THE ST. PETER SANDSTONE IN MICHIGAN

Thesis for the Degree of M. S.
MICHIGAN STATE UNIVERSITY
Michael T. Balombin
1974

THESIS

ABSTRACT

THE ST. PETER SANDSTONE IN MICHIGAN

By

Michael T. Balombin

The Middle Ordovician St. Peter sandstone has not recieved extensive investigation in Michigan. Within the past ten years however, the number of wells drilled to this formation has more than doubled, thereby providing better coverage and a large amount of new data for an examination of this interval.

This study seeks to define the St. Peter in terms of its lithology, distribution and extent in the Lower Peninsula of Michigan and by so doing provide information on the early geologic history of this area.

The St. Peter does not crop out anywhere in Michigan. Its subsurface presence is confined to the western part of the Lower Peninsula where it occurs sporadically. Whether or not it occurs in the Upper Peninsula is subject to speculation and is not conclusively known, although it appears doubtful.

Lithological and depositional characteristics indicate the St. Peter was deposited in a shallow sea

with the eastern edge of that sea in Michigan. Irregular thicknesses of the sandstone throughout the state are due to deposition on the eroded surface of the Prairie du Chien, which is primarily a carbonate terrain. Relief on this surface is greatest in the western part of the state, decreasing in an eastward direction. This is shown by the fairly uniform distribution of the relatively thin Glenwood shale in eastern Michigan where it unconformably overlies the Prairie du Chien.

The St. Peter sea advanced from the south with the sediments derived from the exposed Canadian Shield area to the north and northwest.

The sand of the St. Peter closely resembles that of the Glenwood and Prairie du Chien in samples. Differentiation must be made microscopically.

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By

Michael T. Balombin

A THESIS

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

MASTER OF SCIENCE

Department of Geology

1974

Dedicated to my Wife, Daughter, Mother, and late Father.

ACKNOWLEDGEMENTS

The writer wishes to express his deep gratitude to Dr. James H. Fisher, chairman of the thesis committee, for his valuable suggestions and assistance and under whose guidance this study was undertaken.

Special thanks go to Dr. C. E. Prouty and Dr. B. T. Sandefur, other members of the committee, for their most appreciated advice, suggestions and criticism of this manuscript.

The writer gratefully acknowledges Garland D. Ells of the Michigan Geological Survey for many interesting and stimulating discussions and the Survey staff who graciously assisted in providing geophysical logs and well samples necessary for this study.

Thanks also go to Dr. Robert Shaver of the Indiana Geological Survey and Thomas C. Buschbach of the Illinois Geological Survey who furnished comparison samples from their respective states and to Mr. Vivion Shull of the Microprobe Lab for his helpfulness in the preparation of the photomicrographs.

Finally, the writer would like to express his sincere appreciation for the special assistance provided by his wife in the preparation of this manuscript and

for her patience, understanding, love and encouragement, without which this work would never have been started--or finished.

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INTRODUCTION

The St. Peter sandstone has been studied extensively in the Mississippi Valley region for some time. Authors such as Trowbridge (1917), Dake (1921), Lamar (1928), Thiel (1935), Dapples (1955), and Buschbach (1964) have made comprehensive examinations of the St. Peter. Much of the earlier work on the formation in Michigan was done by Cohee (1945) who described the sandstone and placed a major unconformity at its base. Later work completed by Horowitz (1961) generally agreed with Cohee as to the occurrence and distribution of the St. Peter. Catacosinos (1972) called the same unit a Jordan-St. Lawrence transitional zone with sandstone and dolomite stringers. He does not recognize St. Peter rocks anywhere in Michigan and places the unconformity at the base of the younger Glenwood.

Purpose of Investigation

The purpose of this investigation is to determine if the sand in Michigan, customarily called St. Peter, is indeed St. Peter, and to describe its extent and distribution in the Lower Peninsula. Since the formation does not crop out in Michigan, this study is based entirely on well samples, core chips and gamma ray-neutron logs where available.

It is hoped that the information gained from this investigation will not only provide useful data on the nature of the formation but also help in the interpretation of the early history of the Michigan Basin.

Methods and Procedures

The Michigan well samples and gamma ray-neutron logs used in this study were obtained from the Geological Survey in Lansing, Michigan. The samples consisted of both rotary and cable tool cuttings and core chips. The Survey also provided the facilities and equipment used during the course of the study.

Samples, cores and core chips for comparison purposes were supplied by the Indiana and Illinois Geological Surveys and copies of gamma ray-neutron logs were also obtained from the latter.

A complete list of all samples used may be found in the Appendix.

In the samples, the St. Peter interval was examined in detail and the samples were checked far enough both above and below to recognize overlying and underlying formations. This was done under reflected light using a magnification of 8x. For closer observation, magnification was increased to a maximum of 60x. The lithology of the interval was then recorded with conclusions based in large part on this data. The properties examined included color, grain size, shape, degree of sorting, type of cementation and presence or absence of frosting and pitting.

In the opinion of the writer, the St. Peter does not show a characteristic trace on gamma ray-neutron logs and they cannot be used solely to determine the presence or absence of the formation. Only when used in conjunction with samples can the logs be used accurately.

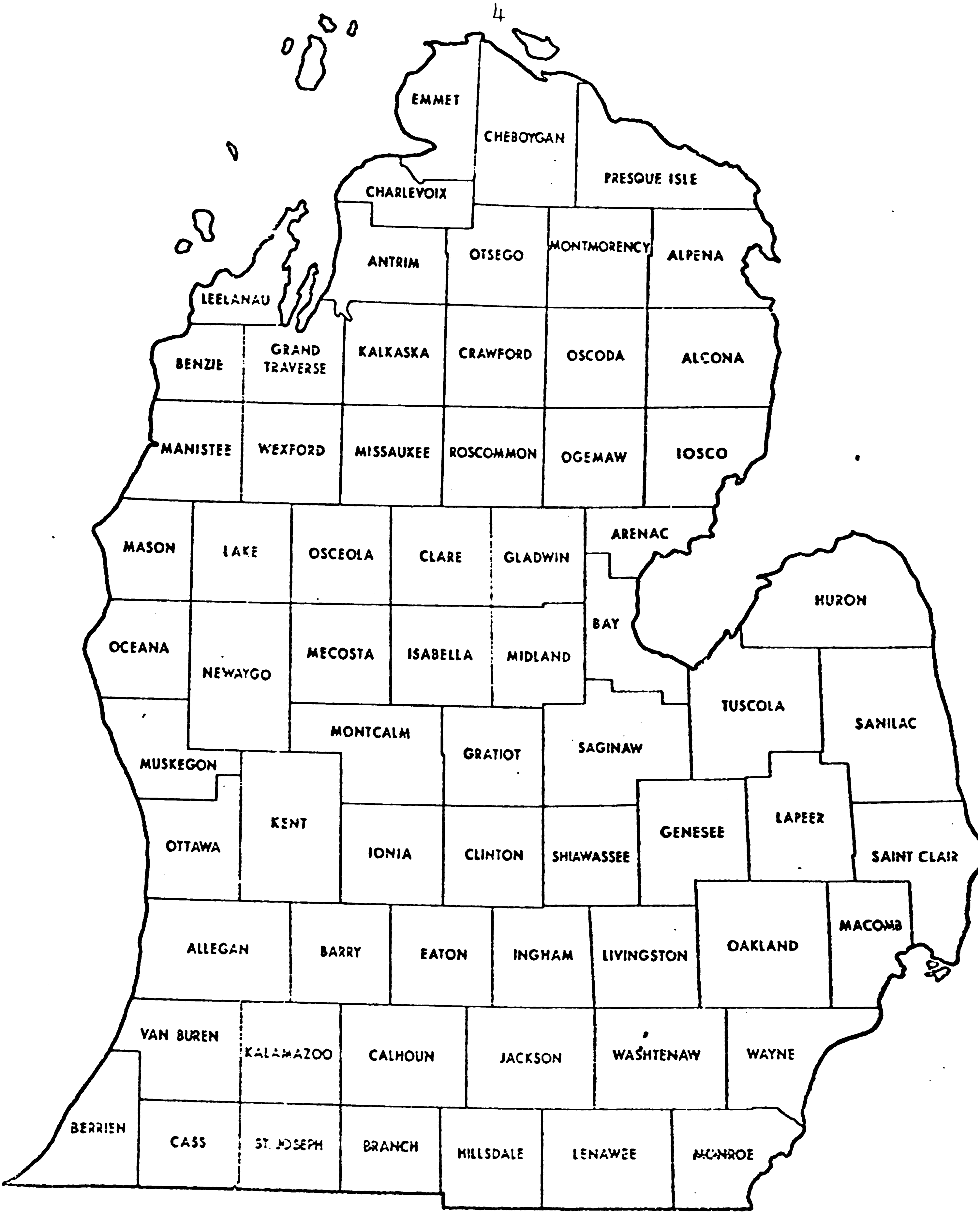


Figure 1. Area of Study

REGIONAL STRATIGRAPHY OF THE ST. PETER SANDSTONE

The St. Peter sandstone was named by D. D. Owen in 1847 from outcrops near the mouth of the St. Peter River (now Minnesota River) in southern Minnesota. The type location is at Ft. Snelling, Hennepin County, on the southeast edge of Minneapolis. The type section is 155 feet thick and is located at the bluff where the Minnesota River joins the Mississippi River.

Lithology

The St. Peter has several distinctive properties which are present throughout its area of distribution in the Midwest and Mississippi Valley region. These include a pure white color, except where locally stained when it may be yellow, brown, orange, pink or red. It is generally friable, usually cemented with a small amount of calcite, dolomite or silica. The sand is fine to medium-grained, well-rounded, well-sorted, frosted and pitted, with a composition of 99% SiO_2 at many locations. Rounded grains are almost without exception completely frosted, but the more angular grains are either not frosted or only partly frosted. Most of the finer grains are unfrosted. Much of the whiteness of the St. Peter is due to the frosted surfaces of the grains (Figure 2).

In outcrop, the St. Peter is stratified, with ripple marks and cross-bedding occasionally present. It is easily distinguishable from other sandstones in the vicinity by the presence of rounded grains, better sorting, much less clay and silt and by the absence of mica. It is rarely fossiliferous.

Distribution

The St. Peter and its equivalents extend as far west as Oklahoma, Kansas and Nebraska, and southward into Arkansas. Its eastern margin is found in Indiana and the Lower Peninsula of Michigan while to the north it reaches into Minnesota and northern Wisconsin (Figure 3). Most of the St. Peter in this area is found in the subsurface but outcrops are present in large areas of Wisconsin, Illinois, Minnesota, Iowa and Missouri. The northern edge appears to have been removed by erosion while the eastern margin seems to be defined as the limit of deposition. This is suggested by the transitional relationship of the St. Peter and overlying Glenwood in western Michigan while thin Glenwood beds unconformably overlie the Prairie du Chien or Trempealeau in the eastern part of the state where the St. Peter is not present. The absence of any outliers of St. Peter anywhere in the eastern half of Michigan appears to indicate a lack of deposition, rather than a period of deposition and erosion.

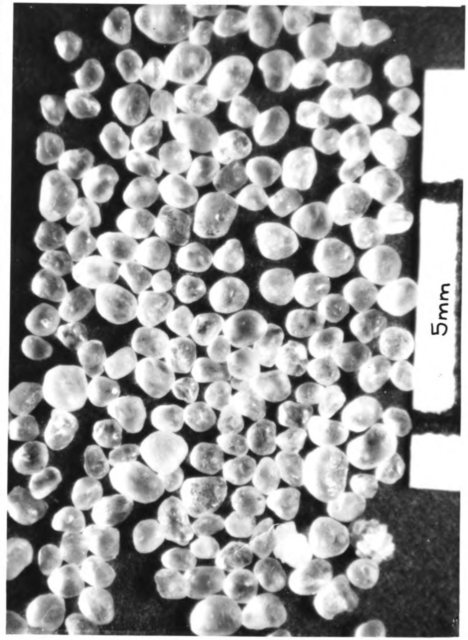


Figure 2. Photomicrograph of
St. Peter Sandstone-6x
(Illinois)

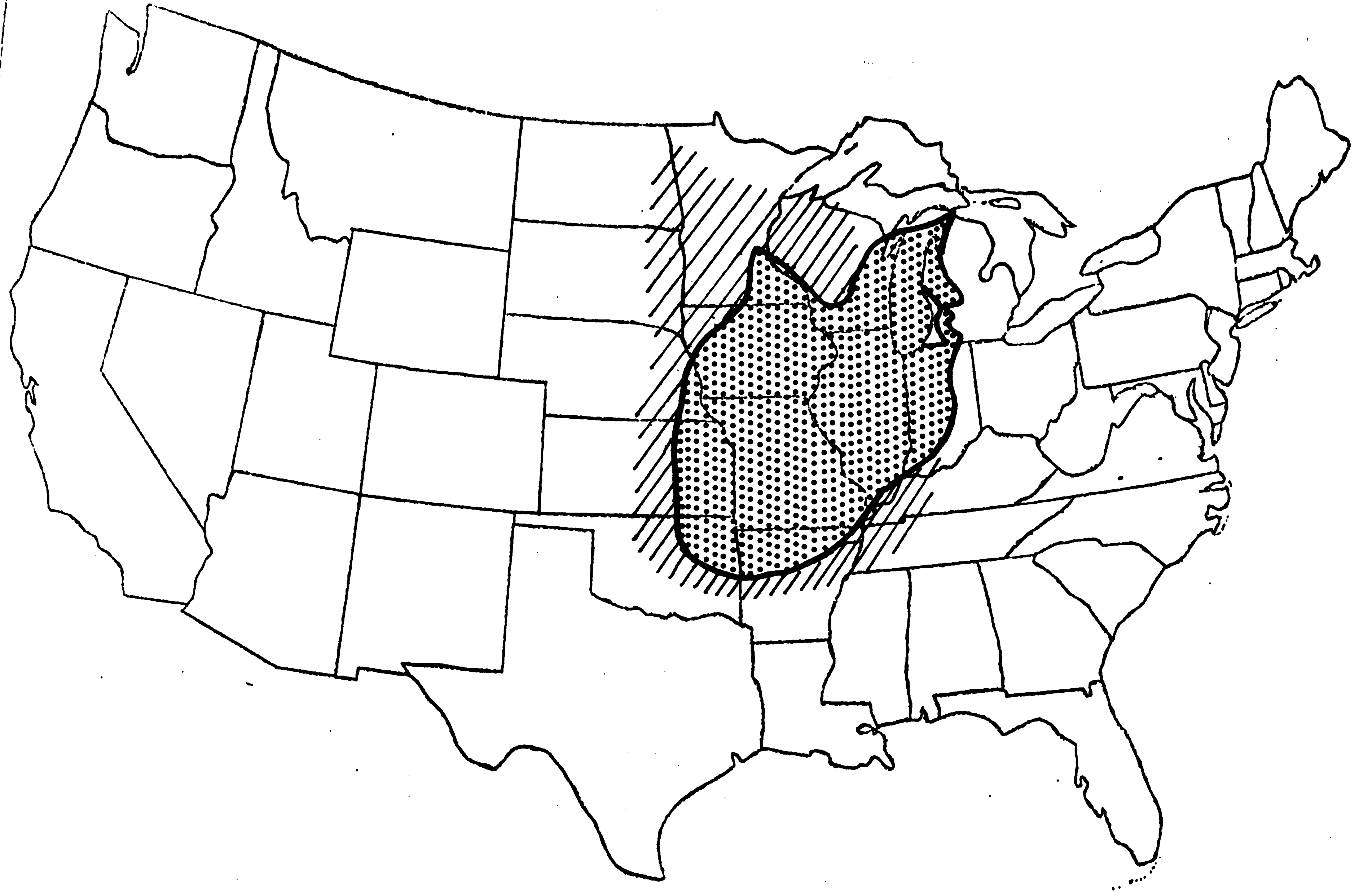


Figure 3. Areal Distribution of St. Peter Sandstone
Modified from Berkey (1906) and Thiel (1935)

The St. Peter shows a great variation in thickness throughout its extent. In Illinois it ranges from 100 to 600 feet in thickness with variations of over 200 feet occurring in wells only a few hundred yards apart indicating an irregular sub-St. Peter surface. Over most of the northern two-thirds of the state the St. Peter is 100 to 200 feet thick. However, in a narrow band across northernmost Illinois, local thicknesses of 400 to 600 feet are encountered (Buschbach, 1964). The formation appears to thin in all directions from this point with a maximum thickness in Wisconsin of 332 feet at Shullsburg (Thwaites, 1923). In eastern Wisconsin, the extreme variability is shown by its thickness of 200 feet in one place and its absence at localities less than three miles to the southeast and less than six miles to the south (Cohee, 1945). Variations of 100 feet in thickness in a horizontal distance of a quarter of a mile have been recorded.

In Indiana, the St. Peter, as a distinct lithologic unit is confined to the western part of the state. A thickness of 120 feet has been recorded in northwest Indiana from which the formation continues to thin markedly to the east and south. Local thin sandstone lenses which may represent the St. Peter occur in the central and southern portion of the state. It is not present in northeastern Indiana (Gutstadt, 1957).

Wasson (1932) doubted the existence of the St. Peter in Ohio and it is not known to occur in Ontario.

South and west into Oklahoma, Missouri, Arkansas and Kansas, the St. Peter has been correlated with the sands of the Simpson group and Everton formation. Thicknesses may reach several hundred feet in this area (Figure 4).

Stratigraphic Relations and Contacts

Along its southern margin, the St. Peter and its equivalents grade into shaly sandstones, calcareous shales and arenaceous limestones. Toward the east, because of the lack of exposures, correlations are based on the order of succession and similarity of rock types rather than on direct field evidence. This is especially true in Indiana, Ohio and Kentucky where limestones and sandstones from 40 to 230 feet thick are correlated with the St. Peter (Thiel, 1935).

In northeastern Illinois the St. Peter overlaps formations down to the Cambrian Franconia and the Eau Claire a short distance to the north. A major erosional unconformity separates the Canadian (Lower Ordovician) and Champlainian (Middle Ordovician) strata. The St. Peter sandstone, which represents the earliest Champlainian deposition in this region, unconformably overlies the Shakopee, New Richmond, Oneota, Eminence, Potosi and Franconia and underlies the shaly and dolomitic sandstones of the Glenwood formation (Buschbach, 1964). The evidence of an unconformity in this area, according to Cady, consists

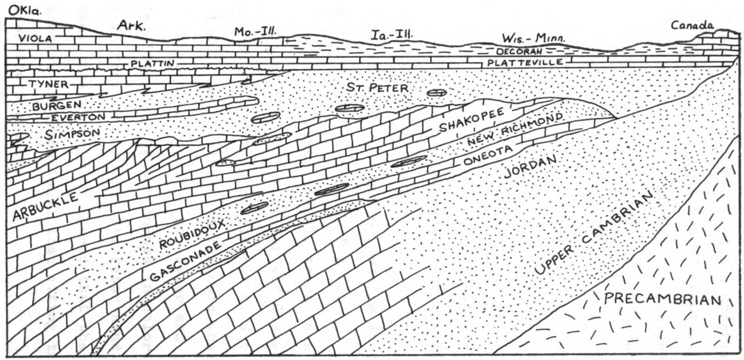


Figure 4. Generalized, Reconstructed, north-south section of the Cambrian and Ordovician Formations of the Mississippi Valley
(Adapted from G. A. Thiel, Geol. Soc. Am. Bull., 1935)

of a contact with irregular pre-St. Peter relief of over 50 feet, together with a basal conglomerate made up of weathered fragments of chert, from the underlying cherty limestones (Dake, 1921). Buschbach concurs, citing the fact that the sub-St. Peter surface is mantled by a layer of angular chert fragments intermixed with red or green shale. Much of the chert is oölitic and was derived from Prairie du Chien strata.

Willman and Payne (1942) also noted the unconformity at the base of the St. Peter showing it to lie on the Shakopee and on successively lower strata down to the Trempealeau to the north and east. Berkey (1906) indicates the unconformity represents a retreat of the Prairie du Chien sea and Thiel (1935) agreed, adding an erosion interval before the deposition of the St. Peter.

According to Lamar (1928), there is a sharp line of separation between the St. Peter and Glenwood suggestive of an unconformity. Others considered it a transition zone as noted by Bevan (1926) in Illinois where the Glenwood appears closely related to the St. Peter and the contact can be determined only by the change in color and the abrupt change from the typical St. Peter sand to fine angular sand. Knappen (1926) agreed that the St. Peter-Glenwood contact is gradational also citing the very sandy basal part of the Glenwood.

The contact in Michigan appears gradational with no evidence of an unconformity.

Source

Several ideas have been advanced to account for the source of the St. Peter.

Dake (1921) thought the St. Peter was largely derived from the Potsdam sandstones to the north and the northwest. The sands were already well-sorted and rounded and were delivered to the sea both by rivers and to a minor degree directly by winds. Distribution was accomplished chiefly by waves and currents. In this way a high degree of purity and rounding was obtained.

Thiel (1935) disagreed, observing that the Potsdam sand shows a smaller median diameter than the St. Peter so there is little justification for postulating that the bulk of the St. Peter was derived from the weathering and transportation of the older Cambrian sandstones. Trowbridge (1917) also doubted a Cambrian source saying no Cambrian sandstone was exposed anywhere at the time the St. Peter was deposited.

Tyler (1936) felt that the upper Cambrian sandstones may have furnished sands to the St. Peter, since they were undergoing erosion during at least part of the time represented by the unconformity at the base of the St. Peter. The absence or extreme rareness of garnet in the St. Peter also suggests that the Franconia and Jordan formations of Wisconsin could not have been the source for the St. Peter.

Templeton and Willman (1963) agreed with Dake and Tyler that the St. Peter was derived chiefly from the erosion of pre-existing sandstones of which the Cambrian Galesville sandstone may have been a major source.

Giles (1930) stated that by a comparison of the average results of a large number of mechanical analyses of St. Peter sand of Illinois, Missouri and Arkansas, it can be shown that the sand increases in fineness proceeding southward in the Mississippi Valley. This increase in fineness is attributed to greater attrition resulting from farther transportation from the original sources of the sandstone in the northern United States and southern Canada.

A Precambrian source was also considered a possibility by Tyler. He points out that since the Canadian Shield has served as a positive landmass throughout much of geologic time, it is to be expected that the Precambrian sediments associated with it may have served as a source for the later Paleozoic sandstones.

Trowbridge (1917) was of the opinion that quartz, liberated from granitic rocks by the decomposition of associated silicate minerals, was broken up, transported by streams, shaped by waves and currents in the sea and deposited near the shore, as the sea advanced over the land. He considered it possible that some sand was picked up by the wind from the beaches, transported a little way inland and later submerged beneath the advancing sea. In this way some eolian deposits may have been incorporated within the formation which he referred to as being generally marine.

Lamar (1928) believed in a dual source. He thought the Precambrian crystallines of the Canadian Shield and the Cambrian and Early Ordovician sandstones lying north of the area of St. Peter deposition to be the source of the St. Peter. The fact that the crystallines were probably well-weathered and the Cambrian sandstones not very firmly cemented resulted in an abundant and readily available supply of sand to the agencies transporting it to the area of St. Peter deposition.

Thiel doubted this theory saying the degree of sorting and rounding that characterizes the formation wherever it occurs, precludes the possibility of the sands having been derived from the mature weathering of igneous rocks.

The best interpretation for the source of the St. Peter appears to lie with the Canadian Shield area of northern Wisconsin, Minnesota and southern Canada.

Deposition

Many authors have speculated on the manner of deposition of the St. Peter. One group considers the sand as an eolian deposit while the other regards it as marine.

Trowbridge (1917) cites several reasons for an eolian origin:

1. The sand is of uniform texture and of a size commonly transported and deposited by the wind.
2. No wind-deposited sand contains abundant fossils.
3. The thickness of the formation varies greatly within short distances, as is true of all eolian deposits.
4. There are locations where irregular stratification appears in the sand, suggesting eolian stratification.
5. The shapes of the sand grains are not notably different from the shapes of sand grains taken from existing sand dunes.

The eolian theory presupposes that the whole area of St. Peter deposition was a desert during St. Peter time and that deposition of sand was so rapid and widespread that the underlying rock surface was buried everywhere. However, Trowbridge finds it difficult to understand how eolian deposits could be distributed continuously over so wide an area as the St. Peter covers. The St. Peter was deposited on an irregular surface of great relief. Rough topographies interfere with sand depositing winds and it is unlikely that sand could be laid down in such a manner as to fill up all the valleys and bury all the hills.

The variation in thickness of eolian sand is due to the irregular piling up of the sand into dunes. Most commonly it is the surface rather than the base of the deposit which is irregular. Except for a slight structural dip the surface of the St. Peter is horizontal. Its variable thickness is due to its irregular base rather than the upper surface. Such variability could be obtained most easily under marine rather than under eolian conditions.

The overlying Glenwood and Platteville (or equivalent Black River) formations are known to be marine and are conformable with the St. Peter. It is doubtful that an eolian deposit could grade conformably upward into marine deposits. Trowbridge concludes, therefore, that at least most of the St. Peter is marine.

Stauffer (1934) also supported marine deposition while not eliminating the possibility of eolian origin. Very little, if any, St. Peter shows typical dune structure. A few marine fossils occur within the formation and their presence suggests the marine origin of the sandstone, although at other places some portions of the same formation may be of eolian origin.

Tyler (1936), citing Twenhofel and Thwaites, said the irregular surface upon which the St. Peter was deposited and the unsorted character of the basal part of the formation is evidence against marine deposition.

Freeman (1939) thought the surface structure of the St. Peter suggested eolian origin.

Twenhofel (1945) felt the St. Peter was best interpreted as water deposits of reworked dune sands, the dunes having been formed in Early Ordovician time following emergence of the Prairie du Chien limestones, with the dunes probably obtaining the sands from Cambrian sandstones.

Thiel (1935) concluded that field evidence indicates that most of the formation is of marine origin. The stratification, ripple marks, cross-bedding and other structures are more typical of water laid deposits than of eolian sediments. His interpretation was that the St. Peter is a composite marine sandstone formed during periods of oscillation of sea level, in a shallow sea characterized by retreats and readvances of the marine environment. Each advance was separated by an interval of erosion during which wind action played a part in rounding and frosting the sand grains.

Buschbach (1964) states much of the sand was probably derived from Cambrian sandstones north of Illinois. Cross-bedding in the St. Peter is of the aqueous type indicating that the sandstone is a marine deposit.

Knappen (1926) thought that following earlier erosion, the sea returned, advancing over a surface of comparatively high relief and the St. Peter was deposited on the ocean floor.

Dake (1922) did not believe that these sands were brought in as a series of drifting dunes in an extensive interior desert. The rounding and frosting which are cited as evidence of this hypothesis are just as well developed in the Roubidoux sands, which is clearly a marine formation and therefore affords no proof. The same is true of the size and degree of uniformity of the sand grains.

The chert conglomerate at the base of the formation shows no evidence of wind action. Even bedding is more prominent than cross-bedding and nothing like dune structure is noted anywhere, even in the more protected valleys of the old erosion surface. Marine fossils have been found in Arkansas in the basal Everton beds, the first deposit above the erosion surface, as well as in the main body of the typical St. Peter in Minnesota.

Dott and Roshardt (1972) considered the St. Peter in southern Wisconsin to have been deposited in complex submarine sand waves, dunes and ridges, as earlier theorized by Pryor and Amaral (1971). The size and form of these were extremely variable, ranging up to heights in excess of 30 feet. For the limited area of study (700 square miles), the net transport direction was toward the west rather than south-southwest as previously postulated from limited data for the Upper Mississippi Valley region.

Dapples (1955) suggested transportation of the sand southwestward from the Canadian Shield region and deposition along shore lines that progressively advanced north and northwestward across the area of St. Peter deposition.

James (1894) believed the discovery of fossils, although in limited numbers, has caused the St. Peter to be generally regarded as having a marine origin. In this regard, Chamberlin (1878) says:

> The existence of the remains of marine life demonstrates that the fossiliferous portions at least are submarine deposits, while the well-rounded character of the grains, the ebb and flow structure, the shaly laminations,

> the conglomeratic portions and its relations to the adjacent formations, leave no doubt that it belongs to the common class of oceanic sand deposits.

The most convincing evidence for marine deposition was supplied by Sardeson (1892), who described 14 genera and 28 species of fossils in the St. Peter of Minnesota, including cephalopods, gastropods, pelecypods, brachiopods and bryozoans.

The properties exhibited by the St. Peter appear to identify it conclusively as a shallow marine sandstone.

Geologic History

After the deposition of the Prairie du Chien Group and equivalents, the sea withdrew and a long period of erosion took place. This produced a surface of considerable relief throughout the Mississippi Valley region upon which the St. Peter sea advanced. The sand was delivered to the sea by streams flowing southward from the exposed shield area in the northern United States and Canada.

The St. Peter represents the littoral or near-shore deposits of this shallow sea. During Glenwood time, the sea apparently continued to advance, overlapping the St. Peter and depositing the Glenwood on the Prairie du Chien unconformity. Therefore, in areas where the Glenwood overlies the St. Peter, the contact is transitional. It is unconformable where it overlies the Prairie du Chien.

It is likely that all of the strata between the Glenwood and Trenton, or the equivalent Decorah formation, were laid down continuously in a sea that transgressed steadily from south to north with no evidence that the area emerged from the sea during this time. In most areas, the St. Peter is succeeded by green or black shales which pass upward into a dolomite sequence which is then overlain by limestone.

STRATIGRAPHY OF THE ST. PETER SANDSTONE IN MICHIGAN

Lithology

The St. Peter sandstone in Michigan is a clear to white basically pure quartz sandstone. Locally it may be brown, orange or yellow due to iron staining. It is sometimes found with associated chert and pyrite fragments.

Grains are often loosely cemented with dolomite, silica or calcite although they are so friable that loose grains are not uncommon. The sandstone is generally fine to medium-grained, sub-rounded to well-rounded, frosted and sometimes pitted. The frosting is most apparent in the larger and more rounded grains while the angularity tends to increase with a decrease in grain size.

The coarsest grains are found in wells in Kalamazoo, Barry and Kent Counties with grain size decreasing in wells to the north. This may indicate deposition in a beach environment while the finer-grained sand farther north could represent sedimentation in slightly deeper water, but still a near-shore area.

Distribution and Thickness

The St. Peter is recognized in a relatively narrow band along the western side of the Lower Peninsula (Figure 5), (Plate 1). East of this area no St. Peter is encountered. The sandstone is very irregular in thickness with a maximum of 137 feet in the Moe well in Ottawa County. Its area of greatest thickness is concentrated in Ottawa, Muskegon and Kent Counties, decreasing from there in all directions. Ostrom (1967) showed the St. Peter extending to the Escanaba area in the Upper Peninsula from Wisconsin, but its occurrence at all in the Upper Peninsula seems doubtful. A cursory examination of well logs in this region shows no St. Peter and most or all of the underlying Prairie du Chien is also absent. A study by Ells (1967) and work by Dorr and Eschman (1970) further supports this interpretation.

Rocks younger than St. Peter rest upon Cambrian sandstones in the western part of the Upper Peninsula. This unconformity indicates that during the time between Late Cambrian and Middle Ordovician, either no sediments were deposited, or if they were, they were subsequently eroded. Whatever the case, it appears that while the St. Peter was accumulating in the shallow marine waters of lower Michigan, the Upper Peninsula was emergent and probably being eroded. This unconformity can be recognized from fossil evidence. Rocks below the unconformity contain fossils of Late Cambrian age while those above contain

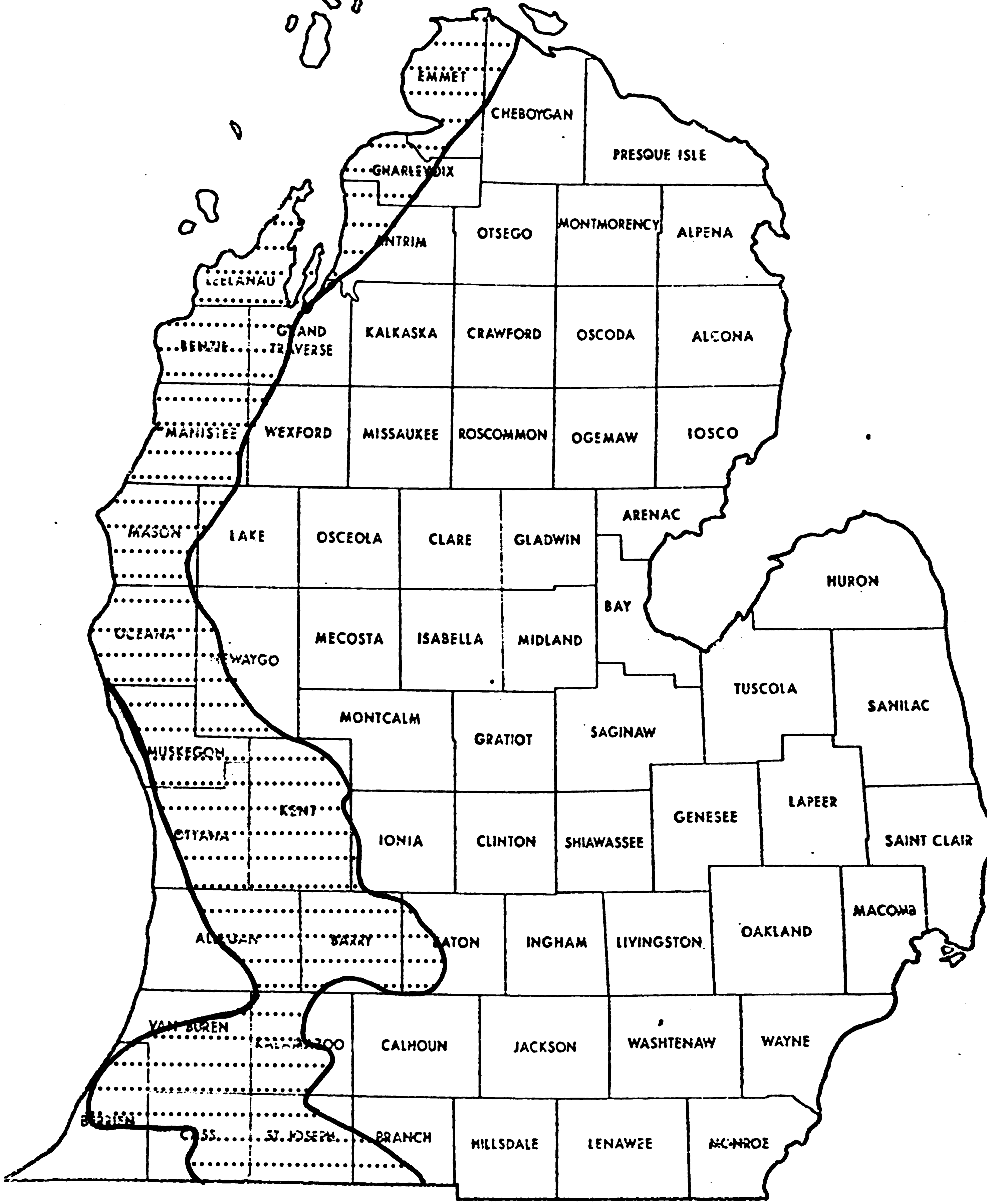


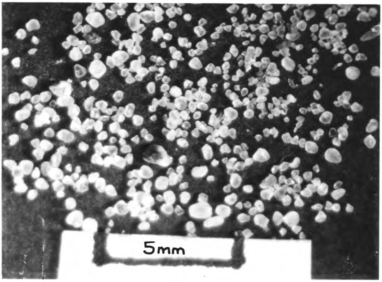
Figure 5. Distribution of St. Peter Sandstone in Michigan

Middle Ordovician fossils. Fossils of Early Ordovician age are missing (Dorr and Eschman, 1970). There is no substantial evidence that the St. Peter exists anywhere in the Upper Peninsula.

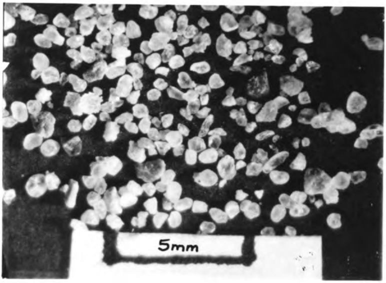
Several areas in Michigan have thick sandstone intervals that lie stratigraphically below the Glenwood and have been thought by many to be the St. Peter. Examples of these are the Beaver Island wells, the Simpson-Lake Horicon well in Otsego County, the Brazos-State Foster well in Ogemaw County and the McClure-Fox well in Clinton County. Apparently this thinking is based entirely on the stratigraphic position the sand occupies below the Glenwood. However, the writer does not recognize St. Peter in any of these wells for the following reasons:

1. The sand grains are more angular than the St. Peter with many grains appearing to show a conchoidal fracture.
2. The grains are not as well-sorted and are not as uniformly frosted as the St. Peter.
3. The sandstones are better cemented than typical St. Peter.

Because of the above reasons, the sand interval of these wells is assigned to the Prairie du Chien Group, probably Oneota formation. The Oneota in places is primarily a dolomite but appears to grade northward into a sandstone in the Lower Peninsula as noted by Cohee (1945) and Ells (1967).



St. Peter Sandstone - 6x
(St. Joseph County)



Prairie du Chien - 6x
(Kent County)

Figure 6. Photomicrographs of St. Peter and Prairie du Chien

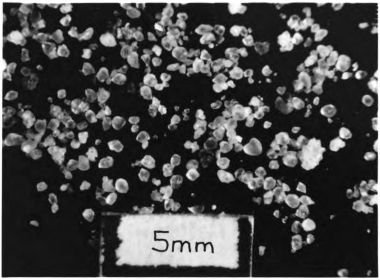


Figure 7. Photomicrograph of Fox Well Sample (Clinton County) - 6x

Stratigraphic Relations and Contacts

The St. Peter in Michigan lies stratigraphically between the Middle Ordovician Glenwood formation and Early Ordovician Prairie du Chien Group (Figure 8). The contact between the St. Peter and Prairie du Chien is unconformable. The St. Peter-Glenwood contact appears gradational because of the presence of sand in the lower Glenwood, although an unconformity exists where the St. Peter is absent with the Glenwood overlying the Prairie du Chien (Plate 2). Sand in the Glenwood closely resembles the St. Peter. However, the following properties of the

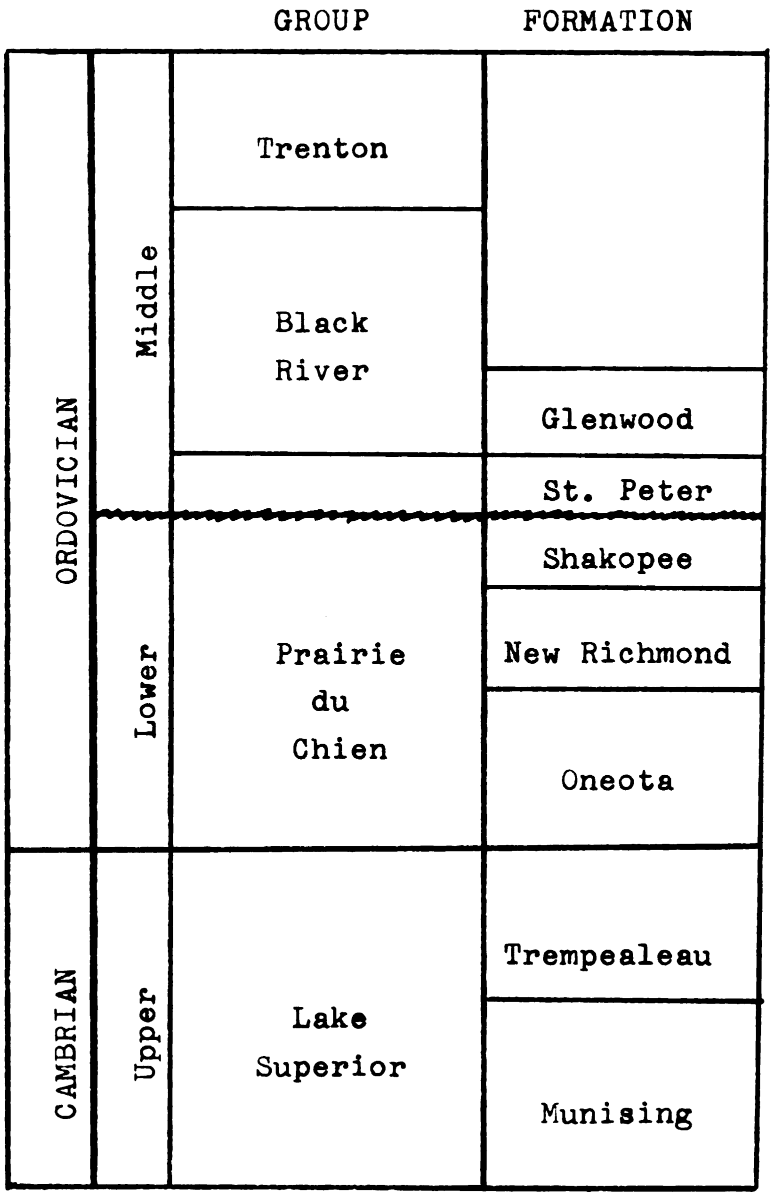


Figure 8. Generalized Stratigraphic Section of Middle Ordovician to Upper Cambrian in Michigan

Glenwood differentiate it from the St. Peter:

1. The sand is finer-grained and more angular.
2. Little or no frosting is present.
3. The sand is not as well-sorted and is often associated with shale.

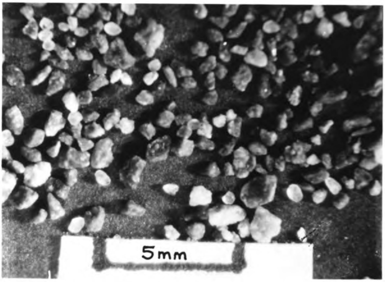


Figure 9. Photomicrograph of Glenwood (Lenawee County) · 6x

The structure contour map of the St. Peter (Plate 3) indicates a smooth upper surface which conforms to the general structure of the Michigan Basin.

Petroleum Possibilities

The St. Peter is not a producing formation for oil or gas in Michigan or neighboring states. It would appear to be a logical deep formation for exploration. In some areas, it is very thick, porous and permeable. In addition, it appears to wedge out under the impermeable Glenwood shale which should provide excellent conditions for oil accumulation.

The scarcity of oil in the St. Peter may be due to flushing, since the formation has been known to contain fresh water. It is also possible that no source of hydrocarbons was available to supply what appears to be an outstanding reservoir. A small show of oil has been reported from a well in Barry County but commercial quantities do not appear probable.

Geologic History

Prairie du Chien time closed with a retreat of the sea followed by a period of uplift and erosion which deeply dissected the land in the Lower Peninsula. Evidence of this unconformable surface is the very irregular thicknesses of St. Peter and presence of chert from the Prairie du Chien intermixed in places with basal St. Peter.

The relief of this surface must have been considerably greater in the western part of the state as shown by the variability in thickness of the St. Peter in that area. In eastern Michigan where the St. Peter is not present, the Glenwood overlies the unconformity and is much thinner than in other areas, averaging only about 15 feet. This indicates that while the St. Peter

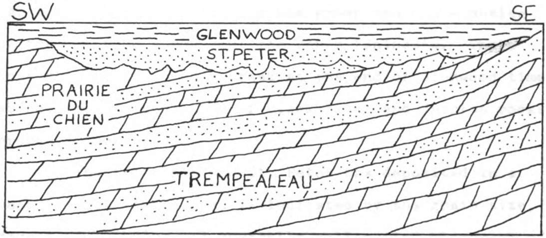


Figure 10. Stratigraphic Interpretation of Glenwood, St. Peter and Prairie du Chien in Michigan

was being deposited in western Michigan, the land was being eroded in the eastern part of the state, creating a surface of much less relief. Evidence that the eastern margin of the St. Peter sea was in Michigan is shown by the absence of St. Peter in Ontario, Ohio, eastern Indiana and eastern Michigan. The fact that no remnants of St. Peter are found anywhere in this area indicates the sand was probably never deposited.

The St. Peter sea advanced into the Michigan Basin from the south with the source of the sand being the

Canadian Shield area to the northwest. A relatively pure, non-sandy carbonate terrain surrounds the periphery of the St. Peter to the south and east, precluding these areas as a possible source.

Rivers carried the sediments to the seas where they were distributed by waves and currents. Wave action rounded the sand grains, depositing them as a near-shore and beach sand. During Glenwood time, the sea covered a far greater area, depositing the green and black shales of the Glenwood throughout the Lower Peninsula. There does not appear to be a break at the end of Glenwood time so continuous deposition of Black River and Trenton rocks probably took place.

The fact that the St. Peter was deposited in a beach or near-shore area is indicated by the grain size, degree of rounding and generally well-sorted character of the sand accomplished with continual reworking by waves in the shallow sea.

SUMMARY AND CONCLUSIONS

The St. Peter sandstone in Michigan occupies a very narrow belt along the western side of the Lower Peninsula. Other areas of thick sand intervals in Charlevoix, Otsego, Ogemaw and Clinton Counties are not part of the St. Peter but are ascribed to the Prairie du Chien Group. The St. Peter was deposited as a beach and near-shore sand in a shallow sea with the eastern edge of that sea in Michigan. This accounts for the absence of the St. Peter in Ohio, Ontario, eastern Indiana and eastern Michigan. Its irregular thickness is due to deposition on the deeply eroded Prairie du Chien Group. The sea advanced from the south as the sands were being carried down by rivers and streams from the exposed Canadian Shield area to the northwest.

Sands of the Glenwood, St. Peter and Prairie du Chien bear a close resemblance to each other in samples. Differences may be detected microscopically, however, and have been presented earlier in the manuscript.

The St. Peter does not have a characteristic trace on gamma ray-neutron logs and cannot be recognized on that basis alone since the Glenwood may sometimes overlie sand intervals in the Prairie du Chien. Only when used in conjunction with well samples can the logs be used with accuracy.

The St. Peter-Glenwood contact is gradational, but where the St. Peter is absent, the Glenwood may unconformably overlie various formations of the Prairie du Chien Group or Trempealeau Formation. In wells where the Prairie du Chien is a sandstone, it may easily be mistaken for St. Peter on the basis of geophysical logs alone.

Over 175 wells have been examined during the course of this study. It is hoped that the information provided by these wells will help in the understanding of the St. Peter sandstone in Michigan and of the early geologic history of this area.

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APPENDIX

LIST OF WELL SAMPLES EXAMINED

County Operator-Farm	Permit Number	Section	Township	Range	Elevation	Total Depth	Thickness of St. Peter	Interval
MICHIGAN WELLS								
<u>Allegan</u>								
1. Strake-Notebloom #1	21865	18	2N	11W	814	4290	-	-
2. Continental Oil-Simpson #1	23685	10	2N	12W	813	4320	-	-
<u>Alpena</u>								
3. PEPL-Ford Motor Co. #1-5	25690	5	31N	9E	684	6380	-	-
4. Teater-Nevins #1	2960	18	32N	6E	803	5665	-	-
<u>Antrim</u>								
5. Ohio Oil-Chamberlain #1	10004	14	31N	8W	738	6150	-	-
6. Lindsay-Wolgamott #1	22639	19	32N	8W	868	5778	20+	5758-TD
<u>Barry</u>								
7. Peake Petroleum-Sharkey Comm. #1	22170	19	1N	7W	900	4801	5	4779-4784
8. McClure Oil-McClellan #1	23363	3	4N	8W	869	5663	-	-

	County Operator-Farm	Permit Number	Section	Township	Range	Elevation	Total Depth	Thickness of St. Peter	Interval
9.	McClure Oil-Allerding et al #1	23573	20	4N	8W	850	5485	12	5450-5462
10.	Sun Oil-Kidder #1	7873	8	3N	9W	796	5013	11	4962-4973
11.	McClure Oil-Schaibly #1	23572	20	4N	7W	869	5700	16	5675-5691
12.	Sun Oil-Afman #1	24504	12	3N	10W	763	5000	15	4890-4905
13.	Miller Bros.-Willison #1	27731	23	1N	9W	953	4703	-	-
14.	Battle Creek Gas-Fee BD #2	BD153	14	1N	8W	930	6625	-	-
	Berrien								
15.	Sprenger Bros.-Herwig #1	6126	10	4S	18W	667	2711	-	-
16.	Security Oil & Gas-Thalmann #1	26112	10	6S	17W	792	5647	-	-
17.	Leighton-Antiss #1-A	23545	14	6S	17W	784	2970	-	-
18.	CPC-Carter #B1-36	24368	36	3S	18W	723	2589	-	-
19.	Perry & Sons-Gifford #1	23823	9	6S	18W	740	2300	-	-

	County Operator-Farm	Permit Number	Section	Township	Range	Elevation	Total Depth	Thickness of St. Peter	Interval
	<u>Branch</u>								
20.	Anderson Oil-Dobron et al #1	28167	33	5S	5W	987	3854	-	-
21.	Perry & Sons-Meadows #1	23860	32	7S	5W	1015	3555	-	-
22.	Hadson O. & G.-Brown #1	23308	14	7S	7W	978	3474	-	-
23.	Hilliard-Wagner #1	22867	7	7S	8W	883	3200	-	-
24.	McClure Oil-Sklar-Loose #1	23639	36	6S	6W	992	3635	-	-
25.	Ohio Oil-Pileri #1	19538	4	5S	6W	969	3925	-	-
26.	McClure Oil-Zias #1	23686	9	8S	6W	996	3406	-	-
27.	McClure Oil-Armstrong et al #1	23564	15	7S	6W	1010	3570	-	-
28.	Mobil-Swain Unit #1	26432	36	6S	5W	1051	3751	-	-
29.	Leonard Oil-Wells #1	23214	33	5S	7W	967	3701	-	-
	<u>Calhoun</u>								
30.	Perry & Sons-Burdick #1	22620	4	4S	7W	910	4039	-	-

	County Operator-Farm	Permit Number	Section	Township	Range	Elevation	Total Depth	Thickness of St. Peter	Interval
31.	Dow-Holden et al #1	24536	5	1S	6W	853	4899	-	-
32.	California Co.-Huepenbecker #1	24353	30	3S	5W	966	4305	-	-
33.	Jones & Sons-Wyatt #1	24715	25	2S	7W	930	4360	-	-
34.	Petrosonic-Maynard #1	23389	15	3S	6W	956	4646	-	-
35.	Turtle Drlg.-Litterbrant-Smith-Schaffer #1	23551	22	4S	4W	1014	4329	-	-
36.	Hathcock-Engelhard #1	23038	16	3S	8W	944	4025	-	-
37.	Palmer-Fountain #1	22880	12	2S	5W	932	4835	-	-
38.	Citgo-Case #1	23635	26	3S	7W	933	4141	-	-
39.	McClure Oil-Davis #1	23563	17	4S	6W	979	4128	-	-
	Cass								
40.	Perry-Wooden #1	23289	8	7S	14W	854	3590	-	-
41.	Van Raalte-Gemberling #1	17414	36	7S	14W	904	3093	38	2621-2659
42.	Perry & Sons-Kaminski #1	23290	26	7S	15W	835	2603	-	-

	County Operator-Farm	Permit Number	Section	Township	Range	Elevation	Total Depth	Thickness of St. Peter	Interval
43.	Spiller Oil-Andersen #1	22913	16	8S	14W	848	3300	-	-
	Charlevoix								
44.	Benedum & MGU-Hand #1	29079	13	34N	7W	730	5022	14+	5008-TD
45.	McClure Oil-St. Beaver Is. #2	23478	6	37N	10W	729	4803	-	-
46.	McClure Oil-Goddard et al #1	23681	19	37N	10W	647	3950	-	-
47.	McClure Oil-St. Beaver Is. #1	23435	27	38N	10W	666	5383	-	-
	Clinton								
48.	McClure Oil-Fox #1	27811	6	7N	1W	760	7787	-	-
	Crawford								
49.	Union Oil-St. Beaver Creek #C-4	28110	21	25N	4W	1226	10142	-	-
	Eaton								
50.	Petrolia-LeMont #1	22672	18	2N	5W	911	5462	-	-
51.	MOCO-Tenis #1	22945	22	3N	6W	890	5612	-	-

	County Operator-Farm	Permit Number	Section	Township	Range	Elevation	Total Depth	Thickness of St. Peter	Interval
52.	Mobil-Kelly #1	29117	24	2N	3W	856	6922	-	-
	<u>Emmet</u>								
53.	Atlantic Inland-White & Burns #1	28212	35	37N	4W	704	3958	-	-
	<u>Genesee</u>								
54.	Dugger-Hutchinson #1	24079	4	9N	8E	827	8525	-	-
	<u>Hillsdale</u>								
55.	Weed & McClure Oil-Summers et al #1	21983	28	6S	2W	1143	4042	-	-
56.	Mobil-Pitcher #1	26460	30	6S	4W	1026	3763	-	-
57.	McClure Oil-Cole #1	20220	32	6S	3W	1137	3896	-	-
58.	Houseknecht-Reynold #1	26278	8	7S	2W	1108	3910	-	-
59.	Critchfield-Adams #1	23059	23	5S	4W	1030	4093	-	-
60.	Bell & Gault-Taylor #1	25271	27	5S	2W	1160	4449	-	-
61.	Leighton-Harris #1	22925	28	7S	1W	958	3661	-	-

	County Operator-Farm	Permit Number	Section	Township	Range	Elevation	Total Depth	Thickness of St. Peter	Interval
62.	Mask, Chopard, & McClure Oil-Swaney #1	22157	16	7S	4W	1147	3794	-	-
63.	Bell & Gault-Sprangel #1	25574	22	5S	1W	1067	4321	-	-
64.	BB & C Oil-Crall #1	27045	32	8S	4W	1000	3463	-	-
65.	McClure Oil-Krieble #1	25153	28	6S	1W	1153	4101	-	-
66.	Union Dev.-Wherle #1	22819	21	8S	1W	893	3429	-	-
	Ingham								
67.	Pure Oil-Harkness #1	24518	16	2N	2W	902	6077	-	-
68.	Ketchum-Basore #1	22607	13	1N	2E	963	5473	-	-
69.	Ambassador Oil-Wild et al #1	24470	31	1N	2E	930	5830	-	-
70.	Colvin & Associates-Glaser #1	10011	14	3N	1E	908	6599	-	-
71.	Hibbard Oil-Seibly #1	28929	33	2N	2W	925	5801	-	-
	Ionia								
72.	Ambassador Oil-Burtle #1	25025	4	6N	8W	707	6146	-	-

	County Operator-Farm	Permit Number	Section	Township	Range	Elevation	Total Depth	Thickness of St. Peter	Interval
73.	An-Son Corp.-Dieterman #1	27021	4	6N	8W	677	6090	-	-
74.	McClure Oil-Troyer et ux #1	23482	28	5N	8W	803	5700	-	-
75.	Ambassador Oil-Cate et al #1	24619	34	7N	8W	765	6201	-	-
	Jackson								
76.	Leitch-Tripp #1	23044	16	4S	2W	1059	4511	-	-
77.	PEPL-Weatherwax #1-33	22568	33	4S	1W	1065	4504	-	-
78.	Ohio Oil-Watkins Farms #1	23656	24	4S	2E	1039	4650	-	-
79.	Petromin-Hartung #1	22808	9	2S	3W	1004	4996	-	-
80.	Kelly-Railer #1	23230	21	4S	3W	1076	4432	-	-
81.	Cobb-Carlson #1	22417	4	1S	3W	939	5280	-	-
82.	Texaco-Benn #1	26548	16	2S	2W	927	5085	-	-
83.	Rovsek & Volk-Burnett #1	22950	31	3S	2W	1030	4668	-	-
84.	Collin & Black-Dancer #1	22275	29	3S	1W	985	6088	-	-

County Operator-Farm	Permit Number	Section	Township	Range	Elevation	Total Depth	Thickness of St. Peter	Interval
Kalamazoo								
85. Turtle Drlg.-Rumsey #1	23035	10	1S	12W	778	3860	-	-
86. Alexander-Bowerman #1	23004	11	4S	10W	881	3632	7	3578-3585
87. Ashland Oil-Hayward #1	27508	31	3S	10W	867	3660	-	-
Kent								
88. Smith Petroleum-Sherk et al #1	11540	21	5N	10W	758	5200	37+	5163-TD
89. Crawford-Hessler #1	20103	27	9N	10W	901	6508	15+	6493-TD
90. An-Son Corp.-Parmeter #1	26908	26	9N	10W	902	6652	12	6608-6620
91. Beacon Resources-Goss #1	27296	35	9N	10W	937	6598	-	-
92. Ambassador Oil-Ten-Have #1	24826	6	8N	9W	857	6560	-	-
93. Ambassador Oil-Francisco #1	24627	35	8N	9W	860	6473	-	-
94. Producers Committee-Riddering #1	9166	30	7N	12W	739	5222	67	5132-5199

	County Operator-Farm	Permit Number	Section	Township	Range	Elevation	Total Depth	Thickness of St. Peter	Interval
95.	An-Son Corp.-Wingeier #1	26946	2	7N	9W	848	6393	-	-
	Leelanau								
96.	Lindsay-Kirt #1	22627	6	30N	11W	913	5750	17+	5733-TD
	Lenawee								
97.	Seven Seas Co.-Francouer #1	22112	18	6S	3E	876	3900	-	-
98.	Farmers Oil-Myers Estate et al #1	23277	5	5S	2E	1004	4406	-	-
99.	McClure Oil-Allen #1	22886	14	5S	4E	859	4046	-	-
100.	Bernhardt O. & G.-Gerber Estate #1	25016	25	7S	5E	680	2901	-	-
101.	Ashland Oil-Muck #1	26411	13	7S	2E	827	3800	-	-
102.	Pannell-Weber #1	22716	29	7S	1E	897	3630	-	-
103.	Socony-Vacuum Oil-Downing Estate #1	3353	36	5S	3E	698	3437	-	-
104.	A.P.A. Oil-Gemple #1	23087	25	7S	3E	750	3427	-	-

	County Operator-Farm	Permit Number	Section	Township	Range	Elevation	Total Depth	Thickness of St. Peter	Interval
105.	Neyer-Brasher & Wife #1	24905	28	8S	1E	830	3306	-	-
106.	Besko Enterprises-Brenke #1	25807	2	6S	4E	790	3752	-	-
107.	Eckert-Taylor #1	10448	32	8S	5E	715	3902	-	-
108.	Trolz-Hawkins, Strubli, & Beal #1	23838	20	6S	1E	977	3962	-	-
109.	Lawton-Drewyer #1	23751	25	6S	2E	860	3752	-	-
110.	Lenawee Co. Road Commission-Wheaton #1	22781	21	5S	1E	1089	4420	-	-
	Livingston								
111.	Strake-Lopez #1	24771	14	1N	6E	915	5618	-	-
112.	Humble Oil-Soule Unit #1	23374	2	3N	3E	928	5685	-	-
113.	PEPL-McPherson Estate #1	2179	35	3N	4E	914	5958	-	-
114.	Brazos O. & G.-Kizer #1	25868	14	2N	4E	927	7205	-	-
115.	Mobil-Messmore #1	27986	11	3N	5E	968	7589	-	-
116.	Patrick Pet.-Kleinschmidt #1	28752	17	2N	3E	948	6092	-	-

	County Operator-Farm	Permit Number	Section	Township	Range	Elevation	Total Depth	Thickness of St. Peter	Interval
117.	Texaco-American Aggregates #1	27720	15	1N	6E	897	5560	-	-
	Macomb								
118.	PEPL-Heide #1	22439	7	5N	13E	777	5721	-	-
119.	M.C.G.C.-Nyland & Ciaranitaro #1	22825	34	3N	13E	598	4695	-	-
120.	CPC-Halmich #3-1	26214	1	4N	13E	690	5214	-	-
	Manistee								
121.	Simpson-Northrup et al #1	24557	8	24N	13W	896	7140	10+	7130-TD
	Mason								
122.	Miller Bros.-Mikula #1	27155	3	20N	17W	674	5519	42+	5477-TD
123.	Van Raalte-Bahr #1	25001	18	17N	16W	705	5890	55+	5835-TD
124.	Superior Oil-Sippy et al #17	18905	25	17N	16W	723	7249	10	6002-6012
125.	Brazos O. & G.-Dow-Brazos-Taggart Unit #1	17789	27	19N	18W	640	6617	65	5360-5425

	County Operator-Farm	Permit Number	Section	Township	Range	Elevation	Total Depth	Thickness of St. Peter	Interval
	Monroe								
126.	Sturman-Chapman #1	11221	29	5S	10E	597	3377	-	-
127.	Consolidated Developers-Bragg #B-2	8449	30	6S	6E	677	3250	-	-
128.	Ferguson & Garrison-Shimp #1	25494	16	7S	6E	678	3671	-	-
129.	Bauer-Madalinski #1	22423	17	8S	6E	673	2492	-	-
130.	McClure Oil-Stotz-Williams #1	25062	10	7S	7E	637	2989	-	-
131.	Bell & Marks-Lennard #1	23659	15	5S	6E	684	3313	-	-
	Muskegon								
132.	Muskegon Oil-Heinz #5	309	8	10N	16W	636	4754	44+	4710-TD
133.	DuPont-Fee #1	Mineral Well	36	12N	18W	643	6514	-	-
	Newaygo								
134.	Miller-Seaman #1	22918	15	11N	13W	803	6236	-	-

County Operator-Farm	Permit Number	Section	Township	Range	Elevation	Total Depth	Thickness of St. Peter	Interval
135. Thunder Hollow-Thompson #1	26662	20	15N	14W	821	6585	-	-
Oakland								
136. Collin-Gowan et al #1	19055	35	1N	7E	1020	5850	-	-
137. Holly Oil-Nelson #1	22665	9	4N	7E	995	6851	-	-
138. Top of Michigan Development Co.-Williams #1	13072	22	4N	8E	1024	6488	-	-
Oceana								
139. Peake Pet.-Skidmore #1	22801	11	16N	16W	976	6062	-	-
140. Pure Oil-Peters #1	24087	36	15N	17W	727	5531	21+	5510-TD
Ogemaw								
141. Amoco-A.B.G. Hunt Club #1	28456	28	23N	3E	865	10195	-	-
142. Brazos O. & G.-State-Foster #1	25099	28	24N	2E	1457	12996	-	-
143. Ohio Oil-Reinhardt Con. #1	12898	35	22N	2E	903	11012	-	-

	County Operator-Farm	Permit Number	Section	Township	Range	Elevation	Total Depth	Thickness of St. Peter	Interval
	Otsego								
144.	Simpson-Lk. Horicon Corp. #1	25873	2	29N	4W	1402	8372	-	-
	Ottawa								
145.	Holland Suco-Disposal Well #1		30	5N	15W	608	5894	-	-
146.	Holland Suco-Disposal Well #2		30	5N	15W	607	5910	-	-
147.	Michigan Pet.-Moe #1	537	6	9N	13W	704	6310	137	5503-5640
	Presque Isle								
148.	Shell-Tarantula #1-13	29372	13	33N	5E	761	6739	-	-
149.	Fain-Porter Drlg.-Weide #1	24999	33	33N	7E	803	5458	-	-
150.	Lindsay-Sellke #1	22638	20	34N	5E	836	5137	-	-
151.	McClure Oil-Ocqueoc #1	27725	24	35N	2E	718	4737	-	-
152.	Pan-Am-Draysey #1	27199	29	35N	2E	792	5940	-	-
	Sanilac								
153.	Humble-Hoppinthal #1	25357	16	9N	15E	760	6784	-	-

	County Operator-Farm	Permit Number	Section	Township	Range	Elevation	Total Depth	Thickness of St. Peter	Interval
154.	Hallwell G. & O.-Spencer #1	26480	27	9N	15E	750	6289	-	-
155.	Phillips Pet.-Long #1	24441	27	10N	16E	760	6503	-	-
	<u>Shiawassee</u>								
156.	Lee-Ferris #1	22379	5	5N	2E	842	6815	-	-
157.	Mobil-Jelinek-Ferris #1	27907	5	5N	2E	831	7056	-	-
	<u>St. Clair</u>								
158.	CPC-CPC BD #1	BD139	31	4N	15E	609	4627	-	-
159.	Bernhardt O. & G.-Puzzuoli #1	25780	17	2N	16E	579	4186	-	-
160.	Goll, Graves & Mechling, Inc.-Baldwin et al Comm. #1	25024	6	6N	16E	678	5492	-	-
161.	St. Clair O. & G.-Hurst #1	196	26	5N	16E	620	4770	-	-
162.	NADCo-Conrad #1	26086	1	6N	15E	696	5496	-	-
163.	Lanphar-Lyle #1	25632	28	7N	13E	806	6337	-	-

	County Operator-Farm	Permit Number	Section	Township	Range	Elevation	Total Depth	Thickness of St. Peter	Interval
	St. Joseph								
164.	Simpson-Reed #1	23839	15	7S	9W	864	3134	-	-
165.	Mahnke-Fee #1	1244	2	6S	11W	833	3520	-	-
166.	Nat. Indus.-Cook #1	28005	14	6S	11W	830	3130	10	3050-3060
	Tuscola								
167.	Simpson-Sattelberg #1	23890	8	13N	9E	668	10130	-	-
168.	Simpson-Novesta Twp. et al #1	25609	16	13N	11E	727	9296	-	-
169.	Rayburn-Watchorn & Wells Comm. #1	20209	5	10N	9E	865	9128	-	-
	Van Buren								
170.	Turtle Drlg.-Kern #1	23524	34	4S	14W	911	3117	10	3050-3060
171.	McClure Oil-Daly #1	27501	30	4S	16W	809	2771	7	2680-2687
172.	Miller Bros.-Jolicoeur #1	28590	16	1S	14W	758	3422	-	-

County Operator-Farm	Permit Number	Section	Township	Range	Elevation	Total Depth	Thickness of St. Peter	Interval
Washtenaw								
173. Peake Pet.-Bohnenstiehl #1	23380	34	4S	4E	917	3951	-	-
174. Sun Oil-Meyer #1	25607	16	3S	4E	965	4524	-	-
175. Trolz-Trolz #1	25950	20	4S	3E	1013	4640	-	-
Wayne								
176. PEPL-Ford Motor Co. #1	25560	19	2S	11E	588	3917	-	-
177. H. R. Ford Well		22	2S	10E	612	4050	-	-
178. Woodson Oil-Det. House of Correction #3	19496	17	1S	8E	892	5483	-	-
179. Taggart-George et al #1	19329	18	1S	8E	855	5130	-	-

County	Section	Township	Range	Type of Sample	Depth of Sample
		ILLINOIS			
1. McLean	19	26N	3E	Core	------
2. Cook	9	39N	14E	Core	1025 Feet
3. LaSalle		33N	3E	Outcrop	------
		INDIANA			
1. Newton	15	31N	8W	Core Chips	1282 Feet 1328 Feet 1369 Feet
2. Newton	25	27N	9W	Core Chips	547 Feet 600 Feet 640 Feet
3. Jasper	6	31N	7W	Core Chips	1320 Feet 1520 Feet 1680 Feet