

UPPER CAMBRIAN AND OLDER ROCKS
OF THE SECURITY-THALMANN
NO. 1 WELL,
BERRIEN COUNTY, MICHIGAN

Thesis for the Degree of M. S.
MICHIGAN STATE UNIVERSITY
Gordon A. Yettaw
1967

THESIS



3 1293 10277 3631



**SUPPLEMENTARY
MATERIAL
IN BACK OF BOOK**

ABSTRACT

UPPER CAMBRIAN AND OLDER ROCKS OF THE SECURITY-THALMANN NO. 1 WELL, BERRIEN COUNTY, MICHIGAN

by Gordon A. Yettaw

Clastic rocks older than the Mt. Simon sandstone have been reported in wells in the Southern Peninsula of Michigan. The Security-Thalman No. 1 is the first well in southwestern Michigan to penetrate the whole Cambrian section and was reported to have penetrated over 1,000 feet of arkosic rock below the Mt. Simon. The problem involved determining the lithology of the arkosic rock, a study of the Cambrian sequence in this well, and comparison of these rocks with their equivalents in Wisconsin, northeastern Illinois, and northern Indiana.

Standard petrographic, mineralogic, sedimentary and geophysical techniques were used to study the well cuttings of the Security-Thalman No. 1.

The arkosic rock is a Precambrian granitic gneiss. The lowermost Cambrian rocks in this well belong to the Munising formation. In ascending order, they are: Mt. Simon sandstone - white and hematitic sandstone, Eau Claire sandstone - glauconitic, sandy dolomite and sandstone, Dresbach sandstone - non-glauconitic, dolomitic

sandstone, and the Franconia sandstone - very glauconitic, sandy and silty dolomite. No justification for subdividing the Trempealeau formation according to the Wisconsin classification was found; it is represented by a slightly cherty dolomite. All the Cambrian formational units in the well may be compared as to their gross lithology with the standard section of Wisconsin.

UPPER CAMBRIAN AND OLDER ROCKS OF THE
SECURITY-THALMANN NO. 1 WELL,
BERRIEN COUNTY, MICHIGAN

By
Gordon A. Yettaw

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirement
for the degree of

MASTER OF SCIENCE

Department of Geology

1967

645765
8/25/67

ACKNOWLEDGMENTS

The writer is deeply grateful to Dr. C. E. Prouty, Chairman of the Department of Geology, Michigan State University, under whose guidance this study was carried out.

Thanks are extended to Dr. J. W. Trow, Dr. W. J. Hinze and Dr. R. Ehrlich for their constructive suggestions and critical examination of the manuscript. Thanks are also offered to G. D. Ells and R. E. Ives of the Michigan State Geological Survey, for generously providing the well samples, and information essential to this study.

Sincere appreciation is extended to the writer's wife, Joan Yettaw, for typing the manuscript, and for her encouragement and patience while this paper was being prepared.

TABLE OF CONTENTS

	Page
ACKNOWLEDGMENTS.....	ii
LIST OF FIGURES.....	v
LIST OF TABLES.....	vi
INTRODUCTION.....	1
General.....	1
Nature and Scope.....	2
LABORATORY PROCEDURES.....	4
Modal Analyses.....	4
Heavy Mineral Analyses.....	4
Fragment Size Determinations.....	5
Particle Size and Sorting Estimates.....	5
Magnetic Susceptibility Measurements.....	6
Mechanical Analyses.....	7
REGIONAL STRUCTURE.....	9
REGIONAL PRECAMBRIAN BASEMENT COMPLEX.....	12
REGIONAL STRATIGRAPHY.....	15
Jacobsville Sandstone.....	15
Munising Sandstone.....	15
Mt. Simon Sandstone.....	16
Eau Claire Sandstone.....	17
Dresbach Sandstone.....	19
Franconia Sandstone.....	22
Trempealeau Formation.....	24
LITHOLOGY OF THE CUTTINGS.....	26
Basal Arkosic Interval.....	26
Mt. Simon Sandstone.....	36
Eau Claire Sandstone.....	37
Dresbach Sandstone.....	38
Franconia Sandstone.....	39
Trempealeau Formation.....	40

	Page
STRATIGRAPHIC IMPLICATIONS OF THE HEAVY MINERALS.....	41
ENVIRONMENT OF DEPOSITION.....	44
CORRELATIONS AND STRATIGRAPHIC IMPLICATIONS.....	47
SUMMARY.....	49
BIBLIOGRAPHY.....	51
APPENDIX.....	56

LIST OF FIGURES

Figures	Page
1. Location of the Security-Thalman No. 1 well.....	8
2. Stratigraphic correlations of Cambrian formations.....	11
3. Lithologic map of Precambrian surface of southern Michigan and adjoining areas.....	In packet
4. Magnetic susceptibility graph.....	29
5. Photomicrograph.....	33
6. Heavy minerals.....	41
7. Sub-Trenton section from southeastern Michigan around the west side of the Michigan basin.....	In packet
8. Gamma ray-neutron log of Security- Thalman No. 1 showing general lithologic descriptions of units.....	In packet

LIST OF TABLES

Table	Page
1. Modal analyses of alteration zones.....	34
2. Modal analyses of the unaltered zone.....	35
3. Wells reported to have penetrated the Precambrian in southern Michigan and adjoining areas.....	63
4. Modal analyses of Precambrian interval..	71

INTRODUCTION

General

The Jacobsville sandstone was named by Lane & Seaman (1907). They applied this term to a red, slightly arkosic sandstone cropping out in Jacobsville, a small town in Houghton County, Northern Peninsula of Michigan. Thwaites (1912) correlated the Jacobsville with the Bayfield group of Wisconsin (Keweenawan age). Hamblin (1958) on the basis of an angular unconformity between the Keweenawan and the Jacobsville in northern Michigan, dated the Jacobsville as lower or middle Cambrian. Ostrum (1964) states that a correlation of the Mt. Simon of Wisconsin and the Jacobsville is obvious on the basis of lithologic similarity. Cohee (1948) reports that some deep wells in southern Michigan have penetrated an arkosic sandstone underlying the Mt. Simon and overlying Precambrian rock. He questionably correlates this with the Jacobsville. Two wells drilled on Beaver Island, Charlevoix County, Michigan, encountered a thick clastic sequence below the Mt. Simon. Gutstadt (1958) suggests that possible equivalents of the Jacobsville may be included in the basal and arkosic portion of the Mt. Simon sandstone in Indiana. Calvert (1964) states that most of Ohio is underlain by a basal arkose. Cohee (1945)

and Fettke (1948) have assigned the name Jacobsville to 135 feet of grayish-red, slightly arkosic sandstone in a Putman County, Ohio well.

These reports have led many Michigan geologists to believe sediments older than the Mt. Simon and possibly Jacobsville equivalent to be present in the subsurface of southern Michigan.

The Cambrian has not been extensively studied in the Southern Peninsula. Cohee (1945, 1947, 1948) has made a limited regional study of Cambrian rocks, concentrating primarily on southeastern Michigan. He is largely responsible for our present subsurface Cambrian stratigraphic nomenclature. Pennington (1967) studied the Cambrian rocks found in the Perry-Wooden No. 1, a well located in Cass County, southwestern Michigan. Kashfi (1967) is presently studying the Cambrian sequence of the State-Foster No. 1, drilled in Ogemaw County, Michigan, east of the present center of the Michigan Basin.

Nature and Scope

The Security-Thalman No. 1 is the first well in southwestern Michigan to penetrate the full Cambrian sequence. On initial study of the cuttings, this well was reported to have penetrated approximately 1,000 feet of possible arkosic sediment underlying the Mt. Simon sandstone.

The problem of the existence or non-existence of a thick arkosic sediment below the Mt. Simon sandstone is a problem of long standing, that is well documented by the literature. The possible arkosic sediment penetrated by the Security-Thalman No. 1 offered an opportunity to study, in detail, the lithologic nature of a reported arkose to determine if it is a clastic deposit, igneous rock, or metamorphic rock.

Since this well penetrated the full Cambrian sequence, it also offered an opportunity to study the lithology and stratigraphy of the Cambrian and its relation to the arkose.

It is hoped that a detailed study of the Security-Thalman No. 1 cuttings, using petrographic, mineralogic, sedimentary and geophysical techniques, may help to better define the lithology and stratigraphic relationships of the Cambrian and older rocks in southwestern Michigan.

LABORATORY PROCEDURES

This study was completely of a laboratory nature, and all work was carried out at the Department of Geology, Michigan State University.

Drill cuttings from the Security-Thalmann No. 1 and other wells which were used for this study were generously furnished by the Michigan State Geological Survey.

Modal Analyses

Modal analyses were done on the basal arkosic interval of the Security-Thalmann No. 1. Samples of drill cuttings for the analyses were selected on the basis of megascopic variation. A small, split portion of each sample was mounted on a glass slide with Lakeside "70" and lapped to approximately .03 millimeters thickness. A polarizing microscope and mechanical stage were used to identify and count 300 mineralogical points for each slide.

Heavy Mineral Analyses

At least one heavy mineral analysis was carried out on each sandstone unit and the arkosic interval of the well. All heavy mineral separations were done with tetrabromethane. The 1/8 to 1/16 millimeter size fraction was selected for heavy mineral study. A

polarizing microscope was used for identification of the heavy mineral grains, and at least 300 grains were counted for each analysis. Because authigenic pyrite often comprised much of the heavy minerals, it was eliminated from calculations made in Figure 6, on all but the granitic gneiss.

Fragment Size Determinations

Under the assumption that the lower 1,000 feet of the Security-Thalmann No. 1 is a clastic deposit, a grain size study was carried out on this portion of the well. For each drill cuttings mount, the long axis of each mineral species was measured. This method revealed no significant grain size variation among mineral species. The length measurements obtained were interpreted to be a function of grinding by the drill bit and the crystallization size of the mineral species present. The data, therefore, are not included in this study.

Particle Size and Sorting Estimates

Suggestions for visually estimating grain size and sorting were taken from Buschbach (1964).

Measurements of grain size were made with a binocular microscope equipped with a micrometer ocular. The median grain size was obtained by visualizing the sample divided into two equal piles; one containing sizes finer than some specific grain, and the other

containing sizes coarser than this grain. The measurement of the width of this grain serving to separate the two piles was used as the median grain size. The maximum grain size was obtained by measuring the width of the largest grain found in the sample.

The Wentworth particle size classification was used for both clastic and carbonate units; and the following classification for sorting was adopted for this study:

SORTING

- Well Sorted - approximately 60 percent of sample
 in 1 Wentworth grade size or less.
- Moderately Sorted - approximately 60 percent of sample
 in 1 to 2 Wentworth grade sizes.
- Poorly Sorted - approximately 60 percent of sample
 in over 2 Wentworth grade sizes.

Magnetic Susceptibility Measurements

Magnetic susceptibility measurements were made only on the arkosic interval of the Security-Thalman No. 1. A Model MS3 Geophysical Specialties susceptibility bridge was used for all magnetic susceptibility measurements. Because drill cuttings were used for these measurements, the following correction was applied to the apparent magnetic susceptibility to correct for percent voids:

CORRECTION FOR PERCENT VOIDS

The drill cuttings sample holder is a test tube of inside diameter (Dc), and has a mark on it indicating a known volume (V). Drill cuttings fill the sample holder above this mark. After completing the magnetic susceptibility measurement and obtaining the reading for the apparent magnetic susceptibility (Z), the sample holder is filled to the known volume mark with water. The volume of water required to accomplish this is (Va).

Let the diameter of the sample well in the center of the magnetic susceptibility bridge be (Dsb), and the true magnetic susceptibility be (MS). Then:

$$MS = \frac{(Dsb)^2}{(Dc)^2} \times \frac{(V)}{(V-Va)} \times (Z)$$

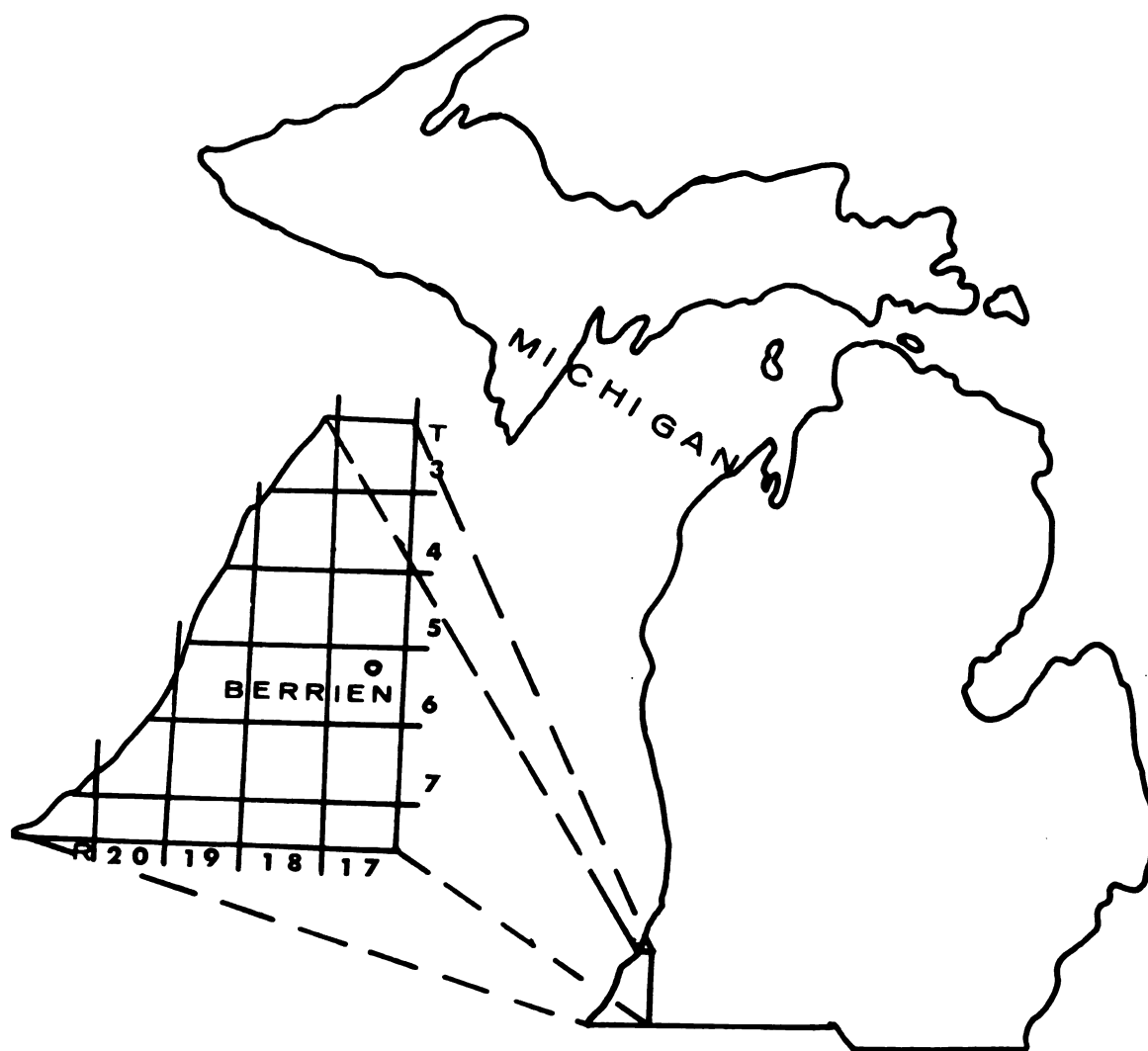


Figure 1. - Location of Security-Thalman No. 1 well,
SE SE SE Section 10, T6S, R17W, Berrien
County, Michigan

REGIONAL STRUCTURE

The Security-Thalman No. 1 was drilled on the southwestern edge of the Michigan Basin and is probably located on the Berrien anticline, a positive structure extending northeast from Berrien County toward the center of the Basin (Pennington, 1967). To the south and west of this well lies the Kankakee arch, a broad positive, structural element separating the Michigan and Illinois basins and connecting the Wisconsin arch to the Cincinnati and Findlay arches. This arch plunges gently southwestward from the Wisconsin arch in central northern Illinois toward the Logansport Sag, a shallow saddle in north central Indiana. A continuation of this sag, the Battle Creek trough, extends northeast-southwest into the Michigan Basin about 40 miles east of the Security-Thalman No. 1 (Asseez, 1966).

Based on gravity measurements in northeastern Illinois, McGinnis (1966) proposes a graben filled with Mt. Simon sediments, comparable to the Red Sea Rift. His map indicates an eastward continuation of this graben into southwestern Michigan.

Structures thought to be present during Cambrian time are the northeastern Illinois graben (McGinnis, 1966), Findlay and Wisconsin arches (Cohee, 1948), Berrien anticline and Battle Creek trough (Asseez, 1966),

and the Michigan Basin (Pirtle, 1932).

Precambrian rocks in southwestern Michigan are contacted at approximately 4,600 feet below the surface and dip to the northeast toward the center of the basin. Topographic relief on the Precambrian surface may be several hundred feet. This is evidenced by two wells drilled on Beaver Island. One well reaches the basement at 4,705 feet below sea level; another, only three miles away, entered the basement at an elevation 700 feet higher (Cohee, 1965).

The top of the Cambrian rocks occurs at about 2,650 feet below the surface in southwestern Michigan. The Cambrian section is 1,958 feet thick in the Security-Thalman No. 1, and also dips to the northeast.

The post Canadian unconformity responsible for removing the Prairie du Chien rocks in other areas was not evidenced in this well. In southeastern Michigan, however, the Cambrian is overlapped by middle Ordovician rocks (Figure 7).

SYSTEM	SERIES	MICHIGAN MICH. GEOL. SURV. 1964		WISCONSIN OSTROM, 1966	NORTHEAST ILLINOIS BUSCHBACH, 1964	INDIANA GUTSTADT, 1958			
UPPER CAMBRIAN	ST. CROIXAN	S. Pen. N. Pen.		JORDAN	EMINENCE	N. W.	N. E. & S.		
		JORDAN							
		LODI							
		ST. LAWRENCE							
		FRAN- CONIA	MINER'S CASTLE					MAZOMANIE LONE ROCK	FRAN- CONIA
		DRES- BACH	WONEWOC					IRONTON	GALES- VILLE
		EAU CLAIRE	EAU CLAIRE					EAU CLAIRE	EAU CLAIRE
		MT. SIMON	MT. SIMON					MT. SIMON	MT. SIMON
		JACOBSVILLE							
		T&M C&M						PRECAMBRIAN	

Figure 2. - Stratigraphic correlations of Cambrian formations.

REGIONAL PRECAMBRIAN BASEMENT COMPLEX

Figure 3 shows the distribution of Precambrian subsurface lithologies encountered in southern Michigan, eastern Wisconsin, northeastern Illinois, northern Indiana, and northern Ohio as reported in publications, sample descriptions and drillers logs.

Rudman and others (1965) have studied the geology of the basement in the midwest. They prepared a geochronological map showing isotopic ages of the Precambrian rocks in the midwest. This map indicates rocks of two age ranges exist in the area of Figure 3. West of a line extending from the southwestern tip of Indiana to the western shore of Saginaw Bay, west of the "thumb" area in southern Michigan, these rocks are considered to be part of what Engel, (1963) termed the central province. Isotopic ages of rock samples from this area range from 1.2 to 1.5 billion years. Precambrian rocks east of this line are considered to be an extension of the Ontario, Grenville province. Isotopic ages of rock samples from this area range from 0.8 to 1.1 billion years (Rudman, et al 1965).

As is illustrated by the figure, the greater proportion of concealed Precambrian rocks in Wisconsin are igneous and among them, granite predominates. Basalt flows occur in some areas as do rhyolite flows. Thwaites

(1931) examined a tube of samples from a water well in the Wisconsin Dells, that had penetrated a basalt. He found quartzite and granite below the basalt. Metamorphosed sediments are especially common in eastern Wisconsin. The northern portion of the large area of metasediments in the figure is called the Fond du Lac range; the southern portions, the Waterloo range (Thwaites, 1931). These ranges are primarily composed of quartzites and Thwaites reports that they are of Huronian age.

Only seven wells have penetrated the Precambrian in northeastern Illinois. All were reported as granite or granodiorite (McGinnis, 1966).

Within the area of Figure 3 in Indiana, there are three basement wells. The eastern most well penetrated a dark, purplish-gray augite andesite microporphyry (Kottlowski, 1953). The other two deep tests were reported to have encountered granite.

According to Summerson (1962) the Precambrian rocks of Ohio may be lithologically divided into two groups; those east of a line from Sandusky Bay to Clermonte County, and those west of this line. The rocks east of this line are primarily granite gneiss and are associated with the east-sloping side of the Appalachian geosyncline. Those west of this line are primarily granites and associated with the Ohio platform.

Two prominent linear gravity trends are present in southern Michigan. One extends from southeastern Michigan northwest-southeast into the upper peninsula and may be genetically similar to the Mid-Continent gravity "high". The second can be traced from northern Kentucky to southwestern Michigan (Rudman et al, 1965). Rudman and others suggest that these trends may be caused by basalt flows of Keweenawan type.

Rocks from only three deep tests in southeastern Michigan have been petrographically identified; the first in Washtenaw County - a chlorite schist, the second in Lenawee County - a granite gneiss (Summerson, 1961), and the third - the granitic gneiss of this study. A well in Monroe County was also reported to have encountered a granite gneiss. All other Precambrian tests were reported to have penetrated granite at the basement contact. The rocks, that have been identified by petrographic means, indicate that southeastern Michigan is underlain by metamorphic rocks probably of Grenville age.

REGIONAL STRATIGRAPHY

Jacobsville Sandstone

The Jacobsville sandstone crops out along the southern shore of Lake Superior to the east and southwest of the Keweenaw peninsula of Northern Michigan. According to Hamblin (1958) the Jacobsville thickens to the north where it may be several thousand feet thick. Hamblin describes the Jacobsville as a reddish-brown mottled sandstone with white streaks, blotches and circular spots. The sandstone is composed primarily of round to subangular quartz grains with fresh or slightly altered feldspar, usually not in excess of 15 percent. The matrix of the sandstone is quartz and sericite.

Munising Sandstone

The Munising sandstone was named for rocks exposed in bluffs near Munising, Michigan. The Munising in northern Michigan has been divided into two members; the Chapel Rock member and the overlying Miner's Castle member (Hamblin, 1958). These sandstones are exposed along the northeastern Northern Peninsula west to Pictured Rocks and along an arc south from there. In southern Michigan, the Munising formation is divided into four members: Mt. Simon, Eau Claire, Dresbach, and Franconia (Michigan State Geological Survey, 1964).

The Chapel Rock sandstone is equivalent to the Mt. Simon and Eau Claire of southern Michigan (Michigan State Geological Survey, 1964). At Pictured Rocks, and apparently throughout Alger County, Michigan, the sandstone ranges in thickness from 40 to 60 feet (Hamblin, 1958). According to Hamblin, the Chapel Rock sandstone is composed almost entirely of quartz, chert, and quartzite grains with a matrix of small angular quartz fragments acting as a clastic binder. He states that a conglomerate is usually present at the base of the Chapel Rock.

The Miner's Castle member is equivalent to the Dresbach and Franconia (Michigan State Geologic Survey, 1964). This member constitutes the upper 140 feet of the Munising formation in northern Michigan (Hamblin, 1958). According to Hamblin, the lithology of the Miner's Castle is a white, fine- to medium-grained sandstone, well- to poorly-sorted and cross-bedded with occasional conglomerate lenses, shale beds and concretions.

Mt. Simon Sandstone

The lithology of the Mt. Simon in southeastern Michigan is described by Cohee (1948) as a medium- to coarse-grained sandstone with subangular to rounded grains and a few beds of sandy dolomite in the upper part. A study of driller's logs and published descriptions reveals that the lower part of this member

is usually hematitic and slightly arkosic at the base. Where it is exposed, in western Wisconsin, local beds of conglomerate and gray, pink or red shale are common (Twenhofel, et al, 1935).

In northeastern Illinois, the Mt. Simon consists of fine- to coarse-grained friable sandstone that is commonly poorly sorted and contains very fine pebbles. Cores show well developed cross-bedding, especially in the coarser grained beds. Pebbles are larger and more abundant in the north central part of the state. Red and green micaceous shale beds occur in the upper part of the Mt. Simon, but they are not continuous (Buschbach, 1964).

According to Gutstadt (1958) the Mt. Simon of Indiana is a fine- to coarse-grained sandstone varying in color from clear to pink, and composed of frosted and well-rounded quartz grains.

The Mt. Simon sandstone reaches its maximum thickness in Will County, northeastern Illinois, where it is approximately 2,800 feet thick (Buschbach, 1964). The sandstone is 1,040 feet thick in southwestern Michigan. In southeastern Michigan, Cohee (1948) cites a thickness of 300 feet for this unit.

Eau Claire Sandstone

According to Cohee (1948) the Eau Claire in southeastern Michigan consists of sandstone, shale and sandy

dolomite, and is locally very glauconitic. The color of the dolomite or the shale may be gray to dark gray, pink, purple or red to brown. The Eau Claire is sandier in western and northern Michigan than it is in southeastern Michigan. In the Perry-Wooden No. 1, Cass County, Michigan, the Eau Claire consists of a lower zone of glauconitic, dolomitic sandstone. The middle zone consisting of siltstone containing abundant dolomite, muscovite and sandstone. The upper zone is composed of glauconitic dolomite which is commonly sandy and shaly. Anhydrite and gypsum were found in the upper and middle zones of the Eau Claire (Pennington, 1967).

Twenhofel and others (1935) separated the Eau Claire in Wisconsin into two zones on the basis of contained fossils. The lower zone was designated the Cedaria and the upper the Crepicephalus zone. The Cedaria zone consists of medium-grained sandstones, interbedded with fine-grained sandstones and siltstones with occasional beds and laminae containing clay minerals. The Crepicephalus zone is composed of thin-bedded sandstones and siltstones similar to those of the Cedaria zone, but glauconite is locally common.

The major lithology of the Eau Claire in northeastern Illinois is a fine-grained, well-sorted, glauconitic sandstone with shale and siltstone becoming predominant southward. Dolomite beds and fossil fragments are common. The contact between the Mt.

Simon and the Eau Claire in this area is usually quite sharp, but in places a transitional zone of coarse-grained sandstone, interbedded with very fine, silty, fossiliferous sandstone is present (Buschbach, 1964).

The Eau Claire in Indiana contains three characteristic lithologies: (1) very fine to fine dolomitic sandstone or siltstone which is usually pink; some beds contain very abundant glauconite; (2) green, maroon, and black shale, all glauconitic and micaceous; and (3) light tan silty or sandy dolomite, some beds being very glauconitic (Gutstadt, 1958). Gutstadt noted no regular sequence of these lithologies.

In southwestern Michigan, the writer found 430 feet of Eau Claire. Cohee (1948) cites a thickness of 250 feet for this sandstone in southeastern Michigan. The Eau Claire, where it is exposed in Wisconsin, has a maximum thickness of 125 feet (Twenhofel, et al, 1935). In northeastern Illinois, the Eau Claire ranges from 375 to 575 feet thick (Buschbach, 1964). Gutstadt (1958) reports a thickness of 800 feet for this unit in central Indiana.

Dresbach Sandstone

The lithology of the Dresbach in southeastern Michigan is a fine- to medium-grained sandstone with angular to rounded, frosted and pitted quartz grains; in some places, the lower portion contains thin beds of

white to buff dolomite (Cohee, 1948). In the Perry-Wooden No. 1, the Dresbach sandstone consists of white and buff dolomitic sandstone which is generally non-glaucanitic, although some glauconite is present near the lower and upper contacts (Pennington, 1967).

In Wisconsin, the Dresbach is presently considered a stage including the Mt. Simon, Eau Claire and part of the Michigan Dresbach equivalent, the Wonewoc formation. The Wonewoc formation is divided into the Galesville and Ironton members (Ostrum, 1966). In its outcrop area in western Wisconsin, the lower limit of the Galesville is placed directly above the disappearance of the Crepicephalus fauna. In the subsurface, and where no fossils are present, the lower boundary is put at the top of the highest shaly dolomite or fine-grained sandstone. As a rule, the Galesville in Wisconsin is a medium-grained, rather well-sorted, massive-bedded, cross-laminated sandstone, and by definition free of glauconite or fossils (Twenhofel, et al, 1935). The Ironton in Wisconsin is ordinarily composed of coarse-grained, poorly-sorted sandstone becoming progressively finer and better sorted toward the top. The member is usually light gray, glauconitic and thick bedded (Twenhofel, et al, 1935).

In northeastern Illinois, the Galesville is a fine-grained, well-sorted, white to light buff, friable, clean sandstone. Buschbach (1964) split the Ironton

into four members. In ascending order, they are:

Buelter - medium-grained sandstone.

Fox Valley - medium-grained to coarse-grained
dolomitic sandstone and sandy dolomite.

Marywood - fine-grained, slightly dolomitic
sandstone.

Mooseheart - dolomitic, glauconitic, coarse-
grained sandstone.

In Indiana, the Galesville alone is considered equivalent to the Dresbach in Michigan (Gutstadt, 1958). Gutstadt found the Galesville only in the northwestern part of the state, where it is a dolomitic sandstone at the top, grading downward to a sandy dolomite. In the eastern part of the state, the equivalent of the Dresbach is not as yet differentiated within the Knox dolomite. Gutstadt suggests that the lower part of the Knox may be Cambrian in age. He describes this portion as a finely-crystalline to saccharoidal dolomite containing less than 10 percent chert, glauconite, silt and shale.

Cohee cites 100 feet as the thickness of the Dresbach in southeastern Michigan. Pennington (1967) reports 413 feet for this member in Cass County, Michigan. At its outcrop area in Wisconsin, the Galesville has a maximum thickness of 75 feet and the Ironston ranges from 3 to 15 feet thick (Twenhofel,

et al, 1935). In central Illinois, the total thickness of the Ironton and Galesville is approximately 200 feet (Buschbach, 1964). Gutstadt (1958) reports a maximum thickness of 200 feet for the Galesville in western Indiana.

Franconia Sandstone

According to Cohee (1948) the Franconia sandstone of southeastern Michigan is a very glauconitic, fine- to coarse-grained sandstone composed of angular grains of quartz and a few beds of dolomite. In the Perry-Wooden No. 1, the Franconia is composed of sandy and glauconitic, dolomitic siltstone (Pennington, 1967).

In Wisconsin, the Franconia is a stage name including the Ironton member, the Lone Rock formation and the Mazomanie formation (Ostrum, 1966). Equivalents of the Dresbach are the Lone Rock and the Mazomanie. Berg (1954) divided the Lone Rock formation into four members on the basis of contained fossils. In ascending order, they are:

- Birkmose - fine-grained, glauconitic sandstone.
- Tomah - non-glauconitic interbedded sandstone and shale.
- Reno - wormstones and green sand, highly glauconitic and constituting over one half of the Franconia stage in much of Wisconsin.

Mazomanie - a non-glaucinitic dolomitic sandstone facies of the Reno, in eastern Wisconsin comprising most of the Reno member. The Mazomanie was later elevated to formational status (Ostrum, 1966)

In northeastern Illinois, the Franconia formation consists primarily of light gray to pink, fine-grained, dolomitic sandstone that is almost always glauconitic, silty, and argillaceous. In the southern half of northeastern Illinois, however, the lower half of the formation is sandy, glauconitic, brown dolomite. This dolomitic facies constitutes the whole Franconia further South (Buschbach, 1964).

In eastern Indiana, Franconia equivalents are probably included in the lower part of the Knox formation described under the Dresbach sandstone. In northwestern Indiana, Gutstadt (1958) felt justified in using the term, Franconia, in only two test wells. He based this application on lithologic descriptions and correlations from work in Illinois by Workman and Bell (1948).

Cohee (1948) reports that the Franconia in southeastern Michigan is 10 to 20 feet thick and in eastern Wisconsin, he cites a thickness of 140 feet for this member. Pennington (1967) states that the Franconia is 95 feet thick in the Perry-Wooden No. 1. In west central Illinois, the Franconia reaches a thickness of approximately 400 feet (Workman & Bell, 1948).

Trempealeau Formation

The three members of the Trempealeau formation of Wisconsin are recognized in places in Michigan. In ascending order, they are: St. Lawrence, Lodi, and the Jordan sandstone. Cohee (1948) described the lithologic character of the Trempealeau members in southeastern Michigan. He reports the St. Lawrence member consists of gray, sandy, very glauconitic dolomite overlain by dark gray to black dolomitic shale and dolomite; the Lodi member is generally white to buff dolomite, slightly sandy, and locally pink; and the Jordan sandstone consists of well-rounded, frosted, and pitted quartz grains. The Trempealeau of the Perry-Wooden No. 1 is composed of glauconitic, slightly hematitic dolomite and dolomitic sandstone at its base. The rest of the formation consists of dolomite containing oolitic chert in the upper 50 feet. Traces of white soft gypsum were found throughout the Trempealeau (Pennington, 1967). Pennington was unable to identify the Trempealeau members in the Perry-Wooden No. 1.

In Wisconsin, the Trempealeau stage is divided into the St. Lawrence and Jordan formations (Ostrum, 1966). Nelson (1956) divided the St. Lawrence into the Black Earth and Lodi members. The Black Earth member overlies the Franconia and is represented by sandy dolomite and interbedded dolomitic siltstone. It is generally massive, brown to buff, slightly glauconitic and has

algal structures locally. The overlying Lodi member consists of siltstone which is generally dolomitic and dolomitic sandstone (Nelson, 1956).

In northeastern Illinois, the Trempealeau stage is divided into the Potosi formation and the overlying Eminence formation (Buschbach, 1964). According to Buschbach, the Potosi overlies the Franconia and consists of fine-grained dolomite that usually contains drusy quartz. The lower part of the formation normally contains some fine sand and glauconite, and a little glauconite occurs near the top. The Eminence formation is composed of sandy dolomite with beds of sandstone at or near the base (Buschbach, 1964).

In western Indiana, the Trempealeau was observed in only two wells. In eastern Indiana, equivalents of the Trempealeau are probably included in the Knox dolomite described under the Dresbach sandstone.

Cohee (1948) reports that the Trempealeau is 500 feet thick in southeastern Michigan. Pennington (1967) assigned 332 feet to this formation in the Perry-Wooden No. 1, Cass County, Michigan. Buschbach (1964) cites a range of 140 to 370 feet for Trempealeau equivalents in northeastern Illinois. In northern Indiana, Cohee (1948) indicates a thickness of 700 feet.

LITHOLOGY OF THE CUTTINGS

Basal Arkosic Interval

The Security-Thalmann No. 1 was completed in an arkosic material 1,040 feet below the base of the Mt. Simon sandstone. There are two possible lithologies for this interval. One - it is an arkosic clastic deposit, or two - it is a crystalline igneous or metamorphic rock. This section of the paper is devoted to describing the methods used to determine the lithology and the results obtained from these methods.

The lower 1,040 feet of the cuttings are composed of a mixture of moderately altered, granitic mineral fragments, gray shale, buff limestone fragments, a few subround, polished quartz grains, and some small sub-round pebbles of limestone, granite, and quartzite. Through a comparison with the lithologic units above the arkosic interval, the writer eliminated the shale, pebbles, and quartz grains as probable contamination.

A comparison of the gamma ray curve (Figure 8) of this interval and the Mt. Simon sandstone above it reveals that the radioactivity is about nine times greater than that of the Mt. Simon. Extremely high gamma ray radioactivity, such as this, is common among igneous and metamorphic rocks. The neutron radiation level within the Precambrian interval is higher than in

any lithologic unit above it. Porosity is commonly determined by use of the neutron curve and a good rule of thumb is that highly porous rocks show low neutron radioactivity, while dense non-porous rocks show high neutron radioactivity. No evidence of shale or limestone beds was found on the gamma ray neutron log.

A large fragment of rock, reported to have been removed from the drill cuttings at the drilling site, was studied. The composition, texture, and optical properties of this fragment are that of a granitic gneiss. All rotary samples of the Precambrian interval were studied megascopically and microscopically for sedimentary characteristics. No definite sedimentary characteristics were found. A complete discussion of the petrography of the fragment and cuttings will be given later in this section.

Drilling rates for footage intervals within the Precambrian were calculated from information recorded in the daily drilling reports of the Security-Thalman No. 1. The average drilling rate was 13.9 feet per hour, but varied from 7.3 to 19.0 feet per hour. A 7 7/8 inch diameter bit was used in this interval. R. A. Cunningham of Hughes Tool Company (1967) estimates a range of 5 to 14 feet per hour for the penetration rate of a fresh granite using a 7 7/8 inch diameter drill bit with 4,200 pounds of weight per inch of bit diameter. According to

Morlan (1965) penetration rates are highly dependent on the amount of weight being placed on the bit. Cunningham states that the upper limits on bit weights, now being used, are in the vicinity of 10,000 pounds per inch of bit diameter. Bit weight information on the Security-Thalmann No. 1 was not available. It would seem quite possible then, due to the altered nature of the rock and/or a heavy bit weight, that a penetration rate of 19 feet per hour could be reached.

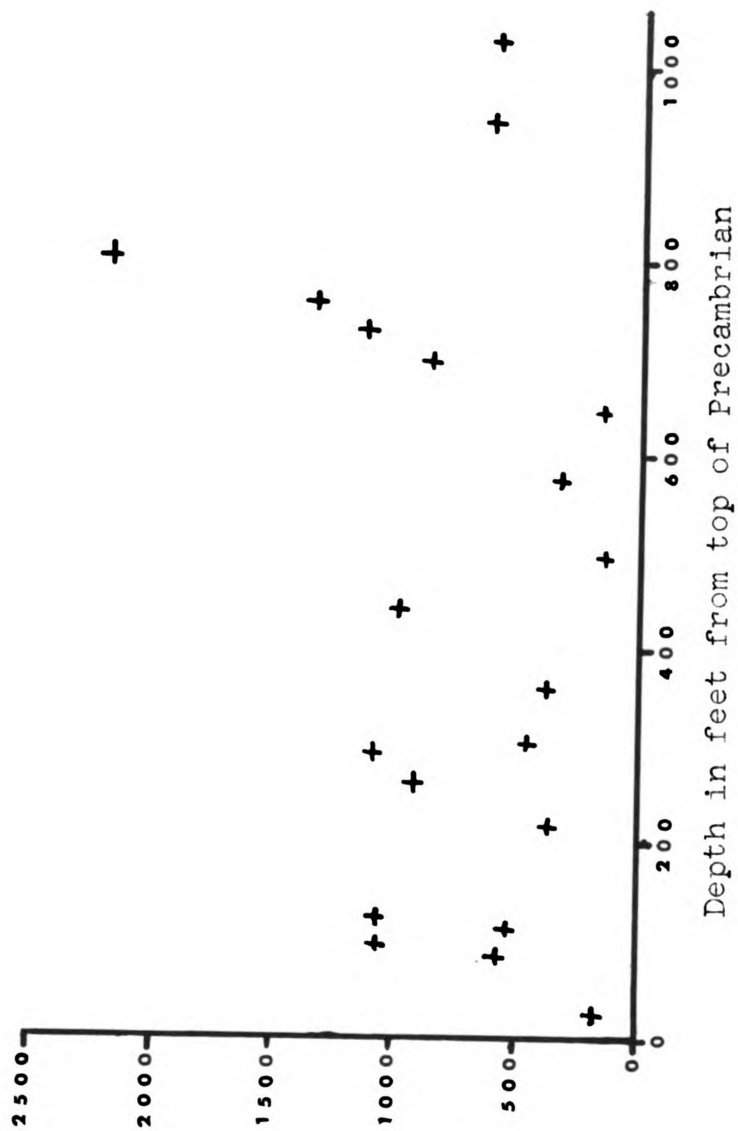
Drilling rates of separate footage intervals are included in the descriptive log in the appendix.

Magnetic susceptibility measurements were made on the granitic portion of the Security-Thalmann No. 1 as an added tool to be used in distinguishing granite from granite wash. Taylor and Reno (1948) studied the magnetic properties of granite wash. They cited 50×10^{-6} c.g.s. units as the maximum magnetic susceptibility of the granite washes they studied. The magnetic susceptibility of 647 granites and related rocks, measured by Magnolia Petroleum Company, ranged from 3×10^{-6} to $6,527 \times 10^{-6}$ c.g.s. units. Values greater than 50×10^{-6} c.g.s. would not prove the rock to be a granite, but would support such a conclusion.

The measurements are presented in Figure 4. As illustrated by the graph, the values obtained are extremely variable. This is probably due to a number of factors; variability in rock composition, amount of

Magnetic susceptibility (10^{-6} c. g. s. units)

Figure 4
Magnetic susceptibility graph



shale contamination within the cuttings, iron particles from the rotary bit, possible errors in instrumentation, the nature of the samples and because an extremely small volume of sample was used to determine the magnetic susceptibilities. Because of the great possibility for error, these measurements are presented here only to establish probable bounds within which the true magnetic susceptibility may fall.

It may be seen from the graph that most of the values are in a range from 100×10^{-6} to $1,400 \times 10^{-6}$ c.g.s. units, indicating that the true magnetic susceptibility is greater than 50×10^{-6} c.g.s. units.

A small chip of rock, from the Precambrian interval, studied petrographically, reveals that this rock is a granitic gneiss, medium-grained, anhedral granular and shows moderate granulation. Orthoclase, some string perthitic and grid twinned microcline are the major feldspars, comprising 43 percent and 12 percent respectively. They occur in anhedral, usually fractured or granulated, grains ranging from 0.07 to 3.6 millimeters in diameter. Quartz, contributing 28 percent, is strained. It ranges from 0.05 to 0.47 millimeters in diameter and occurs as granulation and anhedral grains surrounded by platy orientated chlorite. Feldspar fractures and fractures between mineral grains, some as wide as 0.2 millimeters, are filled with chlorite and calcite. A minor amount of sericitized oligoclase

(An15) and a trace of magnetite and zircon were also found.

Quartz is the dominant mineral of the drill cuttings, and on an average constituted 31 percent of the fragments. Over 50 percent of the quartz contained tiny, transparent, stubby, rod-like inclusions. Negative elongation and crystal form indicate that these are probably apatite. Bubble train inclusions were present in almost all the quartz. Some inclusions of chloritic material were present in the highly altered zones; a full discussion of the highly altered zones will be given later.

Uniaxial quartz predominated, but in all footage intervals sampled, biaxial quartz, usually with undulatory extinction, was found. An increase in the amount of biaxial quartz was noted within the highly altered zones.

Feldspars accounted for an average of 37 percent of the fragments. Orthoclase was the major feldspar and on an average constituted 27 percent, 3.4 percent of which was microperthitic. Polysynthetically twinned microcline averaged 8.4 percent. Oligoclase (An13) was present in amounts less than 1 percent. Almost all feldspar showed some alteration to sericite and clay minerals. Oligoclase, in particular, was severely sericitized and in some cases, probably identified as sericite. In the altered zones, orthoclase, and to a lesser

extent, microcline were altered to a mass of sericite, clay minerals, chlorite and calcite.

Biotite and hornblende on an average constituted 8.8 and 2.1 percent of the fragments respectively. In all footage intervals, both showed some alteration to chlorite and pseudomorphs after them were common. Euhedral rutile and zircon were found as inclusions within much of the biotite and also were found within a few of the chlorite pseudomorphs.

Chlorite composed from a trace to 18 percent of the fragments. It was found along fractures and as patches within orthoclase, microcline, and microperthite, as well as pseudomorphs of biotite and hornblende. Calcite was often associated with chlorite in the fractures, but also occurred as isolated fragments and patches within and associated with the feldspars.

Magnetite, sphene, pyrite, zircon, apatite, hematite, tourmaline and leucoxene were found in minor amounts in the modal analyses.

Two highly altered zones were found in the portion of the granitic gneiss penetrated by this well. The first is near the total depth of penetration and is 70 feet thick. Moderate alteration exists from this zone to the total depth and for 15 feet above this zone. The second is about 50 feet below the Precambrian-Cambrian contact and is 35 feet thick. Slight alteration extends to the top of the gneiss and from the altered horizon

down for 120 feet.

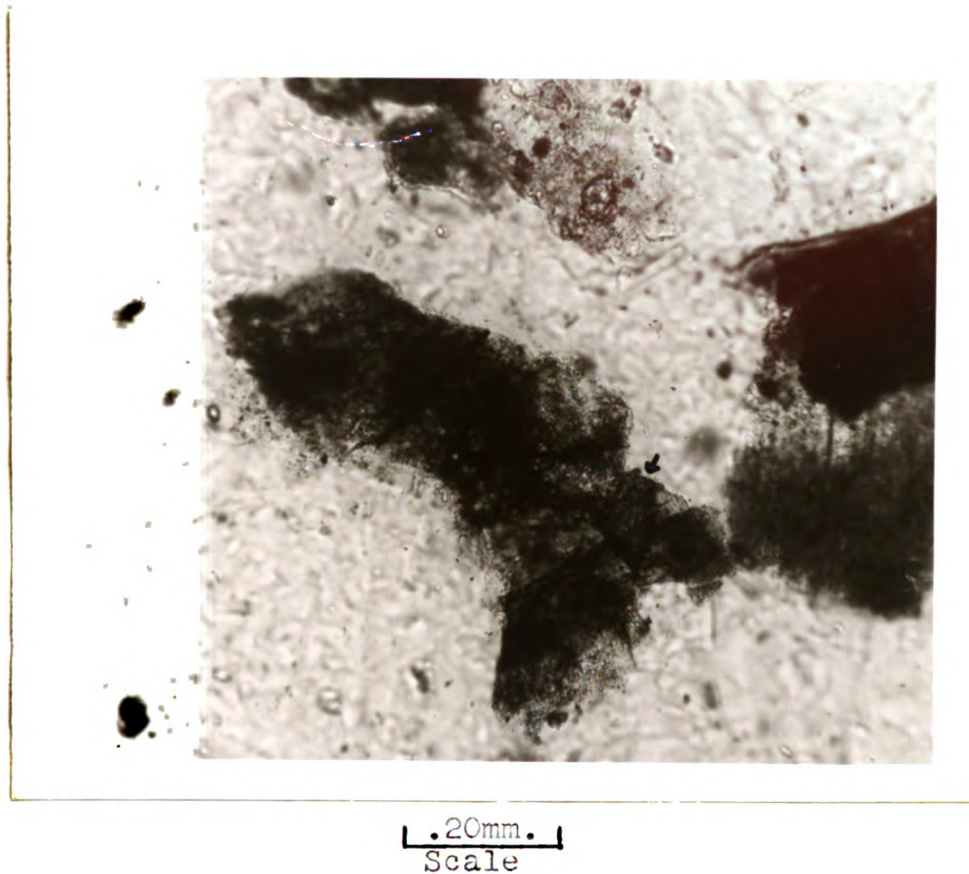


Figure 5-Photomicrograph, plain light, showing red orthoclase (center) highly altered to sericite with a patch of chlorite showing at the arrow and fractures filled with iron oxide.

In the lower alteration zone, feldspars are highly altered to sericite, clay minerals, calcite and chlorite (Figure 5) and dense, red, hematitic pigment is present throughout. Biotite and hornblende are altered to chlorite. Fractures within feldspars are often sealed with chlorite, iron oxide, and calcite. In the upper zone, feldspars were altered to sericite and clay minerals; but chlorite was present only as pseudomorphs of

biotite and hornblende. The alteration in this zone may be due to weathering.

Table 1 gives the mineral frequencies found in both alteration zones.

Table 1. - Modal analyses of alteration zones.

	Upper Zone	Lower Zone
Quartz	22.7%	27.3%
Orthoclase	46.7%	28.3%
Microperthite	3.0%	2.3%
Microcline	1.0%	8.0%
Biotite	-	1.0%
Chlorite	17.7%	11.7%
Sericite	7.7%	15.3%
Oligoclase	1.0%	2.3%
Magnetite	.7%	1.0%
Hematite	tr.	tr.
Zircon	tr.	tr.
Leucoxene	-	.3%
Calcite	tr.	2.0%
Pyrite	-	.3%

The center of the Precambrian interval is composed of 455 feet of unaltered to slightly altered granitic rock. The range of composition within this interval is on the following page, Table 2.

Table 2. - Modal analyses of the unaltered zone.

Quartz	30.0 - 50.3%
Orthoclase	21.0 - 29.0%
Microperthite	2.3 - 7.7%
Microcline	2.7 - 10.0%
Sericite	tr. - 5.0%
Biotite	13.0 - 6.3%
Hornblende	2.3 - 5.0%
Chlorite	1.0 - 3.0%
Plagioclase	.3 - 1.7%
Calcite	.3 - 4.0%
Magnetite	.3 - 1.0%
Sphene	00.0 - .3%
Zircon	00.0 - 2.0%

Magnetite and pyrite composed over 40 percent of the heavy minerals in the gneiss. Magnetite occurs as irregular grains, sometimes rimmed by a light brown iron oxide (limonite?). Pyrite was found as irregular grains usually with a reddish-yellow metallic luster. The red tint is probably due to a hematitic coating. Zircon and sphene were the most abundant non-opaque minerals. They occurred as subhedral and euhedral mineral fragments, probably crushed in drilling. Some hematite, tourmaline, and apatite were also found.

The exact genesis of the granitic gneiss could not be determined from the small fragment of gneiss available. The gneiss could possibly be a metamorphosed granitic rock, a granitic rock with primary flow structure, a granitized sediment, or a metamorphosed sediment. It is apparent, however, that in the later stages of its

formation the rock was badly fractured. Late hydrothermal solutions probably used these fractures as channels and altered, wherever fractures permitted, feldspars to chlorite and calcite, biotite and hornblende to chlorite, and filled the fractures with chlorite and calcite.

A complete list of modal analyses may be found in Appendix A.

Mt. Simon Sandstone

In the Security-Thalman No. 1, 1,040 feet of Mt. Simon sandstone unconformably overlies Precambrian granitic gneiss. This member is a sandstone consisting of clear and frosted, round to angular, quartz grains and some partings of gray, brown and red shale.

The Mt. Simon varies in color from white to light red with an increase in hematitic grain coating. In the lower half, sharp and frequent changes of color are common. The upper half of the Mt. Simon consists of 190 feet of white sandstone at the top, quickly grading to a hematitic pink sandstone, which is continuous for 260 feet.

The basal 5 feet of Mt. Simon is moderately-sorted, coarse-grained and has a median grain size of 0.5 millimeters and a maximum grain size of 0.8 millimeters. With this exception, the Mt. Simon is moderately-sorted and

medium-grained with the median and maximum grain size varying from .3 to .4 millimeters and from 1.4 to .4 millimeters respectively from top to bottom.

The major heavy minerals of the Mt. Simon are ilmenite and leucoxene. Leucoxene occurs as rounded, dull, brownish-white grains. Ilmenite is present in subround to irregular grains, with a purple gray metallic luster. Zircon is the next most abundant mineral. At the top of the sandstone, it comprised 19 percent of the heavy mineral suite and increased to 50 percent in the basal 1/3 of the member. Colorless zircon is the most common variety, but many grains had a light purplish hue. Most of the zircon grains are subround with crystal faces still visible. Tourmaline occurs in minor amounts as rounded elongate grains. Both the brown and the indigo varieties are found. Sphene is present only in the basal 1/3 of the sandstone and occurs as subround light brown pleochroic grains.

Eau Claire Sandstone

The Eau Claire sandstone of the Security-Thalman No. 1 conformably overlies the Mt. Simon sandstone and is 430 feet thick. The basal portion of the Eau Claire consists of a light gray, medium-grained, well-sorted, glauconitic, slightly dolomitic sandstone. Four characteristics of this basal unit made it easily dis-

medium-grained with the median and maximum grain size varying from .3 to .4 millimeters and from 1.4 to .4 millimeters respectively from top to bottom.

The major heavy minerals of the Mt. Simon are ilmenite and leucoxene. Leucoxene occurs as rounded, dull, brownish-white grains. Ilmenite is present in subround to irregular grains, with a purple gray metallic luster. Zircon is the next most abundant mineral. At the top of the sandstone, it comprised 19 percent of the heavy mineral suite and increased to 50 percent in the basal 1/3 of the member. Colorless zircon is the most common variety, but many grains had a light purplish hue. Most of the zircon grains are subround with crystal faces still visible. Tourmaline occurs in minor amounts as rounded elongate grains. Both the brown and the indigo varieties are found. Sphene is present only in the basal 1/3 of the sandstone and occurs as subround light brown pleochroic grains.

Eau Claire Sandstone

The Eau Claire sandstone of the Security-Thalman No. 1 conformably overlies the Mt. Simon sandstone and is 430 feet thick. The basal portion of the Eau Claire consists of a light gray, medium-grained, well-sorted, glauconitic, slightly dolomitic sandstone. Four characteristics of this basal unit made it easily dis-

tinguishable from the underlying Mt. Simon: (1) the Eau Claire is characteristically glauconitic; (2) secondary crystallization of quartz makes the grains of the Eau Claire predominantly angular; (3) the Eau Claire contains a moderate amount of light tan dolomitic cement; the Mt. Simon, on the other hand, contains only a small amount of quartz cement; (4) the Eau Claire, although it has the same median grain size, (0.3 millimeters) as the Mt. Simon, is well-sorted while the Mt. Simon is moderately sorted.

The amount of dolomite and glauconite within the basal sand increases upward and the Eau Claire passes to a pinkish tan, hematitic, very finely-crystalline, glauconitic, sandy dolomite containing some brown, soft, micaceous shale. The dolomite persists throughout the remainder of the Eau Claire with the upper 50 feet of this member being less hematitic.

Irregular to subround grains of ilmenite, colorless subround zircon, and rounded and etched garnet constituted most of the heavy minerals of the Eau Claire. A moderate amount of authigenic leucoxene and a few grains of indigo rounded tourmaline were also found.

Dresbach Sandstone

A change in lithology from the glauconitic dolomite of the Eau Claire, to a non-glauconitic, medium-grained sandstone marks the base of the Dresbach member in the

Security-Thalmann No. 1. This member is 131 feet thick. The lower portion of the sandstone is composed of clear and frosted, well-sorted, angular to round, quartz grains showing much secondary crystallization of quartz, some light tan dolomite, and minor amounts of green-gray shale. The upper portion consists of a very dolomitic sandstone with a 20 feet thick zone containing about 30 percent reddish-brown, micaceous shale, occurring near the top of the member. The median and maximum grain sizes remain fairly constant throughout the member and range from .2 to .3 millimeters and from .6 to .7 millimeters respectively from bottom to top.

Colorless garnet comprised over 40 percent of the heavy minerals; almost all the grains were etched. Rounded grains of ilmenite contributed 34 percent. Green, yellow and indigo tourmaline were present in minor amounts, and occurred as well-rounded oval pleochroic grains. Some zircon and leucoxene were also found.

Franconia Sandstone

The Franconia sandstone overlies the Dresbach and is 141 feet thick. This member consists of very glauconitic, very finely-crystalline, sandy dolomite. The basal portion of this member is light tan; above this, and extending upwards for 25 feet, the Franconia is

composed of light gray dolomite and gray, very silty dolomite. The upper portion of the Franconia is a light gray, very sandy dolomite, becoming brownish red and less sandy near the top.

Trempealeau Formation

The tan pink, sandy dolomite lithology of the top of the Franconia is transitional into the Trempealeau formation. Because of this transition, the base of the Trempealeau was estimated by lithologic variation, but picked specifically on the basis of a decrease in gamma ray radiation from the Schlumberger gamma ray-neutron log (Figure 8).

The Trempealeau in the Security-Thalman No. 1 is 223 feet thick. The lower part of the formation consists of a light tan, slightly hematitic, sandy, finely-crystalline dolomite, becoming slightly cherty upward and containing some green-gray and dark gray shale. The upper portion of the formation is light tan, slightly hematitic, medium- to coarsely-crystalline, cherty, dolomite containing some dark gray shale. This lithology is continuous throughout the Cambrian-Ordovician contact, making it necessary to pick the top of the Trempealeau on the basis of a gamma ray radiation increase (Figure 8).

The writer found no lithologic units within the Trempealeau that justified using member nomenclature.

STRATIGRAPHIC IMPLICATIONS OF THE HEAVY MINERALS

The similarity between the heavy minerals of the gneiss and those found at the base of the Mt. Simon (Figure 6) suggest that the gneiss may have acted as a local source for the basal portion of the Mt. Simon sandstone. Pennington (1967), Asseez (1967) suggest that the Berrien anticline was present during Cambrian time. It is possible that this high furnished a sediment source for a short period during early upper Cambrian time. Tyler (1936) reported the heavy minerals of the Mt. Simon in Wisconsin as being dominantly ilmenite and leucoxene with zircon and tourmaline being common. The apparent deficiency of leucoxene in the Mt. Simon of this study may be explained by considering leucoxene as an alteration product of ilmenite.

Tyler also studied the heavy minerals of the Eau Claire. He found zircon, garnet, ilmenite, and leucoxene to be common to abundant and tourmaline rare. Heavy mineral frequencies comparable to this were found in the Eau Claire of the Security-Thalmann No. 1.

The Dresbach of this study was found to contain a simple, well-rounded, heavy mineral assemblage (Figure 6). Such an assemblage indicates multiple cycle sedimentation. Emrich (1966) noted that the Ironton and Galesville sandstones in Illinois and Wisconsin, have

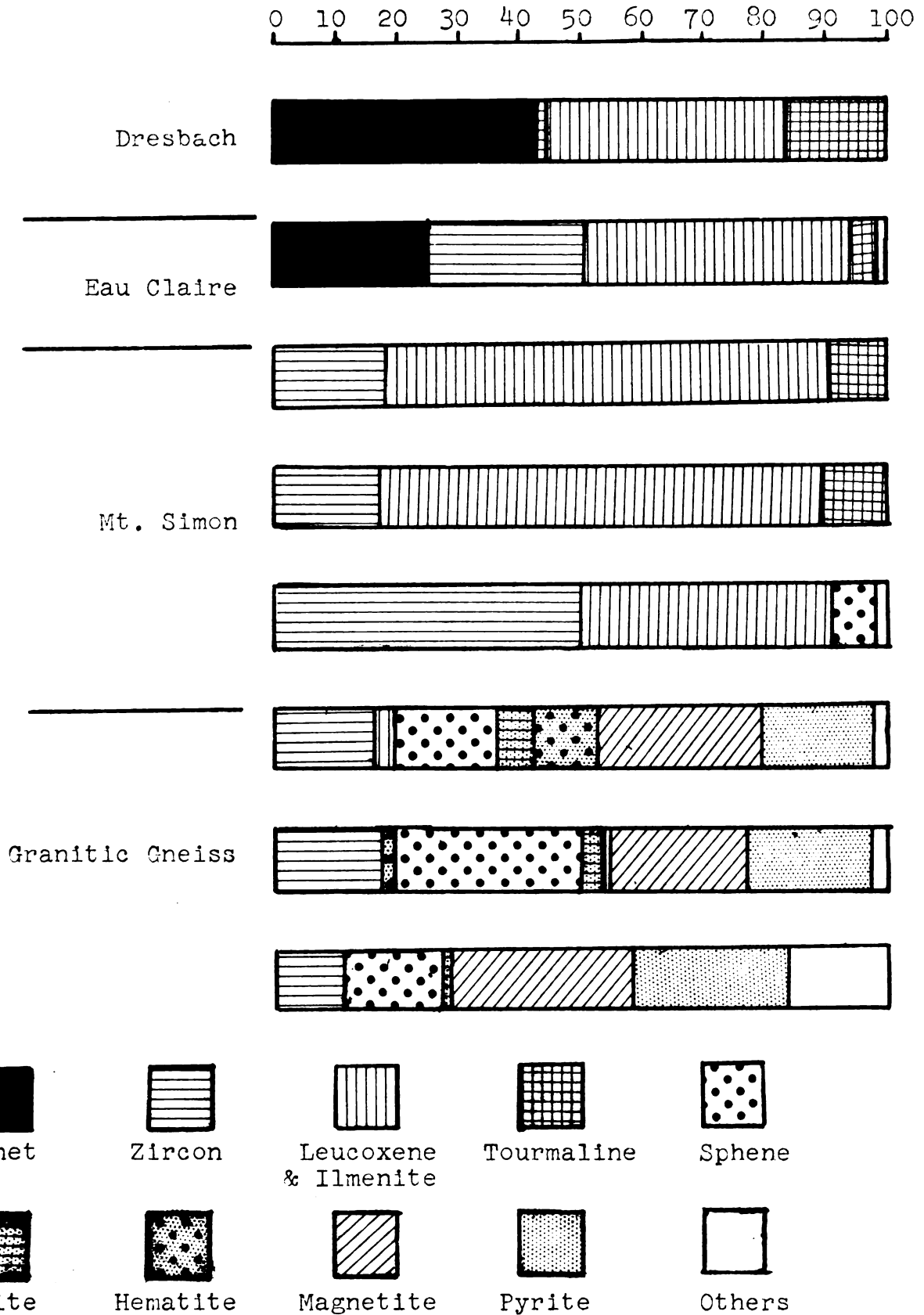


Figure 6 - Heavy minerals

well-rounded, simple heavy mineral assemblages. He also states that the heavy mineral suite of these sandstones is composed chiefly of tourmaline, zircon, ilmenite, leucoxene and varying amounts of etched garnet. Only a small amount of zircon was found in the Dresbach (Figure 6). However, Emrich found the zircon content of the heavy minerals within the Galesville and Ironston may vary from 63 to 2 percent and the garnet content may vary from zero to 61 percent. The assemblage found in the Dresbach is within this variability, but is not a good heavy mineral correlation. It is suggested that further study be done on the heavy minerals of the Dresbach in southern Michigan to find out how much the heavy mineral suite of this member varies.

ENVIROMENT OF DEPOSITION

Assuming that the granitic gneiss of the Security-Thalman No. 1 is the same age as the Precambrian rocks of southeastern Michigan, it was probably metamorphosed about 1.2 - 1.5 billion years ago during the Elsonian Orogeny. It is not known if Precambrian sediments were later deposited on the gneiss. Occurrences of Precambrian sediments have been reported in areas adjacent to the Security-Thalman No. 1. However, if they were present, they have been completely removed by pre-Paleozoic erosion.

During early upper Cambrian time, a sea slowly transgressed into southwestern Michigan. The sea deposited the Mt. Simon sandstone. During this time, a part of the granitic body of this study, had topographic relief and was furnishing clastic material to the Berrien County area. This high continued to supply sediment until it was leveled by erosion or buried by the accumulation of sediment. Concurrent with the granitic source and throughout the Cambrian, a variety of rock types, centered around the Canadian shield, were supplying clastic material (Potter and Pryor, 1961). The sea transgressed throughout Mt. Simon time, and by Eau Claire time, waters were slightly deeper and conditions were suitable for the deposition of carbonates as well

as sand. Prior to Dresbach time, the sea regressed somewhat and the waters became shallow enough for sand deposition to dolomite. Sand deposition prevailed throughout Dresbach time. During this time, the withdrawal of the sea left some areas in northern Michigan exposed. This is recorded by a disconformity between the Chapel Rock and Miner's Castle member (Driscoll, 1959).

By the end of Dresbach time, the sea had begun to transgress and carbonate deposition was under way. The sea continued to transgress through Franconia time and carbonates continued to accumulate forming the Trempealeau.

Gypsum and anhydrite occur in minor amounts in the Eau Claire, Franconia and Trempealeau of the Perry-Wooden No. 1 and the State-Foster No. 1 wells. No evaporites were found in the Security-Thalmann No. 1. Both the wells containing gypsum and anhydrite are located in structural lows. The Perry-Wooden No. 1 is located in the Battle Creek trough and the State-Foster No. 1 well occurs low structurally (Pennington, 1967). Pennington, on the basis of a thicker Trempealeau section in the Perry-Wooden No. 1, concluded that the Security-Thalmann No. 1 was located on a structural high, the Berrien anticline, and suggested this structural relationship may have controlled evaporite deposition by allowing brines, concentrated by evaporation in the shallower structurally higher area, to flow down slope

into the structurally low area. The writer has studied sample descriptions of all Precambrian deep tests in southern Michigan. No Cambrian evaporites were reported in these wells. This indicates that Cambrian evaporite deposition is of a local nature. It is the writer's opinion that restriction by Precambrian highs, sand bars or other structural features supplied the necessary environments for evaporite deposition during Cambrian time. This would explain the local nature of these deposits.

CORRELATIONS AND STRATIGRAPHIC IMPLICATIONS

Gamma ray correlations of sub-Trenton rocks from Beaver Island, Charlevoix County, Michigan, to southeastern Michigan are as shown in Figure 7. Because few wells that penetrate the Cambrian in this area are logged, the correlations into Wisconsin and the Northern Peninsula of Michigan were made on the basis of well descriptions by Cohee (1945) and Dixon (1961).

In the Northern Peninsula of Michigan and in Wisconsin the Trempealeau formation may be subdivided on the basis of lithology, into the Jordan, Lodi, and St. Lawrence members (wells 2 and 3). In the Southern Peninsula these units are usually part of a dolomite sequence and the Trempealeau may not be subdivided. In Indiana (well 5) the Trempealeau is part of the Cambrian-Ordovician Knox Dolomite and the boundary between the two systems can not be picked on the basis of lithology (Gutstadt, 1958) or gamma ray curve characteristics (well 5). Gamma ray curve characteristics have been used by Pennington (1967) to correlate sub-Trenton rocks from southwestern Michigan to northwestern Ohio, but he bypassed Indiana.

The Franconia, Dresbach, and Eau Claire may be correlated into the Northern Peninsula of Michigan, western Wisconsin and northern Indiana by gamma ray-neutron logs and sample descriptions. But the actual

contacts between these members can not always be defined.

The Mt. Simon is the most consistantly correlatable unit of the Cambrian system. This member has been traced throughout southern Michigan, Wisconsin, Illinois, Indiana, and Ohio by various workers.

A slightly arkosic sandstone older than the Mt. Simon was found in the State-Beaver Island No. 2 well (well 5, Figure 7). Over 800 feet of this unit were penetrated in the State-Beaver No. 1 well drilled three miles north of well 5. It is suggested that further work be done on this unit to determine its age and relationship to the Cambrian section.

SUMMARY

The Security-Thalman No. 1 penetrated 1,040 feet of Precambrian moderately granulated, granitic gneiss.

The lowermost Cambrian rocks in the well are members of the Munising formation. The basal member is the Mt. Simon sandstone. It is composed of 1,040 feet of white and hematitic, moderately-sorted sandstone. The Eau Claire member is 430 feet thick. It consists of pinkish-tan, glauconitic, sandy dolomite and a basal well-sorted, glauconitic, dolomitic sandstone. The Dresbach member is composed of 131 feet of non-glauconitic, well-sorted, dolomitic sandstone. The Franconia member is 141 feet thick and consists of very glauconitic, sandy and silty dolomite.

The Trempealeau formation is composed of 223 feet of light tan to slightly hematitic, slightly cherty dolomite. No justification for using Trempealeau member nomenclature was found.

The wide-spread Post-Canadian unconformity is not evidenced in this well, but is present in southeastern Michigan, along the Findlay arch.

The upper Cambrian sandstones of the Security-Thalman No. 1 may be correlated with upper Cambrian sandstones of Wisconsin on the basis of heavy minerals. However, further study of the heavy minerals of the

Dresbach is needed to make a definite heavy mineral correlation between the Dresbach and its proposed Illinois and Wisconsin equivalents, the Galesville and Ironston sandstones.

Correlations of the upper Cambrian rocks of southern Michigan, with those of northern Michigan, Wisconsin and Indiana, were made through use of well descriptions and gamma ray-neutron logs. A slightly arkosic sandstone, penetrated below the Mt. Simon in the State-Beaver Island No. 2 well, was tentatively put in the Cambrian system. Further study of this unit is recommended.

BIBLIOGRAPHY

- Adams, J. and Rhodes, M. (1960) Dolomitization by Seepage Refluxion, Bull. of A. A. P. G., Vol. 44, pp. 1912-1920.
- Asseez, Y. (1967) Stratigraphy and Paleogeography of the Lower Mississippian Sediments of the Michigan Basin, Ph.D. thesis, Michigan State University.
- Atwater, G. I. and Clement, G. M. (1935) Pre-Cambrian and Cambrian Relations in the Upper Mississippi Valley, Bull. of G. S. A., Vol. 46, pp. 1659-1686.
- Berg, R. R. (1954) Franconia Formation of Minnesota and Wisconsin, Bull. of G. S. A., Vol. 65, pp. 857-882.
- Bieberman, D. F. (1949) Stratigraphy of Three Wells in Sullivan and Vigo Counties, Indiana, Rpt. of Prog. No. 2, Ind. State Geol. Surv.
- Bradbury, J. C. and Atherton, E. (1965) The Precambrian Basement of Illinois, Ill. State Geol. Surv., Circ. 382.
- Buschbach, T. C. (1964) Cambrian and Ordovician Strata of Northeastern Illinois, Rpt. of Inv. No. 218, Ill. State Geol. Surv.
- _____. (1965) Deep Stratigraphic Test Well Near Rock Island, Illinois, Ill. State Geol. Surv., Circ. 394.
- Calvert, W. L. (1962) Sub-Trenton Rocks from Lee County, Virginia to Fayette County, Ohio, Rpt. of Inv. No. 45, Ohio Geol. Surv.
- _____. (1963) Sub-Trenton Rocks of Ohio in Cross-Sections from West Virginia and Pennsylvania to Michigan, Rpt. of Inv. No. 49, Ohio Geol. Surv.
- _____. (1964a) Pre-Trenton Sedimentation and Dolomitization, Cincinnati Arch Province: Theoretical Considerations, Bull. of A. A. P. G., Vol. 48, pp. 166-190.

- _____. (1964b) Sub-Trenton Rocks from Fayette County, Ohio to Brant County, Ontario, Rpt. of Inv. No. 52, Ohio Geol. Surv.
- Cohee, G. V. (1945) Lower Ordovician and Cambrian Rocks in the Michigan Basin, Michigan and Adjoining Areas, U. S. Geol. Surv. Oil and Gas Inv. (Prelim.) Chart No. 9.
- _____. (1947) Cambrian and Ordovician Rocks in Recent Wells in Southeastern Michigan, Bull. of A. A. P. G., Vol. 31, pp. 293-307.
- _____. (1948) Cambrian and Ordovician Rocks in Michigan Basin and Adjoining Areas, Bull. A. A. P. G., Vol. 32, pp. 1417-1448.
- _____. (1965) Geologic History of the Michigan Basin, J. of Wash. Acad. of Sci.
- Cunningham, R. A. (1967) personal correspondence.
- Dapples, E. C. (1948) Tectonic Control of Lithologic Associations, Bull. of A. A. P. G., Vol. 32, pp. 124-147.
- Dawson, T. A. (1960) Deep Test Well in Lawrence County, Indiana: Drilling Techniques and Stratigraphic Interpretations, Rpt. of Prog. No. 22, Ind. State Geol. Surv.
- _____, et al. (1960) Catalogue of Well Samples of the Indiana Geological Survey, Geol. Surv. Dir. No. 8, Ind. Dept. of Cons.
- Dixon, R. A. (1961) Lithologic Study of a Cambro-Ordovician Core Delta County, Michigan, M. S. thesis, Michigan State University.
- Dobrin, M. B. (1960) Introduction to Geophysical Prospecting, McGraw Hill Book Co., Inc., New York
- Driscoll, E. G. (1959) Evidence of Transgressive-Regressive Cambrian Sandstone Bordering Lake Superior, J. of Sed. Pet., Vol. 29, pp. 5-15.
- Ekblaw, G. E. (1938) Kankakee Arch in Illinois, Bull. of G. S. A., Vol. 49, pp. 1428.

- Emrich, G. H. (1966) Iron-ton and Galesville (Cambrian) Sandstones in Illinois and Adjacent Areas, Ill. State Geol. Surv., Circ. 403.
- Farkas, S. E. (1960) Cross-Lamination Analysis in the Upper Franconia Formation of Wisconsin, J. of Sed. Pet., Vol. 30, pp. 447-458.
- Fettke, C. R. (1948) Subsurface Trenton and Sub-Trenton Rocks in Ohio, New York, Pennsylvania and West Virginia, Bull. of A. A. P. G., Vol. 32, pp. 1457-1492.
- _____. (1961) Well-Sample Descriptions in Northwestern Pennsylvania and Adjacent States, Pennsylvania Geol. Surv., Bull. No. M40.
- Geophysical Specialties Company (1963) Magnetic Susceptibility Bridge, Model MS-3 Inst. Man.
- Graham, W. A. P. (1933) Petrology of the Cambrian-Ordovician Contact in Minnesota, J. of Geol., Vol. 41, pp. 468-486.
- Grogan, R. M. (1949) Present State of Knowledge Regarding the PreCambrian Crystallines of Illinois, Ill. Acad. of Sci. Trans., Vol. 42, pp. 97-102.
- Gutstadt, A. M. (1958) Cambrian and Ordovician Stratigraphy and Oil and Gas Possibilities in Indiana, Geol. Surv. Bull. No. 14.
- Hamblin, W. K. (1958) Cambrian Sandstones of Northern Michigan, Mich. State Geol. Surv. Publication 51.
- Howell, B. F., et al. (1944) Correlation of the Cambrian Formations of North America, Bull. of G. S. A., Vol. 55, pp. 993-1003.
- Ives, R. E. (1967) personal communication.
- Johannsen, A. (1932) Descriptive Petrography of the Igneous Rocks, Univ. of Chicago Press, Ill.
- Kashfi, M. (1967) The Upper Cambrian Section of the State Foster No. 1 Well, Ogeman County, Michigan, M. S. thesis (in preparation), Michigan State University.

- Kottlowski, F. E. and Patton, J. B. (1953) Pre-Cambrian Rocks Encountered in Test Holes in Indiana, Proceedings of the Indiana Acad. of Sci. for 1952, Vol. 62, pp. 234-243.
- Krumbein, W. C. and Pettijohn F. J. (1938) Manual of Sedimentary Petrography, Appleton-Century-Crofts, Inc., New York.
- _____. and Sloss, L. L. (1956) Stratigraphy and Sedimentation, W. H. Freeman & Company, California.
- Lockett, J. R. (1947) Development of Structures in Basin Areas of Northeastern United States, Bull. of A. A. P. G., Vol. 31, pp. 429-446.
- Lovering, T. S. (1949) Rock Alteration as a Guide to Ore-East Tintic District, Utah, Economic Geology, Monograph 1.
- McCormick, G. R. (1961) Petrology of Precambrian Rocks of Ohio, Rpt. of Inv. No. 41, Ohio State Geol. Surv.
- McGinnis, L. D. (1966) Crustal Tectonics and Precambrian Basement in Northeastern Illinois, Rpt. of Inv. No. 219, Ill. State Geol. Surv.
- Michigan State Geological Survey, 1964, Stratigraphic Succession in Michigan, Mich. Geol. Surv. Chart No. 1.
- _____. (1965) Tests Reported to have Penetrated Basement Rocks in the Southern Peninsula of Michigan.
- Milner, H. B. (1940) Sedimentary Petrography, Nordeman Publishing Company, Inc., New York.
- Morlan, E. A. Designing Large Diameter Hole Drilling Programs, World Oil (April 1962).
- Nelson, C. A. (1956) Upper Croixan Stratigraphy, Upper Mississippi Valley, Bull. of G. S. A., Vol. 67, pp. 165-184.
- Ockerman, J. W. (1930) A petrographic Study of the Madison and Jordan Sandstones of Southern Wisconsin, J. of Geol., Vol. 38, pp. 346-353.

- Ostrom, Me. E. (1966) Cambrian Stratigraphy of Western Wisconsin, Michigan Basin Geol. Soc. Annual Field Conf., Inf. Circ. No. 7.
- Pennington, E. K. (1967) A Stratigraphic Study of the Upper Cambrian of the Perry-Wooden No. 1 Deep Test Well, Cass County, Michigan, M. S. thesis, Michigan State University.
- Pettijohn, F. J. (1949) Sedimentary Rocks, Harper and Bros., New York.
- Pirtle, G. W. (1932) Michigan Structural Basin and its Relationship to Surrounding Areas, Bull. of A. A. P. G., Vol. 16, pp. 145-152.
- Potter, P. E. and Pryor, W. A. (1961) Dispersal Centers of Paleozoic and Later Clastics of the Upper Mississippi Valley and Adjacent Areas, Bull. of G. S. A., Vol. 72, pp. 1195-1250.
- Rudman, A. J., et al. (1965) Geology of Basement in Midwestern United States, Bull. of A. A. P. G., Vol. 49, pp. 894-904.
- Schwartz, G. M. (1952) Chlorite-Calcite, Pseudomorphs After Orthoclase Phenocrysts, Ray, Arizona, Econ. Geol., Vol. 47, pp. 665-674.
- Stauffer, C. R. (1925) The Jordan Sandstone, J. of Geol., Vol. 33, pp. 699-713.
- Summerson, C. H. (1962) Precambrian in Ohio and Adjoining Areas, Rpt. of Inv. No. 44, Ohio Geol. Surv.
- Taylor, G. L. and Reno, D. H. (1948) Magnetic Properties of "Granite" Wash and Unweathered "Granite", Geophysics, Vol. 13, pp. 163-181.
- Templeton, J. S. (1950) The Mt. Simon Sandstone in Northern Illinois, Ill. Acad. of Sci. Trans., Vol. 43, pp. 151-159.
- Thwaites, F. T. (1923) The Paleozoic Rocks Found in Deep Wells in Wisconsin and Northern Illinois, J. of Geol., Vol. 31, pp. 529-555.
- _____. (1931) Buried Pre-Cambrian of Wisconsin, Bull. of G. S. A., Vol. 42, pp. 719-750.

- Trowbridge, A. C. and Atwater, G. I. (1934) Stratigraphic Problems in the Upper Mississippi Valley, Bull. of G. S. A., Vol. 45, pp. 21-80.
- Twenhofel, W. H., et al. (1935) Cambrian Strata of Wisconsin, Bull. of G. S. A., Vol. 46, pp. 1687-1744.
- Tyler, S. A. (1936) Heavy Minerals of the St. Peter Sandstone in Wisconsin, J. of Geol., Vol. 6, pp. 55-84.
- Walcott, C. D. (1914) Cambrian Geology and Paleontology, Smithsonian Misc. Coll., Vol. 57, pp. 345-412.
- Wasson, I. B. (1932) Sub-Trenton Formations in Ohio, J. of Geol., Vol. 40, pp. 673-687.
- Whiting, W. M. (1965) A Subsurface Study of the Post-Knox Unconformity and Related Rock Units in Morrow County, Ohio, M. S. thesis, Michigan State University.
- Wilgus, W. L. (1933) Heavy Minerals of Dresbach Sandstone of Western Wisconsin, J. of Sed. Pet., Vol. 3, pp. 83-91.
- Willman, H. B. and Payne, J. N. (1942) Geology and Mineral Resources of the Marseilles, Ottawa and Streator Quadrangles, Ill. State Geol. Surv. Bull. No. 66.
- Wilmarth, M. G. (1938) Lexicon of Geologic Names (including Alaska), U. S. Geol. Surv. Bull. No. 896.
- Workman, L. E. and Bell, A. H. (1948) Deep Drilling and Deeper Oil Possibilities in Illinois, Bull. of A. A. P. G., Vol. 32, pp. 2041-2062.

APPENDIX

Detailed descriptive log of the Cambrian system of the Security-Thalman No. 1 well.

Cambrian System

St. Croixan Series

Lake Superior Group

Trempealeau Formation (223')

	Thickness (Feet)	Depth to top (Feet)
Dolomite, tan, medium- to coarsely-crystalline, very cherty (oolitic), slightly hematitic, trace of drusy quartz and drusy calcite; some shale, dark gray, dolomitic.	40	2635
Dolomite, tan, medium- to coarsely-crystalline, cherty, slightly hematitic, trace of drusy quartz and drusy calcite; some shale, dark gray, dolomitic.	5	2675
Dolomite, tan, medium- to coarsely-crystalline, slightly cherty, slightly hematitic, trace of drusy quartz and drusy calcite; some shale, dark gray, dolomitic.	10	2680
Dolomite, tan, medium- to finely-crystalline, slightly cherty, and hematitic; shale (10-20%), dark gray to green gray; trace of pyrite.	25	2690
Dolomite, tan, finely-crystalline, trace of pyrite; shale (5-10%), green gray, dolomitic and reddish brown, soft.	30	2715

Thickness (Feet)	Depth to top (Feet)
Dolomite, tan and hematitic pink, finely-crystalline, trace of drusy quartz; a few quartz grains round to subround, pink, frosted; shale (5-20%), green-gray and dark gray, dolomitic.	12	2845

Munising Formation

Franconia Sandstone Member (141')

Dolomite, brownish red (hematitic), very fine to finely-crystalline, glauconite inclusions; some grains frosted; few pieces of pyrite.	63	2857
--	----	------

Dolomite, light gray, very finely-crystalline, much included glauconite; sand grains (20-40%), angular to subround, median grain .3mm, maximum grain .5mm, moderately-sorted; trace of pyrite.	40	2920
--	----	------

Dolomite, dark gray, silty, very finely-crystalline, much included glauconite; sand grains (30%), angular to subround, median grain .3mm, maximum grain .5mm, moderately-sorted; trace of pyrite.	25	2960
---	----	------

Dolomite, light tan to tan, very finely-crystalline, glauconitic; trace of pyrite; some sand grains, angular to round, frosted.	15	2985
---	----	------

Dresbach Sandstone Member (131')

Sand, white, angular to round, medium-grained, well-sorted, clear and frosted, very dolomitic; some secondary crystallization of quartz, median grain .4mm, maximum grain .7mm.	40	3000
---	----	------

Sand, as above, but 30% shale, reddish brown, micaceous.	20	3040
--	----	------

1. The first part of the paper discusses the importance of the study of the history of the English language.

2. The second part of the paper discusses the importance of the study of the history of the English language.

3. The third part of the paper discusses the importance of the study of the history of the English language.

4. The fourth part of the paper discusses the importance of the study of the history of the English language.

5. The fifth part of the paper discusses the importance of the study of the history of the English language.

6. The sixth part of the paper discusses the importance of the study of the history of the English language.

	Thickness (Feet)	Depth to top (Feet)
Sand, white, medium-grained, clear and frosted, well-sorted, angular to round, slightly dolomitic, much secondary crystallization of quartz, median grain .3mm, maximum grain .6mm.	76	3060
Eau Claire Sandstone Member (430')		
Dolomite, dirty brown to gray, very finely-crystalline, much glauconite, sandy; shale, dark brown, slightly micaceous; trace of pyrite.	59	3136
Dolomite, pinkish tan, hematitic, very finely-crystalline, glauconitic, sandy; shale, green-gray, dolomitic; shale, brownish-red, micaceous, soft, dolomitic.	225	3195
Sand, gray-white, some frosted, medium-grained, angular to subround, well-sorted, dolomitic (light tan), slightly glauconitic; trace of pyrite, much secondary crystallization of quartz, median grain .3mm, maximum grain .6mm.	147	3420
Mt. Simon Sandstone Member (1,040')		
Sand, white, frosted and clear, medium-grained, moderately-sorted, round to angular, very little secondary crystallization of quartz, median grain .3mm, maximum grain .40mm; shale (20%), brown-black, soft, shiny, dolomitic.	48	3567
Sand, as above, but shale (15%).	100	3615
Sand, as above, but pure and white, subangular to round.	30	3715
Sand, as above, but hematitic pink; shale (10%), green-gray, soft, dolomitic.	260	3745
Sand, as above, but white.	45	4005

	Thickness (Feet)	Depth to top (Feet)
Sand, as above, but hematitic.	10	4050
Sand, as above, but white.	60	4060
Sand, white, frosted and clear, medium-grained, moderately-sorted, round to angular, very little sec- ondary crystallization of quartz, median grain .40mm, maximum grain 1.40mm; shale (10%), green-gray, soft, dolomitic.	5	4120
Sand, as above, but hematitic.	35	4125
Sand, white, frosted and clear, medium-grained, subround to angular, moderately-sorted, median grain .40mm, maximum grain .85 mm; shale (30%), red, soft, micaceous.	40	4160
Sand, as above, but no shale.	35	4200
Sand, as above, but slightly hema- titic; some shale, red as above; and shale green, dolomitic.	40	4235
Sand, as above, but white.	50	4275
Sand, as above, but hematitic.	5	4325
Sand, as above, but white.	10	4330
Sand, as above, but hematitic.	60	4340
Sand, as above, white, and no shale.	10	4400
Sand, as above, but hematitic.	25	4410
Sand, as above, but slightly hema- titic; some shale, green gray.	10	4435
Sand, as above, but no shale.	30	4445
Sand, as above, but some shale, green-gray.	5	4475

	Thickness (Feet)	Depth to top (Feet)
Sand, as above, but white, and no shale.	20	4580
Sand, slightly-hematitic, coarse-grained, moderately-sorted, frosted and clear, median grain .50mm, maximum grain .80mm; trace of shale, green and brown; trace of feldspar.	6	4600
Precambrian System		
Granitic Gneiss (1,040')		
Granitic gneiss; orthoclase and microcline, orange and white, fresh to dense white with pink mottling; quartz fragmental, clear, some yellow, when associated with biotite and/or feldspar is in an interlocking crystal arrangement; books of biotite, green-black, fresh, shiny black.	60	4606
Granitic gneiss; microcline and orthoclase, primarily dense reddish-brown to light orange; a few feldspar fragments highly altered to dense white with pink mottling; some books of green-black biotite; quartz, clear, fragmental splinters; some chlorite.	35	4660
Granitic gneiss; orthoclase and microcline, mostly white, some light orange, some dense white feldspar; books of greenish-black biotite; (4700 to 4710) highly contaminated with Ellsworth Shale and Trenton Limestone.	216	4695

Calculated drilling rate from 4703 to 4736, 7.3 feet per hour.

The following information is provided for your reference:

1. The first section of the document contains a list of items that are subject to the provisions of the Act.

2. The second section of the document contains a list of items that are not subject to the provisions of the Act.

3. The third section of the document contains a list of items that are subject to the provisions of the Act, but only if certain conditions are met.

4. The fourth section of the document contains a list of items that are subject to the provisions of the Act, but only if certain conditions are met.

5. The fifth section of the document contains a list of items that are subject to the provisions of the Act, but only if certain conditions are met.

6. The sixth section of the document contains a list of items that are subject to the provisions of the Act, but only if certain conditions are met.

7. The seventh section of the document contains a list of items that are subject to the provisions of the Act, but only if certain conditions are met.

8. The eighth section of the document contains a list of items that are subject to the provisions of the Act, but only if certain conditions are met.

9. The ninth section of the document contains a list of items that are subject to the provisions of the Act, but only if certain conditions are met.

10. The tenth section of the document contains a list of items that are subject to the provisions of the Act, but only if certain conditions are met.

	Thickness (Feet)	Depth to top (Feet)
Granitic gneiss; feldspar, primarily white, some fragments of orange feldspar; some dense white, altered; books of black, shiny biotite; quartz, clear fragmental; (5100 to 5135, 5240 to 5260 and 5345 to 5375) highly contaminated with Ellsworth Shale and Trenton Limestone; (5260 to 5320) contains a few water polished sand grains (Pleistocene?).	360	4915
Calculated drilling rate from 4976 to 5097, 17.0 feet per hour. from 5202 to 5266, 12.0 feet per hour.		
Granitic gneiss; feldspar, 70% white and 30% pink; black, pearly books of biotite, some ferruginous; quartz, clear, fragmental.	185	5375
Calculated drilling rate from 5266 to 5378, 14.0 feet per hour.		
Granitic gneiss; feldspar, reddish-orange; quartz, clear, yellow and red, fragmental; biotite, green-black to green; some chlorite.	70	5460
Calculated drilling rate from 5437 to 5560, 15.4 feet per hour.		
Granitic gneiss; feldspar, 70% white and 30% pink; pearly black and greenish books of biotite; quartz, clear to yellow, fragmental.	117	5530
Calculated drilling rate from 5567 to 5647, 19.0 feet per hour.		
Total Depth		5647½

Table 3

Wells reported to have penetrated the Precambrian
in Southern Michigan and adjoining areas and illustrated
in Figure 3.

Michigan Wells						Basement Lithology
Longitude deg.-min.	Latitude deg.-min.	County	Name			
86 18	41 59	Berrien	Security-Thalman No. 1			Granitic gneiss
85 36	45 40	Charlevoix	State-Beaver Island No. 2			Granite
83 54	41 48	Lenawee	Eckert-Taylor No. 1			Granite gneiss
83 46	41 52	Monroe	Ferguson & Garrison-Shimp No. 1			Granite gneiss
83 46	42 28	Washtenaw	Colvin-Voss Comm. No. 1			Granite
83 42	41 52	Monroe	Beck-Sancrant No. 1			Granite
83 42	42 26	Washtenaw	Troy-Roddenberry Comm. No. 1			Chlorite Schlst
83 36	42 20	Washtenaw	Colvin-Meinzinger No. 1			Granite
83 23	42 14	Wayne	Colvin-Theisen Estate No. 1			Granite
83 16	42 10	Monroe	Sturman-Chapman No. 1			Granite
82 49	42 46	St. Clair	Consumers-Brine Disposal No. 139			Granite
82 39	42 52	St. Clair	St. Clair-Hurst No. 1			Granite

Table 3 - Continued

Wisconsin Wells					Basement Lithology	
Longitude deg.-min.	Latitude deg.-min.	County	Name			
89 50	43 58	Adams	Village Well, Adams		Quartzite	
89 49	43 20	Sauk	Badger Ordance Well #5		Granite	
89 48	43 45	Sauk	Artesian test at Wis. Dells		Basalt	
89 48	43 21	Sauk	Basger Ordance Well #3		Granite	
89 47	43 28	Sauk	Baraboo (test well #4)		Quartzite	
89 46	43 16	Sauk	Sauk City (Water works well)		Granite	
89 44	43 22	Sauk	Badger Ordance Well #2		Quartzite	
89 44	44 7	Sauk	Devils Lake (Sp-12)		Quartzite	
89 40	43 28	Sauk	Rock Spring Supply Well		Quartzite	
89 30	44 3	Waushard	Coloma (Village well)		Granite	
89 30	43 8	Dane	Well #4, Middleton		Rhyolite	
89 26	43 4	Dane	Unit Well #1, Madison		Granite	
89 22	43 6	Dane	City Well, E. Sta., Madison		Basalt	
89 22	43 4	Dane	Kennedy Dairy Co., Madison		Trap	
89 20	43 8	Dane	Unit Well #3, Madison		Felsite	

Table 3 - Continued

Wisconsin Wells					Basement Lithology
Longitude deg.-min.	Latitude deg.-min.	County	Name		
89 50	43 58	Adams	Village Well, Adams	Quartzite	
89 49	43 20	Sauk	Badger Ordance Well #5	Granite	
89 48	43 45	Sauk	Artesian test at Wis. Dells	Basalt	
89 48	43 21	Sauk	Basger Ordance Well #3	Granite	
89 47	43 28	Sauk	Paraboo (test well #4)	Quartzite	
89 46	43 16	Sauk	Sauk City (Water works well)	Granite	
89 44	43 22	Sauk	Badger Ordance Well #2	Quartzite	
89 44	44 7	Sauk	Devils Lake (Sp-12)	Quartzite	
89 40	43 28	Sauk	Rock Spring Supply Well	Quartzite	
89 30	44 3	Waushard	Coloma (Village well)	Granite	
89 30	43 8	Dane	Well #4, Middleton	Rhyolite	
89 26	43 4	Dane	Unit Well #1, Madison	Granite	
89 22	43 6	Dane	City Well, E. Sta., Madison	Basalt	
89 22	43 4	Dane	Kennedy Dairy Co., Madison	Trap	
89 20	43 8	Dane	Unit Well #3, Madison	Felsite	

Table 3 - Continued

Wisconsin Wells					Basement Lithology	
Longitude deg.-min.	Latitude deg.-min.	County	Name			
89 18	43 15	Dane	DeForest, Oil Test, Madison		Granite	
89 18	43 4	Dane	Nine Spring Disposal Well, Madison		Basalt	
89 13	42 56	Dane	Stoughton Well #3, Madison		Granite	
89 8	43 32	Forest	Oil Test in Camb. area - Slinger - Roberts		Granite	
89 0	43 17	Dodge	Reeseville Etscheld Farm		Granite	
88 58	44 1	Waushara	Aurora, Harold Gatzke Farm Well		Granite	
88 56	43 58	Green Lake	Berlin (Carnation Milk Co.)		Granite	
88 56	43 6	Jefferson	Lake Mills (City well #4)		Granite	
88 55	43 44	Florence	Fairwater-Am. Stores Dairy #2		Granite	
88 54	43 26	Dodge	Beaver Dam City Well #3		Quartzite	
88 54	43 8	Jefferson	Lake Mills (Emmons Blaine Farm)		Basalt	
88 54	42 54	Jefferson	Ft. Atkinson Well #3		Granite	
88 50	42 58	Jefferson	Jefferson city #4		Granite	
88 48	42 46	Walworth	Delavan (Bradley Krittling Co.)		Quartzite	

Table 3 - Continued

Longitude deg.-min.	Latitude deg.-min.	County	Name	Basement Lithology
88 46	43 12	Jefferson	Watertown City Well	Iron Formation
88 46	43 4	Jefferson	Jefferson Jct. (Ladish Stoppenbach #3)	Granite
88 46	43 32	Dodge	Wis. St. Prison, #3, Waupun	Quartzite
88 44	43 24	Dodge	Juneau (Amer. Milk Company)	Quartzite
88 43	43 48	Florence	Rosedale (Gen. Wis. Canning #3)	Quartzite
88 43	43 20	Dodge	Clyman, Village Well #2	Quartzite
88 38	43 40	Florence	Perry School District	Quartzite
88 36	43 21	Dodge	Hustisford (Canning Well)	Quartzite
88 34	44 1	Winnebago	Oshkosh	Granite
88 32	43 7	Waukesha	Oconomowoc Aeppler Well	Quartzite
88 32	44 6	Winnebago	Winnebago St. Hosp. #2	Granite
88 32	44 30	Dodge	Mayville (Purity Cheese Co.)	Marble
88 28	43 44	Florence	Fond du Lac - Test Well #3	Quartzite
88 28	44 12	Winnebago	Menasha (Kimberly Clark #4)	Granite
88 27	43 30	Dodge	Theresa, Baker Canning Co. #3	Quartzite

Table 3 - Continued

Longitude				Latitude		County	Name	Basement Lithology
deg.-min.		deg.-min.						
88	26	44	42	Shawano	Bonduel (Village Well #2)			Granite
88	26	44	32	Outagamie	Black Creek Oil test			Granite
88	22	42	56	Winnebago	Hartford (City Well)			Quartzite
88	21	43	44	Florence	Mary Hill Park Well			Quartzite
88	20	43	18	Winnebago	Hartford (City Well #7)			Quartzite
88	18	43	4	Jefferson	Jefferson Jct. (Ladish Stoppenbach Company)			Granite
88	17	44	16	Outagamie	Kimberly (Village Well #2)			Granite
88	16	44	16	Outagamie	Kaukauna (City Well #3)			Granite
88	12	43	24	Winnebago	West Bend (City Well)			Quartzite
88	12	43	30	Winnebago	Kewaskum (Resenneimer Malt & Grain Co.)			Quartzite
88	8	44	50	Oconto	Oconto Falls (Village Well)			Granite
88	7	43	12	Waukesha	Menomonee Falls (City Well #3)			Quartzite
88	4	44	56	Oconto	Lena Village Well			Granite
88	4	44	30	Brown	City Well at 9th and Fidge, Green Bay			Granite

Table 3 - Continued

Longitude deg.-min.	Latitude deg.-min.	County	Name	Basement Lithology
87 58	44 30	Brown	Liebmann Packing Co., Green Bay	Granite
87 58	44 28	Brown	Ashwaubenon San. Dist. Well, Green Bay	Granite
87 56	44 28	Brown	Cass St. Well, Green Bay	Granite
87 50	43 38	Sheboygan	Gibbsville (Wis. Oil Ref. Co. #1)	Granite
87 48	45 8	Marinette	Porterfield (Z. E. Oil Corp. #1)	Granite
87 46	45 6	Marinette	Peshtigo (Badger Paper Mills)	Granite
87 38	45 6	Marinette	Marinette Gas Company	Granite
87 38	44 10	Manitowoc	Two Rivers (City Test #2)	Quartzite
All other wells in Wisconsin after Thwaites (1931)				

Northeastern Illinois Wells

89 44	41 44	LaSalle	Vicery-Mathesius #1	Granite
89 4	42 16	Winnebago	Secle-Fee #1	Granite & Granodiorite
89 00	42 10	Boone	N. Ill. Oil & Gas Co. - Taylor #1	Granodiorite
88 50	41 33	La Salle	Lawinger-Miller #1	Granite & Granodiorite

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

Table 3 - Continued

Longitude deg.-min.	Latitude deg.-min	County	Name	Basement Lithology
88	41 41 33	La Salle	Otto-Swenson #1	Granite
88	41 41 56	Dekalb	Schulte-Wyman #1	Granite
88	41 41 26	Will	Reed-McCoy #1	Granite
Indiana Wells				
87	31 41 36	Porter	Bethlehem Steel-Tec #1	Granite
86	50 41 2	Wabash	Asland-Ivan Hudson #1	Granite
85	8 40 56	Allen	Gibson #3	Augite Andesite
Ohio Wells				
84	15 41 3	Putman	Barage	Granite
83	44 41 26	Wood	Killman	Granite
83	38 41 7	Hancock	Noris	Granite Pegmatite
83	24 40 56	Wyandot	Heck	Granite
83	8 41 30	Sandusky	Hetrick	Granite
83	7 41 17	Seneca	Watson	Granite
82	58 41 24	Sandusky	Haff	Granite Gneiss

Table 3 - Continued

Longitude deg.-min.	Latitude deg.-min	County	Name	Basement Lithology
82 48	41 14	Huron	Artling	Granite gneiss
82 28	41 21	Erie	Sayler	Granite gneiss
82 22	41 22	Lorain	Boru	Granite gneiss
81 48	41 16	Medina	Smith	Granite gneiss
81 46	41 12	Medina	Warner	Granite gneiss

Table 3 - Continued

Longitude deg.-min.	Latitude deg.-min	County	Name	Basement Lithology
82 48	41 14	Huron	Artling	Granite gneiss
82 28	41 21	Erie	Sayler	Granite gneiss
82 22	41 22	Lorain	Peru	Granite gneiss
81 48	41 16	Medina	Smith	Granite gneiss
81 46	41 12	Medina	Warner	Granite gneiss

Mineral	Frag- ment	4635- 4640	4660- 4665	4695- 4700	4710- 4715	4725- 4730	4855- 4860	4890- 4895
Quartz	28.3	32.3	22.7	34.0	37.3	39.3	26.0	30.0
Orthoclase	43.3	24.3	46.7	30.7	25.7	29.0	55.7	27.0
Microcline	12.3	8.7	1.0	14.7	11.7	11.7	5.3	4.3
Microperthite	8.7	6.0	3.3	tr.	1.7	4.0	3.0	19.3
Biotite	-	16.0	-	3.3	15.7	14.3	9.3	9.0
Chlorite	4.3	1.0	17.7	4.3	.3	tr.	tr.	4.7
Sericite	tr.	8.3	7.7	8.3	.3	tr.	1.3	tr.
Oligoclase	2.7	tr.	1.0	2.7	-	-	tr.	-
Magnetite	tr.	.3	.7	-	-	.7	tr.	-
Hematite	-	-	tr.	tr.	1.0	tr.	.3	-
Calcite	.7	.7	tr.	tr.	2.7	tr.	.3	.7
Zircon	tr.	-	tr.	-	3.0	tr.	-	-
Sphene	-	.3	tr.	tr.	tr.	tr.	-	-
Pyrite	-	-	-	tr.	tr.	.3	-	1.3
Leucoxene	-	-	-	tr.	.7	-	-	-
Rutile	-	-	-	tr.	-	-	-	-
Apatite	tr.	tr.	tr.	tr.	tr.	tr.	tr.	tr.
Hornblende	-	-	-	2.0	.7	-	1.0	3.7
Tourmaline	-	-	-	-	-	-	-	-

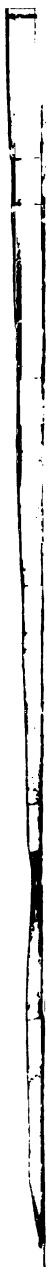
Table 4 - Modal analyses of the Precambrian interval.

Mineral	4900- 4905	4920- 4925	5020- 5025	5265- 5270	5330- 5335	5390- 5395	5525- 5530	5645- 5647
Quartz	35.0	40.0	32.3	50.3	30.0	32.3	27.3	28.3
Orthoclase	31.0	29.0	24.3	21.0	29.3	17.3	28.3	31.0
Microcline	12.3	3.3	10.0	5.0	2.7	12.0	8.0	11.7
Microperthite	3.7	7.0	7.7	1.7	2.3	4.0	2.3	3.3
Biotite	8.3	13.0	16.7	8.0	6.3	3.3	1.0	4.3
Chlorite	1.3	2.0	2.7	1.0	3.0	8.0	11.7	7.7
Sericite	15.0	tr.	tr.	5.0	tr.	14.3	15.3	10.7
Oligoclase	-	.3	1.7	1.3	.3	1.0	2.3	2.0
Magnetite	.3	1.0	.3	1.0	.3	1.3	1.0	.7
Hematite	-	tr.	-	tr.	tr.	tr.	tr.	tr.
Calcite	.3	.3	-	.3	4.0	1.0	2.0	1.0
Zircon	-	tr.	.3	-	2.0	-	tr.	tr.
Sphene	tr.	-	-	.3	1.3	-	-	.3
Pyrite	-	-	tr.	tr.	tr.	tr.	.3	-
Leucoxene	-	-	.3	-	-	-	.3	-
Rutile	-	-	-	-	-	-	-	tr.
Apatite	tr.	tr.	-	tr.	tr.	-	tr.	-
Hornblende	2.0	5.0	-	5.0	2.3	5.3	-	1.0
Tourmaline	-	-	3.7	-	.3	-	-	-

Table 4 - Modal analyses of the Precambrian interval - Continued

Mineral	4900- 4905	4920- 4925	5020- 5025	5265- 5270	5330- 5335	5390- 5395	5525- 5530	5645- 5647
Quartz	35.0	40.0	32.3	50.3	30.0	32.3	27.3	28.3
Orthoclase	31.0	29.0	24.3	21.0	29.3	17.3	28.3	31.0
Microcline	12.3	3.3	10.0	5.0	2.7	12.0	8.0	11.7
Microperthite	3.7	7.0	7.7	1.7	2.3	4.0	2.3	3.3
Biotite	8.3	13.0	16.7	8.0	6.3	3.3	1.0	4.3
Chlorite	1.3	2.0	2.7	1.0	3.0	8.0	11.7	7.7
Sericite	15.0	tr.	tr.	5.0	tr.	14.3	15.3	10.7
Oligoclase	-	.3	1.7	1.3	.3	1.0	2.3	2.0
Magnetite	.3	1.0	.3	1.0	.3	1.3	1.0	.7
Hematite	-	tr.	-	tr.	tr.	tr.	tr.	tr.
Calcite	.3	.3	.3	.3	4.0	1.0	2.0	1.0
Zircon	-	tr.	.3	-	2.0	-	tr.	tr.
Sphene	tr.	-	-	.3	1.3	-	-	-
Pyrite	-	-	tr.	tr.	tr.	tr.	.3	.3
Leucoxene	-	-	.3	-	-	-	.3	-
Rutile	-	-	-	-	-	-	-	tr.
Apatite	tr.	tr.	-	tr.	tr.	-	tr.	-
Hornblende	2.0	5.0	3.7	5.0	2.3	5.3	-	1.0
Tourmaline	-	-	-	-	.3	-	-	-

Table 4 - Modal analyses of the Precambrian interval - Continued



Pocket has:
Figure 3
Figure 7
1 Graph

3

FIGURE 3

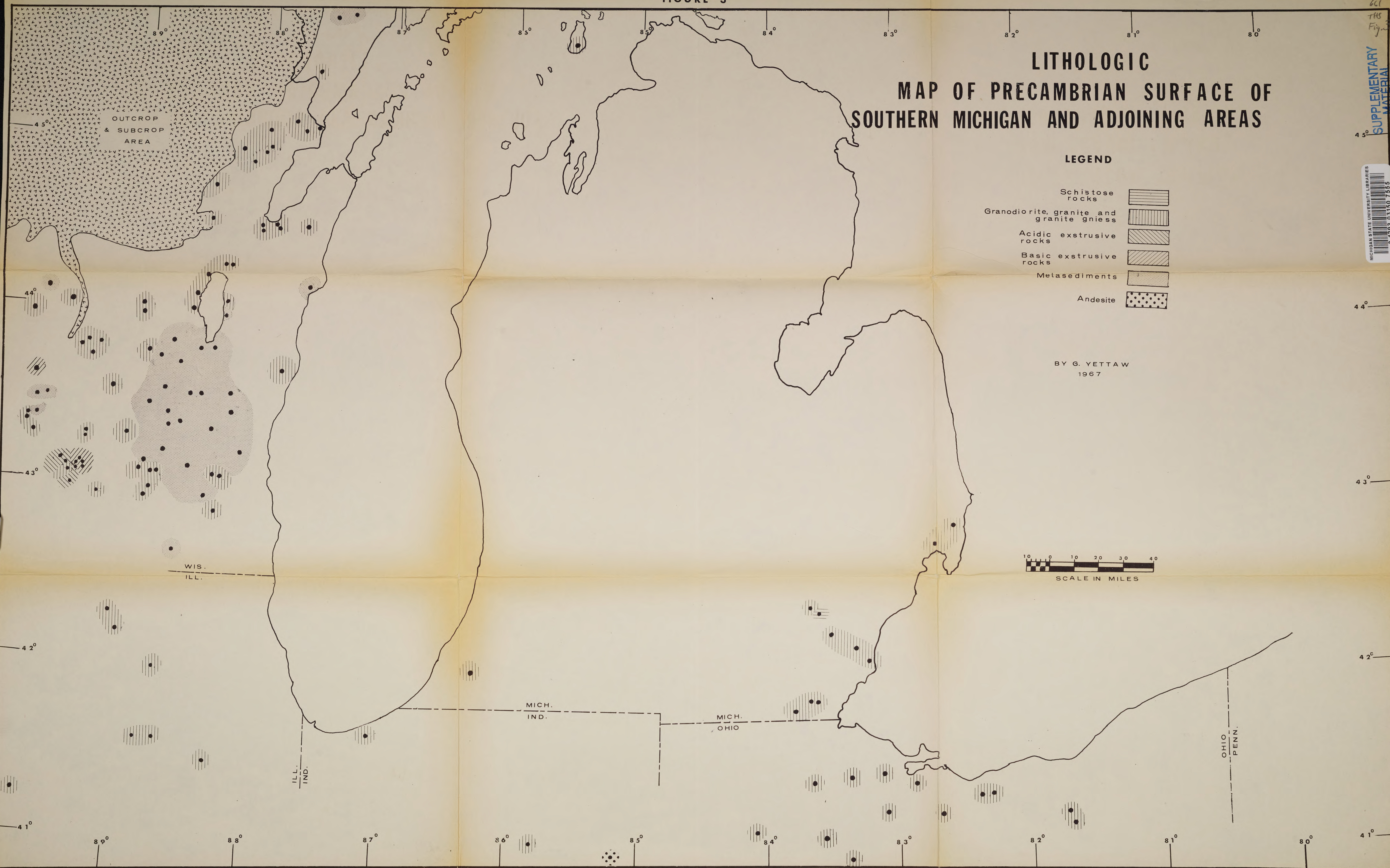
LITHOLOGIC MAP OF PRECAMBRIAN SURFACE OF SOUTHERN MICHIGAN AND ADJOINING AREAS

LEGEND

Schistose rocks	
Granodiorite, granite, and granite gneiss	
Acidic extrusive rocks	
Basic extrusive rocks	
Metasediments	
Andesite	

BY G. YETTAW
1967

10 0 10 20 30 40
SCALE IN MILES



131
661
Fig. 3
SUPPLEMENTARY MATERIAL
MICHIGAN STATE UNIVERSITY LIBRARIES
3 1293 03150 7555

131

601

748

5

MICHIGAN STATE UNIV. LIBRARIES



31293102773631