enchantment area lie unconformably above the Keewatin and unconformably below the Huronian. Evidence used to establish the unconformity between the Keewatin and sub-Huronian

consist of:

- a. A great lithologic change.
- b. The inclusion of underlying rocks in the basal conglomerate of the sub-Huronian sediments.

Criteria used as supporting evidence for the existence of an unconformity between the sub-Huronian and Huronian consist of:

- a. Truncation of the sub-Huronian sediments.
- b. A lithologic change.

The first unconformity is obvious enough, however it is felt that the latter relationship needs more detailed study in other areas. This concealed contact could possibly be a fault contact, rather than an unconformity.

CORRELATION

General: The material below is presented for general information, and to suggest possible correlations, rather than an attempt to make any definite or positive connections.

The problem of correlation in pre-Cambrian areas is a complex one. It has been written*

*Leith, C. K., Lund, Richard J., and Leith, Andrew.,
Pre-Cambrian Rocks of the Lake Superior Region, U. S. Geological Survey Professional Paper 184, p. 3, 1935.

"any correlation of pre-Cambrian areas is limited by lack of fossils and by great variations in metamorphic and structural conditions and in igneous associations. It

is handicapped also by the lack of continuity of surface outcrops, due to the covering of glacial drift, Paleozoic sediments, and many lakes, including Lake Superior itself. About the best that can be done in the way of correlation is to call attention to similarities of lithologic types, to similarities in sequence and to similarities of relations to igneous events. To a person familiar with the field, terms like "Keewatin", "Huronian", and "Keweenawan" designate fairly definite types of materials and conditions, as well as general positions in the stratigraphic sequence, but in the present state of knowledge such terms cannot be construed as fixing precise equivalence in age."

To further complicate the picture, some sediments considered to be of approximate age equivalents are of continental, whereas others are of marine origin.

The term "Timiskaming" brings to mind a great variety of sediments, depending on the area considered. Many sediments have been called Timiskaming at various times. These areas of Timiskaming sediments are so scattered geographically, and the evidence for correlation so meager, that they are more often given local names.

Possible correlations:

1. Fern Creek sediments of the Menominee district, Michigan.
2. Knife Lake series of Vermilion and Mesabi districts, Minnesota.
3. Dore conglomerate of the Michipicoten district, Ontario, Canada.
4. Parts of Kitchi schist of the Marquette district, Michigan.
5. Timiskaming series of Ontario, Canada.

All of the areas listed have been considered to be Timiskaming by some geologist.

In the Fern Creek area of the Menominee district, Michigan, the sediments rest on Archean granites, and consist of a pink arkosic conglomerate, phyllites with pebble and cobble inclusions, and a tillite. They are overlain by Lower Huronian quartzite.

The Knife Lake series of the Vermilion and Mesabi districts, Minnesota, consist of the Ogishke conglomerate, Agawa iron formation, and the Knife Lake slate. The Ogishke conglomerate varies widely in composition, depending on the underlying formation at any locality. If it is greenstone the Ogishke is a greenstone conglomerate. If the underlying material is granite the Ogishke is a granite conglomerate, porphyry, a porphyry conglomerate, chert and jasper, a chert and jasper conglomerate. These unconformable underlying materials are all Archean. The Agawa is a thin iron formation. The Knife Lake slate has many varieties, namely, 1) argillaceous slates, 2) cherty slates, 3) graywacke slates or graywacke, 4) conglomerate, 5) tuffaceous slates, 6) micaceous schists and gneisses, and 7) gray granular rocks. The Knife Lake series is overlain unconformably by quartzite and iron formation of Huronian age.

The Dore conglomerate of the Michipicoten district, Ontario, is composed of dark green schist, granite, ferruginous chert, spotted gray-green schist, porphyry,

felsite, and conglomerate or breccia. This conglomerate is underlain unconformably by Archean rocks.

The Kitchi schist of the Marquette district, Michigan, is agglomeratic in some places and at others it is conglomeratic. It has been suggested by Van Hise, as stated previously, that parts of the Kitchi schist may be younger than the Mona schist. The Kitchi schist is overlain unconformably by Lower Huronian sediments.

The Timiskaming series of the type locality of Ontario, Canada, consist of conglomerate, quartzite, graywacke, and slate. These sediments rest unconformably on crystalline and highly metamorphosed Archean rocks.

The most dominant members of Timiskaming then, appear to be a basal conglomerate, graywackes, and slates.

All of the above areas and the Lake Enchantment area have some similarity of lithologic types and similarity in stratigraphic sequence. The sediments of these areas, if intruded by granite, as they have been at the Vermilion and Mesabi districts of Minnesota, and the Timiskaming of Ontario, are intruded by Algoman granite or a correlative of the Algoman granite.

The Lake Enchantment sediments are not cut by granite, therefore only their similarity in lithology and stratigraphic position can be used for correlation.

Pocket has: 1 map

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