A PRE-PENNSYLVANIAN PALEOGEOLOGIC STUDY OF MICHIGAN

By

Timothy Arthur Strutz

A THESIS

Submitted to

Michigan State University

in partial fulfillment of the requirements

for the degree of

MASTER OF SCIENCE

Department of Geology

1978

ABSTRACT

A PRE-PENNSYLVANIAN PALEOGEOLOGIC STUDY OF MICHIGAN

By

Timothy Arthur Strutz

A study of gamma-ray/neutron logs of four units: the Mississippian Bayport Limestone, the Pennsylvanian System, the Jurassic "Red Beds", and the Pleistocene glacial drift provided the framework for determining the regional distributional patterns and interrelationships of these sediments in the Michigan Basin. Isopach maps were constructed for each of these along with structure contour maps of the Bayport and the Mississippian-Pennsylvanian unconformity, and a pre-Pennsylvanian paleogeologic map.

Stable tectonic conditions have existed in the Michigan Basin since the Late Mississippian. In many areas the Bayport is completely eroded away and is reflective of river drainage systems. Bayport structural "highs" often are indicative of closures in the underlying Michigan Stray sandstone which are known to be productive of gas. Depocenters of all these units are located near the center of the Lower Peninsula of Michigan. The Jurassic implies an asymmetrical aspect to the Michigan Basin configuration.

ACKNOWLEDGEMENTS

The author wishes to thank Dr. James H. Fisher, my thesis committee chairman, for his advice, assistance, and friendship during the preparation of this study. Appreciation is also extended to Dr. A.T. Cross and Dr. F.W. Cambray for their advice and review of the thesis.

I am also grateful to Garland Ells of the Michigan Geological Survey for his cooperation in obtaining data, and the late Harold McClure of McClure Oil Company for allowing me the use of their files. Gratitude is also extended to the Tenneco Oil Company for their financial assistance which enabled the completion of this paper, and to Tom Campbell of Merritt Enterprises for the many hours of help with the computer programing and mapping. Thanks are also extended to Mike Puzio for the final drafting of many of the maps and to Deb Kirchen for the typing of this manuscript.

Finally, I would like to thank my parents, Mr. and Mrs. Arthur C. Strutz, for all their encouragement both prior to and during this study.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF PLATES

INTRODUCTION

Purpose of the Study

The intent of this study is to determine the regional distributional patterns and interrelationships of sediments that range from Late Mississippian through the Pleistocene in the Michigan Basin. It should also be helpful in determining whether the time of deformation of the Michigan Basin is restricted to the Mississippian or if it is evident in the Pennsylvanian. Interpretations of the paleodrainage patterns, origin of the sediments, and the possibility of traps for oil and gas in this area of the Michigan Basin will also be determined.

Methodology

This study is concerned with four different units which range in age from the Late Mississippian to the Pleistocene. They include: the Mississippian Bayport Limestone, the Pennsylvanian Saginaw and Grand River Formations, the Jurassic "Red Beds", and the Pleistocene glacial drift. The mapping of these units is based upon well data obtained from Michigan State University, the Geology Division of the Michigan Department of Natural Resources, and local oil companies.

Extensive well coverage (Figure 1) is available in almost all of the study area and the data used in mapping these units came almost exclusively from gamma-ray (Figure 2), neutron and gamma-ray, and sonic well logs. Additional information was available through core hole records and well samples. The gamma-ray log is the most consistent and accurate means for delineating lithologies in the Michigan Basin while the neutron and sonic logs are useful when looking for variations in porosity. Mechanical logs are made on nearly all the oil and gas wells drilled in Michigan and are valuable data sources for studying the lithology of the subsurface. They have the added advantage of being continuous which alleviates the problems of sample lag, lost samples, sample mixing, and lost circulation.

Sample coverage is fairly extensive and can be valuable. However, sampling error is common and because of this, the accuracy of sample tops may be questionable. Thus, samples were examined only on certain wells to determine the top of the Jurassic "Red Beds" on the mechanical logs, and in an attempt to differentiate between the Pennsylvanian Grand River and Saginaw Formations. Sample descriptions were also of value. These were from published survey logs and served as an aid in checking lithologies in areas where facies merged or units fluctuated markedly. Over 670 well logs were used in this study. First correlations were made along the Albion-Scipio fault trend due to the dense well coverage of that area. From this initial point, extensions were made to include the remainder of the study area.

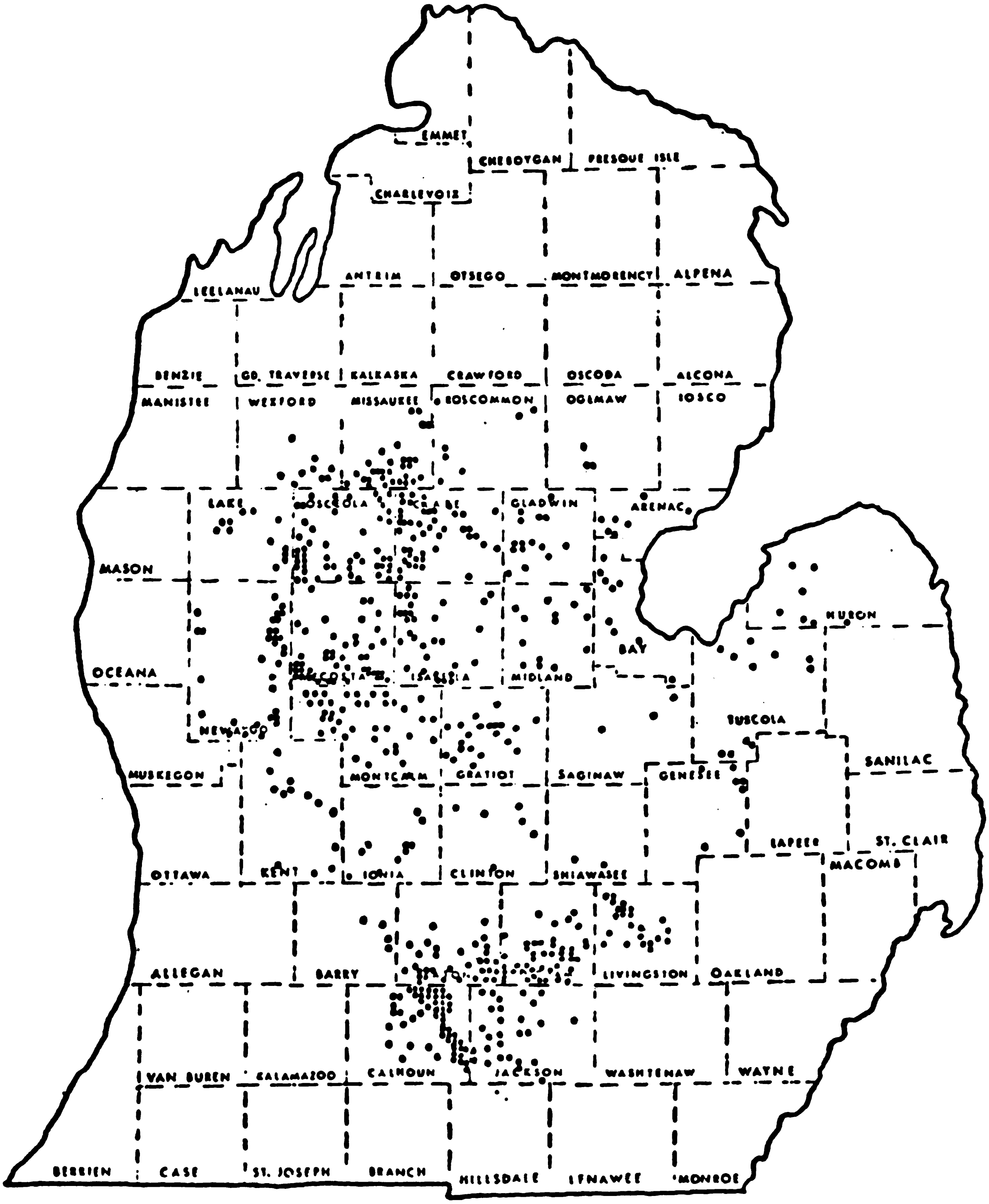


FIGURE-1 CONTROL POINT DISTRIBUTION.

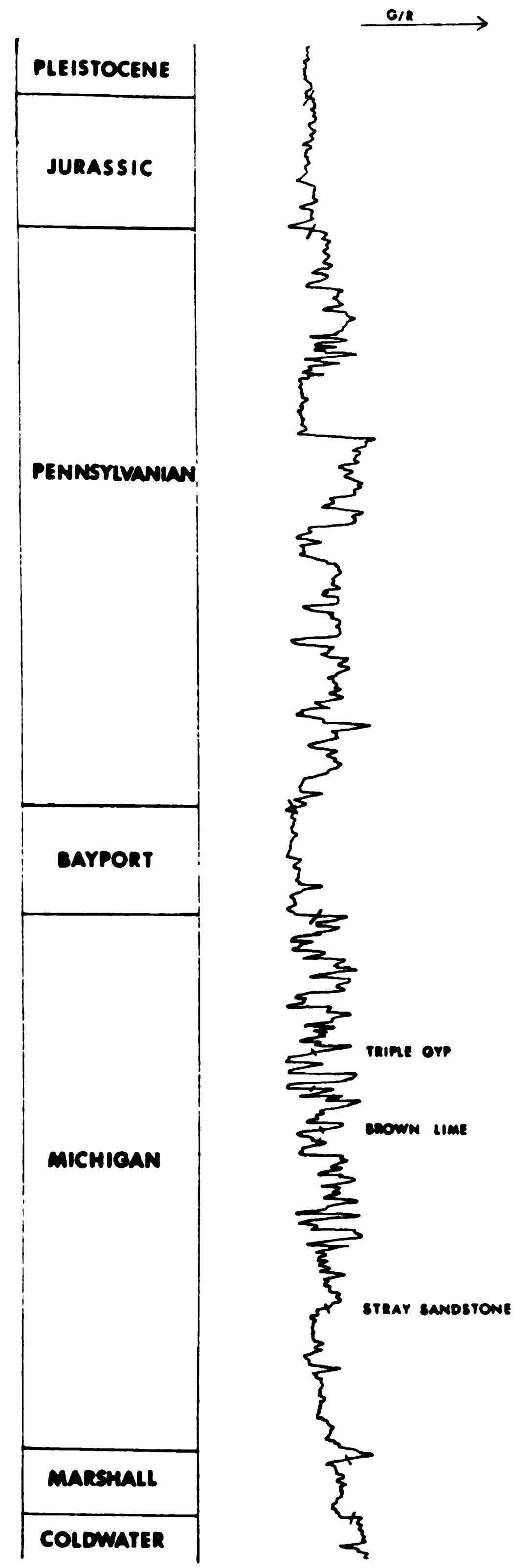


FIGURE-2 STRATIGRAPHIC SECTION WITH TYPICAL GAMMA RAY CURVE

Eight maps were constructed based on the data obtained from the well logs. A Pre-Pennsylvanian paleogeologic map was constructed along with structure contour maps for the Mississippian-Pennsylvanian unconformity and the Mississippian Bayport Limestone. Isopach maps were made for the Pleistocene glacial drift, the Jurassic "Red Beds", strata of the Pennsylvanian System, and the Mississippian Bayport Limestone. A map showing the major Michigan Stray sandstone gas fields in relation to Bayport structural "highs" was also constructed.

The General Purpose Computer Program (GPCP) was used in the initial phase of the construction of many of these maps. This FORTRAN computer program displays functions of two variables graphically as contour maps. It is suited for a number of contouring applications such as, gravitational and magnetic fields, strata depths in geophysics, temperature and barometric pressure in meterology, and in electrical and magnetic field intensity. It is very flexible and is able to present the contours in a form suitable for display on a Calcomp plotter. The surface can be specified either by giving its values at the mesh points of a rectangular array, or by giving its values at random points in a region of interest. This program will grid data. That is, the values of the function at the mesh points of a rectangular array are estimated as are the contours produced from this gridded data. These data are generated from random data by a procedure which analytically constructs a smooth surface passing through every data point.

The resulting contour may be influenced by the 35 nearest data points or less. This feature is of much value in certain problems, such as in geologic mapping where the user needs a certain amount of control over the shape of the contours. These computer maps were then subject to alteration wherever it was deemed necessary.

Previous Investigations

Studies of the Late Mississippian and younger strata in the Michigan Basin have been limited and for the most part, have not been concerned with showing relations between systems. However, there have been some investigations of individual formations or systems from this geologic time sequence.

Work on the Bayport Limestone has been limited. Cohee (1951) and McGregor (1953) both did work on the Mississippian but neither placed much emphasis on the Bayport. Bacon (1971), concluded from his study on the Bayport of the Wallace Stone Company Quarry at Bayport, Michigan, that the formation was deposited in a sabkha environment. Lasemi (1975) did an analysis of the stratigraphy and subsurface geology of the Bayport in the Michigan Basin. He subdivided the formation into three units and drew isopach and lithofacies maps of each unit. From these, he concluded that the upper and lower units were deposited in intertidal or lower supratidal environments, while the middle one was deposited after a major transgression.

The most comprehensive studies of the Pennsylvanian System in the Michigan Basin have been conducted by Kelly (1936) and Shideler (1965). Kelly, provided valuable information regarding Michigan faunas and floras of Pennsylvanian age and also provided needed lithologic and stratigraphic descriptions. Shideler, divided the Pennsylvanian into three intervals and constructed isopach maps for each. The sediments of the oldest interval are Morrowan in age and formed in either a neritic or deltaic environment. The middle unit resulted from alluvial flood plain and shallow neritic conditions and is Atokan in age. The youngest unit is Desmoinesian in age and is mostly fluvial sediments with some minor shallow neritic deposits. According to the Michigan Geological Survey, the youngest Pennsylvanian sediments are Conemaugh. However, no sediments of this series have ever been found in the Michigan Basin (Cross, 1978). Shideler, also provided important information regarding the variability and thickness of the lithology of the Pennsylvanian System in Michigan, and constructed a Pre-Pennsylvanian paleogeologic map of the basin. He found Bayport Limestone to be the prevalent formation below the unconformity while Michigan Formation strata were found along the edges of the basin and in scattered locations in the center.

Additional work on the Pennsylvanian was conducted by Cohee, et al. (1950), and Kalliokoski and Welch (1976). They compiled a great deal of subsurface data and through it, prepared estimates of Michigan's coal reserves.

Prior to 1931, the term "Red Beds" had been referred to only occasionally in the geologic literature of Michigan. Newcombe (1931), referred to them as a series of shales, sandstones, and gypsum which were widespread in the center of the Michigan Basin. From this, Martin (1936) listed them as Permo-Carboniferous. A more recent study was done by Sander (1959). He applied mineralogical, sedimentological, and thickness distribution analyses to paleogeographic considerations and concluded that they formed under marine conditions. Cross (1966) was the first to assign the "Red Beds" of the Michigan Basin to the Jurassic. Shaffer (1969) palynologically determined that they are Jurassic in age.

There have been many studies of the Pleistocene drift of the Michigan Basin. Hough (1958) was concerned with the evolution of the Great Lakes basins. Kelly and Farrand (1967) constructed various maps which show the boundaries of the Wisconsin drift, preglacial drainage patterns, and the principle morainic systems. A more recent investigation was done by Welsh (1971) on the patterns of compositional variation in some glaciofluvial sediments in the Lower Peninsula of Michigan.

GENERAL STRUCTURE

The Michigan Basin is a roughly circular intracratonic basin with an areal extent of approximately 122,000 square miles. It consists of the entire Lower Peninsula of Michigan, the eastern half of the Upper Peninsula, the area underlain by Lake Michigan and Lake Huron, and small portions of Ontario, Ohio, Indiana, Illinois, and Wisconsin.

The basin is surrounded by major positive tectonic structures (Figure 3) that have greatly influenced and partially controlled the configuration of the basin (Ells, 1969). It is bounded to the north and northeast by the Canadian Shield, on the northwest and west by the Wisconsin Arch and Highlands, and to the east by the Algonquin Arch. The Findlay Arch separates it on the southeast from the Appalachian Basin, while the Kankakee Arch marks the boundary between the Michigan Basin and the Illinois Basin. All of these structures have been active in the geologic past and are believed to have originated in either the Precambrian (Pirtle, 1932; Newcombe, 1933) or in the Cambrian (Cohee, 1951).

The Michigan Basin has within it many intrabasinal structural features that include a number of joint systems, and fault patterns. There are two recognizable major trends. The dominant one has a northwest-southeast direction and is

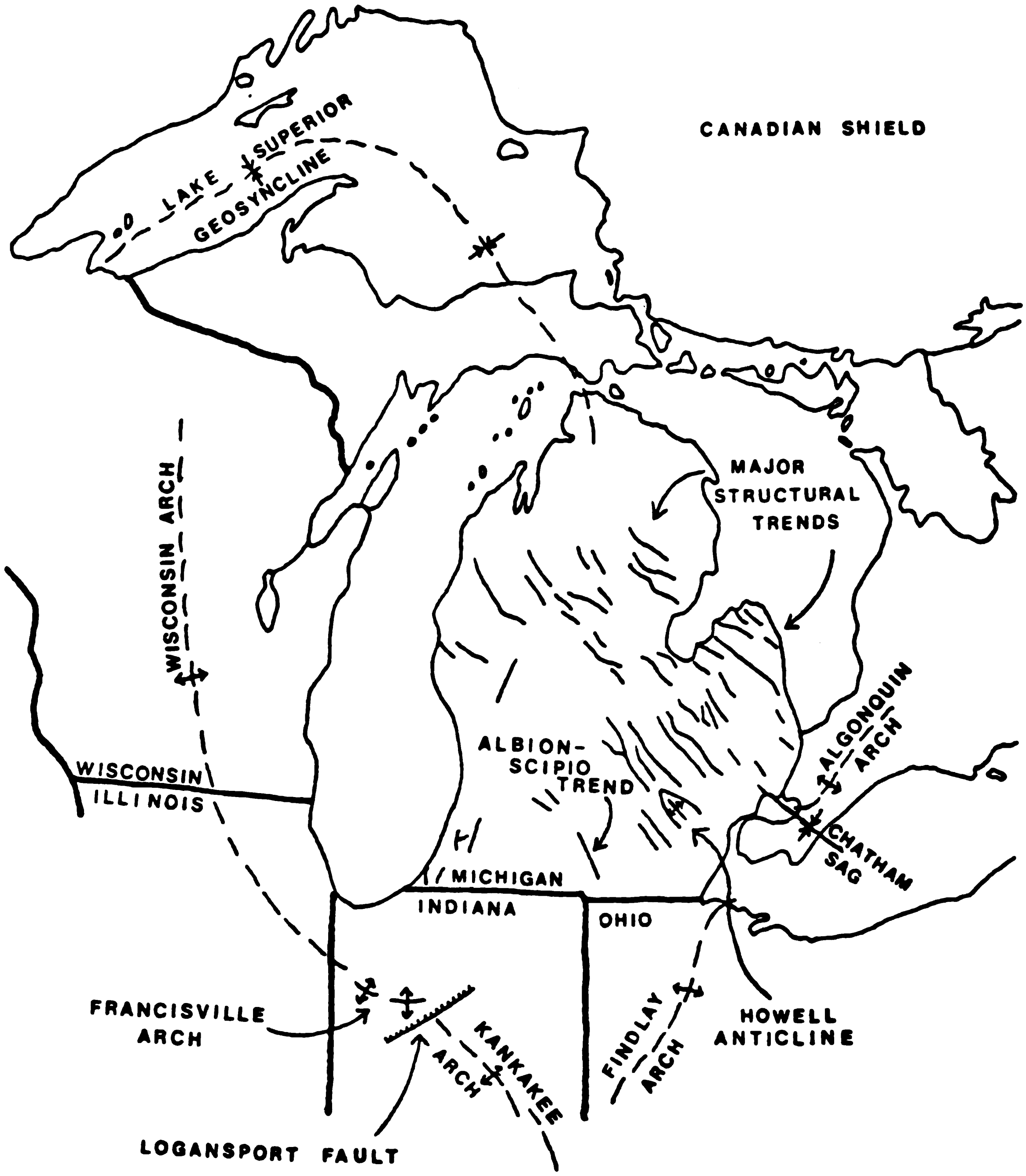


FIGURE-3 MICHIGAN BASIN AND SURROUNDING STRUCTURAL ELEMENTS
(MODIFIED AFTER ELLS, 1969)

concentrated in the eastern, southeastern, and central parts of the Lower Peninsula of Michigan. It includes such features as the Albion-Scipio fault trend and the Howell Anticline. A northeast trend is also distinguishable but occures mostly in the western and southwestern portions of the Lower Peninsula. It is generally accepted that the Precambrian basement complex is primarily responsible for these structural patterns (Pirtle, 1932). Folding occurred throughout the Paleozoic while the major deformation is Late Mississippian (Landes, 1948).

The Michigan Basin in approximately its present day outline first formed in Middle Ordovician time (Fisher, 1969) and is fairly shallow with the depth to the Precambrian being only 14,000 to 15,000 feet. The largest structural feature in the basin is the Howell Anticline. It trends in a northwest direction and is located in Livingston and Shiawassee Counties. It is believed to have formed at the beginning of Coldwater time (Paris, 1977) and is due to recurrent movements along old lines of weakness in the Precambrian basement (Kilbourn, 1947). Thus, the anticline formed as a result of faulting which caused the northeast side of the fault to be uplifted.

There are three dominant theories which have been presented on the orgin of the Michigan Basin. Many (Newcombe, 1933; Fisher, 1978) believe that the structural features of the basin are due to faulting and zones of weakness in the Precambrian basement complex. Hinze (1963) claimed that the formation was due to the addition of basic rocks to the

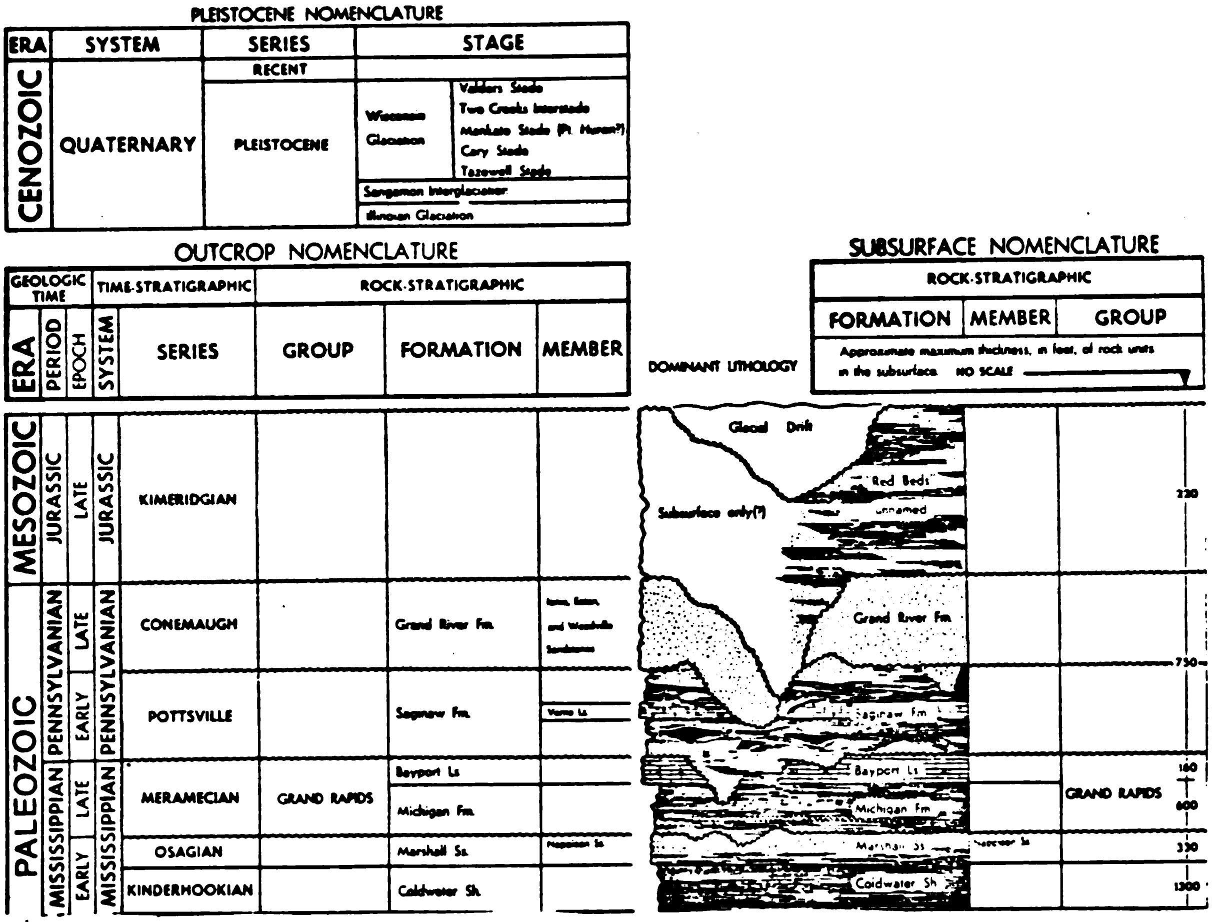
Precambrian basement which was followed by an increase in isostatic subsidence as a result of the added weight. In 1976, Haxby, et al., suggested that diapirs of mantle material moved upward and penetrated the lower crust. The intense heat resulting from this upward progression caused the metastable gabbro to change to ecologite. After cooling, this newly formed denser material caused the basin to subside in an effort to achieve isostatic equilibrium.

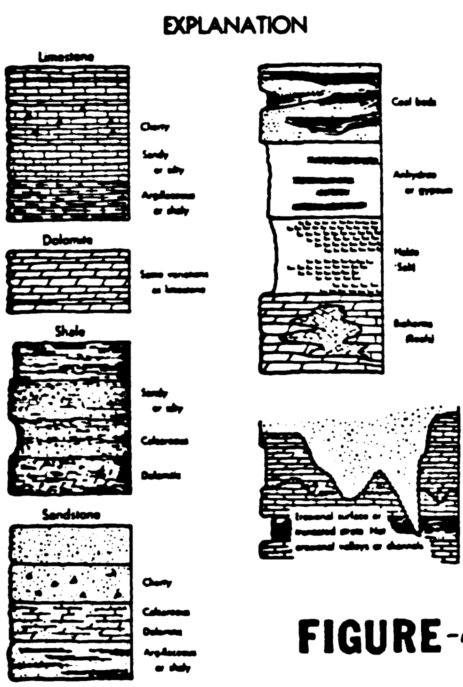
GENERAL STRATIGRAPHY

Some of the names used in this study are based on the State of Michigan stratigraphic chart (Figure 4). Lithologic contacts, with the exception of the Jurassic, were based on work done by the Michigan Basin Geological Society (Fisher, et al., 1969). The Jurassic was picked from mechanical logs after the top was determined through sample analysis and could be consistently correlated with most of the written descriptions.

Mississippian

The Bayport Limestone Formation is Late Mississippian in age and forms a part of the Grand Rapids Group in the Michigan Basin area. It is a buff colored, dense limestone and dolomite that has minor amounts of chert, sand, and shale (Kropschot, 1953). It lies with minor disconformity upon the Michigan Formation which consists mostly of shale, with some dolomite, sand, and gypsum. The Michigan Formation is made up of informal subunits which include: the Triple Gyp, Brown Lime, Stray-stray sandstone, Stray dolomite, and Stray sandstone. Of these, only the Stray-stray and Stray sandstones are known to be producers of hydrocarbons in economic quantities. The Saginaw Formation of Pennsylvanian age unconformably





INFORMAL TERMS

Principal oil and gas pays, and informal terms used in petroleum exploration and applied to parts of formations or groups in the subsurface.

STRATIGRAPHIC POSITION	INFORMAL TERMS	PAYS
Basal sandstones of Saginaw Fm.	Parma sandstone	
In lower part of Michigan	triple gyp. brown lime stray-stray ss. stray dol. stray ss.	 Gas Gas & Oil
Marshall Ss.		Gas & Oil
Coldwater Sh.	Coldwater lime Weir sand Coldwater red-rock	 Gas

FIGURE-4 STRATIGRAPHIC SUCCESSION IN MICHIGAN

MISSISSIPPIAN THROUGH RECENT

(AFTER MICHIGAN DEPARTMENT OF NATURAL RESOURCES) overlies the Bayport Formation and fills the irregular surface which is the result of the post-Bayport erosion. Brachiopod studies (Oden, 1952) have been used to correlate the Bayport with the lower part of the Maxville limestone of Ohio, and the St. Genevieve and St. Louis limestones of the Mississippi Valley. Lithologic observations indicate that the Bayport was deposited in a fairly stable tectonic environment. It may be subdivided into three units on the basis of lithology and fossil rich zones (Lasemi, 1975).

The initial Bayport sediments were deposited after the cessation of the predominantly late evaporite depositional phase of the Michigan Formation. A slight rise in sea level caused the evaporite lagoons to give way to carbonate flat deposition. Both the lower and upper units are similar in lithology and consist mostly of dolomite with some chert and interbedded sandstone. They were deposited in an intertidal or lower supratidal environment (Lasemi, 1975).

The middle unit is comprised of a relatively pure fossiliferous limestone that was deposited after a major transgression. This provided an excellent environment for the development of organisms. It may also indicate that the Michigan Basin was connected to adjacent basins where the open circulation of sea water produced fairly similar environments (Lasemi, 1975). A gradual regression preceded this which provided a similar environment of deposition to that of the lower unit. Fluctuations in sea level did occur and are indicated by sandstone lenses.

After the deposition of the upper unit, the entire area was uplifted and extensive erosion resulted in the removal of much of the upper unit. The major area of subsidence was in the northeastern part of the basin while the major positive features were located to the south, east, and northwest.

An isopach map (Plate 1) illustrates the thickness variations of the Bayport strata. This displays a generally progressive thickening from the peripheral areas towards the interior. However, irregularities in this trend do exist and are due to post-Mississippian erosion. In fact, in many areas of the basin, the Bayport has been completely eroded away as river systems cut downward through the strata as they moved towards the interior of the basin.

The major depocenter (Figure 5) is in southwestern Clare and northwestern Isabella Counties. Smaller centers are found in eastern Mecosta, northeastern and west central Montcalm Counties. The structural center and depocenter of this formation conform quite well with the present basin depocenter which is located in northwestern Arenac and northeastern Gladwin Counties (Fisher, 1978). This suggests that relatively stable tectonic conditions have existed since the Meramecian. The maximum thickness of the Bayport is 252 feet and occurs in Montcalm County. There are areas of abnormal thickness that are found in the east and northeast portions of the basin. These are primarily due to greater post depositionsl erosion of the upper Bayport in the west and southwest areas of the basin.

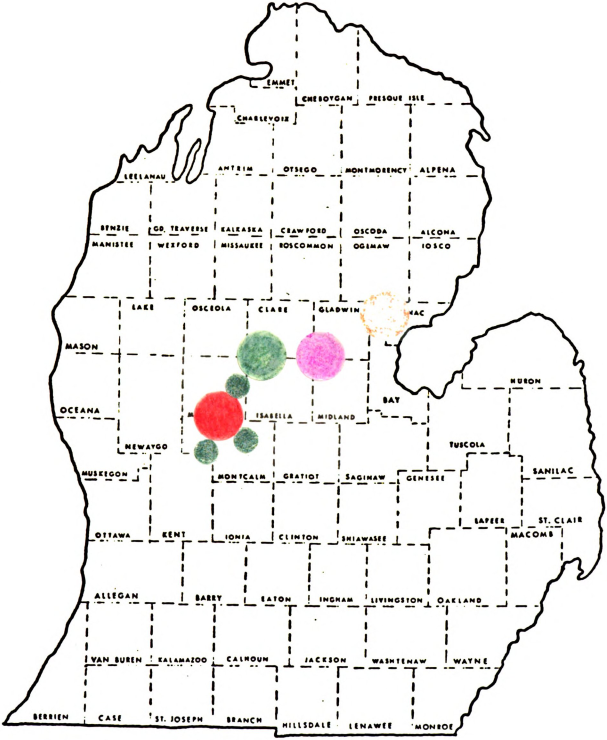


FIGURE-5 COMBINED DEPOCENTERS.

BAYPORT | JURASSIC
PENNSYLVANIAN | PRESENT

A structure contour map (Plate 2) constructed on the base of the Bayport Formation reflects the irregular thickness of the Michigan Formation. It indicates that a number of local basins and domes were present at the time of deposition, or were produced by subsidence at the time of deposition. There is a good relationship between structure and thickness. Thicker Bayport accumulations can be found associated with structurally lower areas while thinner accumulations lie on structurally higher topography.

Many of the Bayport structural highs reflect known closures in the Michigan Stray sandstone (Plate 3). These Stray closures are quite small with most not exceeding 125 feet of relief (Elowski, 1978). These are of economic significance as many are associated with natural gas production. Stray production can be found in Newaygo, Osceola, Clare, Missaukee, Montcalm, Roscommon, and Isabella Counties. These areas besides producting natural gas, are also becoming valuable for natural gas storage.

Not all Bayport structural "highs" correspond to known closures in the Michigan Stray sandstone. Four large closures are located south of all known Stray production. The closest significant structural "high" is in southeastern Montcalm County while the others are found in south central Gratiot, northeastern Clinton, and northeastern Eaton Counties. The one in southeastern Montcalm County is the most probable apparent structure for Stray production. This is based on the fact that the Stray undergoes a facies change to the southeast and thus, is primarily restricted to the seven county area where there is known Stray production. Thus, it may not be found underlying any of the Bayport "highs".

There are five structural highs that are surrounded by Stray production but are themselves non-productive. These areas are located in southwestern Missaukee, eastern Osceola, northeastern Newaygo, eastern Mecosta, and eastern Isabella Counties. The total thickness of the Michigan Formation does fluctuate and it is possible that these highs reflect a thicker sequence of Michigan strata between the top of the Stray sandstone and the Bayport. Thus, the structural closure exhibited in the Bayport may not be present in the Stray. The structures could also lack a necessary source and thus, not be productive. However, there is the possiblity that natural gas may be found associated with these highs and may be located as further drilling defines the apparent structure.

It is possible that the Bayport highs may become more pronounced in the lower strata. Thus, drilling of these areas may prove profitable for the accumulation of hydrocarbons from not just the Michigan Stray sandstone, but from other lower formations as well. Existing Stray structural gas fields may also be indicative of structural closure in deeper formations that may subsequently also be of economic value.

The Mississipian System is separated in the Michigan Basin from the overlying Pennsylvanian strata by a major unconformity. The Mississippian strata have been subjected to much post-depositional erosion and the resulting pattern is illustrated by a Pre-Pennsylvanian paleogoelogic map (Plate 4).

The strata below the unconformity are entirely of Mississippian age and range from Kinderhookian Coldwater Shale to the Bayport Limestone of Meramecian age. The Bayport is the most extensive paleosurface directly underlying the Pennsylvanian strata. It is of quite variable thickness and is found underlying most of the central portion of the Lower Peninsula of Michigan.

The Michigan Formation underlies the Pennsylvanian throughout much of the structurally higher peripheral areas and occurs in the interior as inliers most likely due to erosional activity. Shideler (1965), did paleoslope studies and indicated that Michigan was essentially a topographic basin at the beginning of Pennsylvanian time with stream deposits being dominant over other types of sedimentation. He also speculated that a centripetal drainage system may have existed immediately prior to Bayport time. He based this on the crenulate pattern of the contact between the two formations as an indication of extensive stream dissection.

The Michigan Formation exhibits evidence of stream dissection in at least four areas. The most prominent one can be seen extending towards the center of the basin, northwest and west off the Howell Anticline and the surrounding high peripheral areas. Bayport sediments have also been eroded away by a similar process in Eaton County. This river ran to the northeast and Michigan sediments are exposed as far as

Clinton County. Michigan strata can also be found along the periphery of Arenac County. This channel ran to the southeast towards the interior of the basin. A fourth channel can be seen in Missaukee County. This channel flowed in a southerly direction towards the basin interior.

Marshall Sandstone subcrops below the Michigan Strata are limited in extent and are generally found scattered along the periphery of the basin. Most of them are located along the northwest flank of the Howell Anticline in Shiawassee County and are attributed to the greater uplift and subsequent erosional activity of this area. Smaller subcrops are found in Bay, Eaton, Genessee, Livingston, and Tuscola Counties, and are also due to erosional activity.

The most pronounced erosional effects are exhibited along the axis of the Howell Anticline which trends northwest through Livingston and Shiawassee Counties. In this area, pre-Pennsylvanian deformation and subsequent erosion have resulted in Coldwater Shale being exposed along the crest of the structure. The Coldwater is restricted to Livingston and Shiawassee Counties and represents the oldest formational unit directly underlying the Pennsylvanian strata.

There is no apparent relationship in the Michigan Basin between the structures at the base of the Bayport and the unconformity between the Mississippian and Pennsylvanian Systems (Plate 5). This is due to the nature of the two surfaces as the base of the Bayport reflects the topography of the underlying Michigan Formation.

Pennsylvanian

Pennsylvanian strata underlie an area of approximately 11,200 square miles in the Michigan Basin and are confined to the central portion of the Lower Peninsula (Figure 6). The roughly elliptical distribution pattern extends from central Missaukee and Roscommon Counties in the north to Jackson County in the south. The eastern limit is in Tuscola County while the western boundary is found in Newaygo and Lake Counties. The Pennsylvanian System of Michigan is divided into two major formations, the Saginaw below and the Grand River (Kelly, 1936). These have been divided into a number of informal subunits. The basal sandstones of the Saginaw Formation have been referred to as the Parma sandstone while the Grand River Formation includes the Woodville, Eaton, and Ionia sandstone members. The Parma is a clean, white, quartzose sandstone that has some localized conglomeratic, dark shale lenses. It varies in thickness and has its maximum thickness in Shiawassee County where it is 220 feet locally (Shideler, 1965).

The Saginaw Formation was originally called the "Coal Measures" (Winchell, 1861). This was in reference to the coal bearing strata located between the Parma and Woodville sandstones. It later was expanded (Lane, 1909) to include the other lithologic units of the formation. Presently, the Saginaw is described as a heterogeneous association of terrestrial and marine strata that consists of interbedded sandstones,

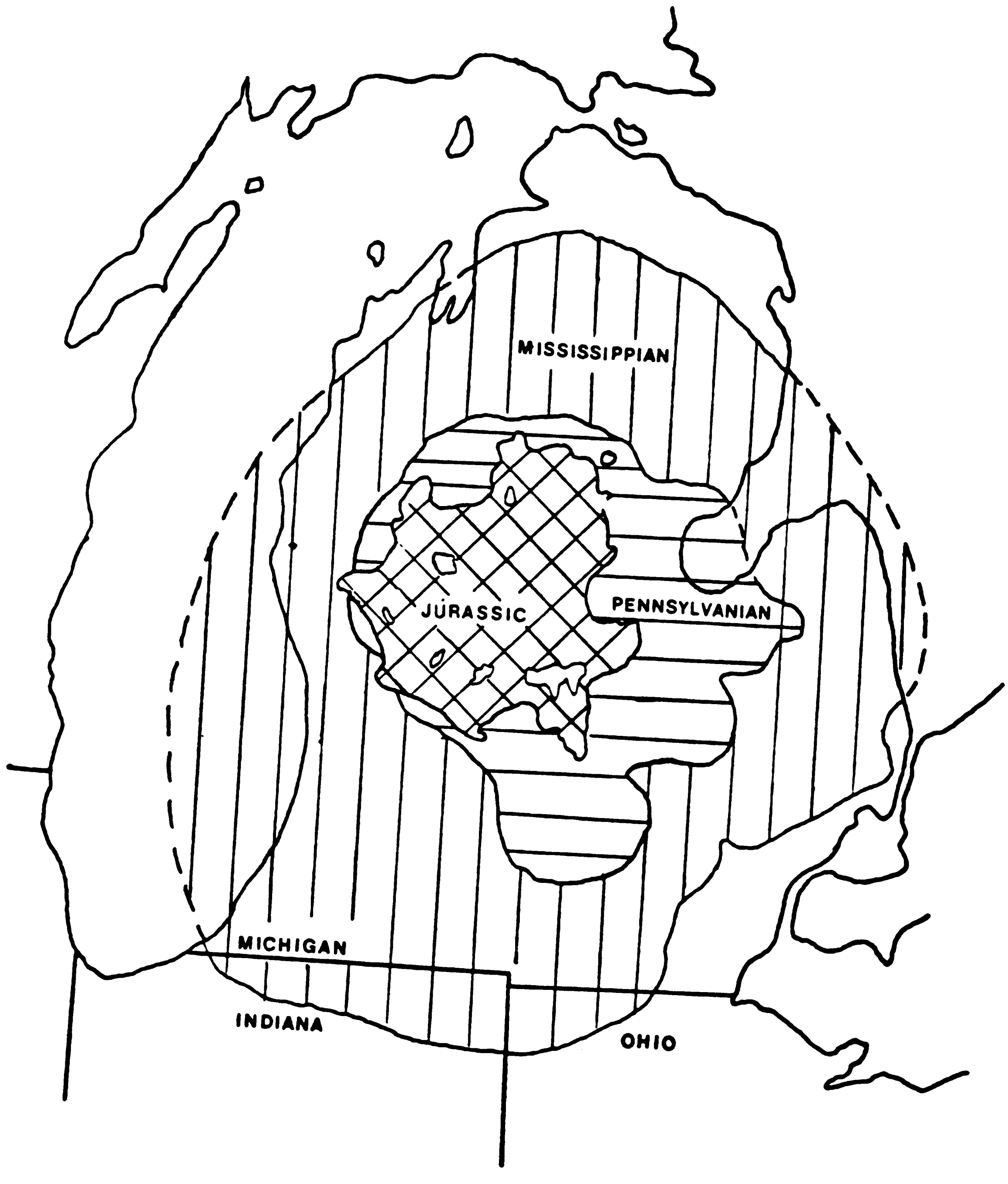


FIGURE-6 DISTRIBUTION OF MISSISSIPPIAN, PENNSYLANIAN, AND JURASSIC STRATA IN THE MICHIGAN BASIN.

shale, coal, and carbonate units. The sandstone is usually argillaceous and fine-grained. The shale is abundantly fossiliferous and ranges from a dark fissile marine shale to a light colored underclay (Schideler, 1965). The coals are quite thin, limited in areal extent, and of little economic value. The main workable seams are usually two to four feet thick and consist of blocky bituminous grade coal (Kalliokoski and Welch, 1976). The carbonate units are thin, very argillaceous, and commonly fossiliferous (Shideler, 1965).

Located above the Saginaw Formation and resting unconformably on it is the Grand River Group. This includes all the post-Saginaw formations of Pennsylvanian age and represents the youngest Pennsylvanian strata within the Michigan Basin. It has been divided into three members (Kelly, 1936), the Woodville, Ionia, and Eaton. It has a distinctive brownish-red color and the basal portions may be conglomeratic.

Shideler (1965) separated the Pennsylvanian of the Michigan Basin into three time-stratigraphic units (Figure 7). The oldest is Morrowan in age and includes all the strata from the Mississippian-Pennsylvanian unconformity up through the shale that usually overlies the Saginaw coal. The next unit is Atokan in age and includes all the strata found between the shale overlying the Saginaw coal and the Verne Limestone member. The youngest Pennsylvanian sediments are Desmoinesian in age and are made up of all the strata from the base of the Verne member up to the base of the Jurassic "Red Beds" or, where the Jurassic is absent, to the Pleistocene

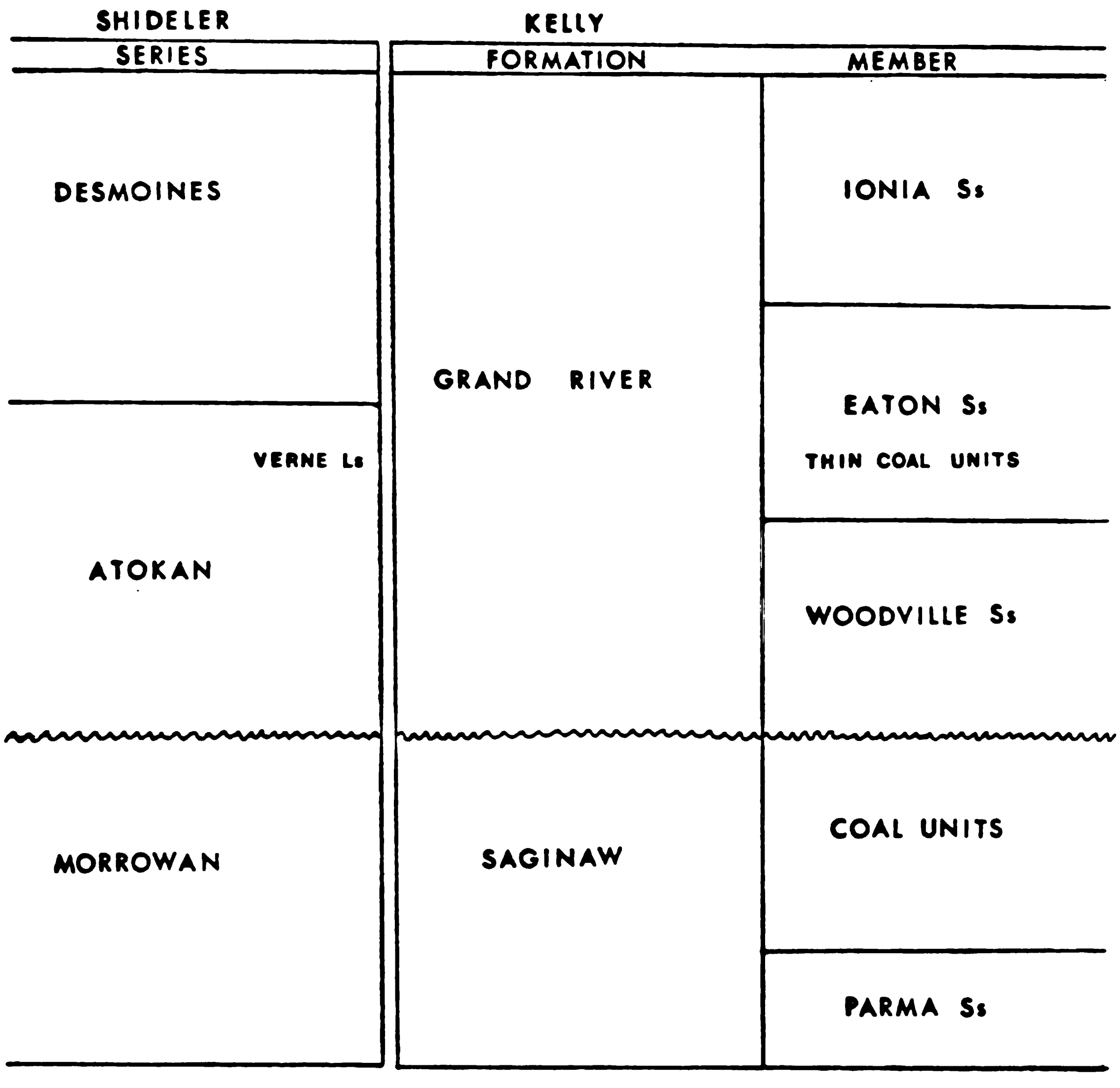


FIGURE-7 THE PENNSYLVANIAN SYSTEM IN MICHIGAN.

drift. The actual age of the youngest interval is difficult to determine due to the sparse fossil content and the unconformable relationship of the assemblage.

The Pennsylvanian strata of the Michigan Basin have been subjected to extensive post-Pennsylvanian erosion and are isolated from the Pennsylvaian strata of adjoining basins. Kelly (1936) postulated that there was a seaway connection between the Michigan and Illinois Basins. This was based on similarities between the marine faunal assemblages of the two areas.

The thickness variations of Pennsylvanian strata are illustrated in an isopach map (Plate 6). The map indicates a progressive thickening from the peripheral areas of the basin towards the interior. Its steepest gradients are located along the western flank of the Howell Anticline and in the northeast in Arenac County. The apparent depocenter (Figure 5) is located in southeastern Clare, southwestern Gladwin, northwestern Midland, and northeastern Isabella Counties.

The maximum reported thickness is 721 feet which is found in Gladwin County. There are several areas of thick sediment accumulation which can be attributed to post-depositional erosion, differential compaction, and to the pre-Pennsylvanian topography.

Jurassic

The Pennsylvanian System of the Michigan Basin is normally overlain by thick deposits of Pleistocene drift.

However, in some localities the material directly overlying the Pennsylvanian is a series of red impure sandstones and shales with interbedded gypsum, which have been identified as the Jurassic "Red Beds".

The Jurassic "Red Beds" are restricted to the subsurface of the central Michigan Basin (Figure 6) and volumetrically represent less than one percent of the sedimentary accumulation in Michigan. The evidence of their distribution, lithology, stratigraphic position and thickness was unavailable until the advent of deeper exploratory drilling towards the center of the basin. The "Red Beds" were seldom mentioned prior to 1931. Some of the early accounts were by Lane (1909) and Smith (1917). They tended to include the "Red Beds" in a sequence of sandstones in the Grand River Group of Pennsylvanian age. Newcombe (1931) introduced the term into the Michigan stratigraphic nomenclature and Martin (1936) claimed that they were Permo-Carboniferous in age. Cross (1966) is credited with correctly placing them in the Jurassic. He based this on the distinctive mid-mesozoic, pre-Angiosperm pollen and spore flora.

The Jurassic of the Michigan Basin has an irregular oval distributional pattern and has an areal extent of approximately 5,500 square miles (Shaffer, 1969). The "Red Beds" are confined to the central portion of the Lower Peninsula and are present over most or all of Clare, Osceola, Mecosta, Isabella, Gratiot, and Montcalm Counties. Peripheral deposits and scattered erosional remants can be found in sections of Ogemaw, Roscommon, Missaukee, Wexford, Lake, Newaygo, Kent, Ionia, Clinton, Saginaw, Midland, Gladwin, and Oceana Counties. The "Red Beds" lie unconformably below the Pleistocene glacial drift and unconformably above the underlying strata. These underlying strata are mostly Pennsylvanian in age, however, some periperal Jurassic beds to the west, directly overlie Mississippian rocks.

The bulk of the "Red Beds" lies somewhat west of the center of the present Michigan Basin configuration and the apparent depocenter (Figure 5) is located in southeastern Mecosta and north central Montcalm Counties. The Jurassic sediments are dominantly a reddish-brown shale with some sandstone and siltstone lenses. Fairly pure gypsum may also occur as a bedded evaporite and be up to eighty feet thick (Sander, 1959).

Color has been the chief criterion used in differentiating the Jurassic strata from the underlying beds. Most of the Pennsylvanian and Mississippian strata that are directly below the Jurassic are gray to black siltstones and sandstones. Besides this, the sandstones of the Grand River Group are usually micaceous and slightly feldspathic while those of the Jurassic are not (Shaffer, 1969).

The maximum thickness of the Jurassic, slightly over 350 feet, is found in Mecosta County. The thickness does vary considerably (Plate 7) within the area of distribution. This is due to the modification by irregularities of the pre-Jurassic topography and by post-"Red Bed" erosion modified by

Pleistocene glacial scouring. The thickest Jurassic areas are situated slightly west of the present depositional center, and because of this, an asymmetrical aspect is imparted to the Jurassic basin. This may be reflective of greater abrasion on the eastern side of the basin, especially by the Saginaw glacial lobe, an originally asymmetrical basin which received Jurassic sediments, or a greater amount of sediment deposition in this area (Shaffer, 1969). The present distribution and thickness of the Jurassic conforms to, and was most likely strongly influenced by the configuration of the Michigan Basin and the pre-exisitng topography. However, in a general sense, the Jurassic slopes basinward at a somewhat more gentle angle on the eastern flanks of the basin than on the west. This may be attributed to the underlying topography.

It is possible that the Jurassic "Red Beds" of the Michigan Basin are not basin related. Recent drillings in Ontario have uncovered "Red Beds" with a Jurassic flora. This has enabled Cross (1978) to postulate that the "Red Beds" of the Michigan Basin were derived from the Canadian Shield and transported into the Michigan Basin area. The Jurassic sediments taper to the southwest and were deposited in the Michigan Basin as a thin cover on the Pennsylvanian topography (Cross, 1978). The sediment cover was apparently always fairly thin as the pollen and spores of this flora have undergone very little catagenic metamorphism (Cross, 1978).

Following the Jurassic and preceding the Pleistocene epoch there was a long time interval represented only by erosion in the Michigan Basin. There is no evidence for deposition of strata during this interval which indicates either erosion and/or non-deposition is occurring. Evidence for a dissected erosional surface can be found in the surface profile of the underlying bedrock. That surface is marked by drainage systems whose main channels appear to have followed the axial trends of Lakes Erie, Huron, and Michigan (Travis, 1966).

Pleistocene

The Michigan Basin was subjected to repeated glaciation during the Pleistocene. The Nebraskan, Kansan, and Illinoian glacial intervals preceeded the Wisconsin and may have affected much of the area. The Wisconsin had four major glacial advances and retreats which apparently removed all recognizable remnants of previously deposited unconsolidated material, as well as some of the underlying bedrock. Three principle ice lobes, the Lake Michigan, Lake Erie, and Saginaw affected the Lower Peninsula of Michigan. The Pleistocene drift unconformably overlies Jurassic and Pennsylvanian strata in the study area. The thickness varies and is illustrated by an isopach map (Plate 8). It shows the thin cover of the Saginaw lobe which extends southwest from the Saginaw Bay area. A progressive thickening occurs to the northwest and the thickest accumulation of drift, nearly 1,100 feet, is found in northeastern Osceola County.

Generalized Cross-Sections

The litholgic cross-sections are constructed with sea level as a datum plane. They are intended to illustrate the gross lithologic variability and the structural attitudes of all the strata found above the Mississippian Michigan Formation in the Michigan Basin.

Cross section A-A' (Figure 8) is based on seven points and it extends across the center of the basin in a southeast direction from southwest Wexford County to eastern Livingston County. It illustrates the general variabilities of the lithologies of the study and their relation to the basin. In particular, it shows that strata have a steeper dip in the southeastern section of the basin than in the northwest. It also indicates that the beds have been restricted in extend due to erosional effects caused by the uplift of the Howell Anticline and that the Jurassic sediments have imparted an asymmetrical appearance to the basin.

Cross section B-B' (Figure 9) is based on six wells and trends across the Michigan Basin in a southwest direction from northwestern Arenac County to southeastern Kent County. It illustrates the general stratigraphic relationships and also indicates that the basin has undergone greater subsidence to the northeast since the Late Mississippian.

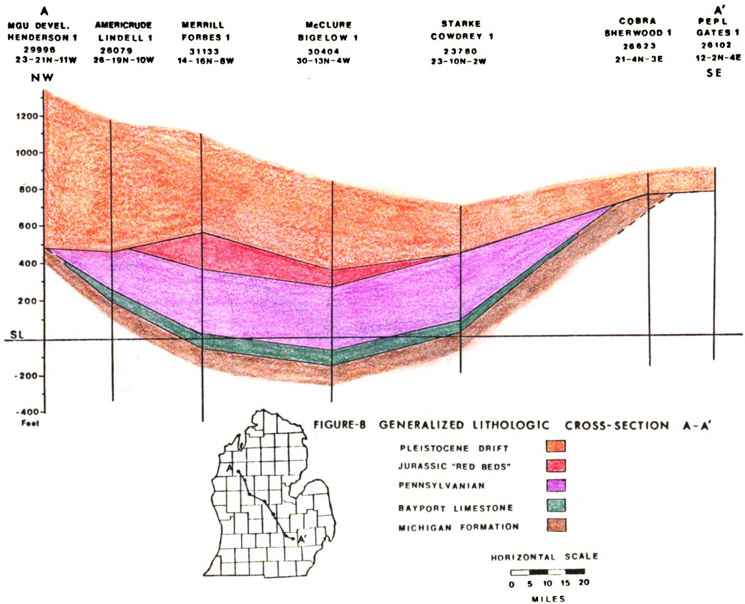


FIGURE-8 GENERALIZED LITHOLOGIC CROSS-SECTION A-A'

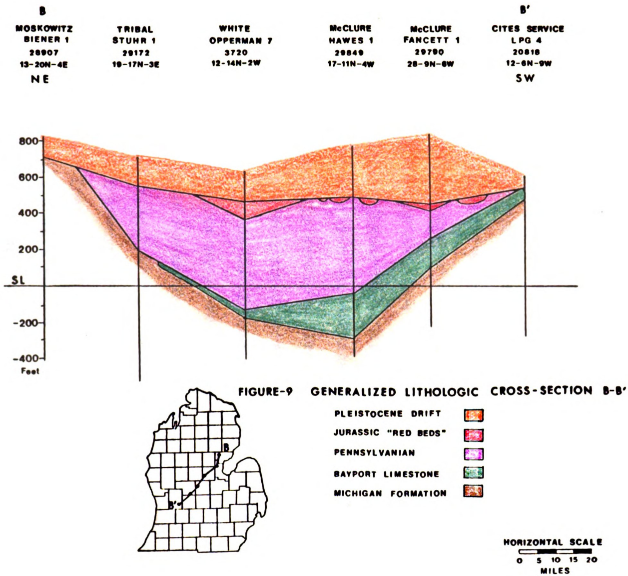


FIGURE-9 GENERALIZED LITHOLOGIC CROSS-SECTION B-B'

CONCLUSIONS

The study of over 670 gamma-ray, gamma-ray and neutron, and sonic well logs of the central portion of the Lower Peninsula of Michigan provided a framework for the study, determination, and re-evaluation of environments and events since the Late Mississippian. The lowest formational unit studied was the Bayport Limestone. It is Late Mississippian in age and directly overlies the Michigan Formation. It was deposited in a relatively stable environment, was later uplifted, and as a result subjected to a substantial amount of erosion. The Bayport tends to thicken towards the interior of the basin. However, in many areas it is completely eroded away, a reflection of river drainage systems. The major depocenter is located in southwestern Clare and northwestern Isabella Counties. The Bayport depocenter and structural center conform with that of the present basin. This indicates that relatively stable tectonic conditions have existed since the Late Mississippian. Some abnormally thick areas do exist and are the result of the pre-existing Michigan Formation topographic lows.

A major unconformity separated the Mississippian and Pennsylvanian strata of the Michigan Basin. The Mississippian was subjected to post-depositional erosion which resulted in some variation in the types of rock exposed at the Mississippian surface. All of the strata found directly below this unconformity are Mississippian in age. The oldest in Kinderhookian and is represented by Coldwater Shale while the youngest is the Bayport Limestone of Meramecian age. The Bayport is the most extensive in areal distribution of the formations directly overlain by Pennsylvanian strata. The Michigan, Marshall, and Coldwater formations are also present directly below the Pennsylvanian Formation but are areally more limited. The Michigan Formation occupies much of the higher peripheral area and reflects at least four directions of drainage systems. One series runs off of the Howell Anticline and surrounding high areas and extends in a northwestward direction toward the basin interior. Another trends in a northeastward direction towards the center of the basin and is identified in Eaton and Clinton Counties. The third is located in Arenac County and flowed in a southeastward direction. The fourth is located in Missaukee County and trends southward towards the center of the basin. If these are part of the same drainage system then their junctions are not clear. The Marshall Sandstone is very limited in distribution below the unconformity and is found scattered around the periphery as inliers. The Coldwater Shale, the oldest formation exposed beneath the Mississippian-Pennsylvanian unconformity is found only along the crest of the Howell Anticline where the erosional effects are the greatest.

There is no apparent relation between the structure of the base of the Bayport and the trend of the Mississippian-Pennsylvanian unconformity.

The Pennsylvanian unconformably overlies the Mississippain and has been subject to extensive post-Pennsylvanian erosion. The strata tend to thicken toward the interior of the basin with the steepest gradients occurring along the western glank of the Howell Anticline and in the northeast in Arenac and Ogemaw Counties. The depocenter is associated with the southeastern Clare County region. The thickness varies from 0 to 721 feet. Areas of abnormal thickness are present and are attributed to a combination of post-depositional erosion, differential compaction, and to a lesser extent, the pre-Pennsylvanian topography. It is unconformably overlain by Jurassic "Red Beds" or Pleistocene glacial drift.

The Jurassic is restricted to the subsurface of the central Michigan Basin and lies west of the axis of the present Michigan Basin configuration. The apparent depocenter is located in southeastern Mecosta and north central Montcalm Counties. The thickness is variable and ranges from 0 to 250 feet. Variations are due to irregularities in the pre-Jurassic topography, Pleistocene glacial activity, and pre-Pleistocene erosion. There is an apparent asymmetrical aspect to the Jurassic basin. This is indicative of greater abrasion on the eastern side of the basin, of an original asymmetrical basin that received Jurassic sediments, or of greater sediment deposition in the area.

Pleistocene glacial drift unconformably overlies the Jurassic and Pennsylvanian strata in the Michigan Basin. There is also a long erosional interval between the Jurassic and the Pleistocene. Pleistocene glaciation removed all of the unconsolidated surface material as well as part of the bedrock. The drift thickness varies from more than 1,100 feet in northeastern Osceola County to less than 50 feet in the area of the Saginaw lobe.

The Bayport "highs" reflect known structural closures in the underlying Michigan Stray sandstone. Economically, the Stray is known to produce natural gas and be of value for gas storage. Stray sandstone production is restricted to Clare, Mecosta, and Osceola Counties. It can also be found in parts of Montcalm, Newaygo, Isabella, Missaukee, and Roscommon Counties. Isolated Bayport structual closures in these counties which are not already associated with Stray production may some day be productive of natural gas or be utilized in the storage of gas. It is also possible that these Bayport highs may become more pronounced with depth and thus, be indicative of oil or gas traps in lower formations.

APPENDIX

ABBREVIATIONS USED

T__N-R__W, sec.___ - Township___North-Range___West, section___

T__S-R__E, sec.___ - Township___South-Range___East, section___

PN - Permit Number

ELEV - Elevation of Datium above sea level

GD - Log bottom of Glacial Drift

Jt - Log top of Jurassic

Pt - Log top of Pennsylvanian

MBt - Log top of Mississippian Bayport Limestone Formation

MMt - Log top of Mississippian Michigan Formation

Mt - Log top of Marshall Sandstone Formation

NA - Not available

MICHIGAN LOG DATA

Location		PN	ELEV	GD	Jt	Pt	MBt	MMt	Mt
				ARENAC					
T19N-R3E	sec. 2	24424	850	240	-	240	-	295	452
	sec. 5	24438	768	109	-	109	-	204	443
	sec. 27	26705	795	101	-	101	-	150	412
	sec. 34	25207	765	144	-	144	-	199	357
T19N-R6E	sec. 1	28577	589	56	-	-	56	78	149
T20N-R4E	sec. 13	28907	815	94	-	-	-	-	94
T19N-R4E	sec. 8	1756	776	134	-	-	-	134	358
				BARRY					
T3N-R7W	sec. 23	28802	936	188	-	188	250	265	397
T3N-R8W	sec. 14	30137	913	315	-	-	-	315	364
T2N-R7W	sec. 36	29092	946	125	-	125	201	220	307
				BAY					
T15N-R3E	sec. 10	31191	628	229	-	229	-	737	1136
	sec. 14	28566	619	165	-	165	-	336	589
T16N-R3E	sec. 2	29122	644	156	-	156	-	507	677
T18N-R3E	sec. 29	28603	738	145	-	145	-	390	532
T13N-R6E	sec. 30	27086	591	96	-	96	571	582	838
T14N-R4E	sec. 1	20607	590	NA	-	NA	-	-	398
T17N-R3E	sec. 19	29172	709	135	-	135	-	511	740
	sec. 32	29135	670	126	-	126	-	598	781
T17N-R4E	sec. 31	29137	618	123	-	123	323	347	485

Location		PN	ELEV	GD	Jt	Pt	MBt	MMt	Mt
				CALHOUN					
T3S-R4W	sec. 3	22151	968	105	-	-	-	-	105
	sec. 4	22873	970	157	-	-	-	-	157
	sec. 9	24451	948	87	-	-	87	112	136
	sec. 10	24236	944	72	-	-	-	-	72
	sec. 14	22214	1014	93	-	-	-	-	93
	sec. 15	22260	1012	104	-	-	-	-	104
T1S-R4W	sec. 7	29737	943	109	-	-	109	136	217
	sec. 18	23770	973	97	-	97	141	159	238
	sec. 19	28488	960	66	-	66	112	124	208
T1S-R6W	sec. 5	24536	853	87	-	-	-	87	94
	sec. 7	30347	856	246	-	-	-	-	246
	sec. 8	30346	854	138	-	-	-	-	-
	sec. 16	30802	931	309	-	-	-	-	309
	sec. 18	30416	844	210	-	-	-	-	210
	sec. 19	30819	941	168	-	-	-	-	168
	sec. 20	30511	898	148	-	-	-	-	148
	sec. 23	30968	934	96	-	-	-	-	96
T2S-R7W	sec. 2	30250	915	115	-	-	-	-	-
	sec. 26	24508	892	96	-	-	-	-	-
T3S-R6W	sec. 9	23031	947	59	-	-	-	59	183
T1S-R5W	sec. 1	27816	961	114	-	114	150	178	278
	sec. 3	29667	943	102	-	102	140	184	271
	sec. 6	22489	909	134	-	-	134	149	221
	sec. 8	25226	931	46	-	46	88	133	195
	sec. 9	29082	944	83	-	83	138	148	241
	sec. 11	28701	928	78	-	78	93	121	214
	sec. 12	24463	965	69	-	69	118	147	240
	sec. 13	29350	950	128	-	-	-	128	217
	sec. 16	26143	922	60	-	60	100	116	199

Location		PN	ELEV	GD	Jt	Pt	MBt	MMt	Mt
	sec. 22	24278	925	NA	-	NA	60	88	140
	sec. 23	23851	928	99	-	-	-	99	146
	sec. 24	29401	942	134	-	-	-	134	197
	sec. 25	27748	949	133	-	133	152	196	298
	sec. 26	25086	928	62	-	62	72	81	131
	sec. 28	30385	946	114	-	-	-	114	132
	sec. 32	30435	938	195	-	-	-	-	195
	sec. 36	27930	964	96	-	-	-	96	161
T2S-R5W	sec. 1	25054	987	57	-	57	60	81	195
	sec. 12	23680	912	56	-	56	60	97	143
	sec. 13	27471	920	196	-	-	-	-	196
	sec. 27	22096	964	199	-	-	-	-	199
	sec. 30	23730	925	91	-	-	-	-	91
T2S-R6W	sec. 17	26689	939	229	-	-	-	-	229
T1S-R7W	sec. 13	30990	842	240	-	-	-	-	240
	sec. 21	30080	841	115	-	-	-	-	115
	sec. 23	30658	872	169	-	-	-	-	169
	sec. 25	30399	954	257	-	-	-	-	257
	sec. 27	30233	950	217	-	-	-	-	217
	sec. 29	29923	914	182	-	-	-	-	182
	sec. 35	30181	933	170	-	-	-	-	170
T2S-R4W	sec. 5	28328	921	93	-	93	108	198	247
	sec. 7	s7381	949	192	-	192	205	225	265
	sec. 17	27071	931	173	-	173	195	208	262
	sec. 18	24446	925	82	-	-	-	82	157
	sec. 19	23757	974	42	-	42	48	84	223
	sec. 20	23982	995	113	-	-	-	-	113
	sec. 28	23032	956	100	-	-	-	-	100
	sec. 29	23033	945	64	-	-	-	-	64
	sec. 32	22754	949	65	-	-	-	-	65
	sec. 33	22548	932	188	-	-	-	-	188
	sec. 34	23369	935	70	-	-	-	-	70

Location		PN	ELEV	GD	Jt	Pt	MBt	MMt	Mt
				CLARE					
T20N-R3W	sec. 36	19385	977	405	-	405	803	841	1297
T18N-R6W	sec. 3	28469	1082	542	542	609	1082	1147	NA
	sec. 4	28428	1053	515	515	596	1029	1115	NA
	sec. 9	29326	1059	534	534	589	1052	1122	NA
	sec. 10	28423	1077	631	-	631	1062	1155	NA
	sec. 11	28983	1078	614	-	614	1070	1124	NA
	sec. 13	28971	1090	555	555	702	1022	1141	NA
	sec. 14	28415	1087	573	573	636	1055	1131	NA
	sec. 15	29315	1071	560	560	638	1056	1103	NA
	sec. 23	29039	1080	623	-	523	1052	1122	NA
	sec. 24	29312	1094	631	-	631	1098	1161	NA
T20N-R4W	sec. 23	25182	1207	558	558	587	852	905	NA
	sec. 35	27394	1205	564	564	773	1094	1150	1573
	sec. 36	17850	1196	570	570	649	1066	1124	NA
T17N-R6W	sec. 18	12337	1050	682	682	727	1039	1174	1637
	sec. 19	12229	1059	717	717	740	1155	1196	NA
	sec. 31	22532	1088	581	581	679	1227	1281	1652
T17N-R4W	sec. 36	31106	813	305	305	397	935	990	1358
T19N-R5W	sec. 3	27390	1141	580	580	590	1085	1186	1599
	sec. 6	26046	1113	538	538	594	1008	1081	1446
	sec. 10	27611	1153	552	552	789	1153	1217	1598
T19N-R3W	sec. 6	17715	1141	513	513	542	997	1066	NA
	sec. 7	17854	1097	494	494	503	978	1032	NA
	sec. 8	18029	1027	427	427	470	942	998	NA
	sec. 16	27265	1003	398	398	465	976	1031	1431
	sec. 25	30563	932	335	-	335	719	797	1350
T19N-R4W	sec. 1	17734	1176	550	550	587	1040	1093	NA

Location		PN	ELEV	GD	Jt	Pt	MBt	MMt	Mt
T18N-R5W	sec. 1	20807	1283	745	745	815	1299	1403	NA
	sec. 17	28219	119	655	655	718	1107	1217	NA
	sec. 19	28111	1097	477	477	635	1100	1180	NA
	sec. 20	28153	1092	551	551	756	1098	1174	NA
	sec. 29	13492	1097	456	456	610	1095	1188	NA
T19N-R6W	sec. 3	20628	1050	536	-	536	922	994	NA
	sec. 6	15880	1017	520	-	520	948	1028	NA
	sec. 10	26003	1075	539	539	572	1003	1092	1486
	sec. 24	29136	1124	640	-	640	1144	1218	1621
T20N-R5W	sec. 5	15926	1099	504	-	504	886	949	NA
	sec. 8	13015	1095	480	-	480	843	902	NA
	sec. 15	14924	1098	560	-	560	923	981	NA
	sec. 16	13085	1081	521	-	521	856	916	NA
	sec. 17	14920	1073	514	-	514	824	891	NA
	sec. 23	24721	1164	633	-	633	990	1043	1409
T20N-R6W	sec. 1	17211	1139	605	-	605	-	974	1400
	sec. 3	9313	1087	533	-	533	822	878	NA
	sec. 4	24691	1006	591	-	591	-	974	NA
	sec. 5	25997	1112	571	-	571	-	1007	NA
	sec. 7	25998	1098	557	-	557	-	1020	1469
	sec. 8	24713	1099	559	-	559	927	1007	1316
	sec. 10	24687	1095	553	-	553	-	972	NA
	sec. 12	19014	1200	613	-	612	781	1002	1429
	sec. 18	9235	1090	525	-	525	921	988	NA
	sec. 19	12717	1127	579	-	579	939	1038	NA
	sec. 30	26408	1144	601	-	601	1001	1050	1398
	sec. 31	12716	1088	551	-	551	893	978	NA
	sec. 32	12818	1082	560	-	560	856	988	NA
	sec. 33	13185	1070	498	-	498	877	969	NA
	sec. 35	15212	1051	530	-	530	880	971	NA

Location		PN	ELEV	GD	Jt	Pt	MBt	MMt	Mt
				CLINTON					
T7N-R2W	sec. 13	26540	754	103	-	103	392	550	756
T8N-R2W	sec. 26	24475	716	106	-	106	368	450	758
T8N-R4W	sec. 35	23030	739	446	-	446	562	591	902
T7N-R1W	sec. 6	27811	760	148	-	148	207	503	824
	sec. 27	24315	773	80	-	80	471	549	713
T5N-R3W	sec. 14	22348	825	41	-	41	268	432	779
				EATON					
T1N-R6W	sec. 2	22497	935	190	-	-	-	190	298
	sec. 13	29115	934	156	-	-	-	156	256
	sec. 17	22541	945	142	-	-	-	142	251
	sec. 22	24485	917	80	-	-	80	117	232
	sec. 24	27461	859	152	-	-	-	152	178
	sec. 36	29530	902	154	-	-	-	154	220
T1N-R4W	sec. 5	28984	923	190	-	190	280	308	365
	sec. 19	29059	934	146	-	146	230	242	310
T2N-R5W	sec. 18	22672	911	115	-	115	172	224	350
	sec. 22	28715	910	142	-	142	184	211	360
	sec. 27	28118	910	118	-	118	210	224	348
T3N-R5W	sec. 10	30432	851	181	-	181	252	294	404
T2N-R4W	sec. 15	28902	928	186	-	186	263	362	436
	sec. 24	29860	901	132	-	132	146	191	431
T2N-R3W	sec. 8	29579	889	204	-	204	282	335	436
	sec. 13	29785	897	109	-	109	273	392	489
	sec. 17	29578	893	177	-	177	317	350	436
	sec. 20	30289	900	117	-	117	206	310	413

Location		PN	ELEV	GD	Jt	Pt	MBt	MMt	Mt
	sec. 21	30153	904	122	-	122	266	341	440
	sec. 35	29000	882	220	-	220	243	275	381
	sec. 36	29007	917	210	-	210	385	403	553
T1N-R3W	sec. 3	27766	897	114	-	114	245	281	446
	sec. 5	30455	895	149	-	149	200	247	430
	sec. 8	29396	934	112	-	112	250	311	370
	sec. 10	29613	913	158	-	158	314	344	368
	sec. 12	29248	911	135	-	135	216	257	371
	sec. 14	30110	933	188	-	188	259	310	371
	sec. 22	31525	912	124	-	124	202	223	NA
	sec. 23	29331	936	117	-	117	203	228	347
T2N-R6W	sec. 9	22516	924	228	-	-	-	228	334
	sec. 25	30214	914	105	-	105	140	202	318
T1N-R5W	sec. 17	28163	872	116	-	-	-	116	227
	sec. 18	21769	891	160	-	-	-	160	227
	sec. 19	27309	876	141	-	-	-	141	193
	sec. 25	30202	926	126	-	126	139	158	256
	sec. 27	28263	908	148	-	-	-	148	256
	sec. 28	30291	892	116	-	116	145	157	227
	sec. 30	22487	872	137	-	-	137	150	210
	sec. 34	29863	949	172	-	-	-	172	275
	sec. 35	29189	943	169	-	-	-	169	257
	sec. 36	29787	903	134	-	-	-	134	228
T3N-R3W	sec. 32	29546	921	221	-	221	391	407	532
				GENESEE					
T6N-R8E	sec. 12	24028	915	74	-	-	-	74	202
T9N-R8E	sec. 4	24079	827	174	-	174	231	257	301
	sec. 11	28156	858	246	-	-	-	246	306

Location		PN	ELEV	GD	Jt	Pt	MBt	MMt	Mt
	sec. 12	28164	861	256	-	-	-	256	300
	sec. 13	28628	898	274	-	-	-	274	343
T6N-R7E	sec. 29	23948	850	87	-	-	-	87	167
T9N-R7E	sec. 3	28340	745	148	-	148	172	195	323
				GLADWIN					
T17N-R2W	sec. 11	24333	729	223	-	223	944	1000	1362
	sec. 19	23880	749	341	-	341	881	998	1328
T18N-R1W	sec. 6	22081	784	402	-	402	708	806	1205
	sec. 10	4463	759	439	-	439	667	773	996
	sec. 36	25617	733	191	-	191	697	769	979
T20N-R1E	sec. 16	26376	817	242	-	242	508	550	960
T19N-R1W	sec. 22	29065	792	486	-	486	823	848	1191
T18N-R2W	sec. 10	20346	833	380	-	380	847	911	1267
	sec. 11	20558	830	357	-	357	921	941	1244
	sec. 14	20785	794	263	-	263	912	929	1223
	sec. 15	20308	820	290	-	290	898	918	1244
T18N-R1E	sec. 15	21809	713	235	-	235	728	772	992
T19N-R2W	sec. 1	28835	844	208	-	208	567	704	1340
	sec. 13	29098	852	192	-	192	824	926	1322
				GRATIOT					
T11N-R3W	sec. 6	30465	761	306	-	306	390	651	780
	sec. 13	23694	769	380	380	401	740	764	969
	sec. 14	30354	769	348	348	401	682	778	983
	sec. 15	29834	771	178	-	178	647	782	1010
	sec. 17	24270	737	313	313	366	691	772	1009
	sec. 23	23760	750	414	-	414	620	737	946

Location		PN	ELEV	GD	Jt	Pt	MBt	MMt	Mt
T11N-R2W	sec. 16	23763	742	328	-	328	653	743	943
T11N-R1W	sec. 2	28362	696	504	-	504	611	705	1031
T10N-R4W	sec. 3	27638	758	410	-	410	645	753	996
	sec. 4	30884	762	289	-	289	681	749	1101
	sec. 6	23452	777	330	330	350	685	740	989
	sec. 8	3641	786	317	317	333	662	725	NA
	sec. 12	30509	762	321	321	350	561	756	1036
	sec. 26	29824	761	339	339	358	689	770	1050
T10N-R2W	sec. 17	30314	738	231	231	278	512	633	1036
	sec. 23	23780	705	231	-	231	603	696	880
T11N-R4W	sec. 11	20396	751	433	-	433	706	740	1050
	sec. 15	23483	779	210	210	313	721	831	1071
	sec. 17	29849	785	282	-	282	730	833	1080
	sec. 26	29859	755	305	-	305	652	792	1043
	sec. 33	30885	764	370	-	370	687	755	1119
				HURON					
T15N-R10E	sec. 10	24699	639	112	-	-	-	112	126
T17N-R11E	sec. 35	29926	637	65	-	65	390	449	482
T15N-R11E	sec. 29	20862	760	125	-	-	-	125	194
	sec. 35	28860	759	84	-	-	-	84	130
T17N-R10E	sec. 36	24040	626	43	-	-	-	43	139
T16N-R11E	sec. 29	31382	647	103	-	-	-	103	182
T15N-R12E	sec. 35	24002	785	70	-	-	-	70	116

Location		PN	ELEV	GD	Jt	Pt	MBt	MMt	Mt
				INGHAM					
T2N-R2W	sec. 6	29174	850	120	-	120	251	331	529
	sec. 11	28842	905	266	-	266	346	410	572
	sec. 16	24518	902	240	-	240	338	394	551
	sec. 25	29043	930	192	-	192	276	392	553
	sec. 26	28746	984	240	-	240	313	420	527
	sec. 31	28999	921	179	-	179	281	343	507
	sec. 33	28929	925	215	-	215	267	351	464
	sec. 35	28745	965	216	-	216	329	397	495
	sec. 36	28816	959	217	-	217	311	388	486
T1N-R1E	sec. 4	30002	965	153	-	153	285	414	573
	sec. 8	29502	967	173	-	173	319	403	559
	sec. 16	28955	947	84	-	84	236	363	521
	sec. 34	29665	960	104	-	104	175	298	430
T2N-R1E	sec. 12	29557	893	101	-	101	296	408	579
	sec. 13	29055	912	121	-	121	354	401	578
	sec. 25	29580	968	212	-	212	310	453	619
	sec. 27	30182	954	120	-	120	293	431	606
T3N-R2E	sec. 15	28739	893	194	-	194	506	542	692
	sec. 21	27910	914	61	-	61	392	511	717
	sec. 29	28145	921	103	-	103	350	482	654
T1N-R1W	sec. 4	29292	958	88	-	88	348	400	493
	sec. 5	29398	963	173	-	173	294	382	481
	sec. 9	28455	1014	153	-	153	326	414	530
	sec. 11	28794	978	152	-	152	280	440	600
	sec. 35	29416	969	101	-	101	242	319	400
T1N-R2W	sec. 1	29498	989	230	-	230	336	413	511
	sec. 3	28970	927	172	-	172	304	337	430
	sec. 7	29545	912	189	-	189	246	327	405

Location		PN	ELEV	GD	Jt	Pt	MBt	MMt	Mt
	sec. 10	28437	916	148	-	148	236	321	408
	sec. 11	28563	967	126	-	126	247	310	440
	sec. 15	29080	929	116	-	116	218	287	394
	sec. 18	28909	928	164	-	164	-	293	370
	sec. 19	29584	945	183	-	183	281	306	376
	sec. 20	30012	905	139	-	139	224	257	345
	sec. 21	29753	948	142	-	142	253	316	387
	sec. 22	29227	946	133	-	133	200	291	362
	sec. 26	29823	960	131	-	131	173	284	370
	sec. 31	30715	954	168	-	168	215	270	353
	sec. 32	31040	990	171	-	171	217	319	380
	sec. 35	30463	960	101	-	101	277	289	360
T1N-R2E	sec. 5	29973	951	130	-	130	341	369	511
	sec. 6	29747	963	120	-	120	251	379	528
	sec. 7	29748	954	78	-	78	233	365	491
	sec. 17	29415	954	105	-	105	213	338	485
	sec. 30	30091	939	105	-	105	247	329	408
T2N-R1W	sec. 7	28834	903	206	-	206	396	424	638
	sec. 15	28304	918	69	-	69	271	407	611
	sec. 17	29485	902	179	-	179	392	408	616
	sec. 19	28947	915	196	-	196	328	394	526
	sec. 21	28953	908	183	-	183	368	418	586
	sec. 27	28696	936	149	-	149	252	401	590
	sec. 29	28266	958	83	-	83	309	384	527
	sec. 32	29420	958	86	-	86	312	389	521
	sec. 36	29500	931	111	-	111	367	407	561
T3N-R1E	sec. 34	29253	929	87	-	87	407	496	619
T2N-R2E	sec. 3	30134	932	78	-	78	372	442	613
	sec. 18	29334	906	186	-	186	467	491	586
	sec. 24	30247	932	163	-	-	-	163	227

Location		PN	ELEV	GD	Jt	Pt	MBt	MMt	Mt
	sec. 25	30288	958	98	-	-	-	98	148
	sec. 29	29554	929	116	-	116	278	402	568
	sec. 32	29297	960	142	-	142	297	410	577
				IONIA					
T6N-R8W	sec. 4	25025	707	147	-	147	258	283	528
T5N-R8W	sec. 28	23482	803	217	-	217	243	251	402
T7N-R8W	sec. 34	24619	765	300	-	-	300	344	551
T7N-R5W	sec. 8	27271	752	272	-	272	475	550	812
	sec. 21	20535	756	397	-	397	522	559	832
T5N-R7W	sec. 15	23754	857	306	-	306	344	393	661
T6N-R6W	sec. 14	30892	783	118	-	118	352	474	729
	sec. 22	30108	782	159	-	159	386	479	647
	sec. 31	27700	860	224	-	224	407	481	642
				ISABELLA					
T14N-R6W	sec. 1	23458	877	425	425	519	975	993	1428
	sec. 25	24206	984	466	466	600	983	1109	1531
T16N-R6W	sec. 5	27025	1224	685	685	974	1278	1412	1791
	sec. 7	27193	1065	655	655	816	1122	1254	1570
	sec. 8	27210	1058	604	604	729	1089	1249	1664
	sec. 10	26256	1107	519	519	705	1169	1321	1727
	sec. 16	31027	1063	664	-	664	1074	1217	1585
	sec. 28	27738	966	737	-	737	889	1016	NA
	sec. 29	11443	1003	526	526	669	906	1086	NA
	sec. 30	27918	1017	511	511	804	948	1107	NA
	sec. 32	11521	981	611	611	678	921	1047	NA
	sec. 33	28345	959	380	380	579	940	1060	NA

Location		PN	ELEV	GD	Jt	Pt	MBt	MMt	Mt
T14N-R5W	sec. 16	23980	869	382	382	583	948	1001	NA
	sec. 17	23905	878	410	410	505	941	1010	1457
T15N-R3W	sec. 30	30734	746	291	291	338	802	940	1305
T13N-R5W	sec. 27	24256	837	540	-	540	772	934	1346
T16N-R5W	sec. 26	25445	897	375	375	441	1019	1190	1607
T13N-R4W	sec. 10	30746	842	310	310	451	864	1036	1471
	sec. 22	29916	799	394	394	435	917	973	1399
	sec. 27	30036	822	383	383	481	840	950	1395
	sec. 30	30404	860	503	503	572	944	1027	1448
T15N-R5W	sec. 3	31080	910	529	529	850	1123	1191	1644
T13N-R6W	sec. 9	3192	973	480	480	609	921	1063	1502
T15N-R6W	sec. 15	21852	930	448	448	537	1050	1078	1538
	sec. 23	22826	928	431	431	650	1052	1076	1419
	sec. 30	21117	1033	654	654	841	949	1070	1581
T16N-R3W	sec. 8	129	797	542	-	542	828	972	1321
	sec. 17	127	794	301	-	301	964	978	1335
				JACKSON					
T3S-R3W	sec. 2	27708	988	178	-	-	-	-	178
	sec. 5	22742	1001	109	-	-	109	150	189
	sec. 19	24449	1027	50	-	-	-	-	50
	sec. 22	22674	1024	100	-	-	100	133	215
	sec. 30	22351	989	50	-	-	-	-	50
	sec. 33	24983	1029	133	-	-	-	133	192
	sec. 35	24840	1065	10	-	-	-	-	10
T3S-R2E	sec. 4	29944	1018	103	-	-	-	-	103
T4S-R2W	sec. 3	28272	1010	143	-	-	-	-	143
	sec. 5	21932	1016	115	-	-	-	-	115
	sec. 8	30293	1033	193	-	-	-	-	193

Location		PN	ELEV	GD	Jt	Pt	MBt	MMt	Mt
T4S-R1W	sec. 33	22568	1065	128	-	-	-	-	128
T2S-R3W	sec. 9	22808	1004	103	-	103	133	154	218
	sec. 13	28394	1004	100	-	-	-	100	162
	sec. 15	21963	1011	90	-	-	-	90	179
	sec. 24	28617	990	97	-	-	-	97	132
	sec. 27	27882	999	82	-	-	-	82	119
T1S-R1W	sec. 2	28733	958	91	-	91	163	278	350
	sec. 5	29501	974	86	-	86	123	311	372
	sec. 10	28778	916	70	-	70	147	227	290
T2S-R2W	sec. 10	26549	961	131	-	131	158	178	212
	sec. 15	26541	972	110	-	-	110	140	213
	sec. 16	26548	927	70	-	-	-	70	132
T3S-R2W	sec. 1	21723	1021	78	-	-	-	78	119
	sec. 31	22950	1030	75	-	-	-	-	75
T1S-R2W	sec. 32	29558	924	118	-	118	158	166	235
T1S-R3W	sec. 2	31337	938	146	-	-	146	201	270
	sec. 4	26481	933	NA	-	NA	128	175	252
	sec. 11	23269	933	109	-	109	150	197	258
	sec. 14	26416	931	101	-	101	162	175	248
	sec. 15	22558	931	99	-	99	136	174	241
	sec. 36	22175	1020	158	-	158	227	246	300
				KENT					
T9N-R11W	sec. 5	16212	838	260	-	260	412	460	665
	sec. 24	11066	749	159	159	195	258	345	595
	sec. 25	11927	769	192	192	250	320	357	634
	sec. 28	8534	728	315	315	357	409	430	537
	sec. 35	21003	904	332	332	347	469	481	714

Location		PN	ELEV	GD	Jt	Pt	MBt	MMt	Mt
T5N-R9W	sec. 3	21780	811	335	-	-	-	335	531
T5N-R10W	sec. 21	21388	777	215	-	-	-	-	215
T9N-R10W	sec. 35	27296	936	447	447	472	543	606	887
T5N-R11W	sec. 17	20993	754	320	-	-	320	422	550
T8N-R9W	sec. 6	24826	857	289	-	289	495	546	832
	sec. 35	24627	860	331	-	331	499	558	837
T6N-R9W	sec. 12	20818	632	95	-	-	95	167	436
T10N-R11W	sec. 9	24455	907	440	-	440	506	612	991
T10N-R12W	sec. 27	23093	821	355	355	-	-	372	665
				LAKE					
T17N-R11W	sec. 2	31028	1240	818	-	818	1073	1138	1490
T19N-R11W	sec. 17	26835	1102	677	-	677	-	716	1081
T20N-R12W	sec. 27	28369	954	470	-	-	-	470	830
	sec. 30	20234	982	488	-	-	-	488	832
T19N-R13W	sec. 8	24314	866	500	-	-	-	500	651
	sec. 9	26850	868	469	-	-	-	469	667
	sec. 17	27168	873	428	-	-	-	428	660
	sec. 18	27770	897	554	-	-	-	554	864
T18N-R11W	sec. 17	27440	1151	668	-	668	908	948	1295
	sec. 24	29041	1179	765	-	765	1009	1036	1420
	sec. 25	29040	1204	758	-	758	1006	1044	1427
	sec. 36	31030	1213	728	-	728	1074	1106	1450
				LIVINGSTON					
T4N-R3E	sec. 21	26623	901	137	-	-	-	137	172
	sec. 22	29089	927	95	-	-	-	-	-

Location		PN	ELEV	GD	Jt	Pt	MBt	MMt	Mt
	sec. 27	28255	921	120	-	-	-	-	120
	sec. 35	24324	892	64	-	-	-	-	-
	sec. 36	29021	932	88	-	-	-	-	-
T3N-R3E	sec. 1	28117	914	72	-	-	-	72	112
	sec. 2	28524	917	94	-	-	-	-	-
	sec. 12	28308	920	99	-	-	-	99	146
	sec. 34	29675	908	265	-	-	-	-	265
T3N-R4E	sec. 6	28949	912	66	-	-	-	-	-
	sec. 7	28440	909	132	-	-	-	132	164
	sec. 18	28482	916	106	-	-	-	-	106
	sec. 27	26815	881	25	-	-	-	-	-
	sec. 34	26775	884	79	-	-	-	-	-
T2N-R3E	sec. 17	28752	948	119	-	-	-	-	119
T2N-R4E	sec. 1	26101	901	87	-	-	-	-	-
	sec. 2	26817	903	97	-	-	-	-	-
	sec. 12	26102	916	136	-	-	-	-	-
	sec. 14	25868	927	149	-	149	156	165	198
T3N-R5E	sec. 11	27986	986	194	-	-	-	-	-
	sec. 13	30033	943	187	-	-	-	-	-
	sec. 25	27034	993	211	-	-	-	-	-
	sec. 28	22853	963	158	-	-	-	-	-
				MECOSTA					
T13N-R10W	sec. 2	25204	968	442	442	646	789	806	1198
	sec. 5	26734	957	566	566	637	793	826	1182
	sec. 6	26503	931	453	453	611	764	795	1156
	sec. 7	26829	932	558	558	609	-	792	1151

Location		PN	ELEV	GD	Jt	Pt	MBt	MMt	Mt
	sec. 8	26901	958	710	710	720	791	828	1184
	sec. 22	27000	983	472	472	692	-	864	1228
	sec. 26	22580	958	460	460	528	-	793	1181
	sec. 27	26847	936	412	421	614	792	810	1167
	sec. 36	20310	949	430	430	600	690	814	1170
T14N-R9W	sec. 3	17117	1064	553	553	774	1040	1056	1353
	sec. 4	11769	1140	604	604	833	1101	1110	NA
	sec. 9	14218	1133	632	632	869	1110	1128	NA
	sec. 10	1176	1168	652	652	873	1130	1157	1466
	sec. 12	13162	1085	522	522	746	-	1077	NA
	sec. 14	27281	1066	622	622	731	-	1051	1369
T15N-R10W	sec. 7	27013	1061	611	611	664	970	982	1274
	sec. 17	27489	1040	546	546	654	930	957	1291
T16N-R8W	sec. 14	31133	1111	540	540	724	1100	1181	1657
	sec. 15	27668	1143	602	602	752	1084	1254	1711
T15N-R9W	sec. 19	25790	944	457	457	528	894	876	1320
T13N-R9W	sec. 35	27658	998	456	456	631	908	969	1338
	sec. 36	30661	973	562	562	721	881	951	1306
T16N-R10W	sec. 1	25639	1001	418	418	588	942	960	NA
T13N-R8W	sec. 9	23977	966	325	325	702	969	986	NA
	sec. 19	30995	971	436	436	714	-	1006	1419
	sec. 23	25828	1006	481	481	669	978	996	NA
	sec. 24	25827	1000	458	458	669	-	1001	NA
	sec. 25	22375	997	451	451	663	-	960	NA
T15N-R8W	sec. 23	24101	1056	560	560	716	1077	1096	1545
	sec. 28	23941	1037	468	468	679	1019	1094	1530
	sec. 30	28295	1062	607	607	704	1094	1118	1560
T14N-R10W	sec. 29	26742	886	443	443	468	652	753	1081
	sec. 31	27019	819	432	432	471	637	690	1118
	sec. 32	26515	870	509	-	509	640	713	1079

Location		PN	ELEV	GD	Jt	Pt	MBt	MMt	Mt
T13N-R7W	sec. 28	18337	990	468	468	619	913	994	NA
	sec. 29	18371	988	462	462	604	831	881	NA
	sec. 30	18425	986	466	466	627	836	983	NA
	sec. 31	22367	1017	398	398	620	943	971	NA
	sec. 32	3459	997	397	397	596	830	967	NA
	sec. 34	2908	1011	471	471	627	900	1011	NA
	sec. 35	18320	958	454	454	578	792	951	NA
T14N-R8W	sec. 12	25432	1048	593	593	735	823	1032	NA
	sec. 22	30472	995	406	406	616	934	1011	1470
	sec. 23	31419	998	418	418	630	845	1028	1491
T15N-R7W	sec. 3	23187	1015	498	498	617	1055	1170	1609
	sec. 15	28361	1052	520	520	687	1063	1146	1556
				MIDLAND					
T15N-R2W	sec. 4	30126	691	315	-	315	811	933	1268
	sec. 15	31134	682	407	-	407	828	952	1278
T14N-R2W	sec. 12	3720	658	179	179	300	794	856	1169
T13N-R2W	sec. 12	4818	678	261	261	539	753	785	1110
T15N-R1W	sec. 12	22678	638	485	485	657	857	911	1215
	sec. 13	22042	637	551	551	633	818	901	1193
T13N-R1W	sec. 10	22782	670	248	-	248	802	850	1078
	sec. 15	23431	688	242	-	242	778	791	1180

Location		PN	ELEV	GD	Jt	Pt	MBt	MMt	Mt
T15N-R2E	sec. 12	30378	660	386	-	386	832	900	1100
T14N-R2E	sec. 36	11718	621	158	-	158	828	843	1114
T16N-R2E	sec. 1	21846	672	206	-	206	-	581	814
	sec. 31	31146	665	323	-	323	925	941	1251
T13N-R1E	sec. 27	27202	669	321	-	321	794	809	1110
				MISSAUKEE					
T22N-R6W	sec. 17	24430	1218	713	-	713	808	832	1381
	sec. 31	23663	1194	648	-	648	828	849	NA
	sec. 35	27105	1159	721	-	721	895	914	1381
	sec. 36	26961	1160	706	-	706	851	880	1367
T22N-R5W	sec. 31	27958	1169	494	-	494	-	1027	1392
T21N-R6W	sec. 1	27104	1152	553	-	553	820	917	1363
	sec. 2	27101	1155	557	-	557	833	912	1369
	sec. 14	25491	1163	602	-	602	906	917	NA
	sec. 26	24623	1139	574	-	574	-	1005	NA
	sec. 27	24583	1138	631	-	631	936	1004	NA
	sec. 31	23147	1160	612	-	612	-	855	NA
	sec. 32	22206	1172	625	-	625	965	1010	1495
	sec. 33	24704	1135	591	-	591	-	877	NA
	sec. 35	9312	1112	542	-	542	862	952	NA
T23N-R5W	sec. 11	30522	1143	373	-	-	-	373	703
	sec. 12	30176	1140	385	-	-	-	385	657
T21N-R5W	sec. 17	27612	1213	623	-	623	1099	1128	1604
T24N-R5W	sec. 15	30543	1168	490	-	-	-	490	628
	sec. 16	29803	1174	514	-	-	-	514	664
T22N-R7W	sec. 25	23665	1201	721	-	721	-	862	NA
	sec. 32	25553	1186	740	-	740	-	1025	NA

Location		PN	ELEV	GD	Jt	Pt	MBt	MMt	Mt
T21N-R8W	sec. 14	31202	1200	746	-	746	1055	1144	1558
	sec. 24	21922	1233	686	-	686	1016	1043	1528
	sec. 31	25416	1465	921	-	921	1196	1219	NA
T21N-R7W	sec. 3	25993	1210	643	-	643	978	1061	1505
	sec. 4	26418	1186	638	-	638	954	979	NA
	sec. 5	25621	1196	618	-	618	949	972	NA
	sec. 8	25994	1181	623	-	623	969	992	1513
	sec. 10	26314	1201	715	-	715	1007	1053	1522
	sec. 12	24582	1211	630	-	630	-	1068	NA
	sec. 14	24933	1172	665	-	665	915	1003	1471
	sec. 15	9801	1208	722	-	722	1038	1062	1530
	sec. 16	23301	1215	705	-	705	980	1001	1492
	sec. 19	21768	1301	806	806	828	-	1169	NA
	sec. 20	22139	1243	677	-	677	917	960	1432
	sec. 21	9180	1189	624	-	624	969	992	NA
	sec. 24	25014	1183	659	-	659	942	964	1397
	sec. 30	21979	1234	741	-	741	1025	1041	1530
				MONTCALM					
T12N-R7W	sec. 2	20059	937	418	418	552	766	880	NA
	sec. 3	3146	958	506	506	588	815	894	NA
	sec. 5	20054	997	467	467	599	838	901	NA
	sec. 6	30930	990	559	559	619	893	965	1369
	sec. 8	3239	780	450	450	594	814	886	NA
	sec. 9	20043	1013	490	490	599	852	956	NA
	sec. 11	22551	949	425	425	576	807	934	NA
	sec. 12	3401	943	512	512	593	830	950	NA
	sec. 15	18411	922	506	506	539	763	892	NA
	sec. 26	30135	951	465	-	465	846	903	1308

Location		PN	ELEV	GD	Jt	Pt	MBt	MMt	Mt
T9N-R6W	sec. 28	29790	823	351	351	395	062	723	1013
T12N-R8W	sec. 23	24594	978	621	621	640	805	904	1303
T10N-R5W	sec. 1	3186	781	329	329	424	600	728	1118
T11N-R6W	sec. 30	30147	955	484	484	534	727	870	1260
T11N-R7W	sec. 19	31085	899	430	430	492	700	782	1183
	sec. 21	26964	916	555	555	628	713	873	1185
	sec. 31	30933	900	441	441	493	672	852	1187
T9N-R7W	sec. 6	30117	873	389	-	389	601	751	1072
T11N-R5W	sec. 8	24011	956	450	450	591	875	950	1269
	sec. 12	28411	793	480	480	546	684	833	1102
T12N-R6W	sec. 27	27876	943	385	385	422	691	948	1260
T11N-R9W	sec. 1	29812	933	490	490	523	669	837	1209
	sec. 13	30470	953	419	419	436	635	783	1225
	sec. 15	27038	933	403	403	581	740	814	1208
	sec. 27	24255	926	410	410	600	727	814	1163
T11N-R8W	sec. 18	2988	945	393	393	483	669	844	1203
	sec. 20	30912	944	413	413	438	660	853	1214
	sec. 30	20335	920	479	479	556	632	816	1213
T12N-R10W	sec. 1	20678	928	377	377	440	663	788	1131
	sec. 2	19565	898	492	492	527	658	768	1126
	sec. 12	30845	908	412	412	544	666	776	1149
	sec. 13	20739	904	373	373	500	623	753	1124
T12N-R5W	sec. 18	30107	892	553	-	553	790	894	1341
T10N-R7W	sec. 3	21873	903	471	471	494	800	850	1182
	sec. 9	26237	891	464	464	516	782	844	1182
	sec. 10	24902	900	438	438	528	781	8484	1174
	sec. 26	25921	843	365	365	426	613	711	1121
T12N-R9W	sec. 6	20085	942	529	-	529	659	802	1151
	sec. 7	28199	937	464	464	551	722	789	NA
	sec. 8	28195	922	561	-	561	649	761	NA
	sec. 17	28253	913	470	470	575	624	753	NA

Location		PN	ELEV	GD	Jt	Pt	MBt	MMt	Mt
	sec. 18	28193	907	484	484	516	601	743	NA
	sec. 28	25922	896	345	345	376	642	779	1174
	sec. 29	25452	891	479	-	479	624	768	1138
	sec. 35	22767	904	393	393	529	639	757	1143
				NEWAYGO					
T11N-R13W	sec. 11	28137	879	364	-	364	-	544	870
	sec. 15	22918	803	363	-	-	363	436	739
T16N-R11W	sec. 30	27347	1072	526	526	643	816	860	1190
T15N-R14W	sec. 20	26662	821	530	-	-	-	530	620
T13N-R11W	sec. 3	26703	994	541	541	594	-	797	1139
	sec. 32	27001	758	250	250	317	460	483	900
T12N-R11W	sec. 20	17331	941	289	289	379	548	631	940
	sec. 29	28644	914	472	472	521	649	681	NA
	sec. 30	28643	881	356	-	356	552	601	NA
	sec. 32	28653	863	230	230	370	-	555	NA
T13N-R14W	sec. 26	22866	890	482	-	-	-	482	793
T14N-Ro4W	sec. 4	19835	813	517	-	-	-	517	579
	sec. 5	26893	872	533	-	-	-	533	661
T14N-R11W	sec. 5	30829	1111	347	347	577	811	869	1197
	sec. 6	30437	1075	346	346	694	769	843	NA
	sec. 7	30260	1016	428	428	570	706	776	NA
	sec. 8	30440	1087	357	357	697	829	872	NA
	sec. 17	30267	1049	571	571	643	787	820	NA
	sec. 23	26626	1009	571	571	616	830	845	1170
	sec. 26	26630	1039	480	480	648	850	869	1221
T11N-R12W	sec. 10	23149	801	519	-	-	-	519	835
	sec. 18	23734	819	483	-	-	-	483	822
	sec. 24	23329	791	375	-	375	415	450	813

Location		PN	ELEV	GD	Jt	Pt	MBt	MMt	Mt
T15N-R12W	sec. 12	27795	978	570	-	570	785	797	1215
T15N-R11W	sec. 16	28031	1087	627	627	730	892	941	NA
	sec. 20	28027	1056	593	593	686	804	881	NA
	sec. 21	28032	1075	608	608	709	881	899	NA
	sec. 29	28033	1054	676	-	676	833	851	NA
	sec. 30	20698	1048	603	603	611	862	882	1197
T12N-R14W	sec. 26	22849	738	326	-	-	-	326	622
				OGEMAW					
T22N-R2E	sec. 22	30922	902	223	-	-	-	-	-
	sec. 34	30924	899	239	-	-	-	-	-
	sec. 35	29775	861	250	-	-	-	-	-
				OSCEOLA					
T20N-R10W	sec. 11	30467	1239	728	-	728	874	977	1407
	sec. 19	22078	1186	701	-	701	875	940	1302
	sec. 20	23088	1190	685	-	685	-	942	1319
T18N-R9W	sec. 28	29758	1196	704	-	704	1040	1121	1609
T17N-R8W	sec. 5	24103	990	462	462	632	958	1051	1494
	sec. 7	27012	1031	471	471	661	1044	1098	1528
	sec. 10	27082	1123	538	538	670	1158	1220	NA
	sec. 18	26661	1132	608	608	652	1181	1204	1631
	sec. 30	27159	1146	541	541	640	1178	1228	1653
	sec. 32	27307	1039	564	564	672	1121	1159	1632
T19N-R8W	sec. 35	26293	1214	767	767	781	1246	1317	1736
T17N-R9W	sec. 4	27999	1136	642	642	835	1108	1179	1587
	sec. 9	27216	1077	571	571	776	1029	1121	1529

Location		PN	ELEV	GD	Jt	Pt	MBt	MMt	Mt
	sec. 10	27666	1044	515	515	726	1019	1125	1498
	sec. 31	27687	1117	531	531	705	1004	1074	1515
	sec. 36	26888	1186	596	596	742	1230	1294	NA
T20N-R8W	sec. 17	26163	1305	843	-	843	1197	1254	1701
T19N-R10W	sec. 22	23311	1222	791	-	791	100	1051	1466
	sec. 26	26079	1197	726	-	726	937	993	1449
	sec. 32	31416	1135	803	-	803	958	976	1383
T18N-R10W	sec. 3	27706	1151	812	-	812	966	1012	1369
	sec. 8	31029	1123	783	-	783	936	972	1335
	sec. 17	29042	1114	676	-	676	846	933	1313
	sec. 18	29659	1163	480	480	681	953	1004	1395
	sec. 19	27939	1136	598	598	692	836	944	NA
	sec. 20	26427	1180	690	-	690	936	983	1308
	sec. 29	30154	1137	696	-	696	903	980	1330
	sec. 30	28346	1163	734	-	734	935	1004	1351
	sec. 31	29259	1127	723	-	723	894	949	1326
	sec. 32	30795	1132	716	-	716	920	957	1331
T20N-R7W	sec. 1	25996	1165	618	618	709	930	981	1524
	sec. 5	26254	1213	631	631	720	1032	1095	1586
	sec. 9	25984	1169	630	-	630	1033	1062	1542
	sec. 15	26619	1158	621	-	621	938	1043	1519
	sec. 25	13423	1131	593	-	593	978	1060	NA
T19N-R7W	sec. 2	26001	1096	579	-	579	986	1063	1563
	sec. 12	26002	1085	564	564	627	1017	1080	1487
T17N-R7W	sec. 2	28065	1042	617	617	715	1112	1174	NA
	sec. 3	13739	1066	536	536	705	1051	1214	NA
	sec. 10	13685	1071	532	532	701	115	1200	NA
	sec. 11	13611	1043	488	488	660	110	1203	NA
	sec. 12	28058	1040	586	586	756	1116	1193	NA
	sec. 13	28066	1037	715	715	790	1107	1166	NA
	sec. 24	31568	1049	670	670	832	1141	1210	1732

Location		PN	ELEV	GD	Jt	Pt	MBt	MMt	Mt
	sec. 28	27145	1065	647	647	724	1137	1228	1622
	sec. 29	22981	1116	610	610	696	1041	1112	1610
T17N-R10W	sec. 5	9466	1102	592	-	592	882	926	1301
	sec. 31	27578	1094	628	628	693	934	1004	1403
	sec. 33	27377	1050	568	568	689	932	1000	1410
T20N-R9W	sec. 14	25007	1586	1194	-	1194	1420	1490	1903
	sec. 23	22962	1380	877	-	877	1204	1306	NA
	sec. 35	28023	1345	833	-	833	1157	1237	1730
T18N-R7W	sec. 32	25385	1057	520	520	609	1080	1190	1655
				ROSCOMMON					
T24N-R1W	sec. 23	21409	1163	408	-	-	-	-	408
	sec. 29	30018	1158	300	-	-	-	-	300
T24N-R4W	sec. 7	31273	1209	445	-	-	-	445	640
T21N-R3W	sec. 19	20486	1128	506	506	555	920	969	1426
T21N-R4W	sec. 30	24530	1102	501	-	501	1013	1051	1518
T22N-R4W	sec. 8	20509	1137	646	-	646	740	763	1156
	sec. 17	25794	1140	492	-	492	690	727	1210
				SAGINAW					
T12N-R6E	sec. 5	22270	596	166	-	166	322	477	771
T11N-R5E	sec. 1	29795	629	118	-	118	236	333	561
T11N-R3E	sec. 33	23429	587	72	-	72	419	505	713

Location		PN	ELEV	GD	Jt	Pt	MBt	MMt	Mt
				SHIAWASSEE					
T5N-R3E	sec. 15	23375	871	118	-	-	-	-	-
T5N-R2E	sec. 5	22379	842	80	-	-	-	80	297
				TUSCOLA					
T14N-R8E	sec. 33	29237	612	45	-	45	-	76	223
T13N-R9E	sec. 8	23890	668	106	-	106	165	223	310
T14N-R9E	sec. 12	23485	654	93	-	-	-	93	171
T14N-R10E	sec. 28	26650	758	122	-	-	122	155	270
T10N-R8E	sec. 31	20557	771	140	-	140	-	161	301
	sec. 32	20480	785	172	-	172	215	286	688
T13N-R11E	sec. 9	28686	733	50	-	-	-	-	50
	sec. 16	25609	727	45	-	-	-	45	116
T10N-R9E	sec. 13	28551	852	203	-	-	-	203	317
	sec. 14	28104	844	195	-	-	-	195	243
T14N-R7E	sec. 25	17860	591	155	-	155	-	226	333
				WEXFORD					
T21N-R10W	sec. 14	25803	1298	786	-	786	-	963	NA
	sec. 33	23636	1228	678	-	678	-	903	NA
T21N-R9W	sec. 7	21872	1308	862	-	862	944	987	1367
	sec. 22	27594	1348	749	-	749	974	1047	1512
	sec. 27	28020	1398	881	-	881	1105	1143	NA
	sec. 28	23837	1323	796	-	796	979	1054	1447

Location		PN	ELEV	GD	Jt	Pt	MBt	MMt	Mt
T22N-R9W	sec. 32	22890	1303	738	-	738	921	956	1342
T21N-R11W	sec. 23	29996	1336	852	-	-	-	852	1357
T22N-R10W	sec. 9	25414	1411	862	-	-	-	862	1247

BIBLIOGRAPHY

BIBLIOGRAPHY

Bacon, D.J., 1971, Chert Genesis in a Mississippian Sabkha Environment, Unpubl. Masters Thesis, Michigan State Univ., 47 p.

Cohee, G.V., et al., 1950, Coal Resources of Michigan, U.S. G.S. Circ. 77, 56 p.

__________, 1951, Thickness and Lithology of the Upper Devonian and Carboniferous Rocks in Michigan, U.S.G.S. Oil and Gas Investigations, Chart OC 41, sheets 4 and 5.

Cross, A.T., 1966, Palynological Evidence of Mid-Mesozoic Age of Fort Dodge (Iowa) Gypsum, Geol. Soc. Amer. Program, Annual Meetings, San Francisco, p. 46.

__________, 1978, personal oral communication.

Ells, G.D., 1969, Architecture of the Michigan Basin, Mich. Basin Geol. Soc. Annual Field Excursion Guidebook, pp. 60-88.

Elowski, R., 1978, personal oral communication, Mich. Dept. of Natural Resources.

Fisher, J.H., 1978, personal oral communication.

__________, 1969, Early Paleozoic History of the Michigan Basin, Mich. Basin Geol. Soc. Annual Field Excursion Guidebook, pp. 89-93.

__________, et al., 1969, Stratigraphic Cross-Sections of the Michigan Basin, Mich. Basin Geol. Soc., Special Publ., 22 p.

Haxby, W.F., et al., 1976, Thermal and Mechanical Evolution of the Michigan Basin, Tectonophysics, v. 36, No. 1-3, pp. 57-75.

Hinze, W.J., 1963, Regional Gravity and Magnetic Anomaly Maps of the Southern Peninsula of Michigan, Mich. Geol. Survey Rept. Investigations 1, 26 p.

Hough, J.L., 1958, Geology of the Great Lakes, Univ. of Illinois Press, Urbana, IL, 313 p.

Kalliokoski, J., and E.J. Welch, 1977, Magnitude and Quality of Michigan's Coal Reserves, Dept. of Geology and Geological Engineering, Michigan Technological Univ., Houghton, MI, 33 p.

Kelly, W.A., 1936, Pennsylvanian System in Michigan, Annual Rept. Mich. Geol. Survey Div., Pub. 40, Geol. Ser. 34, pp. 155-226.

Kelly, R.W., and W.R. Farrand, 1967, The Glacial Lakes Around Michigan, Mich. Geol. Survey Div., Bull. 4, 24 p.

Kilbourn, D.C., 1947, The Origin and Development of the Howell Anticline in Michigan, Unpubl. Masters Thesis, Michigan State Univ., 120 p.

Kropschot, R.E., 1953, A Quantitative Sedimentary Analysis of the Mississippian Deposits in the Michigan Basin, Unpubl. Masters Thesis, Michigan State Univ., 57 p.

Landes, K.K., 1948, Structure of Typical American Oil Fields, AAPG Bull., v. 3, pp. 299-304.

Lane, A.C., 1909, Notes on the Geological Section of Michigan, Pt. 2, Mich. Geol. Survey, Annual Rept. for 1908, 402 p.

Lasemi, Y., 1975, Subsurface Geology and Stratigraphic Analysis of the Bayport Formation in the Michigan Basin, Unpubl. Masters Thesis, Michigan State Univ., 54 p.

Martin, H.M., 1936, The Centennial Geologic Map of the Southern Peninsula of Michigan, Dept. of Conservation, Mich. Geol. Survey Div., Publ. 39, Geol. Ser. 33.

McGregor, D.J., 1954, Stratigraphic Analysis of Upper Devonian and Mississippian Rocks in the Michigan Basin, AAPG Gull., v. 38, pp. 2324-2356.

Newcombe, R.B., 1928, Oil and Gas Development in Michigan, Mich. Geol. and Biol. Survey, Publ. 37, Geol. Ser. 31, Pt. 3.

__________, 1931, Map of Areal Geology of Michigan, Southern Peninsula, Dept. of Conservation, Mich. Geol. Survey Div.

__________, 1933, Oil and Gas Fields of Michigan, Mich. Geol. Survey, Publ. 38, Geol. Ser. 32, 293 p.

Oden, A.L., 1952, The Occurrence of Mississippian Brachiopods in Michigan, Unpubl. Masters Thesis, Michigan State Univ., 52 p.

Paris, R.M., 1977, Developmental History of the Howell Anticline, Unpubl. Masters Thesis, Michigan State Univ., 76 p.

Pirtle, G.W., 1932, Michigan Structural Basin and It's Relationship to Surrounding Areas, AAPG Bull., v. 16, pp. 145-152.

Sander, J.E., 1959, An Analysis of the Permo-Carboniferous "Red Beds" of Michigan, Unpubl. Masters Thesis, Michigan State Univ., 50 p.

Shaffer, B.L., 1969, Palynology of the Michigan "Red Beds", Unpubl. PhD. Thesis, Michigan State Univ., 250 p.

Shideler, G.L. 1965, Pennsylvanian Sedimentational Patterns of the Michigan Basin, Unpubl. Masters Thesis, Univ. of Illinois, 74 p.

Smith, R.A., 1917, Deep Well Borings, Mineral Resources of Michigan, Mich. Geol. and Biol. Survey, Publ. 24, Geol. Ser. 20. pp. 209-256.

Travis, P.A.A., 1966, An Analysis of Pleisotcene Sediments in an Aquifer Recharge Area, Kalamazoo, Michigan, Unpubl. PhD. Thesis, Michigan State Univ., 143 p.

Welsh, J.P., 1971, Patterns of Compositonal Variation in some Glaciofluvial Sediments in the Lower Peninsula of Michigan, Unpubl. Masters Thesis, Michigan State Univ., 98 p.

Winchell, A., 1861, First Biennial Report of the Progress of the Michigan Geol. Survey, pp. 112-127.