STATE OF MICHIGAN
DEPARTMENT OF CONSERVATION
P. J. Hoffmaster, Director

THEY NEED NOT VANISH
A DISCUSSION OF THE NATURAL RESOURCES OF MICHIGAN

Edited by
HELEN M. MARTIN

from contributions by

Shirley W. Allen, Geo. C. S. Benson, *University of Michigan*

Stannard B. Bergquist, L. R. Schoenmann, H. C. Beeskaw, J. H. Kraemer, W. F. Morofsky, J. A. Porter, E. C. Sackrider, *Michigan State College*

G. S. McIntire, H. M. Martin, O. F. Poindexter, C. F. Welch, *Department of Conservation*

M. G. Adams, *Stream Control Commission*

Frank DuMond, *Public Museum*, Grand Rapids

Lynn Heatley, *High School*, Midland.

Contents

FOREWORD

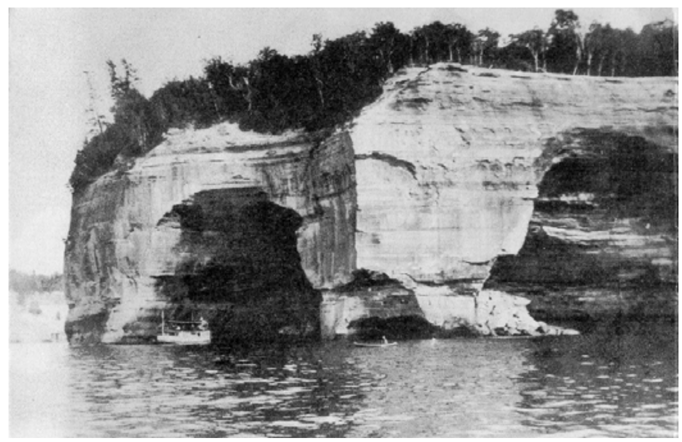
THEY NEED NOT VANISH is Michigan's first attempt to offer the teachers of the State a coordinated and substantial basis for the teaching of the conservation of our natural resources. This volume, with its companion book LEARNING TO CONSERVE OUR NATURAL RESOURCES, published by the Department of Public Instruction, is intended to provide for the teacher and the general reader, not only a background of the history of this state's natural resources and what has been done to prevent waste and to promote better uses, but also to furnish practical aid in passing this information and such principles on to the student.

No conservation program can succeed without the active interest, cooperation and participation of the public. It is believed one of the most effective ways of securing this cooperation is by engendering into the younger generation a sense of the social and economic necessities for using cautiously, and if possible, wisely, those resources with which Michigan has been so generously endowed.

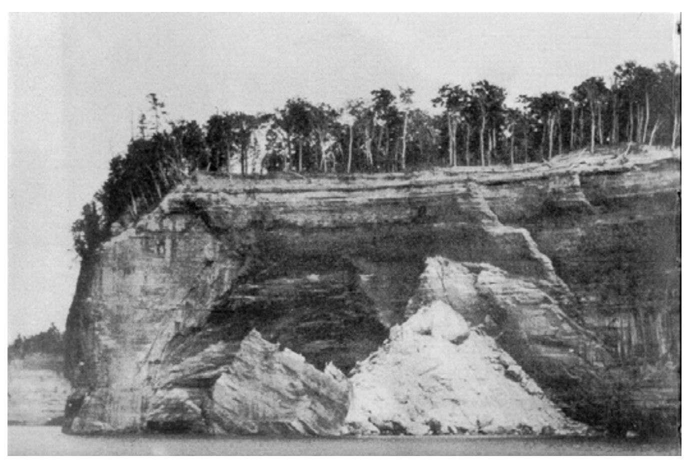
This book is not the result of the work of one person, but rather of a group which has been working for several years with the Department of Conservation and the Department of Public Instruction to produce what we believe to be the first such cooperative effort to give the schools of Michigan something which has long been needed. We sincerely hope this book will satisfy a goodly part of that need.

[Signed] P. J. Hoffmaster
Director
Michigan Department of Conservation.

Photographs from Department of Conservation; Department of Geology and Geography, Michigan State College; U. S. Soils Conservation Service and contributors.



GRAND PORTAL. TEN THOUSAND YEARS IN CARVING. Photo by J. M. Longyear, 1898. Courtesy Mrs. Carroll Paul, Marquette.



DESTROYED BY THE FURY OF A WINTER'S STORM.

Part I. WHY . . . . . ?

For well over two billion years the earth was in preparation for man's coming. Rock after rock was built, burying within its mass minerals and metals later to be used by man. Slowly, grain by grain, rock masses were taken from the land and in the sea they were built into other rocks, which in turn were slowly lifted above the sea or buckled high into mountains. But always, even during the building, the warring forces of nature were at work, slowly, relentlessly wearing down high land, low land, carrying it back into the sea.

Strange animals have lived upon the sea floor and in the waters above. They died and left their hard skeletons to petrify. Later, amazing animals lived upon the land and left their records in the soft mud and sands, about waterholes, or they were buried in asphalt lakes, or mired in marshes. Some of their bones became petrified. Strange forests covered some lands many times. Forests grew, sheltered strange insects, were set on fire by lightning, were blown down by storms, died, and were buried.

Layers upon layers of rock were laid down, pushed up, tilted, filled with minerals—and that process never ceases. Slowly, surely, grain by grain, down came the highlands, back to the sea. Over and over, plant life thrived, died, was buried, until finally the highest form of plant life came upon the land, the hardwoods and the flowers. Over and over, the seas became populated with animal life, but each group was more highly developed than the one that came before, until finally the vertebrates, and at last man, came upon the land.

And there was the earth spread out for man to enjoy. At first he enjoyed the simple pleasures of the lands, streams, forests—food, simple clothing, rude shelter. He did not materially disturb nature's processes, nor was he disturbed by them. Nature remained in balance. But life became complex. Man learned to increase and store his food supply, to use raiment for adornment as well as for protection. He learned to plant and cultivate a crop and therefore established permanent dwelling places. He learned to use the forest materials to protect his rude fields from wild animals and from his neighbors, and with the skins of wild beasts to construct shelters for himself. He tamed wild creatures for his own use; harnessed the currents of the streams to turn his wheels. He made tools of the minerals he found about him. He became civilized.

As he became more and more civilized he used more of nature's gifts, upset more of nature's processes, upset the balance of the endless experiments in taking from the sea and returning to the sea. Nature destroyed but replaced; man destroyed but did not replace. He rudely tilled the fields and in a few short years took from them all the land could give, all that nature had stored through millions of years, then he moved to another region. He accumulated flocks of animals and birds, let them graze as they would, and did not replace the grasses. Nature held back the rains, let the streams run dry. The grasslands grew bare and man and his flocks started the long trek to another land of plenty. He cut the forests, burned them to clear land to till; used their wood to build towns. Later he cut the forests to build ships to carry him ever onward from the regions he had depleted to new regions he could exploit. Over and over man repeated these processes until he had spread over the earth, always depleting faster than nature could repair or could restore. He came to need millions of things he once knew nothing of. Then he came to realize he must repair some of the damage he had wrought. He learned he could halt some of the inexorable onslaughts of nature's forces—weather, winds, water,—that he could restore some of the areas he had devastated. He learned that he need not hasten but could delay changes of the earth's surface that were not beneficial to him. He became aware that he could control the good and bad nature does, could use yet preserve for his descendants—as his ancestors had not used nor preserved for him—many of those resources nature had been storing up for him through more than two billion years. He called this conservation.

True, nature had set the scene, spread her gifts prodigally, hidden many of them, lured man on to find others. About a million years ago a great glacier moved southward over the lands. In Europe, mountain ranges lay across its path and the vegetation could escape only up the mountains and there perished of cold, so that only a few of thousands of species of trees remained when the ice left Europe. Animals could flee southward through mountain passes, but all the animals did not come back. In North America no mountains barred the southward retreat of the trees and animals before the invading, killing ice. The trees did not die, all but the peach returned on the heels of the invader when the ice melted. The Indian came. He took of the forest only what he needed for his immediate use and he scarcely disturbed the soil. Came the white man from Europe and marvelled at the wealth and variety of the forest. The Vikings cut a little timber, the early English explorers took a little more. These haphazard depredations were quickly healed. But the English took back samples of wood to the island kingdom that then, as now, needed ships for the navy which maintained her food lifelines, and they saw the wood was good and came to the land that could supply their forest needs. The age of iron had not come completely into its own. The French coming through the valley of the St. Lawrence marvelled at the forests but they were intent on the quicker riches of the furs. Westward the settlers came and to the ring of the axe, the scrape of the plough, the frenzied scream of the trapped furbearer, the cheep of the dying nestling, the country was settled. Lavishly they used the resources nature gave, and the use was justified on the frontier. But the frontier passed and use was just as lavish. It was not justified. N o shortage of men or tools made necessary squandering of lavishly given resources.

On January 26, 1837, Michigan was admitted to the Union; a state with a vast wealth in soils, waters, minerals, forests, and their products. So sparse was the population, concentrated in the southern tier of counties, that few people dreamed the day would come when the somber, trackless forest would be reduced to pine barrens; when the grayling would no longer leap in the rivers. They little thought that cities would grow up concerned about an adequate water supply. They would not have believed that winds and waters following man's activities would ever reduce the marvelous fertility of the clearings, and the prairie fields. President Andrew Jackson's Thanksgiving proclamation of 1835 expressed thanks for the bountiful supply of wild life—turkeys, geese, ducks, "clouds of carrier pigeons," vast herds of deer, antelope and buffalo*,—an inexhaustible wealth of virgin timber, millions of acres of virgin soil. But within seventy-five years the inexhaustible wealth of 1835 had become the need of 1910. During all these years thinking men, much in the minority, were increasingly alarmed at the waste of our wealth, the depletion of our resources, the ill-use of our possessions. The first Legislature was concerned about the need for salt purchased at great price from New York, and directed the newly formed Geological Survey to find salt within the State boundaries, to determine which, if any, of the 72 sections set aside by the Federal Government for producing salt were productive. That was the first act of conservation in Michigan—to search for, develop, and properly use, without waste, a resource of the State. The State Geologist was authorized to determine if the bog iron ore on certain school lands in Branch County should be mined or schools built thereon—our first experiment in land use planning.

The fur trade had declined before statehood and a few thoughtful persons realized that the forests also could be destroyed and warned the legislature that unless the State protected its forests north of the well-settled districts the best timber would be taken by lumber thieves, the young growth destroyed, "stumps be left to fungus diseases which would infest the whole forest"—but nothing was done about that—"our forests are limitless and inexhaustible."

That alarm, even in those days, was felt about depletion of game birds is shown by placing Act 109 of the Public Acts of 1840 on the statute books. The act prohibited the killing of woodcock, grouse, "quail, partridge and pheasant," during certain seasons in Wayne County, and assessed fines for the illegal killing or possession of such birds. That was the State's first game protection law. These two acts show that some citizens of Michigan have always been conservation conscious, have realized the value of our resources and that they should be and could be used wisely without waste and exhaustion. But they realized also that if left to the individual, our reserves would diminish, and that the State itself should regulate for all or become the custodian of the resources of the public domain. But no laws were made to protect the passenger pigeon, no laws saved the forests that kept the streams cool and clear, no laws saved the grayling. Laws were made later to protect the whitefish, but the trackless, "inexhaustible" forests were hewn and burned to barrens of hot, sandy plains, which the jackpine sought to restore, but from which most wild life had fled before the State awoke to the fact that trees could have been properly lumbered, protected from fire and the forests saved. In January of 1865 Alexander Winchell, addressing the Michigan Agricultural Society, said, "It should at least be required that all abandoned soils subject to work should be planted to trees, which will eventually restore the surface to its primitive conditions and compensate to some extent for the fearful devastation of the mature forest which our citizens are now waging." But the State learned that the individual could not be relied on to do it, the State must assume control. And today we travel miles to the Hartwick Pines to see what the original white pine forest looked like.

The very process of clearing the land for agriculture by burning actually depleted its value by burning the top soil and humus as well as the unwanted timber. Unplanned drainage removed much of the ground water that carried plant food in solution, and in some areas rich top soil dried out and was blown away.

Mineral wealth was also exploited, not so rapidly nor so greedily, because, excepting for salt of which we really have quantities to last several million years, the immediate need of man is for other resources. But the rich ore bodies were depleted and leaner ores and lesser minerals came to be used, although as late as 1881 the Commissioner of Mineral Statistics reported of the Northern Peninsula, "Its mining resources are permanent." Late in the history of the development of the mineral wealth, petroleum was discovered in quantities profitable to produce. It also was wasted by un- wise and inexperienced operators. But the State came to the rescue of this resource in time and passed laws based upon the experience of operators in mid-continent states who by continuous research of private enterprise had found that the best way to conserve natural gas and petroleum is to leave it in nature's storage place—the rock in which it is found—and take it out of storage only as the public needs it. Private industry and government frequently work together to the advantage of each and the future happiness of the public. Private enterprise can, and does, use its monies in patient research to learn new methods of developing and using our resources with a minimum of waste. New uses are evolved for the wastes that are found. Industrial laboratory workers find in the test tube replacements for dwindling natural resources. Probably the best conservationist of the irreplaceable resource is the large industrial user guarding his investment and making profits from the by-products.

Surface waters were impounded as water power operations and drainage projects increased and some streams with their fish population dwindled; cities drained water from underground resources and must seek new supplies. . . .

Many books have been written, many more will be written, about our original natural wealth, those gifts of nature which have enabled men to reach the civilization we now enjoy. But as our resources were exploited and destroyed with little thought of the future, as they dwindled, the cry to conserve them for the future became louder, stronger, clearer, and through the years we have learned that it is possible to use our natural wealth wisely—use but not destroy. We have learned to plan so that the resources will not diminish and will be put to the best possible use for the greatest good. This is conservation.

Given time, nature will repair the damage done by man as well as repair the damage done by her own forces, but nature's mistakes and experiments in repair cover thousands of years, man's mistakes made in a day cannot be repaired in a lifetime. Man is only one of the destructive forces of nature—but he can repair the damage he does, and delay or restrain the activities of nature's older agents.

Natural resources are many, but all are interlocked, all depend on rocks, air, water, and the sun. It is difficult to separate them, and any discussion of one overlaps discussion of another. Man's first needs—wild life, animal and plant, and water resources—were first depleted, and therefore first thought of in conservation. Thus the seeds of conservation were sown in colonial times, as naval stores diminished, and germinated in the early part of this century. When exploitation of our wealth reached the Pacific shores— then something had to be done about it and conservation of the forests and the water supplies was debated over the land. The public became conscious of what it owned. Agricultural lands became less productive. Wind and water warred against formation of soils when man in his greed had removed the grassy protective covering of the plains. Then the farmer and the grazer cried for help. Cities developed and must depend on the agricultural area for foods and upon those natural resources from which could be fashioned the artificial resources upon which city (urban) wealth depends. Thus conserving natural resources became more and more a social problem, and when a social problem becomes acute something is done about it. As city life became complex the simple pleasures of life became remote and more attractive—"The country"—green fields, rippling brooks, hunting, camping, fishing, picnicking, golfing, "living in the open, under the stars" became alluring. A tourist industry was born and grew great, and need came for the conservation of places of beauty, pleasure, and recreation, and restoration of the exploited waste lands.

Individuals, communities, associations, clubs, schools, and colleges, enlisted in conservation; some thought only of fish or game, others only of forests, others of the trillium and arbutus, others of our mineral wealth. But true conservation considers all the resources and the relation of all the resources to all the people— city dweller and ruralite alike, industrialist, farmer, tourist, stay-at-home.

Since 1921 Michigan has had a Department of Conservation, a union of all those agencies of government established after 1837, whose aims were to search for and use and preserve our natural wealth, to replace if possible lost resources, to find means of proper usage without waste of the resources that remain. Departments of Conservation have been established in college and university to help with the problem, but real conservation needs the help of everyone who wishes to use wisely and to enjoy the wealth of our possessions, to aid in the establishment of a permanent program of conservation of our wild life, forests, waters, soils, minerals, our places of recreation, our scenery, and our historic landmarks.

And you in the cities who cannot get out to hunt and fish, who have no time for the beaches, or wildflowers, or copper mines. No place for you in conservation? Your very livelihood depends upon it. Your food and clothing come from the soil—soil erosion increases your cost of living. Depletion of water supplies may destroy, not only your drinking water, but also the air conditioning systems for your shops and theatres; depletion of forests, quarries, mines, destroys your building materials and the raw products upon which your industries are based. Maybe you can't get out in the field and save an orchid—but you can know it is there; maybe you can't stop a forest fire—but you need not start one; maybe gas is just something that comes from the filling station—but you can learn to run your car without wasting it; and you can become informed of the thousand and one ways each one of our natural re- sources enter your daily life. Have you a city park, a place of recreation for everyone? Are the vacant lots weedy eyesores or filled with queen anne's lace and blue chicory? Both are baneful pests to the farmer but a source of beauty in a vacant city lot. Is slum clearance conservation? Removal of billboards and ugly shacks that hide beautiful views? Maybe you can't physically work for conservation—but what about the power of public opinion, and what good is public opinion unless it is well informed? You need not live "near nature" to be a conservationist, because nature lives in your lives, and it is up to you and all of us to see that she is not betrayed by our misuse of the wealth she has stored for us.

We can never forget, however, that nature is an experimenter; that nothing is permanent but change; that through all her kingdoms nature creates, builds up, only to tear down and start all over. Though the pattern is changed the methods are always the same, the agencies used do not vary through the long histories of rocks, plants, animals, man. Man can hasten or slow nature's processes, and when he does this for the benefit of himself and his fellow man now, with thoughts of the needs of the future, when he works and plans with nature, he is a conservationist.

*500 buffalo robes passed the Post at Sault Ste. Marie in 1787.

Part II. THE FIRST TWO BILLION YEARS

THE FOUNDATIONS

Life and living of man, plants, and animals are complex and their many phases overlap, but all are based in the material which makes up the earth—the rocks, the soils made from the rocks, the waters which flow in or on them, the air which surrounds them. So it is well that we start our story from the beginning—a time that goes so far back we cannot comprehend it. But the story has been written by Nature herself for those of us who are willing to read. Today the agent-forces of nature—winds, water, changes of temperature, and others—are making and recording changes on the surface of the earth. Active volcanoes bring molten rock to the surface, quietly or explosively. Pent up forces within the earth cause great masses of rocks to be moved and the earth quakes. It is not too difficult to study the records being made, nor the processes by which Nature works today. Therefore, where we find similar records in the hard rocks we know that nature must have used the same processes to make them. We find that in the rocks nature has left her records of never ending change. Whether the rocks be on top of the highest mountains, at the sea shore, or those we find in the deepest quarries and mines, the records tell the same stories of building rocks, tearing them down, making new from the old—a change in pattern but not in method. Also we find in these tombs and tablets of stone a record of the life that has lived, flourished, died, and been buried, on the earth's surface during millions of years.

We really do not know how the earth was made, but the most likely theory of its origin, upon which the majority of geologists, mathematicians, astronomers, and other scientists agree, is based on what the camera discloses of the activity of the sun today. The camera reveals that the sun is a turbulent mass of hot molten material and gasses, with flaming fountains shooting bolts of sun material and sun gas miles above the sun's surface, but the pull or gravity of the sun causes the ejected material to fall back upon the sun's surface. It is believed that many billions of years ago our sun, larger then, and even more turbulent, was moving in its orderly way through space when another larger sun or star moving with incredible speed passed so near that its gravity (pull) was great enough to draw some of the ejected sun gas away from the sun—just as a swiftly moving motor bus or truck "swooshes" the air from around your car as it passes, or as a baseball makes your hair stand on end when it speeds too near your head. The separated mass of sun material started spinning like an old-fashioned Fourth of July pin wheel, but was prevented from moving off independently into space by the pull of the sun; instead it continued revolving around the sun as a satellite or planet. Several such masses were in like manner detached from the sun to make the several planets. Each mass had a pull of its own and drew to itself all the smaller planetary masses, "planetesimals", about it and thus grew larger and hotter. You know that at times enough heat is generated when a bat hits a speeding base ball to scorch the bat, so you can imagine how much more heat was generated when these little planet masses collided and crushed into each other as they ganged together and were built up into the planets. Eventually each planet drew to itself all the loose planet material about it and all settled down into what we call our solar system—the sun, its planets, and their satellites. Our moon is just another little planet that couldn't get away and wander independently about the sun, but remained attached to the earth by the pull or gravity of the larger planet. About two billion years ago our planet, the Earth, stopped growing by the accretion of in-falling planetary material and the surface of the earth began to take on the form we know now. Occasionally a bit of planet material comes near the earth, gets hot by friction with our atmosphere, and we recognize it as a "shooting star;" if it reaches the earth's surface we have a meteorite, but most of the meteorites stopped falling into the earth long ago.

As the earth mass cooled the heavier ingregients gravitated to the center and developed at hot, solid core surrounded by a less solid mass of molten rock material (the lithosphere), which in turn was surrounded by lighter gasses that, when thinned out, eventually became our atmosphere. The cooling outer surface of the molten rock material crusted over and formed a thin crust of cold but once molten rock which we term fire or *igneous* rock (granites, lavas, and their kindred rocks), and made the first solid surface of the earth—the first terra firma, which wasn't very firm. Because igneous rocks develop mineral crystals as they cool, we call them crystalline rocks also. Continued cooling caused the crust to wrinkle and crack, and to force the lighter gasses from the rock pores to the surface into the early hot atmosphere—just as a frosting on a cake cracks as it becomes cool and dry. A part of the gas was water vapor which eventually cooled and formed the water of the earth's surface—the hydrosphere. Heaving under the strains of forces pent up in the hot interior the crust solidified with a very rough surface, high areas and deep depressions. The water gases or vapors of the thick heavy warm atmosphere condensed, fell on the surface, ran in rivulets down the high slopes to the depressions and partly filled them—thus the oceans were formed and the surface of the earth separated into lands and seas, or continents and ocean basins. And it was then—when the first drop of water condensed from the atmosphere and fell upon the land—that erosion began and has never since ceased.

The early continents were unlike those we know today, they were smaller, had surfaces of igneous rocks. No life lived upon them. Continued squeeze of the cooling shrinking crust caused the pent up forces beneath to revolt many times and push the land masses higher, or crack their edges and there pour forth molten rock in quiet or explosive volcanic activity. High mountain ranges and plateaus were built or pushed up above the level of the ocean until finally the continents settled to the forms of continental blocks our geographies show today. However, the oceans did not settle in the basins we know, but covered much of the continents with shallow seas in which the story of the next billion years was to be recorded. The continental shelves are remnants of those shallow seas and there geologic history of today is being recorded. Sometime during the later part of this first billion years conditions became favorable and life appeared on the earth, a low form of plant life capable of self sustenance, a microscopic one-celled organism living near the shores of the warm, dark oceans of fresh water. This early life form was very similar to its present day descendant which lives in bogs or mineral springs where bog iron ore is being formed—but that is a later story.

What are these records made in the shallow seas?—These tablets of time on which the story of ages is told? When the first igneous rock cracked, when the first drop of water moved, the record began. When the atmosphere cooled and frost arrived the recording became more rapid. When plant and animal life became abundant the record became complicated. Changes of temperature caused the granitic rocks to flake off at the surface, gravity and moving waters carried the loosened rocks down the slopes, rolled them together, broke them into smaller and smaller particles, carried them to the sea where they became sediments that muddied the clear fresh sea water. Some of the sediments were dissolved in the sea water, and as the process kept on through the ages the seas became salty. The sediments, sorted by waves and currents of the first oceans, settled to the bottom of the seas and were spread out on the sea floor. In the course of a long time, as layer upon layer of sediments were piled one on another, they were compressed, cemented, and consolidated into rock which we call sedimentary. Each layer or bed is a stratum and layered or bedded rock is said to be stratified. Various minerals in the ancient igneous rocks were made over into different sediments. The hard minerals like quartz collected together as sand, and being heavy, were not carried so far out to sea. They built up coarse and fine rocks which we call sandstones. Other minerals were broken up into fine clay and silt muds that were carried far from shore but eventually settled on the sea floor and compacted to a rock we call shale. Some of the minerals disintegrated to form lime, calcium carbonate. As the igneous rocks were eroded some minerals dissolved and were carried to the sea in solution; there certain chemical reactions caused the lime to be precipitated and in places to build up great thicknesses of lime mud that eventually solidified into a rock known as limestone. Other chemical reactions caused iron minerals to be formed which in turn settled to the bottom of shallow seas, and later in the geological history gypsum and salt crystallized out of the sea water to form great beds of gypsum and rock salt.

But even in these early warm seas another force was at work building rocks. In some way the first bacteria and one celled plants learned to take lime from the water; they collected in jelly-like masses, these ancient plants; lime collected on them, layer upon layer, and built up great masses of lime rock. Later, when animals came upon the earth they were also one celled creatures living in the sea, but as they struggled for existence they evolved to more complex creatures, and in time they also took lime from the sea water to make protecting external coverings or shells. When these creatures died their shells fell to the sea floor, accumulated in thick masses, were also broken to lime muds, but all in time became limestone rock—the cemeteries of the animals which lived in the seas, and the museums in which the records of past life (fossils) are preserved.

So thousands of feet of sediments—clean sands, clays, silts, lime muds, and mixtures of any two or all of them—were spread on the ocean's floor and thousands of feet of stratified rocks were formed. As they became thicker their weight upset the balance between the high lands and ocean troughs. Then nature readjusted the pressures by shaking, lifting, thrusting, the hardened sediments above sea level, building mountain ranges by pushing molten rocks from beneath the crust near to the surface, in places cracking the surface rock to let the molten rock through. In other places the flat lying sediments were lifted, wrinkled, folded, crumpled, and broken into arches and troughs, making new mountains and rearranging the ocean basins. When peace came again after such a revolution were the rocks the same? No. You know that snow falls in soft flakes, and you have seen the beautiful six-sided crystals of the snow flakes—they are mineral crystals and many of them collected together could be considered rock. If you take a handful of snow, pack it into a snow ball, you rearrange and change the form of those snow crystals by the pressure of packing and actually produce another form of rock—ice. Also in the packing (pressure) some of the snow crystals melt to water. Thus, although perhaps you never thought of water as a rock, in making a snow ball you actually worked on a familiar rock—as nature does on other rocks, you changed the form from a crystal snow flake to ice. In the tea-kettle and refrigerator, on other water surfaces in winter and summer, you have seen water changed from a liquid to a gas or to a solid. Such a change is metamorphosis. When by one of these earth revolutions with pressures and heat nature changes rocks from one form to others, she makes *metamorphic* rocks out of the older igneous or sedimentary rocks. She changes granites to gneisses or schists, sandstones to quartzites, limestones to marbles, shales to slates. So upon the earth we have three types of rocks, igneous, sedimentary, metamorphic. The metamorphic rocks tell this tale of change but in them are many other records buried and lost.

Many times during the two billion years of recorded earth history have these changes taken place. The geologic record shows many periods of unrest within the earth—mountain building times followed by periods of quiet when erosion gnawed the mountains and highlands down to their roots. The record shows a never ending battle between the forces of the hot interior of the earth which builds up earth features, and the forces at the surface bent on their destruction—a never ending effort by one set of nature's forces to lift rock masses out of the sea only to have another set of forces break the rock down and carry it back to the sea. So long as the earth has a molten interior under pressure of a solid crust, disruptive (diastrophic) agencies will continue to construct new surface forms for erosional processes to destroy. The cycle of change will continue to the end of time.

As we divide and subdivide human history into eras and periods that cover certain related events, so we divide and subdivide geologic history into eras and periods. The first and longest era, over a billion years long, when the young earth was forming from the sun and no life existed, we call the Azoic. And we do not know a great deal about it. Following came the time, the Archaeozoic era, some 800 million years long, when the earth was very turbulent, mountain ranges and ocean basins were being built and a very primitive life was upon the earth. Then came 650 million very important years for Michigan as we shall see—the Proterozoic era. Sediments were laid down in shallow seas, bacteria and sea weeds lived and were active, and at the end, the earth, with a final turbulent upfling of mountains, settled down to quiet in the Great Lakes area, and to comparative quiet over the rest of the earth—the earth's youthful turbulence was over.

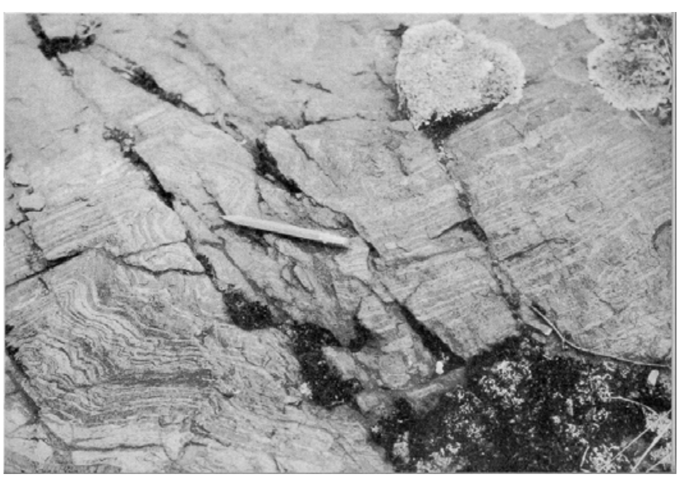
For the next 350 million years, during the Paleozoic era, the time of ancient plants and animals, nature's quiet forces of erosion were at work, gnawing away at the old mountains and carrying the sediments to the seas. Seven times the seas alternately spread over and retreated from the land causing seven new sets of conditions for the formation and deposition of sediments, each time changing the conditions under which plants and animals lived and died. Thus seven sets (or systems) of sedimentary (or stratified) rocks were laid down, one on top of the other, in the shallow seas that covered the continental blocks. These movements of the seas were world wide events, sediments were laid down in all parts of the world; therefore, although the rocks first studied in England and Wales were named for places and early peoples of the British Isles, we carry the names wherever similar rocks with similar records of life and of nature's processes are found. These periods are the Cambrian, Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, and the Permian. Following the era of ancient life came the Mesozoic and Cenozoic, 140 and 60 million years long, in which life leveloped to the present types, the lands and ocean basins came to be as we know them, and for over 198 million years erosion was let loose to work its will on the face of our area. Man appeared upon the earth and a little later, towards the end of the Cenozoic era, the Pleistocene period of glaciation was ushered in; during that time the surface as we know it today was built and made ready for man and his activities.

THROUGH THE AGES

The rocks of Michigan record that the area shared profoundly in all the earth changes. Michigan began when a shield-shaped mass of igneous rock, nearly two million square miles in area and centering about Hudson's Bay, formed the original continent of North America which we refer to as the "Canadian Shield." The point of the shield extended southward across the area now the western half of the Northern Peninsula into Wisconsin, and its southern edge was a northward-bearing arc extending from the Lake Superior region to the Adirondacks. Southward was a shallow sea covering the remainder of the continental block. The granite floor of the sea had many depressions and ridges, but only the basin- shaped depression bordering the shield on the southeast need interest us. The basin shallowed scoop fashion eastward, but the deepest part was about where the Southern Peninsula is now. That was the early setting of Michigan, the basal foundation of the State.

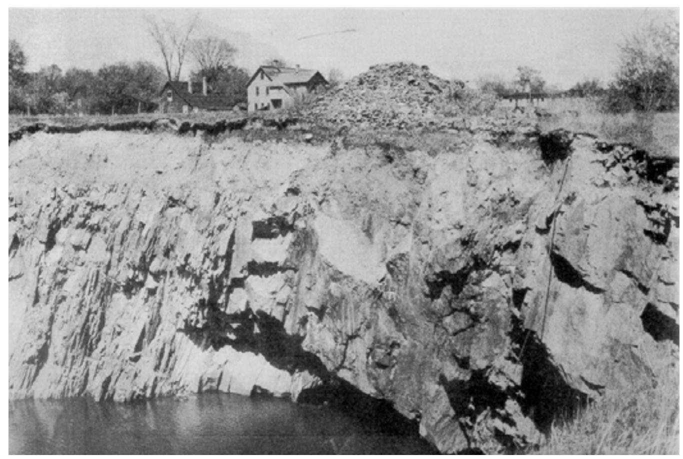
As soon as water fell on the Canadian Shield and the first winds blew, then weathering began; the rocks started to flake off and break up, erosion was started; sediments were carried to and deposited in the seas, the first beaches were formed. Several times in these early turbulent eons the lands at the edges of the seas were lifted into high mountain ranges, only to be worn down and their sediments carried to the seas to build up new shores and to be spread on the sea floor to form stratified masses of sandstones, shales, and limestones. Each newly formed beach increased the land area, carried the strand line southward. With each uplift the sedimentary rocks were bent, folded, broken, twisted, contorted, changed; masses of hot igneous rock were forced into the broken formations, completely changing or metamorphosing them in many places so that the rocks made in the several periods of mountain building and sedimentation became a very complex mass of disturbed, broken (faulted), distorted rock—the oldest rocks that underlie the western half of the Northern Peninsula. All we can see of the oldest rocks are the Huron Mountains and the other granites and their kindred of Marquette, Baraga, and Gogebic counties. (ARL fig. 1) Once they were a mountainous sea coast, but their summits were worn in turn and all but the highest buried under later sediments.

FIG. 1—ROCK FORMATIONS OF MICHIGAN
Pgr, Ps, Psp=Pennsylvanian rocks; Mm, Mn, Mlm, Mc, Ma, Mb, Mdb=Mississippian rocks; Dtb, DT, Dd, Ddr, Dm=Devonian rocks; Ss, Se, Sm, Sme=Silurin rocks; OR, OT, OBR=Ordovician rocks; Φh=Hermansville formation; ЄLs=Cambrian rocks; ARl=Kewatin-Laurentian granites.

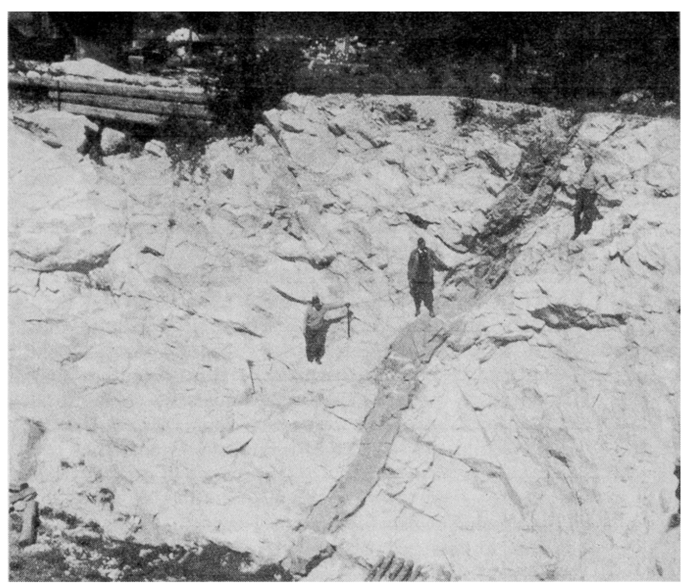


CRUMPLED FRACTURED JASPILLITE. LICHENS AND MOSSES ARE STARTING TO MANUFACTURE SOIL AND START A PLANT SUCCESSION ON THIS BARE IRON-BEARING ROCK. JASPER HILL NEAR ISHPEMING.

During the first part of the Proterozoic era, a long 250 million year-period of quiet, which we name the Huronian from its record north of Lake Huron, thick sediments were laid down in a shallow sea trough that covered the Lake Superior region. In places thick sands were deposited; in others fine muds, and in other places pure lime, accumulated in the shallow but slowly deepening sea. Over the sand great masses of iron minerals accumulated, either by chemical action or by the work of iron forming bacteria, or by both and perhaps other means, until vast thicknesses of sand and iron sediments were built up, and the world's largest iron deposit was in the making in Minnesota, Wisconsin, and Michigan; and in that far ago time the foundations of Michigan's wealth and the automobile industry were laid in the old Huronian sediments we now find in the iron ranges of Marquette, Baraga, Iron, Dickinson, Menominee, and Gogebic counties (AHu fig. 1)



CHAMPION MINE PIT AT BEACON SHOWING ALMOST VERTICAL POSITION OF DISTURBED, ONCE FLAT-LYING BEDS OF THE IRON FORMATION. A VERY THIN BAND OF DARK SOIL HAS DEVELOPED FROM THIS PARENT MATERIAL.



FELCH QUARRY

Rumblings of a new disturbance interrupted the quiet Huronian sedimentation. Again mountain building lifted the sediments, now hardened to rocks, to mountain height, crumbling, folding, contorting them. The sandstones were changed to quartzite, shales to slate, limestones to green and white marbles, and the iron sediments were folded and changed with them. The rocks were cracked and broken; they slipped and moved along the cracks—were faulted—vertically, horizontally; some blocks were shoved up onto others, some were tipped on end until a madly jumbled mass was made of the flat Huronian sediments. The writhing contortions of the red and black jaspillite of Jasper Knob near Ishpeming show some- thing of what happened to the whole area. Into all cracks warm and hot waters, heavily mineral-laden, made their way; left deposits of minerals that are the joy of the collector, although the complex Huronian rocks in which they are found have been the lure, despair, and subject of great dispute among geologists for the last hundred years. The pink pegmatite dike in the glistening white marble of Felch Quarry tells a tale of long sedimentation, of pure lime metamorphosed to marble, perhaps by the very molten rock that cracked and forced its way through the marble, then slowly cooled, forming large crystals of pegmatite. Volcanoes became active in the western Lake Superior region. and ejected volcanic cinder, ash, and bombs in explosive eruption; then, somewhat subdued, poured out lava from long vents in quiet eruption. When the eruption subsided, winds and weather broke up the lava flows into pebbles, gravel, sand, and fine muds, which became cemented together in a rock we term conglomerate. In places the sands and fine muds became sandstones and shales. Lava flows covered the conglomerates, more conglomerates were formed; they in turn were covered until several thousand feet of conglomerates and lava flows with sandstones and shales were built up. (AKU, AKMB fig. 1) In the gas bubbles (amygdules) on top of the lava flows, in the cracks of the lavas and conglomerates, nature stored pure copper and silver and many interesting and beautiful copper minerals, the treasure store of Keweenaw, Houghton, and Ontonagon counties. Time honored usage gives the name trap to the massive lavas, and amygdaloids to their porus upper parts. And the time in which they were formed is named the Keweenawan, the second part of the Proterozoic era in Michigan.

Then the Earth had another fling at mountain building in the Great Lakes district. Igneous rocks were thrust to and near the surface, lifting all the older rocks above them. As they intruded horizontal and vertical cracks, they metamorphosed the older granites, lavas, and their kind, changing the metamorphics as well as the sedimentaries and making confusion worse confounded.

This last turbulence is known as the Killarney revolution from the exposure of the granites of this time at Killarney, Ontario. The Killarney mountain range, 1,000 miles long and higher than the Alps, is now worn down to mere stubs of granite knobs. In Michigan the Killarney granites are exposed in Gogebic and Ontonagon counties; they make the mass of the Porcupine Mountains and a small patch comes to the surface near the tip of Keweenaw Point. These mountains also were worn down, they followed their predecessors into the sea. The Proterozoic era ended.

A shallow sea spread over the continent, the Paleozoic era began. It was a long, quiet era of slow earth movement and oscillations of sea level which caused twenty-four to thirty minor retreats and transgressions of the sea shared by all the Great Lakes area. In addition, in the Michigan area the rocks record at least fifty-one local changes in the conditions of sedimentation and of life in the seas that alternately filled the basin or were spilled from it in whole or in part. (And just to complicate matters further, the fifty-one formations are also subdivided by very restricted local conditions!)*

Somewhere during the long time of the Killarney revolution life had developed from the simple one-celled organisms into highly developed creatures with shells and other hard parts that could be petrified, or from which casts and molds could be made. They found life good in the Palaeozoic seas and swam in hordes. On death they were buried and their records preserved in Palaeozoic sediments so that from this time on we have a pretty complete record of the gradual evolution of plant and animal life to the high forms we know today. The fossils in the rocks play an important part in unfolding the drama of change. To the geologist, changes in assemblages of animals (faunas) means a change in the position of land and sea, and, as each succeeding assemblage is higher in the life scale, the geologist reads a time scale also. To the amateur and specialist, perfect specimens and new species, are the prize of the big game fossil hunter in the petrified graveyards of the sedimentary rocks. So that when the Palaeozoic seas began to spread over Michigan our first important wild life came with them. At times the seas were warm and clear, supporting a myriad of shelled creatures, at other times the seas were muddy, receiving great volumes of fine silts and decayed vegetation from low lying lands. At times desert conditions prevailed, and the seas became excessively salty supporting little life, or were brackish with gypsum. In other times the sea became a huge swamp. Each sea left its records in the sediments piled and spread on its floor. The sediments compacted to rock. The floor of each sea became the basin of its successor; thus each sea was smaller and within the boundaries of its predecessor. Eventually the Michigan basin was filled with a succession of bowl-shaped rock formations, one within the other. Bowls made of sandstone, limestone, shale, rock salt, gypsum in all degrees of purity—shaley-limey sandstones, sandy-shaley limestones, shaley limestones, sandy shales, and all other combinations of sediments one can describe. The formations vary in thickness, some are wedge and not bowl shaped, they do not extend across the basin—we have records which show that barriers prevented the seas making a complete submergence. On the edges of the basin wells can be drilled through thin sedimentary rock to the granite below, but the deepest well in the State, in Bay County, was drilled through over two miles of sediments and did not reach the bottom. The rocks vary in color from jetty black through gray, brown, red, blue, pink to white. They vary in mineral wealth. But all of the Paleozoic formations have a common characteristic, they all slope or dip from their rim edges to the center of the basin.

The first of the Paleozoic seas, the Cambrian, received coarse sandy sediments from swift streams flowing southward from bare highlands to the north. The shore line was somewhere in the Lake Superior trough, and to the west, somewhere near the central part of Keweenaw County. The rocks (Єls. fig. 1) representing Cambrian time of 105 million years are mainly sandstones. As much of the sediment was derived from the iron formations in the west they range in color from a deep dark red to mottled red and white, buff, white, and gray. Towards the end of Cambrian time the sediments became finer, the sea shallower, and its shore farther south; the sediments were clear white sand, some of which through the millions of years have become dolomitic sands. So marked is the difference between these sediments and the earlier Cambrian that we have introduced a new period to our geological time scale, a new system in the system of rocks in North America but not found in Europe. We name it the Ozarkian (Φh fig. 1) In Michigan the Hermansville (named for Hermansville in Menominee County) is the most important Ozarkian formation.

Ancestors of most of the invertebrate animals we know today swam in the Cambrian seas, and some invertebrates lived whose descendants disappeared from the seas forever before the Paleozoic was closed. That queer three lobed creature, the trilobite, is the usually desired possession of beginning fossil hunters—he's big and rare game.

*The Legend of the Centennial Geological Map of Michigan lists and locates all of them.

Gradually the seas deepened, gradually almost two thirds of the North American continent was submerged. As the Ordovician period began in Michigan, the shore line probably pushed farther southward as we find traces of early Ordovician sediments in Houghton County. The rock (OBR, OT, OR, fig. 1) and fossil records show us that this time lasted for 70 million years. At first the seas were deep and clear. Lime muds were laid down on their floor which became the graveyards of millions of shelled creatures that lived in the first of the Ordovician seas—the Trenton (OT fig. 1). These brachiopods and cephalopods, ancestors of the lamp shells, the squid, and pearly nautillus of today, with trilobites, were the bosses of the living creatures of that time. But the ancestors of the corals, bryozoa—"moss animals"—starfishes, sponges, and snails were there also. And an odd creature, an ostracoderm, that wanted to be a fish but wasn't, but did have a backbone, appeared upon the scene, though not very happily as he stayed in the mud for protection from the prowling trilobites. An important creature was this ostracoderm, with his soft body and armored head, for he had a spinal cord and was the first of our vertebrate animals.

Gentle earth movements or perhaps climatic changes caused the late Ordovician seas to be alternately shallow and muddy, or deep and clear, thus the sediments became shales and limestones. The Ordovician shore came southward. How do we know? Because today the sea shells that live and die near the shore are cast up on the shore by the waves, the shells are ground and broken, and their fragments piled on the shores. In the limestones of Menominee County we find masses of fragments of shells rather than whole shells, so we believe that here also was a shore of long ago. Where we find perfect petrified shells we know that burial was in quiet deep water, or quiet muddy water, so deep that the waves could not disturb the bottom.

Again the seas deepened, genial climates set in, the seas were warm and clear. A new period, the Silurian, set in (Sme, Sbb, Sm, Se, SE, fig. 1). Algae and bacteria precipitated lime brought to the sea in solution by clear streams, millions of shelled creatures swam about, corals built the first apartment houses in long coral reefs, and great thicknesses of lime muds were built up. Over 1600 feet of our limestones are Silurian. The thickest are the rocks we term Niagaran (Sme, Sbb, Sm, Se, fig. 1). If we would like to see what these coral reefs were like we can find beautiful fragments of them in the stone piles of Chippewa, Mackinac, Schoolcraft, and Delta counties that are chips from the Niagara limestone that comes to the surface (outcrops) from Manitoulin Island to the Garden Peninsula. We can find the so-called petrified honey- combs and chains—the remains of the walls of the homes of honey- comb and chain corals. Twisted and straight horn-shaped shells of the solitary coral that swam about with his house under him, "butterfly" and "lamp shells", and many other fossils repay a search. Many of these corals and their companions reached perfection and disappeared with the Silurian; thus wherever we find a limestone containing these fossils we know it is Silurian.

Sometime in this pleasant Silurian time one of the denizens of the sea discovered the edge of the sea, crawled out on shore, found that the plants of the land were better food than the sea supplied, found that he didn't have to fight so many other hungry creatures for his food. He learned to breathe air and became the first of the land animals. This pioneer was a scorpion with the horrible name of Paleophonus—or ancient murderer.

But the genial climates came to an end, the close of the Silurian was a long time of aridity in which the seas became so salty that living creatures swam to a more suitable home. Those that couldn't get away died, many had no descendants so their species perished from the seas. Great salt beds were deposited in our basin, and the time is named Salina. In the central part of the basin 2300 feet of alternating salt, shale, and limestone beds have been penetrated in the Salina, with 1600 feet of rock salt. The rock salt bowl becomes thinner towards its rim (Ss fig. 1).

Above the Salina salt beds in the southeastern corner of the State is a limestone named Bass Island (Srr. fig. 1). In the same position in the northern part of the State on both sides of the Straits of Mackinac is a formation we term the Mackinac limestone (Dm. fig. 1). The queer chimney rocks around St. Ignace and all of Mackinac Island are of this formation. These limestones are intriguing puzzles for the geologist—we don't know certainly to which period they belong; we do not know how they were formed, nor why they are broken up in angular blocks, full of cavities that seem to be recemented—a rock we call breccia. You can see the breccia in St. Anthony's rock and Castle Rock near St. Ignace, Arch Rock, Sugarloaf, and many other places on Mackinac Island. The Bass Island rocks are Silurian, maybe those of Mackinac Island are not. But the scenery of these rocks is remarkable, no matter what the geologists say about their age. The fossils suggest that the climate again became genial at the close of the Silurian, the seas warm, and the sea creatures returned to our region. Silurian time was 25 million years.

Then the climate changed to warm and moist as the Devonian period which was to last 35 million years was ushered in. The Michigan area was almost an enclosed pool of the Devonian sea and the northern shore of the sea was somewhere in the Lake Michigan and northern Lake Huron basins. A part of the south- eastern shore cut diagonally across Monroe County from north- east to southwest. Our basin brought its eastern rim closer to Michigan. On the southeastern shore sand dunes were whipped up by the Devonian winds and are now beds of white sandstone—the Sylvania. (Ds. fig. 1). Spreading deep into the basin from the southeast, layers of sand and lime were deposited which became the formation we now term the Detroit River (Ddr. fig. 1). Once we grouped the Detroit River and Bass Island formations together under the name "Monroe"—a name geologists have rejected but the oil fraternity retains. We will refer to it later.

The Detroit River formation thins out somewhere north of Manistee as we do not find it above the Mackinac formation in the northern part of the Peninsula. Above the Detroit River is the Dundee limestone, named from its outcrop near Dundee, Monroe County (Dd. fig. 1). Above the Dundee bowl is 30 to 80 feet of Bell shale (Db. fig. 1), and above and within the shale is the Traverse limestone (DT fig. 1)—the relics of Michigan's "Coral Sea."

The Devonian has been called the "age of fishes" because so many and strange fossil fish are found elsewhere in Devonian rocks. But we had no fish problem then. The Devonian was the time of Michigan's coral seas—clear warm seas in which millions of corals and moss animals lived and built great reefs and layers of lime mud that became from 50 to 1035 feet of limestone. Swimming among the reef-building corals were many other invertebrates,—a little trilobite that could roll up like a ball—so that his fossil remains are the reported "petrified frogs' heads", the solitary "cup coral" living in the top of his house, the winged brachiopod we call the "butterfly" shell, and many others. "Sea lilies" swayed in the clear green seas, their fossilized heads are often said to be petrified nuts, their stems are the disks of stone with a central hole that the Indians used for wampum. The armored fishes lumbered about like scows in the seas, and on the land the first forests grew. But corals were dominant, and from Thunder Bay to Little Traverse Bay are the long domed and flat reefs they built. Like the Silurian these Devonian limestones are the mecca of fossil hunters.

At its close the Devonian seas became shallow and were bordered by low-lying lands from which sluggish rivers brought sediments black with decayed vegetation and gradually the time changed to the Mississippian—the first part of the Carboniferous or Coal Age (M fig. 1). For 35 million years the Mississippian sea alternately entered and partially retreated from the bay which covered most of the Southern Peninsula surface. The conditions of the lands about our Michigan bay varied so that a variety of sediments were deposited; nor were the sediments the same in all parts of the basin and we have incompleted bowls. Thick shales—black Antrim, green Ellsworth, blue Coldwater—underlie the Marshall sandstone, which in turn is overlain by the Michigan shales, sandstones, limestones, and the thick gysum beds which indicate an arid climate and chemical precipitation. Near the end of Mississippian time the Bayport limestone sediments were deposited. The Mississippian fossils are not so abundant as those of the great limestone building times, but we find casts of leaves near the shells and know that plant life was becoming dominant on the land. The age of seaweeds, trilobites, lampshells, corals, was past; land loving creatures with backbones were taking the important place, and plants were becoming very important indeed on land.

Then the earth began preparing for another revolution. Slow gentle movements caused the Mississippian seas in which limestones were being deposited to almost retreat from Michigan, leaving a shallow pool (Ps. Pgr. fig. 1) in the central part of the basin and cut off from the outside sea. The time was the Pennsylvanian, the last 45 million years of the Carboniferous, and the time of the great coal swamps. Deposits in the older seas were marine, but in this Pennsylvanian area sedimentation was partly marine, partly fresh or brackish water in swamps. A layer of sparkling sand was first spread over the last Mississippian limestone and above this in the shallow waters a luxuriant swamp forest flourished—but the trees were quite unlike our modern trees. They were giant fern trees, ground pines, and horsetail rushes that grew tree high. No birds or butterflies or flowers were there, but dark loathsome amphibians and the earliest known reptiles crawled in the muds; giant scorpions and dragonflies flew about. The climate was warm and moist. The swamp vegetation died and fell to the swamp floor, layer upon layer of plant remains accumulated, changed to peat, were buried under a blanket of dark muds which slow streams brought from forest covered lands. Thus protected from the destructive oxygen of the air, they have in the long time since become the coal beds and shales of the central counties.

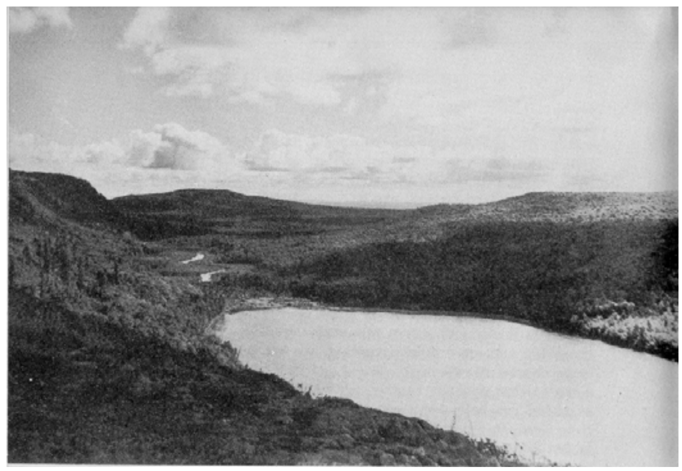
For the last time the seas rather hesitatingly invaded Michigan and a layer of thin sands and marine shales was spread over the coal swamps. Hot winds of the Permian time probably dried the last thin muds of the shallow seas and made a layer of thin red shale with streaks of gypsum in it, covering the last Pennsylvania sandstone. The Michigan basin was filled, the Paleozoic era was ended.

During 350 million years sediments on top of sediments were deposited in our basin, and its central area was gradually depressed by their accumulating weight, so that when the Gulf Oil Company drilled the deepest well in the State, near Kawkawlin in Bay County, the drill was pushed down 10,447 feet, nearly two miles, and the Cambrian sandstone was not reached.* One celled organisms had evolved to vertebrates and primitive forest trees. In those sediments and the organic remains in them were stored all the minerals plants need and many minerals man was to use for his profit and advancement, but Michigan was not quite ready for man.

*The well was started at 599 feet above sea level, about 20 feet above Saginaw Bay, in the glacial drift. 115 feet of glacial lake beds and drift were drilled through, 300 feet of Pennsylvanian rock, 1,280 feet of Mississippian, 3,115 feet of Devonian, 3,774 feet of Silurian, and 1,863 feet of Ordovician. The well was not drilled through the Ordovician.

The revolution came on in earnest, but not with violence. The continental block was uplifted in the east and Michigan shared in the general gentle uplift, but no seas ever again invaded our area, or if they did no records are left, for during the next 200 million years while the rest of the continent was being built up, erosion was let loose to work its will on the face of the Great Lakes region. Erosion, of course, had been in progress on all exposed surfaces as soon as they were above sea level, but at the close of the Permian it became greatly accelerated as our area, sharing the continental uplifts, was lifted higher above sea level when the Appalachian and later the Rocky and Sierra mountains were uplifted. Also during those 200 and more million years gentle warpings of the continent were shared by Michigan, the Lake Superior basin was warped down so that now the vents from which the Keweenaw lavas were extruded are below the lake; Keweenaw Peninsula cracked from Bete Grise Bay to Lake Gogebic, and the eastern part of the block of flat-lying conglomerates, sandstones, and lava flows (trap rock) was so tilted to the west that the cliff ed eastern edges of the strata are now exposed along that great crack—the Keweenaw Fault.—But the western part of these rock flows were tilted east by the downwarp, and now the western edges rise above Lake Superior in our famous Isle Royale. Thus Isle Royale is a "mirror image" of the Keweenaw Peninsula. Upthrust of the Keweenaw block pulled up the edges of the nearly flat overlying Cambrian sandstones so that the western edges of the sandstone beds were tilted almost vertically. Erosion of the almost vertical sandstone has made the curious Rock Wall Ravine near Laurium, Houghton County. The squeeze of the warping, shrinking continent against the great bulwork of the old Canadian shield caused the sedimentary rocks of the basin to arch in wrinkles that trend northwest-southeast across the basin—and thereby hangs the tale of our oil deposits.

All the forces of erosion were at work creating much of our scenery, exposing our mineral wealth and creating some of it. The old pre-Cambrian area west of the meridian of Marquette was eroded most rapidly. The edges of the Cambrian sandstones were worn away off from the old granites and Huronian iron formations, leaving only small caps of sandstone to show where the Cambrian seas had been. The iron formations were not ores when first exposed, but during the long ages of their exposure surface waters leached out other minerals leaving the iron behind, and carried oxygen to the iron sediments, gradually changing the upper few hundred feet, metamorphosed though they were, to iron ore. That explains in part why the upper parts of the iron formations are rich and the lower levels lean in iron.

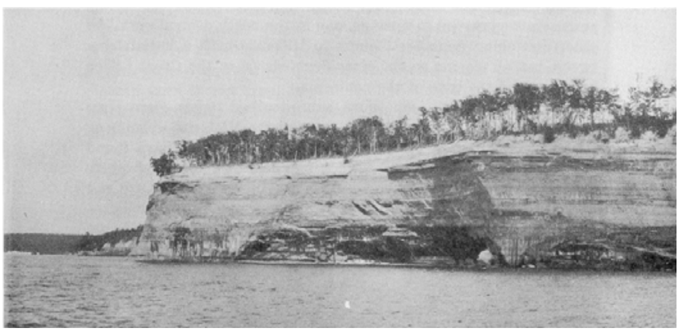


THE FLAT SUMMITS OF THE PORCUPINE MOUNTAINS NEAR LAKE OF THE CLOUDS REPRESENT THE OLD PLAIN WHICH WAS UPLIFTED TO A PLATEAU IN WHICH THE VALLEY OF THE CARP RIVER HAS BEEN CUT. LAKE OF THE CLOUDS—A WIDE STRETCH OF THE CARP RIVER.

The lands of the Killarney mountains had been worn down so that the surface was brought nearer the 20,000 feet of copper-bearing lavas and conglomerates. The rugged land had been brought almost to a plain, but uplift rejuvenated the rivers, gave them swift currents, started their work all over again, and they cut deep gorges in the pre-Cambrian rocks until the whole area became a rugged imposing region of high ridges and deep gorges with many waterfalls. But rugged as the region is to the hiker, the summit levels of the ridges are fairly even and above them lift the high heads of a few individual mountains and knobs that resisted destruction by the earlier erosion—those diorite knobs of the western part of the peninsula, Mount Bohemia, Mount Houghton, and others of the Keweenaw Peninsula.

Today the highest elevations are the Laurentian granites of the Huron Mountains and the Killarney granites and Keweenaw lava flows of the Porcupines in Ontonagon County. Brockway Mountain and its famous drive are on the eastern edge of the tilted Keweenaw block.

WAVE WORK ON LAKE SUPERIOR SHORE—THE TREE LINE FOLLOWS SLOPE OF THE BEDS. ROCK HARBOR, ISLE ROYALE.



WAVE-CUT RAMPART OF EDGES OF CAMBRIAN SANDSTONE NEAR MUNISING FACING NORTH. THE SANDSTONE BEDS SLOPE GENTLY SOUTHWARD UNDER THE SOUTHERN PENINSULA.

In the Paleozoic area the edges of the bowls were beveled off and their rocks exposed. The thin edges of the hard resistant formations were worn away so that the outer edges are now high cliffs or escarpments. Such a structure—a short steep slope over the ex- posed edges of rock layers, and a long gentle slope in the opposite direction down the top of the strata, is a cuesta. The summit of a cuesta may be miles in length. The steep slope of the Cambrian cuesta borders Lake Superior. In the red and white sandstone of the escarpment the famous Pictured Rocks, Miner's Castle, Chapel Rock have been carved. Over the edge of the cuesta escarpment streams fall in misty beauty to the lake and the Tahquamenon drops in majestic grandeur over its ledges from quiet river reaches to rapids below. Back of the escarpment the Cambrian rocks slope gently under the Southern Peninsula.

The Ordovician Trenton limestone stands as an escarpment farther south floored on the Cambrian, but is not so pronounced as another escarpment eight to twelve miles still farther south—the edge of the massive Niagara (Silurian) limestone. The softer rocks between the Trenton and the Niagara were eroded into a deep moat between the two resistant formations so that the limestones stand like ramparts across the peninsula guarding the lands to the south. The forest fire towers are silent sentinels above the ramparts. Other soft rock rims were eroded to moat-like troughs forming the curving channels where we now find Green and Georgian bays, Lakes Michigan, Huron, Erie, and Ontario. In these channels, curving around the Michigan Basin, a river system was developed which carved the basins for four of our Great Lakes. The Devonian limestones were carved into low cuesta ramparts around the northern edge of the Southern Peninsula from Thunder Bay to Traverse Bay. But the Devonian strata of the southeastern part of the State lie flatter and were not carved to pronounced escarpments.

When the older underlying shales were eroded the resistant edges of the Mississippian formations were left as cuestas that almost encircle the Southern Peninsula. Thus the surface of the peninsula was carved to uplands, one in the north central part, the other stretching from the Thumb to Hillsdale with a lowland between, but all sloping to the river lowlands (now the Great Lakes beds) around the edge of the peninsula.

If any great beasts—dinosaurs, sabre-toothed tigers, giant pigs, or little ancestral horse or camel—roamed the Michigan uplands as we know they did elsewhere during this long time, we have found no trace of them. If they were here and died on the uplands their unburied bones were left to bleach, decay, and disappear. Or if not destroyed were carried southward by the four glacier scrapers that ploughed over the State during the long ice age. The story, if any, of the part Michigan played in the evolution of the vertebrate animals and the evolution to the modern upland forests is lost on the missing pages of time after the end of the Paleozoic and before the beginning of the latest chapter of our history.

Near the close of the Cenozoic, in geological very late yesterday afternoon, the climate changed from genial to frigid—the Great Ice Age came upon the northern hemisphere and North America became the most ice-bound of continents. Nature released a force that had been effective in other eras on other areas but had not before reached the Michigan basin—glaciation.

THE WAR OF COLD AND HEAT—THE ICE AGE

THE ADVANCE

For hundreds of millions of years Nature was busy tearing apart some newly made land and using the pieces (sediments) to build up other lands, including Michigan. For over 200 million years she was just as busy tearing Michigan down. Then, a million years ago, she sought to erase the ravages of time from the face of the State, to cover or obliterate the scars of erosion, and to write the latest chapter of the story of the face of

Michigan. And strangely, for her stylus Nature used an unusual crystalline rock—glacial ice.

About a million years ago great ice sheets started to move southward from various centers of refrigeration and accumulation in Canada over the northern half of North America as far south as the Missouri and Ohio rivers. Four times the ice moved over the area and four times melted away. But in Michigan we are interested only in the last advance, in the work of the glacier which moved southward from the Labradorean center developed on the high plateau between James Bay and Labrador. This vast sheet of ice slowly, relentlessly, ploughed over the region of the Great Lakes, pushed onward by the ever thickening mass of ice on the plateau until it was brought to a standstill, 1600 miles away from its center, roughly to the position of the present Ohio River, whose course in part was established along its border.

For almost a million years Michigan lay intermittently buried under blankets of ice two to four miles thick. Changing conditions of temperature and precipitation caused the ice front to fluctuate considerably, moving outward from the centers during times when the climate was cold and moist and retreating by melting when the climate was warm and dry. At one time tropical conditions were so powerful that they drove the glacier far north and palm trees flourished near the site of Toronto, only to be killed and buried by a readvance of the ice sheet.

In its relentless, crushing advance the huge Labradorean ice sheet rasped, scraped off, and absorbed into itself the residual soil and loose rock masses which had covered the old rock surfaces; froze onto, plucked, tore huge blocks loose from bed rock, clutched them in its icy grip, imbedded them in its glacial mass, and used them as tools to erode—scrape, gouge, rasp, and scratch the surface over which it rode roughshod. It used fine sands and clays to sand, smooth, and polish not only the bed rock surface but also the boulders churned within the mill of moving ice.

High areas of hard resistant rock were smoothed off and in some localities were highly polished by the grinding, rasping, rubbing, of the debris-filled ice. In many places the smooth rock pavement is scored with scratches and grooves cut by the sharp rock tools held in the frigid vise at the bottom of the glacier and given power by the weight and movement of the ice. These markings, or striae, wherever preserved on the old rock floor tell the direction of ice movement as they always run parallel to the major directions of glacier advance. In deep valleys the advancing ice dumped some of its load and pressed the debris almost to hard firm rock by its own sheer weight.

In many places softer and less resistant rocks were deeply carved and gouged by ice erosion; thus the pre-glacial stream valleys cut in the softer rocks and the rims of our foundation rock bowls were widened and deepened. The softer rock masses picked up by the ice were usually ground between the harder stones and pulverized to fine sediment in the glacial mill.

In this manner the moving glacier became a great mass of rock debris filled ice carrying an enormous load of coarse and fine, large and small, igneous, sedimentary, metamorphic rocks, jumbled all together, shovelled up in the north and freighted southward.

In its way the moving glacier found those gorges cut in the ancient rocks, the downwarped trough where Lake Superior now lies, and the wide valleys cut in the rims of the bowls—but they were not barriers to its progress, rather they became diversion channels or rock pathways for advance masses of the ice, where the ice could move more rapidly down a slope and became thicker than on the uplands. Thick masses of ice became keeled or footed in the depressions and moved through them as distinct tongues or lobes, acting as independent glaciers, gouging out deep depressions and widening all of them. Just as independent glaciers from the Alpine and Alaskan snowfields and from the Greenland icecap are moving down valley today.

To these various lobes we have given the names of the Great Lakes and bays which eventually occupied the enlarged depressions after the ice had disappeared. Thus we had the Superior Lobe, with the Keweenaw lobe as an offshoot; the Lake Michigan lobe, with its Grand Traverse and Green Bay appendages; the Huron Lobe, with its subordinate Saginaw Lobe which played as important a part as its parent; and the Erie and Ontario Lobes. Slowly the lobes made their way southward out of the valleys and during the climax of the last, or Wisconsin stage of glaciation, all the lobes were welded together south of the Great Lakes region, and advanced southward as one broad sheet of ice or glacier with a slightly lobate front. Not until the ice melted back into southern Michigan did the ice front again become separated into distinct lobes. So it is that the end of the story of the ice age in Michigan is the tale of records left by several retreating glaciers.

<u>THE RETREAT</u>

The advance of the glacier over North America was by a southward movement of the ice, pushed forward by the weight of its own increasing mass from the Hudson Bay and Labrador centers of accumulation. The retreat was a northward recession by self-destruction; that is, the glacial ice melted and, as meltwater, flowed away from the glacier front. The ice could clutch onto and move great masses of rock, but the meltwater could move only the finer material of the glacial debris. The glacier took advantage of all the valleys along its lines of advance. Its retreat was a rout. The melt waters flowed wherever they could and the ice dumped all its booty where it stood, although here and there weak and futile readvances were made. The thicker the ice the more rock waste it carried and the more it had to dump. In places the ice, though thick, carried little rock waste and thus left thin masses of waste when it melted. We have noted that because the glacier moved over igneous, sedimentary, metamorphic, stratified, and crystalline rock areas, it had incorporated within its body loose masses of all these rocks and churned, mixed, and ground them all together in the glacial mill, rounded off sharp edges of the harder rocks, ground the softer rocks to fine sand and clay—"boulder clay."

When the glacier melted from North America it left this mass of "heterogenous" rock debris dumped and spread over the area it had covered. Early geologists believed that all this rock rubbish had been carried by giant icebergs in a great sea that covered the area and therefore gave it the name "drift"—a name we changed to "glacial drift" when we had proof that a glacier was responsible for its location far from its place of origin. Boulders of crystalline granites and other igneous rocks are found resting on sedimentary rocks quite out of place, quite the opposite of their ordinary behavior, so that they were called "erratics." Many are hard and resistant, or have veins of harder crystals and are eroded into fantastic forms—thus being interesting rocks for the rock gardens and stone walls.

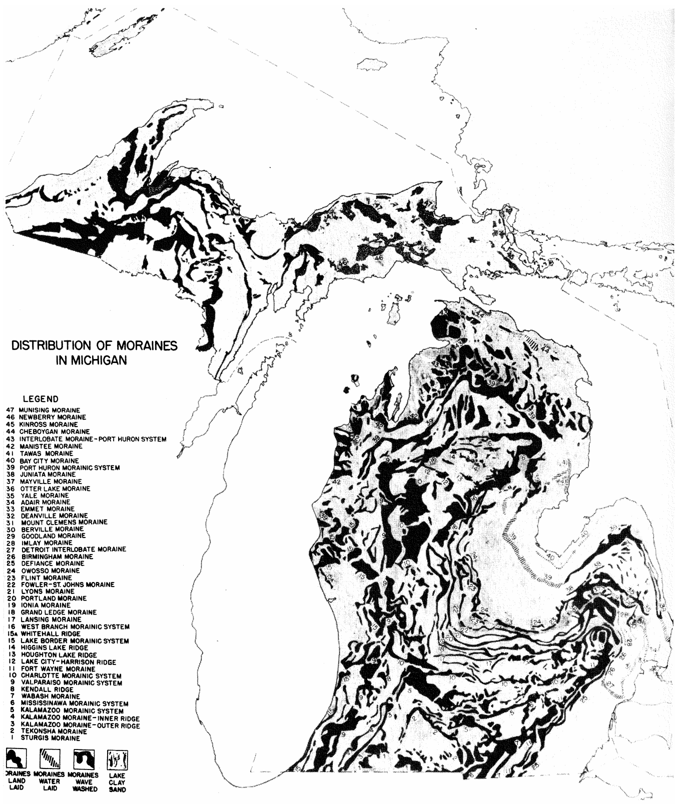


FIG. 2—DISTRIBUTION OF MORAINIC HILLS IN MICHIGAN.

The advancing glacier using its rock tools gouged, grooved, scratched, polished the rock it moved over—records of defacement. It deepened and widened valleys—it was an agent of erosion. But the retreating glacier left a covering of rock waste, building up a new surface, and in large areas burying its own records of erosion in that long gap after the Paleozoic when no sediments were deposited in Michigan, or if deposited were eroded and disappeared.

Of all these glacial drift formations the moraines best tell the tale of the retreat of the ice from the surface of Michigan. They mark the lines of halt and with their accompanying till plains, the lines of retreat. They reveal the halting retreats and slight readvances of the glacier; they show us where the ice held its position for thousands of years. Each glacial lobe built up its own set of moraines which can be mapped and more or less definitely set apart one from the other, and as mappable units have been given names of localities prominent on them.

What is a moraine? A glacial dump or an entrenchment. When the ice front halted, that is, when the glacier could push forward no faster than the ice melted or backward melting equalled forward push, the melting ice dumped its load of rock waste which was added to by the oncoming glacier. Thus a ridge of hummocky hills made of all kinds and sizes of unassorted rocks and ground-up rock debris was piled high along the ice front at every halt. Thick ice with a heavy load built higher dumps, cleaner thinner ice built the low hills. Occasionally, melting ceased and the glacier again advanced over or onto its own entrenching ridge, pushed it higher, added more rock debris to its mass. The great ridge of hummocky hills extending from Illinois to Long Island marks the most southerly position of the ice sheet and is known as the Great Terminal Moraine. In Michigan we are interested in the moraines (fig. 2), left by the glacial lobes,—the ranges of hills stretching from Hillsdale to Hastings, from Kent to Wexford County, from West Branch to Clare, or from Washtenaw and Jackson counties northeastward through Lapeer County.

CUT IN A TYPICAL MORAINE DUMP OF ALL SORTS AND SIZES OF ROCKS. NEW "PARENT MATERIAL."

The Not So-everlasting Hills

The Saginaw lobe was not so thick as the Lake Michigan and Erie lobes and therefore melted faster and was the first to retreat into Michigan. Its first halt after uncovering an area of four or five townships in St. Joseph and Cass counties was near Sturgis, where it built the first and oldest moraine in Michigan—the line of hills passing through Sturgis and bordering the triangular area first uncovered. This hilly ridge has been named the Sturgis moraine (1, fig. 2). The best authorities estimate that the Sturgis moraine was constructed not more than 35,000 years ago. From this outpost the lobe receded step by step into the Saginaw Valley, and at each halt built a moraine, so that its retreat across Michigan is marked by a succession of more or less parallel moraines forming festoons of glacial drift ridges closing in on Saginaw Bay from the south, with their ends tied to the massive moraines of the Erie lobe in the east and the Lake Michigan lobe in the west.

ROLLING "KNOB AND KETTLE" TOPOGRAPHY NEAR CHELSEA, WASHTENAW COUNTY.

Rapid melting caused the Saginaw lobe to retreat to the position of Tekonsha where it built the slender Tekonsha moraine (2, fig. 2). Further retreat brought the Saginaw ice front to the position of the Kalamazoo moraine (5, fig. 2). Here it halted long enough to build up a high, wide, massive, very hilly range. The Kalamazoo moraine extends from Hastings south and east through Marshall to Devil's Lake in Lenawee County where it connects with the Mississinawa moraine which outlines the outermost position of the Erie lobe in southern Michigan. On the west the Kalamazoo moraine of the Saginaw lobe unites with the moraine also called Kalamazoo, which the Michigan lobe was making at that time, extending from Hastings through Kalamazoo and Cassopolis. This Outer Ridge of the Kalamazoo moraine marks the most easterly extent of the Lake Michigan lobe. From this time the pattern of the morainic system is a map of the retreats and halts of all the glacial lobes—Erie, Huron, to the east, Lake Michigan in the west, and the Saginaw lobe between, and the Superior lobe in the north.

Renewed melting of the Saginaw lobe caused its front to recede to the vicinity of Charlotte where it built the less imposing Charlotte moraine. This ridge may be traced from near Milford in Oakland County westward through Brighton, Mason, and Charlotte, to the vicinity of Grand Rapids where it ties in with another morainic system of the Lake Michigan lobe—the Valparaiso, which comes north from Indiana. The Michigan lobe had retreated from the position of the Kalamazoo moraine to make a long stand in the west, during which it built up the high Valparaiso moraine which marks the border of the Lake Michigan lobe from Indiana to central Wexford County (9, fig. 2). This moraine is a typical "knob and kettle" formation. The highways of the region lead from valley up over knobby hill or high steep knoll, from whose summit one may look over a bumpy country of hill and kettle-like basin filled with lake or swamp or drained to rich, dark truck farm land. On the eastern side of the State near Pontiac the Charlotte moraine connects with the Fort Wayne-Wabash morainic systems which were formed at the same time by the Huron-Erie lobe after the retreat from the Mississinawa moraine.

Following the formation of the Valparaiso-Charlotte-Fort Wayne-Wabash systems, the ice began another decided retreat along all fronts. At the next long halt the Lake Michigan and Huron-Erie lobes played the dominant part in moraine building. Retreating from the Valparaiso moraine, the Lake Michigan lobe halted long enough before it retreated into the Lake Michigan basin to build the Lake Border morainic system (15, fig. 2), a complex of low ridges which closely follows the margin of Lake Michigan. The ice over the eastern part of the State was building the massive West Branch and Gladwin moraines north of the Grand River. But south of the river the rapidly retreating Saginaw lobe was building the slender moraines which fray out from the West Branch-Gladwin moraine and mark the halts of the Saginaw lobe as it back-stepped into the bay.

This group of slender, deployed moraines (17-24, fig. 2) do not have the rugged topography of the moraines to which they are tied at either end as the Saginaw lobe was thinner and cleaner than the ice of the other lobes. Named in order of development from the vicinity of Lansing northward, the moraines of the deployed, slender group are: Lansing, Grand Ledge, Ionia, Portland, Lyons, Fowler-St. Johns, Flint, and Owosso. During the building of the Lake Border, West Branch, and deployed group the Huron-Erie lobe was building the Defiance moraine from near Defiance, Ohio, to a few miles east of Pontiac, Michigan (25, fig. 2) and the Birmingham, Mount Clemens and Emmit ridges (26, 31, 33, fig. 2) which lie scattered through the lake plain north of Detroit.

After the next retreat the re-enforced Lake Michigan-Saginaw-Huron lobes took the longest and most determined stand in the Lake region and constructed the most formidable entrenchments— the Port Huron moraine (39, fig. 2). The same determined stand was taken along the entire glacier front from east to west, so that this moraine has been traced more precisely than any other and stretches from the Genesee valley in New York to Lake Michigan north of Ludington, and is readily traced on the western side of the lake in Wisconsin. From Vassar in Tuscola County to the north-western corner of Bay County the Port Huron moraine is low and gently rolling rather than high, massive and rugged as it is elsewhere. Here the ice front stood in deep water and the moraine was water laid. The reason is in the story of the Great Lakes.

The last weak stand of the ice in the Southern Peninsula before it retreated into the narrow valley of the Strait of Mackinac is marked by the slender ridges of the Cheboygan moraine which follows the lake shore from Cheboygan to Mackinac City (44, fig. 2).

The glacial features of the Northern Peninsula were formed in large part by the Superior lobe. This mass of ice was directed into the Superior Basin from the northeast, and pushing out over the rim of the basin, covered the greater portion of the Northern Peninsula. Upon its halting retreat the Superior lobe also left moraines to mark the halts, and in the western part of the peninsula complicated the pre-glacial rugged topography by filling some of the gorges with drift, diverting the courses of some streams and daming others by building morainic dams across their courses. Lake Gogebic lies in the channel of a stream that once flowed to the north but its headwaters were cut off, dammed back by a moraine, and Lake Gogebic formed. These western moraines are not yet named nor correlated with other moraines. The Munising, Newberry, Kinross moraines (47, 46, 45, fig. 2) in the eastern half mark the last stands of the glacier in Michigan. They shared in the final episode of the Ice Age which is also one of the final chapters in the story of the Great Lakes. By the time the Superior basin was completely freed of ice as the Labradorean sheet had retired to the uplands of Canada, a great lake of glacial waters spread out in front of it, covering most of the eastern half of the Northern Peninsula, and inundated or flooded all but the highest morainic ridges, and buried the story the moraines could tell.

The moraines mark the halting places of the glacier as the warming climate forced retreats. But what happened between halts? What became of the water that flowed from the melting ice? Why do we not see the bed rock in the meshes of the pattern of the moraines? And just what are these moraines like, why do some high hills seem not to fit in the pattern of moraines at all? The mass of glacial drift gives the answers and also shows us several other features that the ice left us in addition to the moraines.

KETTLE HOLE, CHARLOTTE MORAINIC SYSTEM NEAR BRIGHTON, LIVINGSTON COUNTY.

In those areas where the edges of two glacial lobes came near, the moraines became complicated and mixed up. Thus at the place of near-union of the Erie and Saginaw lobes, where the Kalamazoo moraine meets the Mississinawa setting in from Indiana, readvance of the Erie lobe pushed its moraine against the also slightly advancing moraine of the Saginaw lobe. Such an area between lobes is an interlobate area and there we have some of our grandest scenery. The Irish Hills near Jackson are interlobate moraines formed at the near junction of the Erie and Saginaw lobes. The rugged morainic topography near Pontiac was formed between the Huron-Saginaw ice fronts, and the Metamora and Hadley Hills and the Highlands in northern Lapeer County were formed at the region of union and squeeze of the two lobes. The high hills north and south of Grand Rapids were developed where the Saginaw and Michigan lobes met, and the rugged hills through the region of Clare, Grayling, Gaylord, were formed by the Huron and Michigan lobes working together. How do we know the rugged interlobate regions were the work of two lobes? By the material in them. For example, the Erie lobe scraped the bed rock from the limestones of Monroe County and we find slabs of that rock on the southeastern slopes of the Irish Hills, but on the northern slopes we find fragments of the Pennsylvanian rocks sledded there by the Saginaw lobe from the bed rock over which it passed. On the hills east of Gun Lake, Barry County, rocks that came from north of Georgian Bay are found, but west of Gun Lake the hills carry fragments of rocks that are the bed rocks of the western Northern Peninsula.

Frequently in the construction of a moraine, blocks of ice broken from the ice front were buried in glacial debris and did not melt until long after the ice had passed. On final melting they left deep, steep-sided depressions in the moraines, some of which later became filled with water. Such depressions are named "kettles" and a moraine having many kettles is a kettle moraine. Such kettles, as well as the depressions caused by unequal bulk of deposited morainic material, account for the hundreds of lake basins we now find in the morainic areas of the State. Not all the basins have lakes in them now for thousands of them have been drained in the past ten thousand years; many kettle lakes are drying up now or their water levels lowered in times of decreased rainfall.

As the ice rapidly retreated by melting or evaporation from one moraine to the next, it left its burden of mixed rock waste just where it melted, just as a persistent winter snowdrift leaves an assortment of clay, sand, and sticks, when it melts in the spring. If the ice carried much rock waste it left a low hill; if the ice was fairly clean, the drift left was thin—like the land between Lansing and Howell, from Ionia to Stanton in Branch County, and many other places—made of the same unassorted material as the morains—cobbles, pebbles, some sand and erratics, but mainly boulder clay which was made, you remember, from the boulders which the ice ground up. These plains are ground moraines or till plains. In the main the till plains are quite stoney clay lands. Erratics are common. In some places the till plains at the present surface were deposited on the ground moraines of an earlier ice, and their undulating topography may be due to the topography of the land upon which they were deposited. They are some of the best, most easily worked farm lands in the State. On the till plains also small blocks of ice were buried for centuries and left depressions when they melted. Water remained in these and other depressions in which vegetation grew and in time filled the depressions with an accumulation of plant material, which accounts for the patches of dark soil on our farm lands.

DRUMLIN NORTHWEST OF ELLSWORTH, ANTRIM COUNTY.

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 south- western 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 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.

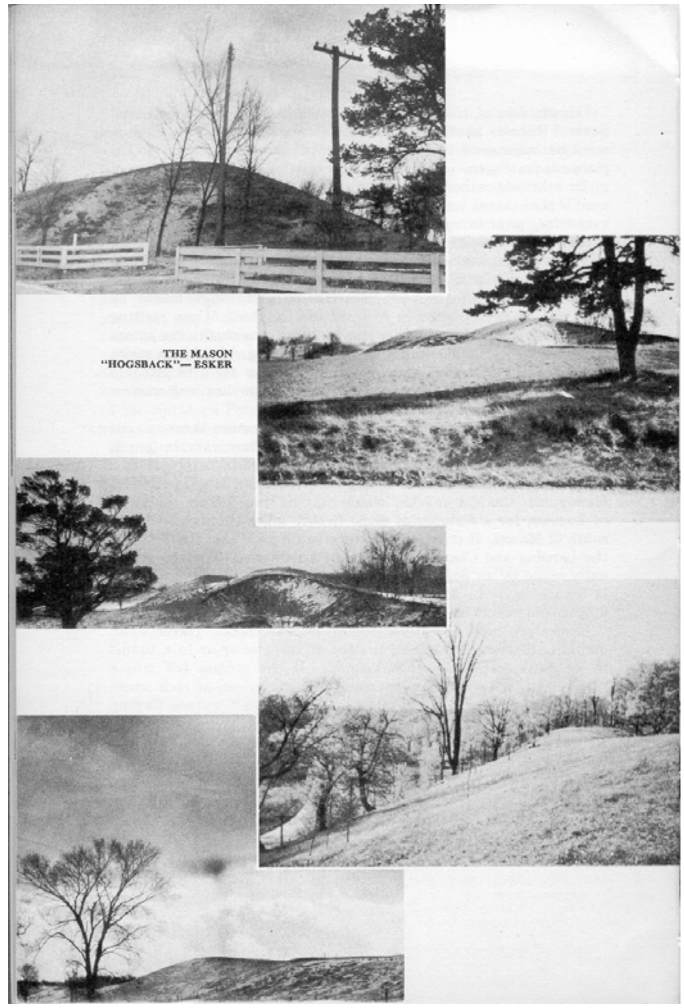
In a few areas in the State the melt waters became ponded into lakes which are recognized mainly by the character of the deposits they left behind. Large areas in central Lapeer County, in Kalamazoo County south of Kalamazoo, and in the northwest corner of Kalamazoo County and extending into Allegan 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.

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.

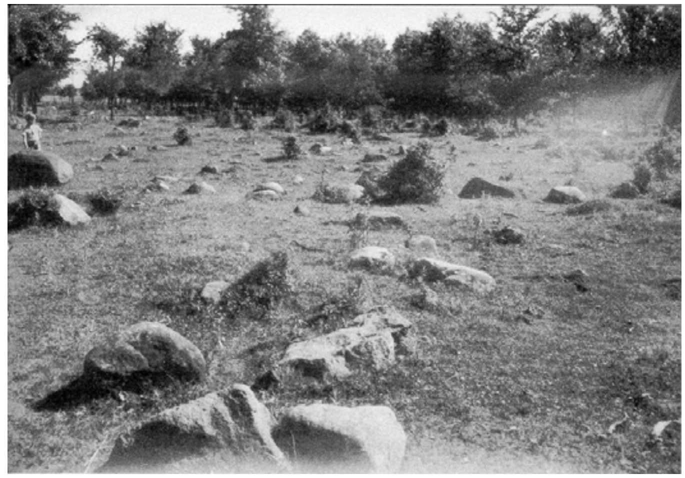


THE MASON "HOGSBACK"—ESKER

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 color 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.

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

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



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

Shortly after the initiation of Lake Maumee the pools at the foot of the Lake Michigan lobe united to a 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 east-ward 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.

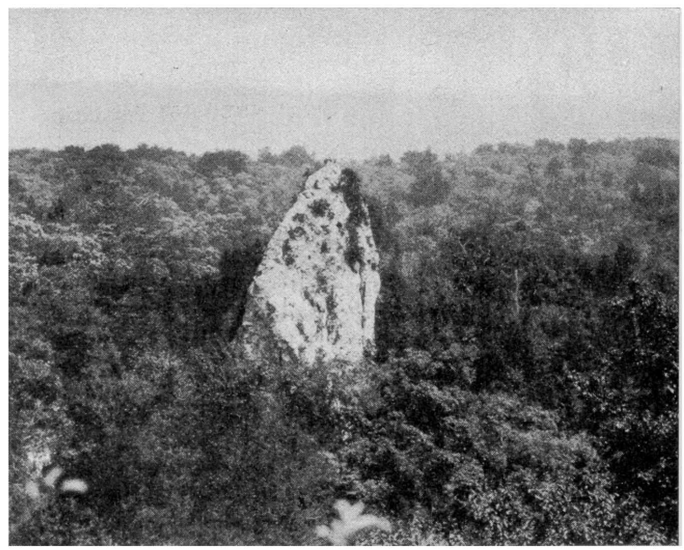
Lake Wayne was destined for a brief existence, a slight readvance of the Ontario lobe blocked the eastward Mohawk outlet and brought the Wayne stage to a close. The ice barrier readvanced to slightly south of Alpena in Michigan and south of Rochester in New York; ponded and lifted the glacial waters 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 narrow 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.



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

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, 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."

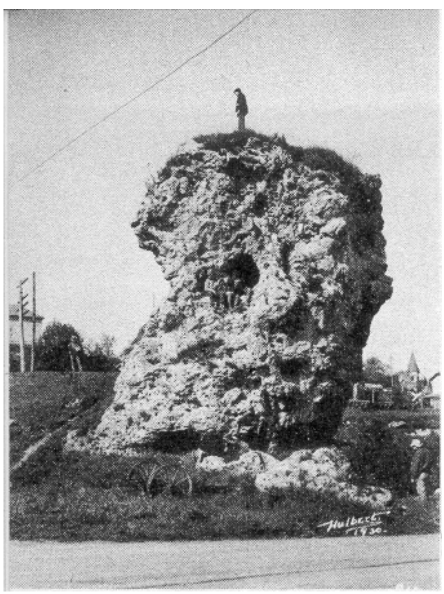
The glacier retreated farther northeast. Lake Algonquin's powerful waves pounded on its shores, built huge beaches and cut cliffs to show us where it had been. Sugar Loaf on Mackinac Island was a chimney-like island on the little island's shore. But now something else was happening to the continent. Released of the weight of billions of tons of glacial ice as the melt waters flowed back to the sea, the continent slowly 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.

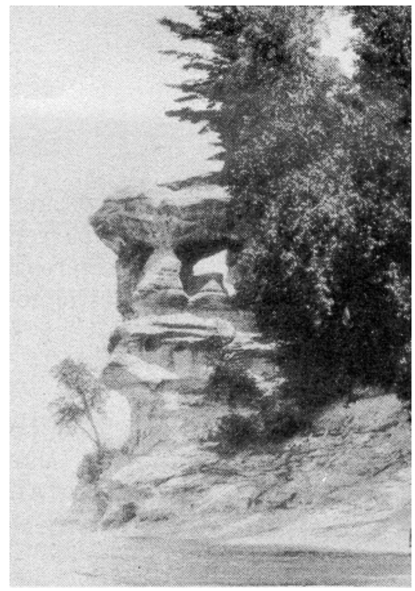
POINTE AUX BARQUES, HURON COUNTY.

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 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 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.

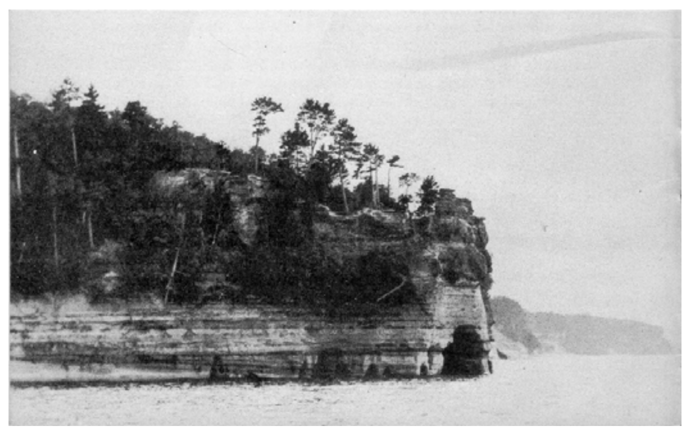


ST. ANTHONY'S ROCK, ST. IGNACE. A CHIMNEY ROCK. REMNANT OF LAKE NIPISSING SHORE.

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.

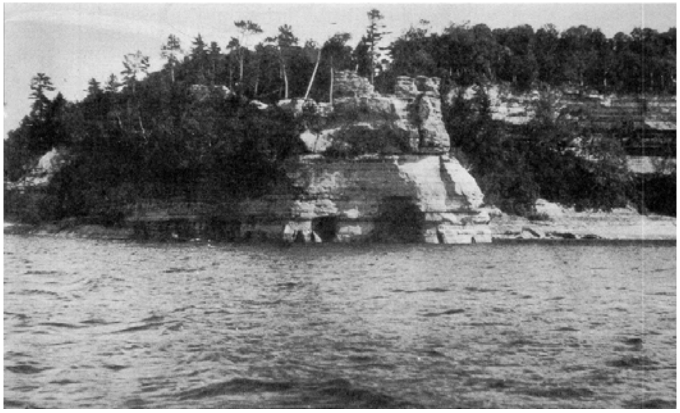


CHAPEL ROCK, LAKE SUPERIOR.



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

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



MINER'S CASTLE FROM THE LAKE.

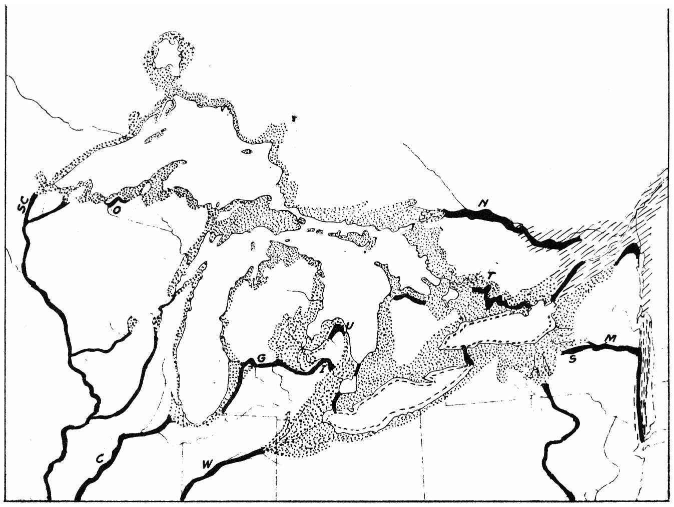


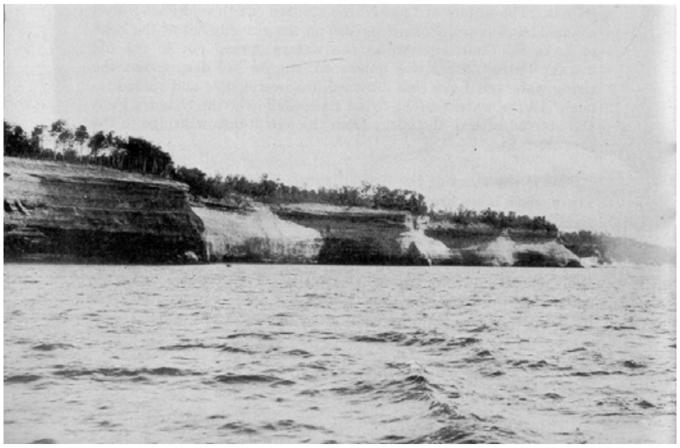
FIG. 3—Areas covered by glacial lakes (stippled) and outlet channels of former lakes. W=Wabash; I-G-C=Imlay-Grand River-Chicago; U-G-C=Ubley-Grand River-Chicago; S=Syracuse outlet; O=Ontonagon outlet; SC=St. Croix-Duluth; M=Mohawk-Hudson River; T=Trent River-Kirkville; N=North Bay-Ottawa outlets. Dashed likes 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.

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.

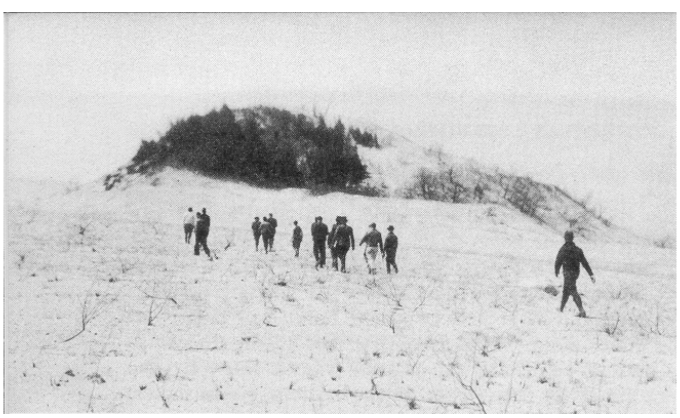
SANDS ON THE MARCH

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 Pau-wau-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.



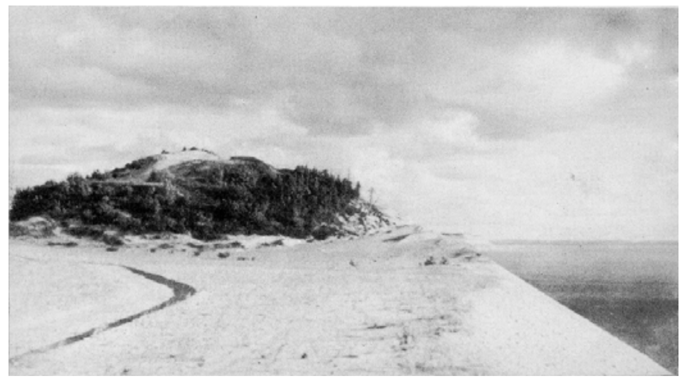
"THE MIGHTY FORTRESS" OF THE PICTURED ROCKS.

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 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.

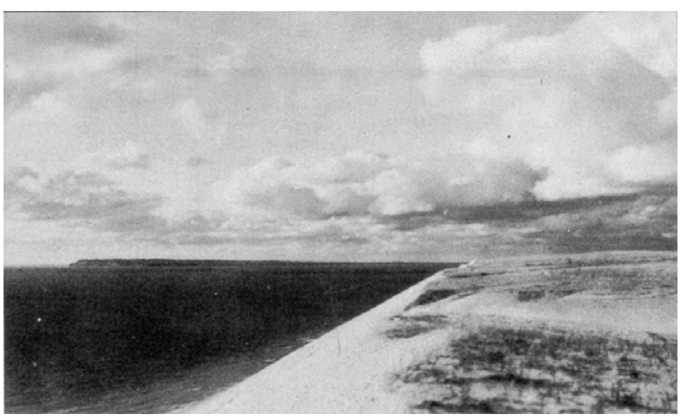


SLEEPING BEAR DUNE FROM NORTH SHOWING 360 FT. DROP OF BLUFF FROM BASE OF DUNE TO LAKE MICHIGAN.

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 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.

FOREST UNCOVERED BY MOVEMENT OF DUNE.



LOOKING NORTH FROM SLEEPING BEAR.

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 Michigan 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.

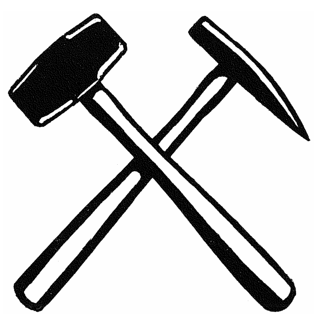
*All the major streams of the Northern Peninsula are described in Professional Paper 154.A United States Geological Survey.

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.

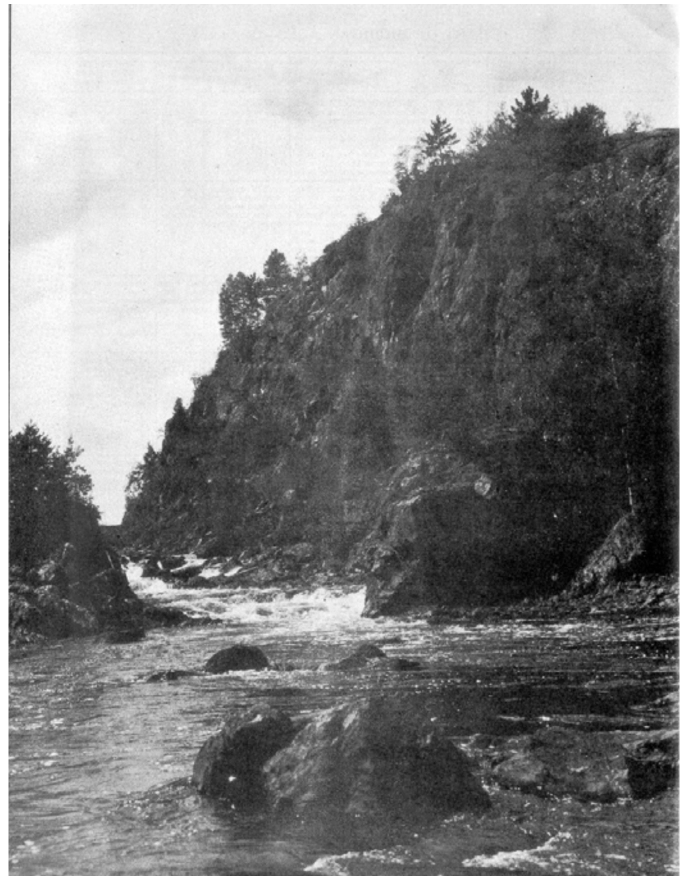
This is the story of the foundations of the State written and recorded through a billion years—the story of the filling of a granite basin, with rock formations which hold our mineral wealth; the tale of the spreading of a blanket rich in minerals plants need, and upon its surface developed that thin 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."

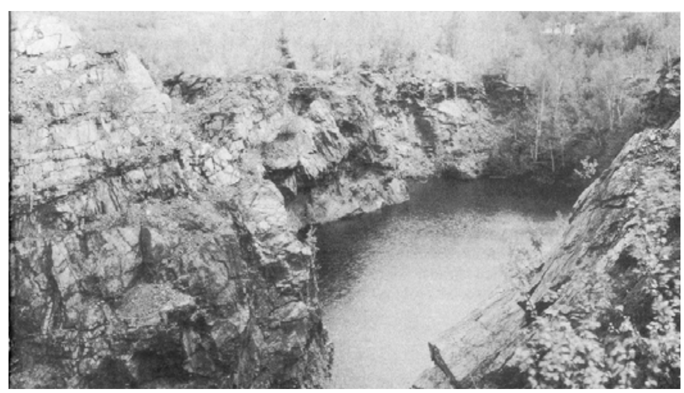


IN THE STOREHOUSE OF THE AGES

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.



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.

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 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.

MINE SHAFT. TOBIN MINE, CRYSTAL FALLS.

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

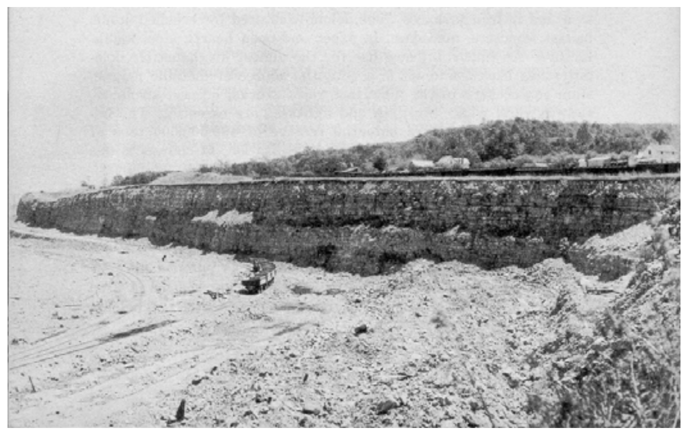
The Cambrian-Ozarkian sandstones are reservoirs of pure water in the Northern Peninsula. The red sandstone, a good building stone, was formerly quarried at Jacobsville and used for building purposes until shipping costs and cheaper cement-concrete materials made production costs prohibitive. We have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

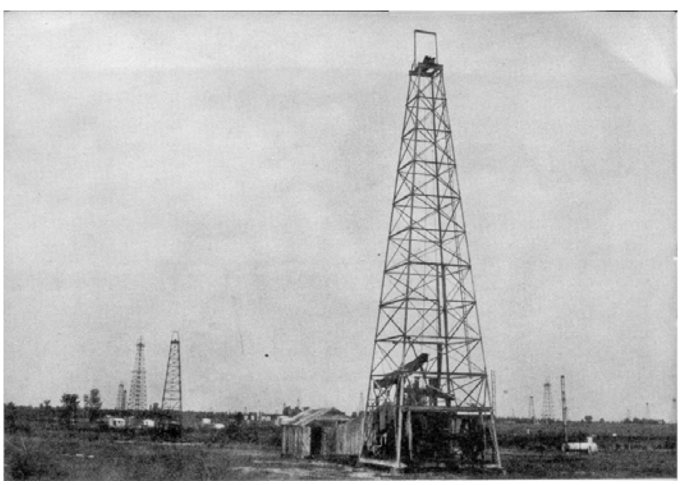
The rock salt is used for packing meat and fish, for the manufacture of soda ash, caustic, bleach, and other chemical preparations, refrigeration, and agricultural purposes. From the upper Silurian limestones of the southeastern Southern Peninsula we obtain mineral waters, fresh artesian water, and from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



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

LOADING LIMESTONE BLOCKS IN ROGERS QUARRY.

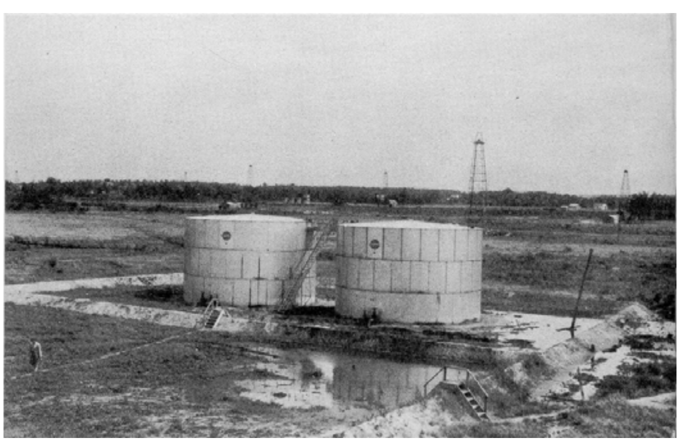
The Devonian rocks supply us with a variety of mineral resources. From the outcrop of the basal sandstone in Wayne and Monroe counties—the Sylvania—we obtain a sand used in the manufacture of glass. Some of this sand is so free from iron, the most vexing impurity, that the sand is suitable for optical 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 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 lime- stone 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 industries and for agriculture. Good conservation finds use for apparent wastes.



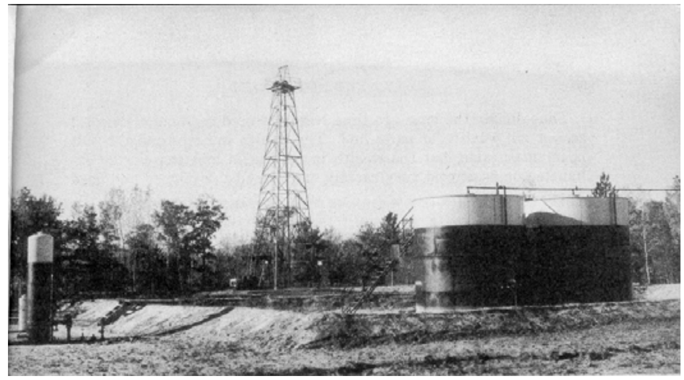
OIL FIELD, MIDLAND COUNTY, ON FLAT GLACIAL LAKE PLAIN.

AERIAL VIEW OF NORTH BUCKEYE OIL FIELD, GLADWIN COUNTY

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 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.



OIL FIELD TANK FARM, MIDLAND COUNTY.



OIL FIELD, ROSCOMMON COUNTY.

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.

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 hone- stones 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 at Manistee and Ludington also, but a deeper brine was used. When the lumber was gone, and the lumber towns vanished, the salt industry vanished with them, but only in the vanished towns. The byproduct industry became most important, the industry continued to develop and to use brines and artificial brines from the Devonian and Silurian as well as the Mississippian formations. In sixteen years Michigan became the leading salt producing state—a position held for most of the time since 1876. The development along the St. Clair and Detroit rivers was independent of the lumber industry as the entire industry is today. The salt industry is just one example of the close relationship of the uses of our natural resources. We were not compelled to cut all the forests to make salt—but because use of refuse did develop another industry we have few unsightly piles of decaying sawdust and lumber mill refuse. Let your imagination soar a bit from a white pine seed to forest—lumbering-refuse-salt brines-salt-bitterns-magnesium-air-plane—?

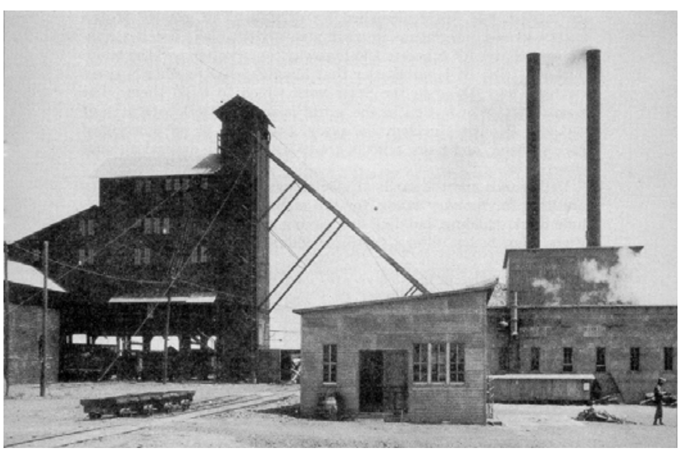
We have found that the end of Mississippian time was a time of shallowing seas in Michigan, and of warm and often arid climates; that the sea deposits were limestones, shales, and gypsum. Along the shores of the old seas waves and currents heaped piles of sand just to the water level, sand bars developed. Today in drilling for oil we find those old bars and discover that in many of them gas has collected. Because the bars are not extensive or regular, nor always at the same depth, oil men dub them "Michigan stray sand" and produce their natural gas wherever sufficient quantity has accumulated.

The gypsum of these rocks mined at Alabaster and Grand Rapids is used for agriculture, and in the building and glass industries. The shales are used for cement; the limestone, last formed of our Mississippian rocks, is now used for agricultural lime, in sugar manufacture, for cement and concrete. It is cut and used for building stone and in ornamental gardens. Many of our roadside parks in the southern part of the State have fireplaces and walls made of the Bayport limestone.

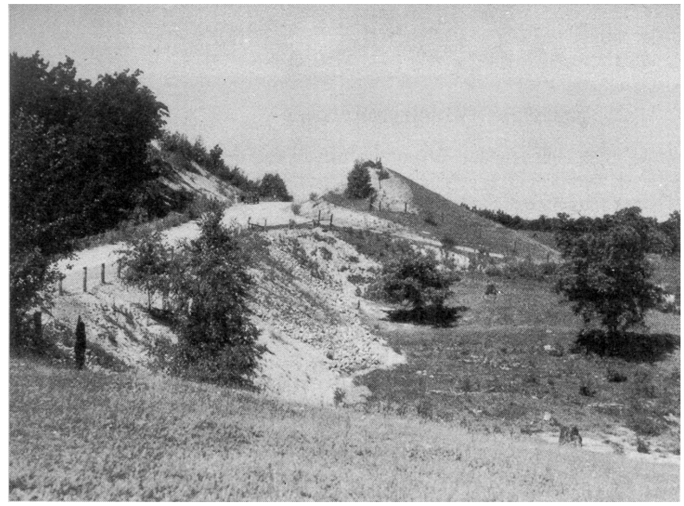
The swamp forests of the Pennsylvanian stored usable wealth for us. The sands at the bottom of the swamp, now hardened into the Parma sandstone, are the reservoir for fresh water in the central counties; in a small area natural gas has been obtained from it. The trees of the forest died, were buried, and became the coal of the Saginaw valley, Grand Ledge, Shiawassee, Ingham, and Jackson counties. The coal is a bit difficult to use in the ordinary furnace, but with the proper type furnace and proper firing methods, it can be satisfactorily used. Some of the Pennsylvanian sandstones have been used for building purposes—quarries were operated near Flushing, Corunna, Jackson, and Ionia.

Many of the shale beds have been used in the brick and tile industry and in cement manufacture. The Grand River has cut a gorge through the upper sandstone that at one time was the mecca for many vacation excursions and boating parties. The revived interest in natural park areas has revived the interest and use of the Grand Ledge park area.

The glacial drift buried much of this treasure store, buried them so deep that we could not get to them until of necessity we learned to make tools that could go through the drift and rock to get to the water, salt, oil, copper, iron. But is the glacial drift only a covering? Is its economic value only in the scenery produced by it? The glacial drift is the most varied resource we have. The granitic boulders supply stone for all sorts of buildings from foundations to complete structures, from markers to monuments. Look at the foundations of the houses on your street and no doubt you will see few houses that are not resting on a granite or crystalline rock foundation. Foundation stones—"hard heads", "glacial babies"—are fireplace stones, stones for rock gardens and fences. In the gravel beds of the moraines, spillways, outwash plains, old lake beaches, and river deltas are supplies of pure water—the most used resource in the State. They contain water imprisoned as the ice melted, and are replenished by rainfall. The gravels of the eskers, kames, interlobate outwash plains, glacial lake beaches, supply aggregates for concrete and highway construction and the building industries. It is no wonder that Michigan has fine highways—we have everything in the State with which to build them. The largest gravel operation in the world is in the interlobate area of Oakland County. Incidentally every gravel pit is an unassorted rock museum and more schools are using them as natural outdoor classrooms.



COAL MINE, UNIONVILLE, TUSCOLA COUNTY.



HIGHWAY CUT THROUGH KAME, LAPEER COUNTY.
GRAVEL FROM CUT USED FOR FILL BETWEEN KAMES.

Drift sands and the sands of glacial lake beds, beaches and dunes are used for foundry sands, for the manufacture of mortar, sand-lime brick, molding, building and paving sands, sands for icy highways, play boxes, filters, fertilizer fillers, for highways and golf courses.

Drift and glacial lake clays are used by the brick and tile and pottery industries. The peat that has accumulated in the drift depressions and glacial lake beds is used for fuel, litter, in greenhouses and for packing. Marl deposited in the glacial lake beds is used for cement and fertilizer. Three cement plants in the State, at Coldwater, Fenton, and Cement City, operate wholly on marl—but would use limestone if it could be obtained as cheaply. The marl comes from thick deposits in kettle lakes in the nearby moraine; soundings show that some of the beds are at least 75 feet thick. Intensive search of the drift deposits would probably locate deposits of fullers earth and slip clay. At one time a flourishing iron industry was based on the bog iron ore found in the swamps of southwestern Michigan. The bog ore and clay-ironstone concretions found in the Coldwater shale nearby supplied several furnaces in Union City—the first iron manufactured in Michigan. Bog iron ore (red ocher) was once mixed with water and used as a cheap paint for the old red barns and the vanished little old red schoolhouse. It has an important but undeveloped use today as paint filler.

Because the drift is so mixed and so scattered no one place has extensive, limitless deposits of drift resources, but the deposits are large enough to supply small local industries—witness the numerous brick and tile, sand and gravel operations. When we consider that one square mile covered ten feet deep with glacial drift would carry 20 million tons of sand and gravel, clay, peat, boulders and all the other odds and ends in the drift we have some idea of how soon this resource will be exhausted as the drift has an average depth of 250-300 feet. However, we often regret that progress in construction makes it necessary to destroy and obliterate long narrow beach ridges of ancient lakes, high conical kamic hills, long narrow winding hogs backs or eskers—and the dogwood that grows on them. Their destruction obliterates not only geologic features of interest but also Indian trails and other relics of Indian culture.

The two greatest resources of the drift are water and soil—the water that is in the drift, fills the depressions, and comes to the surface in lakes and streams; the top few feet and the very top few inches of the drift are the subsoil and soil. These resources, because related closely to so many phases of conservation, must be discussed in later chapters.

Every one of our rock formations carries a valuable resource. Some are spectacular in their use and value, others are so commonplace we do not think of them as expendible, non-replaceable resources. Many are almost limitless, some must be used with wise care. For some, uses must be found, others are waiting discovery. New industries, new test tube discoveries are finding many of our rocks well suited for new uses. But all this building up of the State has been foundation for that thin dark bit of rock through which we draw our life from the sun—the soil.

Since 1837 the Michigan Geological Survey, now the Geological Survey Division of the Department of Conservation, has studied and mapped the mineral wealth of the state and now conducts the Departmental work related to mines, quarries, wells, and mineral resources.

Douglass Houghton Monument, Eagle River, Keweenaw County.

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.