DRUMLIN NORTHWEST OF ELLSWORTH, ANTRIM COUNTY.

accumulation of plant material, which accounts for the patches of dark soil on our farm lands.

On the till plains near Climax and Union City, in Antrim, Charlevoix, Menominee, and Iron counties, and on the lake plain of Cheboygan, Presque Isle, and Alpena counties, are curious long cigar-shaped hills known as drumlins. They are in areas where the ice advanced over previously formed till plains. They are elongate in the direction of ice movement and usually have a front or "stoss" slope at the head end which is somewhat steeper than the lee slope. They are made of clay and many of them have a plastering of little stones or pebbles. The drumlins near Ellsworth, Antrim County, have cores of Ellsworth shale, those in Les Chaneaux Islands have cores of limestone. The roller coaster character of the old roads in Menominee County was caused by the roads crossing drumlins; the new highways cut through them, but the long narrow hills with graceful slopes are quite visible from the highways. Highway 31 is laid for a mile and a quarter on the crest of a drumlin crossing the Antrim-Charlevoix county line. As a rule drumlins are arranged in more or less parallel series and are separated from each other by poorly drained sags or troughs. No completely satisfactory explanation has as yet been worked out to account fully for the origin of drumlins, but geologists have accepted the viewpoint that most drumlins were sculptured by active ice during a readvance over an old till plain.

Running water is a very effective agent of erosion; therefore when ice thousands of feet thick melted, much water must have been upon the land and must have done much work. The drift

shows that much work was done by broad sheets of water and by narrow streams, by water with swift torrential currents and fairly sluggish, and in places stagnant, water.

Rapid melting of the ice as it stood on the moraines gave a rapid current to broad sheets of water along the ice front. Moving swiftly over the morainic material, the water worked it over, sorted it, carried it out from the moraine, and as the currents slackened, dropped the sorted debris, leaving the coarse cobbles, gravel, sand, and clay—spread in that order in front of the moraine. These stratified gravelly, gently undulating to flat plains are outwash or overwash plains—the flat lands of Kalamazoo, Cass, and Roscommon counties and those around Baldwin, Cadillac, and Grayling. They rest on till and are associated with the moraine from which they are constructed. Although resembling each other, outwash and till plains are readily differentiated. A till plain is back (towards the direction of retreat) of a moraine, and the outwash is in front of the moraine; a till plain is of unassorted material of all sizes with much clay, and with scattered erratics, an outwash plain is mainly sorted stratified gravel and sand with no erratics—excepting in those places where the outwash is so thin the boulders of the underlying till plain project through. The till plain has a gently undulating to hilly surface; the outwash is flat or very gently undulating where it is a thin veneer on the underlying till. As a rule flourishing farms are on the till plains; the majority of abandoned farms in the northern part of the Southern Peninsula are on sandy outwash plains. Hardwood forests grow on till plains; conifers on the outwash plains. As the outwash was being built, some icebergs broken from the front of the ice resting on the moraine were carried out into the waters where deposition of glacial sediments was in progress. As in the moraines some of these blocks became buried as sedimentation continued and their melting was delayed for hundreds of years. Eventually the debris-covered ice melted and left basins which have since been filled with water and form "pit" lakes. Houghton Lake, the largest lake in the State, Higgins Lake, Gull, Cadillac, and many other lakes, are in depressions of the "pitted outwash." Probably all such pits were once filled with water but many of them are now swamps, others are dry basins, and others are represented by the patches of black soil on till or outwash.

The cutover lands are frequently referred to as "wastelands"—outwash plains. From this we may get the impression that all outwash plain is waste land, but broad stretches of outwash are the

farm lands between the Tekonsha, Kalamazoo, Valparaiso moraines and others in the southwestern part of the State. In the southwestern part of the State the early settlers found large unforested, very fertile, areas which they called "oak openings" or prairie. They are situated on the till, but mainly on the outwash plains. No completely satisfactory explanation of these has been made.

In places melt water flowing from the ice was confined to channels, and cut spillways through the moraines or was forced to flow in a narrow channel along the ice front. Melt water, so restricted, built valley trains in the drainage ways—deposits of stratified sand and gravel which extended out from and along the borders of the ice. They are similar to the outwash in material and structure, but usually quite limited in extent. Outwash plains are short and wide, valley trains are long and narrow. Valley trains are in the moraines, outwash plains are between successive moraines. Otsego Lake is in a wide valley train. Many old pre-glacial valleys in the western half of the Northern Peninsula were either wholly or in part filled with valley train deposits.

In over a thousand places in the State we find long narrow hills that look like abandoned railway embankments and locally are called "hogsbacks" and "Indian trails." Geologically these hills are eskers—long narrow winding ridges of stratified gravel, sand, and silt.

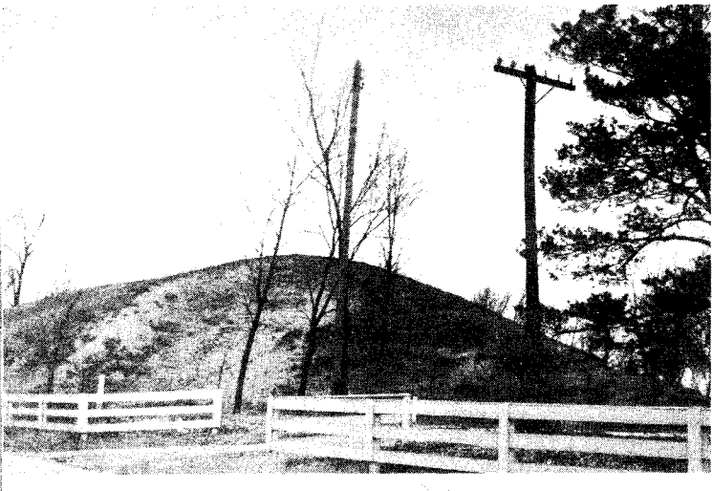
GRAVEL PIT IN CHARLOTTE ESKER BETWEEN POTTERVILLE AND CHARLOTTE, EATON COUNTY.

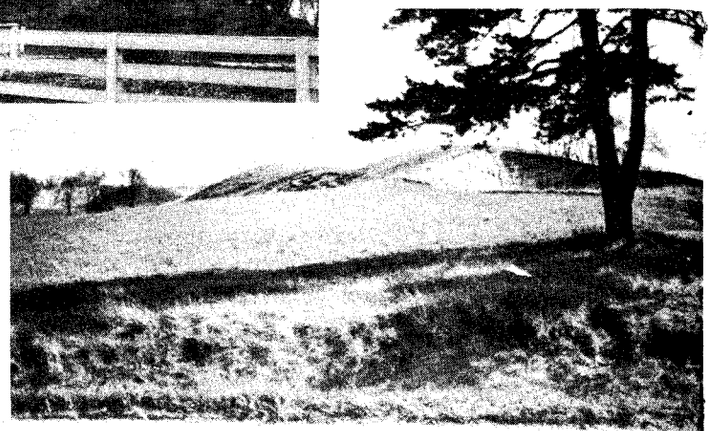
The problem of the origin of eskers is somewhat controversial. Several theories have been advanced to account for their development but none seem to fulfill all the requirements necessary to explain adequately the process. They are believed to have been formed under stagnant rather than moving ice. The explanation commonly used is that eskers were formed by deposition of gravel and sand in subsurface river tunnels in or under the glacier. The mouths of the tunnels became choked with debris, the melt water was ponded back and dumped its load of sediments in the channel. Another theory proposes that eskers are merely chains of kames formed in ice reentrants or crevasses out of material carried through cracks by melt water and deposited in front of the ice sheet. Upon melting of the ice a succession of kames was built up. Eventually the kames became strung together in the form of a winding ridge like a series of beads on a string. Various Michigan eskers could be cited to prove either and both theories. The Mason esker has long narrow ridges and conical hills in its course.

Eskers are usually on till plains although some are known to cut through moraines and even cross drumlins. They vary in length from a fraction of a mile to scores of miles, and in height from a few feet up to several hundred and more feet. The longest esker in Michigan is the Mason esker which may be traced from northeast of Lansing for a distance of some twenty miles through Holt and south of Mason. It crosses the extensive till plain that lies between the Lansing and Charlotte moraines. An interesting esker apparently made by an englacial stream and its tributary, as the esker is branching, is in Arcadia Township, Lapeer County. More than a thousand eskers have been found in Michigan.

Kames are rudely stratified conical hills of cobble, gravel, sand, and silt. Streams flowing on the top of the glacier or in a tunnel in its mass sorted the glacial debris. If the stream fell into a moulin—or "ice well"—its waters swirled their load of rock waste into it, building up a conical deposit. Where melt waters, flowing over the surface of the glacier, plunged into a crevasse or crack in the glacier or fell over the ice front in a waterfall onto the accumulating moraine, conical deposits of debris were left resting on the edge of the ice, as in the Alaskan glaciers of today. Kames are recognized by their "knob-like" structure and by their common occurrences in areas of interlobate moraines.

All these stratified deposits—outwash plains, valley trains, kames, eskers—play a large part in present day industry, for in them are the great gravel pits of the State. The gravel is easily





THE MASON "HOGSBACK"— ESKER

washed and readily sorted into the various sized aggregates needed for construction purposes. These gravel pits are also veritable museums of Michigan rocks and fossils. The largest gravel operations in the world are in the interlobate area of Oakland County near Oxford. The Oxford operations are interesting also in showing how the outwash was built up. As the operations go deeper more large boulders are found near the moraines, and as the cut pushes nearer the Lapeer County line—that is, nearer the interlobate moraine—more and larger boulders are found higher in the gravel deposit. It is interfingering in the moraine. Strata of cobbles between strata of finer gravel in the walls of the gravel pit workings show that powerful currents were at work in the flood stages of glacial outwash streams just as they work in modern rivers.

In a few areas in the State the melt waters became ponded into lakes which are recognized mainly by the character of the deposits they left behind. Large areas in central Lapeer County, in Kalamazoo County south of Kalamazoo, and in the northwest corner of Kalamazoo County and extending into Allegan County, are lacustrine or lake plains. The swampy areas in the Gun Lake valleys and south of Dowagiac were lake beds and many of the flat areas in Allegan and Berrien counties between the moraines are old lake beds.

KAME — MORAINE TOPOGRAPHY, LAPEER COUNTY. SHOWY ORCHID IS A HABITANT OF THE DEPRESSIONS BETWEEN KAMES.

Moraines, eskers, kames, till plains, outwash—they cover much of Michigan but descriptions of none of them fit the broad expanse of level lands from the Ohio boundary around "the Thumb," in the Saginaw Basin bounding lakes Erie, St. Clair, and Huron, scattered flat lands bordering Lake Michigan, the flat plains of the Ontonagon valley, and the marshy lowland of the watershed of the Tahquamenon and Manistique rivers, nor the wide valleys that look like former stream channels leading away from the flats. (fig. 3). Long ridges of sandy gravel border the flats and interrupt their level down to the present lake; and many sand dunes are along their inland slopes far from any body of water. As we cross the level lands we find they are actually terraces leading down to the Great Lakes, each terrace separated from its neighbor by a high or low steep cliff—except where one hundred years of ploughing has leveled them. These lands have areas of heavy clay interspersed with stretches of water-washed sand and gravel (we know they were water-washed because they are sorted in layers—stratified). Locally, clay and sand are intermixed to form loam. These level lands were once lake beds; the ridges of gravel were lake shore beaches and bars; the cliffs between terraces were cut by storm waves when the lake receded to a lower level; the flat stratified sand and gravel plains and clay plains with a veneer of sand or gravel were the fillings of old bays of ancient long-departed lakes and the deltas of rivers flowing into them. The level plain from Seney to Shingleton, Schoolcraft County, was the bed of the old lake which blurred the story of the moraines. The swamps of the Northern Peninsula are the remnants of that lake. These last formed lands of glacial debris are the beds of glacial lakes that wrote their own history as they came into being, existed, and disappeared when the glacier retreated, and through 50,000 years with various changes of area and outlets developed the largest bodies of fresh water in the world—the Great Lakes. By their abandoned high and dry strand lines we read their story and no history of the building of Michigan could be complete without account of the panorama of dramatic events that gave us lakes Michigan, Superior, Huron, St. Clair, Erie, Ontario, and their connecting rivers. No history of our forests, of man's coming to Michigan, of the forts that defended the old Northwest Territory, would be complete without this story of the Great Lakes and their ancestors.

HOW THE GREAT LAKES CAME

When the margins of the various ice lobes had retreated, by melting, back of the high land divides of the old drainage systems, and the melt waters from the retreating ice could no longer escape southward to the Ohio and Mississippi and could not cut across the morainic barriers, drainage from the melting glacier accumulated in basins between moraine and glacier and formed large and small pools along the ice front. Step by step, the ice receded back into the old pre-glacial river valleys; step by step the basins and their pools increased in size, cutting shores in the moraines to the west, but easterly shores were ice walls. The pools became lakes, winds whipped their surfaces to waves which dashed upon the moraine shores, cut them back to cliffs, built beaches and sandbars—did all the work that modern waves and shore currents do in modern lakes, built up the same kind of records modern lakes are making today; but eventually left them high and dry, far from modern lakes —beaches, bars, cliffs, lake terraces, dunes. These old early lakes lived long enough to fill most of the depressions in their beds, making flat plains. Winds whipped up dunes on their shores. By all these records the lakes wrote their story, and as sets of records are at successively lower levels as we approach the modern Great Lakes, we know that the first lakes very strangely became larger as they were lowered. But we can read the record of each stage. The lake stages are known by the position and character of the beaches they built, of the lake beds they made. Their names are derived from a locality prominently located on the beach, from a personality, as Whittlesey, connected with their early study, or a general locality, as Algonquin reflected the Indian lands where that lake was studied. Thus as predecesor of Lake Erie we have glacial lakes Maumee, Arkona, Whittlesey, Wayne, Warren, Elkton, Algonquin; glacial lakes Chicago and Algonquin were the predecessors of Lake Michigan; lakes Brule, Ontonagon, Duluth, and Algonquin were the ancestral Lake Superior. A final set of Nipissing lakes was formed higher than the present lakes after the glacier had entirely retreated from the Great Lakes area.

When the ice front of the Erie lobe retreated eastward from the position of the Fort Wayne moraine it crossed the drainage divide so that the melt waters could not flow freely southward from it, but accumulated in pools along the ice front. The first pools collected in what is now the Maumee basin of northwestern Ohio and

the neighboring parts of Indiana some 30,000 years ago, and grew to a crescent-shaped lake fifty miles wide from its outlet near Fort Wayne to its eastern ice barrier shore near Defiance, Ohio, where the ice front was standing on the Defiance moraine. It was large and deep enough so that its waves built a distinct shore which we can map around the basin of the Maumee River—so we have named this ancestor of Lake Erie glacial Lake Maumee. A narrow arm of the lake extended along the ice front past Adrian to the vicinity of Ypsilanti where remnants of the shore may be traced in the town at an elevation approximately 800 feet above sea level. Summit Street, Ypsilanti, is along the Maumee beach and the water tower is located on it. Ridgeway, Lenawee County, is located on, and named from, the ridge-like beach of Lake Maumee; the level land east of the towns is the bed of the lake. The lake discharged its overflow waters through a narrow col or gap in the moraine near the site of Fort Wayne and thence southward to the Mississippi through a channel which it cut from one to three miles wide and in which the Wabash River now meanders. The highest beaches of this stage show that Lake Maumee (near Ann Arbor) was 812 feet above sea level or 239 feet above the present level of Lake Erie.

Upon further retreat of the ice front more of the pre-glacial valley was uncovered; the basin was thus enlarged eastward and the water level dropped 17 to 27 feet. When the ice finally melted back to "the Thumb" the waters of the new lake formed a mile-wide outlet northward past Imlay City at a level of 750 feet through a channel we name the "Imlay Outlet"—that flat muck land near Imlay City where the celery and truck farms and peat beds are. From this outlet the waters of Lake Maumee were carried westward across northern Lapeer County down the Flint River Valley to the Grand River, near Lyons. Before this time the Grand River valley had been little more than a deep crease in the moraine, but with the sudden addition of all the waters of Lake Maumee the river began cutting the most deeply trenched valley in Michigan—that deep valley we now know, one of the finest glacial river valleys in glaciated North America. In places it is 200 feet below the level of the country and the bluffs, once the river's banks, are 120 feet high. The Imlay Outlet-Grand River channel led to Lake Chicago below Grand Rapids through the wide valley now occupied in part by the Dowagiac River. Parts of the channel enlarged into broad shallow lakes in which were deposited the tell-tale lake clays. One lake in northern Lapeer County named Lake Silverwood, and the other larger and longer-lived Lake Kearsley which extended for

GLACIAL BOULDERS LEFT IN IMLAY OUTLET AS RUSHING WATERS OF GLACIAL LAKE MAUMEE BROKE THROUGH MORAINE AND SCOURED THE CHANNEL. BOULDERS ARE MAINLY ROUNDED AND SCOURED GRANITIC BLOCKS.

seven or eight miles northeast of Flint to Swartz Creek, Genesee County, were two of these lakes.

Shortly after the initiation of Lake Maumee the pools at the foot of the Lake Michigan lobe united to form a lake termed Chicago. Its outlet was southwestward through the DesPlaines River channel to the Illinois and Mississippi rivers—the location of the present Chicago Ship and Drainage Canal. Lake Chicago's history is of a steady enlargement northward, and like the other lakes, becoming lower as it became larger from expansion into the pre-glacial valley. The beach of the first lake is crescent-shaped about Chicago. The lake enlarged around the edge of the ice lobe in a narrow crescent through northwestern Indiana into Michigan and received the Grand River waters from the Imlay-Grand Outlet of Lake Maumee. Unlike the other lakes, Lake Chicago never spread far outside the pre-glacial valley, and its shores were never far from the shores of modern Lake Michigan.

A little later, when the Saginaw lobe had melted back into the Saginaw depression so that a trough was formed between the ice and the bordering moraine, melt waters accumulated there and formed crescent-shaped early Lake Saginaw. The outlet from this shallow lake was westward through a channel now used by eastward flowing Maple River near Maple Rapids to the Grand River near Lyons, joining with the outlet of Lake Maumee. Those old gravel ridges that the farmers of the Saginaw Valley plow are beaches and bars of the first Lake Saginaw and are about 40 feet lower than the Imlay Outlet. They may be traced from the vicinity of Clio through Maple Rapids to west of Mt. Pleasant.

From this time on the development of the lakes became rather complicated by the oscillations of the ice front. Slight oscillations had blurred the record of Lake Maumee which had three stages—a high then a low stage, followed by a rising of the lake as the ice readvanced and lifted the lake level, until the site of Toledo was under 200 feet of water. From this third level the lake dropped 65 to 90 feet to the level we know as Lake Arkona.

The ice withdrew completely from the Thumb; its front stood about 25 miles north of Bad Axe, Huron County, and a strait was opened across the lower part of the Thumb area. The lakes on either side attained the same level, making Lake Arkona which completely filled the Erie basin, spread northward into the Huron basin and merge with the enlarging Lake Superior. Lake Arkona was the first to have land beaches on the Canadian side—along the highland that separated the Huron and Erie ice lobes. The name Arkona comes from a town in Ontario where the beaches thought to be of this level were studied. The water of the two large lakes discharged through the Grand River Outlet to Lake Chicago west of Grand Rapids, a distance of 75 miles.

But Lake Arkona was relatively short lived; it existed just centuries long enough so that its beaches were too strong to be entirely obliterated when the glacier readvanced to take that long determined stand when it built the Port Huron moraine. It is very possible that more detailed study of the region north of Gladwin will some day reveal that Lake Arkona extended much farther north than we can prove today.

The readvance of the ice over the Thumb again separated the lakes in the Saginaw and Erie-Huron basins; Lake Saginaw probably remained at the Arkona level, but the eastern lake was raised

44 feet to within 10 feet of the earlier Lake Maumee. This lake we name Whittlesey.

Lake Whittlesey was so deep that the storm waves did not reach to the bottom and thus did not entirely wipe out all drowned Arkona beaches. In Ontario the Erie-Ontario lobe was separated from the Huron lobe by an island fifty or more miles wide, the present river divide extending northeast of Stratford through Perth, Wellington and Dufferin Counties. Such rock islands standing above the Greenland Ice Cap are called "nunataks" by the Eskimos, so we call this Ontario's dry land projecting through the ice field a nunatak. The waters of Lake Whittlesey also discharged northward along the ice front, standing on the Port Huron moraine, through the Black Bay embayment—which is now the valley of the southward flowing Black River in Sanilac and St. Clair counties. At Ubly, Huron County, at an elevation of 740 feet, or about 160 feet above Saginaw Bay, the outlet turned southwest down the Cass river valley into glacial Lake Saginaw. Above Cass City the waters slackened sufficiently for the current to build a delta at the outer edge of which Cass City is built. Both the Imlay and Ubly outlets left the lakes with very strong currents which washed out all the fine material of the moraine and left the heavy boulders in the boulder belts which we find so prominent in the low valleys of Lapeer, Sanilac, and Huron counties. From Lake Saginaw the lakes drained as before through the Maple Grand outlet to Lake Chicago and the Mississippi. We have found that the glacier made its strongest moraine, the Port Huron, during this readvance. Likewise, the beaches of the lake of this stage, Whittlesey, are the strongest in the southern lake region. Through Ohio and southern Michigan they are like railway embankments and were used first as Indian trails, later as the white man's highways—the Ridge Road that parallels the southern shore of Lake Erie.

During this stage Lake Chicago had expanded northward as far as Manistee in a series of bays between the glacier and the lake border moraines. The low flat lands bordering Lake Michigan from Manistee southward are the bed of Lake Chicago. Its greatest eastward expansion was to within four miles of Grand Rapids—there it received the great Grand River Outlet, which during all this time had been deepening the wide valley through the moraine in which part of old Grand Rapids was located.

Along the eastern border of the ice sheet in New York the glacier-sculptured Finger Lake valleys were filled with small lakes (called Lake Newberry) which shared an outlet to the Susquehanna

River and Chesapeake Bay. From the western edges of the glacier in Wisconsin wide streams were flowing southward to the Mississippi through the St. Croix and Brule valleys.

Lake Whittlesey shared the fate of all lakes—drainage. The ice retreated so far that an outlet 90 feet lower (at 650 feet above sea level) was uncovered in the east, the westward Ubly outlet was abandoned; the waters of the lake along the ice front rushed eastward down the Mohawk River valley collecting Lake Newberry on the way, past the site of Syracuse, New York, to the Hudson and the Atlantic ocean—the first eastern outlet of the Great Lakes. And so Lake Wayne came into existence, named from its beaches near Wayne, Michigan.

In the Superior basin about this time the flat agricultural lands of Ontonagon County were being deposited in a glacial lake that occupied much of the drainage basin of the Ontonagon River. Lake Ontonagon drained westward through a very narrow channel, now a highway, to two other small lakes along the ice front in Wisconsin, which in turn discharged to the St. Croix and Mississippi rivers.

Lake Wayne was destined for a brief existence, a slight readvance of the Ontario lobe blocked the eastward Mohawk outlet and brought the Wayne stage to a close. The ice barrier readvanced to slightly south of Alpena in Michigan and south of Rochester in New York; ponded and lifted the glacial waters 25 to 30 feet above the level of lake Wayne, and Lake Warren came—to write its story in beaches, bars, shore cliffs, but so deep it did not entirely erase the records left by Lake Wayne. Its waters merged with Lake Saginaw, finally expanding to fill the southern end of the Huron basin; again the Grand River Outlet was put to use and the waters of the glacial Great Lakes reached the Mississippi.

Meanwhile the ice lobe in the Superior basin had melted back so far into the Superior lowland that melt waters accumulated along its front in a lake we name Lake Duluth. Its outlet was southward through the St. Croix to the Mississippi. Lake Ontonagon was lowered about 200 feet, its bed became land with a few bays of Lake Duluth extending up the Ontonagon River and its larger tributaries south of the Copper Range.

Then the glacier started on its last halting retreat. Powerful lakes Warren, Chicago, and Duluth gradually lowered but built

faint beaches each time the ice halted long enough for the waves to set to work. At a fairly long halt, after lowering 65 feet, a lake we call Elkton from a village on its strong beach in Huron County, came into existence. Once again, and finally, the Grand River outlet was abandoned; the wide channel—almost a strait as it had a fall of one to one and one-half feet per mile—became a wide shallow lake into which tributary streams brought silt. Vegetation started to grow along the shores and in time filled the wide valley to make the start for the "black land" of the onion farms near St. Johns and the truck farms near Grand Rapids. North of St. Johns wide flat "black land" valleys with very narrow streams now flowing in them are the remnants of the glacial valleys and streams which fed the Grand River Outlet from the north. Lake Chicago continued to spill over the DesPlaines-Illinois-Mississippi valley outlet, but the Huron-Saginaw-Erie basin lakes found a lower route eastward along the ice front past Syracuse, New York, down the Mohawk River to the Hudson. This was the outlet that started excavation of "Clinton's Big Ditch," the Erie Canal, that 20,000 years later in the 1830's brought an influx of white settlers from New England and New York into southern Michigan and began the development of our State. Lake Duluth extended eastward as far as the highlands of the Keweenaw Peninsula; Lake Chicago enlarged northward until it occupied Green and Traverse bays and was beginning to receive considerable drainage from the ice front. During early Lake Elkton the waters of the Erie and Huron basins were connected by a broad shallow strait covering the site of St. Clair River, Lake St. Clair, and the Detroit River. As the waters of short-lived Lake Elkton lowered, parts of the strait narrowed to form the ancestral St. Clair and Detroit Rivers. The northern river flowed over the submerged Port Huron moraine with sufficient current to wash out part of the moraine. It carried the gravelly debris to the deeper part of the strait—ancestral Lake St. Clair—deposited it as its current slackened, and started the building of the delta which is now the St. Clair Flats—the rendezvous of the boatman, duckhunter, vacationist.

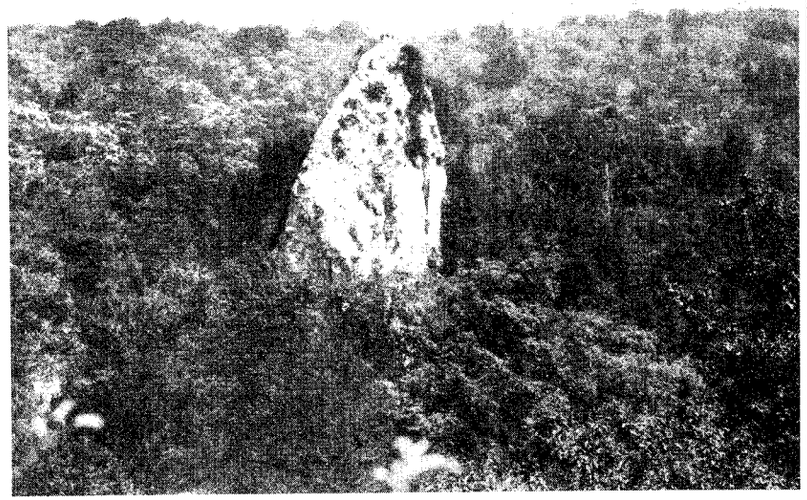
Up to this time the important lakes were in the Erie basin, from now on the northern lakes are most important. When the St. Clair and Detroit rivers developed, the lakes in the Huron-Erie basins were separated and fairly stable conditions established. The first stage of glacial Lake Algonquin was ushered in. Lake Duluth spread far enough east so that it surged southward through a nar-

row outlet to Lake Chicago. It scoured out the rock-floored valley extending southward from near Marquette to Little Bay de Noc—the present channels of the short northward flowing Au Train and the longer southward flowing Whitefish rivers. Several times this low cut across the Northern Peninsula has been considered as a site for a canal connecting Lake Superior and Lake Michigan.

In the meantime the Ontario lobe began to play its important part in fashioning the Great Lakes. In its early stages it had spread southward and up over the high Niagara escarpment—the easterly lip-rim of one of the Michigan rock bowls. Now the melting lobe shrank back so far that it opened a low pass near Rome, New York, below the level of the base of the Niagara rampart. Then the waters of the lake known as Iroquois overflowed the Ontario basin and rushed eastward through the Rome outlet, and lakes Erie and Ontario were separated. The overflow waters of Lake Erie were narrowed to a river about 1300 feet wide which came down 300 feet to Lake Iroquois in a mighty cascade over the jutting ledges of the Niagara escarpment near where Lewiston, Ontario, now stands, and Niagara Falls was born. That happened 18,000 years ago, seven miles north of the present position of the Falls. Soon the cascade became a cataract which cut its gorge 2,000 feet upstream (south) from Lewiston, during the life of early Lake Algonquin.

Then came a rapid retreat of the glacier. It withdrew from the highlands west of Alpena ending the independence of Lake Chicago which united across the tip of the Southern Peninsula with the lake in the Huron basin. Lake Erie was cut off from the Huron basin, and with no tributaries from glacial melting, a small independent lake came into existence within the boundaries of the present Lake Erie. We know this happened because the tributary streams coming in from the south and the Detroit River now have submerged channels which they cut to the lake at this low stage. The lake waters became warm and fresh-water fish, entering from the southern streams, began to populate the lake. Thus 16,000 to 15,000 years ago Lake Erie was probably the original home of many of the finny tribes that later migrated to the other lakes.

The ice retreated farther, broader stretches of the three northern lakes united and finally came the grandest lake of all—the second Lake Algonquin, the lake we mean when we talk about the doings of Lake Algonquin. It filled and overflowed the basins of the three northern lakes and Georgian Bay. Isle Royale, rising some 300 feet above the present level of Lake Superior, the Keweenaw Peninsula,



SUGAR LOAF, MACKINAC ISLAND. REMNANT OF LAKE ALGONQUIN SHORE.

and the borders of the Southern Peninsula (from Port Huron northward) were under water. Of Mackinac Island only the small triangular area on which the fort is located was above water. The outlet river of Lake Algonquin, a broad stream which flowed southwestward from near Kirkfield, Ontario, down the valley now occupied by the Trent River, entered Lake Iroquois not far from the Thousand Islands of Lake Ontario. Lake Iroquois in turn found its outlet past Rome, New York, to the Mohawk, to the Hudson, which was then an estuary of the Atlantic. This was the beginning of those routes to the great northwest which resulted in the settlement of northern Michigan. Lake Erie, with Lake St. Clair its northern bay, was so shallow that its overflow was only enough to enable the Niagara River to cut the narrow one and one-eighth mile long "Old Narrow Gorge."

The glacier retreated farther northeast. Lake Algonquin's powerful waves pounded on its shores, built huge beaches and cut cliffs to show us where it had been. Sugar Loaf on Mackinac Island was a chimney-like island on the little island's shore. But now something else was happening to the continent. Released of the weight of billions of tons of glacial ice as the melt waters flowed back to the sea, the continent slowly rose to the northeast, upcanted somewhat like a trapdoor along a hinge. Proof of this happening is that south of the hinge the beaches are level, but north of the hingeline the beaches slope upward. We know that

water always seeks a level and beaches are made at some permanent or long temporary lake level. So for a time when Algonquin was low enough so that the high parts of the Keweenaw Peninsula were islands, and the high lands of the tip of the Southern Peninsula and Big Beaver Island made an archipelago, the continent came to such a level that Lake Algonquin used all three of the outlets—Chicago, Port Huron, and Trent River in Canada. Lake Algonquin was then 25 feet above present Lake Michigan. Lake Iroquois expanded southeastward to include the Finger Lakes of New York, more water flowed through Lake Erie so that when the Chicago outlet was permanently abandoned and all the waters of the upper lakes fell over Niagara Falls, the river was large and powerful enough to cut the Lower Great Gorge.

The ice retreated from the valley of the St. Lawrence River and the sea, its level raised by the vast quantities of ice water returned to it, entered the valley as far west as Ottawa (fig. 3). Then Lake Algonquin discovered a lower outlet to the north, this time past North Bay of Georgian Bay, Lake Huron, near Callendar of Quint fame.

However, if we trace the Algonquin shore we find that at Point Aux Barques, Huron County, where those interesting little rock ships have been carved in the Algonquin cliff, the shore is but 25 feet above Lake Huron. Follow the shore northward and we find that gradually but surely those once horizontal beaches rise higher and higher above Lake Huron. At Mackinac the Algonquin beach is 194 feet above the straits. In the morainal hills south of Munising on the shores of Lake Superior the beach is 341 feet above Lake Huron (321 feet above Lake Superior), and on the Keweenaw Peninsula the Algonquin beach is at an elevation of 1110 feet at the Cliff mine, or 493 feet above its level at Port Huron. So that north of the Hinge Line which extends across the State from near Richmondville, Sanilac County, to Manistee, Michigan has been tilted up almost 500 feet. We have similar evidence to show that in Canada the uplift has been 600 to 700 feet. All along these shores, now some distance inland, we have evidence of the work of powerful waves—raised beaches, the Arch Rock of Mackinac Island, wave cut cliffs, sea caves and grottos, and beaches of flat stones (shingle beaches)—far above lake level. And on the beaches great masses of dunes prove the powerful work of the winds. Continental uplift has continued ever since and has been responsible for numerous changes affecting drainage in the Great Lakes basin. It has reduced the northward slope of the Tahquamenon, almost destroying

the current and causing the long stretches of quiet water, but has increased the current and cutting power of the Manistique. The very slight, interesting but harmless, earthquakes recorded since the earliest settlement in the Lakes' region are probably caused by uplift and settling started when the ice had melted to the Lake Whittlesey stage.

For a long time Lake Algonquin used the short North Bay outlet from the Great Lakes to the sea, but, as it must to everything, an end came to Lake Algonquin. The ice barrier holding it to the highest level gave way when the ice retreated north of North Bay, and Algonquin started to drop to a lower level and the last of the glacial lakes was ended. The glacier disappeared far to the north and new post-glacial lakes came into existence—the Nipissing Great Lakes. Isle Royale and the northern part of the Keweenaw Peninsula emerged above the waters of the lake, the eastern half of the Northern Peninsula became land covered with a shallow swamp, Manitoulin, Drummond, and the islands of the straits archipelago became larger; but the valleys of Burt, Mullet, and Crooked lakes were still a strait connecting the eastern and western lakes. The northern Great Lakes stood at a level 50 feet above St. Mary's Rapids and the Straits of Mackinac took almost their present outlines. On most of their borders the Nipissing shore is less than a

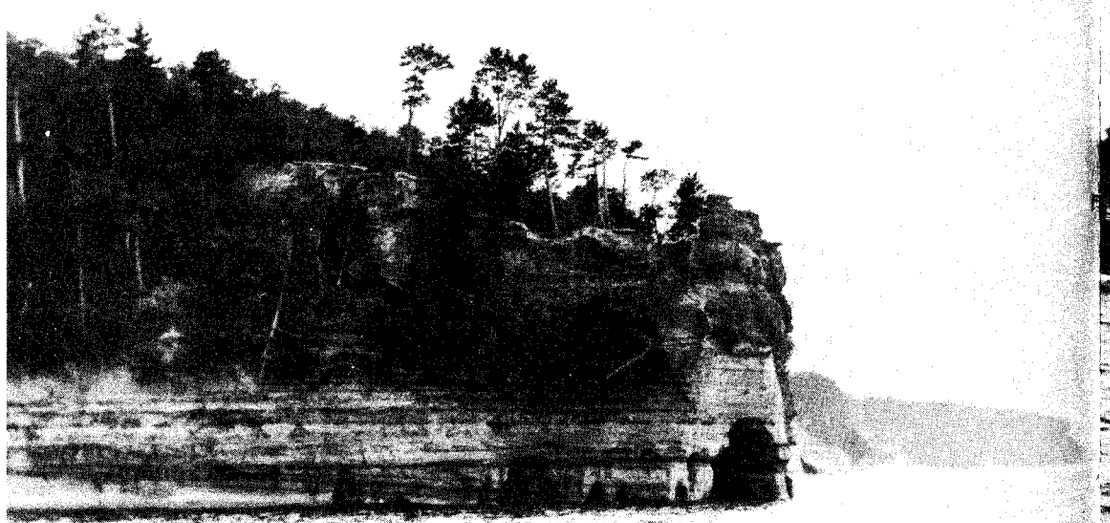
POINTE AUX BARQUES, HURON COUNTY.

ST. ANTHONY'S ROCK, ST. IGNACE. A CHIMNEY ROCK. REMNANT OF LAKE NIPISSING SHORE.

CHAPEL ROCK, LAKE SUPERIOR.

mile inland. Lake Erie and Lake Ontario, however, shrank within their present boundaries, only the waters of the smaller Lake Erie fell over Niagara Falls, and the narrow Whirlpool Rapids gorge was cut. Then old North Bay outlet of Lake Algonquin narrowed and lengthened to a raging river, headed on the northeast shore of present Lake Nipissing, and served as the outlet for the Nipissing lakes. Its old channel is now the wide boulder strewn, water and rock scoured valley, with many lakes and marshes, in which the Mattawa and Ottawa rivers flow east to the St. Lawrence. That

PICTURED ROCKS NEAR MUNISING. WAVE-CUTTING AT LEVELS OF LAKES ALGONQUIN, NIPISSING, SUPERIOR.



is the story of how the route was made which led the early fur traders and the missionaries westward. The spillway of great glacial and post glacial lakes had opened the empire of the west, led to Georgian Bay and St. Mary's Rapids, and to the founding of the oldest town in Michigan—Sault Ste. Marie.

Nipissing, like Algonquin, was a greedy lake, its waves were powerful, and on its shores we find remnants of its savage onslaught on the rocky as well as the less resistant morainic coasts—St. Anthony's Rock in, and Castle Rock near St. Ignace, stacks and sea caves along the rampart of Cambrian sandstone facing Lake Superior, Chapel rock, Miner's Castle, Sleeping Bear, the cliffs and terraces bordering the lakes. Like the Algonquin, the Nipissing beaches also show that the land to the north was uplifted. North of Port Huron the Nipissing beach is 595 feet above sea level, 17 feet above Lake Huron; at Mackinac Island it is 36 feet higher; 56 feet higher at Sault Ste. Marie; and the old North Bay outlet has been lifted over 100 feet! But in the western part of the Superior basin the uplift has caused the lake to be spilled over enough to submerge the Nipissing beach, just as the south shore of Lake Erie is now drowned by spilling of that lake southward. In the Southern Peninsula and Wisconsin parts of the Nipissing shore have been cut into and destroyed by the modern lakes.

During the Nipissing stage Lake St. Clair was probably only a

MINER'S CASTLE FROM THE LAKE.

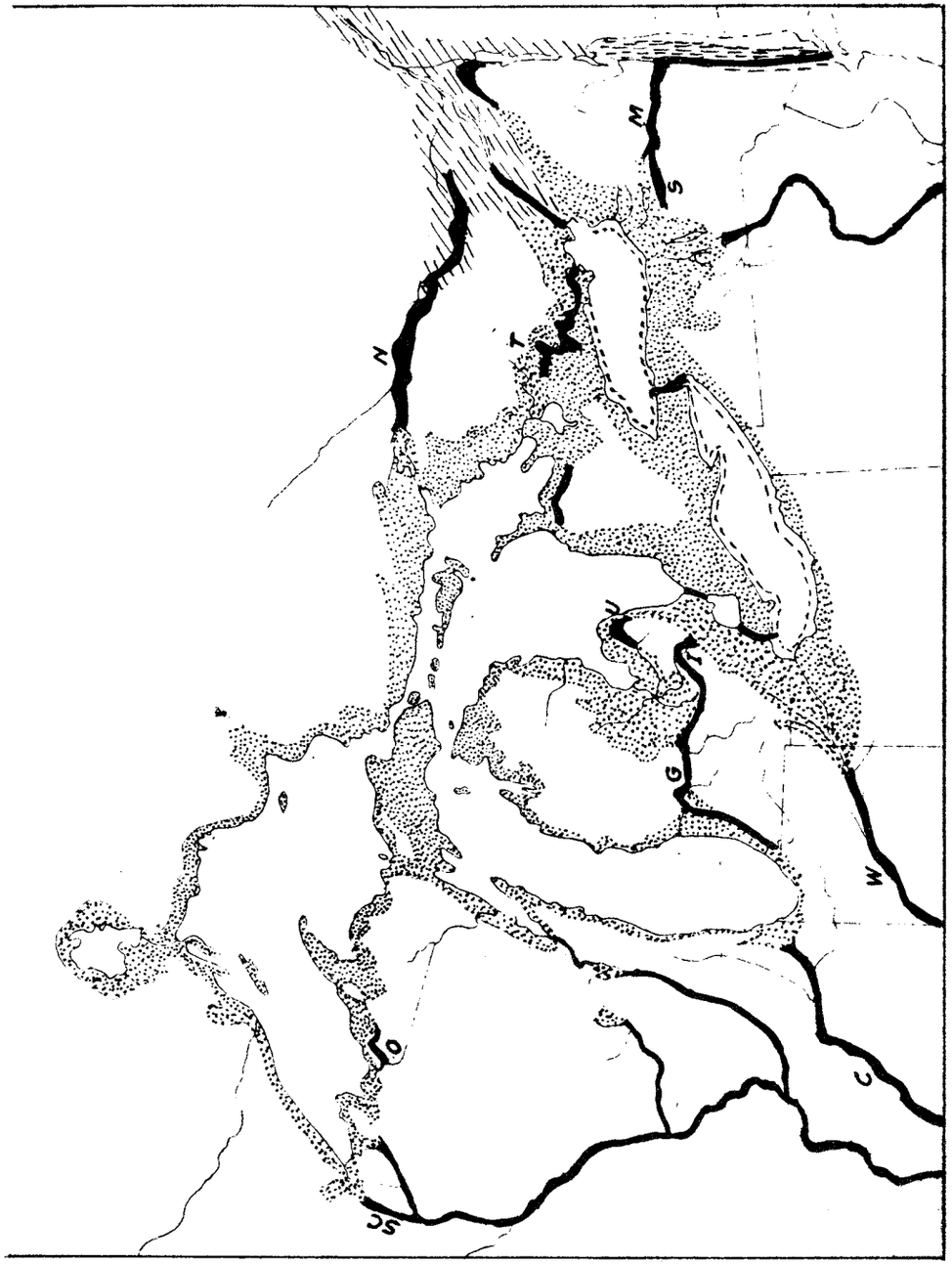


FIG. 3—Areas covered by glacial lakes (stippled) and outlet channels of former lakes. W=Wabash; I-G-C=Imlay-Grand River-Chicago; U-G-C=Ubley-Grand River-Chicago; S=Syracuse outlet; O=Ontonagon outlet; SC=St. Croix-Duluth; M=Mohawk-Hudson River; T=Trent River-Kirkville; N=North Bay-Ottawa outlets. Dashed lines in Lake Erie and Ontario are approximate low level shores of those lakes. Long dashed lines represent areas of ocean incursion up the Hudson and St. Lawrence valleys.

marsh with a sluggish stream flowing through it, past the site of Detroit to the small Lake Erie. St. Mary's River was a broad strait connecting Lake Superior and Lake Huron at the same level. Burt, Mullet, and Crooked lakes of the inside route, Walloon, Charlevoix, Torchlight, all remnants of Algonquin and Nipissing, are bordered by lake cliffs and terraces which the ancient lakes cut on the islands of the former archipelago.

An end came to the Nipissing lakes also. The land continued to rise to the north, lifted the North Bay-Ottawa outlet too high to receive the overflow which was then spilled southward. A sill of Niagaran limestone prevented deepening of the Chicago outlet, but the St. Clair river had been able to deepen the waterway at the Port Huron site, and the lakes dropped 15 feet to the modern level. The land slowly rose, lake currents turned southward, flowed through the St. Clair River, spread out and filled the Erie basin, and 3000 years ago made a route to carry Michigan iron and limestone to the coal of Pennsylvania about the time when King Solomon's argosies were sailing the Red Sea. The modern Great Lakes came on the land at least 15,000 years after Folsom man shot bison with arrows in Arizona. A ridge of Cambrian sandstone barred the way across the strait between the northern and southern lakes so Lake Superior was held up 20 feet above the level of Lake Huron and they were separated. As the Huron lake level lowered the strait narrowed to a river which leaped over the sandstone in St. Mary's Rapids. The waters of Lake Huron scoured out the old Port Huron channel but dumped most of its load on the gravelly flat at the head of Lake St. Clair, revived as the waters spread out in the old marsh; Detroit River was quickened, cut its bed deeper, but the rising waters of Lake Erie drowned its lower course and spread inland. All the waters of the Great Lakes fell over the Niagara Falls and started cutting the gorge from the new Rainbow bridge to the present falls.

This is the story of the Great Lakes—but the tale is not ended. The modern lakes are carving their shores to even greater expression than their predecessors. They are encroaching on their shores. Powerful storm waves are wrecking the castles, grottos, and arches cut by the lakes Algonquin and Nipissing, and have produced cliffs 100 feet high. Many of the marvels of the Pictured Rocks described by the early explorers have fallen into the lake, undercut by ruthless waves. At the same time the lakes are building new

shores, cutting off rocky islets where hard rocks come down to the shore, filling bays and channels in shallow quiet waters, joining rocky islands to the mainland—and slowly the lakes are being filled. Gradually Niagara Falls is cutting southward down the gentle slope of the Niagara limestone, cuting back the larger Horseshoe Falls, no longer horseshoe in shape, at the rate of four to five feet a year. When the falls reach Buffalo they will be lowered so much that Lake Erie will drain out as a river, draining Lakes St. Clair and Huron as well, until they return to the rivers which once occupied the basins. As long as the ledge of Cambrian sandstone holds in the St. Mary's River, Lake Superior will remain a lake, but when that barrier is destroyed Lake Superior will become a river also. The Great Lakes, like all others, are on the way to extinction—some many thousands of years hence, at the rate they are disappearing now. By the records our lakes are making—beaches, bars, wave-cut cliffs, sand dunes, sand and clay covered flats—some future student can read their story as we read the story from first Maumee through the Nipissing Great Lakes.

"THE MIGHTY FORTRESS" OF THE PICTURED ROCKS.

SANDS ON THE MARCH

Piles and heaps of yellow sand, bare sand with "sun kissed ripples," sand that the juniper holds down, sands on which the cactus rose grows. Mount Pisgah on Beaver Island, the ever watchful Sleeping Bear, Grand Sable, the dance floor of the merry Pauwau-kee-wis, Great Sand Bay on Keweenaw Point—all a part of Michigan's sand dunes along the lake shores. Not all the dunes are along the lake shores, some are far inland—placed there by the winds of ancient times on the shores of the ancient glacial lakes. Wherever large lakes develop, waves and currents wash sands on shore, the wind whips up the dry sands and piles them into hills—termed dunes. Dunes were piled on the shores of the retreating glacial lakes, particularly in the eastern half of the Northern Peninsula and in the Erie and Saginaw basins, but are now well inland and covered with vegetation. But often the ripped out roots of a blown down tree have revealed the sand dune on which it grew. In places deep ploughing has destroyed the soil-mat cover and laid open an ancient dune of the old outlet valleys as well as of the glacial lake shores, and the wind begins its work anew. Heaps and ridges of sand crossed by any road leading to the towns on the eastern shores are dune ridges of the glacial lakes, made as their shores receded to the present lake level.

DUNES AT GRAND MARAIS, ALGER COUNTY, ENCROACHING ON FOREST.

SLEEPING BEAR, LEELANAU COUNTY.

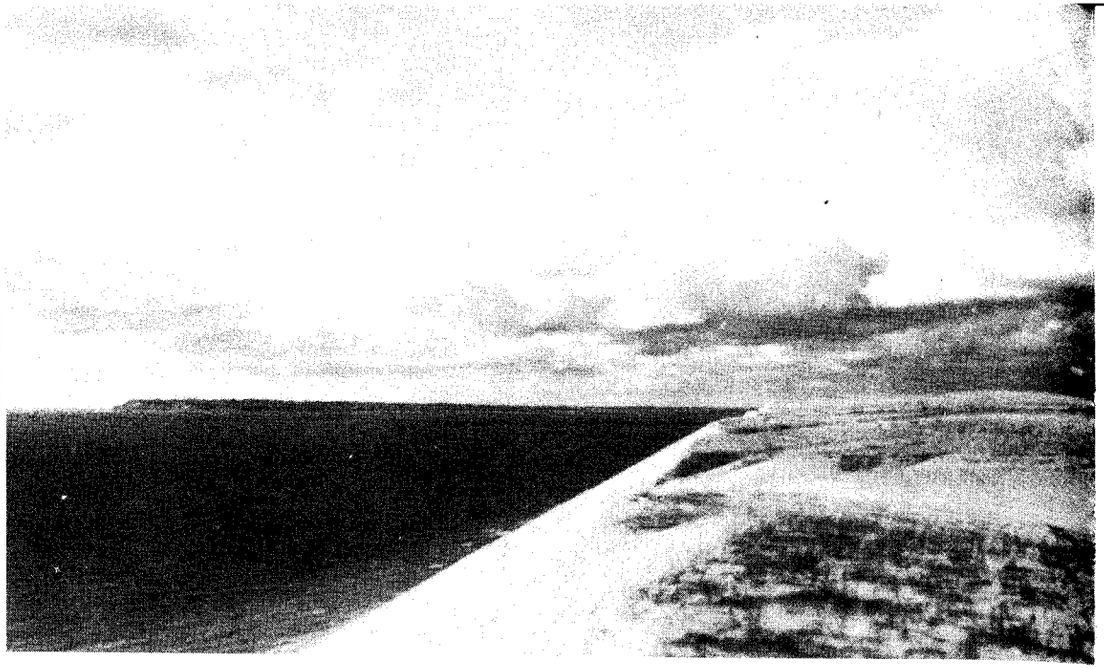
The largest dunes of the State were made in Lake Nipissing times and are now above lake level on the Nipissing shores. The Grand Sable dunes—five square miles of shifting sands near Grand Marais, Alger County—are piled up fifty to seventy feet high on an old shore nearly three hundred feet above Lake Superior. South of the dunes lies Sauble Lake, "the sapphire" of the dunes, gradually being filled by the encroaching sand. Under part of the dunes lies a forest, killed and buried by the sand, and now partly resurrected as the sands march on. From St. Ignace westward are the Brevoort-Manistique dunes piled on the Nipissing shore. An almost continuous succession of dunes borders the Lake Michigan shores from the Indiana line northward beyond Petoskey, the most extensive dunes in the lake region. Some of these dunes belong to the glacial lakes; others are modern, but the highest dunes along the

SLEEPING BEAR DUNE FROM NORTH SHOWING 360 FT. DROP OF BLUFF FROM BASE OF DUNE TO LAKE MICHIGAN.

FOREST UNCOVERED BY MOVEMENT OF DUNE.

southeastern shore of Lake Michigan, highest in the United States and equal in height to the highest dunes in the world, are the work of the winds on Lake Michigan shores.

The shores of glacial Lake Chicago outside its bays, were not far from the modern shores of Lake Michigan. Therefore the dunes of the ancestral lake are now united with the dunes of the modern lake by fore dune ridges which flank their windward slopes, having been blown up from the sands deposited on the beach of Lake Michigan. This accounts for the great massifs of dunes in the



LOOKING NORTH FROM SLEEPING BEAR.

State Parks. The dunes have gentle windward and steep leeward slopes, although along the west coast the windward slopes have been greatly modified by wind erosion, which produced prominent "blowouts" like Old Bald Head near Saugatuck, and Rosy Mound south of Grand Haven. The sand bulk of watchful Sleeping Bear rises 90 to 125 feet above the moraine on which it lies, or 480 feet above Lake Michigan. During all the centuries the Bear has been lying there it has been restless at times and has shifted its position slightly to the north and east and exposed the dead vegetation on which it had been lying. Arborvitae, sand cherry, and dogwood now grow on top and on the northern slope, but the winds are ever blowing on the southern and western slopes and replacing the sand they move by the sands they blow up from the beach and sands they blow out from the moraine. Just as the dunes of Grand Sable are marching into Sauble Lake, so the dunes of the Sleeping Bear region are marching into beautiful Glen Lake.

It is significant that the dunes along Lake Michigan are only in the areas of sand bays and beaches and are well developed where rivers empty into the lake. Probably larger streams, flowing across the sandy morainic upland, have contributed sandy sediments which from time to time have been worked over by the waves into sands sufficiently fine for the winds to carry. Thus we find that modern, like the ancient dunes, are perched on the sand and gravel

bars built at the mouths of streams. Along the Lake Michigan shore, many streams have been ponded back to the lakes bordering the coast—Glen, Hamlin, Portage, Crystal, Muskegon, and others; and on the bars between them and the big lake are the modern dunes.

During the Lake Nipissing stage, the area of Emmet County was an island separated from the mainland to the south by a channel from the site of Cheboygan to Little Traverse Bay—the so-called "Inside Route" of Burt, Mullet, and Crooked lakes. The line of dunes stretching across the head of Little Traverse Bay from near Petoskey to Harbor Springs in Emmet County is upon a bar which closed this channel. The bar and the dune upon it dammed the drainage way, ponded the waters into the deeper depressions, and so formed Burt, Mullet, and Crooked lakes.

Very wisely the dunes are being included in the State parks—for the dunes sport and scenic pleasures they give. But the winds are ever blowing, ever moving the dunes inland, marching them over forests, into lakes, over farm lands. Plants of beach grass and trees hold the sands for a time, but a blown-down tree, a careless foottrack of man or animal with exposure of the sands, and the winds gleefully, wantonly, take up their work of destruction.

MOVING WATERS

In the 35,000 years since the ice front of the Saginaw lobe rested on the Sturgis moraine in St. Joseph County and its melt waters started to flow down the valley of the St. Joseph River to the Kankakee-Illinois, Mississippi drainageway, many changes have been made on the surface of Michigan. The large streams which now control the drainage of the State—the St. Joseph, Kalamazoo, Grand, Muskegon, Manistee, AuSable, Flint—were originally flowing in border channels along the various ice fronts as melt waters concentrated between the moraine and outwash plains. In each back step of the ice border to a new position, the headwaters of the glacial rivers were extended iceward. When the ice moved from the Sturgis to the Tekonsha moraine, the headwaters of the St. Joseph River came from the melting ice on the Tekonsha moraine. When the ice retreated to the Kalamazoo moraine, the Kalamazoo River formed along its border and drained southward to the St. Joseph. So the story goes for each large stream flowing to Lake Michigan, once it was the headwaters of the next major river to the south. As long as the ice covered the Huron basin the drainage was

to the west. Thus the headwaters of each of the major streams now flowing to the east were once the headwaters of a stream flowing west—the Raisin was a headwaters stream of the St. Joseph, the Huron and Maple of the Grand, the AuSable of the Manistee—and so for most of the others. This accounts for the wide valleys at the headwaters of little streams and for the very narrow divides between the headwaters of streams flowing in opposite directions. As soon as the retreating glacier uncovered lower outlets the streams divided on the highlands and took the lowest possible course. The St. Joseph took its present course away from the Kankakee—and each successive stream northward in turn deserted the stream to the south and made its independent way to Lake Michigan. And in this process many of the larger spillways were robbed of their waters and turned into chains of marshy lowlands, that eventually became flat "black lands" for the truck grower. Long narrow channel-like flats of washed gravel show us where a stream with a strong current once flowed.

As a result of changing outlet levels and the distribution of the glacial drift, drainage is haphazard and poorly developed. The familiar tree (dendritic) form of drainage is absent because sufficient time has not elapsed since the ice melted for the tributary streams to be extended headward into the watershed divides. Our thousands of lakes and swamps are evidence of the lack of drainage control. In many areas streams have tapped and partly drained some of the glacial lakes leaving swampy depressions which became peat bogs with the accumulation and compaction of organic matter. Boring with the peat rod proves that many of these bogs were once lake basins. In many of the water logged basins the peat is from 25 to 75 feet thick and rests upon bottoms of sand, clay, gravel, or marl. Various authorities state that in this climate one foot of peat may be formed in 300 years; therefore it may be assumed that a deposit of peat 50 feet thick required 15,000 years to accumulate. This is one of the timeclocks used in determining the years since the glacier melted from the land.

In many areas throughout the State, open basins are surrounded by uplands of drift containing an abundance of finely pulverized limestone. Ground waters have dissolved the calcium carbonate from the drift and redeposited it in the depressions to form marl beds—the gray-white stuff you often see along the banks of a black-land drainage ditch. Marl beds and peat under glacial drift are an evidence of readvance of the ice.

Many streams were formed on melting of the ice and existed as

long as the water-soaked drift supplied water. But unless they cut their beds down as the level—or water table—of the water in the drift was lowered, they disappeared also. The only streams that are permanent are those whose level is below the water table.

Lowering of the level of the Great Lakes naturally lowered the outlet level (base level) of the streams, quickened their currents, made them the streams from which our modern water power projects are developed. A few streams in the Southern Peninsula and many in the Northern Peninsula found their way to the lakes interrupted by the ledges of hard rock athwart their courses. A few Northern Peninsula streams were diverted from their direct course to the Great Lakes and flowed along the edges of the ledges until they found a favorable outlet. Most of the streams, however, dashed across the barrier in the beautiful falls and cascades to be found on nearly all of the Northern Peninsula rivers. They have cut gorges below the falls in the ancient rocks. Many of the streams have been utilized for water power, many of the most beautiful falls are threatened with destruction or with depletion of volume in order to develop the power latent in their fall down the slopes of the Northern Peninsula to Lakes Michigan and Superior. The streams of the eastern half of the peninsula flow in the swampy lowlands left as Lake Algonquin was drained.* Every stream in Michigan has a story. All those streams flowing to the glacial lakes cut their valleys to the levels of the lakes and then widened those valleys; as the lakes lowered, the streams lowered likewise, then could no longer widen their valleys but cut deep into their beds, leaving the earlier valley as a terrace above the new level. Many streams built deltas into the lakes, then cut through the deltas to the new lake level. Bloomer State Park, near Rochester, is built on the delta of an earlier Clinton River, and the deep terraced valley of the Clinton on the edge of the park is the channel cut as the level of the ancestors of the Great Lakes lowered. Nearly all the streams of eastern Michigan have a similar history. Each stream has its own story—but all are tied to ice melting and changes in the Great Lakes.

Nature, as well as man, used the power of moving waters. Man uses it to turn wheels—once to grind his grain, now to develop electricity. Nature uses it in her eternal experiments in remodeling the face of the earth. Lake basins are drained. The hundreds of peat bogs, patches of black soil, swamps, scattered all over Michi-

*All the major streams of the Northern Peninsula are described in Professional Paper 154.A United States Geological Survey.

gan show the location of former bodies of water which have disappeared. It is well to expect then that drainage adjustments will continue, rivers will cut their channels deeper into the easily eroded glacial drift, waterlogged swamps will be drained and become permanently dry. Nature would bring about these changes in thousands of years, but in many places man is hastening the process by over-drainage. In the chapter on soil we find more about how and why the thousands of glacial lakes and bogs disappeared.

Each lake in the State, large and small, has a story of change since it was formed in a depression of the glacial debris-covered surface. But however formed, the tale of a lake is the same—a basin filled with water, shores formed by work of its waves, beaches, bars, and other shore forms, filling by vegetation, wind-blown sand or slumping of cliffed shores, drainage, disappearance, ending in a large area or little patch of black soil.

This, in long telling, is the story of the molding of the face of Michigan. The ice started to retreat from the State 35,000 years ago. Gradually plants and animals returned. Probably subarctic flora came first, then the water-loving plants, and as the land dried out, came the upland types. Snail shells are found in the lowest beach of Lake Chicago, which probably correlates with early Lake Algonquin. Lake Erie was the first lake to be cut off from the ice; thus the first to be warm enough for plant life, and so the first to be populated with fish. As the other lakes became warm, plant life and fish migrated to them. We know elephants and mastodons followed on the heels of the ice as we find parts of their skeletons in glacial gravel pits and bogs. The remains are scanty because few of them died near, or were mired in, bogs. A few of those that died on the uplands were caught by swiftly moving glacial streams and swept along to be buried in the gravel deposit of the stream. Probably many more died on the uplands where their bones were destroyed by action of the weather.

The past thousands of years are but a few seconds in geological time, and the panorama of change still goes on and will continue so long as a single square foot of land surface remains above sea level. The last few seconds have given us Michigan—framed by its inland seas, its hills and plains, rivers and lakes—a surface that is temporary.

This is the story of the foundations of the State written and recorded through a billion years—the story of the filling of a granite basin, with rock formations which hold our mineral wealth; the tale of the spreading of a blanket rich in minerals plants need, and upon its surface developed that thin film of life, the soil, from which man lives; a story of endless, ceaseless change. The tale has been long in telling—it was two billion years in the making. It seeks to recount some facts we must have if we would know why we have our diversified scenery, our wealth of minerals, lands, forests, our agriculture and our industries. Facts we should know if we would explore for water, oil, iron; if we seek for or locate new industries; if we would find new use for old lands. Facts that tell us why we have a beautiful peninsula.

The final chapter has not been written. The relentless forces of nature will continue to produce a kaleidoscope of never ending change far into the remote and distant future. In the words of the eighteenth century geologist, Hutton, "The closest study of the geologic record has revealed no vestige of a beginning, no prospect of an end."

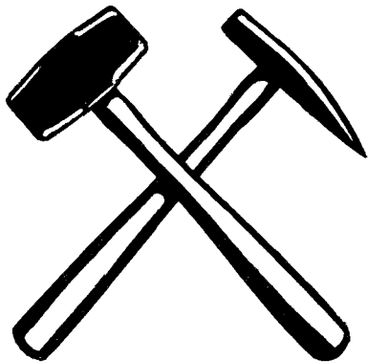


CHART OF MICHIGAN AGES

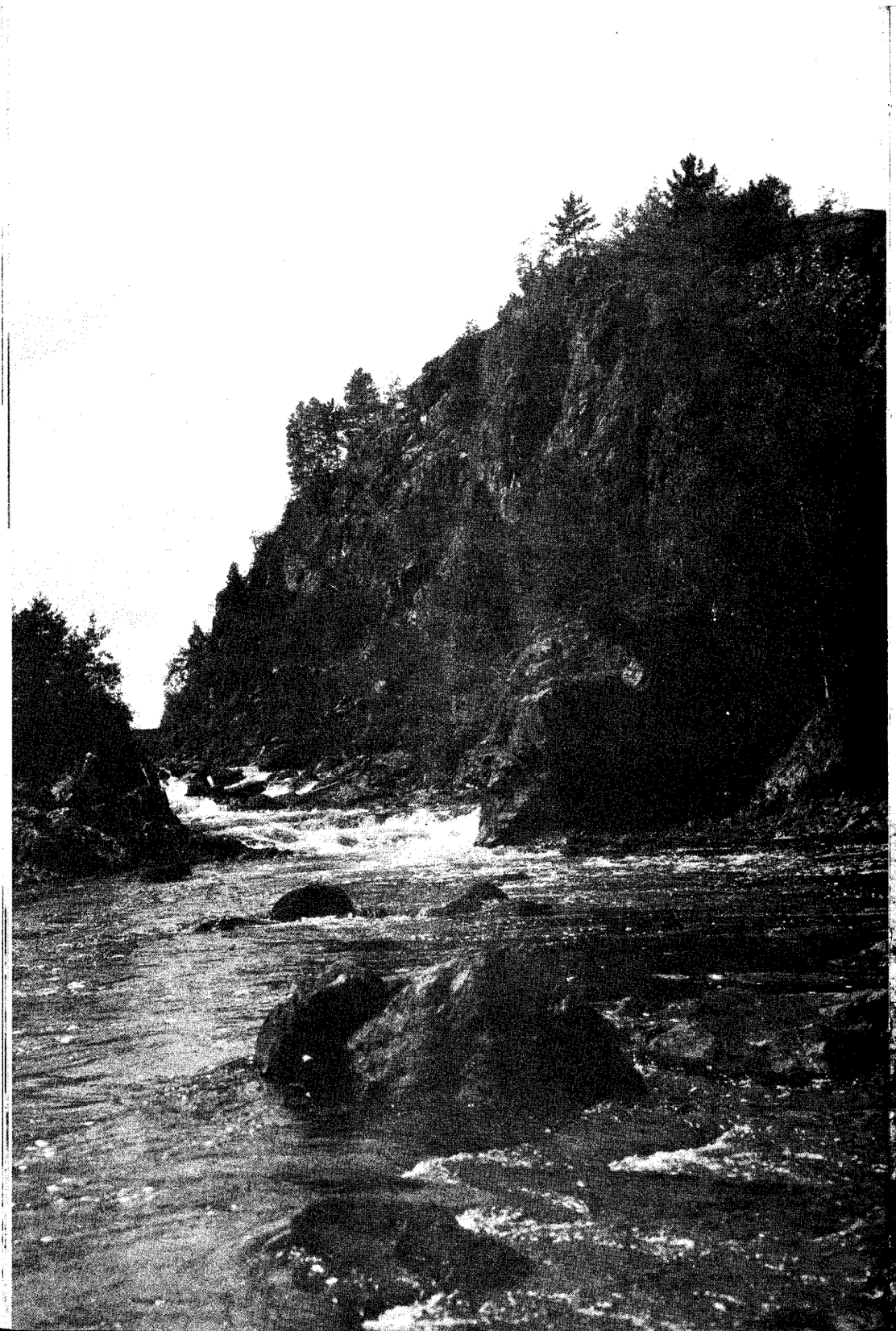
Michigan Department of Conservation—Organized in 1921

Ages	Began* Years Ago	Length*	What Happened	Principal Life Forms in Michigan and Elsewhere	Where You can Find the Rocks and their Fossils
Recent	35,000	35,000	Three thousand five hundred to three thousand years ago Port Huron outlet of Great Lakes became operative. Ten thousand years ago Lake Algonquin drained off the Northern Peninsula. Thirty-five thousand years ago glacier started melting north of vicinity of Sturgis, St. Joseph County, and forests started spreading northward over State. Fish migrated into inland lakes and streams; animals and birds followed spreading forests and grasslands. Marl beds, peat bogs, muck lands, and soils were formed. Marl beds 38 feet thick formed in southern part of Southern Peninsula. Peat maximum thickness in Southern Peninsula 60 feet, rarely 17 in Northern Peninsula. Soils measured in inches.	Sault Ste. Marie first white settlement 1658. White man (French) came in early 17th century. Indians followed Mound Builders. Mound Builders disappeared about 1,000 years ago. Man of Hopewell culture in Michigan probably ten thousand to eight thousand years ago. Primitive man probably came 15,000 years ago. Arctic to sub-Arctic to modern flora. Mastodon, mammoth, modern animals.	Peat, marl, and soils, thickest in southern counties, thin northward. Parts of skeletons of mastodons and mammoths found in bogs and gravel pits, shells in marl beds.
Pleistocene	2,000,000	1,965,000	Four glaciers covered over and melted from the Great Lakes region, deposited hills and plains of sand, gravel, clay, and boulders scraped from regions farther north; thus built most of the surface of Michigan. Left reservoirs of fresh water in lakes, streams, and underground. Climate glacial to subtropical in the interglacial stages. Drift from 0 to 1,000 feet thick.		Concentrates of the drift spread over the State may be found in gravel pits. All rock types and many fossils in rock debris of gravel pits.
Early Cenozoic and Mesozoic eras	60,000,000 200,000,000	58,000,000 140,000,000	Surface of Michigan eroded to highlands and broad valleys. Edges of sedimentary strata beveled. Copper and iron bearing rocks and granites exposed. Shared Continental uplift. Climate variable.	Higher mammals, birds, hardwoods, and flowers, moths, butterflies, and bees appeared elsewhere on the continent following the fall of the great dinosaurs (reptiles) dominant in the Mesozoic era. Some older forms of invertebrates continued, many new types evolved. Modern plants appeared between 100,000,000 and 60,000,000 years ago; the first birds came between 168,000,000 and 130,000,000 years ago; primitive mammals appeared between 200,000,000 and 168,000,000 years ago but no records found in Michigan.	
Permian	235,000,000	35,000,000	Great Lakes region with eastern part of continent lifted above sea level. Red muds or fine sands deposited or windblown in shallow waters in central part of State. Rock beds warped and wrinkled. Keweenaw fault may have been formed and/or movement on an earlier fault may have occurred during this time. Climate mild to arid.	No record found in Michigan. Primitive reptiles in other parts of the continent. Many invertebrates and plant types of older times became extinct; few groups became smaller and hardier.	Rock probably of this age found only in drill cuttings.
Pennsylvanian	280,000,000	45,000,000	Michigan shared eastern continental rising above and sinking below sea level with sandstones, shales, and coal swamps forming. Thin beds of the world's greatest coal deposits were formed here. Climate subtropical. Over 850 feet of rock made from Pennsylvanian sediments have been measured in Michigan.	Giant tree ferns, tree size horsetail rushes and ground pine. Invertebrates common. Earliest reptiles.	Arenac, Genesee, Ingham, Ionia, Jackson, Saginaw, and Shiawassee counties.
Mississippian	315,000,000	35,000,000	Sediments brought into Michigan from low-lying lands, built up shales, and sandstones. Near close basin almost a land-locked sea, limestones and gypsum deposited. Climate warm to semi-arid. Over 3400 feet rock formed from Mississippian sediments have been measured in Michigan.	Last of trilobites. Amphibians important. Invertebrates common. Fragments of plants along shores of Michigan seas fossilized in sandstones and shales.	Alpena, Antrim, Arenac, Branch, Calhoun, Cheboygan, Eaton, Grand Traverse, Hillsdale, Huron, Iosco, Jackson, Kent, Ogemaw, Ottawa, Presque Isle, Sanilac, St. Joseph, Tuscola counties.

CHART OF MICHIGAN AGES—Continued

Ages	Began* Years Ago	Length*	What Happened	Principal Life Forms in Michigan and Elsewhere	Where You can Find the Rocks and their Fossils
Devonian	350,000,000	35,000,000	Time of Michigan Coral Seas. Great coral reefs, thick deposits of limestones that later became petroleum-reservoirs. Some shales. Climate warm. Seas warm and clear. 2,850 feet of rock formed from Devonian sediments measured in Michigan.	Ages of fishes, first amphibians, but corals and other invertebrates dominant in Michigan warm seas.	Alpena, Charlevoix, Cheboygan, Emmet, Monroe, Presque Isle, Wayne counties.
Silurian	375,000,000	25,000,000	Michigan Basin a deep bay of the Silurian sea. Thick lime deposits at beginning, thick salt deposits during later time. Climate warm and genial at first, semi-arid to arid at close. 3,975 feet of rock formed from Silurian sediments have been measured in Michigan.	Age of corals. First air-breathers, a scorpion was first land animal. Land floras appear. Corals and invertebrates in Michigan seas.	Chippewa, Delta, Mackinac, Monroe, Schoolcraft counties.
Ordovician	445,000,000	70,000,000	Time of shifting seas and thick deposits of limestone and shale forming sediments. Climate mild. Over 2,100 feet of rock formed from sediments in the Ordovician seas have been measured in Michigan.	Marine invertebrates. First primitive vertebrate, the "shell-skinned" ostracoderm lived in muds along shores of Trenton sea.	Chippewa, Delta, Houghton, Menominee, Schoolcraft counties.
Cambrian	550,000,000	105,000,000	All of Michigan area excepting probably a narrow strip bordering Lake Superior in Keweenaw, Houghton, Ontonagon, and Gogebic counties, covered by sea. Sediments mainly sands. Climate mild. Over 2,000 feet of rock formed from sediments in the Cambrian sea have been measured in Michigan.	Age of the invertebrates. Shellfish of many kinds. Trilobites flourished.	Alger, Baraga, Chippewa, Houghton, Dickinson, Iron, Luce, Marquette, Ontonagon counties.
Keweenawan	800,000,000	250,000,000	Great eruptions of lava and intrusions of molten copper bearing rocks alternating with deposition of sands and conglomerates. World's greatest deposits of virgin copper in Keweenaw, Houghton, and Ontonagon counties. Mountains uplifted and worn down. Over 35,000 feet of lava flows, conglomerate and sandstones measured in Michigan.	Fossil records lost in Michigan. Probably many primitive invertebrates lived in sea elsewhere, but had no hard parts to fossilize and delicate casts, molds, impressions were destroyed.	Gogebic, Houghton, Keweenaw, Ontonagon counties.
Huronian	1,050,000,000	250,000,000	Shallow seas. Michigan shared in world's greatest iron ore forming deposits. Pure lime muds and shales deposited which later intrusions of molten granite changed to marble and schists. Impure lime muds metamorphosed to verde antique marble. Over 17,000 feet of rock formed from Huronian sediments measured in Michigan.	Bacteria, sea-weed, sponges. Actual fossils imperfect, questionable, or lacking in Michigan.	Baraga, Dickinson, Gogebic, Iron, Marquette, Menominee counties.
Tamiskaming	1,200,000,000	150,000,000	Widespread seas and sediments during early part, followed by mountain-building and intrusions of granite. Sediments removed in Michigan, granite exposed. Unmeasured.		Marquette.
Laurentian-Kewatin	2,000,000,000	800,000,000	Earth cooling, shrinking; crust wrinkling to high mountains and sea basins. Molten rocks break through crust. Oldest Michigan rocks are granitic roots or stubs of mountain ranges of this time. Unmeasured. Many records lost.	Blue-green algae present. Probably primitive one-celled plants and marine animals also present. No fossil records found in Michigan.	Baraga, Dickinson, Gogebic-Iron, Marquette, Monominee counties.
Azoic Era	??	All the time before—probably 1,500,000,000 to 2,000,000,000	Birth of earth from the sun. Rocks formed from original "granite juice." Water and atmosphere developed from gasses surrounding the Earth and emitted from the hot rocks of the Earth.		

*Geologic time is measured by many clocks—by thickness of peat deposits, of leached zone of soil, by numbers of thick-light, and thin-dark layers of clay (varves), by rate of lime deposit, rate of cutting of water falls in known historical times, and the rate of disintegration of radio-active minerals. Round numbers are given although some scientists have calculated the ages of rocks more exactly.



IN THE STOREHOUSE OF THE AGES

Let us briefly, sketchily, inventory the wealth Nature piled up for us in the long geological time. From the ancient granites were derived all the younger rocks, all the minerals in our soils that the plants need. Nowadays the granites and their kindred rocks supply us with building stone and road metal. In the Northern Peninsula, at their outcrop the old igneous rocks can be quarried but are a bit difficult of working and have perhaps a greater value creating the marvelous scenic effects of the Huron and Porcupine mountains. In the Southern Peninsula, the erratics derived from the ancient granites and left in the glacial drift, are an abundant source of building stone.

The Huronian rocks hold the vast wealth of the iron formations. As we have found, those rocks are broken, faulted, some even turned over backward—so cracked and shoved about that the edges of ore bodies are separated a few and also hundreds of feet, which makes mining difficult and the search for ore bodies complicated. But since its discovery in 1844 Michigan has mined one of the

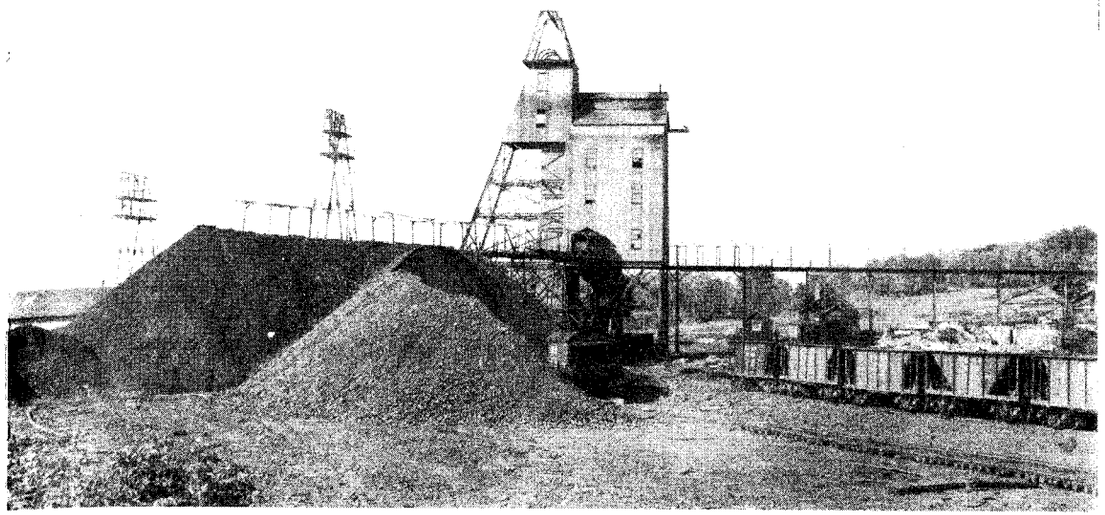
◀ RAPIDS ON MICHIGAMME RIVER NEAR MANSFIELD, IRON COUNTY, CUT THROUGH DARK HURONIAN ROCKS. FROM THE BARE ROCK OF THE IRON FORMATION SOILS ARE FORMED AND TREES FIND A ROOT-HOLD.

▼ JACKSON PIT, SITE OF THE FIRST IRON-MINING IN MICHIGAN.

richest iron ore fields in the world, and for nearly 100 years the wealth and industry of the State has depended in large measure on the iron. How many things in your daily living could you have if we had no iron? At first the iron ore was smelted in charcoal furnaces near Marquette—one of the old furnaces is now a tourist exhibit. The charcoal was made from the "inexhaustible" hardwoods of the original forest, but as the hardwoods were depleted and newer methods of smelting came into use it became cheaper and more expedient to move the iron ore to the fuel—the coal of Pennsylvania. A few furnace towns were abandoned and their buildings left to crumble and stare blankly at the brush growing in the streetways.

We have used much of our high grade ore, but have great reserves of low grade leaner ores which become of more value as means of reducing them are worked out. Iron County has reserves of iron ore so high in phosphorous that they are "penalty" not "premium" ores. But metallurgists are trying to develop a process whereby those ores can be reduced profitably despite the phosphorous. Michigan has not been able to compete with the low grade cheaper ores of the Mesabi range in Minnesota, but as those ores are worked out Michigan's greater reserves of high grade ore will again take the lead, and by that time metallurgists will have solved some of the problems of profitable reduction of the lean ores and those having objectionable impurities. Also explorations conducted by the Geological Survey Division are attempting to locate new ore bodies and to solve the problems of complex structure in the iron formations. Left to Nature the lean ores would be enriched just as the high grade ores were—but man can't wait for Nature's slow but steady processes. When the mines are worked out, what then? Iron is an expendible ore but one not lost by use. True, iron as steel rusts, and articles made of steel are destroyed, but the iron itself has returned to its ore—it can be returned to the furnace, resmelted, and reused over and over, the iron in the rust film being the only loss. The chemists find other metals to add to the iron to make alloys that are harder, stainless, less destroyable. We need not waste the iron we have mined. We need not lose it. But man, being the optimistic creature he is, will not worry about iron waste until he is scared by announcement that the reserves are almost gone, then he will save every scrap of iron for the junk dealer to collect. He might think before he has need to be scared.

When the low grade, easily worked ores of the Mesabi range were opened a social problem was created in Michigan's iron dis-



MINE SHAFT. TOBIN MINE, CRYSTAL FALLS.

tricts—the mines of high grade ore could not compete and unemployment came to the Michigan iron towns. Some of the iron mining companies solved a part of the problem by introducing new industries, notably the wood working industries now centered in Munising. With the upturn in prosperity following the war-need for iron ores unemployment dropped, a modest prosperity is on the return. The newly white-painted dwellings of Ramsey are pleasing evidence of better conditions for both the industry and the man upon whom the industry depends—the miner.

Of lesser importance are the green verde antique and white marbles, graphite, slate, talc, and asbestos of the Huronian rocks. The white marbles of Dickinson County are too badly shattered for use as a building stone, but are in use for stucco, small ornamental work, and paint filler. The green marbles found near Ishpeming were formerly quarried for use as terrazo, but it is possible that blocks large enough for building purposes may be produced. Graphite used for paint was once produced from graphitic slate quarries east of L'Anse. The fine black slate quarries are on the northwestern side of the Huron Mountains near Arvon, Baraga County. When the quarries are operated the slate is used for roofing shingles. Some of the Ford Museum buildings at Dearborn are roofed with this slate. Talc and asbestos are in the rocks north of Ishpeming. Gold has been found in quartz veins of the rocks north of Ishpeming. The most famous and productive mine was the Ropes from which over $625,000 worth of gold was taken. Exploration may reveal more gold-bearing veins. All these mineral resources await future development and use.

WAKEFIELD OPEN PIT IRON MINE. GOGEBIC COUNTY.

The scenery produced by these worn Huronian sediments and their igneous intrusions is not to be ignored as a valuable asset in Marquette, Baraga, Dickinson, Iron, Menominee counties. From the top of crumpled, red and glistening black Jasper Hill, near Ishpeming, one can look over the entire Iron Range. The diorite knobs make imposing Grant Wood landscapes near Ironwood and Ramsey. The open pit iron mines near Wakefield, although almost worked out as open pit mines, are a never-failing source of interest to the tourist. The park system of many towns should include these geologic wonders and curiosities as added attractions. Many towns in the State have within their limits or nearby, natural phenomenon of interest to local and passing population, if attention were called to them.

Into the lava flows of Keweenaw, Houghton, and Ontonagon counties percolating hot waters rising from great depths brought copper and silver in solution, and as it cooled, filled the fissures and the gas cavities—or amygdules of the lavas (trap rocks)—with pure copper and silver, making the greatest deposit of native copper in the world. Copper was also deposited in the cracks in the conglomerates. Many beautiful minerals, as yet of no economic

importance, are associated with the copper lodes. Copper jewelry and amulets worn by the Indians excited the interest of the early white explorers. They learned the Indians had not mined the copper but had found it scattered on the surface west of the Pictured Rocks. Explorers from the time of the Jesuits to Schoolcraft searched without success for the "mother lode." A huge boulder on the Ontonagon River, said by Alexander Henry, the first white man to describe it, to weigh five tons led, in 1770, to the first copper mining venture in the Northern Peninsula—near the boulder twenty miles from the mouth of the Ontonagon. It was unsuccessful. Douglass Houghton, who later became the first State Geologist, while working with Henry Schoolcraft, became convinced that the float copper had its origin in copper veins "in the trappean rocks of Keweenaw Peninsula." This conviction brought about the various treaties with the Chippewas by which Michigan obtained the lands west of the meridian of Marquette and became a State. Mining started in 1844 by the sinking of two shafts near Copper Harbor, both unsuccessful. Profitable mining began in 1845 when at the Cliff mine the first mass of native copper in place was discovered. Other mines were opened along the extent of the copper bearing rocks; some were exhausted in a short time, others continued mining, going deeper and deeper until some of the mines are over a mile in vertical depth and several shafts are over 9,000 feet deep on the incline. The copper became harder and more expensive to mine until finally, when cheaper copper could be obtained from other regions, it became unprofitable to mine copper in Michigan. Michigan's mines, although obtaining pure copper, could not compete with those western mines which obtained copper ores near the surface. Michigan copper is so free of ore that at first the mining companies took what they could get through the stamp mill, and the stamp rock, containing minute quantities of finely divided copper and copper ore, was dumped as tailings. The need for copper is great, the cost of mining prohibitive, the problem of all the people dependent on the copper mines was serious, so the companies set up means of obtaining copper from its ores, and now the reclamation plants are working over the old tailings. However, the reclamation plants could not employ all the people of the Copper Country who depend on operation of the copper mines. We have in the Copper Country an excellent example of the serious problem of employment in a one industry region. New industries must be found for the people who remain there. Nature is generous, other riches may be found to substitute for the hard-to-obtain mineral

wealth, and Nature has made this region one of the most beautiful of the State. True, it is marred by the weather-beaten houses and vacant stores of the once prosperous mine towns, but the tourist industry is bringing new hope to the region—a hope not to be laid aside as war brings a return of the mining industry, for once the need for copper relaxes and the price goes down, once again will the mines have to close. The tourist industry is encouraging the development of native crafts, utilizing the copper and the beautiful copper rocks and minerals. Excellent highways are being made, using the abundance of ready crushed rock from the mine dumps. As the scenery of the beautiful Keweenaw Peninsula, along its marvelous Brockway Drive, becomes known, and Isle Royale National Park is made more accessible by adequate boat service, the region is sharing more and more with the rest of the State in the tourist industry, and new industries will replace the old. At the present time (1941) mining is having a revival, six of the nineteen mines operating a few years ago have resumed operations, as Michigan copper has been pegged at a price that makes operation at the deep levels of the mines profitable. The problem in Michigan mines is not one of the ores depletion—the lodes show no lessening of value with depth—nor related to the geological occurrence of the metal, but a problem of ability of the producers to compete with foreign and western production. Furthermore, new methods of exploration reveal the prospect of greater reserves of near-surface copper. Only twenty-five percent of the country known to have copper bearing rocks has been prospected. The future of the Copper Country is not so drab as its unpainted houses and its ghost towns indicate.

Silver is a generous by-product of the copper mines. Its presence in the copper in microscopic flakes makes Michigan's copper premium metal. Free silver has been found near Ontonagon. Of interest rather than commercial value are the semi-precious gem stones found along the beaches of the copper counties and Isle Royale. The trap rock of the Copper Country, like the traps of the remainder of the pre-Cambrian area, are a valuable resource for road material.

The Cambrian-Ozarkian sandstones are reservoirs of pure water in the Northern Peninsula. The red sandstone, a good building stone, was formerly quarried at Jacobsville and used for building purposes until shipping costs and cheaper cement-concrete materials made production costs prohibitive. We have large reserves

of sandstone in the Peninsula. Near the top of the Hermansville formation the sandstone is free enough of impurities to make it a potential source of glass sand. At present probably the tourist receives greatest value from the sandstone in viewing the scenic effects produced by weathering along exposed edges at the lake shore, and in the little gorges cut back into the cliffs by rivers—Pictured Rocks, Miner's Castle, Miner's Falls, and many others.

The Ordovician-St. Peters sandstone is also a reservoir of pure water. The Ordovician-Trenton limestone supplies building material and crushed stone for road building and fresh water in places in the Northern Peninsula. It is a source of petroleum in the southeastern corner of the Southern Peninsula and a potential source of oil within the basin.

In the Silurian rocks we have the Niagaran limestones and dolomites, the Salina salt beds, the Mackinac and Bass Island limestones. The Niagaran stretches in broad outcrop from the Garden Peninsula to Drummond Island. In the Northern Peninsula its underground beds are a source of fresh water, gas and oil have been found in them in the Southern Peninsula. From quarries cut in its outcrop a calcium magnesian carbonate rock (dolomite), and a calcium carbonate rock, limestone, are obtained. The limestone is used for burning lime and is crushed for road metal, concrete, and cement. It is used in the manufacture of calcium carbide and other chemicals, in paper, sugar, and open hearth steel manufacture, and as a flux in iron furnaces. The dolomite is used for crushed stone, ballast, concrete, macadam, in paper and open hearth steel manufacture. An important new use for the almost inexhaustible dolomites has been found—it is a potential source of metallic magnesium so necesary in the manufacture of trucks, busses, airplanes, railway cars, where strength and lightness are essential. The Niagaran dolomites hold a potential reserve of 400,000,000 tons of metallic magnesium. The problem of utilization, of course, is one of separation of the magnesium from the rock.

From the Salina (late Silurian) salt beds we are assured of a salt supply of some trillion tons. Beds of pure rock salt 400 to 1600 feet thick, with additional thinner beds alternating with shales, dolomites, and gypsum, underly the Southern Peninsula. At Port Huron, St. Clair, and Detroit, hot water is pumped into the salt to form artificial brines which are then pumped up and used in the manufacture of salt and in the chemical industries. The only

salt mine in Michigan is 1100 feet under Detroit in the clear Salina rock salt. The largest gas well in the State is obtaining gas from the Salina formation; thus it is a potential producer of gas in the other parts of the Michigan basin which it underlies.

The rock salt is used for packing meat and fish, for the manufacture of soda ash, caustic, bleach, and other chemical preparations, refrigeration, and agricultural purposes. From the upper Silurian limestones of the southeastern Southern Peninsula we obtain mineral waters, fresh artesian water, and from the outcrops, crushed limestone for road metal and concrete.

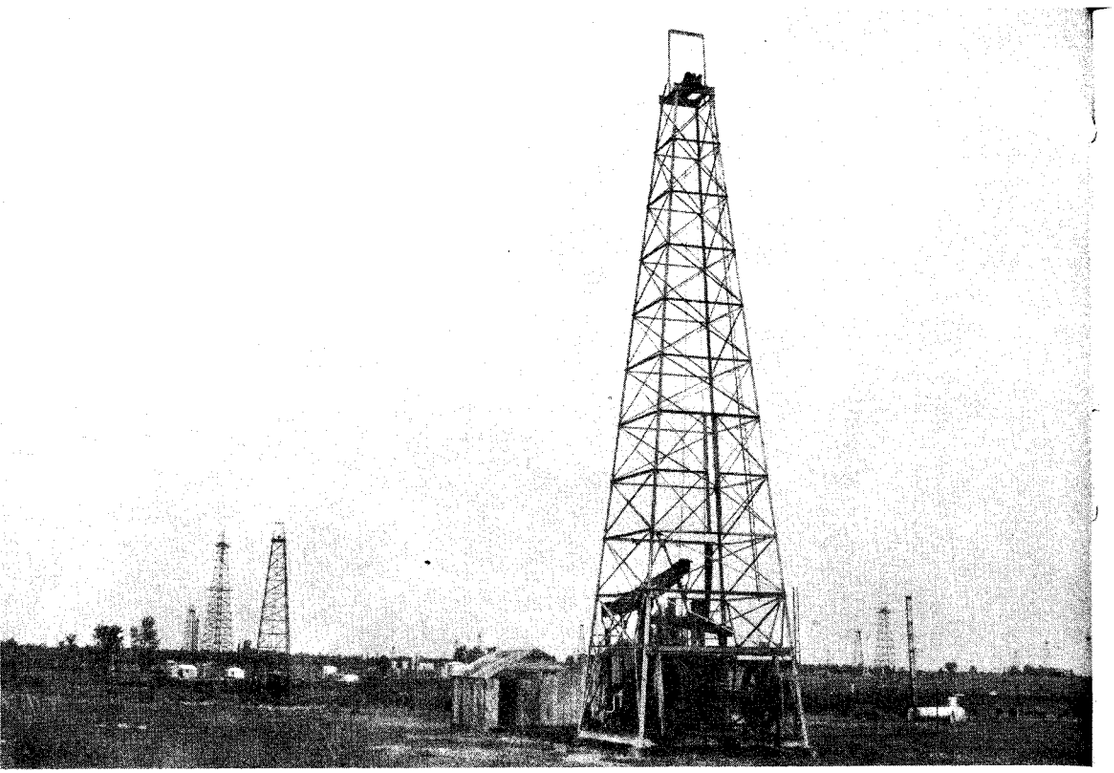
The Devonian rocks supply us with a variety of mineral resources. From the outcrop of the basal sandstone in Wayne and Monroe counties—the Sylvania—we obtain a sand used in the manufacture of glass. Some of this sand is so free from iron, the most vexing impurity, that the sand is suitable for optical glass. During and shortly after World War I most of the glass used for the manufacture of optical glass for the federal government was obtained from the Michigan quarries. The sand is now used for the manufacture of plate glass, fine table glassware, and common glassware of many uses. These sandstone beds are believed to be ancient dunes blown up on the shore of one of our ancient seas. As we trace

ROGERS QUARRY. OVERBURDEN REMOVED, SHOWING PRE-GLACIAL EROSION SURFACE. FACE OF QUARRY WALL SHOWS BENDING OF LIMESTONE BEDS.

LOADING LIMESTONE BLOCKS IN ROGERS QUARRY.

the Sylvania towards the center of the State under the overlying formations, we find from the logs (records) of wells drilled into it that it becomes thicker with lenses of limestone and shale, and that the porous parts of the formation contain brines. These brines are not yet in use but are a potential source of brine reserves for future chemical industries, and also possible oil and gas reserves.

From the outcrops of the Devonian rocks in Wayne, Charlevoix, Emmet, Cheboygan, Presque Isle, and Alpena counties limestone and dolomite are quarried, used for flux, agricultural lime and sugar manufacture, cement, crushed stone, in the chemical industries; in glass and paper manufacture; for water softener, gas purifier, and for construction purposes, and for an important new use developed within the past decade—rock wool which can use limestone unsuited for flux in the steel mills. The largest limestone quarry in the world is in the Rogers City and Dundee limestone near Rogers City, Presque Isle County. For many years the "fines", or waste rock for which no use was known, were dumped into Lake Huron. Now they are being recovered and used in the chemical



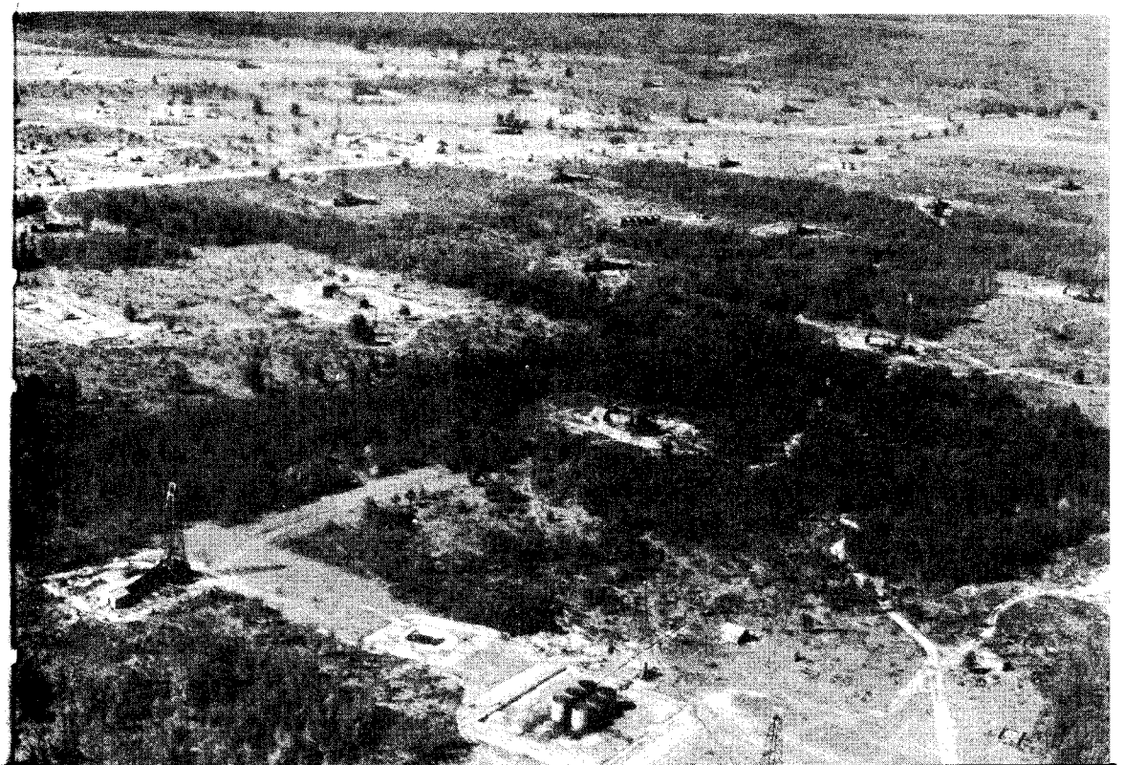
OIL FIELD, MIDLAND COUNTY, ON FLAT GLACIAL LAKE PLAIN.

industries and for agriculture. Good conservation finds use for apparent wastes.

The deeply buried Devonian rocks (above the Sylvania) are probably the most familiar as their mineral contribution has been the most recent and the most spectacular. For many years salt brines have been obtained from the lowest of these rocks (the Detroit River formation) to supply the salt industry in Manistee and Ludington. As long ago as 1886 petroleum was obtained from the next overlying rock—the Dundee—in the wells near Port Huron, a thick oil which was produced for use in manufacture of lubricants until the property on which the wells were drilled became more valuable as a building property. But in the 1920's petroleum and natural gas were found in the buried Traverse rocks which overly the Dundee—the same rocks that come to the surface in an arc and are quarried from Alpena to Little Traverse Bay, then slope southward under the peninsula to its center, but then rise again towards the southern boundary of the State. Wells were feverishly drilled to the oil pools underlying Saginaw and Muskegon, and because people were so eager to get rich quick with the black gold from these

pools, the fields were over-drilled, the natural gas allowed to escape, the oil taken out too quickly so that pressure on the water surrounding the pools was released, water seeped in, drowned the pools, and destroyed the oil and gas wells. Remember we learned (p. 35) that during the slow uplifts which brought the continent above sea level the rocks of the Michigan Basin were wrinkled and warped and great wrinkles or folds made across the State from northwest to southeast. The up-wrinkles are "anticlines,"—the down-wrinkles "synclines". Smaller wrinkles or folds developed across the main folds so that the long main folds have high and low places. Remember also that much organic matter was buried in the lime and clay muds on the floors of the old seas when the animals living in them died, and remained when the muds solidified into shales and limestones. The organic matter was distilled to petroleum and natural gas which collected under the high tops of the main folds as they are lighter than water. When the gas and oil are taken out of the folds—oil men call them "structures"—water takes their place. If the gas and oil is removed too rapidly pressure on the water is released—it can move faster than the oil and drives in and drowns the oil pool. This is just what happened in Saginaw

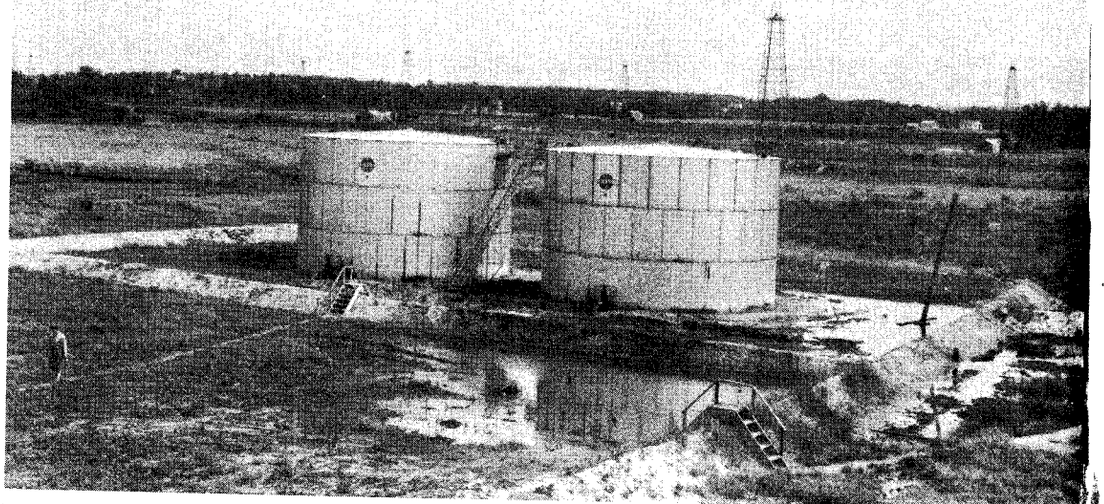
AERIAL VIEW OF NORTH BUCKEYE OIL FIELD, GLADWIN COUNTY

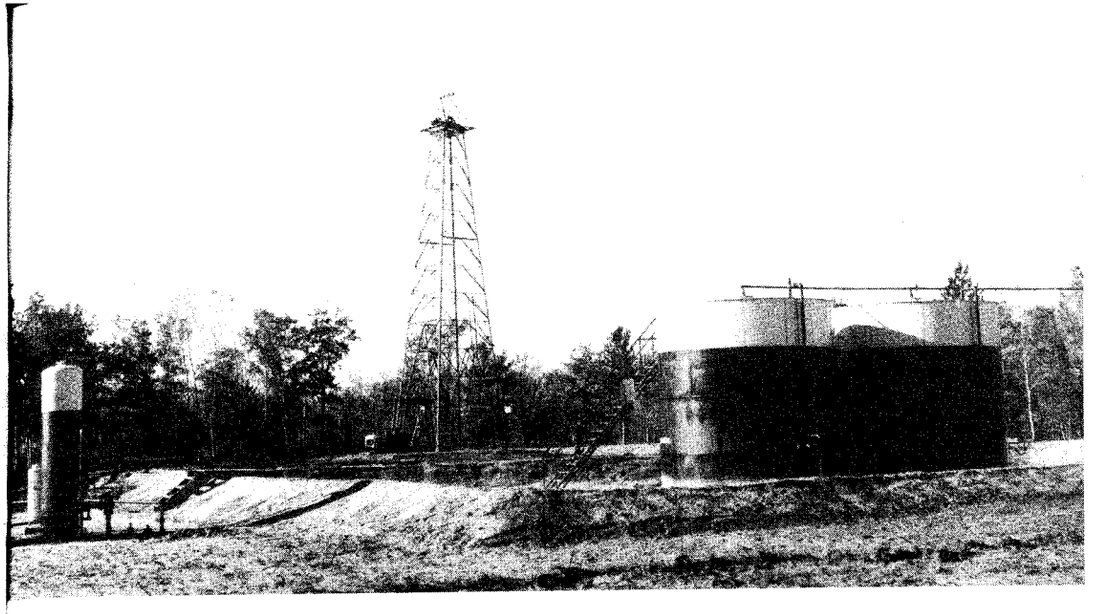


and Muskegon. So the State stepped in to save one of the most valuable but easily expendible resources, one which can most readily be destroyed at its source, and unlike a forest, can never be restored, but one whose life of usefulness can be prolonged by proper development. Laws were passed governing the drilling for and production of oil and gas. (Enforcement of the laws is a function of the Field Administration Division of the Department of Conservation). The essence of the law is that only so much oil as is needed may be taken from the rock reservoir. The law provides that in drilling through the rocks all strata carrying water and (or) brine be so shut off that the oil bearing strata will not be contaminated by water or brine, and that when a well is abandoned—that is, when no oil has been found or the well has been pumped dry—it shall be so plugged that no oil, water, or brine bearing formation be contaminated by fluid from any other stratum the well passed through. In other words, the purpose of the law is to keep our fluid natural wealth—water, brines, oil, and gas—safe from contamination one from another, and keep each protected and in the storehouse nature provided—the rock stratum, or several strata, in which it is found. Therefore, when exploration found more "structures" and drilling proved oil was in them, they were produced by proper conservation methods and the pools, although diminishing in production—for petroleum and natural gas resources are far from inexhaustible—have lasted for some time. Probably the maximum amount of oil has been obtained and water did not encroach upon the properly developed pools until the oil was practically all removed. Proper regulatory measures of developing this one of our natural resources has proved that it is very profitable to "lock the barn before the horse is stolen." The major part of the petroleum industry seeks all measures of oil conservation, new methods of drilling, new methods of opening the pores in the rock to obtain maximum recovery. Formerly the pores were opened by blasting the rock far below the surface—a practice which frequently let water in also; newer methods dissolve the rock gradually by means of acids, and research chemists have discovered ways of making gasoline which will do more work.

Having found profitable quantities of oil in the Traverse limestone, exploration went deeper and found even more oil in the Dundee limestone which is separated from the Traverse by a 40-80 foot bed of Bell shale—named from the old town of Bell, Presque Isle County, where a quarry producing the shale for cement was once operated. Deeper drilling in the Devonian found another reservoir of oil in the Detroit River formation. Salt brine is produced from the formation at Ludington and Manistee but at the top of a fold in the formation under southwestern Roscommon County oil is found in the latest (September 1941) pool found in the State.

OIL FIELD TANK FARM, MIDLAND COUNTY.





OIL FIELD, ROSCOMMON COUNTY.

Thus during the long ago time Nature stored in Michigan's coral seas much wealth for us to find. The wealth in limestone and salt is immeasurable, but the wealth in petroleum and gas can be exhausted or destroyed very rapidly and must be developed and used wisely.

Was the organic matter in the black Mississippian shale, the Antrim overlying the Traverse, the source of the Traverse oil? We do not know (some gas is found in the Antrim), but we do know that the black Antrim, green Ellsworth, and the blue Coldwater shales are very useful in the manufacture of cement, brick, and tile, and that quarries are worked in them in Alpena, Charlevoix, Antrim and Branch counties.

Above and within the Coldwater shales is one of the most interesting of our rock bowls—the Marshall sandstone. The rim of the Marshall comes to, or is near, the surface in many places from the tip of the Thumb where it is carved to interesting scenery, through Huron, Jackson, Calhoun, and Ottawa counties. In the early days many quarries were opened in it and the sandstone used for building purposes. Several small quarries are being operated now. One of our ghost towns is Grindstone City, Huron County, where once a flourishing industry produced the largest and finest grindstones, scythestones, and honestones in the world. Artificial carborundum killed that industry. But when particularly fine grind- and honestones are needed the quarry is occasionally operated. Near its buried edges the Marshall carries pure water and is the source of the water supply for many towns along its rim. But as the rainwater seeps down to the sandstone, then gradually seeps down the slopes toward the center of the basin, it dissolves mineral matter in the rock and when it reaches the bottom of the bowl under Midland County and meets the old sea water of Mississippian time imprisoned there it is a very bitter water carrying much chlorine, iodine, magnesium, sodium, and other salts and minerals in solution. It is the source material for a great chemical industry. Several hundred chemical and pharmaceutical products are made from the brines and have many commercial uses. When we see a motion picture or ride in a car with a purring motor we seldom remember that it may be bromine from the Marshall brine that was used for the silver bromide that makes the film possible, or the tetraethyl lead put in the gasoline to take the knock from our motor. When we ride over a dustless country road we do not remember that it may be calcium chloride from the Marshall brines that is used to

lay the dust. And it is almost beyond imagination to realize that the light truck that passed us or the airplane flying overhead was made from metallic magnesium taken from these brines and that some of the magnesium salts went into the making of flashlight powder, more to make milk of magnesia and other widely advertised internal correctives. True, Michigan's other brines are also a source of chemicals from which hundreds of products are made and are byproducts of the salt and even of the petroleum industry, but until 1940 the only metallic magnesium produced in the United States was from those long buried imprisoned sea waters, the Marshall brines under Midland County. Plants are being erected for the extraction of magnesium from sea water and also from the several magnesian minerals and rocks. Scenery, buildings, water supplies, material for medicines and airplanes, material for dustless roads and knockless motors, chemicals whose proper use as rock solvents make it possible to drill deeper wells, open up tight rocks and let more oil escape, materials for the new plastics—all these and many more were stored up for us in a gray brown sand deposited on a sea floor nearly 310 million years ago. And our oil well drilling laws protect this source bed of wealth also from contamination.

However remarkable the products from the Marshall brine seem now, they were after all first sought and pumped up for the manufacture of ordinary salt. Development of all the other products came after research in ways to use waste bitterns after salt was extracted—they are the byproduct of a byproduct. The story of the salt industry in Michigan after 1859 is really a conservation story, although very few thought of conservation at that time. It is also an illustration that gains and losses may be compensated. The Saginaw valley was the scene of great lumbering activities. Saw mills buzzed and hummed, piling up great heaps of refuse as the logs became lumber—bark, sawdust, slabs. So the East Saginaw Manufacturing Company, having discovered that brines were in the rock at a depth of 650 feet, decided that salt manufacture could be made profitable if the fuel were cheap enough. They found the lumbering wastes were perfectly suited—cheap and as inexhaustible as the forests. The success of the company led to a rapid development of the salt industry throughout the Saginaw valley and spread to all the lumbering towns along the shores of Lake Huron and Saginaw Bay—from Oscoda and East Tawas to Harbor Beach; later it spread inland to St. Louis and Midland. Eventually salt manufacture became a byproduct of the lumbering industry