GEOLOGY NOTES

for

UPPER PENINSULA TRAVELING WORKSHOP

Compiled

by

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FOREWORD

These notes have been prepared specifically for use in the "Upper Peninsula Travelling Workshop", Courses 404 & 502, offered for credit by Michigan State University. The material for a particular location should be read prior to the actual visit to that location. The remarks made and concepts introduced by the resource people at each stop, will then have greater significance. Enough blank space has been provided between paragraphs so that the student can insert notes or comments of his own. The extensive bibliography at the rear will be useful to those wishing to pursue further studies.

Some of the locations described will not be visited, but will be passed enroute. Unless these notes are used in advance, such observations will be lost to students. Perhaps other stops will be made that are not mentioned here. Time limitations preclude actual visits to Fayette or Tahquamenon but reading the material for these spots is recommended nevertheless.

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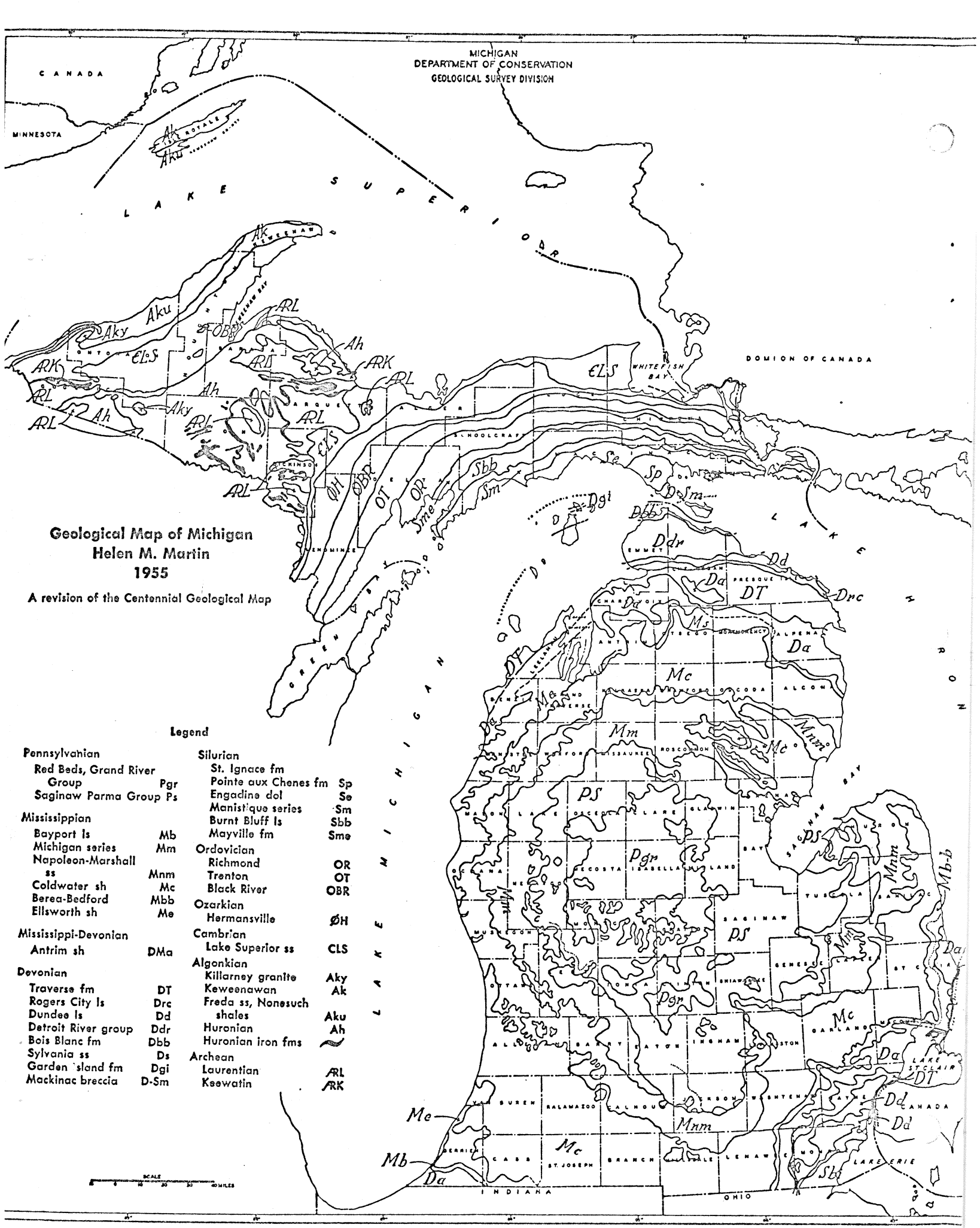
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STRAITS OF MACKINAC

The geologic history of this area commenced some 375 million years ago when there was a shallow granite basin occupying the present-day geographic position of the entire Southern Peninsula as well as the eastern half of the Northern Peninsula. The northern rim of this basin has been partially filled by a layer of Cambrian sandstones, the parent materials of which were derived from the weathering of bordering highlands composed of much older rocks. Although Cambrian rocks in other areas are replete with fossils, we have yet to discover their presence in the Michigan Basin.

The next event was when the greatest flooding of all time took place over North American. The widespread shallow Ordovician seas swept into the Michigan Basin and deposited many layers of fossiliferous limestone and shale before retreating. The best rock records revealing its history are found in Delta Co.

When the shallow marine seas came back, they were somewhat warmer and this ushered in the Silurian period - the age of corals. These invertebrates built vast reefs from the lime they were able to extract from sea water, much as is done by their modern descendants. Through million of years, lime muds accumulated in the Michigan Basin. Many other shelled creatures - snails, clams, starfish lived and died, but the true fishes had not yet arrived. Hundreds of feet of limey muds consolidated and became the rock we now know as the Niagaran formation, a group of hard limestones comprising the prominent escarpment that extends from Lockport, New York, through the Niagara Falls to Drummond Island, through the Northern Peninsula, to the Garden Peninsula and thence southerward to Chicago. It is often referred to as the backbone of the Michigan Basin rock structures. Then the Silurian seas became more muddy, because overlying the Niagaran are some beds of red and blue shale (may be seen at Pte. Aux Chenes - after which they have been named, and at the base of Castle Rock). Following this there was an abrupt change of climate because the record consists of hundreds of feet of layers of rock salt devoid of any remains of life. Warm arid conditions prevailed and the Salina seas became excessively salty by evaporation, and were desolate. But this condition did not persist because yet another sea swept in and deposited thick layers of limestones directly upon the salt layers. The lowest horizons of the rock layers left by this sea contain life forms of the Silurian, whereas the middle and upper parts contain the forms of the next youngest geologic period called the Devonian. These new Devonian limestones, like all limestones, were soluble, but the underlying salt was many times more so. It is believed that both the Niagaran limestone and the Salina salt beds were dissolved away by ground water leaving caverns. In time the roofs of the caverns collapsed, filling the depression with a mass of rubble which was later cemented by lime precipitated from evaporating ground water. This recemented limestone (called "breccia") was harder than the original limestone. As millions of years passed the limestone was eroded away but much of the breccia remained, some of it being left standing as the Arched Rock and Sugar Loaf on Mackinac Island, Castle Rock, Rabbits Back, Bear's Back, Gros Cap, and the other "chimney rocks", "seastacks", or "flower pots" as found in the Straits State Park and elsewhere along the lower road.

During the time of glacial lake Nipissing, the tops of these stacks stood up in the lake as skerries (like the skerries north of Scotland). Weathering now is at work on the stacks and they are being reduced again to rubble. In this area also we have the bed of glacial Lake Nipissing on which the lower road from St. Ignace is built, rising in the cliff to Highway U.S.-2 which is

laid on the bed of Lake Algonquin, and the shore cliff of Lake Algonquin is the cliff to the north. During the existence of Lake Nipissing, the area of St. Ignace was an island--a skerry--but during the slow subsidence of Lake Nipissing, the island was tied to the northern mainland by a series of bars which are very evident in photos. At the same time, the Brevort dunes were piled up on the shores, and Brevoort Lake, Millecoquins and others were cut off from the main lake. They are the remnants of the predecessor of Lake Michigan.

CUT RIVER BRIDGE

The Cut River is presently a very minor stream being only 3 to 4 miles in length. The magnitude of the valley, however, indicates that it was formed by a much greater river originating from glacier meltwater runoff. Presumably the route could have been laid a few miles inland thus eliminating the necessity of a very expensive structure. But it would have also denied the traveller an exceptionally scenic view of the Lake Michigan shore.

LAKE MICHIGAN SHORE NEAR BREVOORT LAKE

The huge blocks of rock strewn at the water's edge were taken from the old Ozark Quarry, and serve as rip-rap to secure the shoreline. This material is a sugary textured, dense, white to bluish Silurian dolomite (a calcium magnesium carbonate)-from the Engadine formation (after the village of the same name). Some of the crushed Engadine along the shoulder probably came from the Cedarville quarry. The other extremely dense crushed gray rock spread along the shoulder in a Silurian lithographic limestone ($CaCO_3$) called the Fiborn and comes from the Hendricks quarry.

PORT INLAND (Inland Lime and Stone Co.)

One of the five major direct-shipping fluxstone ports for which Michigan is noted because, together, they supply most of the U. S. production of a raw material without which there would be no great steel industries. Limestones and dolomites, with coke, are fed into the blast furnaces along with the iron ore. The lime forms a molten flux which removes most of the unwanted impurities (mostly silica) from the raw ore. The glassy waste product,(often resembling obsidian-volcanic glass), resulting from process is called slag. It finds a good use in surfacing driveways.

This particular property, owned and operated by the Inland Steel Company, was originally developed in 1930. Present quarrying sites are some 6 to 7 miles north of Lake Michigan. The stone is a high calcium limestone of the Burnt Bluff formation of Silurian age.

MANISTIQUE

Along the north side of US-2, entering Manistique from the east, are the abandoned quarries of the old White Marble Stone & Lime Company. The deeper quarry is now filled with transparent blue water beckoning the swimmer. Some day, perhaps the hazards will be removed and this will be developed for public recreational uses. The eastern portion of the quarry site now is part of the Manistique High School athletic field - one way of reclaiming "waste" land.

KITCHITIKIPI OR "BIG SPRING"

Kitchitikipi was probably formed by the intersection of two big sinkholes during the slumping resulting from ground water solution of the bedrock. The spring is roughly an oval pool 300 by 175 feet with sides which slope abruptly to a depth of 40 feet. Water enters the bottom under strong hydrostatic pressure, roiling the sandy bottom to such an extent that a boiling effect is seen from the surface. The beautiful emerald green of the water could be due to the luxuriant growth of aquatic vegetation draping the submerged trunks and sides of the pool. The water is highly charged in sulphates probably originating from an underlying layer of gypsum.

FAYETTE

Doubtless this is one of the most picturesque localities anywhere along the entire Niagara Escarpment (excluding Niagara Falls!). Geologists point to it as one of the classic examples of a cuesta.

Here at Fayette Harbor are the ruins of the furnaces and buildings of the once flourishing Jackson Iron Company which shipped in its iron ore from the Negaunee area. Early in the development of Michigan's iron industry, the ore was processed in charcoal furnaces located in the Northern Peninsula. The Fayette furnaces was established in December, 1867, burned down in 1883, but rebuilt. It was closed for good in 1890.

At one time this site had 27 kilns with an average capacity of 70 cords. The company employed 225 men and contracted for 100 more. In 1872 it made 10,092 long tons (2,200 lbs.) of iron, and by 1873 had an accumulated production of 34,252 long tons. Greatest annual production of 14,706 long tons occurred in 1888. The company owned 16,000 acres of timberland in the area, but for a time much of the wood was brought in to conserve this tract. The Burnt Bluff limestone exposed as high cliffs along the shore, furnished the necessary flux as well as the raw material for the lime also manufactured.

WHITEFISH RIVER

This river enters Little Bay de Noc about 1 mile east of the town of Rapid River. During the time of glacial Lake Algonquin, when the glacier front halted in the vicinity of Munising, great volumes of meltwater flowed south through the Au Train - Whitefish depression from Lake Superior to Lake Michigan. At the present time, there is but a slight divide of a few hundred yards separating the headwaters of these two river systems. If and when it ever becomes necessary, this depression can be improved so as to provide a navigation connection between Lakes Superior and Michigan.

BARK RIVER TO HERMANSVILLE

In this area (mostly in Menominee County) Highway US-2 traverses one of the most extensive drumlin belts in the state. Drumlins are long narrow hills that have the shape of an inverted spoon bowl, or the shape of a cigar that has been sliced the long way. The word drumlin is derived from the Irish signifying "little hills". Their size may range from a few hundred to a mile or more in length, from several feet to many hundred feet in width, and from a few feet to a hundred feet or more in height. Some are composed of boulder clay, others are of water-sorted materials (sand and gravels), while many have been found to have a core of bedrock (often shale). When they are all rock, the term "roches moutonnees" is used (after French meaning rock sheep) - but roches moutonnees are considerably smaller than true drumlins. When viewed from a distance they truly resemble a flock of sheep on a hillside.

Drumlins generally occur in swarms on till plains, with their long axis oriented parallel to the direction of ice movement. The mechanics of their origin are unsolved. The classic drumlin area in Michigan borders Grand Traverse Bay. Other drumlin areas are in Chippewa, Cheboygan, Presque Isle, Iron, Alpena, Branch and Kalamazoo counties.

Note the northeast-southwest orientation of these rather unusual features through which you are now travelling. The drumlin at the town of Wilson is an exceptionally good example of this phenomenon.

WAUCEDAH

It might be said that this town is the gateway to the Precambrian complex of the western part of the Northern Peninsula, because here we leave the Paleozoic rocks of the Michigan Basin behind us (to the east and south) and enter a highly different geologic province containing some of the earth's oldest rock formations. Basically these consist of the iron formations and igneous

and metamorphic rocks that have been highly altered chemically and contorted physically through the eons of geologic time. Much of this rock lays bare at the surface because the glacier (more recently) deposited only a thin ragged sheet of drift, or left none at all, in many places in the region.

Since the geologic history for Michigan's three major iron ranges (Marquette, Menominee, and Gogebic) is related, it is suggested that the reader refer to the first three paragraphs in the section "Marquette Iron Range".

The Menominee Range and its western extension - The Crystal Falls-Iron River District - is traversed through almost its entire extent by Highway US-2 from Waucedah to beyond the city of Iron River.

QUINNESEC (Michigan State Highway Dept., Tourist Roadside Park)

Fumee Creek falls over a very dense rock colored with delicate hues of faint red, green, and purple. Superficially it resembles a quartzite, but it is much too soft for this (it can be scratched with a knife blade). Also, when crushed, its powder "fizzes" in warm hydrochloric acid. This is a metamorphic dolomite, called the Kona, of lower Huronian age. Layers of conglomerate are also interbedded in the Kona at this location.

IRON MOUNTAIN

The highway is routed west around the caving Chapin mine from which many millions of tons of iron ore were taken. The large steam Cornish water pump is of interest.

HORSERACE RAPIDS

The valley of the Paint River served as a glacial outlet as the ice border melted eastward. The streams now occupying the old glacial channels have deepened, many to gorges, cut by the swift streams running from the highlands - thus the many rapids, cascades, and falls found in this country. The rock found in the rapids near the campsite is known as a micaceous schist (a metamorphic rock derived originally from granitic materials).

IRON RIVER

The Riverton Pits show the folded slates and iron formations of the Huronian rocks. There are also some drumlins in western Iron County, particularly east of Iron River.

WATERSMEET

About six or seven miles to the southeast is a divide between headwaters flowing to Lake Superior, Lake Huron, and the Mississippi River. The name does have a significance.

WAKEFIELD AND BESSEMER

Located between these two towns is the second largest iron ore pit in the world. Actually there are two pits separated (or connected) by a saddle. The Plymouth pit on the west is owned and operated by the Pickands-Mather Co., while the Wakefield pit on the east is owned by the M.A. Hanna Co. In 1952, the Plymouth pit was exhausted and abandoned and has since filled with water.

LAKE GOGEBIC

Derivation of the name is uncertain but it has been suggested that it came from agojebic (Indian) meaning rocky or rocky shore. Another interpretation is "Where trout rising make rings in the water".

Origin of this lake is not certain but, at any rate, the explanation should take into account the relationship of the wind gap in the Copper Range to the north of the lake. Likewise, the presence of the Iron River flowing directly into Lake Superior beyond this wind gap suggests that the present Lake Gogebic was formerly the headward extension of the Iron River across the range. Perhaps it was stream piracy on the part of the old Ontonagon River that caused it to capture the upper reaches of the Iron.

On the other hand, the explanation could lie in the fact that the glacier halted north of Lake Gogebic, blocking the wind gap and yet allowing ponded waters to escape through the lower Ontonagon River gap - which, incidentally, is the largest stream crossing the Copper Range in Michigan.

PORCUPINE MOUNTAINS STATE PARK

The geologic history of this area is closely associated with that of the Keweenaw Peninsula, or Copper Country. The Porcupine Mountains themselves resulted from the upward pushing of rhyolites (a very finely crystalline granitic type) during the Killarney Revolution. The older lava flows, and their interbedded sandstones, conglomerates, and shales were tilted northwestward leaving cliffs facing southeast. The old copper mines were cut these cliff faces.

Lake of the Clouds is a beaver-dammed river bed between two ridges of tilted lava flows. Carp River, at one segment along the outlet, disappears underground to re-appear further downstream. The escarpment of Lake of the Clouds is the uplifted edge of a broken lava flow - hence the upthrow side of a fault.

The ski slope runs down the top of a tilted lava flow. The lower jump is a shore terrace formed by glacial Lake Nipissing.

Most of the copper in this area is found in a very finely divided state (often pinpointed in the sandstones and shales). Much of it is in a mineral form known as chalcocite (Cu_2S).

Some of the peaks in the Porcupines are numbered among the highest in the state. Government peak is 1,855 feet above mean sea level. An unnamed peak, one mile south of Mirror Lake, is 1,963 MSL. Although, being the highest in the Porcupines, this is some 20 feet lower than the highest known points in northeastern Baraga County. Mirror Lake is 1,531 feet MSL.

WHITE PINE MINE

The original White Pine Mine Co. was organized in 1909 to work the orebody 20 miles southwest of Ontonagon. From 1915 to 1920 it produced about 900,000 tons of ore from which about 18,000,000 pounds of copper, and 260,000 ounces of silver were recovered. Falling prices forced a shut-down in 1920 and later this property was sold to the Copper Range Company. The copper in the old mine was recovered in its native form.

The new mine, developed by the Copper Range Company is on an extension of the old orebody. But, in contrast, the ore now extracted is chalcocite (Cu_2S) -- bypassed originally because it wasn't until quite recently that modern technology unlocked the secret of economically separating the copper from the sulphur. This operation is now producing about 100,000,000 pounds of copper a year (all other Michigan production aggregates about 50,000,000 lbs.) and this may be increased another 50 per cent in a few more years.

This project represents a total investment of more then $80 million, with $57 million provided by an R.F.C. loan. Market is guaranteed through a Defense Minerals Procurement Agency contract which provides for a subsidy price of about 25 cents per pound over a period of seven years dating from the first production (1955). Last year (1956) the price of copper averaged about 42 cents - far above the support level.

The chalcocite occurs in two shale layers separated by a 3-foot bed of sandstone. The lower 8-foot "Parting Shale" is being mined. Its content of Cu_2S averages about 24 pounds per ton with an estimated reserve for about 50 years. Above the sandstone is a 3 to 5-foot "Upper Shale" that also has a potential 50 year reserve. Beneath the Parting Shale is a conglomerate. All are members of the Nonesuch formation of the Keweenawan Series.

The mine entry port is inclined along the crest of a gently southeast dipping anticline. This permits use of vehicular haulage to the surface. Actual mining is about 400 feet below the surface. Most of the mine will have 20-foot pillars spaced 30 feet apart - altogether a comparatively inexpensive method.

The raw ore is fed through a series of crushers which reduce it to a finely divided state. A flotation process then results in a Cu_2S concentrate of 30 to 35 percent. After being dehydrated, it is introduced as a cake into a reverberatory furnace. Along with pulverized coal, limestone flux and pyrite are fed into the furnace. This creates a slag removing aluminum and silica from the ore, and results in a molten "matte" of copper and iron sulphides. (The resulting heat is "conserved" by directing it into the power plant). The ore (now 65 per cent Cu) is then moved into the converting furnace and jetted with oxygen. This oxidizes the sulphur while the iron slags with impurities and some copper. The slag is recirculated to get all the copper. The result is a molten "blister copper" (90 per cent Cu) which is then introduced into the Refining Furnace. When green logs are dipped into the hot blister copper, destructive distillation takes place, thus, reducing the concentrate to pure Cu.

DONKEN

There is a church on the east side of the road across from the lumber mill. Behind the church is a bedrock knob which was probably exposed in grading the church yard. Glacial ice has sculptured and smoothed off this protruding rock mound. The more prominent striae (scratches) are aligned northwesterly. The other minor striae and groovings are aligned more westerly and because of their superposition indicate a younger ice movement.

COPPER COUNTRY

Michigan's Copper Country is one of the most legendary spots in the Great Lakes region. It all came about because of the development of one of the world's richest deposits of native copper. The earliest discovery of the red metal goes back to prehistoric times. Peoples first extracting Lake Superior copper are still much of a mystery to archeologists. Their pits, dug long

before the Indian's occupance, have led to the discovery of many mines. Recent carbon dating evidence indicates mining pits on Isle Royale prior to 2000 B.C. These ancient miners heated the copper-bearing rock by fire and then split the rock with cold water. The Jesuits (with information obtained from the Indians) were the first to make known to the world the existence of Lake Superior copper. One of the earliest published accounts appeared in 1636 (Lagarde).

The earliest mining venture of modern time was started by an Englishman, Alexander Henry. He visited the Ontonagon River in 1765 and again the following year. On his second visit, he saw the famous copper bowlder (now resting in Smithsonian Institute) which he estimated to weigh five tons. A party of miners was organized to extract the bowlder. During the winter of 1771-72 they drove an adit some forty feet just above high water level at the river. In the spring thaw the clay through which the tunnel was driven collapsed and work was abandoned. The original site of the Ontonagon Bowlder is marked by a sign near Victoria Dam.

The first mining of any real importance was in 1844 at the site of the old Cliff mine. The Quincy Mining Company was organized in 1848. The old Minnesota mine opened in 1849 and even though it closed in 1870, was probably one of the richest ever worked, for its production of mass copper was tremendous. The largest mass of native copper ever to be discovered in the Copper Country came from this mine. It measured 12' x 18' 6" x 46' and weighed 527 short tons. It required the work of 20 men for 15 months to hack it into pieces small enough for hoisting. The Minnesota mine was discovered by a line of pre-historic pits. In one of these was a 6-ton mass of copper, raised on skids, on top of which grew a hemlock tree having nearly 400 annual growth rings.

For many years, Michigan was one of the world's foremost copper producers. Although she no longer ranks first in the nation, the production of copper remains a significant activity. In 1956, about 123 million pounds (or about $49 million) were produced from 12 mines and two reclamation operations.

The geologic history dates back some 800 million years during a period when great lava flows spread over much of the region. Many of these flows were frothy in their upper layers as indicated by the gas vesicles (bubbles) that became voids when the lava solidified. Between flows, water and wind broke down the lavas into sand, pebbles, and cobbles that later became the layers of sandstones and conglomerates interbedded with the lavas. Altogether, there are some seven miles of these alternating rock layers piled one upon the other. How much of the record was lost by erosion may never be know. Then during a time referred to as the Killarney Revolution, a great fault (rupture) developed in this series of rock layers. Known as the Keweenaw Fault, it extends more or less continuously the entire length of the Keweenaw Peninsula from Lake Gogebic to Fort Wilkins. This disturbance probably provided the avenue of escape for very hot copper-bearing liquors which had been accumulating deep within the earth's crust. Working their way up, these mineralized solutions invaded all possible openings in the lavas, sandstones, and conglomerates. Upon cooling, copper was trapped in the old gas bubble voids (called amygdules, meaning almond-shaped) in the lavas. Copper was also deposited as veins in the cracks and fissures originating prior to the coming of the hydro-thermal solutions. Interstitial pore spaces and voids in the sandstones and conglomerates were filled with native copper, thus forming a sort of copper concrete. All these events took place over a period of some 250 million years and geologists refer to it as Keweenawan time.

FORT WILKINS AND BROCKWAY MOUNTAIN

The outflowing of the Keweenawan lavas must have produced a deep-seated cavity in the earth's crust between Ft. Wilkins and Isle Royale. As the roof of the cavity subsided, a great basin was formed in western Lake Superior. The more resistant edges of the layered conglomerates and traps then became cuestas during the long erosional period following the Killarney Revolution. Along the northern shores of the Keeweenaw Peninsula, these cuestas face southeasterly and the rock layers dip toward Isle Royale. Conversely, on Isle Royale the same beds form northwesterly facing cuestas and dip toward Keweenaw. This structure is readily apparent when viewed along the summit of Brockway Mountain as well as along the shore line stretch of Highway M-26. The angle of the dip increases from about 25° at Ft. Wilkins to about 70° south of Houghton.

Strewn along the shores of Ft. Wilkins State Park are many colorful pebbles that have weathered out of the old conglomerates and trap (lava). The red of the conglomerates is due principally to the presence of iron in the seas in which the weathered lava rubble accumulated. The greens and blues in the minerals denote oxides of copper. Although there are many different beautiful minerals found along Keweenaw shores, perhaps the most commonly sought after specimens are the world famous Lake Superior agates. The exact nature of their origin is not perfectly understood, but it is likely that they were formed some time after volcanic activity had ceased but while mineral-charged waters were still rising from far below the surface. Upon entering the trap rock, the ascending solutions deposited not only copper, but many other minerals of a non-metallic nature. Agates are composed essentially of chalcedony (a crypto-crystalline variety of silica, or quartz) and were most commonly formed in the gas bubble voids. The variety of shapes and colors of the concentric bands suggests that it often required several successive invasions of fluids to fill the cavity and complete their growth. Occasionally, there is a central cavity lined with minute quartz crystals - a geode within an agate.

Ever since their formation the uppermost beds of lava have been subjected to erosive forces at the surface. The agates, on the other hand, are a much more durable substance and not so adversely affected by weathering. Thus, slowly, the trap rock is forced to release its store of semi-precious minerals. Conditions along shore lines are particularly favorable for accumulation.

JACOBSVILLE SANDSTONE

Along the north shore of Portage Entry on Keweenaw Bay (Houghton County) is the little village of Jacobsville. It is famous for the colorful white-streaked and - splotched red and brown Cambrian sandstones once quarried here and shipped to many parts of the globe. The first quarry was opened up in 1882 and was the result of work developed by George Craig who sold out to J. H. Jacobs (whence the name) in 1884. At the height of operations 800 men were employed. By 1897, demand had lightened due to the development of cement production. Cost of quarrying and transporting finally ended the operation by about 1920.

Here is a partial list of localities where this redstone and brownstone

has been utilized in buildings: Buffalo, Chicago, New York (Waldorf-Astoria), Detroit (Dodge Mansion in Grosse Pointe, Hammond Building, Masonic Temple), New Orleans (First National Bank, et al), Liverpool, England (McKenzie Bank), Memphis, Omaha, St. Louis. Of course, in the Northern Peninsula, the cities of Hancock, Calumet, Marquette and elsewhere, Jacobsville sandstone buildings are everywhere evident.

(For further details, confer with the Daily Mining Gazette, Houghton).

BARAGA

Baraga State Park is on a bench or flat shore made when Keweenaw Bay covered over the flat land upon which the park has been built. The cliff at the edge of the park area was cut by the high waters of the immediate ancestor of Lake Superior--Lake Nipissing-- the great lake which immediately succeeded the withdrawal of the glacial ice from the Great Lakes region. The underlying rock is Jacobsville sandstone--beautifully exposed in the highway cut near St. Joseph's orphanage and also in the highway cut bordering Keweenaw Bay.

About 14 miles due east of Baraga is the highest elevation yet known for Michigan. It is somewhat in excess of 1980 MSL. About 10 miles southeast of Baraga, near the village of Summit, is one of the highest lakes in the state - Little Summit Lake is about 1700 MSL.

LAKE MICHIGAMME

Lake Michigamme is 1,554 MSL. Spruce Lake, 3 miles southwest, is at about 1,708 MSL, placing it among the very highest in the state. In fact the highest known elevations in the state are found in a large area straddling the middle part of the Baraga-Marquette county line. Also, in a small patch in southeastern Baraga County. In these localities the terrain is often above 1,800 MSL and in some cases almost 2,000 MSL.

Rounded granite knobs in the vicinity indicate glacial action. Lake Michigamme basin was carved in the trough of the iron formations. The many islands are rock masses that have resisted erosion.

The Michigamme slates, containing garnets, outcrop north of the lake. At Alberta is an old graphite pit.

MARQUETTE IRON RANGE

Summary of Geologic History

The iron-bearing rocks of the Marquette Iron Range belong to a geological period of time known as the Huronian, which began about 1 billion years ago and lasted approximately 1/4 billion years. Before Huronian time this was an area of very ancient, igneous and metamorphic rocks, part of the Canadian Shield, the core of the North American continent. Huronian time began with the invasion of a shallow marine sea over what is now the Lake Superior region. Mechanical and chemical weathering of the bordering granitic land mass produced sediments which were washed into the sea by early rivers. Deposits of sand, mud and lime were built up on the floor of the sea and over these a thick mass of iron-rich sediments accumulated, which may have been precipitated chemically and/or by the work of bacteria, or perhaps other means. Later other deposits of mud and even volcanic material covered the iron bearing sediments. These sediments gradually became compacted by the weight of the overlying materials and cemented so that the sand became sandstone; the mud, shale; the lime, limestone or dolomite; and the iron-rich sediments, iron formation. Huronian time ended with a period of earth movement during which the Huronian rocks were intensely folded and crumpled. The earth movements exerted great pressure on the rocks and, along with the resulting heat, changed (metamorphosed) the sedimentary rocks. The sandstone was altered to quartzite; the limestone or dolomite to crystalline limestone or dolomite; the shale to slate.

Following this period of mountain building, there was a long period of time of approximately 1/4 billion years during which the rocks were eroded. The hills or mountains which were created by the folding gradually were worn down, so that eventually all the Huronian rocks that were left in the Marquette district were in the down folds, or troughs. In the western part of the Northern Peninsula, especially in the Keweenaw Peninsula region, there was a great deal of volcanic activity during this period and thick deposits of lava were deposited. In the Marquette area, however, igneous activity was limited to the intrusion of dikes and sills into the Huronian rocks. Also groundwaters were active in the iron formations, dissolving chert from these areas and oxidizing the iron carbonate to iron oxide. This resulted in the formation of the rich ore deposits which are being mined today.

About 500 million years ago the area was invaded by another sea, the Cambrian. This sea received coarse sandy sediments from streams draining the surrounding highlands. The sand was deposited against and over much of the Huronian rocks.

Chocolay Quarry

Southeast of Marquette, along US-41 and 1 mile eastward from the Marquette Conservation Headquarters, the east end of the Marquette Trough or syncline can be seen in the Chocolay Quarry. The Marquette Trough extends from Marquette westward beyond Michigamme, in Baraga County, and in it the Huronian rocks have been protected from erosion. These Huronian rocks, with the contained iron formation, form the Marquette Iron Range. At the southern end of the Chocolay Quarry, the old pre-Huronian rocks can be seen. These consist, for the most part, of chloritic schists and represent some of the old land mass which existed before Huronian time. Lying on this rock and dipping steeply to the north is a series of quartzites, dolomites and slates and to the northwest the same rocks can be seen dipping steeply to the south. These are the Huronian rocks which have been folded down into the Marquette Trough. Almost

vertical dikes of igneous rock which have cut through the Huronian rocks can also be seen in the quarry. None of the Huronian iron-formation is found in the Chocolay Quarry. The trough here is too shallow to have protected these rocks from erosion; hence, they have been removed. However, if we go westward to the vicinity of Negaunee, where the trough is deeper, we find the iron formation beds above the same rocks which are exposed in this quarry.

Exposures near Conservation Headquarters

About .9 mile northwest of the Chocolay Quarry, just a short distance east of Conservation Headquarters, along the shore of Lake Superior, is an outcrop of the same quartzite seen in the Chocolay Quarry. Here the rock is steeply dipping to the south, indicating that we are on the north limb of the Marquette Trough. Certain of these beds have very distinct ripple marks, formed in the sand on the bottom of the Huronian sea approximately a billion years ago. Since that time the sand has been changed to sandstone; the sandstone to quartzite; and the quartzite has been folded from horizontal to almost vertical.

But that is only part of the story told by this outcrop. Lapping up against the quartzite at the lake shore is a reddish, coarse-grained sandstone lying almost horizontal. This is the Cambrian sandstone. Approximately 500 million years ago this was the shore of the Cambrian sea. That sea beat upon the Huronian quartzite and broke fragments off and the resulting sand grains were incorporated with the sediments from other rocks in the area to form the sand on the bottom of the Cambrian sea. This material eventually hardened into the rock we refer to now as the Cambrian sandstone. Today the waters of Lake Superior are eroding both the Huronian quartzite and the Cambrian sandstone at this spot, and the resulting material is forming a portion of the sediment on the bottom of Lake Superior. Here then, is an example of how through hundreds of millions of years Nature has been busy tearing apart some old land and using the pieces (sediments) to build up new lands.

Jasper Hill

Located in the eastern part of Ishpeming, a view from its summit commands the greater part of the Marquette Range. The beautiful jaspilite formation shows the effect of intense folding and matamorphism.

Old Jackson Iron Mine

On the northeast edge of Negaunee is a series of large pits, some of which were started as far back as 1847. These comprise the workings of the old Jackson Mining Company, organized July 23, 1845 by Philo Everett. The rock seen in the walls of the pits is the iron formation. That part of the iron formation which had an iron content high enough to be classed as iron ore has been mined out. Some of the rock which overlies the iron formation can be found in the upper part of the walls of the pit, but the outcrops in the area to the west afford better study. The stone monument at this locality is made up of many of the types of rock found on the Marquette Range and marks the spot where the first iron ore was reported to have been found in Michigan in September, 1844 by the Burt survey party.

Production

Until 1877 the Marquette Range was the only iron producing district in the Lake Superior region. Before 1880, the iron mines were all open pits, but beginning in that year underground mining by means of shafts from surface came into being. The first shipment of iron ore was 5 tons from the Jackson location to Newcastle, Pennsylvania, in 1850. Production of iron ore during the early years was small, less than 1,000 tons per year until 1855 when the canal around the rapids of the St. Marys River at the Soo was completed. In 1855, 1,449 tons were shipped from the Cleveland location and thereafter shipments increased, gradually, until by 1873 more than a million tons of ore were shipped. Total shipments of iron ore from the Marquette Range to date have been almost 300 million tons or about 3/8 of the total produced in Michigan.

At present there are 11 underground and 5 open pit mines active on the Marquette Range. In addition, 3 plants are processing low-grade jaspilite into a product superior to the direct-shipping ore of the underground mines. In 1955 the mines of the Marquette Range accounted for $6\frac{1}{2}$ million tons of the more than 14 million tons of iron ore shipped from Michigan.

IRON ORE BENEFCIATION PLANTS

These plants provide an excellent example of conservation principles applied to non-renewable resources, because here vast stores of low-grade materials are being exploited. They were by-passed formerly because they contained only 25 to 35 per cent iron as compared to the 50-55 per cent content of the rich deposits. But several years ago (especially during World War II), the iron producers became concerned about the imminent depletion of the rich ores in the Lake Superior region. Consequently efforts were redoubled in the search for a method of profitably mining the low grade jaspilites. A way was found, and today we find three of these beneficiation plants in operation producing a concentrate (60 per cent iron) which exceeds the best raw iron ores in the Lake Superior region. It is a costly method, but it opens up a new reserve equivalent to the total amount of ore which this region has already produced in the last 100 years. This estimate is very conservative because it includes known jaspilite deposits only to a depth of 100 feet below the surface. It is only the start as far as realizing the full utilization of our iron ore resources--and it will insure a favorable competitive position for us when the full effect of high grade foreign ores materializes. It should be noted, too, that in addition to being extremely important to Michigan economy, beneficiation reduces shipping costs by providing an ore of higher concentration and also by eliminating the unwanted moisture content. Furthermore, the smelter operators benefit because it allows larger and more uniform charges to be placed in the blast furnaces. All this bears out the necessity of fostering research and development in an age in which the demand for so-called exhaustible resources seems to be insatiable.

The purpose of beneficiation is the removal of as much of the silica (average content is about 40 per cent SiO_2) as possible from the raw jaspilite ore. A series of crushers reduces the ore to finger tip size. It is then introduced into large rotating cylinders containing iron balls (hence, called ball Mills) where the ore is pulverized. Also a secret reagent is added. The

materials are removed to a settling tank where the fines are removed and the coarse is recirculated through the ball mills. The next step is the flotation tank in which a froth is formed by adding air. The iron particles have an affinity for the oil which rises and froths up on the surface. The iron is then skimmed off the surface thus completing the mechanical separation from the unwanted silica. After drying, this very fine concentrate (No. 35 mesh) is then formed (pelletized) into small balls about $\frac{1}{2}$ inch in diameter. This is the final state in which the beneficiated ore is stockpiled and shipped.

MATHER A and B MINES

These two mines are owned and operated by the Cleveland Cliffs Iron Co. An underground connection probably makes this among the largest mines in the world. Depth is about 3,000 feet. First ore shipped from the "A" was in 1945, the "B" in 1951.

TOURIST PARK, CITY of MARQUETTE

At the water's edge of the Dead River is a most interesting outcrop of bedrock. Mineralogically this is a chlorite schist which probalby has been metamorphosed from lava -call it a greenstone. The geological age of this formation is Keewatin, the most ancient of all the rocks found in Michigan (or perhaps all of North America !). Note the manner in which this object has been sculptured, scratched, and polished by glacial ice loaded with "carving tools". The oldest grooves and furrows indicate ice movement from a northerly direction. There are two other younger sets of markings oriented about 30° west and 30° east of north. This might be classified as a "roches moutonnees" (see discussion for Menominee County drumlins).

SUGAR LOAF MOUNTAIN (West of Marquette)

This is one of the many knobs of Laurentian granites that intruded the old Keewatin rocks prior to the coming of the iron formations. During the eons of time, erosion has removed the Keewatin rocks thus baring the Laurentian granites. These granite knobs, too, have been reduced by erosion. Sugar loaf stand at 1,079 MSL (Lake Superior is 602 MSL). Hogback Mountain, about $1\frac{1}{2}$ miles due west is 1,237 MSL. Partridge Island, 2 miles east is somewhat over 800 MSL.

HURON MOUNTAINS

The Laurentian granites comprise most of the peaks and knobs in the Huron Mountains. Their geologic explanation is the same as that given for Sugar Loaf Mountain above. If you have the opportunity of climbing Mount Ives (1,340+ MSL), you will readily understand why many folks claim that here is the most beautiful mountain scenery in Michigan. Ives Hill, about 1 mile southeast is about 1,540 MSL. Ives Lake (760 MSL) is drained in the northeast by the River Styx which drops 150 feet in a series of cascades over a distance of about $\frac{1}{2}$ mile before reaching Pine Lake. This outlet was blasted out for a sluiceway during the former lumbering era.

ALGER FALLS

PICTURED ROCKS

The Pictured Rocks are mostly sandstones that were deposited in Cambrian seas some 350 million years ago. These rocks can be traced along the fringe of the south shore of Lake Superior from the Keweenaw Peninsula east into Ontario.

In June, 1840 a field party of the Michigan Geological Survey visited the Pictured Rocks. Douglass Houghton, Michigan's first State Geologist, led the expedition. Among those accompanying him was his able assistant, Bela Hubbard - known to the Indians as Mus-co-me-in-gun (red beard). Bela Hubbard had a remarkable faculty for preparing literary field notes and sketches, and his description of the Pictured Rocks merits your reading. The following is transcribed from one of his notebooks:

> June 13 - 1840 -
>
> "Got under way at four this morning and ran in to breakfast at a small cove just beyond the rock known as LaChappelle.
>
> "The coast has consisted of rock for about 2 miles rising from 30 to 100 feet and forming a perfect mural precipice without so much as a beach on which anything larger than a canoe could be drawn up. The rock is sandstone in layers or partitions of various degrees of hardness from a coarse conglomerate of the hardest cemented pebbles to a very friable rock of aggregated sand. These layers are from 2 to 10 or more feet in thickness. The main color of the rock is a gray, sometimes light and sometimes dark and rusty and charged with the oxides of iron and copper. Bearing in mind this peculiar character of the rock, the variety of aspects and curious forms it assumes find ready explanation.
>
> "For instance, the great variety of hues which gives so beautiful and variegated a character to many of the rock strata

are due to the iron and copper which water has filtered from so porous a stone and left in stains upon its surface. We saw, however, nothing of those representations of various forms in the animal and vegetable kingdom which appear in the highly colored descriptions on the printed page. The colors are indeed brilliant, but as it regards the laying on they convey more nearly the similitude of a house painter's bucket on the outside of which colors of all hues have trickled down and dried in narrow tapering streams. It represents not the picture which Nature has drawn so much as the pallette on which she has cleaned her brushes. Red, green, yellow, blue, orange - in fact all the colors of the rainbow, besides white and black, and in every shade of hue and in every possible alternation are penciled in long lines covering surface of hundreds of feet, the great brilliancy, extent, and variety of these hues thus strangely drawn upon as strange a canvas add a wonderful beauty and effect to the still greater wonders which Nature has here displayed.

"The disintegrating material of which the rock is composed renders it easily susceptible to the effects of the elements and its surface presents evidence indisputable that the lake once washed the cliffs at a height at least 200 feet above its present level. Thus as the strata are of different degree of hardness they are worn into a variety of shapes. Huge cavernous fissures penetrate the solid wall, often to a distance of several hundred feet; pierce through its projecting battlements, leaving the solid mountain supported on bare pillars. These are rounded into the form of columns with arches springing from them, sometimes as at the LePortaille to the height of near a hundred feet.

"Entering this huge vestibule, echo sends back our voices in loud sounds and the discharge of a musket produces a roar like a clap of thunder.

"At LaPortaille are two of these entrances on two of the faces of the lofty cliff which here juts out from the main wall. These gradually narrow down to bare passages which meet and connect entirely through the projecting mass, a distance of about 500 feet.

"The number and perfection of the pillars which seem to give support to the immense mass of stone above them and the various forms of the arches which spring from them bear a resemblance to the orders of architecture so close that design could scarcely have aided the illusion. These pillars are almost uniformly perfectly rounded and at the tops swell out into capitals.

"The huge mass of stone above them having a thickness often of more than a hundred feet, often assumes characteristic forms corresponding to the mock design. For nearly half a mile in one place it resembles one huge entablature in which the cornice jutting out for at least 20 feet and with a graceful curve not exceeded by the best sculpture of antiquity, the pictured frieze, metopes, mouldings, medallions, and other of

those forms which appertain to Grecian architecture are struck out as with the master hand of a giant in magnificant perfection and a freshness which time has not impaired.

"Portions of the structure are occasionally found tumbled down and lying at the foot in heaps of ruins. Thus the cornice will be found broken off suddenly and even the imperfections which exist in many parts of the architecture seem only as if occasioned by the gradual work of decay. So complete is this illusion that it required but little stretch of imagination to view the whole as a portion of some enormous structure, the main body of which has sunk or become engulfed in the waters, leaving only the entablature and the capitals of the supporting pillars above the waves, or as if the lava of Vesuvius had suddenly whelmed it in her liquid ocean. But such a temple as this could enclose half of Pompeii.

"Can it be that a wonder like this was exhibited by any of the rocks of that distant era from which the ancient sculptors borrowed many of the designs which adorn the Parthenon or the Coloseum? And if, as some of the learned suppose, the marble structures of those times received the addition of a paint of glowing colors of which time has now left scarcely a trace we here view the prototype not only of the beautiful forms on which they labored so assiduously but the gilded colorings in the beauty of their original freshness.

"These, however, are but single features in this grand scenic display.

"Passing on to harder portions of the rocks the next angle in the cliff may present to view a vertical and unbroken wall from the water's edge to the very top, its thick layers causing it to seem as if laid in massive blocks 12 feet in width and a hundred feet in length; such stones as the Pyramids were reared with. Had the Pharaohs lived here they could have wished no more magnificent mausoleums.

"At the angle of one of these vertical walls where it is joined by the next abutment, the natural seams aided by the waves have worn a deep fissure having the appearance of an entrance into the interior to which in fact it does extend for a great distance. This opening though perhaps 20 feet in height may be likened to a small portal in the rear of some vast prison house.

"Still proceeding, again you are met with some characteristic change. You are before the walls of some impregnable fortress with its towers and bastions all complete.

"Amid these characteristic forms of rock none is more extraordinary than that which is with much reason styled by the voyageurs "LeChapelle," though owing to its comparatively inferior dimensions it is not invested with equal grandeur. This rock was originally a portion of a solid mass which had been carried away leaving a valley three-fourths of a mile in breadth through which a considerable stream enters the lake,

falling in a sheet of foam over a cliff of 20 feet. Close by, conspicuous upon this cliff, stands what is now known as LaChappelle. It consists of pillars of stone supported by a single uniform arch a flat tabular mass of the same and has a height above the lake of 56 feet. The pillars have somewhat irregular position but are handsomely rounded from 4 to 6 feet diameter in the swell and in front together with their being some 25 feet in height. Two only uphold the front. The character of columns is not altogether preserved. The arch springs to a height of 30 feet giving a 5 or 6 foot thickness to the roof at the center. The span of the arch, as visible from the water is 32 feet from which direction the spectator looks completely through the arched temple into the woodland beyond. The strength of the roof must be immense for its top is clothed with timber and from the very center springs up a tall pine three feet in diameter at the base and at least 80 feet in height.

"This solemn chapel might hold a far greater congregation of civilized beings than are to be found on the whole shores of Lake Superior. Nor would the usual accommodations be wanting for the preacher. A broken column of which the upper half is removed, projects from a recess in the walls of the edifice and has been worn from behind in the form of one of the curves of the letter 8, thus creating a stand which would serve the purpose while it closely resembles a pulpit to which the base forms ascending steps.

"On the cliff without the chapel stands a similar column worn into an urn form and which well represents the baptismal font.

"Similar projections of rock occur at other places and of a height not less than 50 feet.

"Near the west extremity of this range of cliffs the colors are drawn with exceeding brilliancy and have an almost metallic lustre. They have sometimes a background of white, sometimes of yellow. Streaming down over a curved surface they resemble the stripes on a flag as it waves to the breeze or passing down a fractured ledge are contorted into long zig-zag lines. On examination these brilliant hues are found to be produced by shiny oxides which are mostly surface colors so that when the face of the cliff has become dry it presents a less bright and somewhat mottled appearance. Here may be found depicted as if rudely dabbed in by the artist vague pictures in which the imagination may realize verdant landscapes or fierce battle scenes and perhaps even a full set of Raphael's cartoons. As a whole, nevertheless, the general effect of the coloring is so striking, the arrangement has been managed with such a degree of skill, that the appellation of Pictured Rocks is far from ill deserved.

"The whole extent of this range of cliffs is about 15 miles within which distance there is scarcely a harbor for a canoe. During storms the waves must dash with terrific fury against these stern ramparts and woe betide the bark that is then exposed before their savage front.

The surface of these cliffs throughout their whole extent is free from moss or anything of vegetable origin so that except where stained by the coloring matter there is little to conceal the true character of the material of which they are composed.

Tills of water leap from the heights and add picturesquely to the view.

Taken as a whole, a more magnificent display cannot be found in the whole range of the wild and varied scenery of our country."

TAHQUAMENON

Most of the waterfalls of Luce, Alger, and eastern Marquette counties came into being because of certain basic geologic conditions. Beneath the drift are the relatively soft (friable) Cambrian sandstones, the earliest rocks (about 500 million years ago) deposited in the Michigan Basin, overlain by harder Ordovician (Hermansville formation) dolomitic sandstones. These beds dip gently southward and the streams flowing northward to Lake Superior must run across the angle of dip. Streams cut headward (southerly) in the weak Cambrian sandstones to a point where they encounter the harder dolomite. Upon reaching this contact between two rock layers of differential hardness, undercutting continues to proceed in the soft lower bed beneath the upper sill of resistant rock. This accounts for the origin of most of the waterfalls of the eastern Northern Peninsula.

Near the close of glacial times, when the ice front covered eastern Luce County, meltwater flowed southward through the Manistique valley to Lake Michigan. As the glacier retreated northward to Lake Superior, the existing cuesta of Cambrian sandstone was uncovered, and headwaters of the Manistique were diverted eastward to become the Tahquamenon River. Thus developed the largest waterfalls between Niagara and the Rocky Mountains, Big Tahquamenon Falls. Actually the hard Hermansville dolomite is found about 1 mile upstream from the big falls, and in time, will become the site of the principal waterfall.

The Tahquamenon River rises in a small group of lakes in western Luce County about 14 miles south of Lake Superior. It flows gently in an easterly direction for some 50 miles through rather broad flat marshy areas until reaching the vicinity of the Mackinac County line. Then it begins to pick up speed before dropping precipitously 40 feet over the Cambrian sandstone cuesta in Luce County. Below the main falls, the river has cut a gorge in the sandstone, the walls rising 80 to 100 feet. The width varies but is about 200 feet at the falls. Except for two rapids the river flows rather smoothly downstream for about 5 miles. Then it cascades over a series of small ledges of Cambrian sandstone. These are the Lower Falls. An island of sandstone is situated in the river here and this has created twin falls. The main drop on either side of the island is about 13 feet. Both above and below this drop are rapids accounting for an additional descent of 10 to 13 feet. Although the total drop is but 25 feet, some people contend that, scenically, the Lower Falls surpass their big brother upstream. Beyond the Lower Falls, the river resumes its more leisurely flow to Whitefish Bay.

GRAND SABLE BANKS

The Grand Sable Banks lie to the west of the Grand Sable Dunes. The western limit of the dunes is in Section 7, T 49 N, R 14 W. Continuing westward for about 1 mile are the very steep banks which are about 875 MSL (Lake Superior is 602 MSL). It is thought that the banks are merely a continuation of the bay-mouth bar developed along the Grand Sable area during glacial Lake Nipissing. On top of the banks is a sandy, wind-swept plain. Perhaps the dunes were perched on this site, later moving eastward with the prevailing winds.

GRAND SABLE DUNES

The Grand Sable Dunes are the largest mass of dunes in the Northern Peninsula. Situated west of Grand Marais, they occupy an area of about 5 square miles. Their geologic history dates back only a few thousand years ago during the times of glacial Lakes Algonquin and Nipissing. During Lake Algonquin the waters washed against the north flank of the Munising Moraine south of Grand Marais and left wave-cut cliffs and terraces as evidence of former shore lines. Then during an early stage of Lake Nipissing (about 40 feet lower) waves built a sandy bar across a bay between Sable Point and Grand Marais. This impounded the old Sable River and created a large lagoon. The present Sable Lake is all that remains of that lagoon.

When Nipissing waters began to recede below the level of the bay-mouth bar, the winds sweeping landward from across Lake Nipissing, and later Lake Superior, took over the bar sands and piled them into immense dunes. Now the dunes are gradually encroaching upon Sable Lake. The highest elevation of the dunes is about 980 feet MSL (about 380 feet above Lake Superior) and they are perched on the old Lake Nipissing bar which lies about 275 feet above Lake Superior at the present time. Actually, Lake Nipissing was only about 20 feet higher than the present Lake Superior, but ever since the retreat of the ice, this entire northern Great Lakes area has been steadily rebounding from a compressed state at the rate of about 1/2 foot a century.

SABLE FALLS (Section 2, T 49 N, R 14 W)

Sable Creek cascades over about 75 feet of alternating hard and soft layers of Cambrian sandstones, blue shale and conglomerate before entering Lake Superior. The softer layers erode more readily leaving a step-like structure.

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Houghton Agate Shop, Franklin Street, Houghton, Michigan
Ishpeming Rock and Mineral Club, 107 Ridge Rd., Ishpeming
Museum, Ft. Wilkins State Park, Copper Harbor, Michigan
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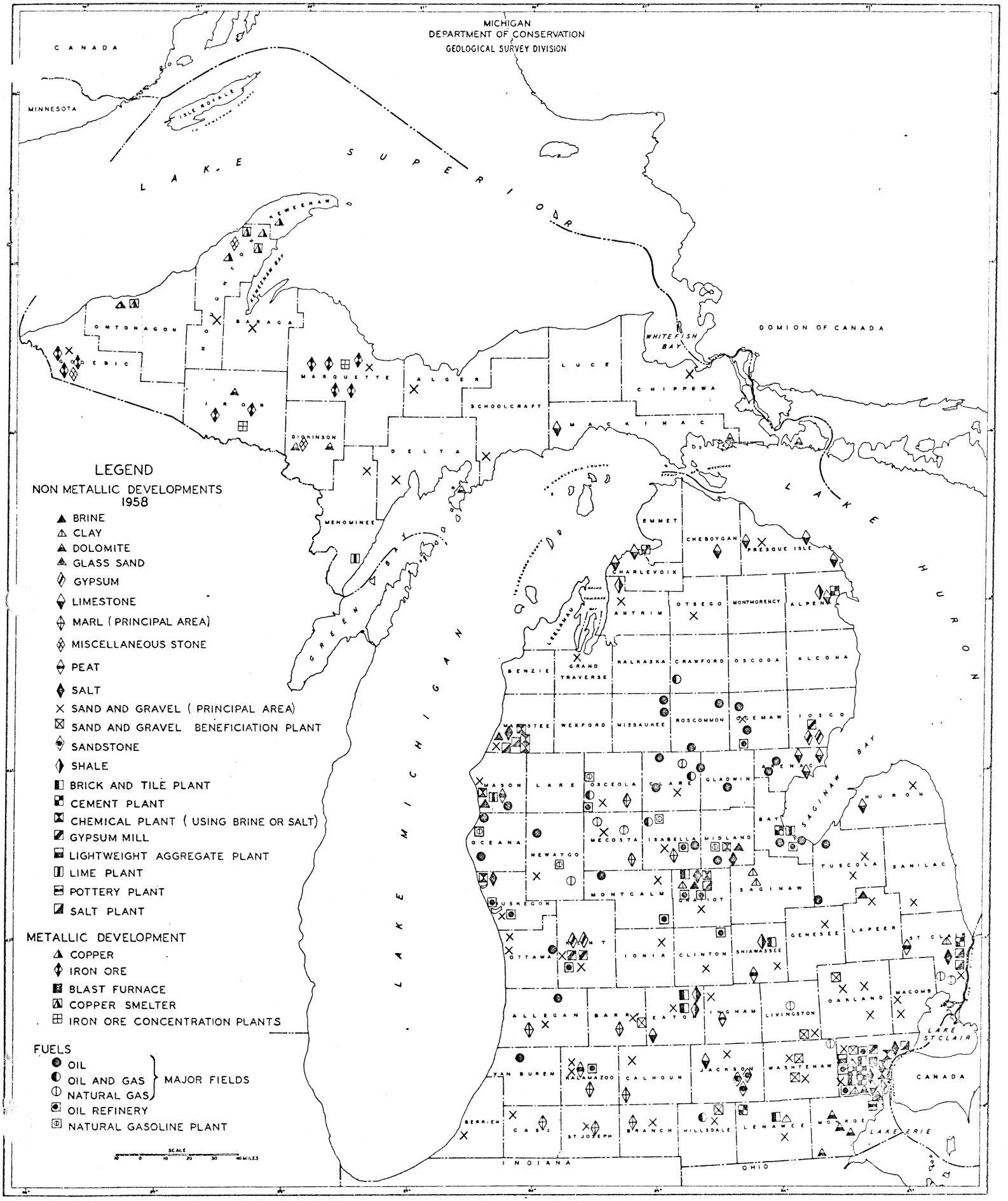
MICHIGAN
DEPARTMENT OF CONSERVATION
GEOLOGICAL SURVEY DIVISION
CANADA
MINNESOTA
ISLE ROYALE
LAKE SUPERIOR
DOMION OF CANADA
WHITEFISH BAY
ONTONAGON
GOGEBIC
BARAGA
MARQUETTE
ALGER
LUCE
CHIPPEWA
SCHOOLCRAFT
MACKINAC
DICKINSON
DELTA
MENOMINEE
GREEN BAY
LAKE MICHIGAN
LAKE HURON
SAGINAW BAY
EMMET
CHEBOYGAN
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OSCEOLA
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MONTCALM
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GENESEE
LAPEER
ST CLAIR
ALLEGAN
BARRY
EATON
INGHAM
LIVINGSTON
OAKLAND
MACOMB
LAKE ST CLAIR
VAN BUREN
KALAMAZOO
CALHOUN
JACKSON
WASHTENAW
CANADA
BERRIEN
CASS
ST JOSEPH
BRANCH
HILLSDALE
LENAWEE
MONROE
LAKE ERIE
INDIANA
OHIO
LEGEND
NON METALLIC DEVELOPMENTS
1958
BRINE
CLAY
DOLOMITE
GLASS SAND
GYPSUM
LIMESTONE
MARL (PRINCIPAL AREA)
MISCELLANEOUS STONE
PEAT
SALT
SAND AND GRAVEL (PRINCIPAL AREA)
SAND AND GRAVEL BENEFICIATION PLANT
SANDSTONE
SHALE
BRICK AND TILE PLANT
CEMENT PLANT
CHEMICAL PLANT (USING BRINE OR SALT)
GYPSUM MILL
LIGHTWEIGHT AGGREGATE PLANT
LIME PLANT
POTTERY PLANT
SALT PLANT
METALLIC DEVELOPMENT
COPPER
IRON ORE
BLAST FURNACE
COPPER SMELTER
IRON ORE CONCENTRATION PLANTS
FUELS
OIL
OIL AND GAS
NATURAL GAS
MAJOR FIELDS
OIL REFINERY
NATURAL GASOLINE PLANT
SCALE
40 MILES