THE UPPER DEVONIAN AND LOWER MISSISSIPPIAN SEDIMENTS OF THE MICHIGAN BASIN AND BAY COUNTY, MICHIGAN

Thesis for the Degree of Ph. D.
MICHIGAN STATE UNIVERSITY
David V. LeMone
1964

This is to certify that the

thesis entitled

The Upper Devonian and Lower
Mississipian Sediments of the Michigan
Basin and Bay County, Michigan

presented by

David V. LeMone

has been accepted towards fulfillment
of the requirements for

Ph.D. degree in Geology

C. E. Prouty
Major professor

Date February 26, 1964

O-169

ABSTRACT

THE UPPER DEVONIAN AND LOWER
MISSISSIPPIAN SEDIMENTS OF THE MICHIGAN
BASIN AND BAY COUNTY, MICHIGAN

by David V. LeMone

Body of Abstract

The Upper Devonian and Lower Mississippian rocks of the Michigan Basin were investigated. Detailed isopach and structure contour maps and radioactive log cross sections were prepared from oil and gas well data. All three were successfully employed in developing the sedimentary and tectonic history of the Michigan Basin during this interval of time. The gamma ray-neutron logs were particularly useful for basinal correlation of the black shale interval (designated the B interval in this paper), which includes those rocks from the base of the Antrim Shale to the top of the Sunbury Shale. The gamma ray logs clearly indicated the stratigraphic relationships between the eastern and western facies of the black shale interval within the Michigan Basin.

The Lower Antrim is continuous throughout the entire basin. The Upper Antrim is found only locally west of a major north-south trending barrier and/or isopach thin axis, herein referred to as the B axis. On the eastern side of the Basin the Upper Antrim shale increases to a maximum on the edge of the B axis. The Berea-Bedford sequence decreases in thickness from east to west toward the B axis on the eastern side of the basin. Berea and Bedford equivalents are observed in the west-central

and northwestern portions of the Basin. The Berea dolomite is tentatively correlated with the Berea sandstone. The Ellsworth Shale of the western side of the basin is the facies equivalent of the Bedford-Upper Antrim of the eastern side of the Basin. Detailed isopach studies in Bay County indicate an east-west channel system for the Berea-Bedford sedimentation in that area. The Coldwater Shale isopach study clearly illustrates the disappearance of the South Michigan Shelf. The Marshall sandstone study indicates a third major tectonic change occurring within the Basin.

THE UPPER DEVONIAN AND LOWER MISSISSIPPIAN SEDIMENTS OF THE MICHIGAN BASIN AND BAY COUNTY, MICHIGAN

By

David V. LeMone

A THESIS

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

DOCTOR OF PHILOSOPHY

Department of Geology

1964

G 2 7 8 0 3
7/2/64

ACKNOWLEDGMENTS

The writer wishes to acknowledge the early encouragement and guidance given to him by Dr. W. J. Hinze, Dr. H. B. Stonehouse, Dr. M. M. Miller, Dr. W. Kelly, Dr. J. Zinn, and Dr. B. T. Sandefur of the Department of Geology, as well as Dr. G. W. Gillett and Dr. G. W. Prescott, of the Department of Botany and Plant Pathology.

The Michigan Geological Survey has been particularly helpful to the writer, singularly, Mr. Garland Ells and, collectively, Mr. R. Ives, Mr. S. Alguire, Mr. W. Mantek, and Mrs. B. Champion.

The writer, likewise, acknowledges the mental stimulation and probing criticism generated by the numerous discussions held with his fellow graduate students, especially Mr. William Steinkraus, Mr. Gholam Sorrwar, Dr. Nurul Islam, Mr. Donald Merritt, and Dr. David Cummings.

For their consideration, direction, and the example they set, the writer cites the four geologists most influential in his professional development: Dr. Jane E. Smith, Dr. C. E. Prouty, Dr. James H. Fisher, Department of Geology; and Dr. Curt Teichert, U. S. Geological Survey, Denver.

Acknowledgment of my gratitude to my wife for her patience, sympathy, and understanding is too deep to record here.

TABLE OF CONTENTS

Page

I. Introduction 1

II. Methods of Investigation 4

III. Structural Units 6

IV. Stratigraphy 13

1. Pre-Traverse Stratigraphy. 13
2. Traverse Group. 20
3. Black Shale ("B") Interval 26
   a. Introduction. 26
   b. Antrim Shale. 28
   c. Bedford Shale 35
   d. Berea Sandstone 39
   e. Sunbury Shale 42
   f. Ellsworth Shale 44
   g. Environmentat Interpretation 48
4. Coldwater Shale. 57
5. Marshall Sandstone 62
6. Post-Marshall Stratigraphy 65

V. Geologic History 69

VI. Summary and Conclusions. 74

Bibliography 78

PLATES (IN POCKET)

I. Isopach maps (State of Michigan)

Plate 1. Traverse Group (including formation)
Plate 2. "B" Interval
Plate 3. Coldwater Shale
Plate 4. Marshall Sandstone

II. Structure Contour maps (Bay County)

Plate 5. Dundee Limestone
Plate 6. Traverse Formation
Plate 7. Antrim Shale
Plate 8. Sunbury
Plate 9. Coldwater Shale

III. Isopach maps (Bay County)

Plate 10. Traverse Group
Plate 11. Antrim Shale
Plate 12. Berea-Bedford
Plate 13. Sunbury Shale
Plate 14. "B" Interval
Plate 15. Coldwater Shale
Plate 16. Marshall Formation

IV. Gamma Ray cross sections (Michigan)

Plate 17. $A-A^1$, $B-B^1$
Plate 18. $C-C^1$, $D-D^1$
Plate 19. $E-E^1$, $F-F^1$
Plate 20. $G-G^1$

V. Regional Distribution of Upper Devonian - Lower Mississippian Black Shales and related rocks

Plate 21

VI. Tectonic Map of Michigan and surrounding areas

Plate 22

VII. Isopach thin axis of the "B" Interval

Plate 23

APPENDICES

Page

I. Bay County Well Data 88

II. Michigan Well Data 97

I. INTRODUCTION

The Southern Peninsula of Michigan is the geographic center of the Michigan Basin. The Basin is frequently referred to as the type example for an autogeosyncline as classified by Marshall Kay (1951). It may be described as an independently sinking intracratonic basin that develops a nearly circular outline. It is bounded on the south by the Kankakee and Findlay arches, which are apparently the bifurcating northern extensions of the north-south trending Cincinnati Arch. The east side of the Basin is established by the Algonquin Axis (the northern extension of the Findlay Arch). A Precambrian complex, referred to as the Laurentian Highlands, forms the north and northeastern boundaries. The Wisconsin Arch or Highlands border the western margin of the Basin (Plate 22).

The Michigan Basin is popularly described as being a stack of saucers slightly warped on the edges. With the realization of the limitations of this apt description, we may consider the Basin as a unit. It is composed largely of Paleozoic rocks which reach a maximum thickness in excess of 14,000 feet. Surface exposures in the Basin consist almost entirely of Pleistocene glacial deposits; however, the Paleozoic rocks do crop out in local weathered areas and at a small number of excellent quarry exposures. In view of the exposure limitations, the data utilized are almost exclusively subsurface.

The major purpose for the study of the Upper Devonian-Lower Mississippian rocks is the correlation of the eastern and western facies of the "B" or black shale intervals. Correlation of the individual units of the "B" Interval are accomplished by utilizing gamma ray-neutron well logs.

In Bay County detailed isopach and structure contour studies were developed to evaluate the utilization of a series of formation tops for possible structure contour intervals.

The black shale problem study of the environmental interpretations is a literature synthesis and review made to determine the most reasonable paleoecological conditions for the black shale units of the Michigan Basin on a local and regional framework.

The detailed isopach maps of the Southern Peninsula were undertaken to study the changing configuration of the Basin, as well as the tectonic features peripheral to the Basin.

A number of prior studies have been made within the sequence. The best of the earlier regional structural contour studies of the state include Cohee (1944a, 1944b, 1945a, 1947b, and 1951) and Monnett (1948).

Lithofacies maps have been made from the studies of the sequence by Hoover (1960), McGregor (1954), Sloss, Dapples, and Krumbein (1960), O'Hara (1954), Hale (1941), and Cohee (1944a, 1944b, 1945a, 1947b, and 1951), and other contributors.

Fisher (1953) attempted to correlate the black shale interval across the Basin using electrical logs. His conclusion, supported by later work, was that the unit did not develop a sufficient character to be used. The Traverse Group has been correlated, apparently with success, by Jodry (1957) and Ross (1957). No prior study of the utilization of gamma ray logs for correlation of the black shale interval in the Michigan Basin has been published.

A number of very excellent regional summary papers have been made on the paleoecology of black shales; especially Hoover (1960), Ruedemann

(1934), Twenhofel (1939), Vine (1962), and Fisher (1953).

The thesis is divided primarily into four basic parts:

I. An isopachous study of the Southern Peninsula Upper Devonian-Lower Mississippian sediments. The formations considered are subdivided into four basic units:

- A. The Traverse Group, including the "Transition Zone."
- B. The "B" Interval. This includes all units between the Coldwater Shale and the Traverse Formation.
  1. Antrim Shale.
  2. Berea Sandstone (east side of the Basin).
  3. Bedford Shale (east side of the Basin).
  4. Ellsworth Shale (west side of the Basin).
  5. Sunbury Shale, which is observed in all parts of the Basin, except in local areas in the far western portion where it has not been recorded. (In these areas the basal Coldwater redrock is used as a marker unit.)
- C. Coldwater Shale
- D. The Marshall Sandstone.

II. Detailed isopachous and structure contour studies of the Upper Devonian-Lower Mississippian sequence in Bay County.

III. An environmental interpretation of Black Shale Interval; and a cursory re-examination of the black shale problem on a regional basis for origin, distribution, and time-stratigraphic analysis.

IV. A gamma ray-neutron log study of the Michigan Basin to determine the significance and the relationships of correlations between the Berea-Bedford-Antrim of the eastern side of the Basin and the Antrim-Ellsworth of the western side of the Basin.

II. METHODS OF INVESTIGATION

The regional study of the Upper Devonian-Lower Mississippian rocks of the Michigan Basin utilized 792 wells located on a township grid throughout the Southern Peninsula (Appendix II). Four isopach maps were from these data (Plates 1-4). Individual units are considered for sedimentary processes, environment of deposition, and tectonic history. Data sources for the information were derived from survey records, radioactive and electric logs, stucco logs, and published logs. The published logs are distributed by the Michigan Geological Survey; they are the written descriptions by state geologists for individual wells. The data sources are from driller logs, samples run by the survey, samples run by individual companies, radioactive log interpretation, and electric log interpretation. Published logs are commonly a combination of two or more of the aforementioned sources.

The Bay County detailed study utilized 208 wells (Appendix I, Plates 5 - 16). Wells are plotted on a grid of one well per section in wildcat areas and one well per quarter section within the fields. One phase of this study is directed at an examination of the reliability of structure contour mapping on the shallower post-Dundee horizons (Plates 5 - 9). Seven detailed isopach studies have been made to determine possible significant variations in the individual units (Plates 10 - 16).

A series of gamma ray log studies (7 cross sections) were made across the Basin for correlation purposes, as well as for delimiting the various facies of the "B" unit (pre-Sunbury-post-Traverse, Plates 17 - 20).

The regional black shale study is directed toward correlations in time and facies, as well as paleoecological considerations that might be applied logically to the Michigan Basin (Plate 21).

III. STRUCTURAL FEATURES OF THE MICHIGAN BASIN

The Michigan Basin is bounded by a series of major tectonic features: the Findlay Arch to the south and southeast; the Algonquin Axis to the east; the Laurentian Highlands, which includes northern Ontario and the Precambrian areas in the Lake Superior region; the Wisconsin Highlands or Arch to the southwest (Plate 22).

The Kankakee and Findlay arches represent a bifurcation of the north-south trending Cincinnati Arch. The Findlay Arch extends from a locality approximately 50 miles north of the Kentucky-Indiana-Ohio three-state point northeast through Findlay, Ohio. It is then extended through Lake Erie to southwest Ontario where it ends in the structurally low area known as the Chatham Sag in Kent County, Ontario. Green (1957a) indicated that, based on the Trenton structure, there is a 600-foot drop between western Ontario on the arch and Wayne County on the flank. The Findlay Arch was originally named the Lima Axis (Orton, 1888); however, Phinney (1891) and Ekblaw (1938) indicated that through popular usage and geographic position Findlay should be adopted as the accepted designation for the structural feature. Cohee (1945a) indicated that the Findlay Arch was elevated several times during the Paleozoic. One of the most profound of the uplifts occurs during Lower Ordovician.

The broad area between the Kankakee and Findlay arches is a relatively high area throughout the Lower Paleozoic; this feature has been called the Indiana-Ohio Platform by Green (1957a). Its northern extension is called the South Michigan Shelf (Garland Ells, personal communication, 1961).

From South-central Michigan east to the Findlay Arch there are three smaller regional structural features that have further influenced

Paleozoic sedimentation from west to east: the Clinton Sag (South-central Michigan); the Lucas-Monroe Monocline (extending from Lucas County, Ohio, to Monroe County, Michigan); and the Howell Anticline (extending northwest-southeast through Livingston, Washtenaw and Wayne County, Michigan).

The Clinton Sag is best indicated by the Silurian isopachs of the South Michigan Shelf.

The Lucas-Monroe Monocline is the northward extension of the Bowling Green Fault, which has been observed in wells in the vicinity of Cygnet, Bowling Green, and Findlay, Ohio. Orton (1888) referred to the structure as the Findlay break; he recorded abrupt structural "drops" of 150 to 175 feet in horizontal distanced of 1000 to 1200 feet. The Lucas-Monroe Monocline was observed by Lindberg(1948) in his study at Deerfield, Michigan.

The Howell is the largest anticline in the Michigan Basin. The anticline is highly asymmetrical and faulted on the western side and might better be referred to as a faulted monoclinal flexure. Newcombe (1933) was first to record the actual faulting when he noted some 88 feet of missing section on the western flank of the anticline. Monnett (1948) in his Coldwater structural contour map indicates 1770 feet of folding and/or displacement near the center of Livingston County.

The Chatham Sag of Kent County, Ontario, was recognized by Pirtle in 1932 as being a saddle connecting the Michigan Basin with the Appalachian Basin. Kay named the Chatham Sag in 1942. Lockett (1947) called the feature the Ontario Sag and indicated that is probably an extension of the south trending Parkersburg-Lorian synclinal trend. Allings (et. al., 1961) indicated that it represents an interconnecting seaway betweén the Michigan Basin and the Ohio Basin.

The northeastward extension of the Findlay Arch across the Chatham Sag is called the Algonquin Axis. North of this axis the exposed Precambrian is referred to as the Laurentian or North Ontario Highlands area. The term, "Laurentian", is generally used to indicate the whole of the northern portion of the Michigan Basin. In other words, a positive Precambrian area that stretched from northern Ontario to western Lake Superior where it connects with the Wisconsin Arch, which has a southern pre-Pennsylvanian extension called the La Salle Uplift or Arch.

The writer does not believe that a vast unbroken Laurentian Highlands region existed across Southern Canada. Paleontological and lithologic evidence (Martison, 1952) in fact, quite clearly show that there must have been a north-south connection between the Michigan Basin and the James Bay Lowland region of southernmost Hudson Bay in the Ordovician, Silurian, Devonian, and possibly lowermost Kinderhook time. The writer calls this north-south Early Paleozoic marine connection simply the "Ontario Seaway". The divided Laurentian Highlands area during this time may be referred to as the eastern and western shores. Pre-Mississippian correlations have been postulated, also, between the James Bay Lowland area and the Manitoba region.

The Ontario Seaway probably was broken during the Mississippian time, and possibly as late as Bayport time. Monnett (1948) indicated that uplift in the Laurentian area supplied conglomerates to the Upper Coldwater and Lower Marshall.

The Wisconsin Arch forms the western boundary of the Michigan Basin.

Pirtle (1932) described the arch as a broad fold with an axis trending N 20° W that extends from central Wisconsin southeastward into Illinois, presumably coalescing with the Laurentian Highlands region in the North. Levorson (1960) called the feature the Illinois-Wisconsin Arch. He has determined from studies in northern Illinois that the last major uplift in this area was post-Upper Chester-pre-Upper Pennsylvanian in age. This movement could be correlated into the Basin and assumed to synorogenic with the post-Bayport basinal movements. This, also, indicates an area of potential source material for the Pennsylvanian sediments of the Michigan Basin. The latter stage of the movement could indicate the time of withdrawal of the Pennsylvanian seas from Michigan. Levorson (1960) called the northwestern-southeastern major Canadian-north central United States feature the La Salle Arch. The southern end of the La Salle Arch is called the Illinois-Wisconsin Arch. This is unfortunate because of the confusion surrounding the term La Salle. Lockett (1947) indicated it as being the western bifurcation of the Wisconsin Arch and continued it to where it died out in the Illinois Basin. Ekblaw (1938) bifurcated the La Salle and the Kankakee at Oregon, Illinois. The eastern bifurcation is referred to as the Kankakee. Green (1957a) presented evidence to drop the term "La Salle" as a valid term in that the anticline is in reality the Oglesby Fault, which forms the western side of the Ottawa Horst. Weller (1957) in a discussion of Green's (1957a) paper questioned the validity of his "unconventional" interpretation of the field evidence. Green (1957b) in his reply to the discussion restated his interpretation of his evidence and indicated that he was not surprised that these new concepts proved to be disturbing for the "time-honored orthodox precepts". Green (1957a) further stated that the northern Wisconsin Arch region has a different geologic history than the southern region; in this he referred not only to the La Salle Arch, but also the Kankakee Arch. Monnett indicated that gentle uplift in the Wisconsin Arch area influenced sedimentation in Coldwater time, as well as supplying the feldspar observed in the southwestern part of the state. Cohee (1948a) stated that the Wisconsin Arch was apparently elevated at different times in the Upper Cambrian and the Lower Ordovician. Ekblaw (1938) was of the opinion that most of the major movement on the arch occurred in Pre-cambrian time.

The Kankakee Arch is the western bifurcation of the Cincinnati Arch. Pirtle (1932) described the Kankakee as a relatively small uplift that trends N 45° W in northeastern Illinois and northwestern Indiana, which connects the Wisconsin and Cincinnati arches which he theorized had a closely related tectonic history. He believed, also, that it is the cause of the north-northeastern structural trends in the southwestern part of the state. Ekblaw (1938) indicated that the first major movement on the Kankakee Arch was after Shakopee time, but before St. Peter time. Lockett (1947) visualized the Kankakee Arch as being an eastern spur of the Wisconsin Arch. He also recognized a western bifurcation off the Cincinnati Arch that he called the Wabash Spur. The two spurs are separated by the Logansport Sag. Green (1957a) suggested that the term "Kankakee Arch" be abandoned. He noted only one arch, which he called the Francisville, which is approximately 45 miles long, was mildly active in the Devonian, located in northeastern Illinois and having an east-west trend. He postulated a broad, slightly tilted, relatively unwarped platform. The platform, named the Indiana-Ohio Platform covers approximately 10,000 square miles, with a maximum separation of 150 miles between the Michigan and Illinois Basins. He also pointed out the fact that no erosional unconformities are needed to explain why units are thin over the shelf. The area is the probable loci of the Silurian reefs.

The Logansport Sag is a structurally low area that has connected the Michigan Basin and the Illinois Basin at various times throughout the Paleozoic. This feature was first recognized by Orton. Lockett (1947) viewed it as the low point between the two basins through which some interfingering of fossils and sediments occurred. Green (1957a) noted that there is a Logansport fault that is some 60 to 70 miles in length, has a maximum displacement of 200 feet, and trends NE-SW.

Within the Basin itself, structure is complicated by several periods of folding. The structures may be considered to occupy two broad provinces. The first is the south-western area, where anticlinal structures are aligned N-S, NE-SW, as well as NW-SE. These trends are reflected on regional gravity maps (personal communication, Hinze, 1961). Faulting is known to accompany the two major flexures in the Basin (Howell Anticline and Lucas-Monroe Monocline). Pirtle (1932) also noted. He was of the opinion that the Kankakee and Wisconsin Arch areas formed a buttress to movements within the Basin.

Anticlinal folds, especially those in the northeast, are asymmetrical with their steep flanks toward the Basin center. The axial plane of many of the folds appear nearly vertical. Pre-Salina disharmonic folding, should it exist, does not seem to validate with the available information. It should be pointed out, however, that the information available on Pre-Salina structure in the central and northern parts of the Michigan Basin is extremely sketchy.

The origin of structures within the Basin may be summarized into five basic theories:

1. Differential compaction around Precambrian highs
2. Basinal settling
3. Compressional forces
4. Gliding tectonics
5. Salt dome bulging

Accurate structure contour maps are available for the Basin from the Dundee top up to the "Clare" dolomite of the Michigan. Units commonly chosen include the Dundee, Traverse top, Sunbury-Coldwater redrock, the "Clare" or "Brown" dolomite of the Michigan Formation, and the "Triple Gyp" of the Michigan Formation. Accurate structure maps below the Dundee top are available in the southern half of Southern Michigan. A series of restricted Pennsylvanian core hole studies have been conducted by some petroleum companies in the central portion of the Basin.

The Michigan Basin was probably initiated as an autogeosynclinal structure during post-Shakopee-pre-Black River time (Cohee, 1948a). Movements continued throughout the rest of the Paleozoic in the Basin. Major periods of movement include post-Shakopee-pre-Black River, the post-Bois Blanc-pre-Sylvania, the post-Bayport-pre-Pennsylvanian, the post-Pennsylvanian-pre-red beds, and the post-red beds movements. Numerous other smaller unconformities such as the post-Bass Island-pre-Salina, post-Rogers City-pre-Traverse and the post-Michigan-pre-Bayport have been observed. In most cases they appear to be local in their distribution.

IV. STRATIGRAPHY

1. Pre-Traverse Rocks

The pre-Traverse Paleozoic strata of Southern Michigan overlies a complex of granites, schists, quartzites, and marbles of Precambrian age. The Cambrian rocks of the Michigan Basin are divided into six formations, which are (oldest to youngest): Jacobsville Sandstone, Mount Simon Sandstone, Eau Clair Sandstone, Dresbach Sandstone, Franconia Sandstone, and the Trempealeau Formation.

The Jacobsville Sandstone is primarily composed of mottled, arkosic sandstones with some conglomerates near the base interbedded with a few red shales. Thwaites (1943), Cohee (1948a), and Cohee and Landes (1958) have done extensive work on the age and distribution of the formation.

The Mount Simon Sandstone is a white, sub-angular to rounded, medium to coarse sandstone. It ranges from a maximum thickness of 2500 feet in northeastern Illinois to locally absent by convergence and/or truncation in parts of southwestern Ontario.

The Eau Clair Sandstone has been divided into three members by Baltrusaites, et. al. (1948). Cohee (1948a) described the lithofacies and isopach relationships of the sandstone within the Basin.

The Dresbach Sandstone is a fine to medium sandstone that contains thin beds of dolomite and argillaceous dolomite, locally. It has an average thickness of 100 feet in the Basin; the fact that it is absent in the northern Indiana indicates activity on the Kankakee Arch during post-Dresbach-pre-Trempealeau time.

The Franconia Sandstone is a glauconitic, dolomitic, fine to medium grained sandstone. Where observed in Southern Michigan, the Franconia Sandstone is commonly 10-20 feet thick (Cohee, 1948a).

The Trempealeau Formation is a buff to light brown dolomite. It is locally sandy. The basal portion of the formation is commonly glauconitic. The Trempealeau has been divided into three units, which are (in ascending order): the St. Lawrence member, the Lodi member, and the Jordan member (Raasch and Edwards, 1935). The St. Lawrence member is a grey, sandy, very glauconitic dolomite. The Lodi member is a white, slightly quartz sandy dolomite. Cohee (1948a) reported that it is locally pink in southeastern Michigan. The Jordan member is a 5 to 30-foot, well-rounded, frosted, and pitted sandstone.

The Lower Ordovician rocks of southern Michigan consist of the Prarie du Chien Group which has been divided into three formation, which are (in ascending order): the Oneota Dolomite, a buff to brown, very cherty, locally oolitic dolomite; the New Richmond Sandstone; and the Shakopee Dolomite, a buff locally argillaceous or quartz sandy dolomite. The Shakopee Dolomite is locally absent in parts of southwestern Michigan and in much of the area along the Kankakee Arch in northern Illinois and northwestern Indiana. Cohee (1948a) interpreted the missing Shakopee as the result of pre-St. Peter movements along the Kankakee Arch rather than non-deposition.

The Middle Ordovician of the Michigan Basin is represented by sediments of Chazy, Black River, and Trenton ages. The Chazyan sediments are represented by the St. Peter Sandstone, an irregularly occurring, well-rounded, quartz sandstone that reaches a maximum reported thickness of 150 feet within the Basin (Baltrusaites, et. al., 1948).

The 10-100 feet, locally absent, pyritic, brown and green, quartz sandy Glenwood Shale forms the base of the Black River Group. It has been lithologically correlated to the Pamelia age sections in Illinois and

Wisconsin. The Black River and Trenton Groups are readily distinguishable in southeastern Michigan and southwestern Ontario, where the basal Trenton develops an argillaceous character. The Black River-Trenton sequence changes facies from a limestone in the east (Ontario and central Michigan) to a dolomite in the west (Wisconsin).

The Chatham Sag (Kent County, Ontario) is indicated by regional thickening of the sequence in that direction. The Black River and Trenton Groups thin over the Kankakee Arch, the northern Findlay Arch, and the Algonquin Axis. Isopach studies by Cohee (1948a and 1948b) clearly indicate the configuration of the Michigan Basin. The thickest sequence of the Black River-Trenton has been reported in southeastern Michigan.

The Upper Ordovician rocks of Southern Michigan have been subdivided into three formations, which are (in ascending order): the Utica Shale, a dark grey to black shale; the Lorraine Shale, grey with thin beds of limestone and dolomite; and the Queenston Shale, similar to the underlying Lorraine Shale, except that it contains red shale which increases eastward across the Basin to Ontario.

The Upper Ordovician thins onto the Algonquin Axis; minor amounts are noted on the Kankakee Arch and the Findlay Arch, especially in Wood County, Ohio, and Wayne and Monroe counties, Michigan.

The Lower Silurian rocks of southern Michigan occur in the Cataract Group, which is subdivided into two formations (in ascending order): the Manitoulin Dolomite, a buff to light brown, locally cherty dolomite with some interbedded shale; and the Cabot Head Shale, a green to greyish green shale with some interbedded red shale.

Local reefing in the Cataract Group adds to the difficulty of correlation (Baltrusaites, et. al., 1948). The Findlay-Algonquin Axis acts as an east-west facies barrier in the Lower Silurian with clastics derived from the Taconic orogeny being largely restricted to the area east of the axis.

During the earlier Silurian, positive elements surrounding the southern part of the Michigan Basin acted as faunal barriers. The Kankakee Arch, the Findlay-Algonquin Arch, and the Cincinnati Arch form the barriers. This corfiguration develops three distinct faunas, which are: the warm to cool water homotaxial Clinton fauna to the east and northeast; the depauperate, cold water Brassfield fauna to the south and west; and the warm water, Michigan Basin Mayville fauna to the north.

The Middle Silurian rocks of the Michigan Basin are generally subdivided into four formations (in ascending order): the Burnt Bluff Dolomite, a light grey to brown calcareous dolomite that is divided into two members--the Engadine Dolomite, a very massive, blue, hard, crystalline dolomite; and the Guelph Dolomite, a fossiliferous, crystalline dolomite. Bryozoan, tetracoralian, and tabulate coral reefs of Niagaran age probably completely surround the Michigan Basin and give an indication of the equitable climate that existed during that time.

The Upper Silurian rocks of the Michigan Basin have been subdivided into a lower, Salina sequence, and an upper, Bass Island. These Cayugan units were separated by Landes (1945a) into a sequence (in ascending order) lettered A through H. Evans (1950), Ells (1958), and Allings and Briggs (1961) have been the major contributors for this portion of the section.

The clearest interpretation of the paleogeography of the area during the Upper Silurian has been made by Alling and Briggs (1961). Lithofacies maps indicate a high area north of Lake Superior. The northern seaway probably connected through the James Bay Lowland area in northern Ontario, where correlatable sequences (Richmond of Cincinnatian, Alexanderian, Lockport of Niagaran, and Cayugan) exist (Martison, 1952). The Silurian and Devonian rocks are separated by a widespread unconformity within the Michigan Basin. The Mackinac Breccia is interpreted as having developed when overlying formations collapsed into Salina sequence caves. The breccia is well exposed in the northern part of southern Michigan.

The Lower Devonian rocks of Michigan are subdivided into three formations and one group (in ascending order): the Garden Island Formation, a fossiliferous, buff dolomite and dolomitic sandstone; the Bois Blanc Formation, a cherty, fossiliferous, light colored carbonate; the Sylvania Sandstone, a nearly pure sandstone interbedded with limestone and dolomite; and the Detroit River Group, which has been subdivided into four formations. The Sylvania has been interpreted to be a time-transgressive unit similar to the Bolsa-Bliss sequence in the southwestern United States (Sabins, 1957).

The four formations of the Detroit River Group are (in ascending order): the Flat Rock Dolomite, a hard porous, dark grey, calcareous dolomite; the Anderdon Limestone, a very fossiliferous calcarenite; the Amherstberg Dolomite, a dolomitic calcarenite; and the Lucas Dolomite, originally defined as a drab, fossiliferous, dolomitic limestone, and is now delimited as essentially an evaporitic unit (Personal communication, Ells, 1963). Martison (1952) has correlated the Michigan Basin sequence into the James Bay Lowland area of Hudson Bay.

The pre-Traverse Middle Devonian in the Michigan Basin is subdivided into two formations which are (in ascending order): the Dundee Limestone and the Rogers City Limestone. Structure contour maps of the Michigan

Basin are commonly drawn on the Dundee-Rogers City top. The Dundee Limestone is commonly described as a buff to brown-grey, fine to coarsely crystalline limestone. In the central portion of the Basin, it is a mixture of limestone and dolomite, and in the far central western region and the southwestern region it is predominantly dolomitic. The Dundee and Rogers City are particularly difficult to separate in the western portion of the Basin (Cohee and Underwood, 1945). Chert is reported in the basal part of the Dundee on the eastern side of the Basin. Spheroidal black spores are abundant in the Norfolk Formation (Dundee equivalent) in southwestern Ontario. In western Michigan abundant black and light brown spores have been reported. The base of the formation in the subsurface, according to Cohee and Underwood (1945), is placed at the top of the first anhydrite or anhydrite and dolomite portion of the Detroit River Group.

The greatest thickness of the Dundee is over 400 feet in the Tuscola-Huron County area. It thins rapidly to the south and west. The Milwaukee Dolomite is apparently overlapped by a probable Traverse equivalent to the upper member of the Abitibi River Formation in the James Bay Lowland area (Martison, 1952); if so, this indicates once again a marine connection to the north. The Dundee is overlapped in the southwestern part of the state.

The Rogers City Limestone underlies most of the northern two-thirds of the southern part of Michigan. It is predominantly calcareous in the eastern part of the state. On the western side of the state it is both calcareous and dolomitic and locally entirely dolomitic. In the subsurface in the central portion of the Basin, it is distinguishable from the underlying Dundee in that it is dark brown to black and has a definite resinous luster (Cohee and Underwood, 1945). Toward the margins of the Basin, it is generally lighter in color. Abundant black and light brown spores have been reported in the Rogers City of northeast Michigan.

Addison reported (Cohee and Underwood, 1945) that as of 1944, approximately 84 per cent of Michigan's total oil production (223 million barrels) had been derived from the Dundee-Rogers City sequence. The porous pay zones may be anywhere from the top to 150 feet below the top of the Dundee-Rogers City. Porosity was developed by primary and secondary dolomitization, as well as solutional cavities in the limestone. The problems and the control of dolomitization have been the subject of many of the studies within the Basin to date.

The unconformity that occurs at the base of the Traverse Formation has been the subject of some controversy. Abundant evidence exists confirming the presence of such an unconformity; however, the major question concerns its regional extent. The previously mentioned Traverse overlaps to the southwest and west, as well as the numerous basal Traverse Group (Bell Shale) disconformable relationships that have been reported. Newcombe (1930) observed that variations in the thickness of the Bell Shale exist on the limbs and crests of structures, as well as on points of equal elevation on the structure. Ehlers and Radabaugh (1937) observed at the Rogers City cement quarry, a disconformable contact between the Rogers City limestone and the overlying Bell shales. Warthin and Cooper (1943) noted the same relationship in Presque Isle County.

2. Traverse Group

The Traverse Formation was designated by Winchell (1871), who described the sequence as a series of thick-bedded, magnesium, buffish, granular limestones overlying the Corniferous Group and underlying the Huron Group in southern Michigan. He stated that, in general, they conformed to the Hamilton Group of New York, a correlation that is still considered valid. He originally referred to the group as the Little Traverse, undoubtedly for the exposures in the vicinity of that bay in Emmet County (Wilmarth, 1938). A. C. Lane (1893) further delimited the group when he indicated that the Traverse Group (100 to 600 feet) was overlain by the St. Clair (Antrim) and underlain by Dundee Limestone (Wilmarth, 1938).

The Traverse Group is recognizable throughout southern Michigan. Much of the exposure shown on the Southern Michigan geologic map (Martin, 1936) is subcrop. Outcrops of the sequence are restricted to the northern counties of southern Michigan. Around the Basin the Traverse equivalents also crop out in eastern Wisconsin (Raasch, 1935), northwestern Ohio, (Ehlers, 1952), southwestern Ontario, and northwestern Ontario (Martison, 1952).

The Traverse Group is essentially a sequence of argillaceous limestone intermixed with a subordinate shale sequence.

Formational terminology used for the Traverse Group within the Basin is for the most part an outgrowth of studies conducted in three separate regions in northern counties of southern Michigan. These units are by areas: (1) the Thunder Bay region (east) (Warthin and Cooper, 1935) in ascending order--Bell Shale, Rockport Quarry Limestone, Ferron

Point Shale, Genshaw Formation, Newton Creek Limestone, Alpena Limestone, Four Mile Dam Formation, Norway Point Formation, Thunder Bay Limestone, and the Squaw Bay Limestone; (2) the Afton-Onaway region (central) (Kelly and Smith, 1947) in ascending order--Bell Shale, Rockport Quarry Limestone, Ferron Point Shale, Genshaw Formation, Koehler Limestone, Gravel Point Formation, and the Beebe School Formation; (3) the Little Traverse area (west) (Pohl, 1930) in ascending order--lower part covered, Gravel Point Formation, Charlevoix Limestone, Petoskey Formation. Cohee (1944a), on the basis of the work of Hake and Maebius (1938), Riggs (1938), and Landes (1944), divides the Traverse into four basic units in southwestern Michigan. The basal unit (1) is divided into three separate subunits.

The paleontology of the Traverse Group is well known. There exist many excellent papers on the micropaleontology and invertebrate paleontology of the unit. Stumm (et. al. 1951, 1953, 1956, 1958) has summarized much of the invertebrate paleontology of the group. A number of excellent systematic papers in micropaleontology, especially ostracods, have been done on the group, particularly in graduate theses at the University of Michigan under the guidance of R. C. Kesling and at Michigan State University under the guidance of Jane E. Smith.

Warthin and Cooper (1943) have, on the basis of invertebrate fossils, tentatively correlated the Alpena with the lower Gravel Point and the Potter Farm and Thunder Bay formations with the Petosky Formation.

Cohee (1947b), in utilizing the formational terminology of the Traverse Group, has made some basinal correlations. An examination of these units indicates a relatively simple correlation in a north-south direction. The east-west correlation, however, indicates a facies change with the Traverse becoming a purer limestone in the western portion of the state. Thinning of the Traverse Group onto the South Michigan Shelf poses a further correlation problem in the south, particularly in the central and western areas. Garland Ells (personal communication, 1961) also noted that this problem exists throughout the Basin. The Michigan Geological Survey Division, as a rule, refers to this sequence either as the Traverse Group or the Traverse Limestone and Traverse Formation.

Jodry (1957), on the basis of two electrical log cross sections, noted that correlation of the formational units was possible over the Michigan Basin. His studies led him to postulate the existence of a barrier and a western lagoon. Jodry's cross sectional evidence was corroborated, in part, by his interpretation of regional gravity data. There is an apparent very rapid east-west change in facies across this Barrier. Jodry reports accumulations of evaporites (gypsum), especially in the Genshaw equivalent, across the postulated Barrier. Cohee (1947b) reported the presence of gypsum also in the Ferron Point, Newton Creek, Potter Farm formations, in addition to the Genshaw. Jodry (1957) also indicated that nearly all of the Michigan Traverse Group reef production is found in association with the West Michigan Barrier.

The Bell Shale, the basal formation of the Traverse Group, forms a sharp easily distinguishable boundary between the Detroit River-Dundee and the Traverse Group. This particular lithologic break is very well developed on gamma ray-neutron logs. The Bell Shale underlies all of central and northern Southern Michigan (Cohee, 1947b). In southern Michigan, the rocks above and below the contact are carbonates. Differentiation utilizing electric or radioactive logs in this sequence is difficult, but possible.

The lower contact of the Traverse Group is probably conformable over much of the Michigan Basin. Ehlers and Radabaugh (1937), however, noted pockets of Bell Shale in apparent disconformable contact with the underlying pre-Traverse in the Rogers City cement quarry. Landes (1944), Newcombe (1930), and Addison (1940) all noted in field studies in Midland, Muskegon, and Gladwin counties, respectively, the thinning of the Bell Shale over anticlinal flexures. Warthin and Cooper (1943) reported an unconformity at the base of the Bell Shale in Presque Isle County.

The Traverse transition zone, referred to as the Traverse Formation by drillers, is a grey to black shale, interbedded with limestone at the top of the Traverse. It has been included with the Antrim Shale by Cohee (1947b) and Hake and Maebius (1938). Bishop (1940) is also of the opinion that the stringers of black shale occurring in the "transition zone" are more closely related to the Antrim than the Traverse. McGregor (1954) has included all the rocks above the Squaw Bay Limestone of the Traverse Group with the Antrim.

Fisher (1953), in his analysis of the black shale problem, examined the Traverse transition zone. His conclusion was that the limestone in the grey shaly sequence is similar to the underlying formations and, therefore, should be properly included with the Traverse Group. The Traverse transition zone is well-illustrated on the regional gamma ray cross sections (Plates 17-20). Prior to 1961, however, gamma ray logs were not available in sufficient quantities to be useful for regional correlation within the Basin with relation to this portion of the section. The zone is delimited in cross sections A-A^1 and B-B^1 (Plate 17). The base of the Antrim, while forming gradational contact with the underlying transition zone, may be placed with relative ease on a gamma ray log.

The writer, on the basis of the radioactive log evidence, places the lower contact of the Antrim Shale at the top of the transition zone.

Jodry's (1957) idea concerning the existence of the West Michigan Barrier seems to be validated in part on the basis of the Traverse isopach map (Plate 1). The spur extending north from the South Michigan Shelf in Ionia and Eaton counties is very significant. The writer believes that is may be controlled, at least in part, by reefing that occurred in the Silurian in this region followed by differential compaction in the Devonian. A spur approximating the position of the West Michigan Barrier is noted to the north of the inferred reefal development. The Traverse Group (Plate 1) in the south thins onto the Ohio-Indiana Platform; this area is referred to as the South Michigan Shelf. The Traverse Group reflects local thickening of the sequence in the area of the Battle Creek Trough in Calhoun and Branch counties, as well as the Chatham Sag in McComb County. Also, there is a suggestion of the Howell Anticline and the Clinton Sag in southeastern Michigan. The thickest sequence of the Traverse Group is observed in Arenac County where it exceeds 850 feet. There is a strong suggestion of an interconnection to the north through the Ontario Seaway, in the fact that no appreciable thinning of the Traverse Group takes place to the north. A correlatable unit (the Williams Limestone) on a paleontological and lithological basis has been observed in the James Bay Lowland area of Hudson Bay (Martison, 1952).

The Traverse Group isopach map in Bay County reflects apparent minor thinning over the Kawkawlin and Mt. Forest fields (Plate 10).

Structure contour studies are available on both the Dundee and Traverse tops throughout the Michigan Basin (Cohee and Underwood, 1945;

Cohee, 1947b). In Bay County studies, the structure contour maps of the Dundee and Traverse Group tops closely reflect the major structures within the county (Plates 5 and 6).

3. "B" Interval

a. Introduction

The "B" Interval is a coined term for the Upper Devonian and Lower Mississippian rocks of the black shale interval. The black shale interval was named for the dominant black shale lithosome of the unit. The formations that are included within this group represent a complex and interdependent facies sequence that is bounded by fairly synchronous, correlatable upper and lower contacts. It includes those rocks of the Michigan Basin that lie between the top of the Traverse Group and the base of the Coldwater Shale. The "B" interval corresponds with the "A" unit of McGregor (1954), except that he used the Squaw Bay Limestone as the top of the Traverse Group. The two units, therefore, differ in that the transition zone of the writer is included with the Traverse. The "B" unit includes the following formations; the Antrim Shale, Berea Sandstone, Bedford Shale, Sunbury Formation, and the Ellsworth Shale. These five formations include the problematical Upper Devonian-Lower Mississippian black shale sequence which will be examined.

Six major stratigraphic problems occur with relation to the "B" interval:

(1) The Ellsworth Shale-Coldwater Shale contact in western Michigan. The lithology of both units is grey shale.

(2) The Bedford Shale-Berea Sandstone contact in eastern Michigan. The contact in many instances is a gradational one.

(3) Nature of the relationship of the western Michigan Ellsworth to the Antrim, Berea, Bedford sequence of eastern Michigan.

(4) The Antrim Shale-Ellsworth Shale contact in western Michigan. The contact locally is a gradational one.

(5) The Traverse transition zone that occurs at the base of the "B" interval (Discussed under the Traverse Group).

(6) The "masked zone". A continuous sequence of black shales extending from the Sunbury Shale to the Traverse Group in a linear zone from Otsego County to Ionia County through north-central Michigan.

The gamma ray cross sections (Plates 17-20) and the regional isopach map (Plate 2) are particularly useful in obtaining a partial solution to these problems.

b. Antrim Shale

The Antrim Shale was originally called the St. Clair Shale (Lane, 1893); however, as A. C. Lane noted in 1901, the name was pre-occupied. He replaced it with Antrim, which was named for the county in which the shales were exposed. Lane further delimited the unit in 1902 when he described it as a bituminous shale that underlies the Berea grit and overlies the Traverse (Wilmarth, 1938). The formation was originally described as being Upper Devonian in age. Newcombe (1933), however, stated that Mississippian fossils are contained in the upper part of the unit.

The Antrim Shale is a fissile to dense carbonaceous shale sequence. The color of the unit is commonly jet black, but it may be interbedded with shales that are dark grey to dark brown in color. The black color of the Antrim is primarily due to the presence of organic material. It is observed throughout the Michigan Basin.

Dark borwn calcareous concretions ranging from two to five feet in diameter are frequently encountered in the basal portion of the Antrim in eastern Michigan. These concretions weather differentially from the enclosing Antrim Black Shale. Frequently the concretions are removed either by disintegration or mechanical means and will leave large rounded pits that are referred to as "kettles" in Ontario. Daly (1900) ran chemical analyses on the "kettles" and found that they contain, in addition to calcium carbonate, approximately twelve per cent of impurities, including magnesium carbonate, iron oxide, four per cent of insoluble residues (HCl) and over three per cent hydrocarbons and water. The minerals reported are anthraconite, marcasite, pyrite, calcite, colomite, and quartz. Hoover (1960) discussed in detail the occurrence, chemical analysis, and origin of the concretions in the Devonian-Mississippian Ohio Shale sequence.

Equivalent units to the Antrim Shale occur in all directions from the Michigan Basin (Plate 21) which are: the Long Rapids Formation, occurring to the north in the James Bay Lowland region of Hudson Bay; the Kettle Point Shale in southwestern Ontario; the Ohio Shale in Ohio and Pennsylvania; the New Albany Shale in Indiana and Illinois; and the Kenwood Shale, occurring to the west at the city of Milwaukee. All of these formations are lithologically similar to the Antrim Shale.

The upper contact of the Antrim can usually be readily distinguished with the utilization of gamma ray logs. Separation of the upper contact may be problematical, however, on a lithologic basis throughout the Basin.

In eastern Michigan the contact between the Antrim Shale and the Bedford Shale can usually be made without difficulty.

In central Michigan there is a problem that exists in the so-called "masked zone". The "masked zone" is an apparently uniform sequence of black shales extending stratigraphically from the Traverse Group to the Coldwater Shale. The "masked zone" is observed in the subsurface from Ionia County in the south to Otsego and Montmorency counties in the north. This lithologically undifferentiated zone of black shales occurs, also, in parts of Crawford, Roscommon, Missaukee, Clare, Osceola, Mecosta, Isabella, Montcalm, Gratiot, and Clinton counties (Cohee, et. al., 1950). Log studies (Plates 17-21), however, indicate that a differentiation of formational units can be made across this zone.

In western Michigan the contact between the Antrim and the overlying Ellsworth is difficult to establish on the basis of sample examination.

The contact between the two may be locally interfingering and vertically gradational. The contact, however, can be made readily when utilizing gamma ray-neutron logs.

The Antrim has been subdivided into two units (upper and lower) by the writer. The lower unit is very distinct and can be correlated throughout the entire Michigan Basin on the basis of its gamma ray log characteristics (Plate 17-21). In all areas, except west-central and southwestern Michigan, the unit is typified by two highly radioactive shale units with a lesser radioactive unit in between them. In west-central and southwestern Michigan the top and base units of the Lower Antrim are distinguishable, but correlation of the middle low radioactive shale unit is not possible.

The upper contact of Upper Antrim Shale is very sharp on gamma ray logs in eastern Michigan. It is gradational but definable, when present, with the Ellsworth Shale in western Michigan. In the central part of the Basin throughout the "masked zone" area the contact between Upper Antrim and Bedford Shale or the undifferentiated Berea-Bedford can be made on gamma ray logs. The character of the gamma ray logs seems to indicate a higher relative radioactive content for the "masked zone", possibly likewise indicating a higher organic content (Swanson, 1961).

Correlation studies of the Lower Antrim seem to indicate an excellent continuous subsurface mapping unit throughout the entire Basin. The Upper Antrim, conversely, is very difficult to use as a unit. Correlation studies clearly indicate that it is intertounguing west of the "masked zone" with the Ellsworth and is being replaced in the upper part of the unit by the Ellsworth type of shale. Tarbell (1941) indicated the general lithologic relationship between the Antrim Shale and the Ellsworth Shale in western Michigan in a series of cross sections accompanying her article on the problem.

Cohee's regional isopach map of the Antrim (Cohee, et. al., 1951) does not give an accurate picture of the Antrim Shale over the Basin. The fact that the Antrim Shale can be differentiated on the gamma ray logs makes all of the prior thickness values in the "masked zone" inaccurate or at least questionable. A similar situation exists in the western portion of the state.

The "B" interval isopach map (Plate 2) clearly indicates a major north-south spur extending from the South Michigan Shelf along the problematic "masked zone" area. It seems clearly apparent that this isopach thin was a controlling factor in the sedimentary variations of the "B" interval. The "B" interval isopach thin axis, or more simply the "B" axis as it is referred to in this study, is the probable result of either non-deposition of sediments or the development of a barrier of some type.

This study considers the "B" axis to be a barrier. This conclusion is based on the writer's interpretation of environmental conditions, as well as facies relationships based on gamma ray correlations. The alternate solution of non-deposition of sediments must also be considered. Non-deposition could result in an isopach thin as a function of such factors as distance from source, selective current action within the Basin, and differential basinal settling.

The "B" axis most likely acted as a facies and probably a faunal barrier during the sedimentation interval between post-Lower Antrim Shale and pre-Sunbury Shale. This barrier would effectively separate the Basin into two distinct areas of accumulation, the western Ellsworth area and the eastern Upper Antrim-Bedford-Berea area. The "B" axis position trends in the same direction as Hale's postulated barrier (1941). There is, however, a considerable divergence between the two axes, 14 miles apart in the south and 42 miles apart in the north (Plate 23). In addition to the "B" axis, sedimentation was also controlled by thinning onto the South Michigan Shelf.

As previously stated, the Lower Antrim is the most critical to the analysis. Its thickness shows little variation throughout the entire Basin. The three members of the Lower Antrim are traceable in all portions of the Basin, except the west-central and southwestern regions where the unit is typified by a single highly radioactive unit with thin interbeds of less radioactive shales. It may, therefore, be pointed out that the barrier may have been partly effective with relation to the Lower Antrim south of Wexford County (Cross section E-E^1, Plate 19). The area would essentially include all of the state south and west of southwestern Osceola County.

The Upper Antrim, east to west, increases in thickness onto the "B" axis in the case of all of the east-west cross sections (B-B^1, Plate 17; C-C^1, Plate 18; E-E^1, Plate 19; and G-G^1, Plate 20). In all instances the Upper Antrim seems to be thickening at the expense of the overlying Berea-Bedford sequence. At the "B" axis the Upper Antrim changes facies into the Ellsworth Shale type. A number of problematic correlations occur along this zone. The increased organic content would seem to color the shales black and cause the "masked zone" development to occur. An excellent example of this problem is observed in the Kent and Ionia wells in cross section F-F^1 (Plate 19). In the case of the Ionia County well what is labeled as Ellsworth should be the Berea-Bedford equivalent. The Kent County well clearly exhibits the character of the Ellsworth, replacing the "Ellsworth" and Upper Antrim of the Ionia well. Cross section D-D^1 (Plate 18) distinctly reflects the fact that the Upper Antrim thins onto the South Michigan Shelf. Some carbonaceous zones of the Upper Antrim are recorded west of the Barrier; however, they are thin, local, and are observed directly above the Lower Antrim.

In Bay County (note Bay County well in cross section G-G^1) the Antrim is a relatively easily distinguished unit, so that it may be used as a local structure contour base within the county (Plate 17). The isopach map of the Antrim in Bay County shows minor variations in thickness (note contour interval equals 20 feet) over the major structures of the county (Plate 11).

The paleontology of the black shale sequence is interesting as well as critical for a paleoecological analysis. Fish remains (Paleoniscid, et. al., personal communication, R. E. Matthews) are recovered throughout the Antrim interval in the Michigan Basin. Invertebrate fossils, especially the brachiopod Lingula, have also been recorded throughout the sequence in Bay County. Fossil wood, generally referred to as Callixylon newberri (Dawson) is frequently recovered from the interval. A systematic study of the fossil wood would probably indicate several species rather than one. The species seems to be used as a catch-all for all fragments of fossil wood in the sequence. Morse (1938) in a doctorial thesis at the University of Michigan systematically studied the abundant Antrim conodonts. The conclusion derived at that time indicated that the Antrim was probably mostly Upper Devonian in age. This group of microfossils needs systematic revision for the Michigan Basin black shale problem.

Systematic palynological examination of the entire "B" interval will eventually provide an accurate correlation of the formations across the state. Winslow (1962), in her classic Ohio Shale paper, indicated lucidly the validity of this type of analysis. It is possible not only to use the spores found in the sequence for correlation, but also to use them as time indicators. Winslow's Ohio Shale work yielded 24 genera, four of which were new. In addition to this, she described 31 new species.

The writer, working with core samples from Bay County, was able to make some preliminary studies with relation to these spore types. He has tentatively recognized the genera *Tasmanites*, *Canthospora*, *Calamaspora*, as well as the Foerstian remains. The Antrim Shale was particularly refractory to chemical techniques in the samples with which the writer worked. The term *Sporangites huronensis*, which is so commonly referred to in the Antrim and Ellsworth shales, has been abandoned as ambiguous by Winslow (1962). She indicated in her study of the genera a close affinity to *Tasmanites* under which she classifies it now. It is the writer's opinion that the species *Sporangites huronensis*, so commonly referred to by workers in the Michigan Basin, is simply an all inclusive waste basket term for all megaspores.

Foerstian remains, which are concentrated in the lower part of the Ohio Shale, are important, also, from an ecological view, as they indicate a pelagic or sargassoic plant community. The writer also recovered an algae thallus from the Bay County core, which he tentatively identifies as the Upper Devonian species *Drydenia foliata* (Fry and Banks, 1955).

c. Bedford Shale

The Bedford Shale was named by Newberry in 1870 for the exposure near that town in Cuyahoga County, Ohio. The term is used in the eastern portion of the Michigan Basin, Ohio, Pennsylvania, and Kentucky (Wilmarth, 1938).

The Bedford Shale is a grey, silty to sandy shale. It is generally restricted to the eastern side of the Basin. The shale becomes more sandy towards the top of the unit, thereby making the contact between it and the overlying Berea Sandstone locally extremely difficult to define. The radioactive character of the upper contact of the Bedford can be distinguished locally in gamma ray logs. The shale is often combined with the Berea Sandstone and referred to simply as the Berea-Bedford sequence.

The Bedford Shale is not subdivided into units whether on the basis of sample examination or on the basis of well log interpretation (radioactive or electric). Landes (1944) in his study of the Porter Field stated that the Bedford locally thins over hte Porter Anticline, indicating that there may be a structural relationship. The writer could not find any additional substantiating evidence for this effect either in his studies or in the literature.

In the examination of gamma ray log cross sections, several interesting features evolve. In section A-A^{1} (Plate 17) the Bedford is traceable southwestward from Iosco County to Midland County. In Midland County the low radioactivity character that separates the Berea from the Bedford phases out and becomes indistinct. The Berea-Bedford zone, however, is identifiable as far southwestward as Barry County, at which point it phases out into the Ellsworth Shale. In section B-B^1 (Plate 17) across the southern end of the state the Berea Sandstone and the Bedford Shale are separable only in the Lenawee County well. The Berea-Bedford, however, can be correlated as far as Branch County. Between the Branch County well and the St. Joseph County well all recognizable characteristics of the Berea-Bedford sequence disappear.

In section C-C^1 (Plate 18), which extends from Ottawa to Sanilac County, east-west across the Michigan Basin, the Bedford Shale is traceable as a separate unit as far as Shiawassee County. From Shiawassee County to Kent County the Berea-Bedford is carried as a single unit. Between the Kent County well and the Allegan County well all traces of the character of the Berea-Bedford unit disappear. In section D-D^1 (Plate 18), which is a north-south section in the southeastern quadrant of the state of Michigan, the character of the Bedford Shale is distinct enough to allow a correlation in the unit throughout its entire extent. There is a slight thinning of the shale onto the South Michigan Shelf.

In section E-E^1 (Plate 19), which is the northern most east-west section, the Bedford as a unit is tentatively correlated across the Michigan Basin. There is a loss of some of the lower portion of the unit to the underlying Ellsworth facies. One of the more interesting things to note in the section is the fact that the Bedford equivalent is actually more radioactive than the underlying Ellsworth; exactly the reverse is true in the case of cross section C-C^1. The F-F^1 cross section (Plate 19) is one of the most interesting of the entire sequence; it extends north-south from south of the Indiana line to Wexford County. It extends for the greater part of its traverse just along the western side of the "B" axis. The terminological confusion that occurs along the barrier is well illustrated in this section. In the wells in both Calhoun and Ionia counties the designation of the Ellsworth Shale for the lower radioactive Berea-Bedford equivalent may be noted. North from the Ionia County well, it is possible to see a rather interesting terminology change once more; the Ellsworth-Upper Antrim now becomes totally the Ellsworth in only seven miles distance. Extending far to the north (40 miles) from this log a well-developed Berea-Bedford equivalent occurs. Once again the Berea-Bedford is more radioactive than the underlying Ellsworth sequence. A Bedford unit appears to be identifiable in Mecosta and Osceola counties, also. The Berea equivalent is also present again in Wexford County. The Bedford thins to the north and west, west of the barrier.

The Bedford Shale in cross section G-G^1 (Plate 20), the central Michigan east-west cross section extending from Muskegon County to Sanilac County, is very thick near the eastern border of the Michigan Basin; it thins gradually to the east to a minimum at the "B" axis. The underlying Upper Antrim, as previously stated correspondingly increases in its thickness. West of the axis the Bedford Shale is extended as far as Mecosta County and is tentatively carried as far west as Newago County. The Bedford, again in this unit, is more radioactive than the underlying Ellsworth Shale facies.

The "B" axis, once more, functions as a facies barrier in the south separating the Ellsworth facies from the Bedford Shale and Berea-Bedford. To the north, however, an intermixing with Bedford Shale and the Berea-Bedford equivalent west of the axis is evident. These eastern units interfinger with the uppermost portion of the Ellsworth Shale. They thin to the west and the north from the axis, most likely in a direct function of their distance from their source area in eastern Ontario.

d. Berea Sandstone

The Berea Sandstone was named by Newberry in 1870 for exposures near the town of Berea in Cuyahoga County, Ohio. It occurs in eastern Michigan, Ohio, Pennsylvania, Kentucky, and West Virginia (Wilmarth, 1938).

The Berea Sandstone is essentially a fine-grained quartz sandstone. Cohee and Underwood (1945), Landes (1944), Sawtelle (1958), and Cohee (1951) all have subdivided the Berea into three units, which are (after Cohee, 1951):

(3) Upper unit - similar to lower unit except shaly and less pyritic.

(2) Middle unit - friable, fine-grained sandstone composed of angular quartz grains. Thin beds of shale and tightly cemented sandstone are interbedded with friable sandstone in places.

(1) Lower unit - sandstone, light grey, fine-grained, dolomitic, silty and shaly, cemented with silica and dolomite, micaceous and pyritic.

The lithologically identifiable Berea-Bedford sequence is not recognized west of the "B" axis. West of the axis, however, at approximately the same stratigraphic position, a sandy to silty dolomite to dolomitic limestone occurs in the section. Commercial gas has been produced from this so-called "Berea Dolomite" in western Michigan. The radioactive logs indicate that the Berea Dolomite is related to the Berea Sandstone of the eastern side of the Michigan Basin. The Berea Sandstone is reported to the south in Indiana and northeast Ohio. It is, however, most likely not continuous with the typical Ohio Berea Sandstone across the Findlay Arch (Pepper, et. al., 1954). The northern limit of the Berea is the subcrop area in northern Southern Michigan. No equivalents to the Berea-Bedford or younger Paleozoic formation are observed in the James Bay Lowland area in northern Ontario (Martison, 1952).

The upper contact of the Berea is easily distinguished by either sample examination or radioactive logs. The Berea equivalent in west-central and northwestern Michigan, when present, can be easily distinguished because of its low radioactivity character.

The correlation of the Berea Sandstone sequence in the Michigan Basin is subject to the same problems as encountered with the Bedford Shale. In many locations toward the "B" axis, and often west of the "B" axis, the unit is recognized as the Berea-Bedford; the two units cannot, on the basis of radioactive character, be separated.

In the four east-west sections (from south to north, [B-B^1 (Plate 17), C-C^1 (Plate 19) and G-G^1 (Plate 20)], the farthest west the Berea may be recognizable is (south to north) Lenawee, Shiawassee, Mecosta, and Wexford counties. The "B" axis was probably an effective barrier, therefore, as far north as Midland County. Recognizable Berea sediments apparently spilled over the barrier in both Mecosta and Wexford counties. The Berea is not recognized in the Osceola County wells. The Berea is notably thinner at its western limits in the Mecosta and Wexford wells.

The Berea-Bedford sequence, however, extends much farther west than the Berea limit. The only wells found on the cross sections that exhibit no Berea-Bedford character are found in the extreme southwestern part of the state, specifically in the wells in Cass, St. Joseph, western Branch, Kalamazoo, Allegan, Ottawa, and Muskegon counties. East of these counties a recognizable Berea-Bedford can be observed in all cases.

Isopach studies were made on the Berea-Bedford interval in Bay County (Plate 12). This isopach study provides the most interesting map of the entire Bay County series. The unit, contoured on an interval of ten feet, indicates a probable channel development in the sequence. These interpreted channels are similar to those developed in the Berea delta of the Ohio Bay (Pepper, et. al., 1954). If these channels are sandy, they could represent a significant gas-oil reservoir in Bay County. The Berea Sandstone has produced gas directly to the north in Arenac County (Cohee, 1951). The trend of the channels in Bay County is in a definite east-west direction. This would indicate that a delta was forming north of Cincinnatia (Cincinnati-Findlay-Algonquin arch positive area). This delta would probably have the same general mountain source areas as the one supplying sediments into Pepper's postulated Ontario River system. The similarity of the isopach studies between the channels developed in Bay County and those on the Berea delta in Ohio (Pepper, et.al., 1954) is striking.

e. Sunbury Shale

The type locality for the Sunbury Shale is near the town of Sunbury in Delaware County, Ohio. It was originally named by Hicks in 1878 (Wilmarth, 1938).

The Sunbury Shale is distinct, black, highly radioactive shale, that is easily distinguished on the basis of both its high radioactivity and distinct black color. It has been reported (Baltrusaites, 1948) to lack the abundance of spore cases found in the underlying, lithologically similar Antrim Shale.

The Sunbury ranges in thickness from being absent in southwestern Michigan to an average of between 30 and 40 feet in Eastern Michigan. The thickest sections of Sunbury are found in the "Thumb" area (Huron, Tuscola, and Sanilac counties) where it ranges in thickness up to a maximum of about 150 feet (note Sanilac wells, section C-C^{1}, Plate 18). In Western Michigan it thins to about 10 to 15 feet, except toward southwestern Michigan, where it is present only in restricted lenses. The Sunbury forms a sharp, distinct upper contact wherever it is found in the Michigan Basin. The Sunbury is not only thin over most of the Michigan Basin but also it is probably synchronous across the Basin.

A study of the isopach character of the formation was made in Bay County (Plate 13). When utilizing a five foot contour interval in this formation, it has an apparent highly lenticular development.

The major importance of the Sunbury, as a recognizable thin unit, is, of course, in the utilization of the unit for structure contour maps. In most areas where the Sunbury shale is missing, a distinct mappable unit some 30 feet or less stratigraphically above it is used; it is called the Coldwater redrock.

Monnett (1948) and Cohee (1951) have both developed excellent structure contour maps of the Michigan Basin on the bases of these two units. In Bay County a structure contour map utilizing the Sunbury Shale was constructed. It agrees very closely with the Dundee, which is commonly used as the standard subsurface reference plane.

f. Ellsworth Shale

Newcombe (1932) first described the Ellsworth Shale from a well in Muskegon County. He delimited it as the 509 feet of blue shale and limey sandstone that underlies the Coldwater Shale and overlies the Antrim Shale. Newcombe later (1933) described an alternate type section exposed south of the town of Ellsworth in Antrim County, Michigan. The section at this location is typified by greenish-grey, sandy shale. The type section is exposed in a cement quarry as a ledge only 30 to 40 feet thick (Tarbell, 1941). This sequence, as the Antrim Shale, is very pyritiferous locally. Frequently, in drilling, balls of marcasite are recovered from the Ellsworth. Ells (personal communication, 1963) states that the balls look like minute osage oranges. The sandy dolomite to oolitic limestone that is observed in the upper part of the Ellsworth is called the "Berea dolomite". This unit is discussed under the Berea. The Ellsworth Shale is restricted to the central and western portions of the Michigan Basin (Wilmarth, 1938).

The Ellsworth Shale is typically a greyish-green to greenish-grey argillaceous shale with interbedded limestone and dolomite lenses. Tarbell (1941) reported minor interbedded red shales, but she does not designate locality or specific stratigraphic occurrence in the Ellsworth. Cohee (1951) reported that the section is siltier in southwestern Michigan.

The relationship of the Ellsworth Shale to the overlying Berea-Bedford is a gradational one which makes the contact extremely difficult to pick when utilizing lithologic samples. The differentiation, however, is possible in many cases when utilizing radioactive logs, as previously discussed under the Berea and Bedford. The Ellsworth Shale, when overlain by the Sunbury, develops a very sharp color, and radioactive break. Where the Ellsworth is overlain by the Coldwater, the contact is imperceptible, both on the basis of radioactive character and lithology; however, within thirty feet or less of the contact, the Coldwater redrock is observed, which makes an easily distinguishable lithologic and radioactive break in the sequence.

The Ellsworth Shale is naturally a less radioactive sequence in comparison to the Antrim and the Sunbury shales. It is, likewise, commonly more radioactive in western Michigan than Bedford equivalents, except areas in west-central and northwestern Michigan where the shale has such a low radioactive value that the Bedford equivalents are more radioactive than the Ellsworth.

The Ellsworth is restricted in its entirety to the west side of the "B" axis in the Michigan Basin. It is an apparent time and facies equivalent of the Upper Antrim and Bedford-Berea sequence. The equivalency of the units is a direct function of how far north the Ellsworth is examined. In the examination of cross section B-B^{1} (Plate 17) it can immediately be seen that the Ellsworth is equivalent to the entire Upper Antrim and Berea-Bedford sequence. In cross section C-C^{1} (Plate 18) it can be seen that the Ellsworth is the equivalent of the Upper Antrim and the lower part of the Berea-Bedford sequence. Farther west from this point in Allegan County the entire sequence phases out into typical Ellsworth Shale. Section G-G^{1} (Plate 20) illustrates the continuity of the Berea-Bedford sequence over the "B" axis. The Berea Sandstone can be traced as far west as Mecosta County in this section. Between the Mecosta County well and the Newaygo County well the Berea either pinches out due to non-deposition, because of distance from the shoreline, or changes facies into the typical Ellsworth Shale sequence, illustrated by the Muskegon well. The cross section E-E[1] (Plate 19) shows that the lower portion of the Bedford and the upper portion of the Upper Antrim phase out to the west into typical Ellsworth Shale. The thinning of the Berea is most likely a simple function of distance from source. Section A-A[1] (Plate 17) indicates the same relationships as illustrated with the previously discussed east-west sections. In the north-south relationship between the Berea-Bedford sequence and the Ellsworth Shale, the Berea-Bedford section increases in thickness from the South Michigan Shelf to Osceola County where the unit reaches its maximum thickness. From Osceola County north to Wexford County the Berea-Bedford sequence thins once more. Slight variations in this sequence can best be explained in the east-west relations. As a fairly reliable rule, it may be said that in wells west of the "B" axis the Berea-Bedford, when present, thickens eastward toward the "B" barrier. The sequences to the south of Wexford County can be said to be dependent on distance from the Berea-Bedford sediment source area and/or in the topography of the submerged "B" barrier.

The Ellsworth Shale contains spores; however, they are far less prolific than those observed in the Bedford and the Upper Antrim sequences. Palynological examination of this sequence utilizing the types established by Winslow (1962) should establish the Devonian-Mississippian boundary.

Isopach studies indicate that the greenish-grey Ellsworth Shale sequence thickens to the north and west. Cohee (1951), also, indicated in his cross section a definite increase in siltiness to the west. The maximum thicknesses of the Ellsworth range from approximately 600 to 900 feet in the northwestern portion of Michigan. The South Michigan Shelf, also, influences the unit in that it thins onto that paleogeographic feature. The source of these sediments would appear to be to the west and northwest. This would not be difficult to develop were it not for the Kenwood Shale of the Milwaukee area (Edwards and Raasch, 1922). This is the black shale unit above the Hamilton Milwaukee Formation. The writer tentatively correlates this unit with the Michigan Basin Lower Antrim sequence. If this correlation is valid, then an interpretation of a regional uplift in the Wisconsin Highlands pouring sediments to the east all along its flank after the Kenwood Shale deposition is reasonable. The Kenwood Shale remains as a probable beveled erosional remnant of the movement. Movements taking place at this time (perhaps synorgenically with the Acadian Revolution) also would be logical in the timing of the uplift of the submerged "B" axis, which could act as an eastward facies barrier to Ellsworth sedimentation.

g. Environmental Interpretation

The "B" interval may be said to contain in general three distinct lithosomes, which are: the black shale lithosome, which includes the complex facies relationships of the Antrim and the Sunbury shales throughout the Basin; the eastern clastic lithosome, which includes the deltaic deposits of the Berea and Bedford; and the western shale lithosome, which includes the Ellsworth Shale.

The black shales of the Upper Devonian-Lower Mississippian sequence in the Michigan Basin are composed of the Antrim, the Sunbury and the undifferentiated black shales of the north-central part of the Basin (see inset, Plate 2).

To work with the black shale lithosome, the black shale problem itself must be introduced. The problem consists of three basic areas, which are: the depositional environment, the time-stratigraphic relationships, and the origin of black shales.

Black shale may be simply defined as a dark-colored, fine-grained, clastic sedimentary rock that contains enough organic material, iron sulfide, and/or manganese oxide to color the rock dark grey or black. The majority of black shales owe their color to finely disseminated organic matter. It has been calculated by Swanson (1961) that at least two per cent carbon must be present to reach a true black color, according to the National Research Committee Color Chart. Invertebrate faunas in black shales are typified by their scarcity and dwarfed morphology.

Black shale often is identified by special names such as sapropelite, gyttja, etc. It is, likewise, often identified with compositional, genetic, and paleontologic variation. Examples of this practice would be such terms as uraniferous shales, oil shale, marine shale, graptolitic shale, etc. Genetic usage with reference to black shale is a common problem; formations are often classified into such catagories as marine, non-marine, deep water, and shallow water.

Black shales, because of their petroleum and uranium content, have been analyzed extensively during the last few years (Conant and Swanson, 1961), (Vine, 1962), (Swanson, 1960), (Landis, 1962), (Glover, 1959), (Hoover, 1960), (Smith, et. al., 1959), etc. The chemical composition of black shales is, of course, dependent on the unit's sedimentary history. Organic black shales, however, are invariably formed under acid and reducing conditions in sea water. It is possible, therefore, to make some generalizations concerning the elements present under these conditions. Mason (1952) points out that in addition to the organic carbon and iron sulfide present, enrichment in the following minor elements were noted: V, U, As, Sb, Mo, Cu, N, Cd. Ag. Au, and metals of the platinum group. Vanadium has been commercially produced from the shales. The uranium potentialities of the black shales have been studied intensively over the last ten years by the U.S. Geological Survey. Carolyn Fix (1958) offered an excellent summary of previous research papers in the field of uraniferous black shales.

The amount of radioactive material present in the Antrim is a critical factor, as it directly influences the gamma ray logs, which are being used for correlation purposes in this paper. The Antrim has been reported to carry 0.01 per cent U_3O_8 equivalent by Westergard (Faul, 1954) and Bain (1950). Swanson (1960) ran uranium analyses of 38 selected cuttings of the Pure Oil 553 (T32 N, R4W) Charlevoix County and the Andy Bonardi (Sec. 34, T8N, R15E) St. Clair County. In the Pure Oil 553 well uranium percentage varies from .0007 to .0036 and in the Bonardi 1, from .0006 to .0035. His samples were also tested for oil recovery and they varied from a trace to 16.9 gallons per ton. In the two widely separated wells (over 200 miles) there is a positive correlation between oil and uranium content.

The organic content of the Antrim is about ten per cent in portions. Sutides by Beers (1945) indicated graphically that a positive relationship exists in the Antrim between carbon content and uranium content. An increase in one results in an increase in the other. Beers' (1945) studies, modified by Swanson (1960), also show that the same relationship exists in the Sunbury and Traverse "Transition zone". Beers and Goodman (1944) also noted a 50 per cent increase in the radiation of smaller than 200 mesh material as opposed to coarser fractions.

Whitehead (Faul, 1954) analysed six Antrim samples and determined that the mean percentage of potassium was 2.77 per cent with a variability of 0.1 per cent. A positive relationship again exists with these elements. Whitehead points out that there is also a very close positive relationship existing between phosporous and uranium from studies of a Miocene nodular clay. No values are available on phosphorous-uranium content of Antrim shales. Beers (1944) also noted this in his studies.

Uranium-bearing black shales, such as the Antrim, have many features in common, which are, according to Nininger (1954):

(1) Black and rich in organic matter and iron sulfide.

(2) They contain only minor limestones.

(3) They all contain petroleum.

(4) They are all relatively thin formations that were deposited slowly over a long period of time.

(5) Most are from geologically older formations.

(6) The uranium is syngenetic in origin.

Swanson (1960) lists fourteen quantitative controlling factors for the uranium distribution in black shales. Ten are considered to be speculative, four demonstrative.

Petrographically, black shales generally consist of very fine silt, quartz, clay, micas, feldspars, pyrite and marcasite, phosphates, and organic matter.

The insoluble organic matter (Kerogen) observed in the black shales may be either sapropelic (marine) or humic (terrestial). Breger and Brown (1962) in a recent article in Science have determined a method that may be utilized to determine the amount of each of the constituents present. The hydrogen percentage of sapropelic material is very much higher (10-12 per cent) than that of humic origin (5.5 per cent). This, of course, is an excellent index, also, of potential oil recovery in any given shale. It has no effect on uranium content of the black shales which apparently relates to the carbon content. Therefore, utilizing this method it might be possible to delimit the origin of many of the black shales of the Upper Devonian-Lower Mississippian sequence in the United States. The writer suspects that it would prove the Sunbury to be a humic accumulation rather than the sapropelic algal type as the Antrim. This suposition is based in part on the development of the very thick Sunbury sequence on the eastern side of the Basin. The Sunbury Shale could represent reworked terrestial organic debris distributed from a source area in the same region as the Berea-Bedford delta.

The paleontology of the black shale sequence has been the subject of a number of detailed studies. Studies of invertebrate paleontology include a minimum of some 23 major papers by some 20 authors. In the vertebrates much of the study has been done with fish, particularly during the early nineteen hundreds. The eleven major researchers in this area have presented some 53 individual papers on the vertebrate fauna. Micropaleontological research has been done for the most part on conodonts. There are about 22 authors of major works in this area of study.

Extensive work has been done with well-preserved paleobotanical specimens of the black shale sequence; a selected list of writers in this field reaches a total of over thirty men. Some nine papers by six authors have been published also on the palynology of the sequence. The great bulk of the researchers in black shale paleontology, in all disciplines, are included in Hoover's bibliography (1960).

The dating of the black shale sequence is problematic within the Michigan Basin. The Devonian-Mississippian boundary occurs within the Antrim Shale. As far as the writer can determine only two reasonable alternatives are practical paleontologically. The first is using conodonts; unfortunately, the zones are not sufficiently continuous laterally within the Antrim; and conodonts are rare within the Ellsworth. The best solution to the dating problem is working with palynology. Spores have been observed by the writer in both the Antrim Shale and the Ellsworth Shale, which form the critical time units. Caution, however, should be exercised in correlation, as deposition of the spores is dependent on such factors as distance from shore, prevailing wind and water current direction, latitudinal and topographic plant zonation, etc., for terrestrial forms. Current distribution represents the major problem with regard to the marine algal forms.

The theories of black shale origin may be classified into some seven broad caragories, which are listed below with some of their proponents.

(1) Shallow water origin - Ruedemann (1935), Hard (1931), Grabau (1919), Fisher (1953)

(2) Deep water origin - Clarke (1915), Shaler (1877), Rich (1948, 1951)

(3) Restricted basins - Schuchert (1915), Strom (1936), Adams, et. al. (1951)

(4) Algal origin - Schuchert (1910, 1915), Ruedemann (1935), Fisher (1953), Orton (1882)

(5) Organic soil erosion - Grabau (1906)

(6) Bitumens and Seeps - Gutschick (1947), Keyes (1938)

(7) Others - Grabau (1919) estuary; Raymond (1942) chitinous skeletal material.

The source of the organic material in the Antrim Shale is a combination of some land plants, spores, the majority of which are probably algal in origin, and very finely comminuted material, probably a combination of marine and non-marine material with the marine being predominant. The discovery of an algal thallus, the frequent observation of Foerstian remains, and the predominance of Tasmanites, a probable algal spore, seems to indicate the possibility of an extensive algal mat forming.

If one makes the presumption that a floating algal mass existed during the development of the black shales, it would probably have belonged most likely to the Phaeophyta. Within the Phaeophyta, one is restricted to the utilization of Sargassum, as the other members of the group require a cool climate and a rocky bottom to attach their holdfasts, which generally in extant forms reach only a maximum length of some 60 feet. The Phaeophyta are not particularly salinity selective so that the form would not require the narrow parameters of such forms as are found in the Rhodophyta.

A sargassoid planktonic algae seems to offer the most likely ecologic and stratigraphic solution for the Upper Devonian-Lower Mississippian seas. This sargassoid mass could be moved in response to local current, wind, and temperature variations.

The intermixture of frequent carbonate zones observed in the core sample examined would seem to indicate as abrupt a chemical as lithological change. This could be accomplished with relative ease with respect to a floating or attached algal mass. If the algae were swept away, Eh and pH values would change. The conditions observed in stagnant waters, such as would result from the development of a widespread algal mass dampening current and wave action, indicate that though the upper surface may have a pH of 8 and an Eh of +0.1 the conditions on the bottom are a pH±7 and an Eh of -0.3 (Krumbein and Garrels, 1952). This helps explain the condition of having a nearly normal marine sequence followed by a black shale sequence.

The grey intertounguing shales in the black shale sequence can result as a simple function of the quantity or organic matter present in the sediment, which could mean a lesser quantity due to either decrease in source of organic material or increase in current action to change the oxidation-reduction potential and the pH of the sea water to less favorable values for preservation.

The writer's theory for the development of black shale lithosome within the Michigan Basin is that the sea in which the lower Antrim was deposited was shallow (less than 100 feet deep) and covered with a mat of sargassoid algae. This algal mat reduced circulation and produced the reducing conditions (negative Eh) necessary for black shale development. A more acidic environment (pH7-7.8) may have existed from time to time through the development of hydrogen sulfide derived from decaying organic debris. After the Lower Antrim had been deposited the sargassoid algae was rapidly displaced toward the "B" axis, as the Wisconsin Highland area began to supply the Ellsworth type of facies.

Ecological conditions for the growth of the algae could have been effected by dissolved salts from the Highlands, current changes, temperature changes, salinity changes, etc. A similar situation developed in the Berea-Bedford southwest Ontario delta, except that in this case there seems to be not rapid displacement of algal material as was in the case of the Western Ellsworth Basin. Gradually the sediments displaced the algal masses till they were virtually limited to favorable ecologic niches in along the "B" axis (masked zone). The black shale sequence then closed with the development of a sheet of probable humic carbonaceous material swept in from the eastern side of the Michigan Basin, the Sunbury.

The Upper Devonian-Lower Mississippian black shale lithosome is found over most of North America. The regional correlations of the black shale are summarized in the map illustrating the Upper Devonian-Lower Mississippian shale sequence (Plate 21). Regional references are included in the bibliography. The black shales as a lithologic unit may be correlated from Montana or Arizona in the west to New York state in the east.

The Berea-Bedford sequence of clastics develop a deltaic pattern similar to the one developed in northern Ohio (Pepper, et. al., 1954). The sediments deposited in the Basin are derived from a source area in eastern Ontario. The Bedford Shale is a grey, silty to sandy shale that overlies the Antrim Shale with a gradational contact. The grey color is a function of organic content. The Berea Sandstone develops an east-west channel sand in isopach studies of that unit in Bay County. The channels may either be the result of channel filling of stream eroded valleys in the Bedford Shale (Pepper, et. al., 1954) or a distributarian channel system such as illustrated by Fisk (1954).

The western Ellsworth Shale lithosome consists of a grey to green, sandy shale. The shale is restricted to the western side of the "B" axis. The source of the clastics derived are from the Wisconsin Highlands region. The upper part of the section reflects the influence of the Berea from the eastern side of the Basin to as far west in the north as Wexford County.

The abrupt change that frequently occurs in the interbedded Antrim-Ellsworth sequence ("Elltrim" of Hale, 1941) indicates a marked lessening in organic content. The green color is developed as a result of the ferrous iron present in the shale; and it is an excellent indicator of a reducing environment condition during deposition.

4. Coldwater Shale

The Coldwater Shale was named by Lane in 1893 for exposures on the Coldwater River in Branch and Hillsdale counties. The Coldwater Shale was described by Lane as underlying the Marshall Sandstone and overlying the Richmondville or Berea Sandstone. The Sunbury was originally included with the Coldwater Shale in the Michigan Basin; however, Cooper, in 1909, designated the unit as a separate formation (Wilmarth, 1938). In 1932 the U. S. Geological Survey restricted the Coldwater and split out the Sunbury Shale as a distinct subsurface formation in the Michigan Basin.

The Coldwater is a blue-grey to greenish-grey shale sequence that develops local thin lenses of limestone, sandstone, and dolomite. It ranges in thickness from a maximum of 1295 feet in Iosco County to less than 550 feet in western Michigan (Plate 3).

The Coldwater has been divided into a western and an eastern facies by Monnett (1948). The boundary between the two facies is west of the "B" axis. The eastern facies is typified by silts, fine sands, and shales. The central area between the two facies, according to Monnett (1948), is essentially a continuous sequence of grey shales a thousand feet or more in thickness. The western facies is characterized by calcareous shales with interbedded minor dolomite. The source area for the Coldwater shales was to the east. The western Wisconsin Highlands were supplying neglible amounts of sediments to Michigan's Coldwater basin.

The upper contact between the Coldwater Shale and the Marshall Sandstone in eastern Michigan is extremely difficult to separate. Both units are coarse-grained sandstones and red siltstone and sandstone (Cohee, 1951) which lithologically are virtually identical locally.

In western Michigan the sequence is fine-grained and the transition into the Marshall Sandstone, while gradational, is easier to pick.

The Coldwater carries four recognizable units:

(1) Coldwater redrock.

(2) Coldwater "lime" or speckled dolomite.

(3) Weir sand.

(4) Richmondville sand.

The redrock is the only Coldwater unit that can be correlated any appreciable distance throughout the state. Monnett (1948) shows that it is absent in the north-central portion of the Basin. The redrock is a red shale, limestone, and/or dolomite unit that ranges in recognizable thickness from six inches to forty feet thick. It occurs near the base of the Coldwater Shale. The redrock has also been divided by Monnett (1948) into an eastern shaly facies and a western calcareous and dolomitic facies. Hale (1941) described the unit as being fossiliferous, especially in the south (crinoid, ostracods, tetracorals, etc.).

The redrock has been tentatively correlated paleontologically with the Rockford Limestone which overlies the New Albany Shale in northern Illinois and Indiana (Cohee, 1951).

The Coldwater "lime" or speckled dolomite is a calcareous marker zone in western Michigan. It has been reported to be from a few inches to thirty to forty feet in thickness (Baltrusaites, et. al., 1948). The Coldwater dolomite may be divided into four facies (Monnett, 1948):

(1) "Speckled" grey dolomitic matrix with embedded grains of light brown dolomite.

(2) "Speckled" dolomitic matrix with pepperings of glauconite.

(3) Crystalline dolomite with pepperings of glaucontie.

(4) Crystalline dolomite with no glauconite.

Hale (1941) observed that on the western outer rim of the Basin the dolomite is much thicker, possibly indicating the presence of a "speckled dolomite" sea to the west in the Lake Michigan area during Coldwater time. She also observed that the crystalline dolomite facies is more common to the north and the east in the western Coldwater facies.

The Weir sand is reworked broken sand which occurs locally in Ogemaw County. It has been described by Newman (1936) in Ogemaw County and the West Branch oil field as being a "stray" sand forty feet in thickness that occurs approximately 250 feet below the top of the eroded subcrop of the West Branch anticlinal structure.

The Richmondville was named for an exposure that occurs at the town of Richmondville in Sanilac County, in western Michigan. It was named by Lane (1893) and described as underlying the Coldwater Shale and overlying the St. Clair Shale (Antrim). Gordon in 1900, however, pointed out that the Richmondville was actually within the Coldwater Shale and some 100 to 200 feet below the top. Therefore, the original Richmondville, as designated by Lane, could not be correlatable with the Berea Sandstone of Ohio (Wilmarth, 1938). The unit was later regarded as a 50 to 80 foot thick "stray" sand occurring in the top of the Coldwater in Sanilac County. It cannot be traced for any great distance in the subsurface as it interfingers with other shales and sand units and has a highly lenticular-like characteristic (Cohee, 1951). Ells (personal communication, 1963) indicated that the survey has not used the unit in years.

No single unit within the Coldwater, with the exception of the redrock, can be used regionally for correlation purposes. Locally in western Michigan the Coldwater "lime" and various other carbonate stringers are used for correlation, but they are, as would be expected, extremely limited in their areal extent.

A. K. Miller (1953, 1955) working with cephalopods of the Coldwater Shale and Marshall Sandstone established the fact that the upper Coldwater Shale contained cephalopods of Kinderhook and Osage age. Miller described the cephalopods (orthoconic nautiloids and ammonoids) as having a very close relationship to the published faunas in Tien Shan, Kazakhstan, Belgium, Western Algeria, and New South Wales.

The most striking characteristic concerning the development of the Coldwater Shale is the thick accumulation of shales in the central portion of the state, just west of the "B" axis (Plate 2). The accumulation is most likely the resultant of either subsidence in this portion of the Basin or proximity to the source area. The very thick sequence developed in northern Iosco County would seem to indicate a more northerly source than that of the preceding eastward Berea-Bedford development. It, likewise, indicates either renewed or sustained uplift to the north and east of the Michigan Basin at this time. Lithologic cross sections (Monnett, 1948 and Cohee, 1951) clearly indicate the necessity of a sediment source area to the north and/or east. The thinner accumulations of mud and carbonate deposited in the western facies might suggest a simple nearshore-offshore facies relationship. This would seem to indicate that the Wisconsin Highlands area was supplying little or no sediments at this time.

The detailed studies of the tcp of the Coldwater Shale show a pronounced difference in the structure contours over the fields in Bay County (Plate 9), thereby making it a less reliable structural indicator than the underlying Sunbury Shale top. Errors developed in this sequence are probably, at least in part, due to inability to pick the Coldwater-Marshall contact in the Bay County area.

The detailed isopach map of Bay County (Plate 15) shows a definite thinning of the Coldwater interval over the anticlinal flexure in the county.

5. Marshall Sandstone

The Marshall Sandstone was originally described by Winchell in 1861. It was later delimited by Lane to include those rocks above the Coldwater Shale and below the Michigan Formation (Wilmarth, 1938). The upper unit of this sequence was originally referred to as the Napoleon Sandstone; it was described by Taylor in 1839 (Wilmarth, 1938). It has now, through usage, come to be referred to as the Upper Marshall, despite the fact that the name antedates that of the Marshall by some 22 years.

Monnett (1948) in his classic study of the Marshall, stated that he sees no suitable basis for the division of the Marshall into two members. The Napoleon Sandstone is distinguishable from the Lower Marshall only in eastern Michigan. This is because there exists both a western and an eastern source for the Marshall sediments (Monnett, 1948; Cohee, 1951; Stearns, 1933; and McGregor, 1954).

In addition to the problem of the questionable contact between the Marshall Sandstone and the underlying Coldwater Shale in eastern Michigan, a problem exists with the upper contact. Over much of the Basin, especially in the central portion, there is a gradational contact that exists between the Marshall and the Michigan Formation. The so-called Michigan stray is on top of the Marshall Sandstone in central Michigan. Hard (1938), Hake (1938), Addison (1940), Monnett (1948), and Wolcott (1948) all indicate that the Michigan stray is equivalent to the Upper Marshall in central and western Michigan. The Marshall-Coldwater contact in western Michigan is relatively sharp due to the sudden increase in grain size that occurs at the base of the Marshall. The lower contact is apparently conformable throughout the state.

The lithology of the lower Marshall is characterized essentially by sandstones, commonly red in color. The sandstone typically cemented with varying amounts of dolomite is very shaly and dolomitic near the base in western Michigan (Baltrusaites et. al., 1948). In the eastern portion of the Basin the unit is much more sandy and, of course, extremely difficult to distinguish from the underlying Coldwater. The Upper Marshall is typically a coarse-grained, white to grey sandstone interbedded with shales and silts toward the top of the section.

In addition to the utilization of the terms, Upper Marshall, Napoleon, Lower Marshall, and Michigan stray for the sequence, the Hardwood Point, Port Austin, Pointe Aux Barques, Huron City, Light House and the "peanut" conglomerate also have been used (Martin, 1936). These terms have since been abandoned.

Stearns (1933) did an exhaustive petrographic study on the Marshall Sandstone of the Michigan Basin. On the basis of the mineral suites that she recovered from selected wells, she was able to determine the provenance of the minerals. She clearly established that two sedimentary provinces exist with relation to sediments within the Basin, an eastern and a western one. The Wisconsin Highlands supplied vast quantities of sand to the southern and western areas of the Michigan Basin. The source of sand for the eastern side of the Basin comes from the Laurentian area. Stearns' (1933) studies are further reinforced by studies by O'Hara (1954), Monnett (1948), and Kropschot (1953).

A. K. Miller (1955), in a study of the Mississippian fauna of the Basin, indicated a probable Osage age for the Marshall Sandstone. All of the known fossils of the Marshall, at the time of his 1955 paper, came from a single 4.5 foot section. He pointed out that every cephalopod species listed from the unit may be recovered from a single six inch bed of extremely fossiliferous limonitic sandstone at the type section. Cohee (1951) was of the opinion that the Marshall is of early Meramec age.

The Marshall bed does not reflect the basinal shape as does the underlying Coldwater (Plate 4). The unit reflects a series of northwestern-southeastern trending thick and thin sand developments. It is generally assumed (Monnett, 1948) (O'Hara, 1954) that the wave action distributed the vast amounts of sand over all submarine irregularities; thus, perhaps at least in part, causing some of the isopach variation recorded.

The Bay County Marshall Sandstone study shows an apparent thinning in the section over the major structures of Bay County (Plate 16).

6. Post-Marshall Paleozoic Sediments

Mississippian

The post-Marshall Mississippian in the Michigan Basin is subdivided into two formations, a lower Michigan Formation and an upper Bayport Limestone.

The Michigan Formation consists of anhydrite, grey to dark grey and greenish shales, limestone, dolomite, and thin lenses of sandstone. It was named by Winchell (1861). It is exposed in Kent, Huron, and Iosco counties. Hard (1938) described a "brown dolomite" in the lower part of the Michigan subsurface, which was delimited by Hake (Swanson, 1955). On electrical logs it is usually referred to as the "brown lime" or "brown dolomite". The "brown dolomite" is approximately 100 to 150 feet above the Michigan stray (Swanson, 1955). Swanson (1955) suggested the name Clare in his thesis for the dolomite, because of its excellent development in Clare County, Michigan. Swanson (1955) subdivided the Clare into five provinces. Four of the Swanson's provinces represent marginal areas of decreasing lithologic and electrical character of the Clare. The fifth or central area province wherein the Clare is apparently consistent includes all of Osceola, Clare, Mecosta, Isabella, Montcalm, Gratiot, Ionia, and Clinton counties, as well as the western halves of Gladwin, Midland and Saginaw counties. Swanson (1955) also subdivided the Clare into three basic lithologies, which are: a central, north central, and western uniform, fine to coarsely crystalline, buff to orange, sucrosic dolomite; and a southern coarsely crystalline, sucrosic, buff dolomite. The Clare, as interpreted by electrical logs, thins to the north and northwest in the Basin; it pinches out to the south, and changes to a limestone facies to the east at the western border of Arenac and Bay counties, and in the center of Saginaw

County. Authigenic pyrite is a fairly common insoluble residue in the Clare. The average thickness of the Clare has been estimated to be between 13 and 16 feet (Swanson, 1955).

Above the Clare there is a 30 to 40 foot thick gypsum zone that may be traced over much of the central portion of the Michigan Basin. This unit is referred to as the "Triple Gyp". The "Triple Gyp" was named by Wolcott in a paper delivered to the Michigan Geological Society in 1948 (Cohee, 1951). The three individual gypsum zones are separated by thin shales. The Clare dolomite and the "Triple Gyp" are easily recognized through the media of electric logs.

Landes (1944) subdivided the Michigan into lower and upper units. His subdivision was based on the lithologic differentiation that occurs in the Porter Field, Midland County, above and below the base of the Clare dolomite equivalent. He further subdivided each unit into two lithologic zones. Addison (1940) followed approximately the same subdivision in Buckeye Field, Gladwin County, except that he places his subdivision at the top of the Clare rather than the base. Baltrusaites, et. al. (1948) placed his subdivision of upper and lower units similarly to Addison. The lower part of the Michigan is typically dolomite, limestone, shale, sandstone, and a subordinant amount of gypsum. The upper unit is characterized by grey to pink gypsum, locally comprising forty per cent of the section.

Cohee (1951) reported that there is evidence of the upper part of the Michigan being eroded before the deposition of the Bayport, as evinced by part of the Michigan being stripped off some anticlinal folds in the vicinity of Saginaw Bay. Landes (1944) and Addison (1940) corroborated this in that they recognized an erosional unconformity in the Porter Field in Midland County and the Buckeye Field, Gladwin

County. The lower contact of the Michigan is gradational into underlying Marshall.

The age of the Michigan is in question. Newcombe (1933) considered it to be late Osage and early Meramec in age, which is similar to the age assigned by Weller (1948). Cohee (1951), however, was of the opinion that it sould be limited to the Lower Meramec.

The Mississippian Bayport Formation consists of a sequence of basal, grey, friable sandstones that are overlain by limestones. The Bayport is bounded by upper (Cohee, 1951) and lower (Landes, 1944) unconformities. Ehlers and Humphrey (1944) described the Bayport (Point Au Gres) as being equivalent to the St. Louis Limestone and possibly the lower part of the St. Genevieve (Upper Meramec). The correlation indicates that there was probably a direct connection to the south and the Upper Mississippi Valley area during Bayport time.

Pre-Pennsylvanian movement of the sediments in the Michigan Basin was probably initiated in Chester time and continued until the end of the Morrow. The principal structural trends (NW-SE) were formed at this time. In arenac, Bay and Tuscola counties, Cohee (1951) reported that the upper part of the Coldwater, the Marshall, the Michigan and the Bayport are eroded away from the top of some anticlinal folds.

The Pennsylvanian rocks of the Michigan Basin are divided into three units, which are (in ascending order): the Parma Sandstone, a non-fossiliferous, medium to coarse-grained, friable, white sandstone; the Saginaw Group, which has been divided into seven cyclothems (Kelly, 1936) at Grand Ledge in Eaton County; and the Grand River Group, which is classically subdivided into three units. These formations of the Grand River Group are (in ascending order): the lower Woodville Sandstone; the crossbedded, coarse grained Eaton Sandstone; and the overlying deep red to purple, crossbedded, slightly argillaceous Ionia Sandstone. Cohee (1951) recorded a maximum of 765 feet in Midland County in his study of the Pennsylvanian.

The Saginaw Group flora indicates a Kanawha age. Cohee (1951) believed that younger floras of Allegheny age may be present. The Verne Limestone (Kelly, 1936), the only one observed in the Saginaw, has a scarce, diagnostic fauna that has been correlated with the uppermost Kanawha Seville Limestone in western Illinois (Wanless, 1944). The Pennsylvanian rocks, as the overlying so-called "Permo-Carboniferous red beds", are both delimited by upper and lower contact unconformities.

The "red beds" overlying the Pennsylvanian are observed in the northwestern part of the state. The apparently nonfossiliferous "red beds" are overlain by Pleistocene glacial deposits. The "red beds" have been considered to be Pennsylvanian by Kelly (1936), Permo-Carboniferous by Newcombe (1933), and Martin (1936), and possibly as recent as Cretaceous. The Lower Cretaceous Mattigami Formation (Martison, 1952) bears a remarkable lithologic resemblance to the "red beds". The writer is of the opinion that the "red beds" age problem could be directly and conclusively solved by a palynological examination of the specimens from the interval.

IV. GEOLOGIC HISTORY

The geologic history of the Upper Devonian and Lower Mississippian sediments of the Michigan Basin is illustrated by a series of changing tectonic features primarily peripheral to the Basin. The four subdivisions used by the writer for the basic stratigraphy of the sequence were useful in illustrating these changes (Traverse Group, "B" interval, Coldwater, Marshall).

The isopach studies of the Michigan during Traverse time point out a series of very interesting features. First is the fact that there exists an eastern "normal facies" and a western evaporitic facies. The basins of deposition are developed in response to a north-south barrier, which has been named the West Michigan Barrier. South and east of this spur a northwest-southeast spur exists that is possibly the result of differential compaction of Devonian sediments over the Silurian reefs. The Traverse Group thickens to Northern Michigan and probably during Traverse time was connected to the north through the Ontario Seaway to the James Bay Lowland of Hudson Bay. A correlatable unit (the Williams Limestone) is observed at this area (Martison, 1952). The Traverse Group sediments on the South Michigan Shelf reflect the influence of the Battle Creek Trough in Calhoun and Branch counties, as well as the Chatham Sag. The Howell Anticline and the Clinton Sag in the southeastern Michigan are likewise reflected in the shelf area. The lower contact of the Traverse Group very likely represents a situation of continuous sedimentation in the Michigan Basin. Minor disconformities that have been reported at this contact may be, in actuality, submarine in their development. The Traverse Group is a section of more or less continuous deposition of argillaceous shales and limestones.

At the top of the Traverse Group there exists a thin zone which is referred to as the transition zone. This zone represents the gradual change that occurs from typical Traverse carbonates to typical Antrim shales. Gamma ray-neutron stratigraphy in the Michigan Basin lucidly shows that the basal portion of the "B" interval throughout the Basin (Lower Antrim) was a time of widespread organic accumulation. The concentration of the organic accumulation is through the development of planktonic sargassoid plant communities. This would fit the widespread black shale that is observed throughout the entire North American continent during this time. Abundant evidence as to the nature of the plant types present may be seen in the Foerstian remains and algal thalli that have been uncovered from the interval. Lower Antrim apparently represents a period of widespread stabilization in the Michigan Basin in that the unit seems to be continuous in its development throughout the entire Basin area. Following the deposition of the basal unit of the Antrim shale (the Lower Antrim), structural activity took place, synorogenically with the Acadian orogeny, in the Wisconsin Highlands region. This movement probably occurred simultaneously with the development of an arch or barrier in the Michigan Basin, which is illustrated on the "B" interval isopach map (Plate 2). The South Michigan Shelf continued to influence sedimentation as it did in the Traverse; the units in the "B" interval thin to the south. After the probable movement on the "B" axis the Ellsworth Shale was deposited and largely confined to the western portion of the Michigan Basin. In the eastern portion of the Michigan Basin to the "B" axis or barrier, ecological conditions developed that led to the formation of the Lower Antrim black shales. At this time the Berea delta developed in Ontario from an eastern source area (Laurentia). This is illustrated by the Berea-

Bedford isopach map (Plate 12). The Berea-Bedford represents a sequence of shales and sands that spread over and gradually replaced the sequence of black shales in the Eastern Michigan Basin. This is observed in the gamma ray cross sections of the Michigan Basin, where there is an apparent increase in the thickness of the Upper Antrim towards the "B" axis or barrier. The Berea-Bedford is apparently later than the Ellsworth Shale.

The Berea Sandstone is found in northwestern Michigan, central Michigan and throughout eastern Michigan. This low radioactive unit is correlated with the commercial gas unit in western Michigan that is referred to as the Berea dolomite.

The masked zone problem that exists along the "B" barrier can be resolved by realizing that this was probably an ecological niche for the sargassoid plants during the accumulation of the upper portion of the "B" interval. The uppermost Ellsworth-lower Coldwater contact problem is solved by the utilization of the Sunbury Shale and Coldwater redrock as correlatable tops. The Sunbury Shale may indicate a brief return to the conditions that existed prior to the development of the Berea and Ellsworth shales dependent on whether the organic material is humic or sapropelic. The deposition of the Sunbury Shale is noted throughout the entire Basin, with the exception of southwestern Michigan; apparently the "B" axis shallows upon the South Michigan Shelf and prevents the spread of organic material into this area. Sediments which are pouring out of the east from the southwest Ontario region, likewise, cannot be intermixed with the Ellsworth in this particular region because of the increasing elevation of the "B" axis or barrier to the south onto the South Michigan Shelf.

The Coldwater Shale is the thickest directly east of the "B" axis.

Two distinct facies are developed at this time-- an eastern sandy and silty facies near the source area and a western calcareous facies at a farther distance from the eastern source region. Only one unit in the entire Coldwater sequence can be used as a regional correlation point. This is the Coldwater redrock, which exists some thirty feet above the base of the Coldwater Shale. The thickest Coldwater Shale section exists in Iosco County, northeastern Michigan. There is a probable shift in sedimentation during Coldwater time. It no longer seems to be coming from directly east as it had in the Berea-Bedford sequence. Provenance is either a combination of sources or a single source coming northeast from the Laurentian area.

The Marshall Sandstone is an extremely thin unit ranging from approximately 100 to 350 feet in thickness. Its sandy character indicates a further change within the Michigan Basin. As with the Coldwater, the South Michigan Shelf as such no longer seems to exist. The Marshall Sandstone in eastern Michigan has its source area to the east in the Laurentian region. Later in the development of the Marshall, uplift takes place in the Wisconsin Highlands with a resultant flood of sediments coming into the Basin from the western margin. It is observed that two facies once again, an eastern and western facies, exist in the Basin. The facies are differentiated on the basis of their sedimentary petrography. The western and southern facies had its source area in the Wisconsin Highland region. The eastern facies had Laurentia as its source area. The Upper Marshall, which is only recognized in eastern facies, represents a change in sedimentation pattern that occurs in the Laurentian area. The sedimentation in the southern and western facies continues without interruption. The upper contact of the Marshall with relation to the

Michigan stray sand indicates that it is a portion of the Upper Marshall and is correlatable to the upper portion of the Marshall in the southern and western facies.

V. SUMMARY AND CONCLUSIONS

The regional study of the Upper Devonian-Lower Mississippian rocks of the Michigan Basin utilizing detailed iospach maps were successful. The maps help solve basinal and tectonic features that existed throughout the Upper Devonian-Lower Mississippian history of the Michigan Basin. They indicate the possibility that a likely synorogenic Acadian or Upper Devonian uplift occurred in the Wisconsin Arch region and may have been attended by the development of a barrier ("B" axis) in the Michigan Basin (Plate 2). The South Michigan Shelf is clearly indicated in the Traverse Group and the "B" interval (Plates 1, 2). The Coldwater map (Plate 3) indicates the dissolution of this particular feature, occurring in the Late Kinderhook time. The Marshall Sandstone indicates (Plate 4) a shallow sheet sand development probably related to the end of the active development of the autogeosyncline. Evidence for the Ontario Seaway is observed in the Traverse Group map (Plate 1) and less obviously in the "B" interval isopach (Plate 2).

The Bay County sequence of isopach maps were useful in that they revealed a channel system extending east-west from southwestern Ontario. It, likewise, establishes an eastern source area direction for the Berea-Bedford clastics. The Bay County structure contour maps on all intervals, except the Coldwater Shale, proved to be reliable. The gamma ray radioactive log cross sections (Plate 17 - 20) illustrate lucidly the lithologic correlations of the Michigan Basin during the deposition of "B" interval.

The Ellsworth Shale-Coldwater Shale contact in western Michigan can be locally problematical when rotary and cable tool samples fail to indicate either the presence of the Coldwater redrock or the Sunbury Shale.

However, when using gamma ray logs, the highly radioactive Sunbury Shale is discernible when as thin as five feet in thickness. The Coldwater redrock is apparently identifiable in thicknesses of less than ten feet. The two units invariably occur stratigraphically within thirty feet of each other.

The gamma ray Sunbury Shale-Coldwater redrock can be utilized as a structure contour interval throughout the entire Michigan Basin. As this contact forms the most reliable datum in the Paleozoic sequence above the Dundee, it is critical, not only to petroleum exploration, but also to field production development.

There are five favorable factors that should be considered with respect to this unit:

(1) The Sunbury Shale-Coldwater redrock is younger than nearly all of the major producing zones in the Michigan Basin.

(2) In any given area, either the Sunbury Shale or the Coldwater redrock is present (more often than not, both are).

(3) The units are nearly synchronous throughout the Basin.

(4) The radioactive gamma ray log can be run through the casing in any given well.

(5) With sufficient control, any structure within the Basin may be accurately delimited provided the structure is reflected in the Devonian-Mississippian "B" interval.

The Berea-Bedford contact in eastern Michigan is often gradational and very difficult to pick when using lithologic sample examination techniques. The Berea-Bedford contact may be picked with realtive ease by gamma ray logs, except in the area south of the Mecosta-Isabella County area along and west of the "B" barrier. The contact cannot be picked on the South Michigan Shelf, west of Lenawee County. West of the barrier in northern Mecosta County and Wexford County the Berea may be separated.

The nature of the east-west relationship between the Antrim-Bedford-Berea and the Antrim-Ellsworth can be solved with gamma ray logs. The Antrim is divided into two units, a lower and an upper. The lower is observed over the entire Basin; the upper is largely restricted to the area east of the "B" barrier. The Ellsworth Shale is equivalent to the Upper Antrim-Bedford-Berea sequence in the southwest Michigan, to the Upper Antrim-Lower Berea-Bedford equivalent in west-central Michigan; and is older than the Berea, but equivalent to the Lower Bedford-Upper Antrim in northwestern Michigan. The source area for the Ellsworth was north and west from the Wisconsin Highlands. The Antrim Shale-Ellsworth Shale contact in western Michigan is difficult to delimit lithologically because of the gradational and interfingering characteristics of the two formations. Gamma ray studies, however, indicate that such a separation is possible and correlative. The Antrim unit represented west of the "B" axis and below the Ellsworth Shale is the Lower Antrim, except in a few places where thin sequences characterizing the Upper Antrim are found locally above.

The Traverse transition zone, which is discussed in the section on the Traverse, is clearly reflected by a gradual change in rock type from the typical Traverse limestone to the typical Lower Antrim black shale, based on the gamma ray-neutron logs.

In the "masked zone", which occurs in central Michigan, along the "B" axis, the entire "B" interval appears to be black shales from lithologic examination. The is attributed to a higher organic content caused by accumulation or preservation that is occurring along the "B" axis. It is in probable response to more desirable ecological conditions that would be found along the axis rather than in either the eastern or western areas of sedimentation.

The regional distribution of the Upper Devonian-Lower Mississippian black shales and their related rocks (Plate 21) is useful in illustrating some of the problems of the black shales and represents an added refinement to Conant and Swanson's (1961) earlier work. Utilizing Sloss et. al. (1960) data inferred isopach clastic sources were established for the Upper Devonian-Lower Mississippian black shale throughout the continental United States.

BIBLIOGRAPHY

Adams, J. E., et. al., 1951, Starved Pennsylvanian Midland Basin: Am. Assoc. Petrol. Geol. Bull., v. 35, p. 2600-2607.

Addison, Carl C., 1940, Buckeye oil field, Gladwin County, Michigan: Am. Assoc. Petrol. Geol. Bull., v. 24, p. 1950-1982.

Allings, Harold L. and Briggs, Louis I., 1961, Stratigraphy of Upper Silurian Cayugan Evaporites: Am. Assoc. Petrol. Geol. Bull., v. 45, p. 515-547.

Baillie, Andrew D. 1953, Devonian System of the Williston basin area: Manitoba Dyst mines and natural resource, Mines branch: Publ. 52-5, 405 pp.

Bain, G. W., 1950, Geology of Fissionable materials: Econ. Geol., v. 45, p. 273-323.

Baltrusaites, E. J., Clark, C. K., Cohee, G. V., Grant, R. P., Kelly, W. A., Landes, K. K., Lindberg, G. D., and Newcombe, R. B., 1948, A Summary of the Stratigraphy of the Southern Peninsula of Michigan: Am. Assoc. Petrol. Geol. Comm. on Geol. Names and Correlations.

Bates, Thomas G., and Strahl, Erwin O., 1957, Minerology, Petrography and Radioactivity of the Chattanooga Shale: Geol. Soc. Am. Bull., v. 63, 10.10.

Baunatyne, Barry B., 1960, Potash deposits, rock salt, and brines in Manitoba: Manitoba Dyst. Mines and natural resources: Mines Branch publ. 59-1 30 pp.

Beers, R. F., and Goodman, Clark, 1944, Distribution of radioactivity in ancient sediments: Geol. Soc. America Bull., v. 55, p. 1229-1254.

Beers, R. F., 1945, Radioactivity and organic content of some Paleozoic shales: Am. Assoc. Petrol. Geol. Bull., v. 29, p. 1-22.

Bishop, Margaret Stearns, 1940, Isopachous studies of Ellsworth to Traverse limestone Sections of southwestern Michigan: Am. Assoc. Petrol Geol. Bull., v. 24, p. 2150-2162.

Breger, Irving A., and Brown, Andrew, 1962, Kerogen in the Chattanooga Shale: Science, vol. 137, p. 221-224.

Campbell, Guy, 1946, New Albany Shale: Geol. Soc. Am. Bull., v. 57, p. 829-908.

Clarke, J. M., 1915, Conceptions regarding the American Devonic: New York State Mus. Bull. 177, p. 115-133.

Cohee, G. V., 1944a, Thickness and Character of the Traverse Group and Dundee Formation in Southwestern Michigan: U. S. Geol. Survey, Oil and Gas Inv., P. C. 4.

Cohee, G. V., 1944b, Geology and Oil and Gas Possibilities of South-Central Michigan: U. S. Geol. Survey, P. M. 11.

__________, 1945a, Sections and Maps of Lower Ordovician and Cambrian rocks in the Michigan Basin, Michigan and Adjoining area: U. S. Geol. Survey, Oil and Gas Inv., P. C. 9.

__________, 1945b, Geology and Oil and Gas Possibilities of Trenton and Black River limestone of the Michigan Basin and Adjacent areas: U. S. Geol. Survey, Gas and Oil Inv., P. C. 11

__________, 1947a, Cambrian and Ordovician rocks in recent wells in southeastern Michigan: Am. Assoc. Petrol. Geol. Bull., v. 31, p. 293-307.

__________, 1947b, Lithology and Thickness of the Traverse Group in the Michigan Basin: U. S. Geol. Survey, Oil and Gas Inv., P. C. 28.

__________, 1948a, Cambrian and Ordovician rocks in the Michigan Basin and Adjoining areas: Am. Assoc. Petrol. Geol. Bull., v. 32, p. 1417-1448.

__________, 1948b, Thickness and Lithology of the Upper Ordovician and Lower and Middle Silurian Rocks in the Michigan Basin: U. S. Geol. Survey, Oil and Gas Inv., P. C. 33.

__________, et. al., 1944, Map and Sections of the Berea sandstone in Eastern Michigan: U. S. Geol. Survey, P. M. 17.

__________, and Landes, Kenneth K., 1958, <u>Oil in the Michigan Basin</u>; Habitat of Oil Synopsium: Am. Assoc. Petrol. Geol. Bull., p. 473-493.

__________, Macha, Carol, and Holk, Margery, 1951, Thickness and Lithology of Upper Devonian and Carboniferous Ricks in Michigan: U. S. Geol. Survey, Oil and Gas Inv., P. M. 38.

__________, and Underwood, L. B., 1945, Lithology and Thickness of the Dundee and Rogers City limestone in the Michigan Basin: U. S. Geol. Survey, Oil and Gas Inv., P. M. 38.

Conant, Louis C., and Swanson, Vernon E., 1961, Chattanooga Shales and Related Rocks of Central Tennessee and Nearby Areas: U. S. Geol. Survey, Prof. paper 357, 91 pp.

Cooper, G. A. et. al., 1942, Correlations of the Devonian Sedimentary formations of North America: Geol. Soc. Amer. Bull., v. 53, p. 1729-1793

Cooper, W. F., 1909, Michigan Miner, v. 11, No. 6, p. 13.

Daly, P. A., 1900, The Calcareous Concretions of Kettle Point, Lambton County, Ontario: Jour. Geology, v. 8, p. 135-150.

Edwards, I. and Raasch, G. O., 1922, Notes on the Occurrence of Upper Devonian Strata in Wisconsin: 1921 Yearbook of the Public Museum of the City of Milwaukee, p. 88-93.

Ehlers, G. M. et. al., 1952, Stratigraphy and Structure of the Devonian Rocks in southeastern Michigan and northwestern Ohio: Mich. Geol Soc. Guidebook, 40 pp.

____________, and Humphrey, W. E., 1944, Revision of E. A. Strong's Species from Mississippian Point Au Gres limestone from Grand Rapids, Michigan: Contr. Mich. Mus. Paleo., v. 6, p. 113-130.

____________, and Radabaugh, R. E., 1937, The Rogers City limestone, a New Middle Devonian formation in Michigan: Mich. Acad. Sci. Papers, v. 23, p. 443.

____________, and Smith, Jane E. and Shelden, Francis D., 1959, Surface Stratigraphy of the Mackinac Straits Region: Mich. Basin Geol. Soc. Guidebook, p. 13-18.

Ekblaw, George E., 1938, Kankakee Arch in Illinois: Ill. State Geol. Survey, Circular no. 40, 6 pp.

Ellison, S. P., Jr., 1950, Subsurface Woodford Black Shale, West Texas and Southeastern New Mexico: Texas Bur. of Econ. Geol., Rept. Inv. 7, p. 1-20.

Ells, Garland D., 1958, Notes on the Devonian-Silurian in the Subsurface of Southwest Michigan: Mich. Geol. Survey, Progress report 18.

Faul, H., 1954, <u>Nuclear Geology</u>: John Wiley and Sons, Inc., 414 pp.

Fry, Wayne L., and Banks, Harlan L., 1955, Three new genera of algae from the Upper Devonian of New York: Jour. Paleo., v. 29, p. 37-44.

Fisher, James Harold, 1953, Paleoecology of the Chattanooga-Kinderhook Shale: Ph. D. Thesis, Univ. Illinois, 119 pp.

Fix, Carolyn E., 1958, Selected Annotated Bibliography of the Geology and Occurrence of Uranium-bearing marine black Shales in the United States: U. S. Geol. Survey Bull., 1059-F, p. 263-325.

Glover, Lyn, 1959, Stratigraphy and Uranium Content of the Chattanooga Shale in Northeastern Alabama, Northwestern Georgia, and Eastern Tennessee: U. S. Geol. Survey Bull., 1087-E, p. 133-168.

Gordon, Charles H., 1900, Geological Report on Sanilac County, Michigan: Mich. Geol. Survey, v. 7, 34 pp.

Grabau, A. W., 1906, Type of Sedimentary Overlap: Geol. Soc. Am. Bull., v. 17, p. 567-636.

____________, 1919, Significance of the Sherburne sandstone in Upper Devonic stratigraphy: Geol. Soc. Am. Bull., v. 30, p. 465-468.

Green, Dorsie A., 1957a, Trneton Structure in Ohio, Indiana, and Northern Illinois: Am. Assoc. Petrol. Geol. Bull., v. 41, p. 627-642.

__________, 1957b, A Reply to the J. Marvin Wellers' discussion of the Writer's Trenton structure in Ohio, Indiana, and Illinois: Am. Assoc. Petrol. Geol. Bull., v. 41, p. 2135-2136.

Gutschick, R. C., 1947, Origin of some bitumen in the Devonian-Mississippian black shales and the Eocene Green River shale: Geol. Soc. Am. Bull., v. 58, p. 1185.

Hake, B. F., 1938, Geologic Occurrence of Oil and Gas in Michigan: Am. Assoc. Petrol. Geol. v. 22, p. 393-415.

__________, and Maebius, J. B., 1938, Lithology of the Traverse Group of Central Michigan: Mich. Acad. Sci. Papers, v. 23, p. 447-461.

Hale, Lucille, 1941, Study of Sediments and Stratigraphy of the Lower Mississippian in Western Michigan: Am. Assoc. Petrol. Geol. Bull., v. 25, p. 713-723.

Hard, E. W., 1931, Black Shale Deposition in Central New York: Am. Assoc. Petrol. Geol. Bull., v. 15, p. 165-181.

__________, 1938, Mississippian Gas Fields of the Central Michigan Area: Am. Assoc. Petrol. Geol. Bull., v. 22, p. 129-174.

Haun, J. D., and LeRoy, L. W., 1958, Subsurface Geology in Petroleum Exploration; Symposium: Colo. Sch. Mines, Johnston Publ. Co., Boulder, Colo. 887 pp.

Hicks, L. E., 1878, Am. Jour. Sci., 3d, v. 16, p. 216-220.

Holland, F. D., Jr., 1952, Stratigraphic Details of the Lower Mississippian Rocks of Northeastern Utah and Southwestern Montana: Am. Assoc. Petrol. Geol. Bull, v. 36, p. 1697-1734.

Hoover, Karl V., 1960, Devonian-Mississippian Black Shale Sequence in Ohio: Ohio Geol. Survey, Inf. Circ. 27, 154 pp.

Jodry, R. L., 1957, Reflection of Possible Deep structures by Traverse Group facies changes in Western Michigan: Am. Assoc. Petrol. Geol. Bull., v. 35, p. 713-23.

Kay, G. M. 1942, Development of Northern Alleghany Syndinorium and Adjoining regions: Geol. Survey Assoc., v. 53, pt. 2.

Kay, Marshall, 1951, North American Geosynclines: Geol. Soc. Am. Mem. 48.

Kelly, W. A., 1936, Pennsylvania System in Michigan: Mich. Geol. Survey Publ. 40, Geol. Series 34, p. 149-226.

Kelly, W. A., and Smith, G. W., 1947, Stratigraphy and Structure of Traverse Group in Afton-Onaway area, Michigan: Am. Assoc. Petrol. Geol. Bull., v. 31, no. 3, p. 447-469.

Keyes, C. R., 1938, Age of Chattanooga black shales: Pan-Am. Geol. v. 70, p. 364-366.

Kropachot, Robert E., 1953, A Quantitative Sedimentary Analysis of the Mississippian Deposits in the Michigan Basin: M. S. Thesis, Mich. State Univ., 57 pp.

Krumbein, W. C., and Garrels, R. M., 1952, Origin and Classification of chemical sediments in terms of PH and oxidation-reduction potentials: Journ. Geol., vol. 60, p. 1-33.

Landes, Kenneth K., 1944, Porter Oil field, Midland County, Michigan: Am. Assoc. Petrol. Geol. Bull., v. 28, p. 173-196.

__________, 1945a, The Salina and Bass Island Rocks of the Michigan Basin, U. S. Geol. Survey, Oil and Gas Inv. P. M. 40.

__________, 1945b, Geology and Oil possibilities of Sylvania and Bois Blanc formations of Michigan: U. S. Geol. Survey, P.M. 28.

Landis, E. R., 1962, Uranium and other Trace Elements in Devonian and Mississippian Black shales in the Central Midcontinent Area: U. S. Geol. Survey. Bull., 1107-E, p. 289-334.

Lane, A. C., 1893, Michigan Geol. Survey Rept. 1891 and 1892, p.66.

__________, 1895, The Geology of Lower Michigan: Mich. Geol. Survey, c. 5, pt. 2.

__________, 1901, Michigan Miner, vol. 3, no. 1, p. 9.

__________, 1902, Mich. Geol. Survey, v. 8.

LeMone, Daivd V., 1958, The Devonian Rocks of Cochise, Santa Cruz, and Pima counties, Arizona, and Hidalgo County, New Mexico, M. S. Thesis, Univ. Arizona, 132 pp.

Levorsen, A. I., 1933, Studies in Paleogeology: Am. Assoc. Petrol. Geol. Bull., v. 17, p. 1107-1132.

__________, 1960, Paleogeologic Maps: W. A. Freeman and Co., 174 pp.

Lindberg, George D., 1948, Deerfield Oil Field, Monroe County, Michigan: Struc. Typical American oil fields, v. 3, Am. Assoc. Petrol Geol. Bull., p. 305-318.

Lockett, J. R., 1947, Development of the Structures in Basin areas of northeastern United States: Am. Assoc. Petrol. Geol. Bull., v. 31, p. 429-446.

Martin, Helen M., 1936, The Centennial Geological map of the Southern Peninsula of Michigan: Mich. Feol. Survey Div., publ. 39, Geol. Survey 33.

__________, and Straight, Merril T., 1956, An Index of Michigan Geology 1823-1955: Mich. Geol. Survey, Publ. 50, 461 pp.

Martison, N. W., 1952, Petroleum Possibilities of the James Bay Lowland Area: Ontario Dept. Mines, ann. rept., v. 61, p. 1-58.

Mason, Brian, 1952, Principles of Geochemistry: John Wiley and Sons, 276 pp.

McCammon, Helen, 1960, Fauna of the Manitoba Group in Manitoba: Manitoba Dept. Mines and natural resources, Mines Branch, Publ. 59-6, 109 pp.

McFarian, Arthur C., 1939, Cincinnati Arch and features of its development Am. Assoc. Petrl. Geol. Bull., v. 23, p. 1847-52.

McGregor, Duncan J., 1954, Stratigraphic Analysis of Upper Devonian and Mississippian Rocks in Michigan Basin: Am. Assoc. Petrol. Geol. Bull., v. 38, p. 2324-2356.

Melhorn, Wilton N., 1958, Stratigraphic Analysis of Silurian Rocks in Michigan Basin: Am. Assoc. Petrol. Geol. Bull., v. 42, 816-838.

Miller, A. K., and Garner H. F., 1953, Lower Mississippian Cephalopods of Michigan; Part II, Coiled Nautiloids: Contr. Mich. Univ. Mus. Paleo., v. 11, p. 111-151.

__________, 1955, Lower Mississippian Cephalopods of Michigan; Part III, Ammonoids and Summary: contr. Mich. Univ. Mus. Paleo., v. 12 p. 113-173.

Monnett, V. Brown, 1948, Mississippian Marshall formation of Michigan: Am. Assoc. Petrol. Geol., v. 32, p. 629-688.

Morse, M. L., 1938, Conodonts from the Norwood and Antrim shales of Michigan: Mich. Univ. Ph. D. disset.

Newberry, J. S., 1870, Ohio Geol. Surv. Rept. Prog. 1869, p. 21-29.

Newcombe, R. J. B., 1930, Middle Devonian unconformity in Michigan: Geol. Soc. Am. Bull., v. 41, no. 4, p. 725-737.

__________, 1932, Geology of Muskegon field, Michigan: Am. Assoc Petrol. Geol. Bull., v. 16, 153-168.

__________, 1933, Oil and Gas fields of Michigan: Mich. Geol. Survey Div., Publ. 38, Geol. Series 32.

__________, 1935, Natural Gas fields of Michigan: Am. Assoc. Petrol. Geol. Bull., Geology of Natural Gas, p. 787-812.

Newman, E. A., 1936, Geology of Ogemaw County and West Branch oil fields Mich. Geol. Surv. Prog., Rept. 2.

Nininger, R. D., 1954, Minerals for Atomic Energy: D. Van Nostrand Co., Inc., 367 pp.

O'Hara, Norbert Wilhelm, 1954, A statistical and Mechanical Analysis of the Marshall sandstone in western Michigan to Determine the environmental pattern of the deposits: M. S. Thesis, Mich. State Univ. 142 pp.

Orton, Edward, 1882, A source of the bituminous matter in the Devonian and subcarboniferous black shales of Ohio: Am. Jour. Sci. (3), v. 24, p. 171-175.

____________, 1888, Economic Geology: Rept. Geol. Survey Ohio, v. 6 p. 1-310.

Pepper, James F., DeWitt, Wallace, Jr., Demorest, David F., 1954, Geology of the Bedford Shale and Berea Sandstone in the Appalachian Basin: U. S. Geol. Survey, Prof. paper 259, 111 pp.

Petri, E., 1956, The Bakken Formation in Manitoba, B. Sc. Thesis, Univ. Manitoba.

Phinney, A. J., 1891, The Natural Gas Field of Indiana: U. S. Geol. Surv., 11th Ann. Rept., p. 647.

Pirtle, G. W., 1932, Michigan Structural Basin and its Relationship to surrounding areas: Am. Assoc. Petrol. Geol. Bull., v. 16, p. 145-152.

Pohl, Erwin R., 1930, The Middle Devonian Traverse Group of rocks in Michigan, a Summary of Existing Knowledge: Proc. U. S. Natl. Mus. v. 76, art. 14, p. 1-34.

Raymond, P. E., 1942, The pigment in black and red sediments: Am. Jour. Sci., v. 240, p. 658-669.

Rich, J. L., 1948, Probable deep-water origin of the Marcellus-Ohio-New Albany-Chattanooga Black shales (abs). Geol. Soc. Amer. Bull., v. 59, no. 9, p. 1346-1347.

____________, 1951, Probable Fondo origin of the Marcellus-Ohio-New Albany-Chattanooga Bituminous shales: Am. Assoc. Petrol. Geol. Bull., v. 35, no. 9, p. 2017-2040.

Riggs, C. H., 1938, Geology of Allegan County: Mich. Geol. Survey Prog. Rept. 4, 29 pp.

Ross, Roy M. 1957, A Quantitative Analysis of the Middle Devonian Traverse Group in the Michigan Basin: M. S. Thesis, Mich. State Univ.

Ruedemann, R., 1934, Geol. Soc. Am. Mem. 2, 141 pp.

Sabins, Floyd F., Jr., 1957, Stratigraphic Relations in Chericahua and Dos Cabezas Mountains, Arizona: Am. Assoc. Petrol. Geol., v. 41, p. 466-510.

Sawtelle, E. Rossiter, Jr., 1958, The Origin of the Berea sandstone in the Michigan Basin, M. S. Thesis, Mich State Univ.

Schuchert, C., 1910, Biologic Principles of Paleogeography: Pop. Sci. Ma., no 76, p. 591-600.

____________, 1915, The conditions of black shale deposition as illustrated by Kupferschiefer and Lias of Germany: Am. Philos. Soc. Print. no. 54, p. 259-269.

____________, 1955, Atlas of Paleogeographic maps: John Wiley and Sons, Inc., New York, 177 pp.

Shaler, N. S., 1877, Notes on the investigations of the Kentucky Geological Survey during the years 1873, 1874, and 1875.

Sloss, L. L., Dapples, E. C., Krumbein, W. C., 1960, Lithofacies Maps on Atlas of the United States and Southern Canada: John Wiley and Sons, inc. 108 pp.

Smith, H. N., Smith J. W., and Kommes, W. C., 1959, Petrographic Examination and Chemical Analyses for several Foreign Oil Shales: U. S. Bur. Mines Rept. Inv. 5504, 34 pp.

Stainbrook, Merrill A., 1935, Stratigraphy of the Devonian System of the upper Mississippi Valley: Ninth Ann. Field Conference, Kansas Geol. Soc. p. 248-260.

Stearns, Margaret D., 1933, The Petrology of the Marshall formation of Michigan: Journ. Sed. Petrol., v. 3, pp. 99-112.

Stockdale, Paris B., 1939, Lower Mississippian Rocks of the East-central interior: Geol. Soc. Am. Spec. Papers 22.

Strom, K. M. 1936, Land-locked waters: Det norske videnskapp-Akademi i Oslo, Nat. Naturv. Klasse, v. 1, no 7. p. 1-85.

Strumm, Erwin C., 1951, Check list of fossil invertebrates Described from the Middle Devonian Traverse Group of Michigan: Contr. Mich. Univ. Mus. Paleo., v. 9, p. 1-44.

____________, 1953, Trilobites of the Devonian Traverse group of Michigan: contr. Mich. State Mus. Paleo. v. lo, p. 101-157.

____________, Kellum, Lewis B., and Wright, Jean Davies, 1956, The Devonian Strata of the London-Sarnia area, Southwestern Ontario: Mich. Geol. Soc. Guidebook, 21 pp.

____________, and Wright, Jean D., 1958, Check list of Fossil invertebrates described from the Middle Devonian Rocks of the Thedford-Arkona Region of Southwestern Ontario: Contr. Mich. Univ. Mus. Paleo., v. 14, p. 81-132.

Sutton, Robert G., 1957, Lithofacies map of Upper Devonian in Eastern United States: Am. Assoc. Petrol. Geol. Bull., v. 41, p. 750-755.

Swann, David H., et. al., 1951, Eastern Interior Basin, Possible Future Petroleum Privinces of North America: Am. Assoc. Petrol. Geol. Bull., v. 35, p. 406-498.

Swanson, Roy Ivar, 1955, The Extent of the Clare Dolomite, a Marker Horizon of Michigan: M. S. Thesis, Mich. State Univ., 81 pp.

Swanson, Vernon E., 1960, Oil Yield and Uranium Content of Black shale: U. S. Geol. Survey Prof. Paper 356A, 44 pp.

__________, 1961, Geology and Geochemistry of Uranium in Marine Black Shales: A Review: U. S. Geol. Survey Prof. paper 3560, p. 67-112.

Tarbell, E., 1941, Antrim-Ellsworth-Coldwater Shale formations in Michigan: Am. Assoc. Petrol. Geol. Bull., v. 25, p. 724-733.

Taylor, W. H., 1839, Mich. Geol. Surv. Rept. State Geol. in improvement of State Salt Springs, Mich. Leg. H. R. Doc. 2.

Thwaites, F. T., 1943, Stratigraphic Work in Northern Michigan: Mich. Acad. Sci., v. 28, p. 501.

Twenhofel, W. H., 1915, Notes on Black Shale in the Making: Am. Jour. Sci., ser. 4, v. 40, p. 272-280.

__________, 1939, Environment of Origin of Black Shales: Am. Assoc. Petrol. Geol. Bull., v. 23, p. 1178-1198.

Vine, James D., 1962, Geology of Uranium in Coaly Carbonaceous Rocks: U. S. Geol. Survey Prof. paper 356-D, p. 113-170.

Wanless, Harold R., 1948, Correlation chart of Pennsylvanian strata exhibited at Geol. Soc. America Ann. meeting, New York, N. Y. as referenced in Cohee et. al., 1951.

Warren, P. S., 1937, Age of the Exshaw Shale in the Canadian Rockies: Am. Jour. Sci., ser. 5, v. 33, p. 454-457.

Warthin, A. S., and Cooper, G. A., 1935, Hamilton Correlations in Ontario and Michigan: Geol. Soc. Am. Proc. (1934), p. 362-363.

__________, 1943, Traverse rocks of Thunder Bay Region Michigan: Am. Assoc. Petrol. Geol. Bull., v. 27, p. 571-595.

Weller, J. M., and Sutton, A. H., 1940, Mississippian Border of Eastern Interior Basin: Am. Assoc Petrol. Geol. Bull., v. 24, p. 765-858.

__________, et. al., 1948, Mississippian formations of North America: Geol. Soc. Am. Bull., v. 59, p. 91-188.

__________, and Workman, L. E., 1948, Structural Development of Eastern Interior Basin (abst): Am. Assoc. Petrol. Geol. Bull., v. 32, p. 302.

Weller, J. M., 1957, Discussion of Dorsie Green's Trenton Structure in Ohio, Indiana and Northern Illinois: Am. Assoc. Petrol.Geol. Bull., v. 41, p. 2132-2135.

Wild, Robert C., 1958, Sedimentary Analysis of Middle Devonian Sylvania sandstone in the Michigan Basin: M. S. Thesis, Mich. State Univ.

Wilmarth, Grace M., 1937, Lexicon of Geologic Names of the United States: U. S. Geol. Survey Bull. 896, pt. 1 and pt. 2.

Winchell, A., 1861, Mich. Geol. Surv. 1st Bien Rept. Prog., pp. 80, 139.

________, 1871, Mich. Geol. Surv. Rept. Prog., p. 26-33.

Winslow, M. R., 1962, Plant Spores and other Microfossils from Upper Devonian and Lower Mississippian Rocks of Ohio: U. S. Geol. Survey Prof. paper 364, 93 pp.

Wolcott, Richard H., 1948, Consulting Geologist, paper read before the Mich. Geol. Soc. in Cohee, et. al. 1951.

APPENDIX I

PERMIT NUMBER	LOCATION	WELL NUMBER	ELEVATION	COLDWATER	SUNBURY	ANTRIM	TRAVERSE	DUNDEE	MARSHALL	COLDWATER	SUNBURY	BEREA-BEDFORD	ANTRIM	TOTAL 'B'	TRAVERSE
	T13N R4E														
20114	NE/NE/SW-4	1	607.4		-1480	-1676	-2009	-2649			22	174	333	529	640
10275	C/S½/SW-7	2	632.3	-443	-1423	-1618	-1968	-2616	187	980	45	150	350	545	648
	T13N R6E														
8746	NW/NW/NE-3	3	588.6	-443	-1493				182	1085	35				
	T14N R3E														
10868	SE/SE/SE-9	6	629	-671	-1624	-1846	-2191	-2877	225	995	20	160	345	525	686
19861	NE/NE/NE-17	7	637		-1671		-2217	-2890			26			546	673
3237	SW/SE/NE-18	8	656	-665	-1704	-1880	-2256	-2922	190	1039	24	152	354	530	688
16399	NW/SE/SW-19	9	661.1	-704	-1773	-1939	-2314	-2080	180	1069	11	155	375	541	655
17943	NE/NE/NW-20	10	650.6	-712		-1919	-2229	-2011	265				310		682
4423	S½/SE/SW-27	11	647.3	-618	-1623	-1818	-2151	-2809	210	1005	28	167	333	527	658
10853	NW/NE/NW-31	12	661.3	-689	-1759	-1947	-2301	-2939	225	1070	20	168	354	540	638
	T14N R4E														
15318	NE/NE/NE-1	13	599.1	+65	-906	-1137	-1471	-2166		971	23	208	334	565	695
20876	CN½/SW/NE-1	14	588.0		-897	-1112	-1459	-2146			38	177	347	562	687
9658	CN½/SW/SE-1	15	589.4	+9	-896	-1116	-1449	-2148	165	905	25	195	333	553	699
13501	CN½/SE/SE-2	16	592.1		-883	-1085	-1423	-2148			37	165	338	540	725
5441	S½/SE/SE-2	17	599	+134	-891	-1096	-1441	-2121		1025	23	182	345	550	680
20263	CS½/SW/SE-2	18	583.3	+88	-906	-1114	-1453	-2139	150	994	10	198	339	547	686
9986	CS½/NE/SE-3	19	596.3	+52	-948	-1159	-1494	2182	174	1000	21	190	335	546	688
20701	CS½/NW/NW-3	20	600.2	+100	-980	-1185	-1531	-2217	81	1080	25	180	346	551	686
5831	CE½/NE/SW-10	21	599.5		-1287	-1495			186	980	24	185	326	538	681
15572	N½/NW/NW-11	23	601.3	+21	-1001	-1213	-1539	-2220	182	980	24	188	326	538	681

PERMIT NUMBER	LOCATION	WELL NUMBER	ELEVATION	COLDWATER	SUNBURY	ANTRIM	TRAVERSE	DUNCEE	MARSHALL	COLDWATER	SUNBURY	BEREA-BEDFORD	ANTRIM	TOTAL'B'	TRAVERSE
10121	CN½/NW/SE-12	24	591.9	+17	-963	-1164	-1498	-2193	255	980	15	186	334	535	695
15468	S½/NW/NW/-12	25	594.4	+85	-916	-1120	-1447	-2126	144	1001	19	185	327	520	697
	T14N R5E														
BD125	E½/NE/SW-10	26	591.0	+31	-1039	-1224	-1584	-2269			10				
20368	CN½/SE/SE-4	27	587.0	+85	-955	-1163	-1496	-2197	154	1040	26	182	333	541	695
19460	CS½/SW/NW-4	28	585.1	+155	-942	-1155	-1496	-2189	90	1097	28	185	341	554	693
15801	S½/NW/SE-5	29	589.3	+99	-938	-1151	-1493	-2183	165	1037	19	194	342	555	690
19777	CN½/SW/NW-5	30	584.4	+79	-957	-1157	-1498	-2138	142	1036	21	179	341	541	687
19622	CS½/NE/NE-6	31	585.1		-940	-1144	-1494	-2138			25	179	350	554	689
16994	NE/NW/NW-6	32	594.1	+49	-931	-1148	-1472	-2180	130	980	25	192	324	541	708
10967	CS½/SE/SW-6	33	597.4	+77	-903	-1128	-1452	-2138	131	980	30	195	324	549	686
16062	N/SE/NW-7	35	593.2	+83	-907	-1117	-1450	-2133	185	990	26	184	333	543	683
14773	CN½/NW/SW-7	36	593.9	+59	-938	-1142	-1479	-2165	159	997	28	176	337	541	686
18205	S½/SW/SE-8	37	592.4	+67	-945	-1158	-1495	-2175	175	1012	23	190	337	550	680
17695	N½/NW/SW-8	38	596.3	+121	-951	-1164	-1495	-2178	120	1072	25	188	331	544	683
11703	N½/NW/NE-9	39	587.6	+178	-961	-1182	-1514	-2208			25	196	332	553	694
16876	CN½/SW/NW-9	40	591.4	+91	-975	-1175	-1519	-2204	132	1066	8	192	344	544	685
19514	S½/NW/NW-9	41	588.8		-964	-1176	-1510	-2201			20	192	334	546	691
11482	CNE/NE/SE-12	42	585.7	+144	-873	-1089	-1390	-2074		1017	9	207	301	517	684
BD-93	SW/NE/NE-15	43	587.5		-1163	-1375	-1719	-238-	94	1027	34	178	344-	556	661
7086	NW/NW/NW-17	44	596.5	-3	-1060	-1274	-1613	-2293	135	1057	23	191	339	553	610
	T14N R6E														
11454	NE/SW/SE-7	45	585.7	+173	-871	-1085	-1415	-2064	41	1044	28	186	330	544	649
12281	SE/NE/NW-7	46	584.6	+90	-869	-1066	-1412	-2078		1006	20	177	346	543	666
10859	S½/NW/SW-7	47	585.1		-860	-1065	-1396	-2080			30	175	331	536	674
11132	SW/SW/NW-8	48	587.1			-1068	-1385	-2060					317		675
20690	SW/NE/SW-8	49	586.0	+149	-847	-1052	-1382	-2067		996	30	175			685
13366	SW/SW/SW-9	50	586.2		-864	-1079	-1389	-2077			6	203	310	519	688

PERMIT NUMBER	LOCATION	WELL NUMBER	ELEVATION	COLDWATER	SUNBURY	ANTRIM	TRAVERSE	DUNDEE	MARSHALL	COLDWATER	SUNBURY	BEREA-BEDFORD	ANTRIM	TOTAL 'B'	TRAVERSE
	T14N R6E (cont.)														
15628	SW/NE/SE-15	51	585.1		-905	-1060	-1405	-2177			25	130	345	500	682
15784	SW/NE/NW-15	52	583.9	+174	-926	-1078		-2086	133	1075	25	152			
15312	NE/SW/SW-15	53	586.4	+41	-874		-1369	-2090					355	495	721
11324	SW/NE/NE-16	54	585.2			-1080	-1376	-2079		1072					703
20198	SCW/SE/NW-16	55	588.0		-861	-1062	-1386	-2070			20	181	324	525	684
12044	SW/NW/NE-17	56	588.6	+79	-865	-1061	-1385	-2061		944	25	171	324	520	676
11404	NE/SW/SE-17	57	588.6	+114	-919	-1121	-1461	-2130	55	1033	30	172	340	542	669
11213	NE/NE/NE/-18	58	585.9	+166	-861	-1069	-1398	-2069		1027	30	178	329	537	671
12070	NE/NW/NE-21	59	586.8	+44	-885	-1113	-1412	-2101	193	929	43	185	299	527	689
15233	NE/NE/NE-22	60	585.0	+79	-905	-1115	-1445	-2104		984	31	179	330	540	659
4276	NE-23	61	582	+122	-963	-1078	-1440	-2123	155	1068	42	108	362	504	683
	T15N R3E														
17074	NE/NW/SW-6	62	653.9	-381	-1362	-1550	-1917	-2656	209	981	22	166	367	555	739
18140	SE/SE/NE-10	63	630.2	-188	-1167	-1358	1727	-2440		979	30	161	369	560	713
10728	CS½/SE/NW-13	64	624.6	-62	-1100	-1310	-1637	-2348	154	1038	27	183	327	537	710
12364	SE/SE/NE-24	65	631.5	-116	-1140	-1303			146	1024	24	139			
19445	SW/SE/NW-31	66	656.7	-654	-1663				176	1009	55				
	T15N R4E														
13690	NW/SE/NW-5	67	619.8	-200	-1230				181	1030	32				
19093	SE/NW/NW-8	68	621.3	-148	-1174				169	1026	21				
8403	SW/SW/NE-20	69	615.7	+79	-917	-1194	-1551	-2299		996		151	357		748
19949	CS½/SW/NW-21	70	597.4	+2	-1038	-1243	-1582	-2293	145	1040	30	175	339	544	711
19625	CS½/SW/SW-22	71	602.3		-1023	-1236	-1573	-2294			20	193	337	550	721
10563	CS½/SW/SE-26	72	594.5		-960	-1171	-1500	-2205			21	190	329	540	705
12599	N½/S½/SW-26	73	598.2		-950	-1167	-1502	-2194			27	190	335	552	692
19025	CS½/NE/SW-27	74	599.4		-976	-1183	-1518	-2210			21	186	335	542	692

PERMIT NUMBER	LOCATION	WELL NUMBER	ELEVATION	COLDWATER	SUNBURY	ANTRIM	TRAVERSE	DUNDEE	MARSHALL	COLDWATER	SUNBURY	BEREA-BEDFORD	ANTRIM	TOTAL 'B'	TRAVERSE
	T15N R4E (cont.)														
16193	S½SW/NE-28	75	606.1		-980	-1181	-1524	-224			22	179	343	544	700
16282	S½/SW/NW-28	76	607.7	+9	-980	-1192	-1527	-2227	158	989	32	180	335	547	700
15290	CN½/SE/SW-28	77	603.8	-4	-972	-1176	-1514	-2206	170	976	11	193	338	542	692
13486	CS½/SE/NE-29	78	611.2		-1003	-1230	-1532	-225			[illegible]	206	302	529	719
16423	SE/NE/SE-29	79	608.1	+11	-1001	-1198	-1537	-2224	137	1012	23	174	339	536	687
10300	CS½/SE/SE-32	80	604.8	+177											
BD103	S½/NE/NE-33	81	602.5	+69	-937	-1147	-1490	-2197	114	1008	25	183	343	551	707
13742	CN½/NE/NW-33	82	604.7		-980	-1185	-1519	-2209			25	180	334	539	690
13412	N½/NE/SE-34	83	599.0	+12	-903	-1134	-1471	-2165			18	213	337	568	694
10551	SE/SE/SE-34	84	613	+91	-897	-1097	-1429	-2117		988	16	184	332	532	688
13395	S½/SW/SW-34	85	600.7	+121	-902	-1142	-1461	-2169	110	1023	19	221	319	559	708
15360	CS½/NW/SE-35	86	596.2	+106	-929	-1134	-1469	-2169	90	1035	19	186	335	540	700
15289	CS½/SE/NW-35	87	595.1		-930	-1111	-1497	-2176	82	1003	18	188	335	547	700
13923	NW/SW/SE-36	88	604.0	+72	-952	-1151	-1491	-2200	134	1024	24	190	340	539	709
15319	SE/SE/NW-36	89	599.8	+88	-979	-1153	-1496	-2208	102	1067	24	150	343	517	712
	T15N R5E														
19019	SW/SW/SE-31	90	588.5	+84	-936	-1136	-1461	-2193		1020	27	173	325	525	732
	T16N R3E														
4876	NW/SE/NE-6	91	671.6	-317	-1358	-1508	-1903	-2670	184	1041	28	122	122	545	767
10417	CS½/SW/SW-9	92	667.2	-313	-1316	-1515	-1893	-2328	205	1003	25	174	174	577	735
12407	NW/NE/NE-12	93	625.5	+16	-1099	-1293	-1654	-2692			25	169			
16991	NE/SW/SW-14	94	648.1		-1254	-1452	-1799	-2557			27	171	347	545	758
18814	SE/NW/NW-17	95	661.2	-337	-1369	-1559	-1943			1032	26	164	384	574	
12476	NE/SW/NW-19	96	653.4	-325	-1345	-1415	-1923	-2650	196	1020	28			578	727
13174	NE/NE/NE-20	97	663.3	-323	-1345				216	1022	20				
4461	NW/NW/SW-20	98	656.8	-286	-1319	-1514	-1901	-2625	153	1033	34	161	387	582	724
10320	NE/NE/SE-21	99	650.4	-270	-1316	-1506	-1827	-2590	195			190	321		763

PERMIT NUMBER	LOCATION	WELL NUMBER	ELEVATION	COLDWATER	SUNBURY	ANTRIM	TRAVERSE	DUNDEE	MARSHALL	COLDWATER	SUNBURY	BEREA-BEDFORD	ANTRIM	TOTAL 'E'	TRAVERSE
	T16N R3E (cont.)														
11932	NW/NE/NE-22	100	648.7		-1261	-1460	-1816	-2588							
12795	NW/NW/SE-23	101	643.2	-254	-1267	-1471	-1777	-2565	215	1013	27	177	306	510	788
16140	NW/NW/NW-23	102	643.8	-186	-1265	-1472	-1820	-2555	135	1079	19	188	348	555	735
13337	SE/NW/SE-26	103	639.1	-255	-1291		-1857	-2586	170	1036	26			565	730
16549	SE/NE/SW-30	104	657.0	-276	-1296	-1473	-1863	-2573	118	1020	22	155	390	567	710
12633	NW/NE/SE-31	105	649.1	-144	-1275	-1446	-1809	-2541				171	363		732
11722	SW/SE/NW-33	106	640.9	-284	-1418	-1599	-1968	-2724				181	369		756
3247	SE/SE/SE-35	107	641.7	-168	-1232	-1421	-1783	-2532	240	1064	30	159	362	551	749
	T16N R4E														
12399	SE/SW/SE-1	108	588.5	+209	-886	-1108	-1437	-2201	110	1095	32	190	329	551	764
13823	CNW/SE-1	109	598.9	+328	-871	-1086	-1416				25	190	330	545	
12923	NE/SE/SE-2	110	592.8	+173	-947	-1099	-1429	-2221				152	330		792
14555	NW/SE/NW-2	111	607.7	+123	-892	-1117	-1462			1015	56	169	345	570	745
12638	SW/NE/NE-3	112	605.2	+80	-924	-1135	-1445	-2227		1004	31	180	310	521	782
17769	NE/SE/SE-3	113	608.4	+57	-956	-1157	-1502	-2247	165	1013	36	165	345	546	745
16030	NW/NW/NE-4	114	605.3	+75	-952	-1146	-1495	-2263		1027	21	173	349	543	768
15949	NW/SW/NE-10	115	611.8	+33	-1003	-1213	-1548	-2298		1036	20	190	335	545	750
21853	SE/SE/SW-10	116	600.0	+90	-1058	-1260	-1490	-2353		1078	29	173	350	552	793
11138	SW/NW/SW-12	117	586.6		-918	-1143	-1485	-2247			25	200	342	567	762
22290	SE/SW/SW-15	118	607.6	-92	-1157	-1367	-1662	-2447	155	1065	33	177	342	552	738
21663	NE/SW/NW-22	119	606.0	-161	-1208	-1420	-1764	-2504	183	1047	34	178	344	556	740
14434	SW/NW/NW-30	120	656.6		-1247	-1463	-1827	-2586			46	170	364	580	758
	T16N R5E														
4613	NW/NW/SW-7	207	585	+180	-910	-1120	-1448	-2224	110	1905	30	180	328	538	776

PERMIT NUMBER	LOCATION	WELL NUMBER	ELEVATION	COLDWATER	SUNBURY	ANTRIM	TRAVERSE	DUNDEE	MARSHALL	COLDWATER	SUNBURY	BEREA-BEDFORD	ANTRIM	TOTAL 'B'	TRAVERSE
	T17N R3E														
14431	SE/SE/NE-1	121	638.5	+211	-878	-1061	-1423	-3278	53	1089	28	155	362	545	755
20330	SW/NE/SE-2	122	651.5	+167	-923	-1101	-1477	-2266	110	1090	23	155	376	554	789
4510	NE/SE/SE-9	123	683.4	+186	-1037	-1192	-1582	-2356	107	1318	20	135	395	550	774
14330	NE/NE/SW-11	124	651.6	+54	-958	-1133	-1507	-2314	188	1012	32	143	374	549	807
20243	SW/NW/NW-12	125	643.1		-942	-1117	-1482	-2269			25	150	365	540	787
13421	SW/SE/SW-12	126	643.9	+224	-943	-1101	-1502	-2291	120	1167	20	138	401	559	789
18894	NE/SW/SE-13	127	643.5	+72	-952	-1126	-1484	-2256	162	1024	22	152	358	532	772
18756	NE/NW/NE-24	128	640.7	+66	-947	-1092	-1494	-2278	170	1013	31	154	362	547	784
14359	NE/SE/SW-24	129	638.0	+123	-962	-1162	-1501	-2282		1085	45	155	339	539	781
4698	SE/SE/SE-27	130	652	-28	-1166	-1353	-1725	-2482	82	1138	27	160	372	559	757
	T17N R4E														
13766	SE/SE/NE-6	131	636.3	+136	-874	-1061	-1411	-2149	165	1010	35	152	350	537	738
21882	NE/NE/NW-6	132	635.0		-870	-1055	-1405	-2198			35	150	350	535	793
3690	SW/NW/NE-12	133	590.2		-845	-1031	-1360	-2159			20	166	329	515	799
17303	NW/NE/NW-13	134	602.2	+123	-865	-1060	-1382	-2170		009	20	175	322	517	788
12455	SE/SE/NE-16	135	610.6	+105	-919	-1109	-1424	-2239	141	1024	21	169	351	541	779
2107	NW/NE/NW-17	136	632.8	+145	-915				110	1060	37				
18104	SW/SW/NW-17	137	631.2	+91	-924	-1104	-1469	-2272	150	1015	40	140	365	545	803
13437	SW/NW/NW-18	138	639.6	+66	-928	-1112	-1473	-2278	196	994	37	147	361	545	805
18958	NE/NE/SW-18	139	639.8	+90	-922	-1105	-1468	-2244		1012	38	145	363	546	776
13301	SW/NW/NW-20	140	630.2	+126	-880	-1138	-1475	-2278		1004			337		803
16332	NE/NW/SW-19	141	636.1	+76	-949	-1143	-1503	-2279	173	1025	21	173	360	554	776
16656	SE/SE/SE-20	142	616.7	+137	-968	-1138	-1486		155	1105	25	145	348	518	
15309	SW/SW/SW-20	143	623.0	+1-1	-960	-1147	-1494	-2280	152	1061	27	165	347	534	786
16658	SW/SW/SW-21	144	615.0	+89	-930	-1116	-1473		188	1019	30	156	357	543	
20134	CNE/SE-23	145	596.1	+141	-885	-1087	-1424	-2236	178	1026	33	169	337	539	812
17476	SE/SW/SE-24	146	587.8	+188	-887	-1112	-1433	-2246	131	1025	34	191	321	546	813
18030	CE½/NW/NE-25	147	588.0		-892	-1099	-1424	-2277			30	177	325	532	853

PERMIT NUMBER	LOCATION	WELL NUMBER	ELEVATION	COLDWATER	SUNBURY	ANTRIM	TRAVERSE	DUNDEE	MARSHALL	COLDWATER	SUNBURY	BEREA-BEDFORD	ANTRIM	TOTAL 'B'	TRAVERSE
	T17N R4E (cont.)														
18040	SW/SW/NE-25	148	585.5	+146	-904	-1109	-1443	-2226	80	1050	35	170	334	539	783
22960	SE/SW/SW-25	149	592.4		-942	-1116	-1443	-2201	155	1065	33	177	295	505	785
17955	SE/SE/SE-26	150	600.3	+132	-905	-1112	-1443	-2223	148	1037	26	181	331	538	780
2749	SE/SW/SW-27	151	602.4	+107	-918	-1125	-1463	-2283	105	1135	40	167	338	545	820
16657	NW/NW/NW-28	152	613.8	+94	-936	-1119	-1476		170	1030	23	160	357	540	
16397	SW/NW/NE-20	153	617.0	+124	-944	-1133	-1492		103	1068	32	157	359	548	
15604	NE/NE/SE-29	154	613.1	+93	-922	-1104	-1465			1015	40	144	359	543	
15476	SW/SE/NW-29	155	618.3		-950	-1145	-1494	-2278		1102	41	154	349	550	784
14859	SW/NW/NW-30	156	632.1			-1153	-1503	-2280		1036	27	164	352	543	799
15453	NE/NE/NE-32	157	611.5	+192	-933	-1123	-1458	-2246		1125	40	150	335	525	788
13838	NE/NW/NW-32	158	616.2	+145	-972	-1169	-1420	-2276	91	1117	29	168			
22404	SW/SW/NE-33	159	608.0		-926	-1119	-1465	-2235			32	161	346	539	770
13688	SE/SE/SW-34	160	602.0	+84	-931	-1133	-1476	-2251	174	1015	19	183	343	545	775
13765	NW/SW/SE-35	161	595.5	+121	-932	-1134	-1474	-2238	155	1053	27	175	340	542	764
16492	SE/NE/NW-35	162	606.0	+156	-909	-1114	-1451	-2233		1065	35	170	337	542	782
17174	NW/NW/NW-36	163	595.2	+140	-921	-1128	-1451	-2203	85	1061	24	183	323	530	752
13738	SW/NE/SW-36	164	390.3		-886	-1095	-1429	-2214			32	177	334	543	785
	T17N R5E														
17958	W½/NW-30	165	588.1	+91	-857	-1062	-1390	-2198		948	26	179	328	533	808
17716	NW/NE/SW-31	166	587.6	+138	-862	-1086	-1406	-2193		1000	20	204	320	544	787
	T18N R3E														
20757	NE/NW/NE-1	167	699.0	+258	-761	-942	-1285		131	1019	33	148	343	524	
18412	NE/SE/SW-1	168	673.7	+224	-785	-964	-1324		140	1009	28	151	360	539	
15134	NW/SE/NE-2	169	699.1	+242	-801	-976	-1331	-2119	147	1043	30	145	355	530	788
16299	SE/SW/SE-2	170	695.1	+220	-7[illegible]4	-970	-1325		175	1015	28	147	355	530	
15430	SW/SE/SW-2	171	701.0	+151			-1337	-2114	183						777

PERMIT NUMBER	LOCATION	WELL NUMBER	ELEVATION	COLDWATER	SUNBURY	ANTRIM	TRAVERSE	DUNDEE	MARSHALL	COLDWATER	SUNBURY	BEREA-BEDFORD	ANTRIM	TOTAL 'B'	TRAVERSE
	T17N R5E (cont.)														
13695	NW/NW/SE-8	172	770.4	+146	-900	-1070	-1445	-2231	135	1046	32	138	375	545	786
4734	SW/SE/NE-9	173	730.8	+189	-856	-1045	-1416	-2197	91	1045	33	156	371	560	781
16135	NE/NE/NE-11	174	687.4	+214	-783	-958	-1329		138	997	30	145	371	546	
15832	NE/NW/NW-11	175	700.1	+203	-800	-980	-1344		162	1003	24	156	364	544	
16578	NE/NE/NW-12	176	680.5	+221	-784	-964	-1317	-2119	155	1005	30	150	353	533	802
16579	SE/NW/NW-12	177	681.6		-785	-963	-1327				29	149	364	542	
15960	NW/SW/SW-12	178	681.1	+216	-824	-999	-1364	-2155	105	1040	20	155	365	540	791
19224	NW/NE/NW-15	179	701.2	+191	-852	-1034	-1401	-2181	170	1043	22	160	367	549	790
17224	SW/SE/NE-19	180	769.9	+83	-930	-1100	-1485	-2285	144	1013	23	147	385	555	800
22146	SW/NW/SE-20	181	736.0	+96	-885	-1084	-1484	-2265	140	981	58	141	400	599	781
15133	NE/SE/NE-22	182	695.2	+105	-840	-1035	-1400	-2200	154	945	25	168	367	560	800
18335	SW/SW/SE-22	183	689.2	+119	-865	-1041	-1419	-2226	182	984	38	138	378	554	807
12957	NE/NW/NE-23	184	683.1	+2-3	-867			-2200	50	1070	30				
18084	SW/SW/SE-24	185	662.9		-882	-1057	-1418	-2224		985	30	145	361	536	806
16404	SW/SE/SW-25	186	650.1	+125	-857	-1030	-1396	-2188	48	982	15	158	366	539	792
18578	SW/NW/NW-26	187	679.1	+132	-852	-1021	-1397	-2191	160	984	27	142	376	545	784
11119	NE/NE/NW-27	188	693.8	+139	-876	-1081	-1424	-2261	150	1015	25	180	343	548	804
12743	SW/NE/NE-28	189	701.1	+120	-899	-1047	-1428	-2221	81	1019		148	381		793
4770	SE/SW/SW-28	190	706.1	+76	-914	-1094	-1474	-2258		990	30	150	380	560	784
7362	CN½/NE/NE-29	191	731.5	+72	-928	-1098	-1478	-2268		1000	25	145	380	550	790
16474	SE/NE/SE-29	192	717.3	+57	-918	-1103	-1493	-2293	85	975	28	157	390	575	800
20615	NE/NW/NW-29	193	744.5	+47	-925	-1107	-1490	-2263		972	33	149	383	565	773
11954	SW/SW/NE-32	194	710.2	+37	-990	-1170	-1562	-2338	143	1027	25	155	392	570	776
13892	SE/SW/SW-33	195	685.4	+38	-948	-1132	-1421	-2331	182	986	24	160	391	575	808
6461	CN½/NE/SW-34	196	676.2	+56	-944					1040	40				
12830	SE/NW/SW-26	197	650.8	+151	-875	-1049	-1395	-2204		1026	24	150	346	520	809

PERMIT NUMBER	LOCATION	WELL NUMBER	ELEVATION	COLDWATER	SUNBURY	ANTRIM	TRAVERSE	DUNDEE	MARSHALL	COLDWATER	SUNBURY	BEREA-BEDFORD	ANTRIM	TOTAL 'B'	TRAVERSE
	T14N R5E NW/NW/SW-14	198	592	-493	-1441	-1779	-2093		225	980	20				
	NE/SW-22	199													
5288	T15N R3E SW/SW/SW-10	200	625	-165	-1155	-1365	-1736	-2426	200	990	20	190	371	581	690
18649	NW/NW/SW-31	201	651.6	-713	-1689	-1871	-2248	-2953	145	976	19	163	371	559	705
1016	T16N R4E SW/SW/SW-9	202	618	0	-1066	-1282	-1623	-2384	245	959	38	188	341	567	649
2058	NE/NE/NE-19	203							216	1022	20				
19285	T18N R3E NE/NW/NE-20	204	739.7	+80	-911	-1086	-1475	-2272		991	36			564	797
1126	SW/SW/NE-21	205	710	+66	-875	-1110	-1441	-2246	209	941	18	217	322	557	805
2054	T15N R4E SE/SW/NW-10	206	608		-1177				88	1122	30				
4613	T16N R5E NW/NW/SW-7	207	585	+180	-910	-1120	-1448	-2224	110	1095	30	180	328	538	776
2210	T15N R4E NE/SE/SW-14	208	588.7	-71	-1095	-1338	-1646	-2372	183	1024	27	216	308	551	720
	T13N R5E	209													

APPENDIX II

PERMIT NUMBER	LOCATION	MAP NUMBER	MARSHALL	COLDWATER	SUNBURY	BEREA-BEDFORD	ELLSWORTH	ANTRIM	TOTAL 'B'	TRAVERSE
	ALCONA									
2951	NE-10 T26N R7E	1		426+	30	155		359	544	698
11519	SW-34 T26N R8E	2		155+	37	181		364	582	696
NONE	12 T26N R9E	3				179				
NONE	22 T27N R9E	4								710
	ALLEGAN									
6234	SW-24 T1N R11W	5	80	926			359	163	522	346
	NW-26 T1N R12W	6					415	130	545	230
6440	SE-10 T1N R13W	7					421	151	572	294
9128	SE-36 T1N R14W	8					435	150	585	310
15327	SE-29 T1N R15W	9					468	110	578	240
15814	SE-11 T1N R16W	10					492	107	599	253
10759	SE-29 T2N R11W	11					493	142	635	232
21684	NE-25 T2N R12W	12	30	723			418	132	550	302
9660	NW-12 T2N R13W	13		678			419	215	634	230
14790	NE-31 T2N R14W	14		371			473	122	595	288
21243	SW-9 T2N R15W	15		451			517	98	615	
20413	SE-2 T2N R16W	16					510	140	650	242
22728	SW-17 T3N R11W	17		848			400	167	567	311
21103	NW-4 T3N R12W	18		670			475	123	598	365
21039	SW-22 T3N R13W	19		682			463	128	591	295
20570	NE-1 T3N R14W	20					525	105	630	359
21811	SE-9 T3N R15W	21					516	145	661	
18984	NW-1 T3N R16W	22					565	136	701	
20706	SW-32 T4N R11W	23		843			449	126	575	376
21645	SW-19 T4N R12W	24		772			503	120	623	358
21589	NW-17 T4N R13W	25		750			541	111	652	366
21559	NW-9 T4N R14W	26		758			447	180	627	394
21655	SW-28 T4N R15W	27					555	109	664	233
16586	SW-35 T4N R16W	28					569	125	694	274
	ALPENA									
11671	NE-9 T29N R5E	29								740
576	NE-25 T30N R6E	30								772
	SW-30 T31N R8E	31								627
11	SE-20 T31N R8E	32								695
	ANTRIM									
	NE-25 T29N R5W	33					486	165		
16645	SE-19 T29N R6W	34			110		390	171	671	769

PERMIT NUMBER	LOCATION	MAP NUMBER	MARSHALL	COLDWATER	SUNBURY	BEREA-BEDFORD	ELLSWORTH	ANTRIM	TOTAL 'B'	TRAVERSE
	ANTRIM (cont.)									
16325	NW-16 T29N R7W	35			22		505	172	699	779
18385	SW-25 T30N R5W	36						160		
10019	SE-3 T30N R6W	37						165		783
10232	NE-17 T31N R5W	38						147		840
10605	NW-9 T31N R7W	39						130		780
17180	SW-14 T31N R8W	40						129		781
22639	SE-19 T32N R8W	41						98		762
	ARENAC									
21661	NW-14 T18N R4E	42	165	1040	25	157		348	530	805
22590	SE-6 T18N R5E	43	105	1020	35	145		360	540	818
20213	SW-26 T19N R3E	44	71	1099	32	150		364	546	
21465	NW-29 T19N R4E	45	152	1054	10	155		362	527	873
21232	SW-32 T19N R5E	46	122	1100	29	165		357	551	820
14637	SW-12 T19N R6E	47	127	1055	47	220		354	601	785
21166	NW-28 T20N R3E	48	185	1039	25	135		376	621	819
19323	SE-20 T20N R4E	49	181	1057	35	164		350	549	808
20314	NE-17 T20N R5E	50	170	1125	28	172		346	546	823
13827	SE-29 T20N R6E	51	113	1207	28	208		375	611	793
10835	NE-16 T20N R7E	52	120	1275	50	185		367	602	785
	BARRY									
9884	SE-19 T1N R7W	53	140	1013			227	118	345	315
21342	SW-8 T1N R8W	54	263	902	5		225	141	371	
12890	NE-6 T1N R9W	55	185	993			248	150	398	317
14782	SW-21 T1N R10W	56		909			400	133	533	
6612	NW-17 T2N R7W	57	230	980	10		200	150	360	
6231	SE-22 T2N R8W	58	138	1055			230	148	351	
20732	NW-34 T2N R9W	59			5		260	125	390	312
20875	NE-33 T2N R10W	60					353	126	379	339
21987	NE-22 T3N R7W	61	310	949	7		237	87	331	340
5806	SW-19 T3N R8W	62		1040			195	189	384	
18526	SW-14 T3N R9W	63		920			273	129	402	333
12780	SW-6 T3N R10W	64		915			372	120	492	349
17268	NW-29 T4N R7W	65	237	1004	5		12	335	352	227
15586	NW-6 T4N R8W	66	263	960			292	125	417	348
15541	SE-9 T4N R9W	67	222	915			285	160	445	240
6308	NW-3 T4N R10W	68	271	852			328	166	495	364
	BAY									
10275	SW-7 T13N R4E	69	187	980	45	150		350	545	648

BAY (cont.)

PERMIT NUMBER	LOCATION	MAP NUMBER	MARSHALL	COLDWATER	SUNBURY	BEREA-BEDFORD	ELLSWORTH	ANTRIM	TOTAL 'B'	TRAVERSE
8746	NE-3 T13N R6E	70	182	1085	35					
3237	NE-18 T14N R3E	71	190	1039	24	152		354	530	688
15572	NW-11 T14N R4E	72	182	980	24	188		327	538	681
18205	SE-8 T14N R5E	73	175	1012	23	190		337	550	680
15312	SW-15 T14N R6E	74		925	115	25		355	495	720
10728	NW-13 T15N R3E	75	154	1038	27	183		327	537	710
19949	NW-21 T15N R4E	76	145	1040	30	175		339	544	711
19019	SE-31 T15N R5E	77		1020	27	173		325	525	732
12476	NW-19 T16N R3E	78	196	1020	28				578	727
22290	SW-15 T16N R4E	79	155	1065	33	177		342	552	738
4613	SW-7 T16N R5E	80	110	1095	30	180		328	538	776
18894	SE-13 T17N R3E	81	162	1024	22	152		358	532	772
18104	NW-17 T17N R4E	82	150	1015	40	140		365	545	803
17958	NW-30 T17N R5E	83		948	26	179		328	533	808
13965	SE-8 T18N R3E	84	135	1046	32	138		375	545	786

BENZIE

PERMIT NUMBER	LOCATION	MAP NUMBER	MARSHALL	COLDWATER	SUNBURY	BEREA-BEDFORD	ELLSWORTH	ANTRIM	TOTAL 'B'	TRAVERSE
19279	SE-13 T25N R13W	85			8		605	163	768	
15921	NE-29 T25N R14W	86						237		

BERRIEN

PERMIT NUMBER	LOCATION	MAP NUMBER	MARSHALL	COLDWATER	SUNBURY	BEREA-BEDFORD	ELLSWORTH	ANTRIM	TOTAL 'B'	TRAVERSE
11916	NE-2 T3S R17W	87					408	119	527	
7815	NE-34 T3S R17W	88					385	190	575	145
19453	NW-22 T3S R18W	89						104		
10140	NW-24 T4S R17W	90					345	150	495	
11780	SW-20 T4S R18W	91					387	99	486	131
7046	NW-35 T4S R19W	92						120		185
19137	NW-12 T5S R17W	93					408	64	472	146
19259	NW-2 T5S R17W	94					401	86	487	
6452	NW-12 T5S R18W	95						80		160
14041	SE-33 T6S R17W	96						145		
19529	SE-4 T6S R19W	97								
13879	NW-2 T7S R17W	98							75	145
15253	NW-32 T7S R18W	99								
6364	NE-8 T8S R20W	100								108
942	SE-10 T8S R21W	101						53		

BRANCH

PERMIT NUMBER	LOCATION	MAP NUMBER	MARSHALL	COLDWATER	SUNBURY	BEREA-BEDFORD	ELLSWORTH	ANTRIM	TOTAL 'B'	TRAVERSE
21862	NW-5 T5S R5W	102			9	24	60	201	234	230
19538	NE-4 T5S R6W	103			17	45		195	257	216

PERMIT NUMBER	LOCATION	MAP NUMBER	MARSHALL	COLDWATER	SUNBURY	BEREA-BEDFORD	ELLSWORTH	ANTRIM	TOTAL 'B'	TRAVERSE
	BRANCH (cont.)									
21694	NW-20 T5S R7W	104			7		60	204	271	213
8206	NE-34 T5S R8W	105			37		33	215	285	
19967	SW-1 T6S R5W	106			13				225	193
21519	SW-29 T6S R8W	107			7	20		220	247	165
21378	SE-29 T7S R6W	108			12	12		198	222	174
18528	SE-10 T7S R7W	109			12			219	231	189
20685	NE-15 T7S R8W	110			7		20	215	242	215
22071	NE-15 T8S R5W	111			18	29		188	235	152
1030	NE-11 T8S R8W	112								
	CALHOUN									
21895	SW-32 T1S R4W	113	282	1018	12	10		237	259	262
22526	SE-22 T1S R5W	114		984	13	23		232	268	263
19831	SE-8 T1S R6W	115		1016	14	7	73	215	309	
4768	NE-10 T1S R7W	116		1057			47	273	320	
22527	SE-18 T2S R4W	117		1011	10	23		205	238	269
22880	NE-12 T2S R5W	118		1014	10	20		232	262	269
21757	SE-13 T2S R6W	119		879			256		256	320
19824	SW-23 T2S R7W	120		1045			288		288	
22610	SW-11 T3S R4W	121		1001	17	35		219	271	239
12329	SE-34 T3S R7W	122			9		126	150	285	
20241	SW-22 T3S R8W	123			13		28	261	302	249
22400	NW-1 T4S R5W	124			8	43		211	262	242
21647	NW-17 T4S R6W	125		947	10	53		227	290	226
7618	NE-3 T4S R7W	126			5		47	235	287	
7749	SE-17 T4S R8W	127			9		204	95	308	
	CASS									
18573	SW-5 T5S R13W	128					376	101	477	
8893	SE-19 T5S R14W	129					247	220	467	
7794	SW-17 T5S R15W	130					351	109	460	207
10199	SW-14 T5S R16W	131					387	90	477	
18554	SE-15 T6S R13W	132					334	98	432	
18806	SW-23 T6S R15W	133					374	87	461	
	SW-4 T6S R16W	134					388	87	475	
19002	NW-32 T7S R13W	135					328	76	404	
17414	SW-36 T7S R14W	136					318	77	170	
837	SE-3 T7S R16W	137								269
22047	SE-3 T8S R14W	138					268	78	346	164

PERMIT NUMBER	LOCATION	MAP NUMBER	MARSHALL	COLDWATER	SUNBURY	BEREA-BEDFORD	ELLSWORTH	ANTRIM	TOTAL 'B'	TRAVERSE
	CASS (cont.)									
12135	SW-15 T8S R15W	139						124		
579	SW-2 T8S R16W	140					225	132	357	
	CHARLESVOIX									
19194	N-24 T32N R5W	141						125		750
18747	NE-14 T32N R6W	142						256		759
	CHEBOYGAN									
163	SE-12 T33N R3W	143								632
19422	NW-7 T34N R2W	144								640
	CLARE									
20940	SE-12 T17N R3W	145	240	955	38	34		500	572	723
19494	NW-31 T17N R4W	146	197	926	28	14		542	584	655
17271	SE-12 T17N R5W	147	205	908				585	585	699
10687	NW-7 T17N R16W	148	170	840				650	650	632
19257	NW-22 T18N R3W	149	233	937	33	20		530	583	708
17087	NE-29 T18N R4W	150	195	949				568	568	705
20618	NE-1 T18N R5W	151	200	909	45		15	564	624	674
10169	SE-14 T18N R6W	152	226	867				638	638	658
19266	SE-6 T19N R3W	153	256	898				572	572	741
7306	SE-11 T19N R4W	154	171	967	43	18		552	624	730
16863	NE-1 T19N R5W	155	206	975				545	545	729
9676	SE-1 T19N R6W	156	191	860				685	685	626
21884	SW-36 T20N R3W	157	174	1002	28	15		525	568	768
20116	SW-35 T20N R4W	158	200	925	20	50		517	587	741
11444	NW-7 T20N R5W	159	163	848				683	683	676
17484	NE-12 T20N R6W	160	165	857			425	235	660	692
	CLINTON									
19451	SW-32 T5N R1W	161	250	1075	25	69		299	393	318
	SW-18 T5N R2W	162	207	1050	30	50		306	386	353
8274	NW-14 T5N R3W	163	196	1066	17	64		313	394	339
13619	NW-29 T6N R1W	164	208	1038	12	86		187	285	463
10484	SW-17 T6N R2W	165	170	1095	50	35		397	382	383
19367	SE-2 T6N R2W	166	102	1050				311	311	435
5042	SE-19 T6N R3W	167	210	1075	20	50		335	405	342
11278	SW-3 T7N R1W	168	265	1015	20	36		359	415	415
19696	NE-1 T7N R2W	169	221	1046	17	69		320	406	

PERMIT NUMBER	LOCATION	MAP NUMBER	MARSHALL	COLDWATER	SUNBURY	BEREA-BEDFORD	ELLSWORTH	ANTRIM	TOTAL 'B'	TRAVERSE
	CLINTON (cont.)									
14767	SW-22 T7N R3W	170	181	1075	21	38		329	388	399
9033	SE-21 T7N R4W	171	200	1062	8	18		347	373	420
2341	NE-4 T8N R1W	172	270	1000	25	60		325	410	468
10335	SE-3 T8N R2W	173	227	1145	15	55		332	402	450
13586	SE-9 T8N R3W	174	165	1060	17	39		362	418	433
11082	SE-4 T8N R4W	175	136	1091	15	13		400	428	416
	CRAWFORD									
11807	SE-30 T25N R1W	176	118							752
4278	SW-33 T25N R3W	177	122	1036	10			627	637	748
17829	NE-21 T25N R4W	178	105	965	25			613	638	717
11774	SE-16 T26N R2W	179	90							
17234	NE-36 T26N R3W	180		875				625	625	767
21027	SE-26 T27N R1W	181		1063	40			527	567	715
18631	SW-16 T28N R3W	182						635	635	738
	EATON									
18459	NW-14 T1N R4W	183	305	1034	23			205	228	
21769	SW-18 T1N R5W	184		960				258	258	317
429	NW-8 T2N R6W	185	226	976	20	35		263	318	300
	NW-8 T2N R3W	186	305	1038		30		330	360	387
2767	NW-11 T2N R4W	187	295	1040				325	325	313
22672	SW-18 T2N R5W	188	292	1003	10	25		247	282	233
1806	SE-5 T3N R4W	189	291	1048	24	25		238	287	375
564	SW-28 T3N R5W	190	280	983	10	15		216	241	
1090	NE-17 T4N R5W	191	220	1096	15	44		223	282	
	EMMET									
4376	SE-15 T35N R4W	192								
790	SW-16 T37N R5W	193								
	GENESEE									
2828	SW-3 T5N R5E	194			16	194		198	408	406
7275	NW-13 T6N R5E	195	125	975	33	209		202	444	406
7665	NW-11 T6N R7E	196	113	1015	20	225		182	437	395
2114	NW-33 T7N R6E	197			41	185		235	461	409
12380	SE-6 T8N R5E	198	185	960	26	219		213	458	445
760	8 T8N R7E	199			25	232		210	467	

PERMIT NUMBER	LOCATION	MAP NUMBER	MARSHALL	COLDWATER	SUNBURY	BEREA-BEDFORD	ELLSWORTH	ANTRIM	TOTAL 'B'	TRAVERSE
	GENESEE (cont.)									
10913	NW-29 T9N R5E	200		1011	20	210		230	460	486
9669	NE-11 T9N R7E	201	132	1065	42	237	220	499		
9090	SW-5 T9N R8E	202	170	943	41	226		215	482	489
	GLADWIN									
20774	NE-2 T17N R1E	203	157	1032	24	134		443	601	742
22655	NW-18 T17N R2E	204	154	1043	14	134		447	595	743
17197	SW-32 T17N R1W	205	219	998	29	69		487	585	713
18551	SW-36 T17N R2W	206	197	990	38	52		498	588	710
22547	SE-16 T18N R1E	207	156	1062	28	97		456	581	742
4690	SE-22 T18N R2E	208	198	1026	22	126		425	273	778
22081	NE-6 T18N R1W	209	229	1036	30	64		484	578	729
20902	NE-10 T18N R2W	210	208	1015	32	48		493	573	734
18771	SW-12 T19N R1E	211	162	1025	25	110		443	578	772
5352	SW-29 T19N R2E	212	178	1028	24	104		438	566	765
16894	NE-12 T19N R1W	213	155	1040	30	75		465	570	774
14627	NE-34 T19N R2W	214	197	1020	39	48		475	562	764
16158	NW-16 T20N R1E	215	205	1030	30	70		470	570	761
17279	NE-31 T20N R2E	216	173	983	30	26		504	560	749
21631	SW-26 T20N R1W	217	147	1039	34	59		475	568	769
20298	SE-31 T20N R2W	218	161	995	25	30		529	584	729
	GRAND TRAVERSE									
18512	NE-26 T25N R9W	219	97							
	SW-9 T25N R10W	220			25		593	262	880	763
	SE-11 T25N R12W	221								826
	NE-23 T26N R11W	222					480	215	695	752
	NE-25 T26N R12W	223						142		679
	GRATIOT									
12110	SE-31 T9N R1W	224	297	968	32	73		340	445	448
7787	SE-36 T9N R2W	225	259	1024	18	65		340	423	550
11991	SE-13 T9N R3W	226	230	1025	15	50		345	410	475
21296	SE-18 T9N R4W	227	139	1102	18	17		373	408	447
10525	SE-32 T10N R1W	228	235	1062	20	68		325	413	460
20812	SW-8 T10N R2W	229		1017	36	25		361	422	498
8482	SW-6 T10N R3W	230	277	996	24	35		372	431	499
21788	NW-14 T10N R4W	231	233	1065	26	16		410	452	469

PERMIT NUMBER	LOCATION	MAP NUMBER	MARSHALL	COLDWATER	SUNBURY	BEREA-BEDFORD	ELLSWORTH	ANTRIM	TOTAL 'B'	TRAVERSE
	GRATIOT (cont.)									
9864	SE-10 T11N R1W	232	260	1045	30	75		375	480	461
4453	SE-18 T11N R2W	233	280	998	13	90		356	459	539
8497	SE-6 T11N R3W	234	261	994	28	30		409	467	518
9929	NE-35 T11N R4W	235	240	1058	35	16		384	445	447
	SE-13 T12N R1W	236	210	1035	9	60		417	486	587
3210	SW-1 T12N R1W	237	181	1021	28	100		365	493	
2576	SE-10 T12N R2W	238	200	1021		80		390	470	548
10107	SE-31 T12N R3W	239	257	1040	22	23		402	447	517
10193	SE-5 T12N R4W	240	247	1012	35	29		396	460	555
	HILLSDALE									
21516	NW-20 T5S R1W	241		970	5	58		168	231	216
21224	SE-25 T5S R2W	242		1102	14	51		125	190	183
21918	SE-23 T5S R3W	243			10	40		137	187	244
22011	SE-7 T5S R4W	244			15	15		206	236	204
21109	NW-18 T6S R1W	245			16	36		196	248	174
22732	SE-8 T6S R2W	246			10	35		197	242	185
21737	SE-21 T6S R3W	247		1009	7	26		196	229	204
21745	SE-1 T6S R4W	248		1019	18	13		193	224	197
21782	NW-8 T7S R1W	249				40		189	229	204
21869	NE-25 T7S R2W	250			13	29		176	218	176
21571	SE-3 T7S R3W	251		962	7	16		192	215	148
22863	NE-32 T7S R4W	252			7	15		195	217	167
22147	SE-5 T8S R1W	253			40	35		148	223	203
22021	SW-23 T8S R3W	254			5	45		174	224	163
22216	NW-1 T8S R4W	255			10			190	200	184
21773	NE-5 T9S R4W	256			15	45		156	216	174
	HURON									
20764	NE-34 T15N R9E	257	92	1102	57	258		254	569	716
16222	NW-27 T15N R10E	258			62	263		252	577	722
21290	SW-29 T15N R11E	259		1067	69	289		249	607	702
1166	NW-32 T15N R12E	260			70	309		250	629	684
	NE-31 T15N R16E	261				307		222		605
842	SE-36 T16N R9E	262		1120	63					
12907	NE-2 T16N R10E	263			66	250		302	618	748
3679	NW-27 T16N R11E	264		1225	67	291		255	613	718
4240	SE-30 T16N R12E	265		1135	87	257		234	578	764
5519	NW-27 T16N R13E	266			91	335		250	676	686
10876	NW-27 T16N R15E	267			120	285		252	657	

PERMIT NUMBER	LOCATION	MAP NUMBER	MARSHALL	COLDWATER	SUNBURY	BEREA BEDFORD	ELLSWORTH	ANTRIM	TOTAL 'B'	TRAVERSE
	HURON (cont.)									
2180	SE-28 T17N R10E	268	167	1148	80	225		305	610	763
17855	NE-20 T17N R14E	269			101	305		244	650	
11834	SW-22 T17N R15E	270			131	301		261	693	636
18019	SW-12 T18N R12E	271			104	303		263	670	706
18849	NW-27 T18N R13E	272			112	318		234	664	695
	NW-28 T18N R14E	273			128	204				
13236	SE-31 T19N R13E	274			111	298		275	684	
	INGHAM									
8132	NW-15 T1N R1E	275	206	1067	13	122		258	393	
9477	SW-1 T1N R1E	276	188	1035	11	106		245	326	
4918	NW-23 T2N R1W	277	276	1010	32	55		260	347	283
10011	SE-14 T3N T1E	278	242	1030	10	98		282	390	265
20566	NW-2 T4N R1E	279	260	930	20	112		267	399	358
792	NW-21 T4N R2E	280			10	127		246	383	280
9987	SW-22 T4N R1W	281	255	1051	26	85		257	368	306
	IONIA									
10865	NE-4 T5N R6W	282	288	1027			8	347	355	445
7503	Se-29 T5N R8W	283	190	1008			282	153	435	357
5993	SE-5 T6N R5W	284	217	992	75	26		338	439	405
14166	SW-11 T6N R6W	285	238	1098				338	338	420
	NE-12 T6N R7W	286	252	1095				325	325	384
11121	NW-6 T6N R8W	287	200	1010		53		409	462	418
20535	NW-21 T7N R5W	288	216	1083	1	7		372	380	409
20289	SE-3 T7N R6W	289	202	1098				385	385	449
11027	SE-6 T7N R7W	290	140	1036	21		12	387	420	409
2908	SE-8 T7N R8W	291	219	990				499	499	371
20707	SE-22 T8N R5W	292	182	1079				393	393	422
20765	NE-24 T8N R6W	293	209	1043				393	393	429
14331	SE-14 T8N R7W	294	195	1028	26			358	358	412
11472	SW-26 T8N R8W	295	163	1001	18		32	394	444	400
	IOSCO									
12531	SE-4 T21N R5E	296	177	973	34	151		392	577	783
17259	SE-21 T21N R5E	297	175	1295	35					
10420	NW-16 T21N R6E	298	247	1222	18	225		370	613	774
12788	SW-3 T22N R5E	299	145	1285	35	155		395	587	757
15685	SE-23 T22N R6E	300	213	1270	34	179		384	597	750
12163	NE-1 T22N R8E	301		962	64	204		331	599	756

PERMIT NUMBER	LOCATION	MAP NUMBER	MARSHALL	COLDWATER	SUNBURY	BEREA-BEDFORD	ELLSWORTH	ANTRIM	TOTAL 'B'	TRAVERSE
	IOSCO (cont.)									
10732	NW-29 T2N R5E	302	160	1295	31	144		390	565	785
10632	SW-33 T23N R9E	303			50	220		325	595	745
17142	SW-10 T24N R9E	304			43	210		265	518	780
	ISABELLA									
13595	NE-20 T13N R3W	305	165	1009	21	45		445	511	434
16440	NE-22 T13N R4W	306	275	993	27	25		408	460	582
19058	SW-32 T13N R5W	307	259	968	31	16		430	477	543
13414	SW-28 T13N R6W	308	228	995	27	20		471	518	523
16395	SE-1 T14N R3W	309	185	1011	22	47		433	502	611
17165	NW-20 T14N R4W	310	256	989	30	25		430	485	617
1073	SW-7 T14N R5W	311	235	948		10		519	529	584
11864	NW-13 T14N R6W	312	263	913	13	4		535	552	578
21151	SW-2 T15N R3W	313	165	985	28	14		480	522	673
19590	NE-11 T15N R4W	314	216	932	7	27		473	507	647
15796	NE-9 T15N R5W	315	149	930	36	15		506	557	612
17561	SW-8 T15N R6W	316	291	839	35	13		532	580	604
22152	SW-13 T16N R3W	317	159	1030	43	20		489	552	682
20801	NW-26 T16N R4W	318	180	913	27	21		488	536	630
19050	NE-30 T16N R5W	319	155	896	36	15		500	551	615
11184	SW-29 T16N R6W	320	180	873	30	30	345	200	605	596
	JACKSON									
21992	SE-26 T1S R1E	321	268	967	20	100		257	377	230
7149	SE-26 T1S R1W	322	270	1051		105		254	359	202
22719	SW-14 T1S R3W	323	310	1010	20	30		226	276	259
9881	NE-8 T2S R1W	324	310	1000	20	70		249	339	
21633	SE-8 T2S R3W	325		1040	15	30		263	308	207
21898	NE-26 T3S R1E	326		1112	9	105		203	317	211
18265	SE-7 T3S R2E	327		937	29	81		245	355	
21736	NE-35 T3S R2W	328		957	10	58		203	271	205
22107	NW-14 T3S R3W	329		975	10	50		212	272	225
21982	SE-7 T4S R1E	330		680	20	50		238	308	197
22017	NE-19 T4S R2E	331		1015	10	110		183	303	222
22568	SW-33 T4S R1W	332		929	11	67		200	278	182
22288	NE-8 T4S R2W	333		990	10	48		205	263	202
22416	SW-28 T4S R3W	334		970	14	33		206	253	214

PERMIT NUMBER	LOCATION	MAP NUMBER	MARSHALL	COLDWATER	SUNBURY	BEREA-BEDFORD	ELLSWORTH	ANTRIM	TOTAL 'B'	TRAVERSE
	KALAMAZOO									
	14 T1S R9W	335		1025		11		366	377	
20572	SE-27 T1S R10W	336					301	135	436	290
7313	SW-13 T1S R11W	337					332	123	455	
20323	SE-15 T1S R12W	338					400	125	525	260
7180	SW-21 T2S R9W	339					310	98	408	
16838	NW-8 T2S R10W	340					342	90	432	
13483	SW-31 T2S R12W	341					405	110	515	230
6876	SW-8 T3S R9W	342			6		225	165	396	
21182	SW-29 T5S R10W	343					325	93	418	
RD92	NW-13 T3S R11W	344					329	113	442	170
18817	SW-25 T3S R12W	345					375	105	480	
11857	SE-17 T4S R10W	346					325	91	416	
6026	SW-8 T4S R11W	347					345	135	480	
18664	NE-36 T4S R12W	348					353	65	418	
	KALKASKA									
17276	SW-12 T25N R5W	349	150	1055						720
18664	SE-16 T25N R6W	350	145	903	85		461	209	755	749
16339	SW-26 T25N R7W	351	121	9985			577	132	709	
14659	SE-27 T25N R8W	352			55		554	237	846	770
10762	NW-8 T26N R5W	353			129		351	219	699	784
15121	SE-17 T26N R5W	354						309		774
17982	NE-27 T27N R5W	355			152		341	186	679	754
20133	NW-10 T27N R6W	356			60		425	241	726	772
16632	SW-2 T27N R7W	257			65		520	149	734	806
20466	SW-6 T28N R7W	358			58		495	178	731	788
17890	NE-36 T28N R8W	359			22		508	210	740	755
	KENT									
	SE-26 T5N R9W	360	280	9311			282	146	428	355
21388	NW-21 T5N R10W	361		839	3		380	118	501	358
20933	NE-17 T5N R11W	362	337	701	12			568	580	360
4984	SW-14 T5N R12W	363		879			429	211	640	372
20818	NW-12 T6N R9W	364	305	890				472	472	396
9786	NW-23 T6N R10W	365	247	877			323	174	497	396
6462	NW-27 T6N R11W	366	263	791	23		418	143	584	359
7511	SW-14 T6N R12W	367	252	825			380	220	600	275
7905	SE-30 T7N R9W	368	225	860				500	500	430
3601	SW-25 T7N R10W	369	230	882	8		353	192	553	397
6823	NE-3 T7N R11W	370		797			395	184	579	376
9166	SE-30 T7N R12W	371	263	708			502	128	630	405

PERMIT NUMBER	LOCATION	MAP NUMBER	MARSHALL	COLDWATER	SUNBURY	BEREA-BEDFORD	ELLSWORTH	ANTRIM	TOTAL 'B'	TRAVERSE
	KENT (cont.)									
11422	SW-22 T8N R9W	372	175	897			300	199	499	422
13276	SW-32 T8N R10W	373	320	805			470	90	560	399
12370	SW-2 T8N R11W	374	289	804				392	592	424
19076	NE-4 T8N R12W	375	251	740			477	181	658	404
20103	SE-27 T9N R10W	376	185	858	3		374	205	582	410
16270	NE-35 T9N R11W	377	235	821			478	100	578	444
18027	SE-32 T9N R12W	378	277	693			527	151	678	392
19837	SE-1 T10N R9W	379	232	915				497	497	459
20487	SW-12 T10N R10W	380	137	993				487	487	400
10826	NE-30 T10N R11W	381	206	821	57		275	267	599	435
18496	SE-10 T10N R12W	382	190	714			546	137	683	440
	LAKE									
12767	NE-20 T17N R11W	383	199	568	12		496	275	783	603
13941	NW-22 T17N R12W	384	218	599	14		556	205	775	595
9829	SE-30 T17N R13W	385	247	553	39		556	218	813	600
18881	NE-36 T18N R11W	386	240	638	15		585	185	785	633
17893	NE-20 T18N R12W	387	262	579	19		584	218	821	604
14776	NW-24 T18N R13W	388	238	655			470	255		648
10798	SE-24 T18N R14W	389	133	565				821		610
1105	NW-22 T19N R11W	390	152	600	25		530	317	872	630
16032	NE-23 T19N R12W	391	280	550	23		595	285	903	638
11423	NW-11 T19N R13W	392	180	536	30		588	254	872	644
21412	NE-19 T19N R14W	393		610	20		620	215	855	625
22683	NE-24 T20N R11W	394		635	30		590	268	888	
20234	SW-30 T20N R12W	395	157	562	30		604	266	900	661
9899	SE-34 T20N R13W	396						267		645
15419	SW-12 T20N R14W	397		536	16		586	228	830	652
	LAPEER									
3413	SW-29 T6N R9E	398		888	34	211		181	426	390
12933	NW-25 T6N R11E	399			53	229		205	487	337
18530	NW-4 T7N R9E	400	219	997	42	236		200	478	446
2127	NW-26 T7N R10E	401	175	970	40	270		200	510	348
11286	NE-8 T8N R9E	403	190	1035	42	240		206	488	449
10117	NW-5 T8N R10E	404		953	43					
2689	SE-17 T8N R11E	405	237	975	60	239		161	460	485
10936	SW-28 T9N R9E	406	193	990	53	246		159	458	500
14827	NW-8 T9N R10E	407	178	1017	58	260		205	523	493

PERMIT NUMBER	LOCATION	MAP NUMBER	MARSHALL	COLDWATER	SUNBURY	BEREA-BEDFORD	ELLSWORTH	ANTRIM	TOTAL 'B'	TRAVERSE
	LAKE (cont.)									
17457	NE-20 T9N R10E	408	89	1106	49	206		218	473	467
12969	SW-33 T9N R12E	409	150	922	69	285		208	562	413
20761	NE-30 T10N R10E	410	220	1075	55	269		216	540	491
10466	SE-27 T10N R12E	411			93					
	LEELANAU									
1037	SW-6 T28N R11W	412								795
5505	NW-34 T28N R14W	413								
10103	NE-5 T29N R12W	414								
	LENAWEE									
22010	NE-18 T5S R1E	415			10	79		204	293	190
18835	SE-5 T5S R2E	416			12	93		204	309	174
18914	SE-1 T5S R3E	417			8	112		180	300	156
22886	SW-14 T5S R4E	418			12	123		149	284	168
19161	NW-16 T5S R5E	419						140		170
21637	NE-22 T6S R3E	420			9	98		186	293	148
130	SE-5 T6S R5E	421						151		155
9800	NE-7 T7S R1E	422			20	50		218	288	134
2077	SW-6 T7S R3E	423			15	85		190	290	130
983	NE-2 T7S R5E	424								130
21916	NW-27 T8S R1E	425			9	72		197	276	102
16693	NW-18 T8S R4E	426						170		107
1167	NE-13 T8S R5E	427								100
8049	N-12 T9S R1E	428			10	70		195	275	71
	LIVINGSTON									
16690	SW-28 T1N R3E	429		856	12	154		181	347	288
958	SW-32 T1N R4E	430			12	178		155	345	145
15875	NE-6 T1N R6E	431			25	185		175	383	300
19793	SE-2 T1N R6E	432						151		326
10038	SW-9 T2N R3E	433	207	975	15	148		231	394	253
9568	SE-7 T2N R4E	434	285	950	25	160		205	390	285
11818	NW-25 T2N R5E	435			12	205		181	398	333
12737	NE-32 T2N R6E	436				210		168		286
19063	NE-36 T3N R3E	437	264	996	22	146		197	365	315
20858	SW-35 T3N R4E	438			20	165		182	367	342
9782	NW-35 T3N R5E	439			10	182		200	392	349
9426	NE-14 T3N R6E	440			38	165		170	373	350

PERMIT NUMBER	LOCATION	MAP NUMBER	MARSHALL	COLDWATER	SUNBURY	BEREA-BEDFORD	ELLSWORTH	ANTRIM	TOTAL 'B'	TRAVERSE
	LIVINGSTON (cont.)									
22642	NE-28 T4N R3E	441			15	140		202	357	343
16625	SW-31 T4N R4E	442			15	180		214	409	331
17	NE-15 T4N R5E	443			24					
	MACOMB									
4793	SE-14 T1N R12E	444								232
8813	NW-27 T2N R13E	445						165		271
596	SE-5 T2N R13E	446								247
19898	NW-36 T3N R13E	447						220		307
22752	NW-5 T3N R14E	448			4	258		174	436	250
22720	SE-1 T4N R13E	449			79	261		170	510	265
22482	SW-32 T4N R14E	450			79	245		179	503	252
22937	NW-32 T5N R12E	451			59	277		110	446	334
23023	SW-13 T5N R13E	452			81	261		161	503	289
22545	SW-18 T5N R14E	453			82	272		175	529	282
	MANISTEE									
10205	NW-34 T21N R14W	454					610	242	852	563
21950	NW-21 T21N R16W	455						236		658
21605	SW-13 T21N R17W	456						232		656
18697	SE-14 T22N R14W	457					580	235	815	671
914	NW-34 T22N R16W	458						150		797
6344	NW-23 T23N R14W	459					550	250	800	717
7666	NW-31 T23N R15W	460						189		770
15424	NE-22 T23N R16W	461						138		732
18212	SW-22 T24N R13W	462						801	801	697
16064	NE-4 T24N R14W	463						220		765
18213	SE-34 T24N R15W	464						182		736
16757	NW-27 T24N R16W	465								731
	MASON									
19816	NE-9 T17N R15W	466		565			620	180	800	610
22455	SW-20 T17N R16W	467					568	194	762	618
21816	SW-16 T17N R17W	468			22		568	185	775	601
18665	NE-2 T17N R18W	469					707	136	843	585
19934	SE-17 T18N R16W	470			6		582	221	809	615
22300	NW-23 T18N R17W	471						869	869	599
16753	SE-3 T18N R18W	472						162		613

PERMIT NUMBER	LOCATION	MAP NUMBER	MARSHALL	COLDWATER	SUNBURY	BEREA-BEDFORD	ELLSWORTH	ANTRIM	TOTAL 'B'	TRAVERSE
	MASON (cont.)									
8159	SE-13 T19N R15W	473		541			585	242	827	655
4614	SW-36 T19N R16W	474		530			605	288	893	
18002	SW-20 T19N R17W	475						136		654
19065	SW-11 T19N R18W	476						126		654
9511	SW-22 T20N R15W	477					597	244	841	641
15245	SW-3 T20N R16W	478					418	206	624	687
18274	NE-2 T20N R17W	479						156		661
16499	SW-26 T20N R18W	480						158		
	MECOSTA									
11332	SW-4 T13N R7W	481	259	921				515	515	579
19955	SW-32 T13N R8W	482	135	952	25	16		516	541	543
10173	SW-16 T13N R9W	483	153	865	28			594	638	484
21938	SE-27 T13N R10W	484	175	813	40		360	215	615	503
18272	NW-7 T14N R7W	485	304	839				577	577	561
18177	SE-17 T14N R8W	486	255	841			308	273	581	556
14672	SW-12 T14N R9W	487	261	803			367	265	632	548
17912	NE-19 T14N R10W	488	145	820	30		405	160	595	532
9841	SE-21 T15N R7W	489	140	902		108		509	617	572
17892	NW-11 T15N R8W	490	244	809				622	622	606
19965	NW-29 T15N R9W	491	280	759	130		239	266	635	521
20833	NW-10 T15N R10W	492	270	727	72		304	279	655	575
16329	NW-3 T16N R7W	493	265	840				649	649	603
17151	SE-15 T16N R8W	494	290	781				640	640	625
17013	NW-19 T16N R9W	495		681	97		275	298	670	582
22295	NE-14 T16N R10W	496	236	695	77		353	265	695	569
	MIDLAND									
18916	SW-13 T13N R1E	497	181	1001	29	116		397	542	596
11711	NE-24 T13N R2E	498	185	1000	56	150		360	566	618
22028	SW-10 T13N R1W	499	199	998	20	126		388	634	577
1901	T13N R2W	500	223	1045		105		380	485	572
17788	SE-36 T14N R1E	501	180	1030	22	134		383	539	629
14035	NW-18 T14N R2E	502	252	982	11	85		412	508	611
16696	SW-20 T14N R1W	503	174	1029	17	98		409	524	632
20819	NW-7 T14N R2W	504	205	975	35	70		405	510	638
19502	SW-21 T15N R1E	505	149	1040	18	131		421	570	694
22249	NW-35 T15N R2E	506	186	1027	43	129		369	541	684
22042	NE-13 T15N R1W	507	180	1025	35	107		406	548	697
21257	NE-28 T15N R2W	508	158	1005	6	55		459	520	645

PERMIT NUMBER	LOCATION	MAP NUMBER	MARSHALL	COLDWATER	SUNBURY	BEREA-BEDFORD	ELLSWORTH	ANTRIM	TOTAL 'B'	TRAVERSE
	MIDLAND (Cont.)									
11046	NE-36 T16N R1E	509	161	1053	19	133		417	569	737
21846	SW-1 T16N R2E	510	158	1081	34	134		410	578	768
21977	NW-23 T16N R1W	511	163	1015	25	130		447	602	708
16428	SW-34 T16N R2W	512	200	983	24	62		438	524	677
	MISSAUKEE									
9934	NE-8 T21N R6W	513								706
12836	SW-1 T21N R6W	514	153	879			298	388	686	712
22190	NW-21 T21N R7W	515	210	799	81		442	251	774	696
20465	SW-31 T21N R8W	516	142	716	20		570	237	827	695
17299	SE-22 T22N R6W	517	173	957	40		394	227	661	697
9249	NW-31 T22N R7W	518	172	793				830	830	681
9534	NE-8 T22N R8W	519	159	778	23		557	227	807	699
16020	SE-10 T23N R5W	520	140	953			474	193	667	755
17806	NE-10 T23N R6W	521	113	903	22		478	217	417	747
11675	NE-19 T23N R7W	522	92	811	15		463	380	858	668
10849	SE-14 T23N R8W	523		790			615	222	837	688
16965	SW-20 T24N R5W	524	129	968	17		473	205	695	722
16122	SE-7 T24N R6W	525	142	384			553	199	752	734
18124	NW-15 T24N R7W	526	136	845				794	794	711
	MONROE									
	MONTCALM									
21823	SW-33 T9N R5W	527	232	1061	12	8		375	395	441
21285	SW-14 T9N R6W	528	232	1008	23			396	419	435
20082	NW-22 T9N R7W	529	178	1010				398	398	446
20996	NW-3 T10N R5W	530	170	1055	13			422	435	485
19655	SW-33 T10N R6W	531	128	1054				446	446	465
20104	SE-29 T10N R7W	532	261	911				471	471	466
20495	SE-14 T10N R8W	533		940				474	474	495
21178	NE-11 T11N R5W	534	226	1011	26	10		397	433	513
17873	NE-35 T11N R6W	535	67	1032				426	425	483
20390	NE-29 T11N R7W	536	165	992	20			444	464	477
21484	SW-21 T11N R8W	537	193	905	20	6		478	504	506
20713	NW-8 T11N R9W	538	201	840	20			550	570	475
21211	NW-7 T12N R5W	539	263	985	32	12		407	451	556
20804	NW-26 T12N R6W	540	204	1027				445	455	510
17650	SW-35 T12N R7W	541	147	993				509	509	499
21091	NE-8 T12N R8W	542	143	925				539	539	525

PERMIT NUMBER	LOCATION	MAP NUMBER	MARSHALL	COLDWATER	SUNBURY	BEREA-BEDFORD	ELLSWORTH	ANTRIM	TOTAL 'B'	TRAVERSE
	MONTCALM (cont.)									
21331	NE-32 T12N R9W	543	160	847	23	45		510	578	495
20739	NE-39 T12N R10W	544	177	810	25			585	610	490
	MONTMORENCY									
1241	NW-15 T30N R3E	545								694
	SE-30 T30N R4E	546								589
18565	SW-27 T31N R2E	547								708
	MUSKEGON									
18173	SW-27 T9N R14W	548	254	640			580	126	706	401
14422	NW-4 T9N R15W	549		602			578	143	721	432
13464	SW-33 T9N R16W	550		447			597	123	720	409
17379	SW-19 T10N R13W	551	260	650			570	145	715	422
17141	NE-16 T10N R14W	552	269	622			545	182	727	433
18553	SW-3 T10N R15W	553		628			643	73	716	430
22603	NE-9 T10N R16W	554		570			610	138	748	
132	NE-16 T10N R16W	555					482	222	704	462
17554	SW-15 T11N R15W	556		599			560	172	732	436
12616	SW-11 T11N R16W	557		602			478	234	712	426
15838	SW-30 T11N R17W	558		545			590	135	725	473
18227	SE-13 T11N R18W	559		531			579	154	733	
15789	NW-19 T12N R15W	560		670			455	263	718	440
19332	NW-15 T12N R16W	561		596			577	149	726	
18666	NW-20 T12N R17W	562		650			480	195	564	460
20084	NE-12 T12N R18W	563		540			370	225	795	409
	NEWAYGO									
19519	SE-7 T11N R11W	564	152	738			474	208	682	460
13168	SW-25 T11N R12W	565	216	755			554	230	784	448
21730	SE-16 T11N R13W	566	201	692			528	180	708	468
15629	NW-36 T11N R14W	567	267	659			551	186	737	
15373	NW-29 T12N R11W	568	152	762				656	656	465
19853	NE-2 T12N R12W	569	154	715			542	169	711	488
19784	SW-11 T12N R13W	570	159	650	34		481	218	733	488
21959	NW-9 T12N R14W	571	133	620	6			726	733	490
20617	SW-33 T13N R11W	572	140	753				679	679	494
20182	NE-28 T13N R12W	573	181	736	10		535	192	737	488
20587	NW-4 T13N R13W	574	135	655	4		533	220	757	509
19687	SW-9 T13N R14W	575	214	619			522	250	772	421

PERMIT NUMBER	LOCATION	MAP NUMBER	MARSHALL	COLDWATER	SUNBURY	BEREA-BEDFORD	ELLSWORTH	ANTRIM	TOTAL 'B'	TRAVERSE
	NEWAYGO (cont.)									
21400	SW-1 T14N R11W	576	155	747	20		465	203	688	537
16565	SE-26 T14N R12W	577	718					733	733	
13457	NE-18 T14N R13W	578	156							524
20716	NE-1 T14N R14W	579	174	584	33		542	180	755	532
21087	SE-36 T15N R11W	580	153	616			584	175	759	532
10649	SW-3 T15N R12W	581	141	706			490	306	796	523
21767	SE-36 T15N R14W	582	147	619	31			733	764	518
16880	NE-34 T16N R11W	583	250	691	17		439	275	731	678
13813	NW-6 T16N R12W	584	145					196		563
15977	SE-23 T16N R13W	585	245	611	32		467	265	764	569
15649	SW-18 T16N R14W	586	150	588				777	777	549
	OAKLAND									
20274	SW-35 T1N R7E	587						140		263
19218	SW-31 T1N R8E	588								273
B.D.64	NE-27 T1N R11E	589								248
21298	NE-35 T2N R7E	590				250		140	390	310
22665	NE-9 T4N R7E	591		656	21	185		179	385	364
13072	SW-22 T4N R8E	592			33	233		150	416	345
12454	SE-16 T4N R9E	593			18	156		270	444	328
21706	SE-29 T4N R11E	594		458	58	259		141	458	283
22848	SW-36 T5N R11E	595			50	277		130	457	313
	OCEANA									
20418	NW-2 T13N R15W	596	131	630				764	764	504
2123	NW-23 T13N R16W	597		601			528	252	780	
18548	NW-12 T13N R17W	598		569			587	154	741	481
15537	NW-15 T13N R18W	599					555	165	720	502
20759	SW-34 T14N R15W	600	215	600				775	775	493
20385	SW-28 T14N R16W	601			5		505	221	731	476
18031	NW-13 T14N R17W	602		555			548	197	745	530
21127	SE-19 T14N R18W	603					562	178	740	521
17242	NE-13 T14N R19W	604					580	130	710	534
20473	SE-8 T15N R15W	605	129	585			588	169	757	553
19805	NW-36 T15N R16W	606	145	598	6			709	715	579
20199	NE-36 T15N R17W	607		553	21			699	720	579
19213	NW-35 T15N R18W	608					626	130	756	535
22651	NW-20 T16N R15W	609		557			568	219	787	565
21911	SE-9 T16N R16W	610					607	172	779	489
21818	NE-34 T16N R17W	611						771	771	572
20941	SE-36 T16N R18W	612					531	223	754	574

PERMIT NUMBER	LOCATION	MAP NUMBER	MARSHALL	COLDWATER	SUNBURY	BEREA-BEDFORD	ELLSWORTH	ANTRIM	TOTAL 'B'	TRAVERSE
	OGEMAW									
19580	SE-15 T21N R1E	613		1119	31	83		455	569	799
19683	SE-1 T21N R2E	614				135		420	555	785
20010	NW-5 T21N R3E	615			14	126		398	538	776
4814	SW-31 T21N R4E	616			21	154		376	551	780
21943	SE-10 T22N R1E	617		1067	25	70		500	595	799
19762	NE-18 T22N R2E	618			20	79		456	555	755
18346	NW-2 T22N R3E	619		1125	26	131		414	571	770
17127	SW-22 T22N R4E	620		1040	19	157		398	574	774
21798	NE-3 T23N R2E	621			26	99		446	571	765
3825	NW-29 T23N R3E	622			30	100		435	565	789
20948	SE-16 T24N R1E	623			83			470	553	768
21799	NW-34 T24N R2E	624			18	86		445	549	725
20296	NW-4 T24N R3E	625						544	544	729
8616	NW-33 T24N R4E	626			24	86		440	550	781
	OSCEOLA									
21000	NE-10 T17N R7W	627	200	815				644	644	649
21653	SE-22 T17N R8W	628	160	760				690	690	606
16343	NE-8 T17N R9W	629	286	667	75		375	274	724	626
21017	NW-8 T17N R10W	630	165	700				680	680	563
15727	NE-8 T18N R7W	631	153	937				668	668	622
21835	NE-30 T18N R8W	632		762	52			645	697	602
21019	NE-33 T18N R9W	633	88	810	15			623	638	624
16590	SE-35 T18N R10W	634	241	530			495	277	772	603
5479	SW-26 T19N R7W	635	160	861			355	350	705	651
16379	SE-15 T19N R8W	636		768				756	756	617
10159	NE-1 T19N R9W	637	153	727			503	318	821	628
19381	SE-17 T19N R10W	638		615	25			812	827	646
16317	SE-5 T20N R7W	639	162	784				807	807	653
18698	NE-18 T20N R8W	640	176	759	11		414	384	798	665
17793	NW-21 T20N R9W	641		775				805	805	697
22078	SE-19 T20N R10W	642	184	640	23		594	250	844	673
	OSCODA									
20834	SW-16 T25N R2E	643			30	65		435	530	765
19728	NE-29 T25N R3E	644			25	95		455	575	774
13130	NW-30 T26N R3E	645		1272	33	75		467	575	749

PERMIT NUMBER	LOCATION	MAP NUMBER	MARSHALL	COLDWATER	SUNBURY	BEREA-BEDFORD	ELLSWORTH	ANTRIM	TOTAL 'B'	TRAVERSE
	OTSEGO									
17787	SW-13 T29N R1W	647					371	175	546	742
16902	NE-15 T29N R2W	648					407	159	566	750
18254	NW-9 T29N R4W	649						181		766
18467	NW-10 T30N R1W	650					378	161	539	
9847	SW-22 T30N R3W	651					413	162	575	789
17036	SE-31 T32N R3W	652						157	[illegible]	761
	OTTAWA									
21288	SW-35 T5N R13W	653					525	122	647	361
20949	NE-11 T5N R14W	654		728			487	187	674	346
21724	SE-34 T5N R15W	655					562	140	702	353
13224	SW-12 T5N R16W	656					165	555	720	245
22153	NE-12 T6N R13W	657	254	708			555	125	680	
20414	NE-32 T6N R14W	658		705			537	138	675	
21020	NW-31 T6N R15W	659		613			622	142	764	309
8139	NW-34 T7N R13W	660		690			565	150	715	367
9880	SW-4 T7N R14W	661		653			499	226	725	
22085	SE-3 T7N R15W	662		614			576	147	723	447
20492	SW-3 T7N R16W	663		585	7			721	728	410
19911	NW-32 T8N R13W	664		640			574	164	738	325
11103	SE-11 T8N R14W	665		745			412	225	637	387
18148	SE-26 T8N R15W	666		608			602	112	714	402
19833	SW-1 T8N R16W	667		577			553	159	712	
18589	SW-6 T9N R13W	668	272	636			550	160	710	392
	PRESQUE ISLE									
22639	SW-20 T34N R5E	669								
	ROSCOMMON									
14589	SW-5 T21N R1W	670	172	1032	30		326	212	568	784
	SE-35 T21N R2W	671	255	1020	40	18	546		604	750
20918	NE-30 R21N R3W	672	139	1027	29			533	562	752
20747	NE-14 T21N R4W	673	188	941				608	608	771
18973	NE-26 T22N R2W	674	238	1001	39			547	586	767
19135	NE-16 T22N R3W	675	140							744
20509	SE-8 T22N R4W	676	122	987				642	642	771
18121	NW-18 T23N R4W	677	128	956				584	584	756
20248	NE-22 T24N R1W	678			22	30		495	547	769
19271	SW-15 T24N R2W	679			17			557	574	750
20419	NW-28 T24N R4W	680	132	956				638	638	737

PERMIT NUMBER	LOCATION	MAP NUMBER	MARSHALL	COLDWATER	SUNBURY	BEREA-BEDFORD	ELLSWORTH	ANTRIM	TOTAL 'B'	TRAVERSE
	SAGINAW									
20288	NE-15 T9N R1E	681		975	15	91		350	456	
9858	SE-2 T9N R3E	682	180	980	20	160		290	470	489
10355	NE-11 T9N R4E	683	203	981	16	205		255	476	500
11700	NW-3 T10N R2E	684	177	1010	29	109		336	476	519
20953	SE-21 T10N R3E	685	189	993	14	142		309	465	499
20957	NE-13 T10N R5E	686	219	966	23	217		243	483	537
21699	SE-25 T10N R6E	687	212	952		261		219	480	504
15547	NW-1 T11N R1E	688	173	1018	9	71		399	479	564
19694	NE-8 T11N R2E	689	171	1027	23	130		335	465	551
21320	SE-29 T11N R3E	690	195	972	25	107		339	471	523
16570	SE-1 T11N R5E	691	209	999	25	203		283	511	569
21322	NE-15 T12N R1E	692	203	1035	18	115		374	507	574
15395	SW-11 T12N R2E	693	332	892	10	152		352	514	601
11503	SE-7 T12N R3E	694	242	1018	15	159		338	512	597
11347	NE-35 T12N R5E	695	167	1031	25	195		290	510	574
22270	NE-5 T12N R6E	696	215	1070	30	199		280	509	611
18772	NW-6 T13N R3E	697	198	1050	20	162		357	539	646
11597	NE-20 T13N R4E	698	148	996	32	179		328	539	559
	SANILAC									
11492	NE-9 T9N R15E	699			124	240		188	552	428
18725	SE-30 T9N R16E	700						196		409
11405	SE-15 T10N R15E	701			131	226		231	588	450
18305	NW-35 T10N R16E	702						219		417
18725	NE-5 T11N R15E	703			45	253		228	526	519
10921	NW-2 T12N R13E	704			100	200		177	577	636
10386	SE-14 T13N R12E	705	125	780	87	264		244	595	637
9275	NW-14 T14N R12E	706		982	63	294		266	623	667
	SHIAWASSEE									
22379	NE-5 T5N R2E	707		1120	35	160		173	368	497
3129	SE-31 T5N R3E	708			22	162		233	417	349
8968	NE-4 T5N R4E	709			16	185		220	421	394
18935	SW-14 T6N R3E	710	162	963	19	189		227	435	409
14349	SW-3 T7N R2E	711	220	1015	12	142		285	439	410
9396	NW-4 T8N R1E	712	203	994	25	79		272	376	505
21138	NE-12 T8N R4E	713			20	208		228	456	465

PERMIT NUMBER	LOCATION	MAP NUMBER	MARSHALL	COLDWATER	SUNBURY	BEREA-BEDFORD	ELLSWORTH	ANTRIM	TOTAL 'B'	TRAVERSE
	ST. CLAIR									
22764	SW-1 T3N R15E	714						193		219
22643	SE-10 T3N R16E	715						200		222
22661	SE-22 T4N R15E	716						186		237
22579	NE-8 T4N R16E	717						190		260
21575	NW-19 T4N R17E	718						213		230
22162	SW-12 T5N R15E	719				293		195	488	280
22002	SE-11 T5N R16E	720			17	149		159	325	274
21556	SE-18 T5N R17E	721						197		305
22409	SE-33 T6N R13E	722			77	280		164	521	306
21369	SW-17 T6N R15E	723				252		186	438	314
14072	SE-21 T6N R16E	724						188		308
13352	SW-16 T6N R17E	725						140		299
22410	NW-18 T7N R13E	726		653	80	279		191	550	355
13702	SE-15 T7N R15E	727			69	196		182	447	343
22615	NW-1 T7N R16E	728								350
18561	SW-20 T7N R17E	729		671	159	227		221	607	388
10793	NE-27 T8N R16E	730								400
17051	SW-8 T8N R17E	731						224		383
	ST. JOSEPH									
18405	SW-2 T5S R9W	732			4			342	346	
17184	NW-3 T5S R12W	733					365	93	458	
21155	NE-27 T6S R11W	734			5		310	88	403	207
14283	SE-16 T6S R12W	735					310	110	420	
	TUSCOLA									
21261	SE-30 T10N R7E	736	115	1060	25	224		226	475	508
20577	SE-5 T10N R9E	737		1074	45	215		211	471	501
20209	SE-5 T10N R9E	738	273	903	46	253		216	515	522
17409	SE-35 T11N R8E	739	199	1044	44	247		228	519	537
64	NE-33 T11N R11E	740			76	273		231	580	515
2315	SW-8 T12N R8E	741	85	1040	45	275		243	563	611
3082	SW-9 T12N R10E	742	130	1155	36	288		255	579	590
4484	NW-8 T12N R11E	743	228	870	60	255		245	560	623
12808	SE-4 T13N R9E	744	229	1030	51	278		247	576	646
18718	NE-1 T13N R10E	745			60	230		276	566	649
17438	SE-10 T13N R11E	746		1167	58	311		239	608	630
21141	NW-25 T14N R7E	747	120	1019	44	213		275	532	666
20682	NW-28 T14N R8E	748		1019	48	266		278	592	665
18882	NW-10 T14N R9E	749	143	1147	62	235		288	585	714

PERMIT NUMBER	LOCATION	MAP NUMBER	MARSHALL	COLDWATER	SUNBURY	BEREA-BEDFORD	ELLSWORTH	ANTRIM	TOTAL 'B'	TRAVERSE
	TUSCOLA (cont.)									
20178	SE-17 T14N R10E	750		1150	50	280		235	565	670
18910	SW-31 T14N R11E	751			57	282		235	574	646
20159	SW-29 T15N R8E	752	204	1049	43	198		308	549	717
	VAN BUREN									
20214	NW-29 T1S R13W	753					456	92	548	
21194	SE-8 T1S R14W	754					432	154	586	269
12543	NE-18 T1S R15W	755					458	98	556	244
21900	NW-28 T1S R16W	756						550	550	240
14912	NE-23 T1S R17W	757					453		571	
21901	NW-36 T2S R13W	758						505	505	259
19686	NW-10 T2S R14W	759					443	98	541	
16579	SE-20 T2S R15W	760					417	106	523	210
17298	NE-29 T2S R16W	761					437	95	532	202
19383	NE-35 T2S R17W	762					430	100	530	
6792	SE-13 T3S R13W	763					390	111	501	237
12025	SE-28 T3S R14W	764					386	125	511	207
18616	SE-30 T3S R15W	765					380	137	517	
20843	NE-3 T3S R16W	766					438	82	520	
18559	NE-5 T4S R13W	767					382	113	495	174
19130	NE-32 T4S R14W	768					409	88	497	
18854	SW-24 T4S R15W	769					410	95	505	
21597	SE-7 T4S R16W	770					335	160	495	
	WASHTENAW									
21477	SE-6 T1S R3E	771			11	143		200	354	247
19371	NW-33 T1S R5E	772			15	175		174	364	234
13626	NW-1 T1S R6E	773								258
19678	NE-2 T1S R7E	774						130		253
19751	SW-14 T2S R3E	775			5	137		190	332	223
19891	SW-33 T2S R4E	776			5	145		173	323	222
19202	NW-28 T2S R5E	777			17	160		149	326	211
11341	NW-12 T2S R7E	778			15	227		131	372	225
18701	NE-1 T3S R3E	779			24	141		179	344	226
21903	SE-6 T3S R4E	780			12	150		168	330	222
18948	SE-26 T4S R3E	781			9	124		175	308	156
20571	NE-28 T4S R4E	782			15	117		177	309	180
19778	NW-32 T4S R5E	783			10	143		144	297	171
22292	SE-28 T4S R6E	784								174

PERMIT NUMBER	LOCATION	MAP NUMBER	MARSHALL	COLDWATER	SUNBURY	BEREA-BEDFORD	ELLSWORTH	ANTRIM	TOTAL 'B'	TRAVERSE
	WAYNE									
19634	SW-6 T2S R8E	785								290
	WEXFORD									
21872	SE-7 T21N R9W	786	173	686			626	253	879	689
20742	NE-13 T21N R10W	787	173	678	17		610	248	875	703
16018	NE-28 T21N R11W	788	265	655	15		585	235	835	660
		789								
11008	SE-1 T22N R9W	790			50		560	230	840	697
17109	SW-13 T22N R9W	791	235	668			593	110	703	
10661	SW-24 T22N R10W	792	150	680	56		541	257	854	688
14307	NE-16 T23N R9W	793	205	682			612	260	873	719
10303	SE-11 T23N R11W	794	262	517	22		581	225	828	696
13335	SW-21 T24N R9W	795	111	754	39		558	259	856	