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DEPARTMENT OF PUBLIC INSTRUCTION

MICHIGAN TODAY
Its Human and Physical Resources as They Affect Education

BULLETIN No. 307

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FOREWORD

Michigan Today is the third publication of major scope to appear in the Michigan program of curriculum revision. It was preceded by the *Instructional Guide for Elementary Schools,* published in August, 1936 and reprinted in a second edition in January, 1937, and by *What Does Research Say?,* published in August, 1937.

The purpose of this series of curriculum publications is obvious. Written for the teacher, they are designed to give a better understanding of the child's environment and a better command of techniques and practices of the art of teaching. To a teacher who is content to let the child's mind nourish itself solely on the information that is imprisoned between book covers, *Michigan Today*, and for that matter its companion volumes as well, will be of little value. In Michigan, however, such teachers are rare. This book has been prepared for the far greater number who realize that living yields the choicest subject matter for learning, and who therefore are constantly on the alert for learning situations in the child's own time and place.

Though still in its early stages, the Michigan program of curriculum revision has been entered into with interest and eagerness by the teachers of our state. The Curriculum Steering Committee began its work in the fall of 1935. At that time there was hardly a clue to the tremendous amount of latent interest in curriculum change that was shortly to be made manifest. I should like to record my sincere admiration for the way in which the Curriculum Steering Committee and the groups which it has created or with which it has allied itself have organized our professional resources and used them so as to enlist the support and confidence of the teaching profession.

From high school and elementary school teachers I anticipate a cordial welcome for *Michigan Today*. The committee and the authors have performed a noteworthy task in preparing a bulletin on the social and economic trends in Michigan with their educational implications. They have combined scholarship, workmanship, and skill in choosing and presenting items of interest and value. This much the bulletin says for itself. What it can not tell is the zeal, the self-sacrifice, and the long hours of patient preparation that were involved in the project.

To the members of the committee and other contributors I offer sincere thanks.

EUGENE B. ELLIOTT
Superintendent of Public Instruction

PREFACE

In the preparation of this bulletin the authors have had one major purpose in view; to present clearly, simply, and accurately such facts concerning the physical and human resources of Michigan as will enable educators to adjust the school curriculum in the light of the implications these resources have for the education of children. To achieve this end the authors have described *Michigan Today* in such a way as to stimulate the understanding and imagination of the reader. It is hoped that the picture of Michigan here presented will give the reader impressions which will guide him in a choice of further studies of the resources of the state and their effect on education. An understanding of the social and economic status of Michigan with its educational implications will help to erect a series of guide-posts for the construction of a new school curriculum.

The authors wish to acknowledge the aid of the various firms and institutions which furnished illustrative material: United Air Lines, Ford Motor Company, Chrysler Corporation, General Motors, New York Central System, National Education Association, United States Office of Education, Michigan Department of Conservation, Greyhound Management Company, Great Lakes Transit Corporation, Reo Motor Car Company, Pennsylvania-Central Airlines, Michigan Emergency Welfare Relief Commission, Michigan Education Association, State Highway Department, State Department of Aeronautics, Michigan Historical Commission, Michigan State College, State Planning Commission, and United States Department of Agriculture.

The chairman gratefully acknowledges the work of the authors who gave freely the benefits of their knowledge and experience.

GEORGE H. FERN
Chairman

STATE CAPITOL, LANSING

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CHAPTER ONE
THE GEOLOGICAL AND PHYSICAL FEATURES OF MICHIGAN

By Helen M. Martin
Research Geologist
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Almost from the time that the North American Continent was formed on the surface of the Earth planet, the area we now know as Michigan has been unique and set apart: first, as a geologic unit through long geologic ages of millions of years; second, as a physiographic unit where the retreating ice of the Great Ice Age left records different from its records in other parts of the continent; and finally, as a geographic unit of 57,980 square miles with boundaries man-made on the basis of boundaries erected by Nature thousands and millions of years before man arrived on the planet.

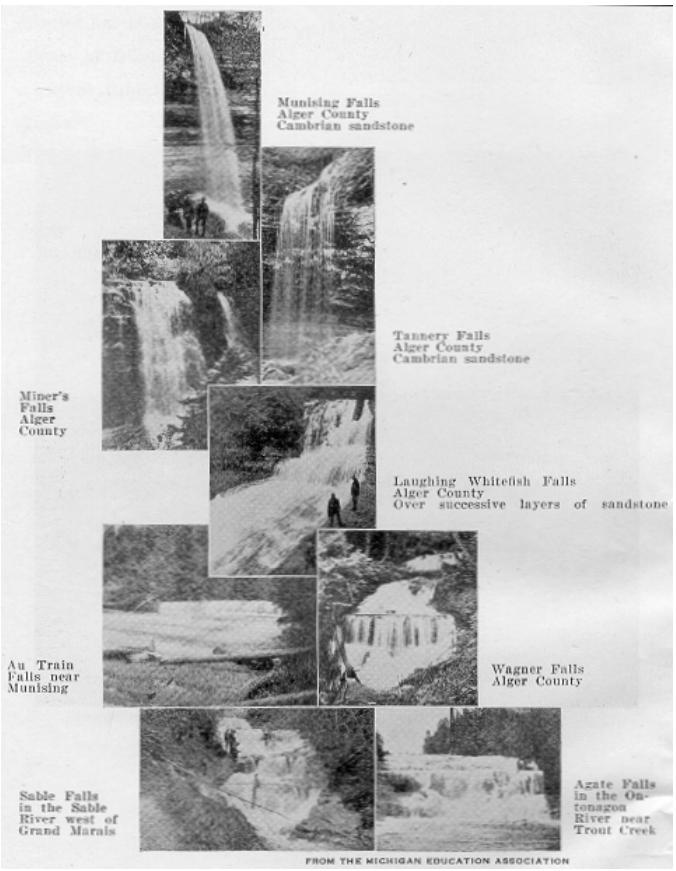


FIGURE 1. MICHIGAN WATERFALLS

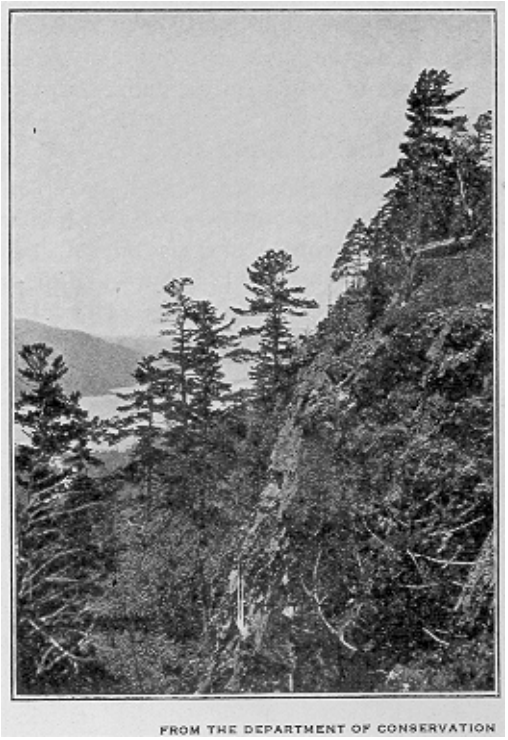
The Geologic Record

Briefly, the Michigan area has always been an irregularly circular-shaped basin bordered by land masses of granites which are still visible in Canada and Wisconsin but are buried elsewhere. Along the northwestern rim, of the basin which bordered on an ancient land mass, volcanic activity of the convulsive rather than the violent eruptive type disturbed the edge of the basin. Lavas welled upward from the interior of the continent, lifted the overlying rocks to mountain heights, turned the flat lying rocks on edge, and tip-tilted some of them so that they are almost overturned (*folded*). Erosion wore these ancient mountains almost to their roots and exposed the rocks which, by virtue of volcanic and ground water chemistry, contain the copper, iron, silver, gold, and other valuable metals and minerals. So was formed the area we now know as the western half of the Northern Peninsula,—the Copper Region and the Iron Districts. The Huron Mountains and the Porcupine Mountains, in which is the highest peak in the state (2,023 feet), are remnants of this ancient range.

Frequently the rocks were cut by vertical cracks (*joints*). In places we find that the rocks on either side of the joint do not match; that some movement along the crack, either vertically or horizontally, or both, has separated the edges. The rock is then said to be faulted and the crack a fault. Nature objects to empty spaces. Therefore most of the cracks were filled by minerals first dissolved from the rocks by water and then re-deposited

as the water evaporated. It is in such mineralized veins and in the ancient lava flows that the wealth of the mining regions is found.

Faults are much more common in the tipped-up rocks of the region west of Marquette than in the basin proper, and are of much greater extent. The longest fault extends from the tip of Keweenaw Peninsula, Bete Grise Bay, to the southern border of Ontonagon County south of Lake Gogebic. This part of the state has many other faulted areas with faults of varying length and showing various degrees of movement on them. The whole problem of the geology west of Marquette is perplexing even after one hundred years study. The lava flows, faulting, and slipping of the rocks as well as the subsequent erosion have jumbled the whole area but have also produced magnificent scenery and vast mineral wealth in copper, silver, iron, gold, marble, verde antique, and semi-precious stones as well as granites and other rocks of economic value.



2. LAKE OF THE CLOUDS
From the summit of Porcupine Mountains, the highest peaks in Michigan

Geologically this part of Michigan is classed as pre-Cambrian—the oldest area of the state. The remainder of the state is the Michigan Basin proper which extends from Lake Superior into Ohio, Lake Superior lies in a trough bordering the northern rim of the basin which was produced by earth disturbances during the pre-Cambrian time.

Geologic history is a record of the making and destruction of rocks of the wrinkling of the earth surface into mountains and basins and the wearing down of the mountains and filling of the basins. So through a long geologic history of one or two billion years the Michigan Basin was at times filled with a sea, at times was land, in whole or in part, and at times land with a shallow sea or swamp covering. At times desert conditions prevailed and the sea waters were excessively salt; in other ages the water was warm and teemed with animal life. Several times the basin was emptied by evaporation of the sea or by earth movements which actually spilled the seas from the basin. When the seas re-entered, swift livers from the land masses brought sands to cover the bottom and edges of the basin. When the waters were shallow, warm, and clear, lime was deposited; when the surrounding land masses were covered with vegetation the rivers brought to the sea fine sediments, clays, fine sands, silts, and dissolved minerals. As the shelled animals and corals living in the seas died, the shells or skeletons fell to the bottom and were buried by the sediments. In time many of them became “petrified” leaving an animal record which we know as *fossils*. As the seas slowly evaporated, the dissolved minerals were left behind as salt and gypsum mixed with other sediments (and so impure) or on top of them (and so pure).

Ages passed. The sands hardened to sandstones, the clays to shales, the limes to limestones and dolomites, the salt to rock salt, and the gypsum to rock gypsum and alabaster. These rocks known as *sedimentary* rocks vary in all degrees of purity, hardness, and porosity; we have limey sandstones and shales; shaley limestones and sandstones; sandy shales and limestones; sandy salt beds and pure rock salt; sandy, limey, shaley gypsums; glistening pure white gypsum and white and pink alabaster. We have *massive* sandstones and limestones with beds many feet in thickness and *thin bedded* rock strata with beds and laminae only a few inches thick. The shales usually are thin bedded to almost paper thin (*fissle*). The sandstones and limestones may be very porous and filled with water, gas, or oil; or very “tight”—so tightly cemented no water, gas, or oil can enter. Shales as a rule are non-porous and impervious to oil, water, or gas. The rocks also vary in color; the limestones from black through grays and blues to a dazzling white; the shales from jetty and brown-black to light blue gray and often green and red; the sandstones from all the shades of red-brown to gray, blue, and white. Each layer of rock is a *stratum*, several layers are *strata*.

The Seven Major Geologic Periods

These processes were repeated in whole or in part over and over until there were seven periods of maximum sea invasion, the Cambrian, Ozarkian, Ordovician, Silurian, Devonian, Mississippian, and Pennsylvanian. During this time the rock register shows twenty-four to thirty major invasions and retreats of the sea and consequently, between drownings, long periods of time when the basin was alternately practically out of water and again practically submerged. During the major invasions there were minor retreats and periods of evaporation and minor times when land was at the

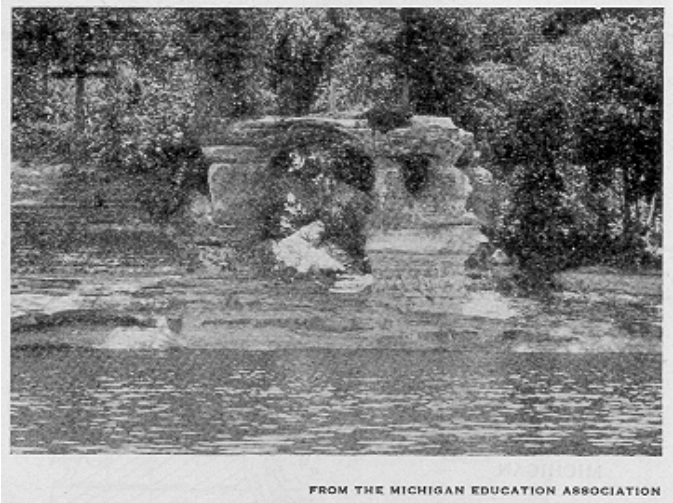
surface. During the times of maximum emergence there were times of short submergence. All the basin was not entirely submerged or wholly out of water at the same time.

Rock Saucers the Characteristic Geologic Formation

Curiously, too, the seas were not always deepest at the same place. So we have a rock basin filled with sets of rock saucers (*formations*) of sandstone, limestone, shale, rock salt, gypsum, laid down as irregularly shaped saucers of varying thickness. Each set and each saucer fits into the one above and the one below like a nest of huge rough rock mixing bowls, because each succeeding sea was smaller and shallower than the one before. All rocks excepting the pre-Cambrian of the western half of the Northern Peninsula slope (*dip*) into the basin centering west of Saginaw Bay.

The rocks deposited during the major sea invasions are grouped together for convenience of study and reference as *groups*, then sub-divided into *formations, members, beds*, and also for convenience they are named. Because the English geologists studying the rocks of Wales were first in the field with results of their studies published in English, the names which they gave the sedimentary rocks of that area have been given all over the world to rocks which are in the same relative position and carry the same fossils. The rocks found to be the oldest of the sedimentaries English geologists named the Cambrian (from Cambria in Wales)—hence our term pre-Cambrian for all older rocks whether they are sedimentary or volcanic or *metamorphosed* (sedimentary or volcanic rocks changed to some other form, i.e., limestone to marble, shale to slate and many others). The succeeding Ordovician and Silurian were named from ancient British tribes that inhabited Wales; the Devonian from the rocks of Devonshire; the Carboniferous because those rocks showed so much evidence of plant life and held the great coal beds of Europe. In America this term was too inclusive and so American geologists divided it into the Mississippian and the Pennsylvanian and added a third division, Permian, from the province of Perm in Russia. Also it was found that in America another set of rocks are between the Cambrian and Ordovician. They are named Ozarkian.

Taken together rocks of these periods are the Paleozoic or early life, as the life records (fossils) are all of the more primitive type. After the Paleozoic came a long period of time—measured in millions of years—the Mesozoic (middle life) and the Cenozoic (modern life) during which life developed to its present stage with man at the top of the scale. This long time is, however, a geologic blank in Michigan.



3. CHAPEL ROCK, PICTURED ROCKS
Erosional remnants of Lake Superior (Cambrian) sandstone on rim of lowest rock saucer of Michigan Basin

The Michigan rock saucers do not have smooth surfaces nor present a smooth curve from rim to rim. Slow earth movements have caused them to be warped, wrinkled, domed, and broadly arched and troughed. An up-wrinkle, arch or fold is known as an *anticline;* the downfold or trough is the accompanying *syncline*. In the Michigan Basin the direction of the major folds across the saucers is from the southeast to the northwest. In some places earth movements have caused minor folds in the opposite direction (*cross folds*) which close one end of the anticline so that it is something like an upturned canoe and is known as a *structure* important as the trap in which oil and gas accumulate. Some faults are known in the Paleozoic rocks of the basin but they are small and, in so far as we know now, are of minor importance. Some evidence exists that a long fault extends from southwestern Shiawassee County across Livingston County through Howell. Faults in the sedimentary rocks are important as they cause traps for the accumulation of oil and gas as well as affect the movement of the waters, fresh and brine, in the rocks.

The Cambrian Rocks

The lowest and oldest of the rock saucers is the Cambrian, the edge of which we can see in the reddish sandstones which form the Pictured Rocks along Lake Superior, and make the ledges over which the rivers fall to reach the lake—the Au Train, Tahquamenon and others. Elsewhere the beveled edges of this saucer are buried. We do not know how deep the Cambrian rock is in the basin. A well in Newaygo County over 6,600 feet deep did not reach it and a well in St. Clair county on the rim drilled into granite below 4,700 feet.

The rock saucer within the Cambrian is the Ozarkian which outcrops in a few places just south of the arc of the Cambrian outcrop and forms ledges where rivers cross it to reach Lake Superior.

Next above and within is the Ordovician set, made up of smaller saucers of limestones and some shales. The

northern rim of this saucer is also exposed in the Northern Peninsula but covered to the south. Next above this Is the Silurian set, mainly dolomitic limestone with two shale and one limestone saucers, a 200-1,200 feet thick bed of pure rock salt, and some petroleum. Silurian rocks are exposed in the southeastern part of the Southern Peninsula and in the Northern Peninsula.

FIGURE 4. GEOLOGIC SYSTEMS OF ROCK FORMATIONS

Devonian Formations

Above and enclosed by the Silurian rocks are the Devonian sandstones, limestones, and shales. By Devonian time the basin was so filled and the sea so small that its shores encircle the present Southern Peninsula. Some of the rocks of this period were not so hard, a fact to be remembered later when the Great Lakes basins are discussed. Devonian rocks *outcrop* (are exposed at the surface), in Monroe, Wayne, Alpena, Presque Isle, Cheboygan, and Charlevoix counties. The lowest formation of the Devonian set is the Sylvania sandstone, important because it is made up, at its outcrop in Monroe County, of a pure white sand suitable for the manufacture of the finest glassware and optical glass. Near the middle of this saucer set is found the Dundee limestone, at present the greatest source rock for petroleum in the central part of the state and of limestone for blast furnaces at its outcrop. The largest limestone quarry in the world is in the Dundee strata at Rogers City. A stratum of dark shale above the Dundee is used at its outcrop in Presque Isle County for cement. Next above is the Traverse saucer, important for limestone at the outcrop in Alpena, Presque Isle, and Charlevoix counties and in the central part of the state for the oil it contains.

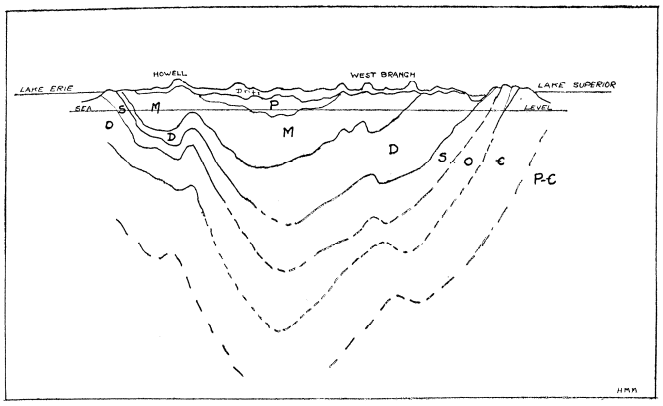


FIGURE 5. DIAGRAMATIC CROSS SECTION OF THE MICHIGAN BASIN
From Lake Superior to Lake Erie through West Branch, Ogemaw County and Howell, Livingston County, showing sets of rock saucers tilling basin and indicating their irregularities. Based on records of deep drilling

P—Pennsylvanian	O—Ordovician
M—Mississipian	C—Cambrian
D—Devonian	P-C—Pre Cambrian
S—Silurian	

The vertical scale is greatly exaggerated.

The Carboniferous Coalfields

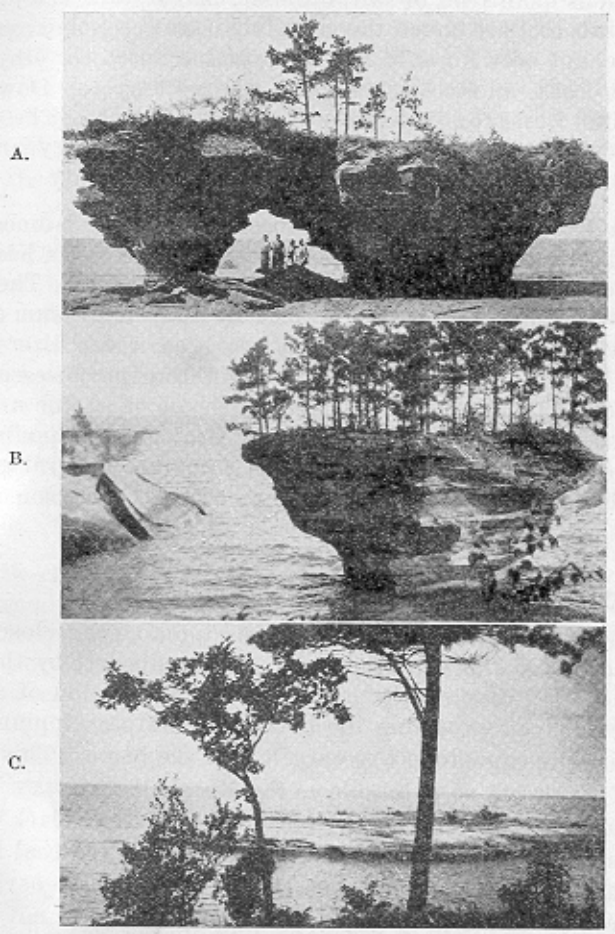
Following the Devonian age came the Carboniferous, the time when trees and plants became so abundant on the earth that they were more important than any other form of life and left more significant remains—the coal fields. During this time the seas were not very deep and great swamps existed in which grew huge trees, not like our present forest of pine, maple, beech, or oak, but great ferns and gigantic horsetail rushes. Some of their descendants live today in the tropical forests and others have dwindled to the weeds and rushes we know as the horsetail rushes that grow along the railroad tracks and swampy lake shores.

As the trees fell they filled the swamps, were buried, and through the centuries were pressed and baked to soft coal (*bituminous*). Where the earth movements caused greater pressure and baking, the soft coal became metamorphosed to *anthracite*. Similar processes are taking place today in the formation of peat, near the surface and with the action of air, in the shallow swamps of peat bogs.

Mississippian Shales, Sandstones, and Limestones

As stated before, the Carboniferous age has been sub-divided into the Mississippian, Pennsylvanian, and Permian. In Michigan, the Mississippian sea was almost an inland lake or a brakish water lagoon of the greater sea in the central part of the continent. The bottom of the Mississippian saucer is a black shale, Antrim shale, which contains some gas and out-crops in Alpena,

Antrim, and Grand Traverse counties. A part of this saucer is covered by a coarse grey sandstone, the Berea, important as a gas reservoir in Muskegon and Arenac counties and as a source of salt brines in Huron and St. Clair counties, and oil in Saginaw county and elsewhere.



6. EROSIONAL REMNANTS OF MARSHALL (Mississipian) SANDSTONE

A. "Double Turnip" rock, near Oak Beach, Huron County
B. "Uncle Sam's Turnip" rock, Pointe aux Barques, Huron County
C. "Flat Rock", at Port Austin, Huron County

The Berea and the rest of the inner Mississippian saucer is covered by the Coldwater shales, outcropping near Coldwater and used for cement manufacture. Above the Coldwater shales is the Marshall formation of sandstones. This formation is one of the most important in the state. Near the outer rim the sandstones contain water and are the great source of pure water in the state. In the central part of the state, however, the waters have become charged with enormous quantities of salt, bromine, magnesium, calcium, and other minerals and are one of the most important economic resources of the state, not only for salt, but for bromine (used for ethyl gasoline, kodak films, and medicine); for magnesium (for Dow metal and medicine); and for thousands of other chemicals. These sandstones outcrop in Jackson and Calhoun counties. They are scenically beautiful at Pointe Aux Barques in Huron County.

Above and within the Marshall saucer are the sandstones, limestones, and gypsum of the Michigan series. These rocks have been of commercial importance for over one hundred years. They were explored for salt by drilling as early as 1834 and the gypsum of their outcrop at Grand Rapids was early used as a fertilizer—"land plaster". Now the gypsum is used for building purposes and the alabaster found in Iosco and Arenac counties is of so fine a quality that it is used for the bed upon which optical glass is poured. In some of the sands in the central part of the state natural gas was trapped. From this sand, "The Michigan Stray", come some of the largest gas wells.

The Pennsylvanian Problem

The gypsum and salt show that Mississippian time closed with almost desert conditions for they are the deposits left by the evaporation of the sea of that age. Then came the invasion of another sea, the Pennsylvanian, filling the basin in the Mississippian rocks. First a sparkling sandstone was spread over the basin. This is now a source of water not so palatable as the Marshall water, and which often becomes salty in the wells. Above this sandstone black carbon-filled muds and vegetable material settled to form the coal beds of the Saginaw valley, Jackson, and Grand Ledge. Pennsylvanian rocks outcrop at Grand Ledge and Ionia. Geologists are not certain what happened after the swamps disappeared. The drilling records of wells drilled for oil, gas, and water in the central part of the state show that a red shale with gypsum and sandy beds is above the coal formation and may belong to the Permian. This is just another little problem in geological time. But the red rock and gypsum mean that the region was almost a desert and the water of the small sea covering the inner part of the coal formation saucer became brakish, bitter water which left the gypsum, on evaporation, as desert conditions continued and the last sea dried up.

The Geologic-Physiographic Record

For millions of years during the time known as Mesozoic and Cenozoic, the Appalachians were being folded up into mountain ranges, worn down to *base level* (a gentle plain sloping to the sea), lifted again as a great plateau, and again cut by rivers to the present Appalachian mountains. The Great Plains were being built and the Rockies and Sierras were being lifted to rugged mountains. Life changed from sea to land forms. Huge reptiles appeared during the Mesozoic era and quadrupeds, followed at last by man, during the Cenozoic period.

While all this was taking place elsewhere, exactly what happened in the Michigan Basin is not known definitely. No more rocks were deposited but there is evidence to indicate that rivers and the weather combined to cut down what previous centuries had built up. During this time, the edges of the saucers were beveled, the rock

evidences of channels to the continental seas were destroyed, and the softer rocks around the rim of the basin were removed leaving wide valleys in which rivers flowed. In what direction they drained the land is still a question which may never be solved. But the valleys formed at that time are occupied by Lakes Michigan, Huron, and Erie.

At the close of this time, of which there is so little record in Michigan and during which the continent of North America assumed almost its present form, a climatic change took place. The winters became not so much colder but longer, so long that the snows of one winter were not melted by the summer sun before another winter set in. This time we know as the Pleistocene, the age of the great continental glaciers which built the final rock chapter in the history of Michigan.

The Physiographic Record

During hundreds of years snows accumulated around the region of Hudson's Bay and as they increased in depth packed into ice just as old snow drifts do today. Finally they became so thick they pushed outward by their own weight just as a mass of dough spreads outward on a bread board. Once started to move, the mass of snow-ice became a glacier. Then through thousands of years snow accumulated, packed to ice estimated to be eventually from, two to six miles thick, and moved outward until its southward movement had carried it 1,600 miles from the center into the Ohio Valley.

Another climatic change caused the summers to be longer and the ice to melt at its southward front and on top. But it did not melt rapidly because it was not clean ice. As the glacier moved from its center it froze onto and picked up all loose soil and rock over which it passed. The great weight of the ice caused the granite boulders frozen in its base to act as ploughs which ploughed, gouged, and scraped the rock over which it passed, and the finer rock sand and clay frozen in the base scratched (*striated*) and polished the rock surfaces. These gouges, scratches, striations, and polished surfaces are the record the ice left to show where it came from, and its direction of movement. Boulders (*erratics*) torn from bed rock to the north were left on totally unlike rocks to the south to show where the ice started and where it moved.

How Nature Writes History

Nature is very generous with the records she leaves for future study when we learn the key. Rock material was accumulated from all the rock over which the ice passed. Granites, limestones, sandstones, huge boulders, small pebbles, dust, and the shales ground back to clay were all mixed together within the ice. So that when the ice melted, rock waste which the ice brought from the north was left in the south and mixed with rock from places on the way.

At times the glacier pushed forward from the north as rapidly as its front was melted off at the south so that the rock waste was piled up in hummocky ridges in front of the ice. Such ridges in front of present day glaciers in Switzerland are known as *moraines*. So although the ice is gone, similar moraines form the hummocky hill ridges which stretch from the Ohio valley to Canada to mark the stops or halts of the retreating glacier. Streams flowing from the front of the ice washed out the rock waste, sorted it, and carried the finer material farther from the front to form *outwash aprons* or *plains* which are gravelly near the moraine and finer farther south. When the sun could melt faster than the ice pushed forward, the rock waste was left just where the melting ice carried it and so built up *till* or *boulder clay plains* between the moraines. In places large boulders are left scattered over the till and outwash plains. Sometimes the cold was greater than the heat and the ice pushed forward over the outwash plain and into the moraine next to the south—just to complicate matters for the future student. But in the main the retreat, although halted, was steady.

As the ice pushed southward, for ease of movement it took advantage of any valleys in its path and moved forward rapidly in the valleys just as the Alpine glaciers do today. If the valleys were in soft or easily eroded rocks (like the great salt beds, and the soft shales of the Silurian and Devonian rock discussed earlier) the ice gouged them wider and deeper. As explained in an earlier paragraph, such valleys had been *eroded* (carved) from the softer saucers around the rim of the Michigan basin. Naturally the ice would be thickest in these valleys.

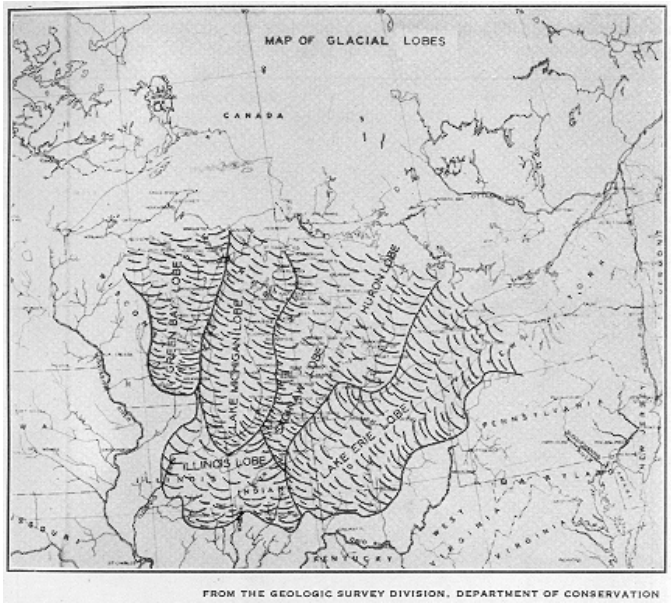


FIGURE 7. LOBES OF THE GREAT GLACIER

Ice Lobes Form Moraines and Lakes

As the ice melted on the highlands between the valleys it left the thicker ice as tongues of ice or *lobes* in the valleys. Moraines left around the ends of the lobes mark their position. So we find the Lake Michigan lobe

occupied the valley later to be filled with Lake Michigan, a lobe in the Huron valley united with one in the Erie Valley to form the Huron-Erie lobe, later to be again divided by melting. A smaller tongue or small lobe extended into the Saginaw valley, to become the Saginaw lobe. Retreats and halts of the glacier left moraines, till, and outwash plains festooned about the valleys marking the positions of the former ice fronts. The most noticeable festoons are the narrow moraines and broad outwash plains marking rapid retreats and short halts as the ice melted into the Saginaw valley. The most striking hills are those of Oakland and Washtenaw counties where the moraines of the Huron and Erie lobes met and pushed together forming a jumble of high hills; and in the high area of Wexford, Missaukee, Roscommon, and Ogemaw counties where the moraines of the Michigan and Saginaw lobes meet. The moraines in northern Osceola County are the highest in the state. One of the hills near the Wexford-Osceola county line about seven miles south of Cadillac has an altitude of over 1,700 feet.

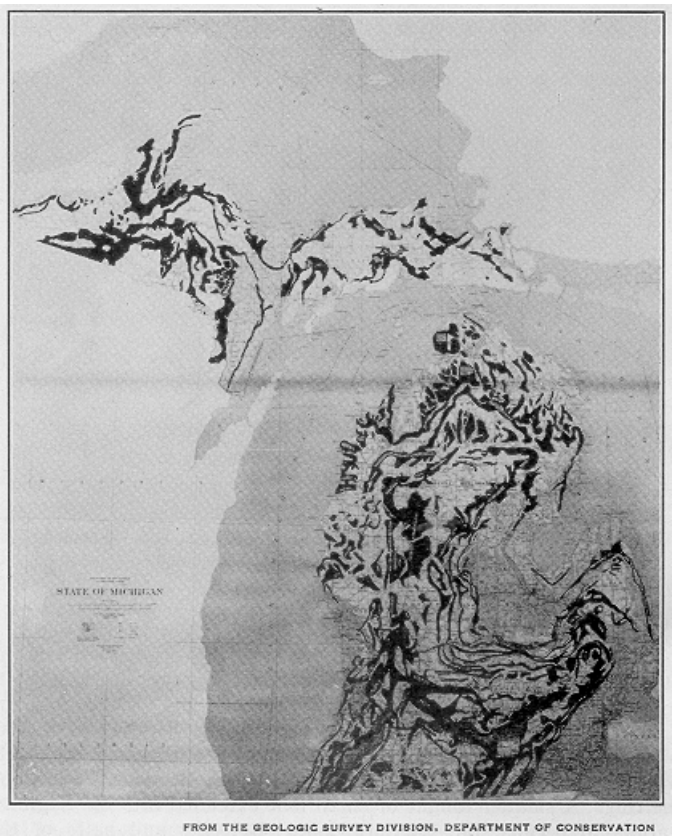


FIGURE 8. DISTRIBUTION OF MORAINES (after Leverett)

The Great Lakes

The retreat of the ice was marked by another phenomenon which was to make Michigan the Land of the Inland Seas. Where the built moraines or pre-glacial rock ledges were so high that the melt water could not flow away, it formed a lake in front of the ice, a lake with moraine shores on the land sides and ice shores toward the glacier. In the beginning, the lakes were very small. The first to be formed was in front of the Lake Erie lobe just east of the moraine at Fort Wayne, Indiana. The lake managed to produce an outlet through a low place (*col*) in the moraine and the waters escaped down the valley of the Maumee westward to the Ohio and the Mississippi. A similar lake at the foot of the Lake Michigan lobe was drained southwestward through the valley of the present DesPlaines and Illinois Rivers to the Mississippi. In time Lake Duluth was formed at the western edge of the Superior lobe and drained southward also to the Mississippi.

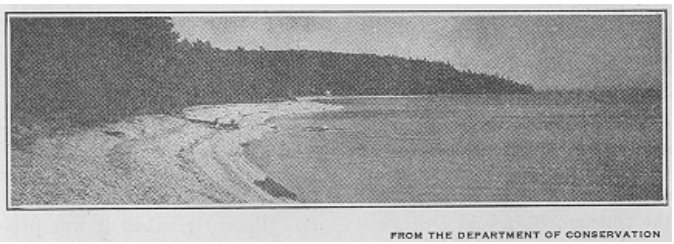
Drainage Channels Become Today's River Valleys

These old drainage channels still exist but are occupied by small rivers flowing eastward in a wide valley which narrows to the east, whereas normally a river valley narrows upstream. Historically they have been routes of travel and trade from the east to the west. The outlet of early Lake Chicago is now occupied by the Chicago Ship and Drainage Canal. Recently, when it was proposed to deepen this channel, Ohio, Wisconsin, and Michigan protested, and carried the case to the United States Supreme Court. An argument of their protest was that if Lake Michigan once flowed to the Mississippi, deepening the channel might destroy the ledge of limestone at Chicago which holds Lake Michigan in its present valley, and permit it to be drained southward.

Physiographic History Repeated

Present day lakes are making shore lines—beaches, strands, and shore ridges where the waves wash sediments onto the shores; streams are building deltas into the lakes; heaps of sand distinct from, other sands are being piled along the shore by the waves and sorted and carried farther by the wind. If the lake dries up, such records are left and show where the lake once was; as water seeks a level, these shores are level-horizontal; if the lake becomes smaller new shores, dunes, etc., are built at the lower level and again are horizontal.

So, too, the early lakes in the Maumee and DesPlaines valleys at the foot of the ancient ice mass left their horizontal shores, beaches, and shore ridges as evidence of their position. One may walk for miles along these horizontal shores; in fact they are so level that they are used for highways. For example, the Ridge Road along Lake Erie is an old beach. If we cross the beach in the direction of the ice retreat we enter a flat plain, the old lake bed. An interesting illustration of this can be found on U. S. Highway 112 from Ann Arbor to Detroit. Summit Street, Ypsilanti, a high ridge which drops abruptly to a flat plain to the east, is the high shore of the first of the glacial lakes. Traveling on to the east several other beaches are crossed. Some are rather faint and look as if they had been flooded, as they were; others are marked by heaps of yellow sand—the old dunes along the ancient shores. Similarly all roads leading to Detroit or Monroe cross the old ridges of the lakes in the Erie valley. A similar, but not so striking, tale may be told of the other lake valleys.



9. BEACH LOOKING SOUTH FROM BRITISH LANDING, MACKINAC ISLAND
A beach of the modern lakes to show characteristics typical of beaches left by ancient great lakes. Step notches in headland in background are beach cliffs made by lakes Algonquin and Nipissing

What the Ice Left

From these and other records it is evident that in the halting retreat of the ice from Michigan the lakes steadily increased in size to the northward and left beaches at each stage where an ice halt caused the melt water to be ponded in front of it.[1] Sometimes the ice actually readvanced and then the melt waters washed over but did not always quite obliterate the old beaches. New outlets were established as the ice retreated northward and uncovered lower levels for the water to escape.

[1]Numbers appearing thus in the text refer to the bibliography placed at the end of each chapter.

In the first stage the lakes had outlets through several small lakes to the Mississippi. During the second great stage (Maumee II), the lake waters flowed from the Erie basin northward past Imlay City to a lake in the Saginaw valley, thence across Michigan to make the wide valley in which the Grand River now flows; a later stage poured the lake waters through the Finger Lakes region of New York into the Atlantic. Still later, the lakes had an outlet through the Mohawk River past Rome, New York, which made the first excavation for the Erie Canal. A later outlet was through the Ottawa River in Canada to Lake Champlain; then through Georgian Bay to the Ontario basin. Finally, the lakes reached their greatest expansion, and in the northern part of Michigan built the highest beaches found today at the tops and bases of the cliffs about the upper lakes and also about the great inland lakes, Torchlight, Charlevoix, Walloon, Mullet, Douglass, Burt, and others. In the region of Mackinac Island the wave work of the lakes was very intense, making such shore features as The Stack and Arch Rock on Mackinac Island as well as shore cliffs and beaches. This is known as the Algonquin stage.

Finally the ice retreated from southern Canada. Then the Great Lakes almost reached their present state but with the outlet through Lake Nipissing in northern Ontario, Canada, to the Ontario Basin, Lake Erie was not part of the Great Lakes during “Nipissing” times.

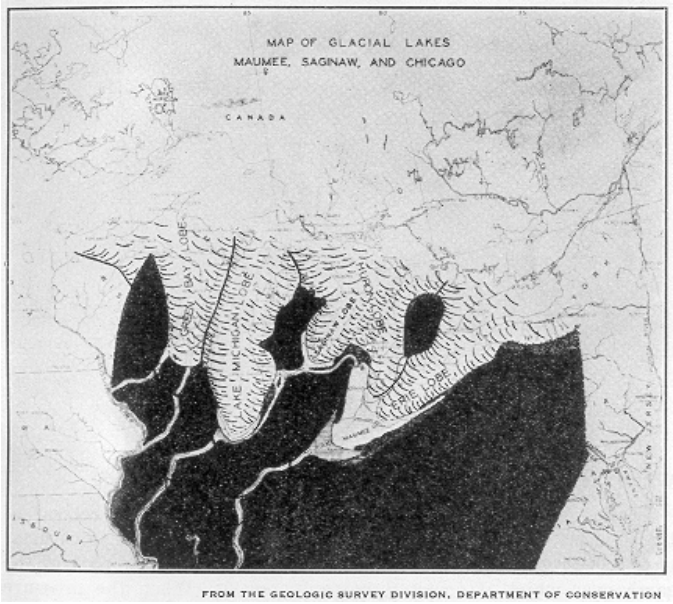
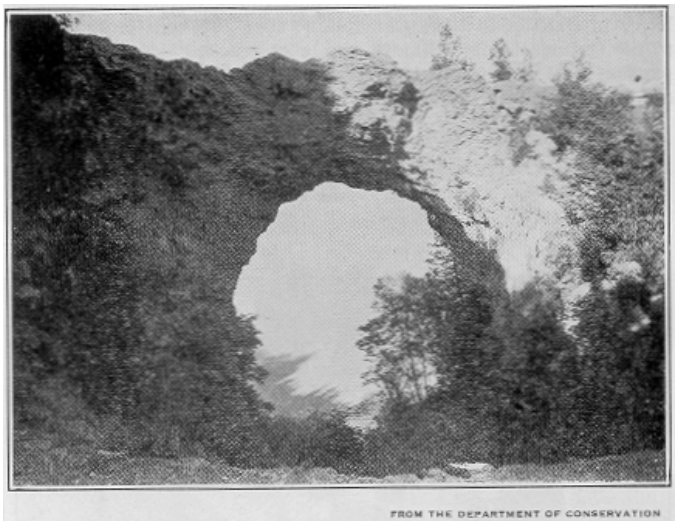


FIGURE 10. LAKE DEVELOPMENT IN THE MAUMEE STAGE
(Modified after Leverett and Taylor)



11. ARCH ROCK ON MACKINAC ISLAND
A record of wave work of glacial Lake Algonquin in Devonian rock

When the Continent Tilts

But something else happened with the oncoming and retreat of the ice mass. It is evident that ice from two to six miles thick must have had great weight and must have pressed down the part of the earth over which it accumulated and moved. When the pressure of this ice was released, the earth must have uplifted to seek its own level again and be in equilibrium. The beaches of the old lakes show that this is just what did happen. Beaches are horizontal yet the Algonquin beaches northward suddenly tilt upward. Water does not make a tilted beach; something else tilted them. Years of study have shown that all the beaches north of a line extending from near Port Huron to Manistee are tilted like the upcanting of a trap door and so this line is called

the *hinge line*. The effect of the first uplift along the hinge line was to spill the waters of the great lakes back into the Erie basin through the St. Clair and Detroit Rivers, and the present Great Lakes came into existence.

The present day effects of the tilting of the continent in its effort to regain equilibrium are the little earthquakes noticed in the lake region and which may be expected until equilibrium is attained; the fact that trees which early settlers reported as being well back from the Lake Superior shore are now at the waters edge; streams which entered the lake over falls now enter through a valley; and rapids and falls have developed in the streams entering the lake from the north. Measurements of the beaches show that North America is rising at the rate of one inch every ten years for each 100 miles north of the hinge line. So that if left alone the Great Lakes might again drain to the Mississippi but are prevented from doing so by dams, canals, and diversion of water for electric power. A continuation of the earth shocks in the lake region may be expected, but will not be serious enough to be disturbing.

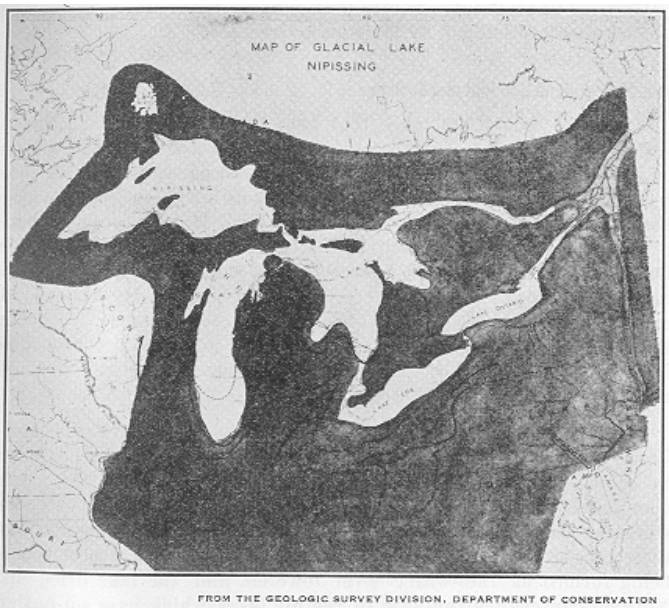


FIGURE 12. LAKE DEVELOPMENT IN THE NIPISSING STAGE
(Modified after Leverett and Taylor)

The Drainage Pattern Becomes Established

The physiographic record, then, is made on the basis, first, of ice activity which built a new surface on top of the old surface carved on the bed rock. As always, as soon as the land was formed, the agencies of weathering and rivers proceeded to change the face of Michigan. Rivers developed from the melt water of the ice and their story is bound up with the story of the Great Lakes but is even more detailed.

Rivers now flowing east, in their headwaters at least, once flowed west—the Raisin, Huron, AuSable. The St. Joseph, Kalamazoo, Grand, and Muskegon rivers once reached the Mississippi. The Raisin was once a part of the St. Joseph. The Huron successively emptied into the St. Joseph, the Kalamazoo, the Grand before its present eastward drainage was established. The Kalamazoo was a tributary of the St. Joseph; the Grand, of the Kalamazoo; the Muskegon, of the Grand; the AuSable, of the Muskegon. Many other interesting routes were followed by the streams before the lowering of levels to the present Great Lakes established the drainage pattern we know today,—routes fashioned to fit the morainic surface plastered over Michigan by the waning ice sheet.

Melting Ice Also Forms Lakes

The more than 5,000 lakes that help to make Michigan a great resort state were also created by the ice. Sometimes large blocks of ice became detached from the main mass and, covered with protective rock waste, did not melt until long after the melt water had made a plain in front of the moraine. It was probably centuries before the blocks melted. Even today, small blocks of ice buried in the sands of the Lake Superior shore will frequently remain nearly through a summer. When these great ice blocks did melt, they left steep walled pits into which water entered to make the many circular steep walled lakes we find on the plains and also in the hills. Other lakes and swamps were formed in the hollows of the moraines.

Geologically, lakes are anything but permanent features of a landscape. They exist only where the surface is young, and disappear by being drained away or by being filled by vegetation. The great drought of the past few years shows what may happen to lakes when the ground water level is lowered. Many resorters have found their lake-side cottages well back from, the shore and a new beach being formed as the water level lowered and the lake dried up. Nothing can change the level of the pit lakes which have no outlet once the ground water level is lowered except prolonged times of rain. Drainage of swamps and clearance of river channels often lower the dam which holds water in the lakes. Once lowered, vegetation destroys the lake site. Houghton Lake, the largest in the state, (31 square miles) is being destroyed by vegetation, particularly wild rice, the delicacy liked by ducks.

Erosion Modifies Surface Contours

Wind, weather, frost, and all the forces of erosion have modified the character of the surface since the ice melted off. Studies of soil thickness are the basis for an estimate that the ice left the southern tier of counties of Michigan about 30,000 years ago and melted from the Superior region about 10,000 years ago. In only a few areas do the bed rocks appear to form the topography of the state. Elsewhere the state is covered by that plastering of rock waste made of nil sorts of rock, coarse and fine, granite and limestone, coal from the youngest of the Pennsylvanian rocks mixed with boulders which are actually bits of the “petrified” shores of the Cambrian

seas—all mixed together in a heterogeneous mixture of rock waste known as the *drift*. The *topography*, (the surface features) of the state is glacial, therefore it is young. The hills are moraines and the flats are till plains, outwash plains, lake beds, or wide river channels.

13. SLEEPING BEAR DUNE
North of Empire, Leelanau County

Eskers, Drumlins and Dunes

The long steep sided sinuous ridges or "hogbacks" called eskers are the waste which choked channels of rivers which flowed in tunnels in the glacier and which settled on the plain when the ice melted. Eskers are mainly gravel and so of great economic importance. They were first studied and named in Scandinavia and Ireland. The longest esker in the world extends from a few miles north of Lansing through Holt and Mason almost to Leslie. It is called the Mason "Hogback" or esker.* Other queer hills are those long bottom-up canoe shaped hills made of clay, the *drumlins*, found on the plains in the southwestern and northwestern parts of the Southern Peninsula and in the Northern Peninsula. The lakes are the remnants of larger glacial lakes, or are pits and hollows in the moraines and plains filled with ground water. The swamps and peat bogs are remnants of undrained areas. The eastern half of the Northern Peninsula is largely swamp, muskeg, and bog because the ice left it so recently that drainage has not been established and also because the underlying bed rock does not permit rapid drainage. The dunes along the lake shores are glacial and lake sand blown up on shore. Many dunes along Lake Michigan such as Sleeping Bear Point are modern dunes perched on the dunes of the earlier lakes, *perched dunes*. The soils are varied also because they are either glacial deposits or sorted material brought by the ice. The moraines have all sorts of soil; the outwash plains are gravelly; the till plains, loam and clay of all varieties; the lake beds mainly sand, sandy loam, and clays; and the old river deltas are mainly sandy at the outer edge and gravelly at the inner edge.

*See p. 102.

How the River Systems Grew

Again because the topography of Michigan is glacial in origin, the drainage is very young and the story of the rivers is long and complicated. Some of the streams have cut their own channels and valleys but more of them occupy the wide channels of rivers which were old glacial spillways. The rivers receive their water supply from the rains that fall on the upland areas or from the more than 6,000 lakes and swamps they drain.

The headwaters of most of the eastward flowing streams once drained into rivers entering what is now Lake Michigan. As rapidly as the ice retreated a new river was formed at the halt. It flowed along in front of the moraine until it found a lower outlet. This accounts for the fact that so many streams have long branches entering from one direction. The river poured through the outlet often as a rushing torrent such as made the channel of the Grand when the valley was the outlet of the glacial lakes in the Erie and Saginaw basins. The valley and outlet were cut rapidly and the headwaters of neighboring streams diverted to the new lower outlet. The drainage map of the state shows that none of the rivers have the tree-like (*dendritic*) pattern we associate with rivers.

The story of the rivers is too long to be told here but a few physiographic facts about some of them may be of interest. The St. Joseph is the oldest river. It once drained to the Kankakee and the Mississippi. The Raisin and the Huron were once its headwaters; the Kalamazoo once entered it in the northern part of St. Joseph County. The Grand is the longest river, but it is made up of older rivers which have been diverted from the original channels. Its valley is the channel of a mighty glacial torrent. The Muskegon has the longest and narrowest valley, 45 miles wide, with few tributaries and but one stream of any importance entering from the south.

The Saginaw is the shortest major river, 20 miles long and its mouth is almost at the center of the Michigan Basin due to the indentation of Saginaw Bay; but it has the largest drainage area of the state by virtue of its long tributaries the Tittabawassee, Shiawassee, Flint, and Cass. The Tittabawassee and Cass are interesting because of their arc-shaped courses and the fact that they have no tributaries on the Lake Huron side of their valleys. They flow close to a moraine.

The AuSable is the swiftest river in the Southern Peninsula with a fall of 669 feet. The shorter Rifle is almost as swift as the AuSable and one of the few streams in the Peninsula which flow over rock rapids. The Ocqueoc in Presque Isle County is the only river in the Southern Peninsula having falls in its course. The falls are formed by the river flowing over outcropping ledges of Devonian limestone. The St. Clair is the third youngest river in the state and the only river in the world which flows from a lake, yet is building a delta. The Detroit River, although the widest, 2,200 feet at Woodward Avenue, Detroit, was the last river to be formed.

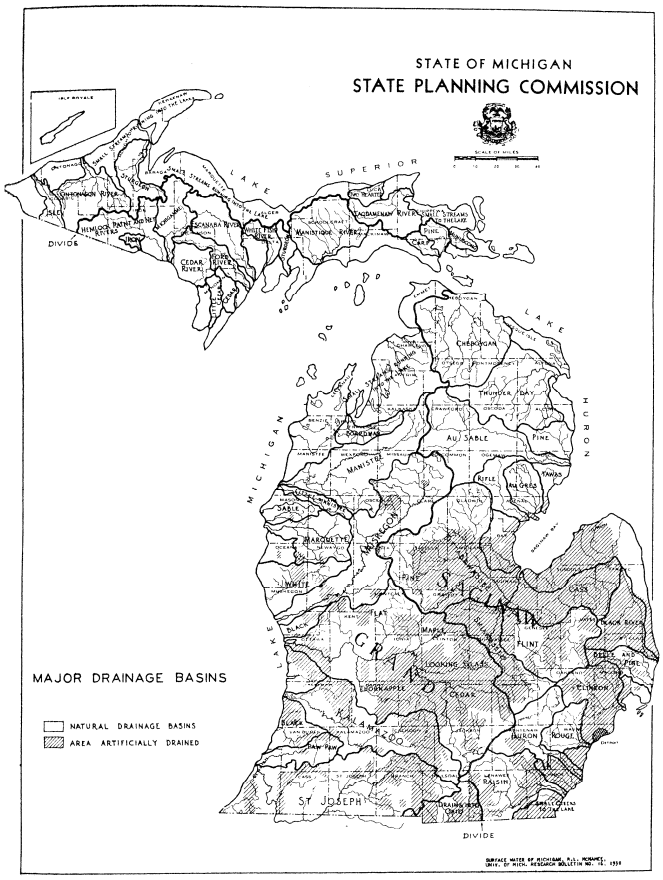
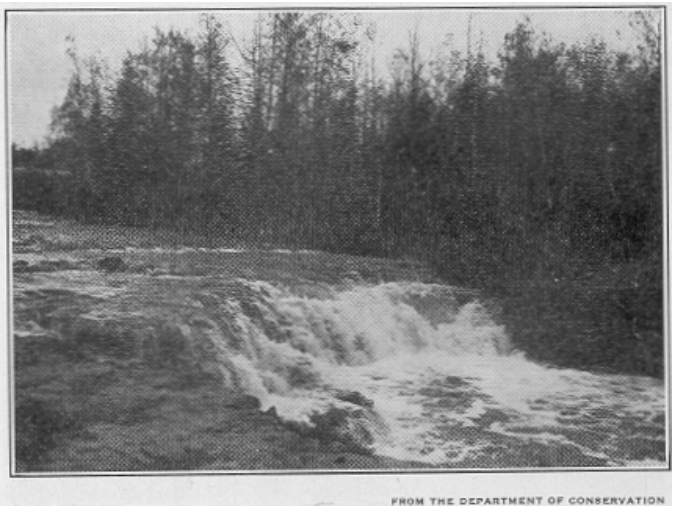


FIGURE 14. MAJOR DRAINAGE BASINS



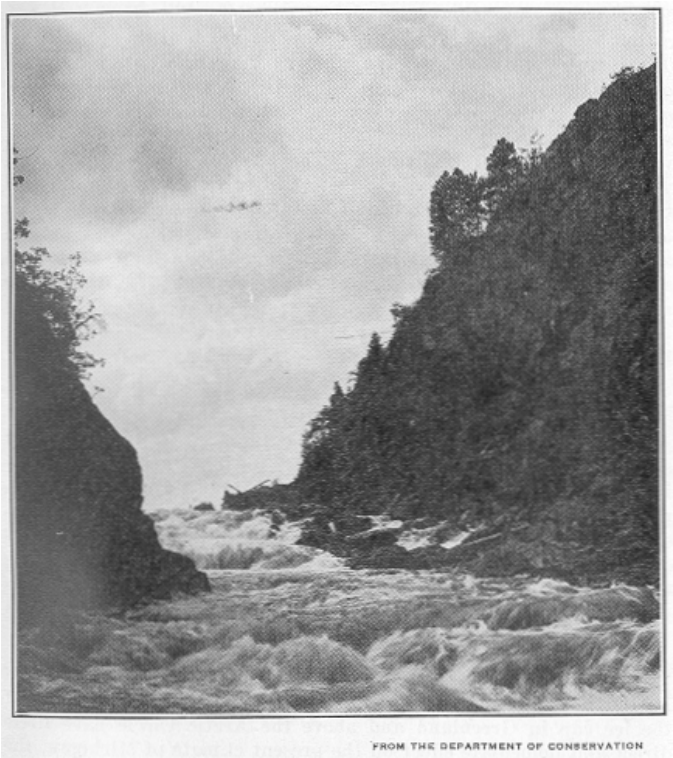
15. OCQUEOC FALLS, PRESQUE ISLE COUNTY
Only waterfall in the Lower Peninsula. Over Devonian Limestone

Northern Streams Are Different

The drainage of the Northern Peninsula is even younger than that of the Southern Peninsula. The streams have more rapids and falls and the uplands have more swamps. Most of the rivers drain to the south. Those that enter Lake Superior are short and are characterized by falls where they tumble over the ledges of Lake Superior sandstone, the old Cambrian rim of the lowest of the rock saucers, and over the Hermansville limestone. The eastward flowing Tahquamenon is the most interesting river because it has the largest falls* west of Niagara and is celebrated as the river down which Hiawatha sailed:

> "Down the rushing Taquamenaw,
> Sailed through all its bends and windings;
> Sailed through all its deeps and shallows."

*See page 58.



16. RAPIDS OP THE MICHIGAMME RIVER, IRON COUNTY
Through a gorge cut in metamorphic rock

The Manistique has many almost parallel northern but no southern tributaries. The Escanaba, Menominee, Manistique, and Sturgeon fall 1,000 feet from their headwaters to Lake Michigan in a series of rapids and smooth stretches. The Black and Presque Isle Rivers in Gogebic county are almost parallel. The Black is interesting because its mouth is almost directly north of its headwaters. These rivers entirely cross the state as their headwaters are just over the boundary line in Wisconsin. All the streams west of Marquette are marked by falls, cascades, and rapids and by the gorges which they have cut for their channels in the pre-Cambrian granites, volcanic rocks, and sandstones. The streams east of Marquette which flow north enter Lake Superior after tumbling over falls of Cambrian sandstone or Ozarkian limestone a short distance south of the lake. The southward flowing streams drain vast swamp areas. St. Mary's river is just a little older than the Detroit and spills over the cascades and the Falls of Sault Ste. Marie on the rim of the Michigan Basin.

Rivers Have Economic Importance

The economic importance of the streams has varied with the industrial progress of the state. Originally they served as highways for the birch canoes first of the Indians, then of the early settlers. Later they became the runways for logs during the lumbering days. Always they have been a source of food and water supply. They offer a potential as well as a utilized source of hydroelectric power. They, with the lakes, temper the climate and produce the scenic beauty, the fishing, and other sports that allure the tourist.

Climate

One of the after effects of the ice age important to the people of Michigan is the climate of the state. Although the remnants of the ice cap in Greenland and above the Arctic Circle have little direct and immediate effect on the present climate of Michigan, the great Ice Age did, for it carved the ancient valleys deeper and, in melting, left them filled with the Great Lakes. These great bodies of water absorb the heat of summer and release it during the winter thus making our winters warmer on the average than the winters of neighboring states. Likewise the waters, having cooled more slowly than the land, warm more slowly and thus the westerly winds blowing over the lakes carry cool breezes to modify the heat of summer. The great cold waves are robbed of some of their cold as they cross the lakes in winter or are deflected by the warmer water so that in the Southern Peninsula the great extremes of heat and cold are absent and the climate equable.

Michigan Fruit Belt Profits by Tempered Climate

The fruit belt along Lake Michigan exists because of this modifying influence. Across the lake in Wisconsin the winters average ten to twenty degrees colder. In spring the fruit buds are not opened too early because the cool lake modifies the hot winds from the southwest. Although the fruit belt does occasionally suffer from spring frosts, the loss is not so great as in the regions un-tempered by great lakes; early frosts are delayed and a longer growing season (160 days or more) results. But in the Northern Peninsula and at a distance from the lakes in the Southern Peninsula the growing season is shorter by ten or twelve days. The shortest growing season is 80 or less days in the Northern Peninsula and 90 in the Southern.

Temperature conditions in Michigan are about the same as in the states 150 to 200 miles to the south, averaging 43 to 50 degrees. In addition the growing days are longer due to the latitude. There are long days and short nights in summer and the opposite condition in winter. In June in the Northern Peninsula, daylight lasts from 3 a. m. to 9 p. m. In the Southern Peninsula the longest day is about fifteen and a half hours long. This condition serves agriculture by promoting growth with long hours of sunlight. The short nights prevent frosts in the spring and early frosts in the autumn. The long frosts of the winter aid the fertility, depth, and ease of working the soil.

The moraines stop the warm lake winds of winter and cause the great snowfall in those areas where the moraines are highest in the Southern Peninsula just as the highlands of the Northern Peninsula stop the winds and increase the snow depth, but also prevent the dissipation of heat across the state and conserve it. The modifying effect of the lakes is shown by the fact that during those few winters when Lake Michigan has been covered with floe ice the winters have been severe.

Adequate Rainfall Promotes Agriculture

Agriculture is profitable where the rainfall averages from 20 to 24 inches per year and has a proper seasonal distribution. Weather Bureau records kept for a long period of years show that the average rainfall for the state is 30.5 inches with the maximum 38 to 40 inches. As this rainfall comes mainly in the growing season there is sufficient moisture for crops. Occasionally in a drought year like 1930 or 1933 the precipitation falls to less than 23 inches. Berrien County is the wettest area of the state and Midland, on the lee of the high Lake Michigan moraine, the driest.

A favorable location protects the state from long-time droughts although short irregularly timed periods of drought may affect any part of the state in any season. In the cyclical repetition of climatic conditions, rainy and drought seasons are periodic over a long time.

The winds for the greater part of the year are from, the west with an average velocity of twelve miles per hour in March and April and a minimum velocity of nine miles per hour in August. At times the winds reach tornadic (not cyclonic*) velocity and are accompanied by heavy rainfall. The path of such storms crosses the southern part of the state but occasionally one gets off the beaten track and the central part of the state suffers. Southerly winds are usually warm and moist; northerly winds cool and dry; easterly winds portend bad weather; and westerly winds settled weather. In summer the prevailing winds are southwesterly across Lake Michigan all along the western coast of the state. This clean, cool air, free from ragweed pollen is making that part of the state a medical haven for sufferers from asthma and hay-fever.

Geology Influences Industrial Development

The development of Michigan has been determined largely by its geological history. Early settlers were loath to enter the state believing it to be just an area of swamps and rocky lands fit for savages. Its vast forests were diversified because of the glacial soil upon which they grew and because they were so little removed from glacial time that the oaks had not advanced upon the younger forest types. Later its forests, maple and beech to the south, and pine and hemlock to the north, were

opened for lumbering. The stand of pine and hardwoods proved to be one of the richest in the world.

Its varied soils became known as the forests were cleared. Its salt springs and mines were opened to secure cheaper salt and to meet the need for using the refuse of the lumber industry, and then expanded into a ranking industry as the lumbering days were forgotten. From the gravel beds in the glacial drift came, in most areas, a copious supply of pure water. Below the drift, each of the rock saucers produced its minerals, to add to the wealth of the state: water and coal from the Pennsylvanian; gypsum, limestone, pure water, natural gas, brine, petroleum, and shale for cement in descending saucers of the Mississippian set; limestone, glass sand, brine, salt, gas, and petroleum from the Devonian set of rock saucers; rock salt, limestone, and petroleum from the Silurian; pure water, limestone, and oil, from the Ordovician; building stone from the Cambrian; and copper, iron, gold, silver, marble, semi-precious stones, and building stone from the pre-Cambrian.

*In this latitude a *cyclone* is a whirling mass of air which may move very slowly or very swiftly. It brings the weather changes. A cyclone, whirling counter clockwise across the country, brings bad weather. An anti-cyclone, whirling clockwise, brings fair weather. A *tornado* is a violent little whirl of destructive velocity within the cyclone or along its edge.

Natural Resources Determine Industrial Development

Limestones and other building material are obtained from the outcrops of these rocks. Natural gas, petroleum, brine, water, and salt have been reached by the drill. Gypsum and stone come from the quarries, and coal, rock salt, and metals from the mines. The proximity of limestone and iron ore and the cheap water carrier routes of the lakes have contributed to industrial development and have changed much of the Southern Peninsula from an agricultural to a manufacturing area. The mines have been the chief resource of the Northern Peninsula as well as the reason for building the St. Mary's canal which opened Lake Superior to commerce and led to the development of industry in the south after the forests had been cut.

The varied soils have led to a diversified agriculture. It has been said that Michigan could produce all its food needs except coffee because of its variable but equable climate and variety of soils. This climatic factor in addition to the scenic beauty of the state, the lure of lake and stream and the good roads made possible by the abundance of road material in the drift and the few outcrops, is rapidly increasing the second industry of the state—the recreational industry. Old glacial spillways have served as routes of primitive commerce and as trail and road routes for more civilized travel. In the lumbering days the streams now occupying the spillways and the newer streams of the state provided a logging route. Today the streams supply electric power although many of them, especially in the Northern Peninsula, are not yet power-harnessed.

Resources Satisfy Developing Needs

New discoveries and new needs tend to continue the search for economic materials within the state. Gypsum was first used as land plaster fertilizer. Commercial fertilizer took its place but the building trades found a use for the gypsum and an important industry arose. Limestone was first burned to secure agricultural lime for fertilizer; then used for stone fences, for building material, and road construction. Now the largest quarry in the world is operated at Rogers City because Michigan limestones are so pure that they are valuable as flux in steel manufacture. Bed rock was first penetrated by the drill in the search for pure water in areas where the drift is thin and the water supply too variable. Later, in the search for salt, brines were found and much later the drill found the deep reservoirs of petroleum and natural gas. Quarries opened the limestone, gypsum, sandstone, trap rock, and glass sand deposits; mines penetrated the deposits of rock containing minerals and metals. So to "if you would see a beautiful peninsula, look about you" could be added "if you would seek a fruitful peninsula, look into it." The foundations of the development and progress of Michigan were laid when the basin was formed in the pre-Cambrian granites and were increased as the sets of rock saucers filled the basin and the glacier added a plastering of heterogeneous rock waste and the Great Lakes. Finally modern physiographic conditions carved it to be ready for his exploitation when man found it over 300 years ago.

Helpful Reading

1. Bergquist, S. G. *The Pleistocene History of the Tahquamenon-Manistique Region with a Foreword on the Glacial History of the State*. Michigan Geological Survey, Publication 40, Geological Series 34. Occasional Papers on the Geology of Michigan, Part I. Lansing: Geological Survey Division, Department of Conservation.
2. Blackwelder, Elliot and Barrows, H. H. *Elements of Geology.* Chicago: American Book Company, 1911.
3. Brown, Geo. Grainger. *Molding Sands of Michigan*. Michigan Geological Survey, Publication 41, Geological Series 35. Lansing: Geological Survey Division, Department of Conservation.
4. *Centennial Geologic Map of Michigan*. Michigan Geological Survey, Publication 39, Geological Series, 33. Lansing: Geological Survey Division, Department of Conservation. *The legend is a detailed description of the rocks of the State and their economic resources*.
5. Hotchkiss, W. O. *Story of a Billion Years*, Baltimore: Williams and Wilkins Company, 1932.

6. Kelley, W. A. *The Pennsylvanian System in Michigan*. Occasional Papers on the Geology of Michigan. Publication 40, Geological Series 34. Part II. Lansing: Geological Survey Division, Department of Conservation.

7. Leverett, Frank. *Surface Geology of Michigan*. Michigan Geological Survey, Publication 25, Geological Series 21. Lansing: Geological Survey Division, Department of Conservation.

8. Leverett and Taylor. *The Pleistocene of Michigan and Indiana*. United States Geological Survey Monograph 53. Washington, D. C.

9. Scott, I. D. *Inland Lakes of Michigan*. Michigan Geological and Biological Survey. Publication 30, Geological Series 25. Lansing: Geological Survey Division, Department of Conservation.

CHAPTER FOUR
MINERAL RESOURCES

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Michigan State College

Mineral Resources Necessary to Industrial Development*

It is a well established fact that a nation is powerful and capable of industrial development and expansion in proportion as it possesses within its confines reserves of those raw materials in the form of minerals which are necessary to supply the machines of industry and transportation. In this modern age of machine culture, demands for raw mineral material are ever growing and will continue to increase as man becomes more possessed of leisure time in which to utilize and enjoy the products manufactured therefrom. For many years the United States has held a commanding position among the nations of the world in the production of minerals. Wars of conquest have been fought primarily to gain advantages in mineral wealth. That nation which normally possesses vast resources of a wide variety of minerals usually finds itself in a position to command greater security than one whose supplies are limited.

The United States has gained its position in the front rank of mineral production at great expense. Vast deposits of high-grade ores and minerals have been drawn on with but little or no consideration of the future. No serious effort has been made to enforce conservation measures for the protection of mineral industries. The policy of "first come—grab all" has been in vogue in this country almost since the beginning of mineral utilization. In many instances, private interests have grown rich by unwise utilization of mineral resources, which should have been administered with the welfare of the entire nation in mind.

Michigan has played an important role in the production of those mineral resources which have given this country its high standing. Her deposits of iron and copper have found their way into the industrial channels of the state, the nation, and the world. Vast resources of non-metallic minerals have placed Michigan in a formidable leading position in the production of salt and gypsum. Extensive deposits of high grade limestone and dolomite have gained for the state a strong position in the manufacture of cement and the production of fluxing limestones. Coal mines in the interior portion of the state have for many years supplied domestic and commercial fuels for local needs.

*In the compilation of this chapter the author has drawn freely on material contained in the various publications of the State Geological Survey.

Unlimited potential supplies of high grade shale distributed through various parts of the state make possible the development of numerous brick and tile industries. Gravel, sand, and clay from surface glacial deposits have contributed to provide the state with material essential to the construction of one of the finest highway systems in the world. Recent discoveries of oil and gas in the central part of the state have placed Michigan in front rank among the oil producing states east of the Mississippi River.

Mining as an industry in Michigan dates back to the early beginnings of the state. Several mining operations were started long before the timber was cleared from the areas where the deposits occur. In the early days of iron production the ore was smelted in crude stone stack furnaces by means of charcoal made from the wood of the adjacent forests. In several instances, mineral deposits such as salt were opened up and developed as by-product industries along with the lumbering operations.

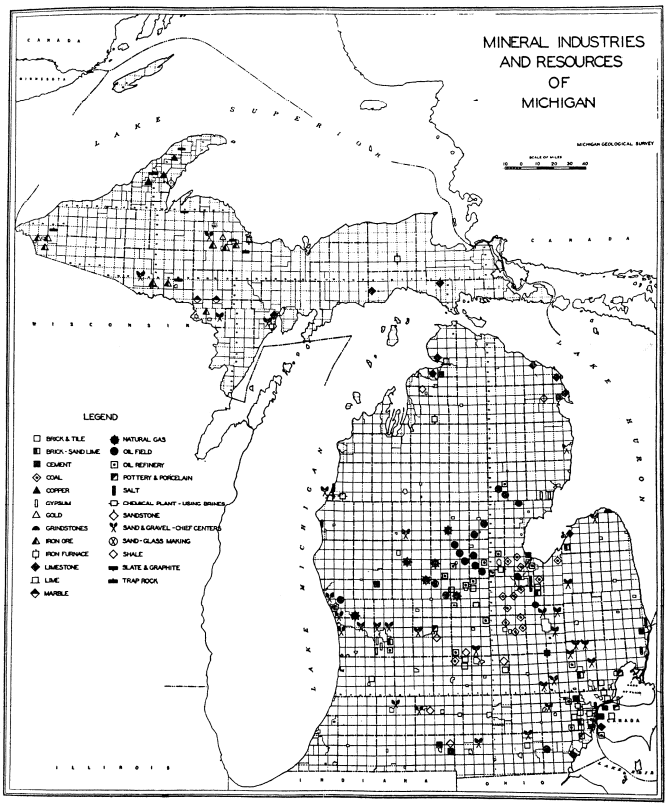
Although many of Michigan's mineral deposits have been worked for nearly a century and have contributed greatly to the wealth of the state, there still remain resources ample for future development. The extent to which the reserves of non-metallic minerals are henceforth exploited will depend somewhat upon the demand for new products which may be manufactured from them.

Iron Ore in Michigan

Discovery of Iron Ore in Michigan

In his geological report for 1841, Dr. Douglass Houghton,[8] the first geologist of the State of Michigan, states "Although hematite ore is abundantly disseminated—it does not appear in sufficient quantity at any one point that has been examined to be of practical importance." It is no reflection on his ability as a geologist that Dr. Houghton failed to discover the iron deposits, for most of his examinations of the area were made by boat along the shore of Lake Superior. Had he traveled into the interior wilderness of the region there is

no question but that he would have observed the outcrops of the iron formation.



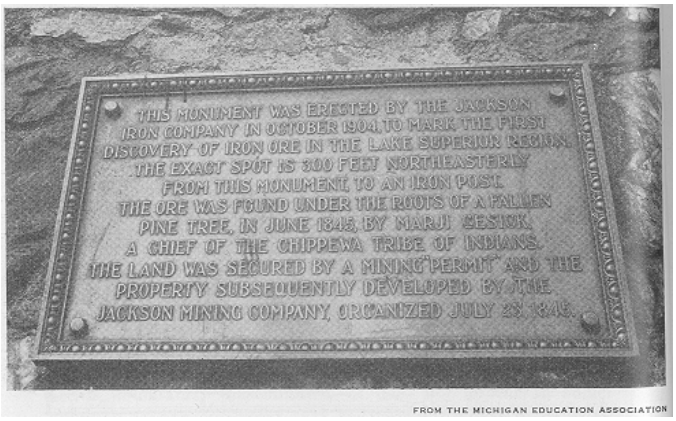
33. MINERAL INDUSTRIES AND RESOURCES

The earliest discoveries of commercial deposits of iron ore were made in 1844 by a party of United States surveyors under the direction of William A. Burt and with the guidance of two Indians. The first company organized for the purpose of mining the ore in northern Michigan was incorporated as the Jackson Iron Company. The articles of association of this company were executed at Jackson, Michigan, on July 23, 1845.

After several years of exploratory operations and testing of the material by working it into iron bars in a blacksmith forge, the Jackson Company finally opened up the first iron mine in Michigan.

According to Brooks,[2] the original shipment of iron ore from the Jackson pit, located near Teal Lake on the north edge of Negaunee in Marquette County, was made in 1852. "Seventy tons of hematite were taken to Sharon, Pennsylvania, and these made into pig-iron in the 'Old Clay Furnace.'" The first regular shipments of ore from the Jackson mine were begun in 1856, when 5,000 tons were removed.

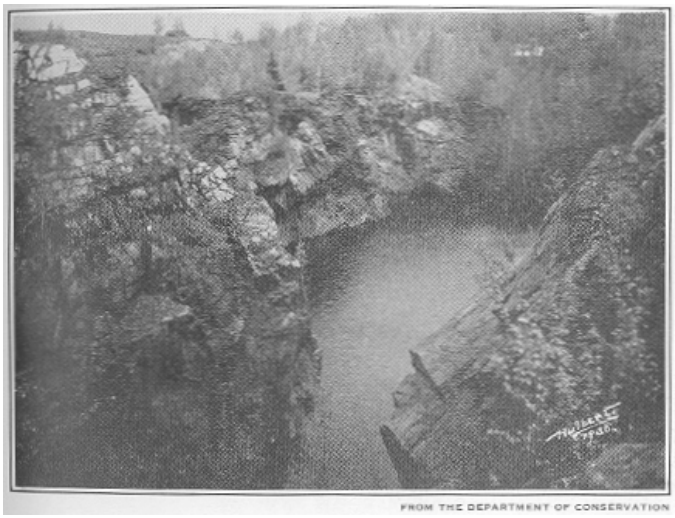
Later discoveries of iron ore in the Northern Peninsula resulted in the opening and development of the Menominee Range in Dickinson County, with first shipments in 1877. Seven years later the Gogebic Range in the western end of the Peninsula was opened for the production and delivery of iron ore.



34. FIRST IRON MINE, NEGAUNEE

Millions of Tons of Ore Shipped Annually

In the eighty-five years since the first shipment of ore from the Jackson mine, Michigan has produced in excess of half a billion tons of iron ore. In the period from 1916 to 1935, inclusive, the annual shipments of iron ore from the state have averaged about 12,000,000 tons. The largest output during this twenty-year period was 18,812,972 tons in 1916. Much of this production was employed in the manufacture of armament for the World War which was then in progress. The lowest shipment was 978,371 tons during the trough of the depression in 1932.[13]



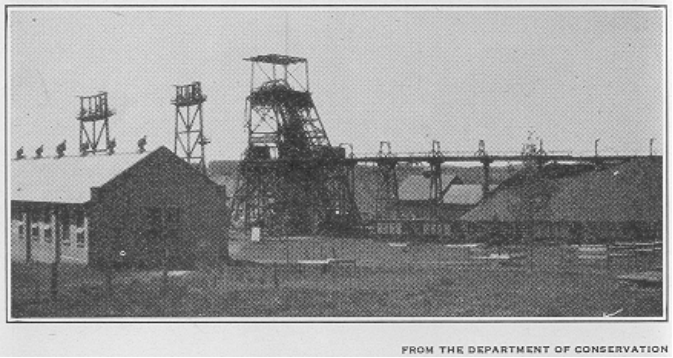
35. JACKSON IRON PIT

According to statistics compiled in the Minerals Yearbook for 1936[19] the estimated visible reserves of merchantable iron ore in Michigan have been placed at slightly less than 165,000,000 tons. At the normal rate of production, this known reserve of high-grade ore would be exhausted in a period of 15 to 20 years if it were not for the fact that ore is developed and new deposits are found in connection with mining operations. Pardee* makes the statement that "since 1911 the estimated visible reserves of iron ore in Michigan have never exceeded 200,000,000 tons and in that time some 300,000,000 tons have been shipped out of the state.

These figures show how new discoveries have maintained a large reserve of ore in spite of shipments, but a time will come when the high-grade ores will be exhausted or cost too much to extract. At that time the lower grade or marginal ore, of which there are immense tonnages in reserve, will be treated or beneficiated and the industry will continue to exist for many years thereafter."

*Pardee, Frank—Personal Communication.

With the exception of a rather limited area in Wakefield on the east end of the Gogebic Range, where open pit methods of mining are employed, the bulk of high-grade iron ore produced in Michigan is mined through shafts. Low grade siliceous ores of iron are mined through surface operations in the vicinity of Marquette and Iron Mountain. The iron mines of Michigan are relatively deep when compared with those of other iron districts throughout the world, some of the deeper shafts extending to vertical depths exceeding 3,000 feet.

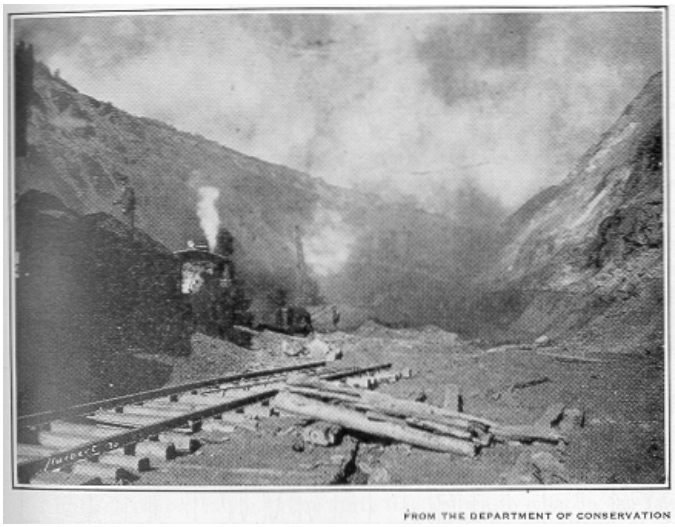


36. SURFACE SHAFT—IRONWOOD

Value of Annual Shipments

Osgood,[13] in his report on the Iron Industry of Michigan, states that "values placed on iron mining properties by the State Tax Commission increased from $82,000,000 in 1913 to $117,000,000 in 1921, and have since that time shown a gradual decrease until on January 1, 1935, the total recommended valuation was set at $63,000,000. The valuation placed on the iron mines represents but one per cent of the total valuation of the state, but on the other hand, it comprises nearly 25 per cent of the total valuation of the Northern Peninsula." He states further that "approximately 8,500 men were employed in the iron mines in 1930, earning an average annual wage of about $1400. The low point of employment was reached in 1933, when only 2,739 men were employed, but 1934 and 1935 have seen improved conditions and 1936 will probably be the best year since 1930."

In the period 1930-1935, the average cost of mining and transporting iron ore to the lower lake port furnaces amounted to $4.36 per ton. This in itself is most certainly a remarkable achievement in view of the fact that the ore must be moved during the relatively short period when the lakes are free of ice. "One of the marvels of this great industry is the efficiency with which it extracts these large tonnages from mother earth and moves them to the furnaces."



37. OPEN PIT—WAKEFIELD

Use of Scrap Iron and Alloys Conserves Natural Ore

According to information obtained from Pardee, "the average iron ore shipped down the lakes carries about 50 per cent metallic iron, which means that it requires about two tons of iron ore to produce one ton of pig iron or steel. If it were not the case that immense tonnages of scrap iron go back to the furnaces each year there would of necessity be many more mines in operation to supply the needs of the country." The use of scrap material in the steel industry goes a long way in conserving the natural iron ore resources of the state.

A program of conservation is being forced upon the iron mining industry by steel manufacturers. The use of alloys of other metals in producing high-grade steels lessens, to a certain degree, the amount of iron required in the process. In the fabrication of many steel products, various types of plating are employed. These serve to protect the surface of the metal from excessive corrosion and thus aid in prolonging its life.

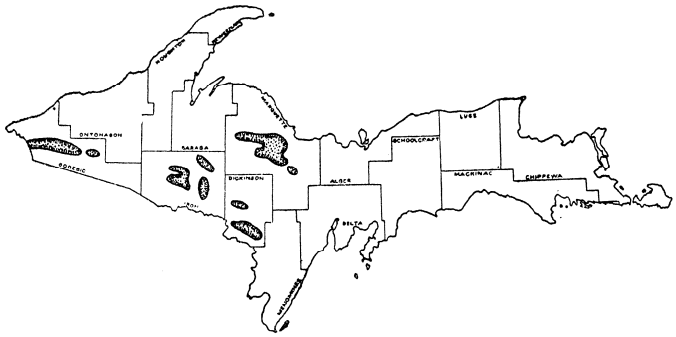


FIGURE 38. LOCATION OF THE IRON DISTRICTS
There is no iron in the Lower Peninsula

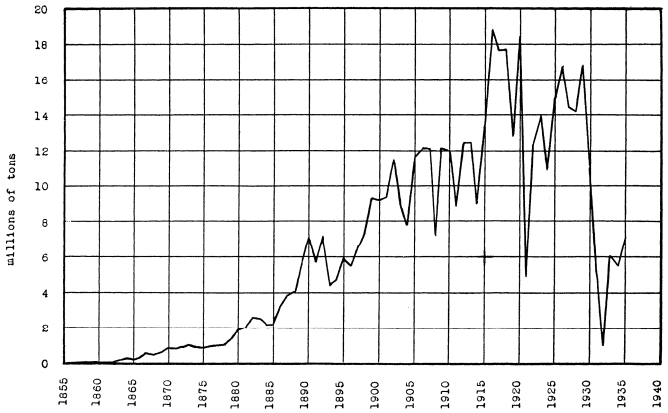


FIGURE 39. PRODUCTION OF IRON ORE IN MICHIGAN

Copper in Michigan

Indians Discover Copper in Michigan

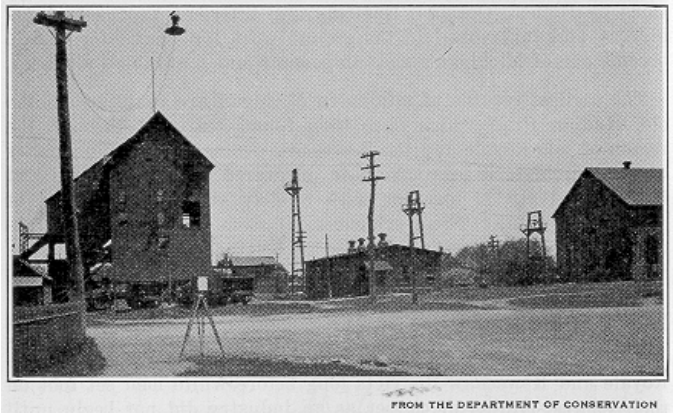
The first references to the existence of copper in Michigan are made in a book published by LaGarde in Paris in 1636. The reports and narratives of the early Jesuit missionaries who roamed the wilderness tracts of the Great Lakes in the early decades of the 17th century contain fragmentary sketches of the occurrence of copper along certain of the shores of Lake Superior. Subsequent explorations by French, German, English, and American prospectors, engineers, and surveyors laid the ground work for what later was to become one of Michigan's most important and profitable industries.

The earliest records of mining in Michigan are contained in the old "Indian Pits" which have been found scattered through the region of Isle Royale and the Keweenaw peninsula. In the vicinity of these prehistoric pits have been uncovered piles of charcoal and half burned sticks, together with crudely shaped implements of copper and stone. These evidences all seem to point to the conclusion that the early Indians were the original miners and artisans of the metal in Michigan.

Mining of Copper Begins

Although copper in its native state was known to exist in the Isle Royale and Keweenaw districts long before white men set foot on their shores, mining of copper as an industry did not begin until 1845. In that year the state produced 26,880 pounds of the metal, obtained by prospectors and independent miners mostly from outcrop veins and shallow deposits. From this small beginning nearly a century ago, the copper industry in Michigan made rapid strides to become one of the greatest of its kind in the world. For a period of forty years, from 1847 to 1887, Michigan was the foremost producer of copper among the states of the Union. To the close of the year 1935, Michigan had produced a total of almost nine billion pounds of copper.

Osgood,[13] in his report on *The Copper Industry of Michigan* published in 1936, states that "in 1930 the valuation of the copper mines of Houghton and Keweenaw counties amounted to $33,368,000 or about 58 per cent of the total valuation of all property in those counties which was approximately $57,500,000. The assessed valuation of the copper mines in 1936 amounted to only $7,250,000." This represents a shrinkage in valuation of over $26,000 000 in a period of five years or the equivalent of more than $5,000,000 per year. This downward trend in valuation of Michigan copper mines was due to a number of factors, many of which had their origins in the recent disastrous depression.



40. SHAFT HOUSE AND SURFACE EQUIPMENT, OSCEOLA COPPER MINE, CALUMET

Causes of the Copper Depression

The copper industry in Michigan was affected by the rise to importance of mines in Africa and the resultant competition with foreign trade. The exploitation of extensive deposits of copper ore in the western states, where low mining costs are largely defrayed by the valuable by-product minerals recovered in smelting operations, set up an economic barrier against Michigan's copper industry. It was possible for western copper to be mined, smelted, and placed in the New York market at a price below that of the actual cost of mining the native metal in Michigan. In the face of this serious competition it was not surprising that the copper mines of the state suffered a serious relapse. The increased use of scrap copper in the metal industry together with the increasing depth of recoverable ore bodies in several Michigan mines and the consequent exhaustion of major ore bodies assisted in giving the final blow. The general decline of industrial activity which began in 1929, followed shortly by a collapse of the copper market, had an abrupt and widespread effect on the mining activities in Michigan. The price of copper declined to an unprecedented low of 6.3 cents per pound in 1932. In 1935, the average price of copper was slightly more than 2 cents higher and in 1936, the average market price was 9.47 cents.

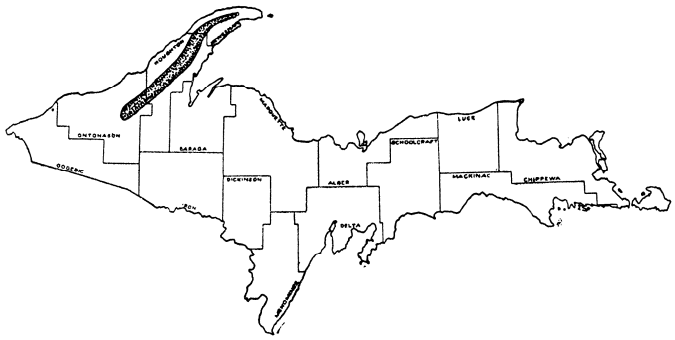


FIGURE 41. LOCATION OF COPPER DEPOSITS
There is no copper in the Lower Peninsula

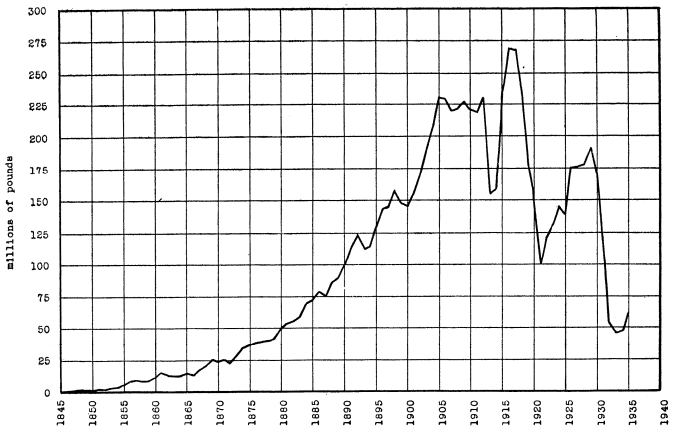


FIGURE 42. PRODUCTION OF COPPER ORE IN MICHIGAN

Mine Shafts Go Deep

Michigan copper occurs essentially as native metal and is now being mined by means of deep shafts, some of which extend to vertical depths of over a mile. In 1934 the average yield of copper per ton of ore mined underground in Michigan was 69 pounds.

The average cost of producing Michigan copper for the market in 1930, the last year for which figures are available, was 12½ cents per pound.* Costs during the past six years have declined somewhat, however, due to improved methods of mining, closer selection of the ground mined, and the closing of marginal mines.

Michigan's copper industry has supported about 10,000 workers in a district whose population of approximately 58,000 inhabitants (1930 census) is largely dependent on the mines for its existence. During the depression, when the mining industry was at its lowest ebb, a large proportion of the population of Michigan's "copper country" was forced out of employment. Recovery in that area has been slow and will continue to lag because many mines have found it necessary to shut down operations permanently.

Unless new and extensive deposits of high grade ore at relatively shallow depths are discovered, it is quite obvious that the Keweenaw district will rapidly lose its prestige as a mining center and soon fade out of the national picture so far as copper production is concerned.

Salt and Gypsum in Michigan

Salt Deposits From Evaporated Sea Water

The extensive beds of salt and gypsum in Michigan were formed by chemical precipitation from the saline waters of the great inland sea during periods of excessive evaporation.** The oceans in which these deposits were concentrated received their supply of mineral material largely from river waters which carried salts dissolved out of surface and subsurface rock over which they flowed. In experimental studies made of saline deposits it has been found that upon evaporation of sea water a series of minerals precipitate out of solution in order of increasing solubilities. When sea water is evaporated to the extent of 80 per cent, gypsum (hydrous calcium sulphate) is precipitated from solution and not until 90 per cent evaporation is reached does salt (sodium chloride) come out. Because these deposits were concentrated by evaporation of salts from solution they are commonly referred to as evaporites.

*Pardee, Frank—Personal Communication.

**See Chapter I, p. 20.

Economic Importance of Salt and Brines

The occurrence of salt springs in the Southern Peninsula of Michigan was known to the Indians long before the advent of the white man. The economic importance of salt lands was clearly recognized in 1835 by the Convention assembled in Detroit for the purpose of formulating a state constitution. In the proposed Constitution submitted to Congress that year was an ordinance which contained an article as follows: "All salt springs within the state, and the lands reserved for the use of the same, at least one section including each spring, shall be granted to the state, to be used and disposed of as the Legislature may direct."

For a period of several years following the admission of the state into the Union, the Legislature made various attempts to develop the state salt lands, as pointed out by Cook.[4] Several wells were drilled by the state through appropriations made by the Legislature but because of an inadequate knowledge of the geology of the formations the undertaking proved a failure. In 1840, while the state was employed in drilling a well on the Grand River three miles below Grand Rapids, Lucius Lyon began a well within the corporate limits of the present city of Grand Rapids. This well was completed the following year at a depth of 661 feet and produced a strong flow of water with a relatively low concentration of salt.

State Promotes Manufacture of Salt

Finally in 1859, the Legislature passed "An Act to encourage the manufacture of salt in the State of Michigan". This act made provision for the exemption from taxation of all lands employed in the industry of salt

manufacture and authorized the payment of a bounty of ten cents per bushel for all salt obtained in the state by drilling. This was the stimulus needed to engage private enterprise and from this point on the industry made rapid advances. Twenty-five thousand dollars was expended to drill wells and to promote the salt industry in Grand Rapids but because of the low content of salt in the brine the project was abandoned. At the same time drilling operations were being pushed at East Saginaw. Early in 1860 the first brine was encountered in the Saginaw area and a plant for the evaporation of salt was placed in operation that same summer.

Scientific Development Makes Michigan Leader

The geological references contained in Winchell's[20] first report, published in 1860, laid the foundation for the development of a scientific plan of exploring for salt deposits in Michigan. The rapid promotion of the industry in the Saginaw Valley, coupled with new discoveries and development of deposits in other portions of the state, enabled Michigan ultimately to become the leading producer of salt in the United States, a position which it has held for the past quarter of a century.

Generally speaking, the salt industry of Michigan may be considered as a stepchild of lumbering operations. The early history and development of salt production is intimately linked with the activities of the sawmills whose waste fuel was employed to heat the pans in which the brines were evaporated.

Three Geologic Formations Contribute Salt

At Midland, Saginaw, and Bay City, salt is produced by evaporation of brines obtained from the Marshall formation.* At Detroit, St. Clair, and Port Huron the salt is manufactured from artificial brines formed by dissolving beds of rock salt in the Salina formation. The natural brines employed in the manufacture of salt at Ludington and Manistee are pumped from the Detroit River formation which contains beds of rock salt as well as brines.

Bock salt is mined by means of the deep shaft method in but one locality in the state, at Oakwood in Wayne County. This shaft was started in 1900 and completed after many serious difficulties and delays in 1910. The salt is taken from various beds of the Salina formation at a depth of approximately 1150 feet.

The first successful well in Midland County was drilled in 1878. The brine produced in this area comes from the Marshall formation and is utilized by the Dow Chemical Company in the manufacture of bromine, iodine, magnesium, calcium chloride, and other chemicals.

In Macomb County, a well was drilled for oil in the late sixties. From the standpoint of petroleum the well was a failure but a strong brine was encountered at a depth of 1000 to 1100 feet. A "salt block" was erected in Mount Clemens for the purpose of manufacturing salt but because of the high percentage of bitter salts (*bitterns*) in the mother liquid the project was unsuccessful. It was soon discovered, however, that brine from this well possessed certain remedial properties for the treatment of rheumatism and there grew up a mineral water industry which has since gained widespread recognition.

*See Chapter I, p. 20.

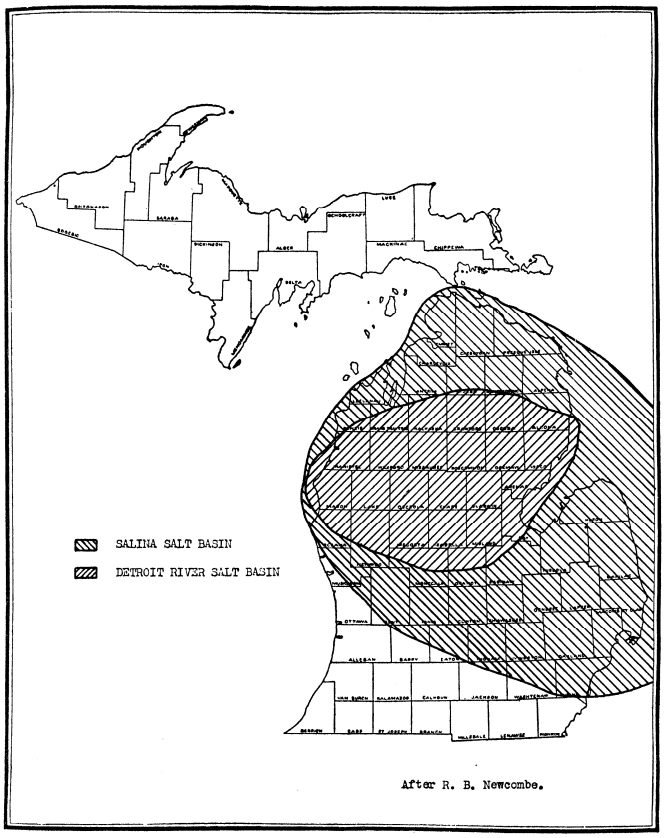


FIGURE 43. AREAS OF SALT PRODUCING FORMATIONS

Salt Deposits Could Supply Entire World Need

In the twenty-five and more years since the commercial development of salt deposits, Michigan has produced a total of 550,000,000 barrels of salt valued at $242,000,000. Still, with all this production, Michigan's reserves of salt and brines have scarcely been touched. Dr. R. A. Smith, the state geologist, makes the statement that Michigan has known deposits of salt which alone could supply the entire needs of the world for thousands of years to come. Michigan's future in the salt industry is safeguarded by vast reserves of high quality and readily obtainable brines. The extent to which the industry in the state will expand and develop depends largely upon the competition which may be expected when the tremendous Permian deposits of the western states, especially Kansas, Oklahoma, Texas and New Mexico, are more fully exploited for commercial production.

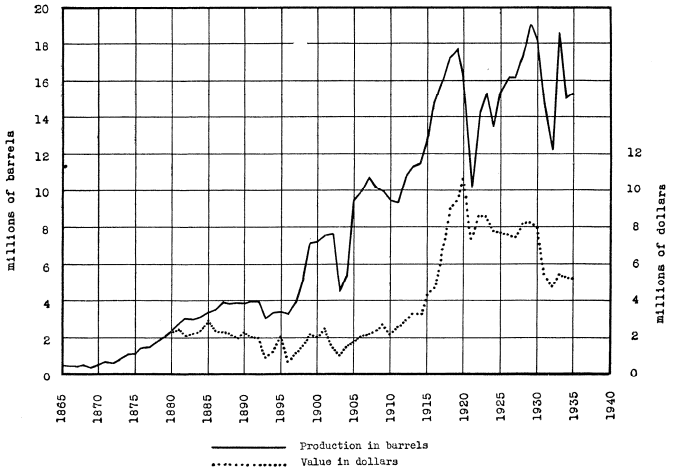


FIGURE 44. PRODUCTION AND VALUE OF SALT IN MICHIGAN

Brines Become Problem to Oil Industry

Since the recent development of Michigan's oil industry, deep wells drilled for petroleum have encountered beds of salt deposits from 700 to 1500 feet thick. Such deposits will produce unlimited supplies of raw material for an indefinite period. Since the development of the oil industry in central Michigan, large quantities of valuable brines, released from wells drilled for petroleum, are annually being wasted. The problem of brine disposal in a manner which will not contaminate surface streams and lakes or pollute sources of drinking water is rapidly becoming more serious. The State Department of Conservation, with a staff of scientific men working in the field, is making a thorough study of this problem in an attempt to control a situation which could easily prove disastrous.

Gypsum

Gypsum First Discovered in Kent County

Gypsum was first discovered in Michigan in 1827 near the mouth of Plaster Creek in Kent County. Its value was not known until ten years later when Dr. Douglass Houghton, the first state geologist, made an examination of beds exposed near Grand Rapids. Grimsley,[6] in his report, states that in the period from "1837 to 1841 gypsum rock was brought from Plaster Creek and ground on a small scale in corn mills." The ledge which supplied the rock varied in thickness from six inches to eight feet.

In 1840 Dr. Houghton again called attention to the outcrops of gypsum in the Grand Rapids area and in the following year, the first mill was erected for the purpose of working the deposits. Although some small amounts of gypsum were manufactured into calcined plaster, the bulk of the material was ground into land plaster, shipped by boat to Detroit and there sold to the farmers for application to the soil. Because of the limited uses to which gypsum was originally adapted the industry made little growth until 1890 when a total of practically 75,000 tons was mined and sold.

Industry Now of Major Importance

With the development of new uses for gypsum and consequent increased demands for the products manufactured therefrom, the industry grew and has become one of major importance in Michigan. From a pioneer enterprise producing less than 500 tons in 1842 the industry has developed to such an extent as to place Michigan among the ranking producers of gypsum in the country. In 1916, the gypsum industry in Michigan reached the million dollar mark with a volume of 457,375 tons mined. In 1924 the state set an all time high with a production of gypsum and gypsum products valued at slightly less than $6,000,000. For several years thereafter the industry continued to maintain a steady high production but with the stagnation of the building trades in 1929 the market dropped. Although there have been wide fluctuations in the amount of gypsum mined from year to year, Michigan crept into second place of production in 1930, a position which it has held ever since.

Principal Mines in Kent and Iosco Counties

The principal gypsum producing areas of Michigan are located at Grand Rapids and Grandville in Kent County and at Alabaster and National City in Iosco County. According to Newcombe[11] "The upper beds of the gypsum series at Grand Rapids are 6 and 12 feet thick respectively and occur near the surface. A third bed in the western part of Grand Rapids averages about 22 feet in thickness with a parting bed of one foot of shale near the middle, and is found at a depth of 60 feet below the surface. At Grandville the quarry exposes an upper bed 11 feet in thickness which is separated from a lower 14 foot bed by four feet of hard limestone and shale."

The upper gypsum bed which is extensively quarried at Alabaster and National City is from 18 to 30 feet thick.

Other Deposits Found

Gypsum deposits of minable thickness have been worked on a small scale in the vicinity of Turner and Twining in Arenac County. Newcombe[10] states that these beds are likewise associated with the Michigan formation but occur at from 50 to 100 feet above the Alabaster bed.*

Gypsum beds in the vicinity of St. Ignace in the Northern Peninsula are described by Grimsley as occurring at Pointe Aux Chenes and in St. Martin's and other nearby islands. These deposits which have been recently correlated with the Salina formation of Silurian age, are reported to have an aggregate thickness of 60 feet. Studies of samples taken from deep wells in the central part of the state show the presence of extensive quantities of gypsum. The reserves of gypsum are practically inexhaustible but, in general, the beds within

the state are so deeply situated as to be of no immediate commercial importance.

FIGURE 45. AREAL EXTENT OF THE GYPSUM PRODUCING DEPOSITS

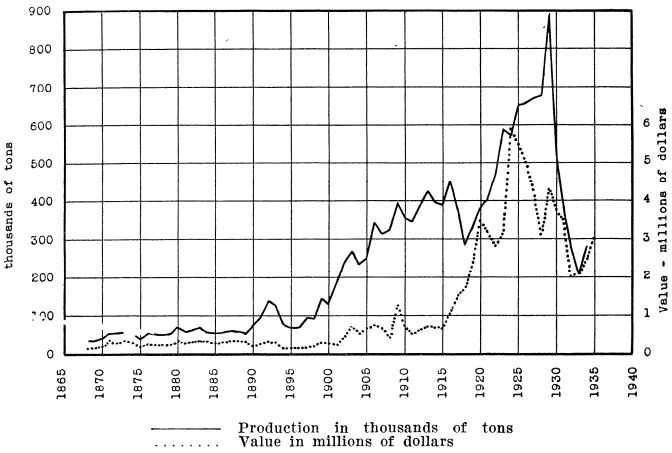


FIGURE 46. PRODUCTION AND VALUE OF GYPSUM IN MICHIGAN

A Growing Industry

The outlook for the gypsum industry in Michigan is favorable. Extensive areas of shallow, workable deposits of high grade material are still available for development. The larger producers of gypsum are ever on the alert to extend the utility of the material and thus create new and more permanent markets for its products. Today the bulk of the calcined gypsum is manufactured into material which finds its way into the channels of the building trades. The welfare of the industry is to a large extent closely linked up with the construction program of the nation. Researches on a broad scale should be carried on to develop new uses for gypsum and its products in an attempt to make the industry more independent of such seasonal and sporadic activities.

*See Chapter I, p. 20.

Coal in Michigan

How Coal Is Formed

The deposits of bituminous coal* which occur in Michigan were formed during the Pennsylvanian period, at a time when the area was an arm of the sea in which swamp-like conditions prevailed. The first stage in the formation of coal is that involved in the development of peat. Peat is partially decomposed organic matter made up of recognizable remains of plant leaves, stems, roots, fibres, spores, etc., more or less intimately interlaced. It is formed by the activity of *anaerobic* bacteria slowly destroying vegetation which is more or less completely submerged in swamp-like basins of water.

If these areas of organic deposits are partially or completely drained so that the peat becomes exposed to the air and *aerobic* (oxygen loving) bacteria have an opportunity to cause complete decay, then the peat is changed into a type of soil referred to as muck. If, on the other hand, the waterlogged peat is gradually buried under accumulations of sediment carried into the basins by rivers from adjacent uplands, it may eventually become subjected to pressures sufficiently great to form coal.

Formation of Coal a Slow Process

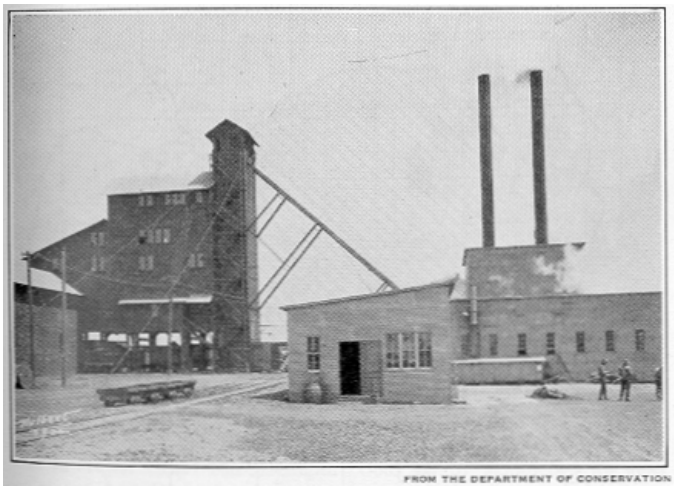
It has been determined that in a region such as that represented by Michigan, peat will form at the rate of approximately one foot in three hundred years. About twenty feet of peat are required to form one foot of compacted bituminous coal so it is readily seen that considerable intervals of time were required for the process of organic accumulation alone. Much longer time was needed to complete the changes from peat to coal.

Coal Mining Began About a Hundred Years Ago

The presence of coal in Michigan was known through drilling records at least fifty years before the deposits were extensively opened up for commercial exploitation. Many of the major discoveries of coal in the Saginaw basin were made during the early sixties in association with the drilling of salt wells. Developments in the coal industry were retarded because during the early days of lumbering operations there was an “inexhaustible supply of pine” which furnished the fuel then required to meet the limited demands of industrial activity.

*See Chapter I, pp. 18, 20.

According to the accounts of the Geological Survey of Michigan[9] the earliest coal mining operations were probably carried on in the vicinity of Jackson in 1835. Active mining of coal was also conducted on a small scale near Grand Ledge in the period from 1838 to 1839. Some small developments took place in the vicinity of Millets in Eaton County during 1858-59 and still later successful operations were begun at Williamston.



47. MINE TIPPLE AND HOISTING HOUSE, RANDALL COAL MINE, NEAR MIDLAND

As the supply of pine slabs from the sawmills gradually diminished, a need developed for other sources of cheap fuel to supply the rapidly developing salt and other industries. In the period from 1895 to 1897 numerous coal mines were developed in the region around Saginaw, Bay City, and St. Charles. A few years later coal deposits were discovered in Huron, Tuscola, and Genesee counties, but these have since been largely worked out and the mines are now abandoned.

Peak of Activity Came Early in Present Century

In the period from 1900 through 1911 there were between 30 and 38 mines in operation in various parts of the state. The peak of production was reached in 1907 when 2,035,858 tons of coal were mined. In this year, however, the average price received for the coal at the mines was $1.80 per ton and the total output was valued at only $3,660,833. In 1920, the eighteen active mines of the state produced a total of slightly less than one and one-half million tons with a value of $7,346,000. During the depression, coal mining slumped decidedly. Only a half dozen mines were in operation during the four years from 1928-1932. In 1931 the six major operating mines delivered a total of 359,403 tons valued at $1,094,000, the lowest production since 1900. A slight improvement in the industry was noted in 1933 when 13 mines on the active list produced 406,741 tons valued at $1,171,000. In 1935, there were about twenty mines in operation with a total production of 628,384 tons valued at $2,017,000.

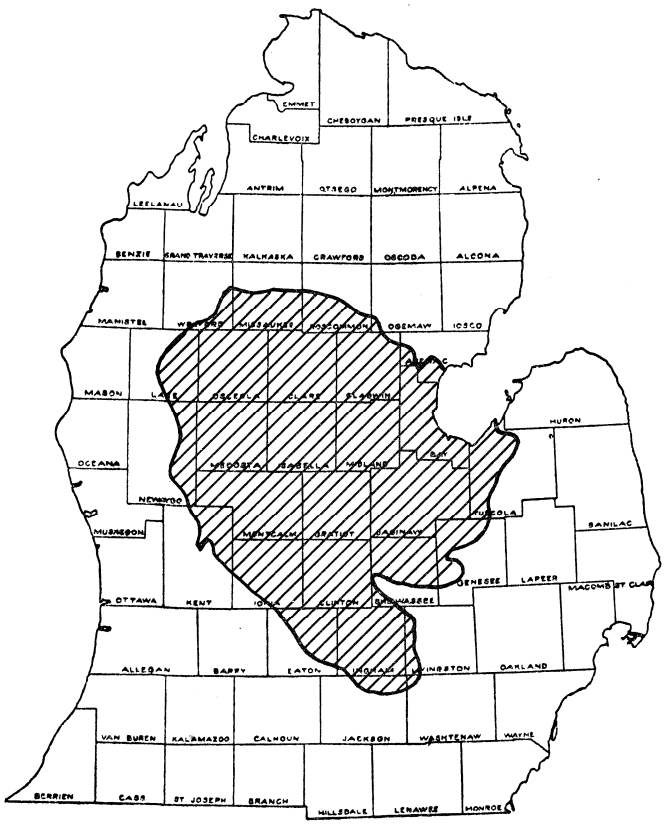


FIGURE 48. LOCATION OF THE COAL BASIN

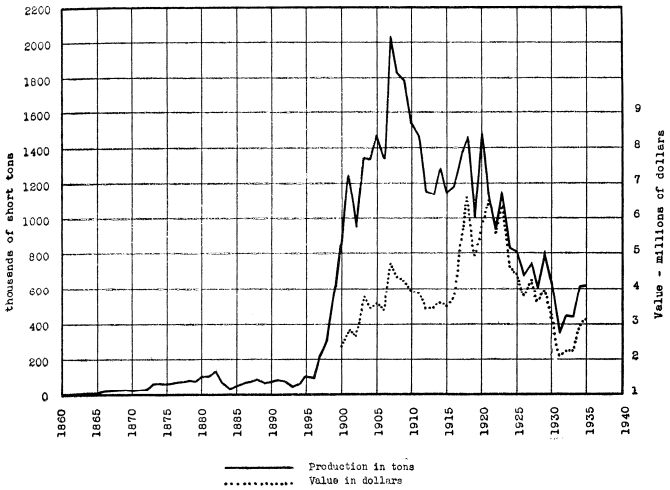


FIGURE 49. PRODUCTION AND VALUE OF COAL IN MICHIGAN

Characteristics of Michigan Coal

It is stated[10] that the Michigan "Coal Basin" comprises an area estimated to include from 6,500 to 11,000 square miles of territory covering all or parts of 29 counties in the central section of the Southern Peninsula, although only about one-third of the beds contain workable coal.[9]

Michigan coal is generally of lower grade and poorer quality than the competing coal from Ohio, West Virginia, and Pennsylvania. It is frequently weak and crumbly and thus tends to slack readily, a property which leads to serious difficulties in shipping and storage. Although the

heat values of Michigan coal are relatively high, ranging from 12,500 to 13,700 B.T.U., there are certain properties such as high sulphur and ash content which tend to place restrictions on its uses.

Most of the mines obtain the coal through underground workings from seams which vary in thickness from two and one-half to live feet. Except in regions where the coal lies near the surface it is unprofitable to mine beds with a thickness of less than 30 inches. In the vicinity of Grand Ledge and Williamston, however, thin seams of coal are mined by open pit methods as a by-product in the quarrying of shale which is employed in the manufacture of brick and tile. During the depression small open pit mines were opened up for the production of coal in the vicinity of Williamston, Mason, and other localized areas.

Although the mining of coal has been an established industry in Michigan for over a hundred years there remain some reserves which have not yet been touched. Much of this reserve coal lies too deeply buried or is found in seams too thin to warrant development under present market conditions.

Oil and Gas

Origin of Petroleum

Geologists are quite generally agreed that petroleum is generated by natural distillation of organic matter included in sediments laid down in ocean basins. Through biochemical changes caused by bacteria the cellulose of the organic material is altered to waxes and fats. The globules of oil thus set free are dragged down to the bottom of the sea along with minute particles of gelatinous (colloidal) clay and lime. These fine sediments are compressed to form stratified oil-bearing deposits of dense bituminous shale and limestone.

The great pressures eventually developed allow the oil to be squeezed out into adjacent layers of porous rock. Once the oil is in the porous rock it is free to migrate either alone or with water and always tends to seek its highest level. If buoyed up by water the oil eventually moves into natural sealed reservoirs where it is gathered into pools.

How Oil Reservoirs Are Formed

Petroleum and gas usually accumulate in the upfolds or anticlines of folded areas, the gas in the summits of the folds and the oil immediately below being held in by the underlying water. The reservoir rock in which the petroleum and gas accumulate must be of a porous material, such as sandstone or fractured limestone. This in turn must be underlain and capped with impervious beds, such as shale, to prevent escape of the lighter oils and gas.

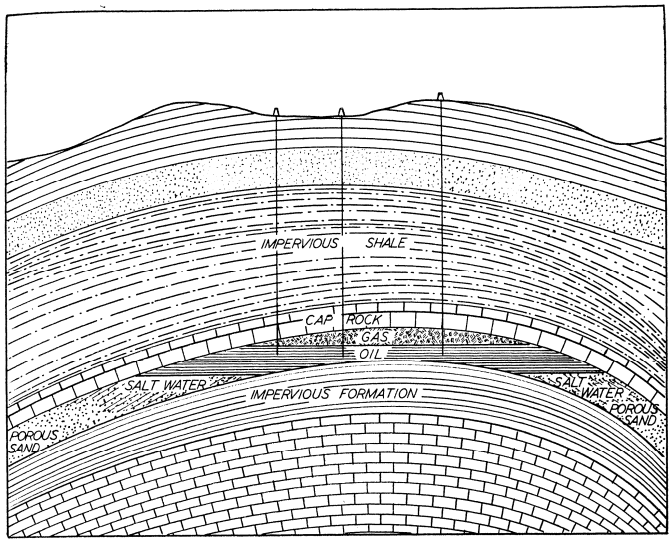


FIGURE 50. AN ANTICLINAL STRUCTURE AND THE RESERVOIR CONDITIONS ESSENTIAL TO THE ACCUMULATION OF OIL AND GAS

Natural Gas Important in an Oil Field

Although gas may occur in a reservoir without oil, it is a rare situation to have oil without gas. It has been estimated that fairly productive sands may contain from 6 to 12 pints of oil to the cubic foot, of which not more than 25 per cent is obtainable unless gas is present to move it under pressure through the pores of the rocks.

Gas is an extremely important agent in oil fields and every effort should be made to conserve and utilize it to the maximum. It functions to decrease viscosity in the oil and to increase the flow of the oil globules through the reservoir rock. Most important of all, the gas in the reservoir supplies the energy necessary to lift the oil from the deeper rock formation to the surface. But as the gas is used up or wasted, pressures in the reservoir decline and expensive pumping operations must eventually be resorted to in order to bring the oil to the surface.

Since gas volume and pressure are so essential for withdrawing oil from the pools, it is important that measures be taken to prevent waste. The gas available in the field should be utilized so as to force the maximum amount of petroleum through the rock and still maintain the highest possible gas-oil ratio of production.

The Petroleum Industry in Michigan

For a number of years prior to 1920, according to Robinson[16] “petroleum in Michigan was produced from a few wells in the Port Huron area. The wells were very small with an initial yield of from three to seven barrels per day, but the yield rapidly decreased to an average of one-half barrel per day.”

Smith18 points out that early explorations for oil in the Port Huron area were begun in 1886. In this period to 1911 about 22 wells were drilled to the west and

northwest of the city and the first commercial production of oil in the state was obtained. The oil in this field was obtained from the Dundee formation* at a depth of 500 to 650 feet. The estimated maximum production of oil from the Port Huron field was 70 barrels per week. By 1920 the output had declined to such an appreciable extent that the wells were abandoned.

The Saginaw Field

Although the possibility of oil in the Saginaw region was pointed out as early as 1902, no tests for oil were made until 1912. In that year a group of business men in Saginaw organized a company and financed the drilling and completion of 10 wells.

Unfortunately, these wells were all drilled just outside of the oil bearing formations, so that production was negligible and the operations were abandoned. In 1925, the Saginaw Prospecting Company drilled a few wells north of the city limits of Saginaw and brought in the first commercial production for that field. The excitement created by this early success was responsible for an oil boom which led numerous other companies to enter the field. By June 1, 1927, 190 wells had been completed and the field was producing its maximum of approximately 1400 barrels per day. A total of over 300 wells were finally drilled in but the output continued to decline rapidly.

The productive life of the Saginaw oil field was relatively short. Because of the extremely rapid development of the oil industry in the Saginaw area, the state was unable to draft and put into effect regulatory measures and laws for the control of drilling operations until it was too late to do any good. Much of the producing oil area was situated directly under the city which led to the wasteful practice of town-lot drilling and excessively close spacing of wells. In some of the area within the city limits the wells were so close together that legs of adjacent derricks intersected each other. Naturally enough, each individual who owned a plot of land in the proven area was interested in having his own oil well and the chief thoughts in the minds of owners, promoters, and operators were those motivated by personal gain.

*See Chapter I, p. 18.

Development of the Saginaw Field an Extravagant Venture

Development of the oil industry in the Saginaw field proved to be a costly and extravagant venture for all who were engaged in its activities. The 300 or more wells which were ultimately completed represented an average investment of practically $10,000 per well. There is no question but that 50 wells systematically spaced in the field could have produced as much or more oil than the 300 which were actually drilled. The natural gas contained in the reservoir was either blown out into the atmosphere or otherwise wantonly destroyed in the wasteful methods employed in drilling. Consequently the pressure in the reservoir was reduced to the point where the oil refused to migrate through the pores of the rocks or to be lifted to the surface under natural pressure. It is doubtful if more than 25 per cent of the available oil in the rock reservoir in the field was actually recovered. The remainder lies “frozen” in the pore spaces and in all probability will never be retrieved.

51. AN OIL WELL RIG

Oil in the Saginaw field was obtained largely from the Berea sandstone* at a depth of slightly more than 1800 feet. Some small production was obtained also from the Traverse and Dundee formations. The wells in the field came in with an initial production of 10 to 90 barrels per day, although one well in the Traverse formation was brought in with an initial output of 500 barrels during the first 24 hours.

In the fall of 1934 a new field was opened up near Birch Run in the southeastern part of Saginaw County. Within the period of a year 19 Berea wells were completed in the area with a daily production exceeding that of the 83 wells then producing oil in the original Saginaw field.

The Muskegon Field Develops Early

The Muskegon oil field began commercial production in December, 1927. In the early stages of development of the field the oil was obtained largely from near the top of the Traverse formation* at depths of 1620 to 1680 feet. In 1928 deeper drilling resulted in the discovery of a much more prolific horizon, the Dundee, about 400 feet below the Traverse formation. Excitement created by large flows of oil and gas from the Dundee formation stimulated drilling activities and by August, 1929, the field had reached its peak of production with an average daily yield of 18,570 barrels. In May, 1932, the average production of the district had declined to 1160 barrels

per day and by 1936 the average production had decreased to 280 barrels per day. Newcombe[11] states that "the largest oil well in the Muskegon district produced about 3000 barrels daily and the largest gas well had an initial flow of 25,000,000 cubic feet". The gas was obtained largely from the upper Traverse formation.

The Muskegon field was developed in much the same way as was that of the Saginaw district. A portion of the field was situated in an area which had been subdivided into town lots. Town-lot drilling resulted in close spacing of wells and a consequent overdrilling of the area. Because of inadequate facilities for handling the gas and the lack of a substantial market to absorb the rapidly growing production much gas was wasted and the life of the field was greatly shortened.

*See Chapter I, p. 20.

Central Michigan Field Extends over Several Counties

The Central Michigan Area consists of a number of individual pools centered largely around the city of Mt. Pleasant and scattered through various parts of Mecosta, Isabella, Midland, Gratiot, and Montcalm counties. This district includes the Mt. Pleasant and East Extension, Porter, Yost-Jasper, Vernon, Leaton, Crystal, Edmore, and Beaverton oil pools and the Austin, Clare, Broomfield, and Six Lakes gas fields.

The discovery well in the district was completed in February, 1928 with an initial production of 100 barrels per day. This well was located in Midland County about 10 miles east of the city of Mt. Pleasant. Drilling soon became very active and the field developed rapidly. Oil in the Mt. Pleasant area is obtained largely from the Dundee formation at an average depth of approximately 3500 feet. The most spectacular development in the Central Michigan area was the discovery of the East Extension (May, 1931). This field has been one of the most productive in the state. The Porter field, discovered late in 1931, at the end of 1935 had produced more oil than any other field thus far developed, practically one-third of the total production of the state up to that period. The Crystal field came into commercial production with the completion of the Durbin well in March, 1935 with an initial flow of 3900 barrels per day. In his report on the Crystal Field, Eddy5 makes the following statement: "From the completion of the discovery well to May, 1937, 123 oil wells, 6 gas wells, and 46 dry holes have been drilled. At the present time May, 1936, there are 24 wells drilling or completing in the area. By May 1, 1936, 4,839,565 barrels of oil had been produced and the field had an average daily production of 8,100 barrels."

The West Branch Field

The West Branch Field in Ogemaw County[12] was discovered in 1933 and next to the Central Michigan area just described was the most productive in Michigan. The total production to August 1, 1936, was 1,083,383 barrels. The 128 active wells on that date were producing about 2300 barrels or an average of 18 barrels per well per day.

Production Fluctuates

In the period of fifty years since the discovery of the first commercial production in the Port Huron area, the petroleum industry in the state has grown to one of considerable importance. In 1935, Michigan produced 15,776,237 barrels of oil and ranked eighth among the oil producing states. During the last quarter of that year the daily average production was greater than that of Pennsylvania, and Michigan became the leading oil producing state east of the Mississippi. During 1936, however, there was a rather serious decline in production but new areas opened up within the last six months give promise of adding considerable to the future output.

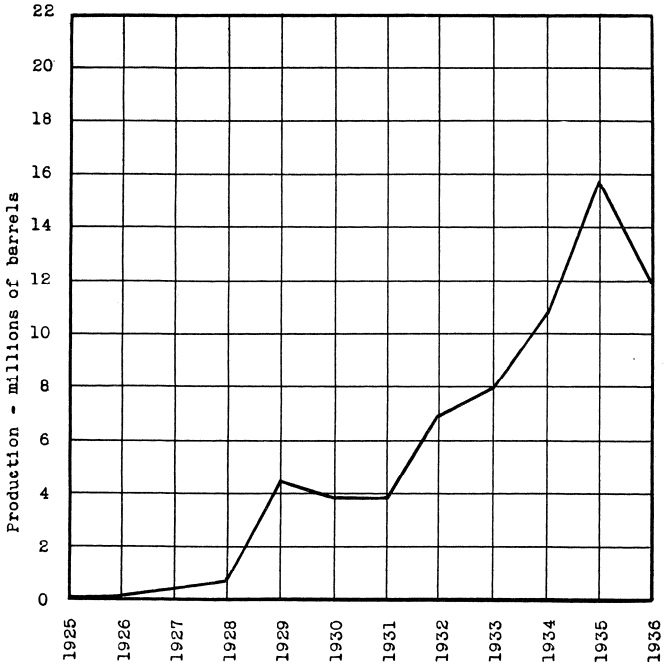


FIGURE 52. PRODUCTION OF OIL IN MICHIGAN

It is the consensus of opinion among the geologists engaged in the job of finding oil bearing structures that the vast reserves of oil in the state have to date been merely touched. The deeper formations give promise of oil and undoubtedly will be developed when the shallow resources have been exhausted. Already the state and the United States Geological Survey are working cooperatively to locate, by electrical methods, these new areas.

Since the development of the original Saginaw field, the state has made rapid strides in placing the oil industry on a substantial basis and has enacted certain laws which will provide for a far-reaching conservation program. Representatives of the major oil companies realize that the future welfare of the industry in Michigan is

dependent upon strict regulation and the enforcement of laws to prevent wastage.

The original policy of drilling expensive offset wells was one of the most extravagant practices in the industry. The most effective remedy to combat the too close spacing of wells and consequent overdrilling in a producing field is a cooperative plan of unitization. A great deal of money which now goes into the well drilling program could be piled up as profit if owners within the limits of a proven field would pool their acreage, drill only a limited number of wells and prorate the expense of development and the returns of production. Such a program, built up on good faith and removed from selfish motives, would be a step forward in the general plan of conservation of natural resources.

Natural Gas in Michigan

The history of the natural gas industry in Michigan is related closely to the development of oil production. The reservoirs of gas which have recently been developed for commercial production were in large measure discovered in fields which were originally drilled for the purpose of finding oil. Mention has already been made of the unwise utilization of gas in the Saginaw field. In the development of the original Muskegon field a limited supply of natural gas was piped to the city of Muskegon to be used for commercial purposes. Still larger amounts were wasted because of extravagant practices employed in drilling, together with utter disregard for conservation policies.

The commercial utilization of natural gas has developed slowly due to uncertainty as to available supplies and the lack of pipe line facilities to transport the gas from the fields. As new areas were opened up it became apparent that the potential reserves in the state were adequate to justify the construction of transmission lines to supply nearby markets with this fuel.

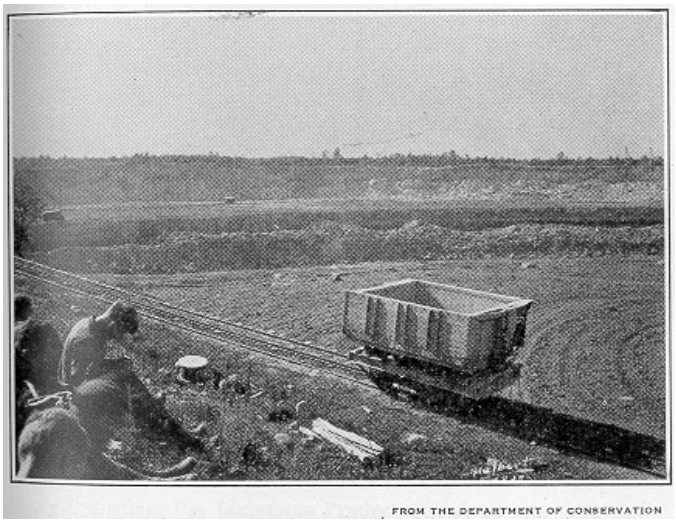
Today a large amount of “dry” gas for commercial purposes is being obtained from the Michigan “stray sand” which lies about 2000 or more feet above the oil producing Dundee limestone. The most important gas producing fields of the state may be listed as follows:*

*Based on information available May 1, 1937.

1. The Austin Field with 21 producing wells is serving the cities of Muskegon and Big Rapids. To the close of January, 1937 a total of 2,438,220,700 cubic feet of gas had been withdrawn.
2. The Broomfield Field had 48 wells on proration on January 31, 1937, and is supplying gas to Saginaw, Bay City, and Midland. The total withdrawal from the Broomfield reservoir at the end of January, 1937 was 4,334,770,500 cubic feet.
3. The Clare Field to the close of 1936 had produced 270,540,300 cubic feet of gas serving the cities of Mt. Pleasant and Clare. Five wells were in production on that date.
4. The Ferris-Crystal Field with five wells on proration at the close of January, 1937 had produced a total of 84,022,200 cubic feet of gas. The gas from this field was used principally in Alma.
5. The Six Lakes field in Hinton, Millbrook, and Belvidere townships had 206 wells on proration on January 31, 1937. The total volume of gas withdrawn to that date was 2,776,028,700 cubic feet. Lansing, Grand Rapids, Saginaw, and Bay City were connected up to the field.
6. The Leaton Field on January 31, 1937, was producing gas from five wells. A total of 78,647,000 cubic feet had been withdrawn for utilization in the city of Mt. Pleasant.
7. The East and West Vernon Fields together had 12 wells on proration on January 31, 1937. 983,757,000 cubic feet had been withdrawn from the area and sent to market in Mt. Pleasant.
8. The New Haven-Sumner Field with 33 wells on proration had produced 208,147,200 cubic feet of gas to the close of January, 1937. This field is connected up to the pipe line which supplies gas to Lansing and Grand Rapids.
9. The Ravenna Field recently opened up near Muskegon with nine wells on proration at the end of January, 1937 had supplied 40,799,900 cubic feet of gas to industries in Muskegon in addition to the 54,856,900 cubic feet which had been withdrawn from the old Muskegon Field to the close of 1936.

The Newest Major Enterprise

The oil and gas industry is one of the newest of the major enterprises in Michigan. It has been responsible for the rejuvenation of a large area in the central part of the state. Extensive drilling operations, the construction of pipe lines for transmission of gas, the development of refining plants, and many other activities directly related to the petroleum industry combined to instill new life in a region which otherwise would have suffered untold hardships during the recent depression. The oil producing areas of the state experienced their greatest boom at a time when other industrial and manufacturing centers were in distress. Many of the oil and gas fields of the state have developed in areas of marginal and submarginal land where agricultural pursuits had been difficult and unrewarding. With the discovery of oil and gas, property values increased and business flourished.



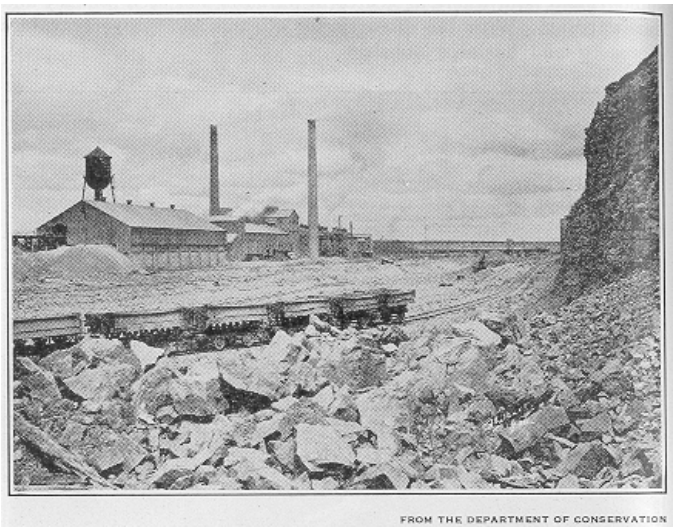
53. LIMESTONE QUARRY, MICHIGAN ALKALI COMPANY, ALPENA

Limestone and Dolomite in Michigan

Although the occurrence of vast deposits of limestone in Michigan has been known since the days of early explorations,* the actual development of the industry did not take place until late in the nineties when it was stimulated by activities involved in the manufacture of cement. The early history of the industry dates back to the burning of limestone in the southeastern part of the state. A number of kilns were erected as early as 1850, in the region of Monroe and Dundee in Monroe County, for the purpose of supplying lime to the markets of Detroit and other nearby cities. Other small kilns for burning lime were erected later in the vicinity of Bellevue and Jackson. These early lime-burning industries were developed chiefly in areas where abundant supplies of wood were available to provide fuel for the operations. With the removal of the forests in the southern part of the state and the consequent settlement of new territory to the north, quarry operations, on a small scale at first, were begun in the region of Thunder Bay and Little Traverse Bay.

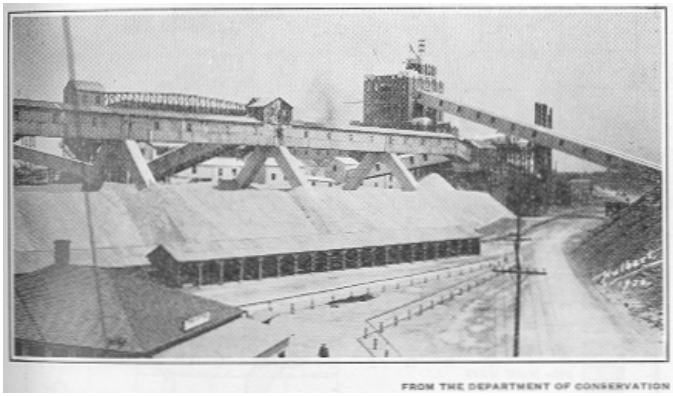
*See Chapter I, p. 18.

The development of the cement industry in the period from 1899 to 1903 was a real stimulus to the limestone operations in the state and several small quarries were opened up at that time to supply growing needs for the material. Owing to the fact that many of the early cement plants of the state utilized marl instead of limestone in the manufacture of the product, the limestone industry was slow in making definite progress. Smith[17] states that in the period between 1899 and 1901, the so-called “boom” years of the Portland Cement industry in Michigan, twenty companies were organized for the purpose of manufacturing cement from marl. Only ten of the companies reached the productive stage and but five were in operation when his report was written in 1915. In the period from 1896 to 1915 thirty-four different cement plants had been projected or built in the state but only twelve were actually producing cement in 1915.



54. LIMESTONE QUARRY AND CEMENT PLANT. PORTLAND CEMENT COMPANY, PETOSKEY

In his elaborate report on marl, Hale[7] presents a very interesting picture of the origin and occurrence of marl and its use in the manufacture of cement. During the early stages of its history the marl-cement industry flourished. But when the rotary kilns, with their much greater capacities, finally replaced the old vertical kilns it was found more economical to employ ground limestone and the use of in oil became a subordinate factor in the cement industry. At the present time there are only three plants in the state which make any attempt to utilize marl in the manufacture of cement. Two of these plants are located at Coldwater and the third is at Fenton.



55. CRUSHING AND DISTRIBUTING PLANT, MICHIGAN LIMESTONE AND CHEMICAL PLANT, ROGERS CITY

Many Industries Use Limestone Products

Limestone has a variety of uses and finds its way into many channels of industrial activity. Michigan limestones, by virtue of their high purity, are especially adapted for use in the manufacture of chemicals and as a blast furnace flux in the manufacture of steel. According to Poindexter[15] approximately 50 per cent of the limestone produced in Michigan is sold for flux,

which means that the industry in the state reflects to a large degree the activities in the steel mills. A large portion of the limestone quarried is employed in the manufacture of Portland cement which is utilized in the building trades and for road construction. Considerable quantities of Michigan limestone are used in the manufacture of calcium carbide, alkalies, and various chemical compounds. Because of the relative thinness of individual beds and the jointed and fractured character of the formations, it is difficult to obtain large blocks of the stone suitable for construction purposes.

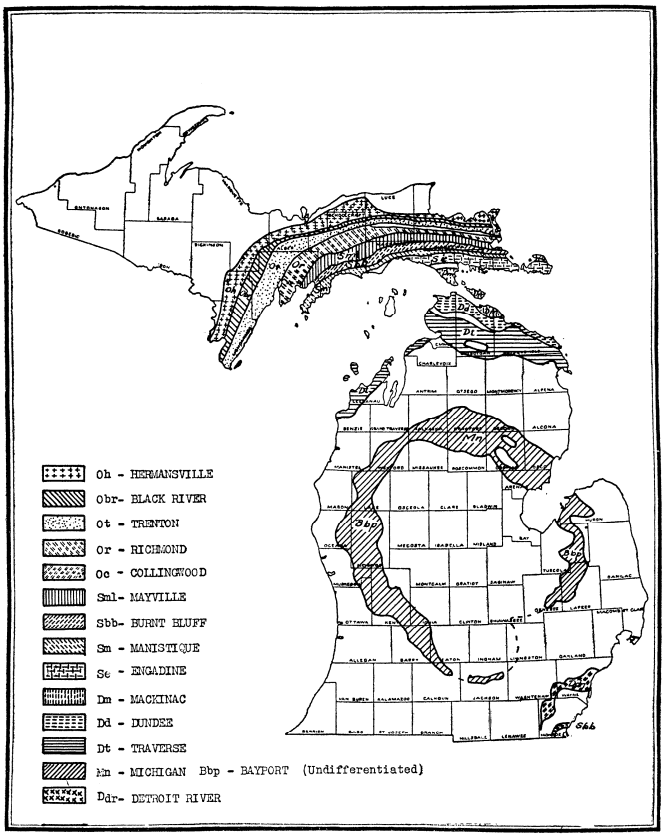


FIGURE 56. AREAL EXTENT OF LIMESTONE AND DOLOMITE FORMATIONS

Large deposits of high-grade limestone and dolomite occur in many areas throughout the state. Quarrying operations, however, are more or less restricted to those localities near the shores of the Great Lakes where facilities for cheap transportation by water are available. The most important quarry operations in the Southern Peninsula are located at Afton, Alpena, Bayport, Monroe, Petoskey, Presque Isle, Rogers City, and Sibley. In the Northern Peninsula, pure dolomite is being quarried from an extensive belt of exposed formations in Chippewa, Mackinac, and Schoolcraft counties. Minor operations are centered in Delta and Dickinson counties.

Revival of Trade Will Bring Increased Production

In 1933 Michigan ranked third among the states in volume of production but sixth in value owing to the low prices received for fluxing and chemical limestones. The peak of production was reached in 1929 when a total of 13,572,010 tons of limestone valued at $8,425,261 was sold on the market. During the depression years of 1931 to 1934 the limestone industry suffered a decided setback with production less than half normal. In 1935 Michigan produced 8,175,430 tons of limestone valued at $4,159,915. Renewed activities in the building trades, steel industry, road construction, and chemical plants, will undoubtedly be reflected in a revival of the limestone industry and a consequent increase in production.

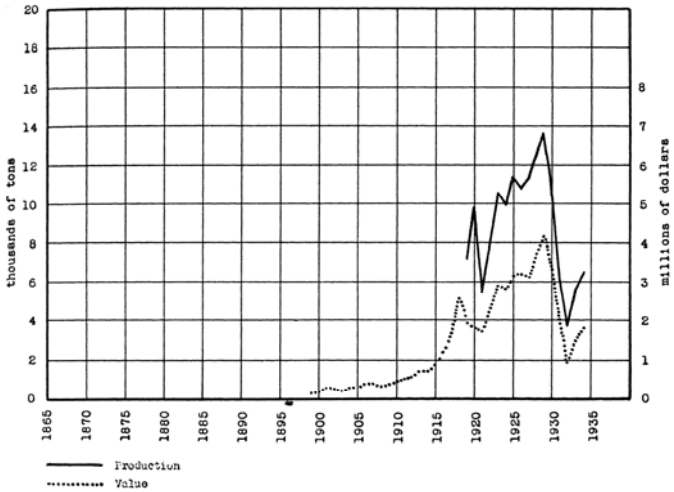


FIGURE 57. PRODUCTION AND VALUE OF LIMESTONE IN MICHIGAN

Michigan's deposits of high grade limestone and dolomite are of sufficient extent to insure a long time activity. The future of the industry in the state is well protected by virtue of the fact that extensive workable deposits are situated in close proximity to cheap lake transportation. The opening up of large quarries in the interior deposits of the state will undoubtedly be limited by freight charges in rail transportation.

Gravel and Sand

The most important sources of gravel and sand* in Michigan are found in association with deposits formed by the activities of waters which flowed out from the melting ice during the recession of the glaciers which at one time covered this section. The commercial gravels are obtained chiefly from stratified deposits which were laid down in the form of outwash plains, valley trains, eskers, kames, and lacustrine plains.

Where Gravel Is Found

With the exception of valley trains, which are, for the most part, localized in old pre-glacial valleys in certain restricted areas of the Northern Peninsula, these features are widely distributed throughout the state and afford readily accessible supplies of reasonably cheap gravel and sand for the general construction and road building markets.

Outwash plains are generally level deposits of interbedded gravel and sand usually of widespread

extent and constitute in large part the so-called “jack pine plains” of the state.

Valley train deposits are composed of stratified sand and gravel usually developed in the form of long, tenuous trains of sediment which may extend for miles down the valley ways. Valley trains are of common occurrence in various portions of the western half of the Northern Pensinsula and are especially well developed in the Crystal Falls-Iron River section of Iron County.[1]

Eskers are long narrow strings of sand and gravel, commonly referred to as “hogbacks” or “Indian trails”. The most noteworthy example is the Mason esker which has its source in Mount Hope cemetery near Lansing and extends southward as a serpentine ridge for a distance of practically twenty miles through and slightly beyond the town of Mason.

Kames are small rounded knobs of stratified sand and gravel somewhat restricted in extent which contribute important supplies of assorted material suitable for road construction and other commercial purposes.

*See Chapter I, pp. 22 and 31.

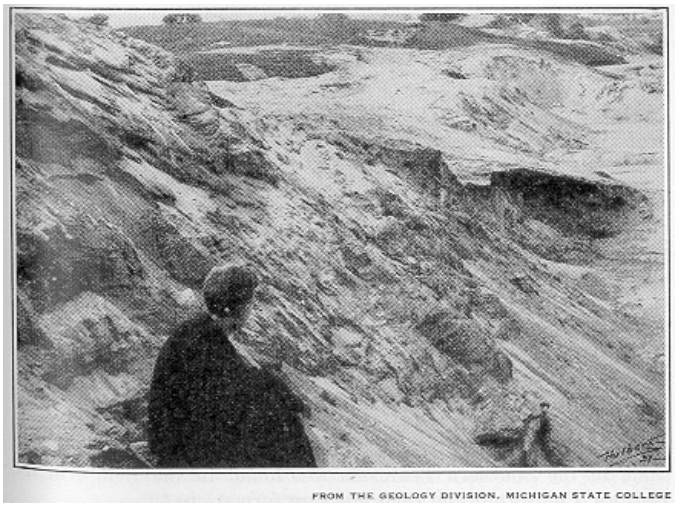
58. ALTERNATING BEDS OF GRAVEL AND SAND IN VALLEY-TRAIN DEPOSIT, BERKSHIRE CAVE, NEAR IRON RIVER

The lacustrine deposits of sand and gravel are so named because they were formed in the beach lines, off-shore bars, and wave-built shores of former lakes. They occur as long, tenuous ridges which may extend for miles across the level stretches of old abandoned lake plains.

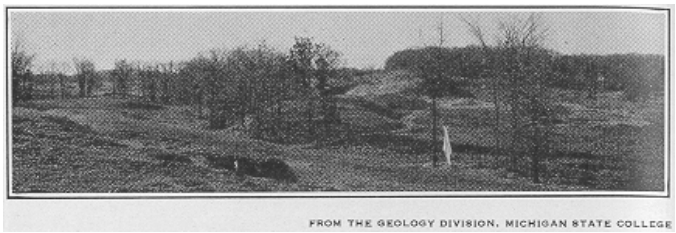
Michigan Sand and Gravel Used in Making Concrete

A large percentage of the gravel and sand produced in Michigan is used in the manufacture of the concrete employed in highway and building construction. It may well be said that Michigan owes its splendid network of highways to the widespread occurrence and relative abundance of gravel deposits.

Extensive undeveloped deposits of gravel and sand scattered over the surface of the state assure for Michigan a supply adequate to meet the ever increasing demands of future industrial growth and development. The Geological Survey in cooperation with the Highway Department of the state is constantly searching out commercial deposits in those areas where new highway systems are being projected.



59. SECTION OF MASON ESKER, SOUTHEAST OF LANSING, SHOWING STRATIFIED LENSES OF GRAVEL AND SAND



60. A CHAIN OF GLACIAL KAMES, NORTHEAST OF BATH

Shales

Shale Used in Manufacture of Vitrified Products

Shale may be defined as consolidated clay or mud. It is formed of finely divided colloidal material deposited in basins such as oceans and lakes. Shale deposits of marine origin are widely distributed throughout much of the Southern Peninsula, but surface exposures of workable beds are somewhat limited. The shale deposits of Michigan are used largely in the manufacture of vitrified products such as brick, tile, and pottery, and to a great extent in the cement industry. The most important sources of commercial shale in the Southern Peninsula are found in the Bell, Antrim, Bedford, Coldwater, and Coal Measure formations.*

*See Chapter I, pp. 18-20.

The Bell shale is a soft blue shale, plastic in character. It occurs in beds ranging in thickness from 60 to 80 feet and appears in outcrops in various localities in Alpena and Presque Isle counties. Brown[3] states that “the Bell shale is fine grained and plastic and seems to be suitable for brick, tile and possibly some pottery uses

where a red burning clay is not objectionable". The Bell shale exposed in the vicinity of Alpena was at one time quarried and utilized by the Huron Portland Cement Company in the manufacture of cement. At present it is not used for this purpose.

61. BRICK PLANT AND SHALE QUARRY, WILLIAMSTON

The Antrim-Bedford shales are black at the bottom and generally grade into a bluish and grayish color at the top. They frequently contain pyrite which is responsible for the rusty hues assumed by the material upon weathering. The Antrim-Bedford shales vary in thickness from 150 to 575 feet. They are exposed as outcrops in Charlevoix, Antrim, Emmet, and Cheboygan counties. Antrim shale is quarried at Paxton in Alpena County for use in the manufacture of cement by the Huron Portland Cement Company. Bedford shale, obtained from the Ellsworth quarry in Antrim County, is utilized in the cement industry of the Petoskey Portland Cement Company near Petoskey and the Newaygo Portland Cement Company at Newaygo. According to Poindexter,[15] "tests show the Antrim shale to be good material for common brick, face brick and tile if treated to develop plasticity and carefully burned". Brown[3] states that "the lower shale is bituminous and must be carefully oxidized in burning".

The Coldwater formation is the thickest series of shale beds in Michigan. It ranges from 700 to 1000 feet in thickness. The shale is typically blue gray to greenish in color, although dark gray beds occur locally. The Coldwater shales are exposed near water level along the shore of Lake Huron between Forestville and White Rock. In Branch County it is quarried at Coldwater and Union City for use in cement manufacture. The shale possesses chemical and physical properties which make it suitable for the manufacture of brick and tile.

The Coal Measure shales of the Saginaw formation are exposed in the vicinity of Grand Ledge, Jackson, Corunna, and Williamston where they are employed in the manufacture of various types of vitrified products. Where they occur in sufficient quantities these shales are invariably suitable for brick, tile, and similar vitrified products.

Clays

Clays are widely distributed through various parts of both peninsulas. The *lacustrine* clays, formed in basins of present or former lakes, are usually stratified and in many areas the beds contain thin layers of silt and fine sand. Relatively pure deposits of these clays are found in the beds of the ancestral Great Lakes and in some localities are of sufficient extent to be commercially important. They are, as a rule, surface deposits, often highly plastic and suitable for brick and earthenware.

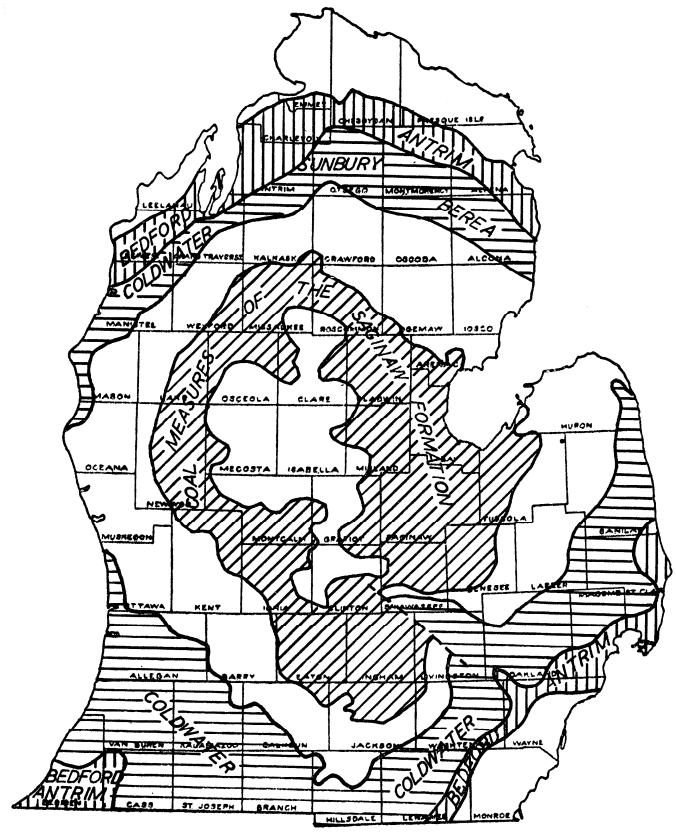


FIGURE 62. EXTENT OF SHALE FORMATIONS
There is no shale in the Upper Peninsula

Glacial clays were deposited in the wake of melting ice sheets. They are variable in chemical composition and physical properties and usually occur in deposits which consist of inter-mixtures of all types of material ranging from the finest rock flour to boulders which measure many feet in diameter. Clays of glacial origin are usually tough, dense, and gritty and quite often contain numerous pebbles and larger stones. Workable deposits of pure, plastic glacial clays are relatively small and of little commercial value.

The deposits of marine shales and of lacustrine and glacial clays in Michigan have been exploited only in those areas where developed markets are near at hand. Vast potential reserves of high grade commercial shales and clays lie so far removed from possible areas of consumption that no attempt has been made to utilize

them. Long transportation hauls place a prohibitive cost on both raw material and the manufactured products.

Helpful Reading

1. Bergquist, S. G.—*Valley-Train Deposits in the Northern Peninsula of Michigan*. Papers of the Michigan Academy of Science, Arts and Letters. Vol. XX. 1934-1935. p. 439.
2. Brooks, T. B.—*Geological Survey of Michigan*. Volume I, Part I, Iron Bearing Rocks (Economics), p. 19. 1873. Lansing: Geological Survey Division, Department of Conservation.
3. Brown, George G.—*Clays and Shales of Michigan*. Michigan Geological Survey, Publication 36, Geological Series 30, 1924, p. 194. Lansing: Geological Survey Division, Department of Conservation, 1924.
4. Cook, Chas W.—*The Brine and Salt Deposits of Michigan*. Michigan Geological and Biological Survey, Publication 15, Geological Series 12, 1913. Lansing: Geological Survey Division, Department of Conservation.
5. Eddy, G. E.—*Geology of the Crystal Oil Field*. Michigan Geological Survey, Progress Report Number 1, July, 1936. p. 2. Lansing: Geological Survey Division, Department of Conservation.
6. Grimsley, G. P.—*The Gypsum of Michigan*. Geological Survey of Michigan. Volume IX. Part II. p. 43. Lansing: Geological Survey Division, Department of Conservation, 1904.
7. Hale, David J.—*Marl and Portland Cement*. Michigan Geological Survey, Vol. VIII, Part III, 1903. Lansing: Geological Survey Division, Department of Conservation.
8. Houghton, Douglass—*First Annual Report to the Legislature, 1838*. Lansing, Michigan: Michigan Historical Commission, 1928.
9. Lane, A. C.—*Coal of Michigan*. Michigan Geological Survey, Vol. VIII, Part II, pp. 143-144. Lansing: Geological Survey Division, Department of Conservation.
10. Newcombe, R. B.—*Mineral Resources of Michigan with Statistical Tables of Production and Value of Mineral Products in Michigan*. Michigan Geological Survey, Publication 37, Geological Series 37, Geological Series 31, 1928. p. 103. Lansing: Geological Survey Division, Department of Conservation.
11. Newcombe, R. B.—*Oil and Gas Fields of Michigan*. Michigan Geological Survey, Publication 38, Geological Series 32, 1933. p. 136. Lansing: Geological Survey Division, Department of Conservation.
12. Newman, E. A.—*Geology of Ogemaw County and West Branch Oil Field*. Michigan Geological Survey, Progress Report Number 2, August, 1936. p. 10. Lansing: Geological Survey Division, Department of Conservation.
13. Osgood, W.—*Production and Value of Minerals and Mineral Products in Michigan*—1930 to 1934 and Prior Years, Michigan State Geological Survey. Statistical Summary, Report No. 2. 1936, Chapter on the Iron and Copper Industries. Lansing: Geological Survey Division, Department of Conservation.
14. Poindexter, O. F.—*Mineral Products in Michigan*. Michigan Geological Survey, Publication 37, Geological Series 31, 1928. p. 67. Lansing: Geological Survey Division, Department of Conservation.
15. Poindexter, O. F.—*"Stone"—Production and Value of Minerals and Mineral Products in Michigan.* Michigan Geological Survey, Statistical Summary, Report No. 2, 1936. p. 26. Lansing: Geological Survey Division, Department of Conservation.
16. Robinson, W. I.—*The Possibilities of Oil and Gas in Michigan.* Michigan Geological Survey, Publication 32, Geological Series 26, 1922. p. 103. Lansing: Geological Survey Division, Department of Conservation.
17. Smith, R. A.—*Limestones of Michigan*. Michigan Geological and Biological Survey, Publication 21, Geological Series 17, 1915. p. 340. Lansing: Geological Survey Division, Department of Conservation.
18. Smith, R. A.—*The Occurrence of Oil and Gas in Michigan*. Michigan Geological and Biological Survey, Publication 14, Series 11, 1912, p. 50. Lansing: Geological Survey Division, Department of Conservation.
19. U. S. Department of the Interior—*Minerals Yearbook.* Washington, D. C: U. S. Department of the Interior, Bureau of Mines, p. 380. 1936.
20. Winchell, Alexander—*Salt*. First Biennial Report of the Progress of the Geological Survey of Michigan, pp. 165-193. 1860.

GENERAL BIBLIOGRAPHY

Adams, James Truslow—*The Epic of America*. Boston: Little, Brown & Co., 1931.

Adjustment Service Reports. New York: American Association for Adult Education, 60 East 42nd street, 1935. 12 pamphlets.

Bagley, William Chandler—*Education, Crime and Social Progress*. (Chap. IV and V). New York: The Macmillan Co., 1931.

Barnes, Harry Elmer and David, Henry—*History of Western Civilization*, 2 vol. New York: Harcourt, Brace & Co., Inc. 1935.

Beard, Charles A.—*A Charter for the Social Sciences in the Schools*. Chicago: Charles Scribner's Sons, 1932.

Bruner, Herbert B.—*Some Suggestions for the Study of Modern Problems*. New York: Bureau of Publications, Teachers College, Columbia University, 1934.

Bryan, Malcolm H. and Askew, Thomas J.—*Readings to Accompany a Course on Contemporary Georgia*. Athens: University of Georgia, 1935.

California State Curriculum Commission—*Teachers' Guide to Child, Development for Kindergarten and Primary Teachers*. Sacramento, California: Department of Public Instruction, 1930.

California State Curriculum Commission—*Teachers' Guide to Child Development in the Intermediate Grades*. Sacramento, California: Department of Public Instruction, 1936.

Caswell, H. L. and Campbell, D. S.—*Curriculum Development*. New York: American Book Co., 1935.

Coe, George Albert—*Educating for Citizenship*. pp. 1-37, 177-200. New York: Charles Scribner's Sons, 1932.

Counts, George Sylvester—*Dare the School Build a New Social Order?* New York: John Day Co., Inc., 1932.

Counts, George Sylvester—*The Social Foundations of Education*. New York: Charles Scribner's Sons, 1934.

Dewey, John—*Liberalism and Social Action*. Chap. III. New York: G. P. Putnam's Sons, 1935.

Dewey, John—*The Child and the Curriculum*. Chicago: University of Chicago Press, 1902.

Draper, E. M.—*Principles and Techniques of Curriculum Making*. New York: D. Appleton-Century Company, 1936.

Everett, Samuel—*Democracy Faces the Future*. New York: Columbia University Press, 1935.

Frayser, Mary E.—*The Play and Recreation of Children and Youth*. Bulletin No. 275. Clemson College, South Carolina: Clemson Agricultural College, 1931.

Harap, Henry—*The Technique of Curriculum Making*. New York: The Macmillan Co., 1928.

Hart, Joseph Kinmont—*A Social Interpretation of Education*. Chap. XV and XXXV. New York: Henry Holt & Co., c 1929.

Hawthorn, Horace—*The Sociology of Rural Life*. New York: The Century Co., 1926.

Judd, Charles Hubbard—*Education and Social Progress*. New York: Harcourt, Brace & Co., c 1934.

Judd, Charles Hubbard—*Problems of Education in the United States*, pp. 6-36. New York: McGraw-Hill Book Co., Inc., 1933.

Kilpatrick, W. H.—*Education for a Changing Civilization*. New York: The Macmillan Co., 1927.

Kilpatrick, W. H.—*The Educational Frontier*. New York: The Century Co., c. 1933.

Kilpatrick, W. H.—*Education and the Social Crisis*. New York: Liveright Publishing Corp., 1932.

Koopman, G. Robert (editor)—*Helping Children Experience the Realities of the Social Order*. Chapter IX, *Excursions;* Chapter X, *Local Resources Survey and Social Planning;* Chapter XI, *Ann Arbor's Adjustment.* Ann Arbor: Ann Arbor Public Schools, 1931.

Leisure for Living. Bulletin No. 18—II. Washington, D. C.: U. S. Office of Education, 1936.

Leven, Maurice and others—*America's Capacity to Consume*. Washington, D. C.: The Institute of Economics of the Brookings Institution, 1931.

Merriam, W. B.—"Field Work as a Factor in Dynamic Geography." *Journal of Geography*, Vol. 34, April, 1935, pp. 157-160. Chicago: National Council of Geography Teachers.

Myers, G. E.—*The Problem of Vocational Guidance*. New York: The Macmillan Co., 1927.

National Education Association, Department of Elementary School Principals. *Fourteenth Yearbook*. "Socializing Experiences in the Elementary School." Washington, D. C.: National Education Association, 1935.

National Education Association, Department of Superintendence. *Fourteenth Yearbook*. "The Social Studies Curriculum". Washington, D. C.: National Education Association, 1936.

National Resources Board (Functions now under National Resources Committee)—*Report of December 1, 1984*. Washington, D. C.: U. S. Government Printing Office, 1934.

National Society for the Study of Education—*Twenty-sixth Yearbook, Part II*. "Foundations of Curriculum Making." Bloomington, Ill.: Public School Publishing Company, 1926.

National Society for the Study of Education—*Twenty-second Yearbook, Part II*, "Problems of Contemporary Life as a Basis for Curriculum Making in the Social Studies." Harold O. Rugg. Bloomington, Ill.: Public School Publishing Co., 1923.

Norton, John Kelley and Norton, Margaret M.—*Foundations of Curriculum Building*. pp. 4-59. Boston: Ginn & Co., 1936.

Ogburn, William F.—*Recent Social Changes in the United States Since the War and Particularly in 1927*. Chicago: University of Chicago Press, 1929.

Pennsylvania State Department of Public Instruction—*One Teacher Elementary School Course of Study and Handbook of Organization*. Harrisburg, Pa.: Department of Public Instruction, 1935.

Polakov, Walter Nicholas—*The Power Age: Its Quest and Challenge*. New York: Covici, Friede, Inc., 1933.

Porter, Martha Peck—*The Teacher and the New School*. Yonkers, N. Y.: World Book Company, 1930.

Rugg, Harold Ordway—*American Life and the School Curriculum*. Boston: Ginn & Co., 1936.

Rugg, Harold Ordway—*Culture and Education in America*. New York: Harcourt Brace & Co., c. 1931.

Rugg, Harold Ordway and Shumaker, Ann—*The Child-Centered School Chicago:* World Book Co., c 1928.

Sanchez, George I.—*Mexico—A Revolution by Education*. New York: Viking Press, 1936.

Sheppard, Muriel—*Cabins in the Laurel*. Chapel Hill: University of North Carolina Press, 1935.

Steffansson, Vilhjalmur—*The Friendly Arctic*. New York: The Macmillan Co., 1921.

Taylor, Carl C.—*Rural Sociology*. New York: Harper & Bros., 1926.

U. S. Department of the Interior. *Conservation in the Education Program*. Bulletin 1937, No. 4. Washington, D. C.: U. S. Department of the Interior, Office of Education.

Vocational Guidance and Junior Placement. U. S. Children's Bureau, Publication No. 149. Washington, D. C.: U. S. Government Printing Office, 1925.

Vocational Guidance. White House Conference on Child Health and Protection. New York: The Century Co., 1932.

Zimmerman, Erich Walter—*World Resources and Industries*. New York: Harper & Bros., 1933.

Some Novels about Life in Michigan

Compiled by William Webb, Public Library, Flint

Armstrong, H. H.—*Zell*. New York: Alfred A. Knopf, Inc., 1921.

Atkinson, Eleanor—*Hearts Undaunted*. New York: Harper & Bros., c 1917.

Baker, R. R.—*Red Brother*. Ann Arbor, Michigan: George Wahr, c. 1925.

Brill, E. C.—*When Lighthouses Are Dark*. New York: Henry Holt & Co., Inc., 1921.

Brill, E. C—*White Brother*. New York: Henry Holt & Co., Inc., 1932.

Brody, Catherine—*Nobody Starves*. New York: Longmans, Green & Co., 1932.

Catherwood, M. H.—*Mackinac and Lake Stories*. New York: Harper & Bros., 1899.

Clark, J. W.—*In the Sight of God*. Chicago: Washington Book Co., 1924.

Crowley, M. C.—*Daughter of New France*. Boston: Little, Brown & Co., 1901.

Curwood, J. O.—*Courage of Captain Plum*. New York: Grosset, 1919.

De Jong, D. C—*Belly Fulla Straw*. New York: Alfred A. Knopf, Inc., 1934.

Detzer, Karl W.—*Pirate of the Pine Lands*. Indianapolis: Bobbs-Merrill, c. 1929.

Drago, H.—*Where the Loon Calls*. New York: Macauley Co., 1928.

Ford, R. C.—*Sandy Macdonald's Man*. Lansing, Mich.: Michigan School Service, Inc., c 1929.

Pox, F. M.—*Magic Canoe*, New York: Laidlaw Bros., Inc., 1930.

Fox, F. M.—*Nancy Davenport*. Chicago: Rand McNally & Co., c 1928.

Frederick, J. T.—*Greenbush*. New York: Alfred A, Knopf, Inc., 1925.

Fuessie, Newton—*Gold Shod*. New York: Boni & Liveright Publishing Corp., 1921.

Genung and Hayes—*Valiant Dust*. New York: Lee Furman, Inc., 1936.

Gilman, M.—*Fig Leaves*. New York: Siebel Publishing Co., 1925.

Gingrich, A.—*Cast Down the Laurels*. New York: Alfred A. Knopf, 1935.

Hamlin, M. C. W.—*Legends of Le Detroit*. Detroit: T. Nourse, 1884.

Harriman, K. E.—*Ann Arbor Tales*. Philadelphia: Jacobs, 1902.

Harriman, K. E.—*The Girl Out There*. Philadelphia: Jacobs, c 1906.

Herrman, John—*Summer Is Ended*. New York: Covici, Friede, Inc., 1932.

Hoover, Bessie R.—*Opal, sequel to Pa Flickinger's Folks*. New York: Harper and Bros., 1910.

Hoover, Bessie R.—*Pa Flickinger's Folks*. New York: Harper & Bros., 1909.

Hoover, Bessie R.—*Rolling Acres*. Boston: Small, Maynard, 1922.

Kelland, C. B.—*Steadfast Heart*. New York: Harper & Bros., 1921.

Lange, D.—*Silver Island of the Chippewas*. New York: Lothrop, Lee & Shepard, c 1913.

Lewis, Janet—*The Invasion*. New York: Harcourt Brace & Co,, 1932.

McCallum, M. R.—*Tents of Wickedness*. New York: D. Appleton-Century Co., Inc., 1928.

McClinchey, Florence E.—*Joe Pete*. New York: Henry Holt & Co., Inc., 1929.

McHarg, William—*The Indian Drum*. Boston: Little Brown & Co., 1917.

Matson, Norman—*Day of Fortune*. New York: The Century Co., 1928.

Merwin, Samuel—*His Little World*. New York: A. S. Barnes & Co., 1903.

Munroe, Kirk—*At War with Pontiac*. New York: Charles Scribner's Sons, c 1895.

Orr, M. David-—*White Gold*. Detroit: Capper, Harmon, Slocum, Inc., 1936.

Pound, Arthur—*Once a Wilderness*. New York: Beynal & Hitchcock, Inc., 1934.

Pratt, E. B. A.—*Seedtime and Harvest* by Eleanore Blake. New York: G. P. Putnam's Sons, 1935.

Rankin, Mrs. Carroll W.—*Adopting of Rose Marie*. New York: Henry Holt & Co., Inc., 1908.

Rankin, Mrs. Carroll W.—*Castaways of Pete's Patch*. New York: Henry Holt & Co., Inc., 1911.

Rankin, Mrs. Carroll W.—*Cinder Pond*. New York: Henry Holt & Co., Inc., 1915.

Rankin, Mrs. Carroll W.-—*Dandelion Cottage*. New York: Henry Holt & Co., Inc., 1904.

Rankin, Mrs. Carroll W.—*Finders Keepers*. New York: Henry Holt & Co., Inc., 1930.

Rankin, Mrs. Carroll W.—*Girls of Gardenville*. New York: Henry Holt & Co., Inc., 1906.

Rankin, Mrs. Carroll W.—*Gypsy Nan*. New York: Henry Holt & Co., Inc., 1926.

Ross, M. I.—*Kaga's Brother*. New York: Harper & Bros., 1936.

Severance, H. O.—*Michigan Trailmakers*. Ann Arbor, Mich.: George Wahr, 1930.

Skinner, H. D.—*Heart and Soul*. New York: Harper & Bros., 1901.

Smith, G. P.—*Invincible Surmise*. Boston: Houghton-Mifflin, 1936.

Steele, James—*The Conveyor*. London, W.C.I, England: Martin Lawrence, Ltd.

Taylor, B. F.—*Theophilus Trent*. Chicago: Griggs, 1887.

Thwing, Eugene—*The Man from Red Keg*. New York: A. L. Burt, Inc., 1903.

Thwing, Eugene—*The Red Keggers*. New York: A. L. Burt, Inc., 1903.

Titus, Harold—*Below Zero*. Philadelphia: Macrae-Smith, 1932.

Titus, Harold—*Black Feather*. Philadelphia: Macrae-Smith, 1936.

Titus, Harold—*Code of the North*. Philadelphia: Macrae-Smith, 1933.

Titus, Harold—*Flame in the Forest*. Philadelphia: Macrae-Smith, 1933.

Titus, Harold—*Man from Yonder*. Philadelphia: Macrae-Smith, 1934.

Titus, Harold—*Timber*. New York: A. L. Burt, Inc., 1922.

Waldo, Harold—*Magic Midland*. Garden City, N. Y.: Doubleday, Doran & Co., Inc., 1923.

Waldron, Webb—*Road to the World*. New York: The Century Co., 1922.

Walker, Mildred—*Fireweed*. New York: Harcourt, Brace & Co., 1934.

White, S. E.—*The Riverman*. Garden City, N. Y.: Doubleday, Doran & Co., Inc., 1908.

Whitlock, Brand—*Stranger on the Island*. New York: D. Appleton-Century Co., Inc., 1933.

Williams (Whitney), Mrs. Elizabeth—*Child of the Sea*. Harbor Springs, Mich.: Mrs. Elizabeth Williams (Whitney), 1905.

Wright, John C—*Northern Breezes*. Harbor Springs, Mich.: Lakeside Press, 1915.

Wright, John C—*Stories of the Crooked Tree*. Harbor Springs, Mich.: Lakeside Press, 1915.

Wright, J, N.—*Where Copper Was King*. Boston: Small, Maynard & Co., 1905.

Visual Aids in Michigan

Motion picture films covering forestry and land use.—"Michigan Forests", 3 films, and "Michigan Natural Resources Inventory". Lansing, Michigan: State Department of Conservation.

Lantern slides and film strips. Ann Arbor, Michigan: University of Michigan.