GEOLOGIC HISTORY OF MICHIGAN
and
GUIDE TO GLACIAL GEOLOGY
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FOREWARD

The writer takes credit for nothing original in the following writing; knowing that the accumulated facts and information were inherited from others through associations or writings.

It is inspiring to know that many associated with road construction are not only interested in the soils with which they work but are intensely inquisitive in the geological background for these same soils.

Numerous requests into this relationship between Michigan soils and geology from the writer's associates have prompted this paper.

The questions range as follows:

X. CORAL REEFS - OUTCROPS

A. Locations - Petoskey, Alpena, Long Lake, Grand Lake.
B. Cement Plants - Petoskey and Alpena.

XI. PLEISTOCENE GLACIATION - GEOMETRIC SCUPTURING OF STATE, Fig. 13, 14 & 15.

A. Keewatin-Labrador - continental ice sheet. Page 33
B. Local Ice Lobes - Erie, Huron, Saginaw, Michigan and Superior.
C. Land Forms.

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2. Ground moraines or till plains. Page 36
3. Glacial discharge rivers.
4. Outwash plains - South Boardman to Elmira, Page 37,39, Inter-lobiate area - Oxford-Drayton Plains, 39, Manistee East, Baldwin North, South and West.
5. Valley trains, Braided river valleys-between Defiance and Fort Wayne Moraine-Northville North and South, Page 37,39.
6. River terraces.
7. Kames-Lachine, M-72 Rapid City to Barker Creek, 40,41.
8. Eskars, Jackson to Lansing, Page 41.
9. Drumlins, Antrim-Charlevoix-Leelanau and Cheboygan Counties. Also Soo South-floating in 65' of lacustrian clay of Post Glacial Lake Algonquin. Page 42.
10. Glacial and Post Glacial Lake beds and plains. Page 43.
11. Beach Ridges-Shorelines South of Charlevoix on US-31. 43, 44.
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13. Ice ramps, Page 44.
14. Cliff cut shorelines, Nipissing and Algonquin Old Mission Penninsula, West Shore of West Bay - Traverse City North to Suttons Bay - Petoskey. Page 45.
15. Continental uplift - Hinge line. Pages 46, 48, 52, 57 and 60.
16. Sand Dunes - All along East shore of Lake Michigan and East Shore of Saginaw Bay-Southwest of Pte. Aux. Barques, North of Ludington, North of Manistee, Glen Arbor, Petoskey. Also in thumb East of Pte Aux Barques. Page 47.

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   a. Fort Wayne Outlet, Fig. 16.
   b. Brown City Outlet, Fig 17.
   c. Imlay City Outlet-Lake Kersley, Pine and Maple Rivers Page 54, 55 and 56. Fig. 17.
2. Lake Arkona and Lake Saginaw. Page 58, Fig. 18.
   a. Grand River Outlet. Page 49, Fig. 17.
3. Lake Whittlesey and Ubly Outlet, Port Huron River Estuary and Cass River and Grand River Outlet, Page 49, 58, Fig. 17.
4. Lake Wayne, Page 59.
   a. Syracuse - Mohawk - Hudson.
5. Lake Warren, Page 59, Fig. 20.
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8. Lake Toleston, Lake Algonquin, and Lake Duluth/AuTrain-Whitefish channel.
    a. First stage of Lake Algonquin.
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    b. Second stage.
        1. Kirkfield Outlet, Georgian Bay - Kirkfield-Trent Valley - Lake Iroquois.
        2. Three outlets: Kirkfield, Port Huron and Chicago, 56,60 & Fig. 23
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    c. Autrain - Au Train River - White Fish River - Rapid River, Fig. 22.

XII. Radio-Carbon-Dating, Page 60.

The writer will try to explain the above within the limits of his ability to do so. Notes relative to central statements will follow them and be slightly indented. The writer has also interposed various notes not directly associated with Geology. eg. Ores, steel furnaces, transmutation of elements such as occures in atomic Fission and Fusion, table of atomic numbers, hydrocarbon series etc. These can be simply ignored if found un-interesting.

EARTH - ARCHEAN PERIOD

THICKNESS: First of all let us study this earth as a sphere approximately 8,000 miles in diameter and 25,000 miles in circumference.

We think of our earth as being quite stable and solid. This is not true. Actually, we are living upon a paper thin sheet of rock over a blast furnace, or upon a huge skillet.

Occasionally this thin surface is torn allowing molten rock to ooze up through the cracks. It is no wonder that natives in lands frequented by volcanic action believe Hell to be in the center of the earth.

This thin, cooled, solidified surface insulates us against the hot fluid interior. This surface is 3.5 miles thick beneath oceans and some 30 miles thick on the continents.

The increased skin thickness on the continents is due to successive volcanic eruptions (extrusions of compressed molten or igneous rock from the interior). The extrusions pour out of the ruptured surface and pile up heavy masses of rock upon the surrounding area, which cool and solidify upon exposure to the atmosphere.

The newly built up extrusive rock is similar to a surcharge used in constructing a road grade through a peat marsh. The great weight of the concentrated surcharge eventually builds up to an unbalanced and unstable condition which results in the downward movement or sinking in of the general area.

When the surcharge reaches a height of 5.5 miles above the surface of the earth, the area begins to settle. This seems to be the greatest height of mountain mass that can be floated above the sea level before an unstable condition arises.

After many successive volcanic eruptions and the accompanying sinking-in operations, a 30 mile thickness of solids is formed.

> This thickness can be checked very easily. The heat gradient in the earth raises at the rate of one degree fahrenheit for every additional 60 feet depth as you descend into the earth. (For example)

$$\frac{30 \text{ miles} \times 5{,}280 \text{ ft.}}{60 \text{ ft.}} = 2640^{\circ} \text{ F.}$$

FUSION AND BOILING POINTS OF MATERIALS

Note: This note is introduced to establish within the reader's mind that most metals and earthly minerals and man made rocky substances fuse or melt between 2500°-F and 3000°-F.

The following are the melting or fusion points and the boiling or vaporizing points of some common rock minerals, metals (elements) and man-made earthly products.

Volcanic rocks of granite and basalt melt at between 1800°-F and 2700°-F.

Portland cement consists of a filler and anhydrous calcium silicates and fuses to a clinker at 2700°-F. Calcium sulphate (Gypsum) is added and the whole mass is ground to a fineness of a 360 screen.

Fire brick of refractory brick consists of hydrated aluminum silicates $(Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O)$ plus minerals of high aluminum oxide content (Bauxite, Diaspore and Kyanite) plus sources of silica (sand and quartzite) plus chromite (chromic oxide) plus carbon and plus mica (Vermiculite).

This man-made earthy product is used to line kilns in the production of clinkers for portland cement and in lining open-hearth basins and bessemer converters in the cooking of ifon ore to make steel.

This product melts between 2768°-F and 3614°-F.

Glass is made by fusing sand (Silica) and limestone (C $ca_2 \cdot CO_3$) into calcium silicate. This product boils at between 2372°-F and 2912°-F.

Pure iron melts at 3004°-F. Iron with 5% of Ferric Carbide melts at 2440°-F.

METAL		ATOMIC NO.	MELTING POINT	BOILING POINT
Iron	Fe	26	2756°-F	4955°-F
Copper	Cu	29	1976	4703
Silver	Au	47	1760	3632
Gold	Aq	79	1950	4712
Lead	Pb	82	622	3164
Mercury	Hq	80	-40	675

The heated surface of the sun is 10,000° F., while a nose cone of an I.B.M. reaches a temperature of 15,000° F. through air pressure when re-entering our atmosphere at a velocity of 15,000 miles per hour.

Meteors entering our atmosphere acquire a temperature of 16,000° F.

These latter temperatures appear fantastic but become comprehensible and reasonable when we consider the volatile or boiling point of iron at 4955° F.; that calcium carbide is made in an electric furnace at 5400o F. Air heated by a flaming electric arc can reach 14,000° F., while agron gas can be heated to 17,500° F. by an electrical principal called magnetohydrodynamics.

Even common fuels can produce fair temperatures, e.g., wood fire 800° - 1100° F., charcoal fire 2200° F., coal fire 2400° F.

THICKNESS

Returning to the sphere, we note that the solid crust is only 30 miles in thickness or less than 1% of its radius.

$$\frac{30 \text{ miles (crust)} \times 100\%}{4000 \text{ miles (radius)}} - 0.75\%$$

The earth's shell compared to a two inch diameter apple would be less than the thickness of the apple skin.

It is no wonder that this thin skin occasionally becomes wrinkled and tears open allowing the extrusion of melted rock to form lines of mountains, such as the copper range (backbone of the Keewanaw Peninsula), the Rocky Mountains, Japan and the Aleutian Islands. If the cracks do not extend completely down to the molten rock, water will enter them forming periodic explosions and expulsions of water in the form of geysers and hot springs (Yellow Stone Park).

Note: One BTU (British Thermal Unit) is the amount of heat required to raise the temperature of one pound of water one degree fahrenheit. One BTU equals 778 foot-pounds of work. It takes 972 BTU's to convert one pound of water at 212° F. into steam at atmospheric pressure of 14.7 lbs./sq. in. This same volume of water expands explosively 1696 times into steam.

DENSITY

The density of this earth skin is approximately 180 pounds per cubic foot. This holds true for most sedimentary, metamorphic and igneous rocks. It is easy to see how this rock will float over the heavier 500 pounds per cubic foot densities for iron and nickel formations in the core of the sphere.

COMPOSITION

Igneous rock is formed from volcanic magmas in the form of intrusive and extrusive lava flows, e.g., granits, basalts.

Some sedimentary rock is formed from disintegrated igneous rocks. The minerals are sorted out, graded, transported by wind and water to a location where they are deposited in layers.

Other sedimentary rocks such as limestone is formed from the skeletons of small marine life such as uni-valves and bi-valves and snails. Their bond structures are ground up by water action and first form marl. Marl upon compression forms limestone.

Also limestone held in solution as calcium-bi-carbonate is precipitated as calcium carbonate (limestone) when acted upon by carbon-di-oxide. This action also forms marl.

Compression cements them into rock., e.g., limestone, shale, sandstone.

Metamorphic rock is igneous or sedimentary rock which has its structure altered through heat and pressure, e.g., gneiss, schist, marble, slate.

DENSITY

The earth's surface can now be compared to the flux of limestone and silica (slag) that floats upon the molten surface of iron in a steel mill furnace.

It is interesting at this point to compare the 5.5 mile mountains of this earth with the 9 mile high mountains on the moon. All indications are that these later mountains were formed when the moon's outer shell was relatively thick compared to its 2000 mile diameter, and could float higher mountains over its fluid core.

EXPANSION AND C[illegible]TRACTION

Eruptive, explosive, volcanic action is caused by the shrinking of the earth's crust through cooling action. The outer surface, as previously shown, has cooled about 2500° of fahrenheit and has contracted 70 feet per lineal mile of surface.

e.g. Expansion - contraction of granite - 1 part per 187,560 per 1 deg F.

$$\frac{5280 \text{ ft.} \times 2500^{\circ}}{187560} - 70 \text{ ft.}$$

This contraction amounts to about 1.3% and represents 330 miles in a 25,000 mile circumference around the world.

This shrinking action of the earth's skin compresses the interior fluid mass. The earth's crust can sustain compression in the amount of 175 tons pressure per square foot. However, its elasticity or capacity to stretch is practically zero. Therefore, when the exterior surface contracts, it splits open, and molten igneous magna (rock) flows up through the fractured surface creating volcanic cones (sometimes islands) and mountain ranges.

A reptured surface can be compared to a crack in the skull of a hard boiled egg; the extrusive rock to the white coagulated albumen issuing from the crack.

It is desired to establish in the above paragraphs: that the earth is a huge sphere whose core is molten iron and nickel (sp. gr. - 8) and whose solid crust is of volcanic rock (sp. gr. - 2.7); that the earth's crust is relatively very thin in comparison with the nucleus of iron, less than 1%; that the earth's skin continues to tighten and shrink accompanied by surface failures which result in faults, such as earthquakes, hot springs, geysers, volcanic islands, and mountain ranges (backbones of continents).

STABILITY

For those interested and worried about the present and future thermal picture and stability of this earth, the following short appendix is added at this time.

Notes: Even though the earth's crust is very thin and the core directly beneath it is molten, there is no danger that the surface will ever collapse and become submerged in the core. Because of its smaller density, it will always float above it.

However, this does not mean that there will be no more faults - earthquakes, volcanoes or volcanic flows. They will continue to occur infrequently. However, they are very insignificant in size when compared to the total area of this sphere. (Total area refers to both continents and ocean beds).

The earth has formed a solid crust which will continue to grow in thickness with age.

In this atomic age, the question often arises as to whether an atomic explosion could set off a chain reaction in the earth's rocks and minerals which would result in the sphere disintegrating. This is impossible for the following reasons:

Even though all mass constituting this sphere is emitting radiation, the radio-active material causing this is so infinitesimal and so finely dispersed that its concentrated effort is negligible.

Furthermore this particular energy is being dissipated at a regulated rate just like the precision beats of a pendulum on a clock - they can't be hurried up or slowed down except in the laboratory under special concentration and control.

The atom bomb is actually a newly formed laboratory element which is very unstable and when allowed to break down into more stable elements. Fission does so with the release of tremendous amounts of energy. Nuclear power plants in ships and electric power plants use this same atomic bomb to produce the heat energy. However, the release of energy from the atomic pile is controlled and is not spontaneous.

The "H" bomb is called a thermonuclear bomb and is a fusion bomb. It too is an unstable artifical or laboratory produced element which gives off tremendous amounts of heat energy when it breaks up. However, this element builds up into heavier elements during fusion where as the fission element breaks down into lighter elements. Fusion occurs all the time in stars such as our sun.

Now let us study pitchblende. This is the chief source of uranium, an ore in which radio active material is highly concentrated in contrast to the small amounts found in most all other materials.

This ore furnishes the nucleus for atomic bombs. In spite of its high concentration of radio active material, this ore could not be exploded or atomic chain reaction set off by an atomic bomb.

Furthermore, the amount of this ore is just a small fraction of the earth's mass. All the rest of the earth's mass is in a high state of stability and would require much more energy to break down their atomic structures than could be salvaged from energy released when new atomic structures are created, for example:

> Gold can be made from lead. However, it takes so much energy to remove the three electrons from lead in converting it to gold that the process is expensive. In an experiment it cost one million dollars to make one dollar's worth of gold from lead.

Now let us concentrate our attention upon Michigan

Michigan is unique in that practically everything that has ever happened in the geological history of this world has occurred to some varying degree right here: We have ore bearing rocks in the iron and copper

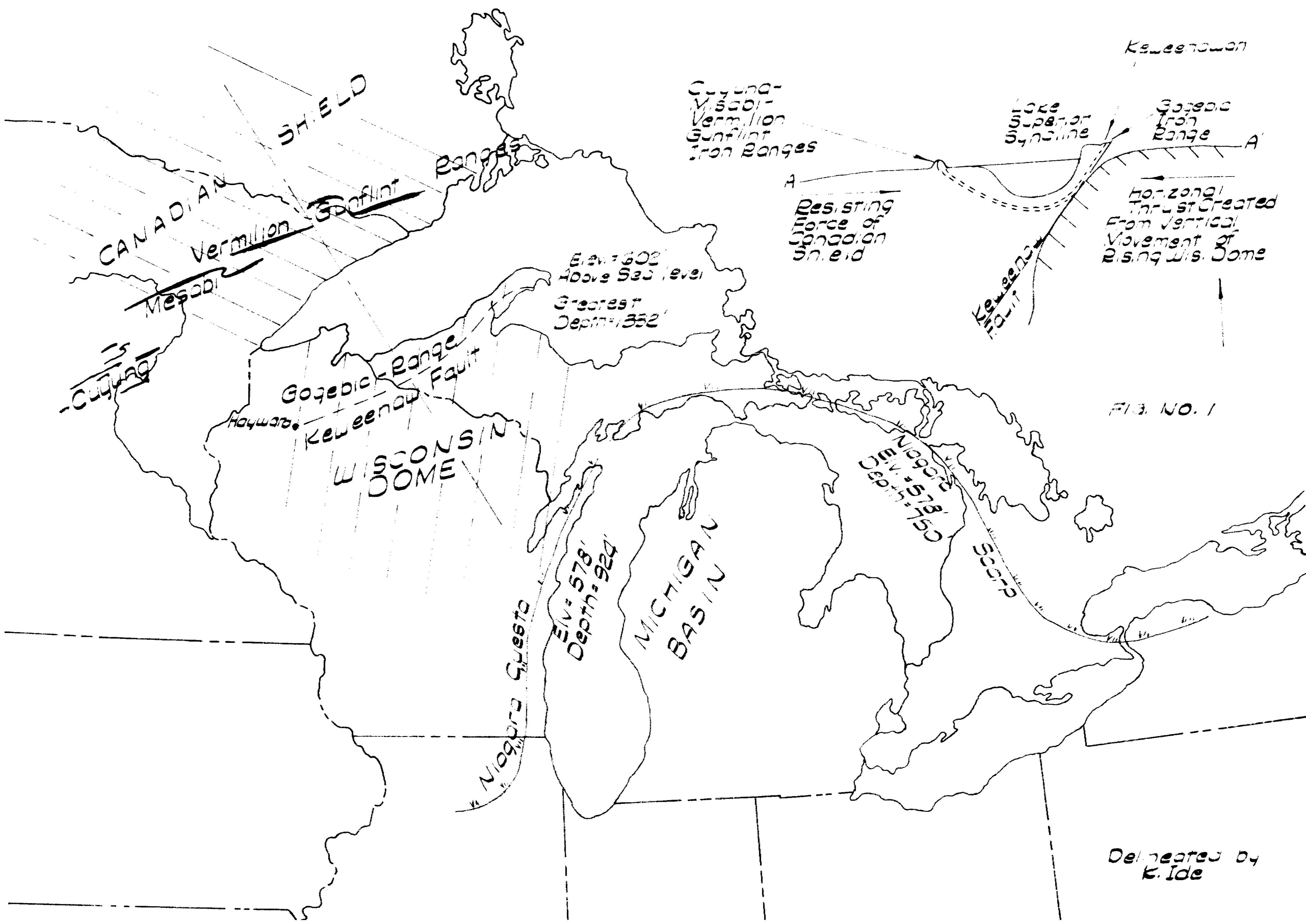
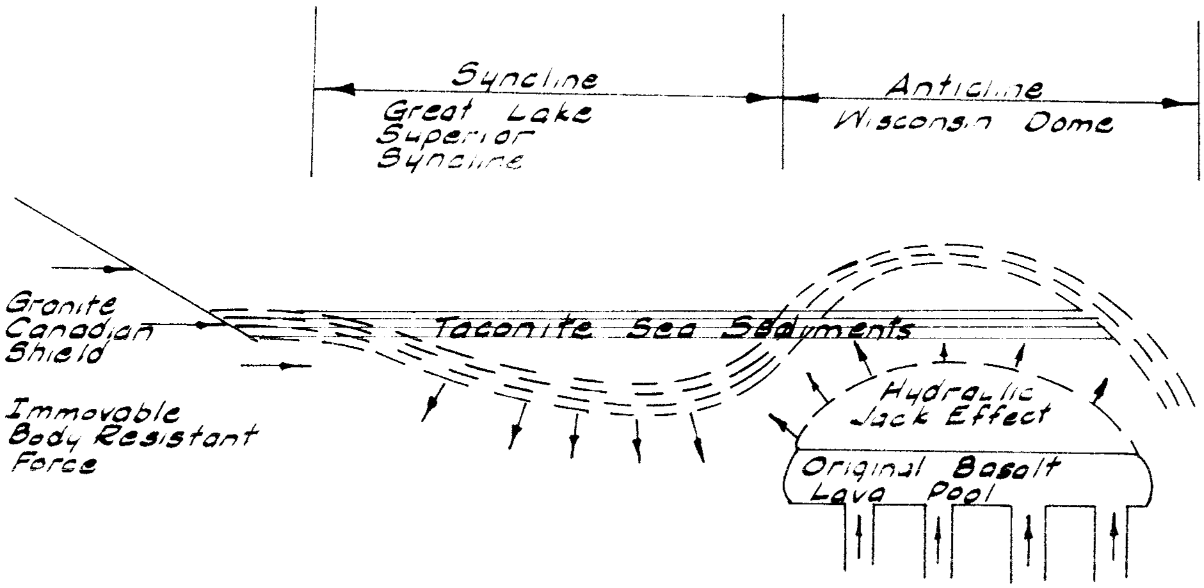


FIG. NO. 1

Delineated by K. Ide



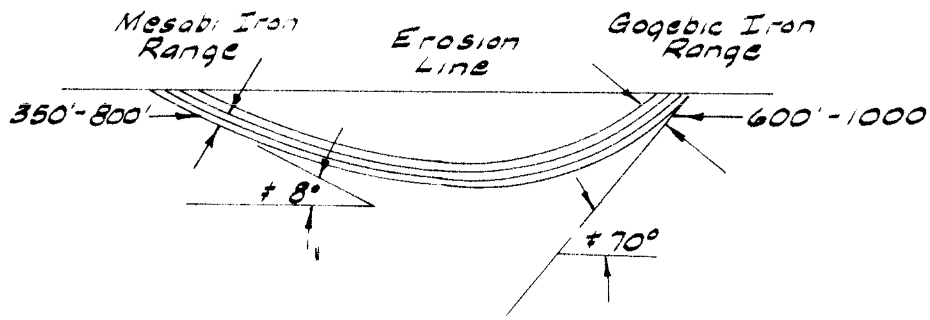


FIGURE NO. 2

DEVELOPMENT OF THE WISCONSIN DOME
AND THE LAKE SUPERIOR GREAT SYNCLINE

Delineated by
K.D. Ide

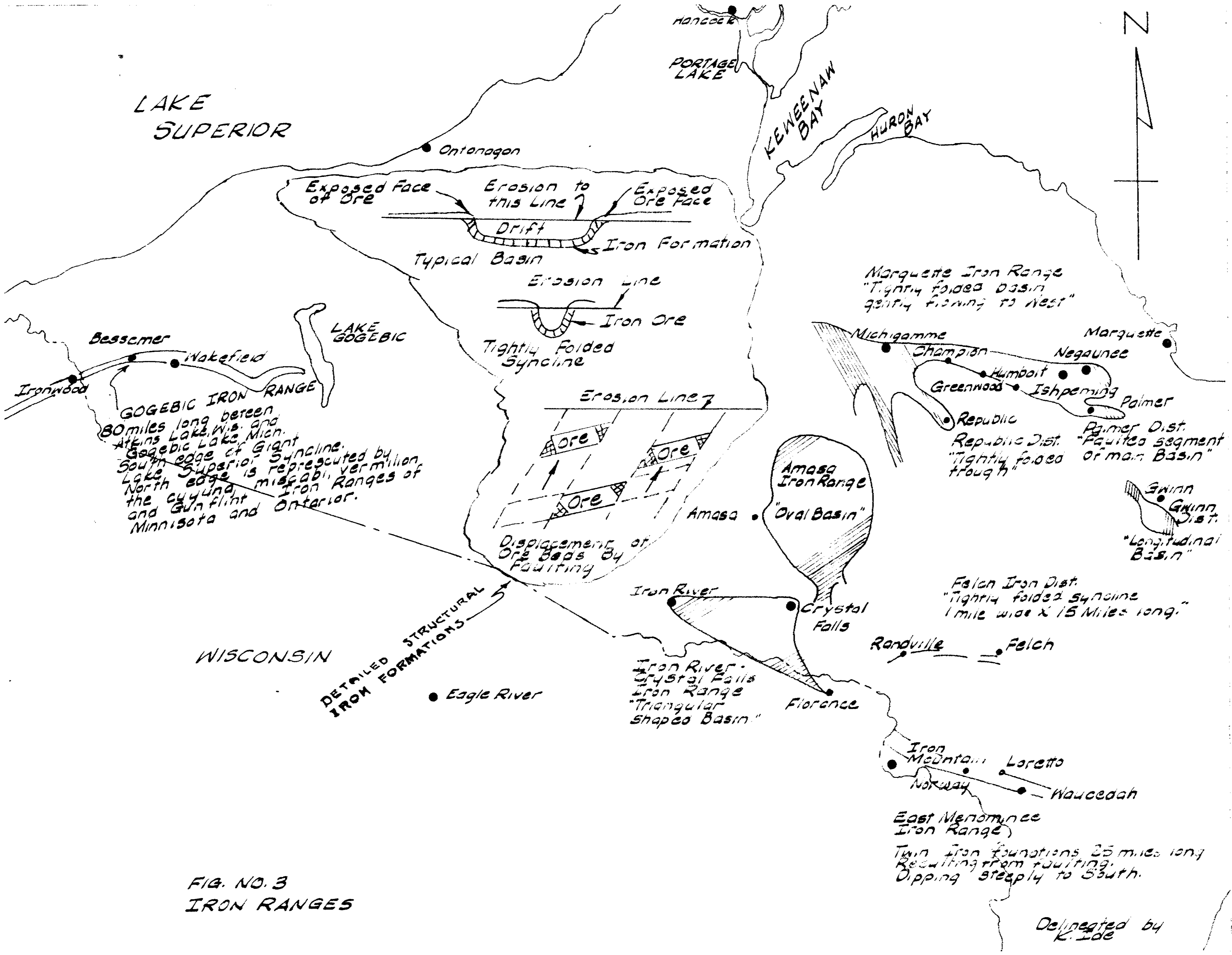


FIG. NO. 3
IRON RANGES

Delineated by K. Ide

country (sedimentary, metamorphic and volcanic); great sedimentary rock beds (silting in of the Michigan Basin); coral reefs formed in tropical salt water seas (exposed at Petoskey and Alpena); great earth faults such as the Keweenaw Fault and the structural collapse of the Straits of Mackinac; continental hinge lines (Arcadia eastward to Forestville); Karst Region limestone sinks and caves (Alpena and Presque Isle Counties); Glaciation accompanied by great deposits of glacial drift in varying land forms; post glacial lakes and drainageways and many other minor geological changes.

Let us treat each geological age separately and in chronological order.

Iron Range - Huronian Period
Fig. Nos. 1, 2, & 3

ORIGIN

About two billion years ago this earth was relatively young. The igneous magmas and volcanic lava flows had cooled, solidified and hardened into the Granitic Canadian Shield, backbone of the North American Continent.

Some of the volcanic lavas extruding through cracks in this huge shield were rich in both iron and silica, e.g., greenstones of the Vermilion Range in Minnesota.

These rocks and sililar ones, through disintegration, erosion and transportation, furnished the iron and silica for the ore deposited in Michigan, Minnesota and Wisconsin.

Sometime between two billion years and 700 million years ago, a shallow continental depression developed in the area of the above states. This depression is not to be confused with the Michigan Basin or the Lake Superior Basin both of which developed later.

This depression became a huge reservoir covering the Western part of the Upper Peninsula of Michigan, Northern part of Wisconsin and much of Minnesota.

Into this lake poured water saturated with silica (sand) in solution and iron rust which had eroded from the iron rich volcanic rocks.

These minerals accumulated in thicknesses of between 300 feet and 800 feet in the deepest recesses in the lake and formed at this time the original Taconite, iron ore deposits (iron oxides - rusts - in a matrix of sand).

Erosion continued to remove minerals from areas of the Canadian Shield farther North and to bury the Taconite beneath heavy sedimentary beds of sands, silts and clays which under pressure turned into sandstones and shales.

Pressure and heat later metamorphised the sandstones into quartzites and the shales into slates.

The next great dynamic geological change was the elevation of the North American continent well above ocean levels. At the same time the Taconite sea basin flattened out to some extent and was then re-shaped.

Internal pressures within the earth's crust warped the ore bearing stratifications into local pockets and basins into Local Synclines and Ccotinental Synclines such as the Lake Superior Syncline and interrupted their continunity in faults. See Fig. No. 2 and 3.

The Wisconsin Glacier (fourth invasion of the continental ice sheets) with one center of accumulation East of James Bay (Labradorian), and the other center of accumulation West of Hudson Bay (Keewatin)covered the ore deposits with still additional material in the form of glacial drift.

The Taconite was now compressed by the heavy surcharges of sedimentary lake beds and superimposed glacial drift into rock.

Soon changes began to appear in the Taconite. Because of its elevation above a ground water table, gravitationally motivated waters began to seep through the ore veins.

This seepage dissolved and removed much of the silica (sands) enriching the remaining iron ore. Some ore beds became concentrated in iron as much as 68% (Heratite).

ORES AND ENRICHMENT

These ores can be shipped directly to the smelting mills. Other ores called wash ores are crushed and the sand rinsed from them leaving them highly enriched. The sand weighing 90 pounds per cubic foot is easily separated from the iron oxide weighing 350 pounds per cubic foot because of the great difference in densities.

The unaltered Taconite has between 20% and 35% iron and must be specially treated to concentrate the iron to above 50% before it can be shipped South to the coal fields and the steel mills.

Notes: On ores and ore enrichment. Taconite containing hematite must be finely ground and the sand separated from the iron by (1) water action and vibrating screens and, (2) "Heavy media separation", an alloy of 85% iron and 15% silica, called ferrosilicon, is mixed with water to produce a liquid with a specific gravity between 2.8 and 3.3. In the heavy media seperation, silica floats to the surface of this liquid while the iron sinks to the bottom. The ferrosilicon is magnetic and because of this property can be salvaged and re-used.

Taconite containing magnetic must be finely ground and magnets used to separate the sand from the iron. Some ores are listed below:

ORES

Hematite, Fe_2O_3, iron rust, is colored red to blue and has between 65% and 70% iron with a sp. gr. of between 5.0 and 6.5. Practically all the silica has been removed by nature.

Specular Hematite is a metamorphised hematite and its crystals shine and sparkle like diamonds. Placed in concrete the crystals give the effect of fine frost crystals glistening in the sun.

Limonite, 2. $Fe_2 O_3 3H_2 O$ (Goethite - Bog Iron) is a hydrated hematite in which three molecules of water are attached to a double molecule of iron rust. This ore is bright yellow to a rich brown in color

Magnetite, $Fe_3 O_4$, magnetic iron oxide (iron rust) has 70% metalic iron, is dark colored and resembles iron. It has a sp. gr. of between 4.9 and 5.2.

Silderite, $Fe CO_3$, is a carbonate of iron and is found principally in England in clay formations called Clay Ironstone. It is grey, yellow, brown or black and has an iron content of 48%.

Meteorites are distinguished by the high percent of nickel, 3% to 8%.

Notes: On Iron and Steel Manufactor.

Iron ore has to be reduced or caused to lose its oxygen in order to convert it into iron. This is done by heating it with coke or charcoal, a fuel which when burned with a restricted amount of oxygen, sets free carbon monoxide, CO, an unstable gas that has a great affinity for additional oxygen to make it into a stable gas, carbon dioxide, CO_2. The excess CO unites with the oxygen in the iron rust, liberating the iron.

Limestone is also mixed with the ore and in melting the limestone enters into chemical union with the silica of ore to form an impure glass called slag, $Ca Si O_3$. This floats above the molten iron and is easily removed from it.

Iron is first smelted in a cupola or silo. The silo is filled with alternate thin layers of charcoal, limestone and iron ore. These layers are repeated upward until the silo is filled. It is then fired and eventually gray cast iron is formed and drawn off. This iron has no tensile strength.

Wrought iron is what is called puddled cast iron and has both tensile and compressive strengths and can be hammered into shape while in the plastic condition. Also iron, pure iron, malleable iron.

Steels are irons alloyed with other elements to develope specific desired characteristics. Open hearth steel is cooked in an open vessel or retort by hot gases. Passing over the retort open hearth steel is cooked for several hours.

Bessemer steel is made more repidly in open kettles and is cooked by forcing hot ignited gases up through the iron broth through jets in the bottom of the vessel. Electric furnaces get their heat from carbon electrodes that arc.

Notes: Cast iron and steel alloys and their specific charactorics.

IRON AND SPECIAL STEELS

Cast iron swells in cooling: is hard and can take compressive stresses but is also brittle and has no elasticity or tensile strength.

Various alloys of other metals with iron produces steel with specially desired characteristics.

Manganese - alloy-steel is tough and not brittle and is used in the jaws of rock crushers.

Vanadium-Chromium alloy steel is so tough that it can be bent double without failing.

Nickel alloy-steel has great strength and elasticity and is used in cables.

36% nickel alloy steel is called Invar, has practically no coefficient of expansion and is used in engineering tapes.

IRON RANGES AND LAKE SUPERIOR SYNCLINE

The four Iron Ranges of Minnesota: The Cuyuna, Mesabi, Vermilion and the Gunflint (Minnesota-Ontario) all strike (have their axis) in a Northeast of West direction and are parallel to the Gogebic Iron Range across Lake Superior in Michigan (See Fig. 1)

The Mesabi and Gunflint Ranges dip gently 8 degrees (perpendicular to their axis) Southerly towards Michigan while the Gogebic Range dips steeply 60 to 70 degrees in the opposite direction, or Northerly. This would indicate that the ranges were the same sedimentary beds and were the opposite limbs of a huge downfolding arch called a syncline. The actual thickness of the Iron Formation bed in the Mesabi is between 350 and 800 feet, and compares well with the 600 to 1,000 feet thickness of the Iron Formation in the Gogebic.

This is part of the foundation of the Lake Superior Sybcline, a down-warped basin. This indicates that there were tremendous horizontal pressures exerted upon the once horizontal sedimentary beds that lay between the Canadian Sheidl on the North and the Wisconsin Dome on the South, which caused it to bend downward.

All the iron ore bodies in the Upper Peninsula rest upon the Wisconsin Dome. Originally the Taconite Rock (iron formation strata) rested horizonally ypon this area. Convulsive earth movements and horizontal pressures from a Southerly direction caused wrinkles in this thin skin of rock. Later planation and erosion removed all the evidence of the Taconite except that which was folded into the earth's wrinkles.

Four of the Michigan Iron Districts: The Marquette, Guinn, Amasa, Iron River-Crystal Falls and the Randville-Felch were formed as down warped basins.

A. Marquette Range: This extends as a tightly folded basin for some thirty three miles in an East-West direction between Michigamme and Negaunee, and is between three and six miles in width.

At the East end is a faulted segment of the main basin called the Palmer District. This is an area of open pit mines similar to those of the Mesabi. At the West end, near Lake Michigamme, there is a small trough that strikes to the Southeast and is called the Republic District.

B. The Quinn District is a spoon shaped basin about six miles long and two miles wide, and appears to be a decimated segment of the Republic Trough, lying South of the City of Marquette and in line with the Republic Trough.

C. The Amasa Oval is a circular rim of exposed iron formation and is in the shape of a bowl or basin.

D. The Iron River-Crystal Falls, Florence, Wisconsin, Iron Range is a triangular shaped basin with these cities at the apexes of the geometric figure. It is also a true basin with mines lining the exposed rims or edges.

E. The Sandville-Felch Iron District is a long tightly folded syncline one mile wide and fifteen miles long, or an elongated basin.

The East Menominee Iron Range consists of two exposed limbs of iron striking in an easterly direction for some twenty-five miles between Iron Mountain and Waucedah. They parallel each other and are separated by between one-half and four miles. They are the same Iron Formation but were split up by faults. This formation dips steeply to the South.

The Iron Mountain end of this district is the site of more open mines like those of the Mesabi.

As stated previously, the Iron Formation Taconite is a thin sedimentary bed with between 2 and 25% of natural iron. The iron ore lies in this bed and has its natural iron content concentrated to about 51% and is only about one percent of the total Taconite bed.

EROSION

Notes: Factors contributing to the disintegration and erosion of volcanic rocks.

1. Thermal changes within the rock mass; whenever the surface of rock is heated or cooled by contact with wind, rain, streams of water or heat radiated by the sun, great internal tensile stresses are set up between the layers having different temperatures. Rock can withstand between 150 and 300 tons per square foot in compression, but zero stress in tension. The thermal change creates either expansion or contraction of the outer layer in relation to the internal mass which in turn creates horizontal stresses (tension) between the two layers, therefore, there is a tendency of layers to slide upon each other and to shear off (sealing action).

2. The intrusion of water into voids in the surface of rocks results in two actions: (a) Water will dissolve out soluble minerals and

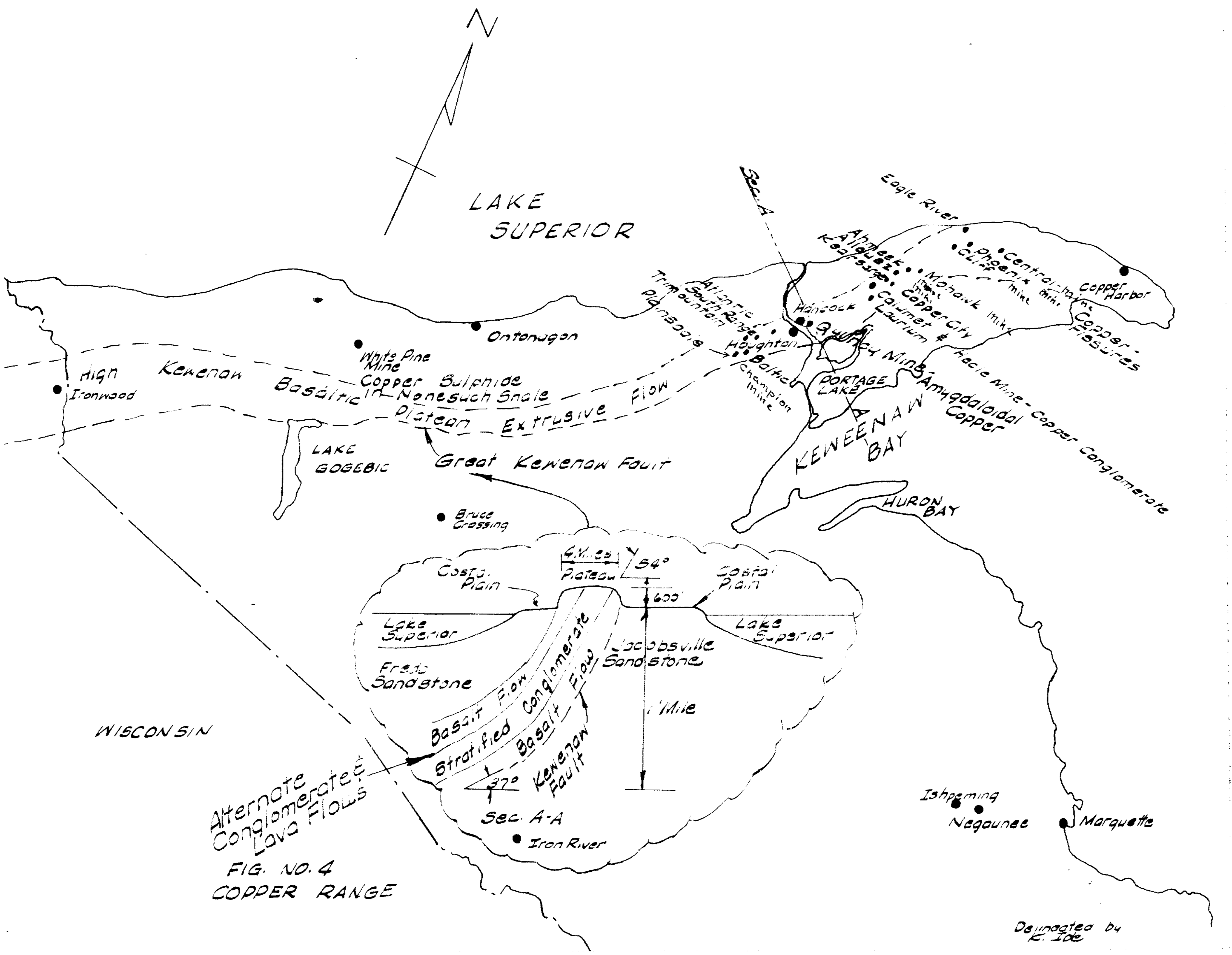


FIG. NO. 4
COPPER RANGE

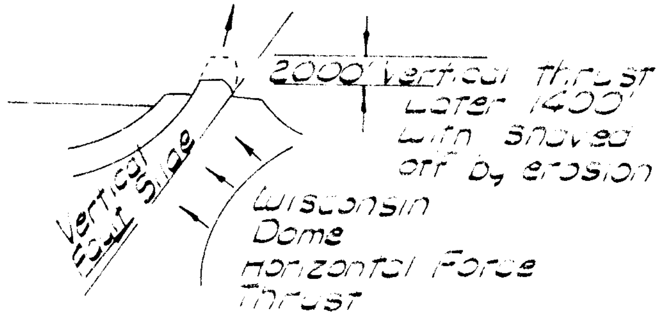
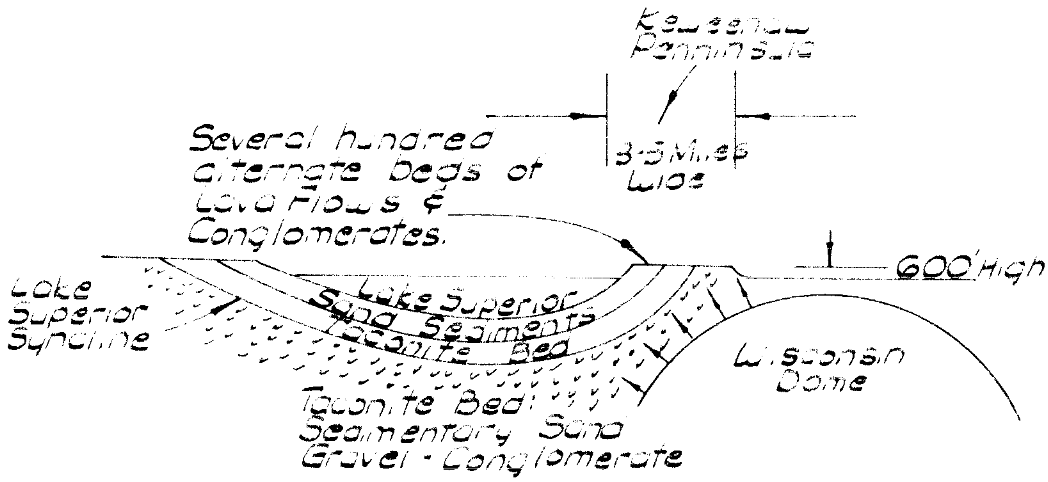
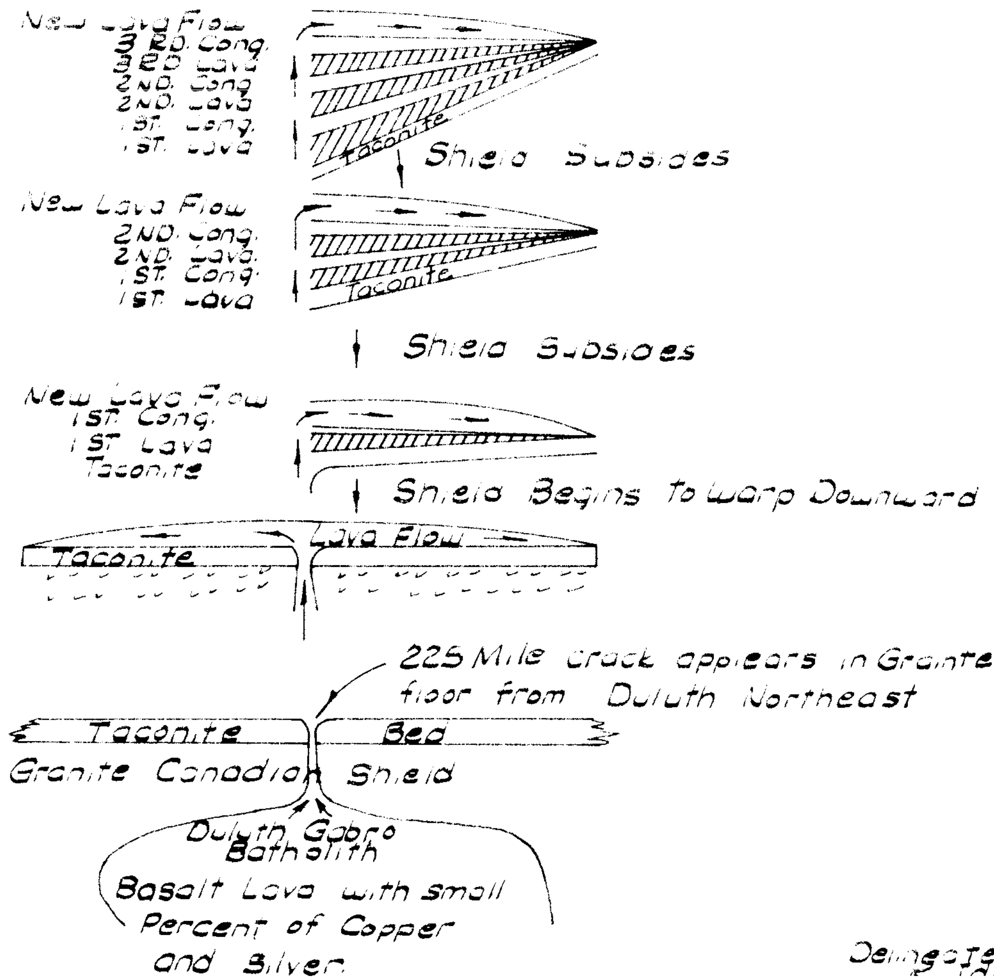


Figure No. 5

Figure showing Keweenawan lava flows, subsistance of Canadian Shield, formation of Lake Superior syncline and creation of Keweenaw Fault.





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destroy the rock structure. (b) Water captured by rock voids will expand 1/11 when changing into ice and at the same time will exert a pressure of 2000 pounds per square inch. This pressure results in throwing portions of the rock again into tension - a stress which it is incapable of withstanding. Therefirem we have spalling action and deep cracking in the rocks.

3. Water and ice masses will mechanically grind boulders one against the other as in a tumbling mill, and boulders against sheet rock abrasively as in sand papering furniture.

4. Wind will also sand blast rock; transport the particles and relay them in segregated layers.

5. Plant life and bacteria in search for food and moisture will to a minor degree assist in rock disintegration.

<u>COPPER RANGE FIG. NOS. 1, 4 & 5 - KEWEENAWAN PERIOD</u>

The geological history of the Copper Range is even more complex and interesting than that of the Iron Range.

TACONITE SEA Notes: Sedimentary beds developed in the iron rich Taconite Sea. This is the same iron rich sea that covered most of Minnesota, Wisconsin and the Upper Peninsula of Michigan. It had a sea floor (foundation of granite) plastered over with sedimentary rocks. These sedimentary rocks were laminated and consisted of alternating layers of shale, sand stones and conglomerate which warped and conformed to any changes or adjustments that occurred in the granite floor. This we will see happen in the development of the Lake Superior syncline.

WISCONSIN DOME Notes: The Wisconsin Dome is of crystalline rock and is about 250 miles in diameter. Fig. 6.

Boundaries:

Eastern - Marquette, Michigan to Waucedah, Michigan
Eastern - Waucedah, Michigan to New London, Wisconsin (25 miles NNW of Oshkosh, Wisconsin
Southern - New London, Wisconsin to Wisconsin Rapids
Southwestern - Wisconsin Rapids to Abotsford, Wisconsin
Southern - Abotsford to Chippewa Falls
Western - Chippewa Falls to Hayward
Northwestern - Hayward to Ironwood
Northern - Ironwood to Roselawn
Northwestern - Roselawn to L'Anse to Huron Mountain
Northeastern - Huron Mountain to Marquette

Let us now briefly reappraise the geological conditions that existed and were developing at the time of the Keweenawan Lava Flows which flows were highly impregnated with copper, and which also carried lighter loads of silver and gold.

First we have a fairly flat rocky foundation of granite called the Canadian Shield which covered our immediate area of Ontario, Michigan, Wisconsin and Minnesota.

Resting upon this Canadian Shield was the fairly thin sedimentary and metamorphic deposites of the shallow taconite sea.

MICHIGAN BASIN Next we had the beginning of the subsistance of the Lower Penninsula of Michigan to form the Michigan Basin.

WISCONSIN DOME The Wisconsin Dome began to arrise.

LAKE SUPERIOR SYNCLINE The giant continental thrust from the Northwest began to down warp the Canadian Shield in the neighborhood of the present Lake Superior to finally form the superior syncline.

Consider the Lake Superior region as flat with the surface of the Canadian Shield level with the lake as it exists today.

DULUTH BATHOLITH GABRO Now consider a great crack appearing in this granite floor beginning at Duluth and traversing Northeasterly half way between the Keweenaw Penninsula and the North shore of Lake Superior and ending midway between Copper Harbor on the Keweenaw Penninsula and Port Arthur, Ontario. This crack traveresed somewhere near this hypothetical line and actually extended farther North in the Lake Superior region.

KEWEENAWAN LAVA FLOWS Volcanic extrusions of molten lava burst forth all along this giant crack and flowed Southeasterly to a point slightly beyond the Keweenaw Penninsula.

This extrusion is similar to that which occured when the Pacific Ocean tore open between Japan and Alaska forming the Aleutian Islands and Japan.

Hundreds of individual lava flows occured. Long periods of time occured between some of the flows. During these sort of rest periods the exposed surface of the most recent lava flow was subjected to weathering to form gravel. Erosion then partially transported this material down the slope to the neighborhood of the new Keweenaw Penninsula. It was deposited in a thin sedimentary gravel layer over its parent, the most recent lava flow.

Eventually there was another volcanic eruption. This new lava flow moved Southeasterly as its sister did and covered up the thin recently deposited sedimentary bed of gravel. It's heat cemented and metamorphized this gravel bed into a conglomerate.

This is the way the alternate beds of lava and conglomerate were formed. Of the hundreds of lava flows and intermittant conglomerate beds only about a total of eighteen flows and beds have been mined and have proved financially successful ventures.

During all the time of the lava flows the superior syncline was slowly developing. Therefore the most Easterly beds or primary beds are much more vertical then the final beds. Or as you cross the Penninsula from East to West the dip of the beds decreases.

The sedimentary beds, although not truly vertical, dip between 76° and 27° downward toward Lake Superior to the Northwest:

Dip at Gogebic = 76°, at Copper Harbor 27°

COPPER ORIGIN

While the basalt magma was still hot and plastic, a flow of pyrothermal-hydro currents carrying copper in solution, originating from the same liquid basalt chamber, flowed in the same path taken by the basalt lava.

As these thermal currents cooled and their hydro station pressure was released, they deposited their loads of copper. This was deposited in three ways:

VARIOUS LOCATIONS

a. In dikes, fissures and fine veins (cracks) in the solid basalt rock., e.g. Phoenix Central Mines - vicinity of Central Michigan.

b. In amygdaloids (gas bubbles - voids in the basalt rock)., e.g. Quincy and Pewabic Mines - vicinity of Hancock.

c. Interbedded in the porous conglomerates (not jasper or quartzite conglomerates), e.g. Calumet and Hecla Mine - vicinity of Calumet.

NOTES

Keweenaw copper conglomerate is a sedimentary gravel cemented in a matrix of copper. This is in contrast to the jasper and quartzite conglomerates with which we are more familiar. These latter are also found in this formation. They are gravel beds which were metamorphized by direct contact with molten basalt lava that flowed over them. They were literally cooked and fused together by the great heat.

Pyro-hydro-thermal currents are actually super heated liquid steam (temperature of boiling rock = 2500°F.) kept liquid by tremendous external pressures acting upon them. (Some pressures that extruded the molten rock). Melting point of copper is 2000°F.

KEWEENAW FAULT

Formation of the Keweenaw Fault   Fig. No. 6

The same horizontal pressure which created the Lake Superior syncline continued to increase until an almost vertical shear crack appeared at the contact point between the South basaltic edge of the sybcline and the lowland plains on its right. This shear crack ran logitudinally the length of the Keweenaw Peninsula and continued to the vicinity of Hayward, Wisconsin on the West side of the Wisconsin Dome. The fault can be traced all the way to Kansas City, Missouri.

The South lip of the Lake Superior syncline then shot upward until there was a total displacement of some 2,000 feet between the areas on each side of this crack. This is called a thrust fault. This is visible Southwesterly to Hayward, Wisconsin. Erosion since has removed much of this elevated basalt plateau until only about 600 feet of it remains today.

It is over 150 miles long; between 2 and 8 miles in width; between 500 and 600 feet above Lake Superior; sliced through occasionally by low transverse valleys and is flanked by lowland sedimentary plains on each side. Lake Superior has an elevation itself of 602 feet above ocean level. It is truly the backbone of the Keweenaw Peninsula. It extends well into Wisconsin.

This fault could be compared to a blow-out of a slab of concrete pavement. The pressures built up by expansion through the absorption of heat become greater than the slab's ability to withstand such pressures under compression.

To make the copper more difficult to find, the Wisconsin Ice Sheet dumped between 100 and 200 feet of glacial drift over all the peninsula.

LAKE SUPERIOR SYNCLINE

Syncline dips to the Northwest. The inclination of the Keweenaw Basalt toward the bottom of Lake Superior is rather flat at the end of the peninsula (27°) and rather steep at the foot of the peninsula (76°).

MINE DEPTHS AND TEMPERATURES

Mine	Dip at Surface	Dip at Lower Levels
Central	27°	21°
Calumet & Hecla	38°	36° (one mile)
Quincey	54°	37° (one mile)
Champion	73°	

Mine temperatures increase with depth

Vertical Distances	Ave. No. feet required per degree F
60' to 1000'	99'
60' to 2000'	106'
60' to 3000'	119'
60' to 5400'	117'

This is lower than the average distance of 60' per degree Fahrenheit as given on Page 5.

Calumet and Hecla Shaft No. 5 has an inclined distance of 8100' and a vertical height of 4900'. Rock temperature at 4900' is 86.2°F.

Shaft No. 1 has an inclined distance of 9600' and a vertical distance of 5684'.

The Quincy Mine has a shaft (No. 2) with an inclined distance of 10,000' and a vertical distance of 6300'. It had the largest steam hoist in the world with a drum 33' in diameter.

This is one of the few sources of pure copper in the world. Other locations are Bruce Mines, 50 miles East of Sault Ste Marie, Ontario and in the Red Sandstones at Coro Coro, Bolivia.

Free copper is removed from the rock matrix by passing it through a crusher or a stamping mill to separate it from the rock gangue. It is then smelted with a flux to make it flow together and to remove the gangue as slag. The furnace used is a reverberatory or open hearth type.

Gangue is a term for the rock matrix in which ore is lodged.

Melting point of copper is 1976°F.

MICHIGAN BASIN

The Michigan Basin is roughly 400 miles in diameter and has, generally speaking, the following boundaries: (These will be pin-pointed in a later discussion). Fig. No. 6 & 7.

Northern - South shore of Lake Superior from Marquette, Michigan to Sault Ste Marie, Michigan.

Eastern - East shore of Lake Huron (Inland in Ontario).

Western - West shore of Lake Michigan (Inland in Wisconsin).

The fluid Basalt pool beneath Michigan was depressed by the subsistence of the Michigan Basin. This displaced fluid rock found relief in raising the Wisconsin Dome.

LAKE SUPERIOR SYNCLINE

Creation of the Lake Superior syncline:

(Downward arched sea floor between the Canadian Shore line on the North and the Keweenaw Peninsula on the South) created by horizontal pressure between the Canadian Shield and the Wisconsin Dome.

This Southeast side thrust from the rising Wisconsin Dome was resisted by a continental thrust from Northwest and had three results:

1. The sedimentary beds (Ancient Taconite Sea) with the Keweenawan lava flows perched on them which normally sloped gently to the South from the Canadian Shore were tilted upward in the vicinity of the Keweenaw Peninsula. This action was similar to driving a giant wedge under this area.

2. Compressive forces (horizontal) now bowed the sea floor downward to form the syncline. Fig. No. 1, 2, 4 and 5.

3. Excessive forces (horizontal) created the Keweenaw Fault. Fig. No. 4 and 5.

The upward thrust on the plane of failure was approximately 2000'.

A syncline is an earth structure that curves downward. An anti-syncline is an earth structure that arches upward like Roman Arch.

The erosional shearing off of 1400' of the top of the syncline on the South limb (Keweenaw Peninsula). This exposed the open faces of the sedimentary beds of the Taconite Sea and the Keweenawan Basaltic Lava Flows. These resembled the end of a piece of plywood and were exposed horizontally. The exception to the statement that this is entirely a source of float, free or native copper is found in the White Pine mining location near the Porcupine Mountains and at the Southwest end of the copper district.

OTHER LOCATIONS

The copper found in the Western States of Montana and Arizona is also the sulphide.

This ore supplies copper bottom in the free state and as copper sulphide (Chalcocite) and is found in the Nonesuch Shale, a sedimentary bed.

REFINING COPPER SULPHIDE

Common treatment includes:

a. Roasting to drive off some sulphur as SO_2, leaving CU2 and Fe_2O_3.

b. Blast furnace treatment with new green (unroasted ore), sand and coke to remove iron as silicate in slag.

c. Bessemer furnace treatment with additional sand to remove the rest of the iron in slag.

d. Blister copper (Cu and Cu_2O) is melted and "poled" with green wood. The hydro carbons in the wood reduce the Cu_2O to copper.

Further refinement can be had by the electrolytic method. As a matter of curosity and interest the following table is given:

PALEOZOIC SEAS AND THE GIANT MICHIGAN BASIN

Fig. Nos. 6, 7, 8, 9 and 10

We have already discussed the creation of the Lake Superior syncline, the Wisconsin Dome and the Michigan Basin.

MICHIGAN BASIN

Concentrating on the Michigan Basin, we find that it is some 400 miles in diameter and between 2.5 and 3.0 miles in depth. It is a granite basin and relatively shallow with relationship to its diameter.

CONNECTING TROUGH AND BASINS

Originally it had two troughs (inlets and outlets) which connected it to two other basins - the Illinois Basin to the Southwest and the Allegheny Basin to the Southeast.

Notes: The Logansport Trough or Sag is 65 miles wide and 5000 feet deep at the weir * (Kankakee Arch). Its axis lies on a Southwesterly line between Battle Creek, Michigan and Logansport, Indiana.
* Weir or channel throat.

The Chatham Trough or Sag is 40 miles wide and 4000 feet deep at the weir (Findlay Arch). Its axis lies on a Southeasterly line passing through Port Huron, Michigan.

The three mile thickness of sediments and glacial drift prohibits the exploration of any iron or copper ores which may exist in the granite foundation for this basin.

Any promotion for the sale of mining stock for gold, silver, copper or iron in the Southern Peninsula of Michigan would be strictly a fraud.

The sedimentary rock beds that fill the basin only produce salt water, petroleum oils and gas along with halogen salts (solium and calcium salts of iodine, fluorine, chlorine and bromine), gypsum, limestone, dolomite, shale and highly sulphurous coal.

BOARDERING DOMES

The Michigan Basin is not only connected to two adjacent basins but is surrounded by four continental domes: Wisconsin Dome to the West, Laurentian Highlands to the North, Ontario Dome to the East and the Cincinatti Arch to the South.

GREAT SEAS

Six times this basin was invaded by foreign waters creating major seas: Cambrian, Ordovician, Silarian, Devonian, Mississippian and Pennsylvanian.

Each period sea was divided into many subordinate seas, each of which left their own individualistic sedimentary beds as they evaporated; e.g., salt beds, gypsum, limestone, shale.

The distinguishing feature, however, in each period sea was its fauna and flora life (marine animals and plants) which differed greatly from that which existed in any other period sea. Therefore, the fossil life sealed in a bed of sedimentary rock, immediately classifies the sea to which it belonged.

This remains true over the entire world: A cambrian sandstone from Pictured Rocks (U. P. Michigan) is the same aged sea deposits as the Cambrian sandstone found at Wisconsin Dells, North shore of the Bristol Channel, Wales or in the deep off-shore oil wells at Louisiana and California, or in the deserts of Arabia.

It must be remembered that as each sea evaporated its sediments formed a crust within the basin similar to the caked lime in a tea kettle, thereby reducing the volume capacity of the basin.

Each succeeding sea became smaller in area and shallower until the entire basin was "silted in". The original Cambrian Sea was 460 miles in diameter and three miles in depth. The final sea, Pennsylvanian, was only 125 miles in diameter and less than 600 feet deep.

CONTINENTAL POND

If the basin had not silted in, Michigan would have been a continental pond today.

Gravitational pressure from the more recently formed upper beds compressed and cemented the lower beds into rock.

SEDIMENTARY BEDS*EG SALT

The numerous sedimentary beds of salt, limestone, dolemite and gypsum resulted from saline ocean waters. The salt became concentrated as the ocean waters evaporated and were renewed many times. This repeated cycle built up salt beds to thicknesses of over 1700 feet in the saline bed of the Salurian Sea.

LIMESTONE AND DOLOMITE

The limestone and dolemite beds were formed from the skeletons of marine life, such as clams, snails and coral. Their body structures became ground up and pulverized and formed a marly matrix or mortar which encased a few undestroyed fossils. Pressure from overlying beds dehydrated the beds and compacted them into rock. Further pressure and heat converted (metamorphized) this rock into marble.

SANDSTONE

The sandstone, shale and conglomerate rocks derived their source of minerals from the four Continental Domes. The granites and basalts disintegrated and were carried into the seas by streams and rivers (fluvial) and were deposited there.

ORIGIN OF MINERAL SEDIMENTS

<u>Notes:</u> Granite disintegrates into quartz, feldspar and mica. the quartz (sand) forms sandstones which if metamorphized changes into quartzite.

The feldspar and mica form shale beds which if metamorphized changes into slate.

The gravels become porous conglomerates and if metamorphized changes into quartz conglomerates and jasper conglomerates.

COAL

The coal measures are confined entirely to the last period sea, the Pennsylvanian. The vegetation in the marshes decayed forming peat beds which in turn became compressed into coal by sedimentary mineral beds of overburden (lacustrian clay deposits which formed shale beds and sands which became sandstones).

Michigan coal is found in very thin beds which very rarely approach three feet in thickness. It is an organic deposit and is bituminous in contrast to the metamorphized form called anthracite coal. Coal is primarily the element carbon.

OILS AND GAS

We have seen how the skeletons of marine life and coral formed the extensive limestone and dolomite beds. The fleshy organic fats from this same sea life became concentrated and lodged within layers of sedimentary rocks as new beds were formed above them. These mineral oils (actually organic oils) moved longitudinally between parallel beds towards the upper edges of the basin until they reached minor wrinkles in the beds. The oils then became trapped in these folds or anticlines (upward arches) and formed pools of oil.

These oils belong to what is termed the hydro-carbon series and all follow exactly the following formula whether they are the simplest gas called methane or the complex heavy asphalt. $C_nH_{2 \cdot n+2}$ where n equals the number of units of carbon in the molecule.

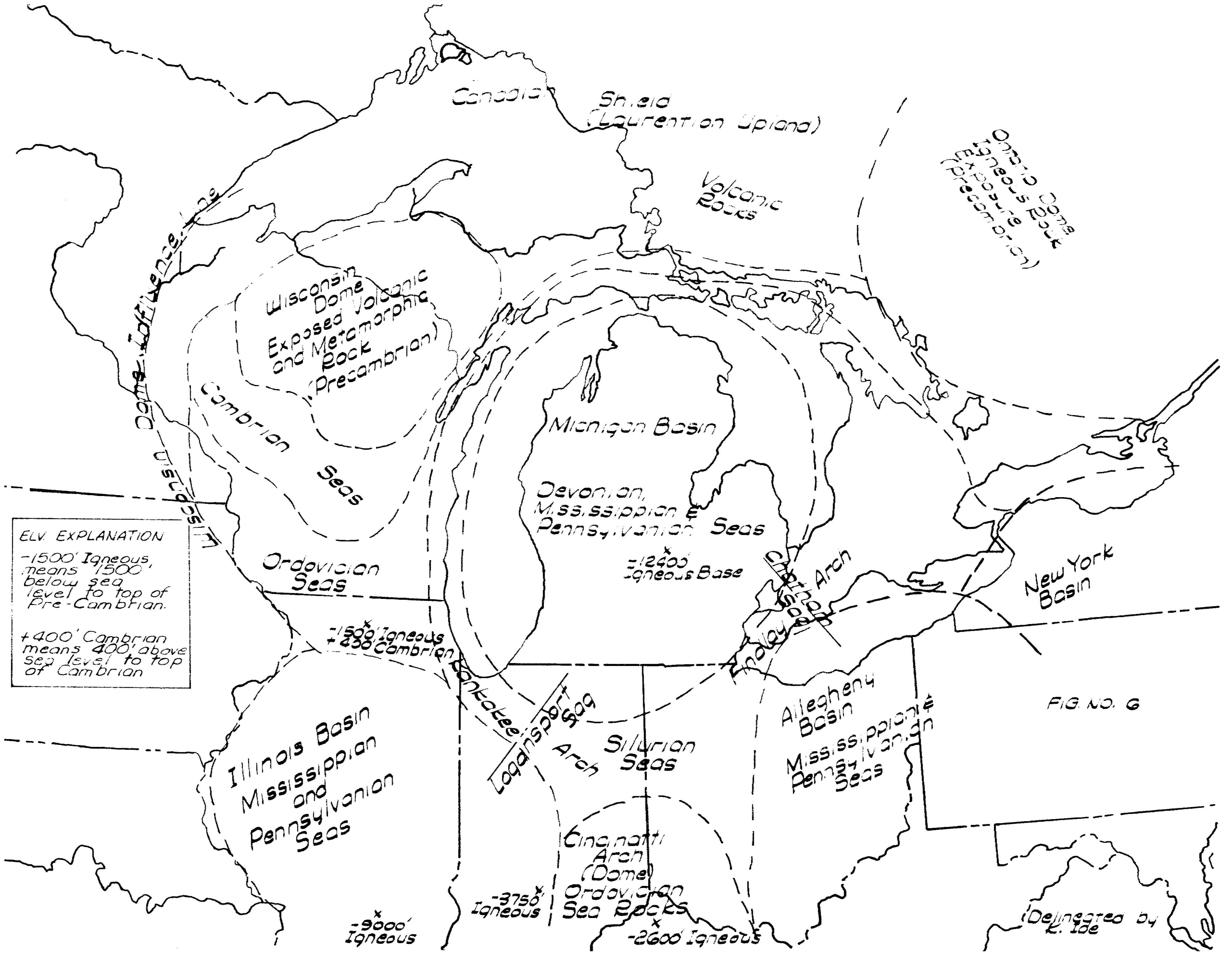
Note:	Methane	- CH_4	
	Ethane	- C_2H_6	
	Propane	- C_3H_8	
	Butane	- C_4H_{10}	
	Pentane	- C_5H_{12}	Petroleum ether
	Hexane	- C_6H_{14}	Naptha or ligroin
	Heptane	- C_7H_{16}	
	Octane	- C_8H_{18}	
	Nonane	- C_9H_{20}	gasoline
	Decane	- $C_{10}H_{22}$	kerosene
	Hexadecane	- $C_{16}H_{34}$	
	Vaseline	- $C_{17}H_{36}$ to $C_{21}H_{44}$	
	Paraffin wax	- $C_{22}H_{46}$ to $C_{27}H_{56}$	
	Asphalt	- $C_{64}H_{150}$	

Notes: Crude petroeum is a mixture or a solution of the above hydrocarbons from the simplest gas, methane, to the highly complex asphalt.

In oil wells the gas is removed first, followed by the oil and finally by the salt water. When the brine (heaviest) appears, the well is exhausted of oil and gas.

Some wells have between 500 and 1,000 pounds per square inch of gas pressure when first opened up. After the removal of the gas and oil, if the reservoir is large, it can be used to store gas piped in from foreign fields. Gas can be stored in safety and without fear of loss until the original field pressure is reached.

Because they all conform rigidly to the C_uH_{u+2} formula, the larger compounds can be "cracked" down into those hydrocarbons that we use as fuels for heat and combustion engines and lubricating oils and greases in addition to the asphalt fraction used in bituminous pavements.


Canada Shield (Laurentian Upland)
Volcanic Rocks
Ontario Dome Igneous Rock Exposure (Precambrian)
Dome Influence Line
Wisconsin
Wisconsin Dome Exposed Volcanic and Metamorphic Rock (Precambrian)
Cambrian Seas
Michigan Basin
Devonian, Mississippian & Pennsylvanian Seas
Ordovician Seas
ELV. EXPLANATION
-1500' Igneous, means 1500' below sea level to top of Pre-Cambrian.
+400' Cambrian means 400' above sea level to top of Cambrian
-12400' Igneous Base
Chatham Sag
Arch
Findlay
New York Basin
-1500' Igneous +430 Cambrian
Kankakee
Logansport Sag
Arch
Silurian Seas
Allegheny Basin Mississippian & Pennsylvanian Seas
Illinois Basin Mississippian and Pennsylvanian Seas
Cincinatti Arch (Dome) Ordovician Sea Rocks
-3750' Igneous
-9000' Igneous
-2600' Igneous
(Delineated by K. Ide
FIG. NO. 6

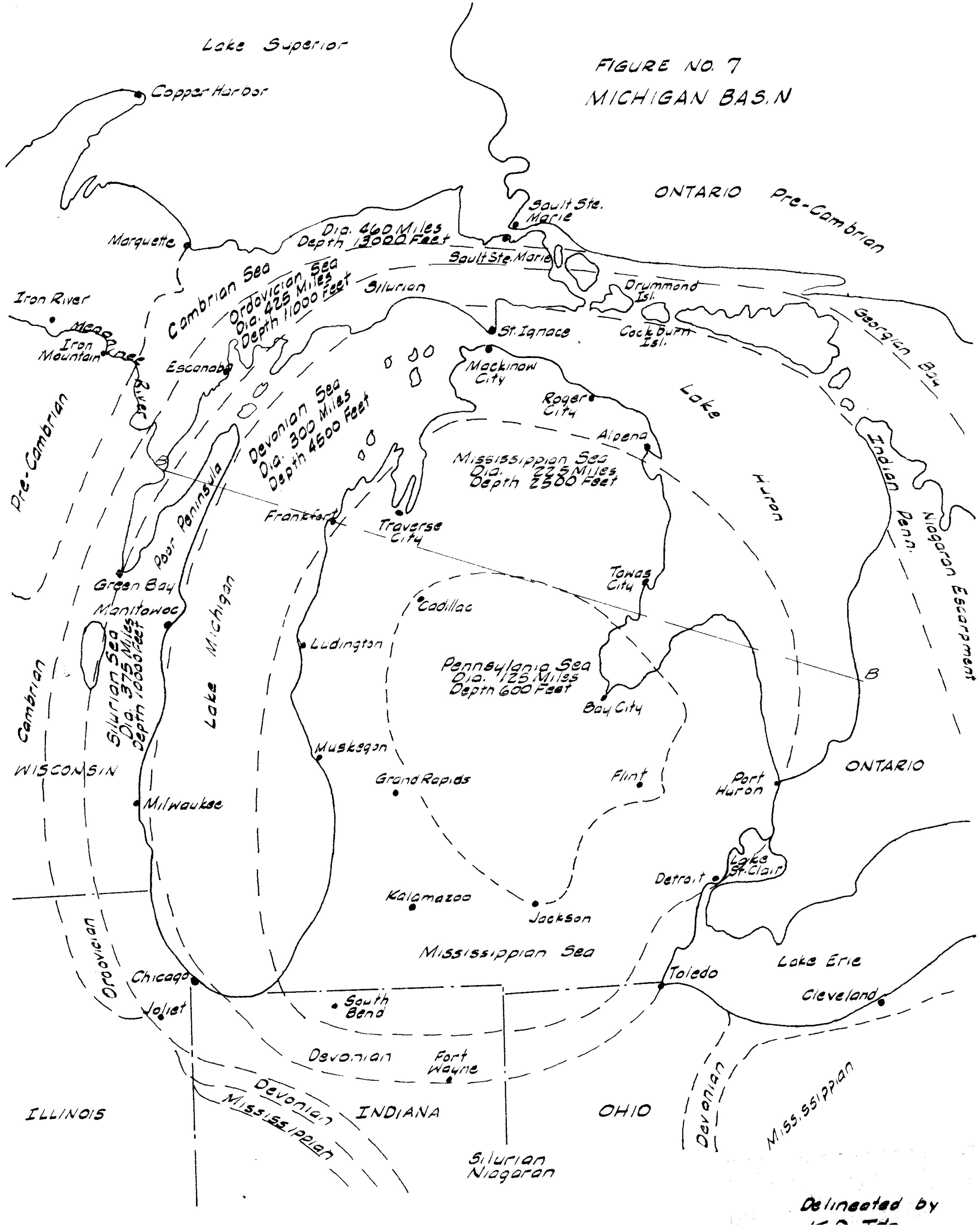


FIGURE NO. 7
MICHIGAN BAS.N
Lake Superior
Copper Harbor
Marquette
Iron River
Iron Mountain
Menominee River
Escanaba
Pre-Cambrian
Cambrian Sea
Ordovician Sea
Dia. 425 Miles
Depth 11000 Feet
Dia. 460 Miles
Depth 13000 Feet
Sault Ste. Marie
Silurian
ONTARIO Pre-Cambrian
Drummond Isl.
Cockburn Isl.
St. Ignace
Mackinaw City
Georgian Bay
Roger City
Alpena
Lake Huron
Devonian Sea
Dia. 300 Miles
Depth 4500 Feet
Mississippian Sea
Dia. 225 Miles
Depth 2500 Feet
Door Peninsula
Frankfort
Traverse City
Indian Penn.
Niagaran Escarpment
Green Bay
Manitowoc
Tawas City
Cadillac
Ludington
Lake Michigan
Silurian Sea
Dia. 375 Miles
Depth 10000 Feet
Pennsylvania Sea
Dia. 125 Miles
Depth 600 Feet
Bay City
B
Cambrian
WISCONSIN
Muskegon
Grand Rapids
Flint
Port Huron
ONTARIO
Milwaukee
Lake St. Clair
Detroit
Kalamazoo
Jackson
Mississippian Sea
Lake Erie
Ordovician
Chicago
Toledo
Cleveland
Joliet
South Bend
Devonian
Fort Wayne
Devonian
Mississippian
Devonian
Mississippian
ILLINOIS
INDIANA
OHIO
Silurian Niagaran
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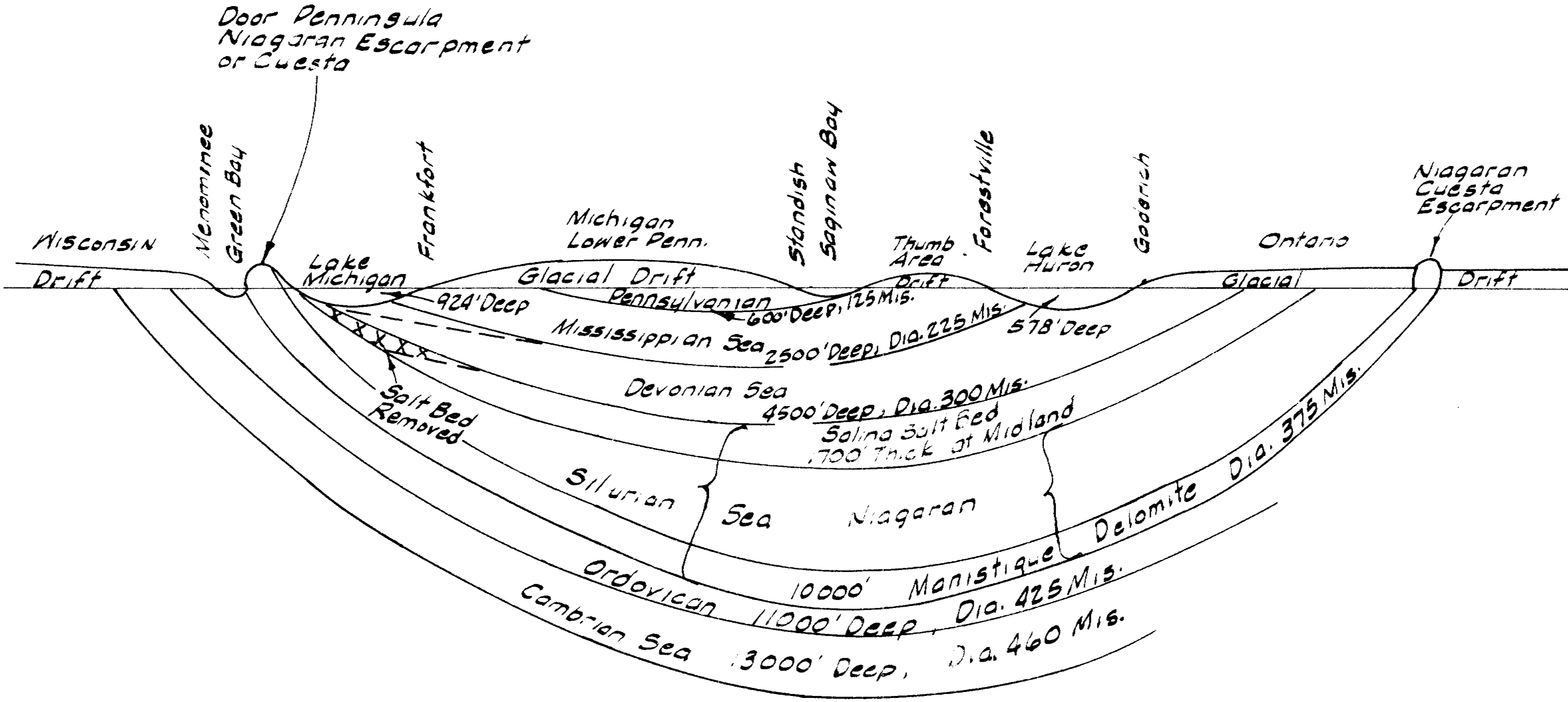

FIGURE NO. 8

MICHIGAN BASIN

Section B-B

Delineated by
K.D. Ide

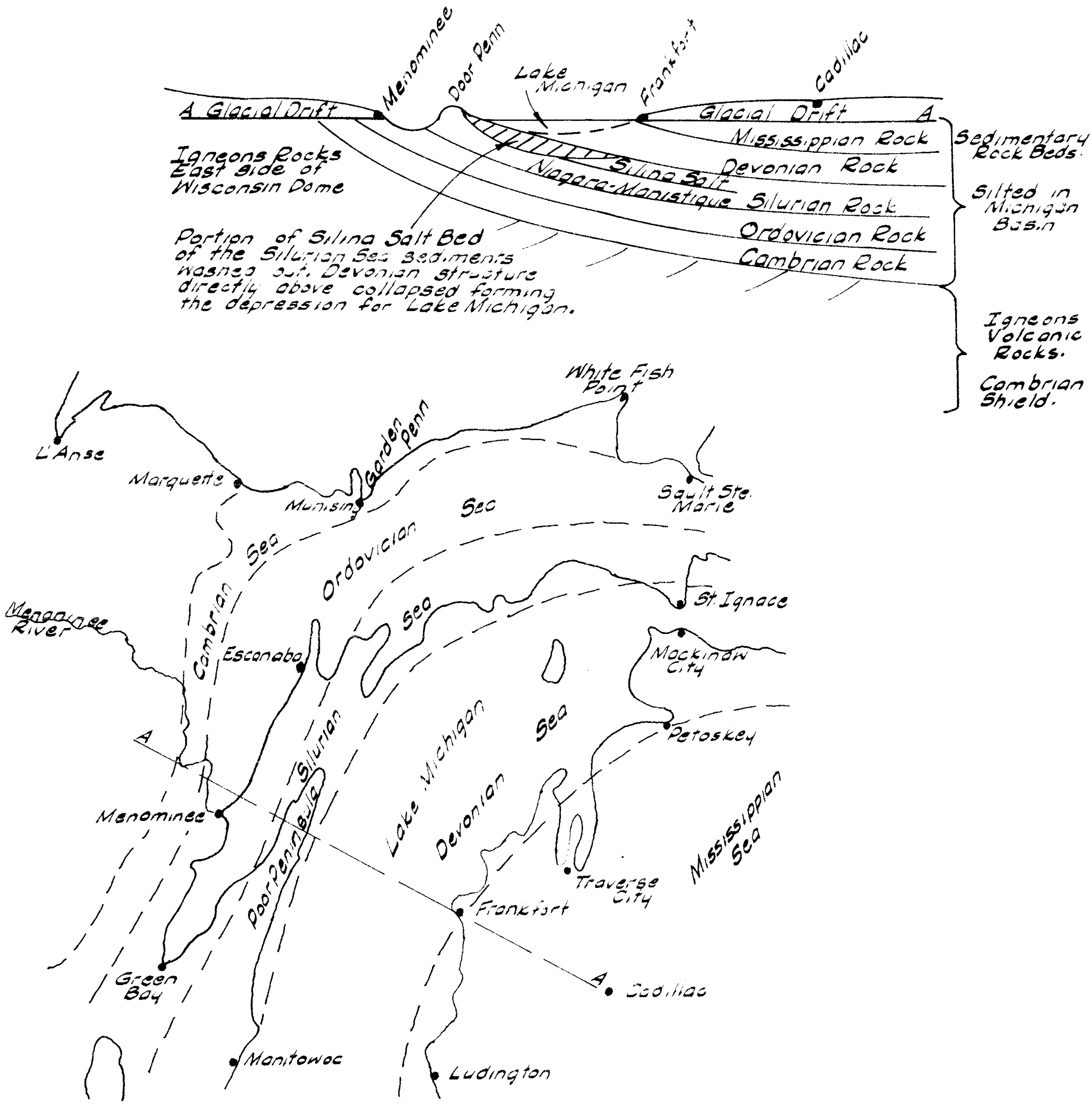

FIGURE NO. 9

FORMATION OF LAKES MICHIGAN & HURON & STRAITIES OF MACKINAC

Delineated by K. O. Ide

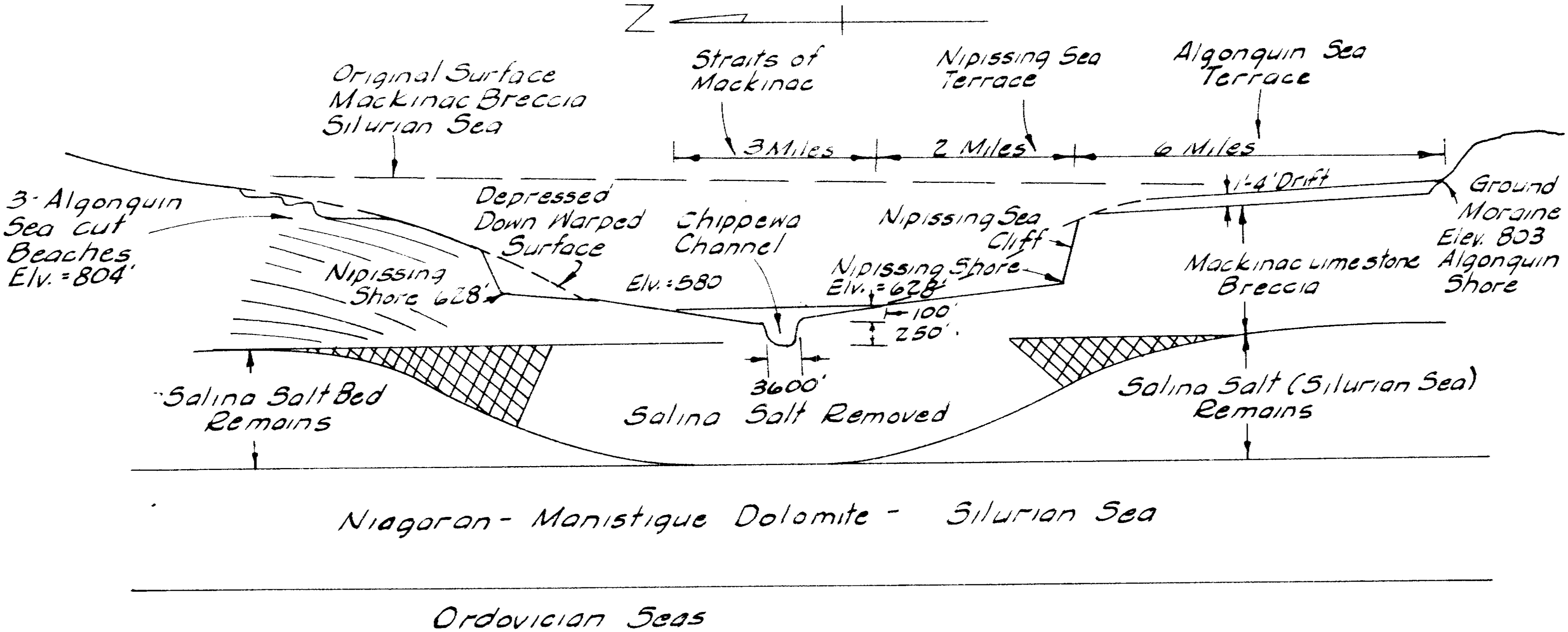

FIGURE NO. 10

DEVELOPMENT OF STRAITS OF MACKINAC SHOWING PORTION OF SALT BED REMOVED CAUSING THE OVERLYING MACKINAC BRECCIA TO WARP DOWNWARD.

Delineated by
K D Ide

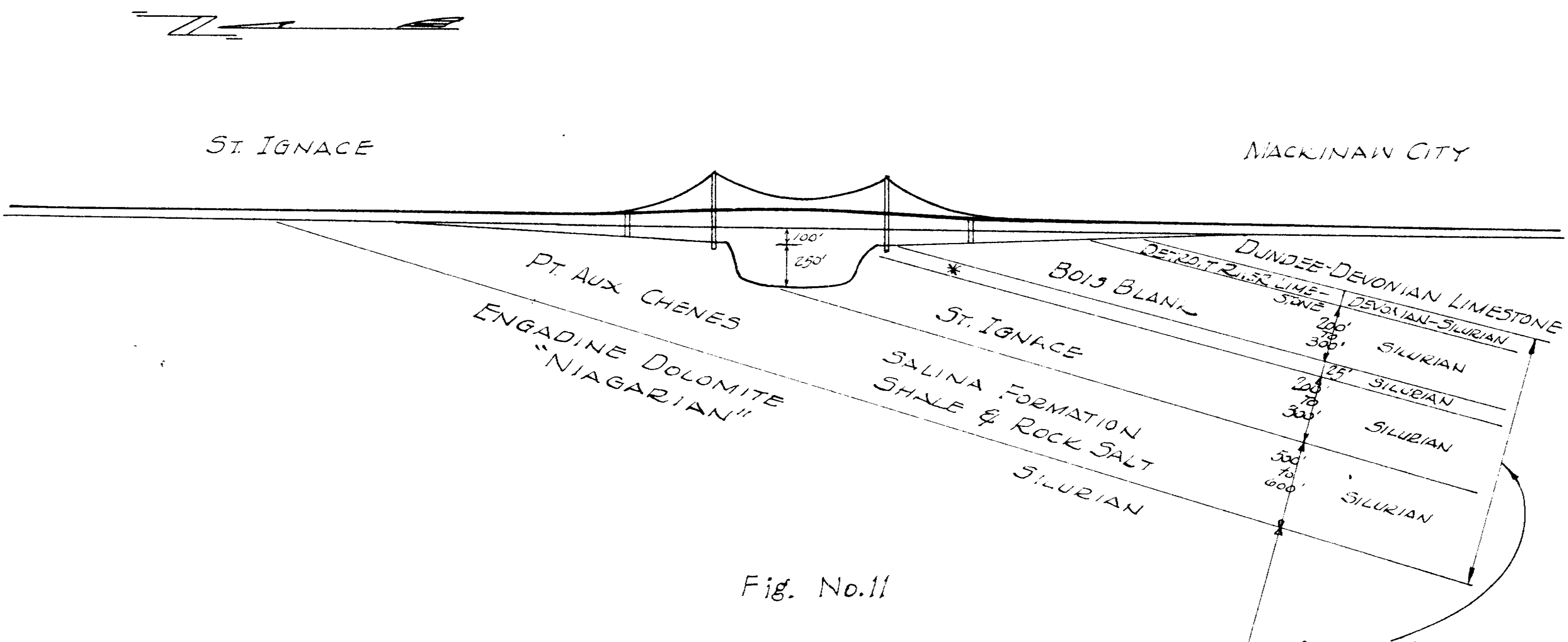

Fig. No. 11

MACKINAW STRAITS
FORMATION

MACKINAC "BRECCIA"
Formation collapsed after
salt was leached out of
PT. AUX CHENES formation.

* Garden Island Formation not Garden Penninsula formation.

Delineated F.N. '61

SEAS OF MICHIGAN - [illegible] SEAS AND THEIR DEPOSITES

Let us return to the condition in which the basin is completely "silted-in" or filled level with its rim with sediments.

The continent rose elevating the surface of the basin about 600 feet above the oceans.

EROSION

Streams and river systems began to develop in the exposed edges of some of the softer beds. These beds were quarried broader and deeper by tongues of glacial ice that streamed down from the North.

DISSOLUTION OF SALT

Salt beds (also sedimentary rocks) were eroded at their exposed surfaces and also leached out beneath other beds causing the overlying beds to collapse. A combination of these three actions (steam erosion, ice quarrying and the removal of rock salt through dissolving into solution) created the Lake Michigan-Lake Huron-Lake St. Clair drainage course.

MICHIGAN AN ISLAND

If erosion had continued through Ohio and Indiana, Southern Michigan would have been an island today.

As previously mentioned, six major continental seas invaded the Michigan basin. These major seas were subdivided into several individual minor seas. Altogether the minor seas totaled around 55. Their deposites hardened and eventually silted in the entire basin creating a level table land from Ontario to Wisconsin with the exception of the Ontario, Cincinnati and Wisconsin Domes and arches.

The six major pleistocene seas are the Cambrian, Ordovician, Silurian, Devonian, Mississippian and Pennsylvanian and will now be examined and we will go into detail on only a few of the many individual sub-seas.

The boundry descriptions are often where outcrops appear. However this is-not so in all cases because of overlying glacial drift. In those areas the boundaries were located directly or were calculated from water, oil or salt well logs.

CAMBRIAN SEA

The earliest sea was the Cambrian. It secured its nourishment from fresh waters flowing off the Canadian Shield to the North. These waters flowed around the West and South side of the Wisconsin Dome and entered the Michigan basin from the Southwest.

The Northern edge of this sea forms the south boundary of Lake Superior and is beautifully exhibited from Sault Ste. Marie to Tahquamenon Falls to Picture Rocks at Munising to Marquette in Michigan.

These sandstone deposites vary in color from snowy white to a rich brown to a dull red.

From Marquette the outcropping turns southerly skirting the East side of the Wisconsin Dome and entering Wisconsin at a point five miles West of Wausaukee at the Michigan-Wisconsin boarder.

From here it outcrops southerly to Lake Poygan, to the Wisconsin Dells, to Madison thence south easterly to Jamesville near the Illinois-Wisconsin boarder. Between Lake Poygan and Lake Mendota at Madison this outcrop of Cambrian spills westward out of the Michigan Basin; overflows the basin edge and sweeps westward to the banks of the Mississippi in the vicinity of Lacrosse where the Mississippi has knifed deeply into it leaving sharp vertical cliff faces very comparable to those Lake Superior carved cliffs at Picture Rocks.

The Dells and the unglaciated area are also Cambrian. In Wisconsin the Cambrian sandstone varies in color from a honey to a golden color and resembles light brown granular sugar.

In Illinois the Cambrian Sea overflowed the edge of the Michigan Basin and swept southward down into the Illinois Basin. It outcrops only on a fault line running southeasterly between--Flagg and Sandwich (Flagg is 25 miles south of Rockford and Sandwich is 15 miles west of Aurora). The edge of the Michigan Cambrian Basin appears to be headed for Kankakee.

In Indiana the Cambrian Sea continues to slush southerly over the basin edge and down into the Illinois Basin with no outcrops.

In Ohio the Cambrian Sea continues to spill out of the Michigan Basin but this time in an easterly direction towards the Cumberland and Allegheny Basins. The come in Ohio is called the Cincinnati Arch and although the Cambrian bed raises up to it, yet it does not outcrop on it.

In Ontario the Cambrian Sea raises as it approaches the Ontario Dome and should make its appearance between the Trenton-Black river formations of the Ordovician Seas and the Pre-Cambrian Rocks of the Dome. However, it is absent on this westerly contact line and soundings show that its Easterly edge contacts the basement rocks from St. Clair County Northerly under Lake Huron to the Soo. This completes the boundaries of the Cambrian Seas.

The Cambrian Seas facinate the writer more than any other seas. I believe this is due to reverence for its age. It is the oldest sea in which any life appears: Very primitive Algae, Fungi, Bacteria and fossil. Algal reefs were developed. Its name comes from a land division in England called Cambria. The writer has seen this sandstone as a matrix in conglomerates at Porth Caul along the Bristol Channel in South Wales.

It appears as an escarpment at Tahquamenon Falls, at Picture Rocks near Munising, and its contact with earlier metamorphic rock (resting upon it) can be seen along Lake Superior three or four miles north of Marquette. At this location is a conglomerate formed by rock tallus falling off the cliffs into the sea and later becomming recemented into a brecciated rock.

Just north of Iron River is an old abandoned mine shaft. The mine shaft cuts down through the Cambrian Sandstone and metamorphic rock at the line of contact between these two. It is almost like standing upon sacred ground to look at the cross-section exposed by the sloping shaft. Here we can see the basic rock sloping up at about a 75 degree angle with the horizontal bedding of the sandstone butting up against it. This happens not only to be the point of contact between the two but also it is the earliest shoreline of the most ancient sea. The principle sub-seas are: Jacobsville, Dresbach, Trempealeau, Eav Claire, St. Croixan, Potsdam, Mr. Simon and Franconia - all Sandstones.

ORDOVICIAN

The next sea to form in the basin created by the consoliated sediments of the Cambrian sea is called the Ordovician. It has a diameter approximately 25 miles and is composed principally of limestone beds. This sea received its nourishment from the East South and West.

The outcrop in Michigan is a band about 15 miles in width and forms an arc from Neebish Island to Big Bay De Noc with towns of Barbean, Rexford, Newberry, McMillan, Seney, Steuben and Escanaba along its center axis.

This axis can be traced southerly in Wisconsin from Green Bay to Lake Winnebago to Juneau to Jefferson to Sharon near the Wisconsin-Illinois Boundary.

In Illinois it can be traced southerly from Jamesville to Rockford to Sycamore to Wilmington towards Kankakee. This sea also spills over the Michigan Basin southerly into the Illinois Basin.

In Indiana the Ordovician continues to overflow into the Illinois Basin. Only one small outcrop occurs and that in a small arc progressing easterly from Jonesboro to Eaton to Portland, an area 50 miles south of Fort Wayne.

There is a discontinuity in tracing the edge of the Michigan Basin between Indiana and Ohio. However the Ordovician Beds outcrop in southern Ohio in a band 0 to 40 miles wide on the Cincinnati Arch (Dome) from Hamilton to Batavia to Georgetown.

In Ontario the outcropping shows up in a band 30 miles wide from Trenton (Lake Erie) to the south end of Georgian Bay. It is washed out or at least it disapprears in the trough of Georgian Bay and North Channel and appears again on Neebish Island in Michigan.

Much of this limestone bed is very soft and has been eroded both by streams flowing along its outcropping horizontal face or by the quarrying action of glacial ice streams. This action has cut away so much of this bed vertically that the Niagara Cuesta of the next described Silurian formation was created. In some areas this erosion has been so deep as to construct Georgian Bay, North Channel, Big Bay De Noc and Green Bay. If erosion had been more complete in this formation, water would completely circumscribe the Lower Pennisula and we would be living on an island.

Two important sub-seas are the Trenton and the Black River formations.

SILURIAN

The next sea or seas to form in the consolidated sediments of the Ordovician Sea is called the Silurian and is approximately 275 miles in diameter.

NIAGARIAN ESCARPMENT

One very impressive bed of this sea is named the Niagarian with sub-seas of Engadine Dolomite, Manistique Dolomite and Burnt Bluff Limestone. These important beds form what is called a Cuesta or a cliff like face which faces away from the Michigan Basin and is caused by the erosion of beds of softer material along its outer edge. This sea received its nourishment from the East, North and South.

It forms a huge escarpment all the way from Niagara to Hamilton to Collingwood in Ontario. It forms the backbone of the Bruce Pennisula from Owen Sound northerly to Tobermory; the backbone of Manitoulin, Cockburn and Drummond Islands and forms a band 15 miles wide across the Upper Pennisula backbone of the Garden Pennisula with the following towns spotted along its axis: Detour, Ozark, Calspar, Cooks Garden and Fairport.

In Wisconsin this outcrop forms the backbone of Washington Island, the Door Pennisula and borders Lake Michigan in a band 20 miles wide southerly all the way to Chicago. This Cuesta travels nearly to Chicago.

In a band between Juliet and Chicago and Gary, Indiana, it swings southeasterly to Monon where most of our aggregates for Bituminous Concrete are manufactured.

It then swings easterly to Decatur. The Ordovician outcrop from Jonesboro - Eaton - Portland splits the Silurian Formation.

In Ohio this bed moves easterly pinpointed along its axis by the following cities: Van Wert and Delphos; thence northeasterly through Fostoria, Fremont and Port Clinton at the westend of Lake Erie where it disappears into Lake Erie and reappears at the Escarpment at Niagara.

STRAITS OF MACKINAC

Another very important bed in this Silurian Series is the Salina Salt Beds. These beds dissolved out and formed the Straits of Mackinac in the following manner:

DISSOLUTION OF SALT BED

An under gound stream formed in the Salina Salt Bed between the Lake Michigan and Lake Huron Basins, and carried water from one basin to the other. Eventually quite a large bed of salt, up to three hundred feet in thickness and between three and five miles in width was dissolved out.

COLLAPSE OF BEDS

The overlying beds of Mackinac Limestone and Pt. Aux Chenes shales having no reinforcing steel in them and not being a perfect arch failed. These formations collapsed and down warped in a sort of syncline. The various beds maintained their continuity but they were completely broken up by the fall into small brick-like blocks called brecciation. These brick-like parts still remained in the same relationship to each other as they did before the beds became all cracked up.

The brick-like particles eventually became recemented into beds referred to as brecciated limestone or rotten limestone.

The down warping of the Mackinac Limestone can be seen in the rock cut on US-2 or I-75 on the North approaches to the Straits of Mackinac Bridge.

These change from level, laminated beds to as much as 30 degrees of dipping towards the channel.

STRAITS GORGE

This syncline should not be confused with the 350' deep by 3800' wide canyon that swings up through the middle of the Straits and which dictated the span for the suspension bridge between the two sets of towers. The towers straddle this canyon or gorge. This gorge was eroded during the latter part of the Pleistocene era of Lakes Chippewa and Stanley and will be discussed later.

SALINA SALT BED

This salt is mined at Detroit from a 400' bed, pumped from wells; Midland 1700' bed, Ludington from a 600' - 800' bed, Manistee from a 600' - 800' bed. They are 1200 feet thick at Alpena. Lake Michigan is 920 feet deep, Lake Huron is 750 feet deep. It is easy to see how a salt bed varying between 400' and 1700' in thickness if dissolved out could easily create depths that would satisfy these lakes.

Of course there were other contributing factors to the construction of these lakes such as erosion by streams of water and ice in their troughs.

The Salina formation of the Silurian Sea furnishes brine from its mineral beds at St. Clair, Port Huron, Ludington and Manistee. Hot water is pumped down into the bed rock from one pipe. The rock salt is dissolved and forms brine and is returned to the surface by another pipe located 1000' away from the first pipe.

These brines are rich in sodium salts of the Halogen Family: Chlorine (table salt), Iodine, Fluorine and Bromine.

Table salt and rock salt are sometimes the end products of evaporation. Sometimes through mechanical and chemical processes other salts are removed. Through chemical processes the Halogen gases are also separated and used either as gases or are united with other elements to form other compounds.

The brine pumped to the surface at Midland is also Salina and comes from almost inexhaustable sources. The Salina is 1700' high in this location and supplies Dow with base chemicals for many pharmaceutical products and drugs.

The Salina bed is near enough to the surface in the Detroit area so that 1000' shafts can be sunk down to and into the 400' thick bed. This bed is mined in the same manner as coal and metal mineral ores are mined in dry conditions.

DEVONIAN

The Devonian Series of lake beds were formed in the basin created by the solidified sediments of the Silurian Seas. This sea was 300 miles in diameter and has a number of very important beds and received its nourishment from the East.

One of the most interesting beds is the limestone formation at the Straits of Mackinaw called the Mackinac Limestone. This bed was mentioned in the preceeding discussion of the Salina Sub-Sea of the Silurian Seas. This will now be briefly reviewed.

At the Straits it is in a brecciated condition so called from the brick like sharp edged and plain faced particles that are cemented together as opposed to water rounded edges of conglomerate aggregates.

This brecciated condition came about through the following action: A lower bed of Salina salt from the Silurian Sea previously mentioned dissolved out leaving a cavern. The Mackinac limestone formed the ceiling of this cavern and having no steel reinforcement and not being in the shape of a perfect arch, collapsed. Upon falling it kept its same continuity as a bed but cracked up into innumerable small pieces. These pieces through age and limestone cohesive influence became recemented into a low grade limestone.

Another important bed of the Devonian Series is the Sylvania Sandstone which outcrops at Sylvania, Ohio. This is the source of a uniformly, graded, rounded sand called Ottawa which is universally used in making cement - sand bricketts - for testing tensile strengths of cement.

Another very important bed is the Dundee which outcrops at Dundee and Monroe and in the Detroit River Bed and is a very reliable source of oil and gas through out the state.

It also outcrops at Rogers City where the largest limestone quarry in the world exists. This quarry is also termed "Calcite" and is owned by United States Steel and is shipped by Lake freighters - Bradley Fleet also owned by United States Steel. This stone is used for road and concrete aggregates and as a flux in the cleansing and refining of molten iron ore and as ingredient in the manufacture of Portland cement.

Another very important Devonian bed is the Traverse Drift which is divided into four important limestone beds eg. Long Lake, Alpena, Thunder Bay and the Traverse.

There is one other Traverse bed called Bell Shale. This is a very thin bed 15' or more in thickness and is called a tracer formation and is always found between the Long Lake and the underlying Dundee.

The Alpena bed outcrops in the Detroit River Bed and at Alpena and at the Escarpment at Bay View and Petoskey. At the Alpena and Petoskey locations it is in the form of old coral reefs and is quarried and used in the manufacture of Portland cement.

In the manufactor of cement, both Petoskey and Alpena plants use shale to furnish the argillaceous or clay mineral required along with the limestone to form the initial clinker. These are secured from near by shale beds of the Mississippian Seas. Petoskey uses Ellsworth Shale, a shale that comes in pastel colors of blue and green. Alpena uses Antrim Shale, a black-brownish shale.

West and North of Alpena is a Karst region which is not as well developed as the cave areas in Kentucky. Nevertheless, the sinks are present at Lachine, Long Rapids, Fletcher Park and the Narrows. The Narrows is the outlet channel for Long Lake. Most of the sinks are about 50' to 100' in diameter with shear vertical rock walls 75' to 100' deep. These sinks, when plotted, outline an underground river whose ceilings have collapsed at points along its route. This will be discussed more fully in the end of this chapter.

MISSISSIPPIAN

A very colorful sea series is the Mississippian which is 225 miles in diameter. This formed in the basin of the Devonian Beds and received its nourishment from the south.

Black Antrim shales make their appearance on the east shore of Lake Michigan one mile south of Norwood on the north shore of Lake Charlevoix, south shore of the East Arm of Lake Charlevoix (west of Boyne City) at Paxton (7 miles west of Alpena and on Squaw Bay 5 miles south of Alpena.

This shale is black and has crystals of iron pyrites imbedded in sort of bubbles in the laminations. The shale at Paxton furnishes the argillaceous element in the calcarious clinker in the manufacture of Huron Portland cement at Alpena as mentioned earlier in connection with the Devonian - Traverse Beds.

Ellsworth shale outcrops on the west side of the valley leading north to East Jordan. This is colored a pastel blue which upon exposure to the air becomes a pastel green and then a yellow. This shale furnishes the argillacious mineral used in the manufacture of Petoskey cement, as mentioned earlier in connection with the Devonian - Traverse Beds. This shale is correlative with Coldwater shale but not the Coldwater shale and outcrops in the southern part of the State in the vicinity of Coldwater. Both are beautiful shales and impose real problems in road building. Gypsum beds appear as outcrops at National City and Alabaster and are cut from large open quarries at these locations and are mined at Grand Rapids.

Another interesting formation or bed of this sea is the Marshall sandstone used in oramental stone work. This outcrops at Marshall and also at Point Aux Barques on Saginaw Bay in the Thumb region and is called the Thumb Nail of Michigan.

A little east of Point Aux Barques is Grindstone City where this same sandstone was quarried years ago for cutting into grind stones. A 2" to 4" vein of pea gravel in this formation ruined many blocks of stone. The advent of emery, carborundum and aloxite manufactured stones also contributed to the abandoment of this quarry. The bed of a little creek on the east side of the quarry is alive with a coccina formation of fosselized tiny brachiopods called Camerotoechia. These are average between 1/4" and 1/2" in diameter. Another location for these fossils is in the rock escarpment (Ferruginous Sandstone) along the Huron shore at the Huron County Lighthouse Park, two miles east of Huron City.

At Bayport and across Saginaw Bay at Augres are outcrops of a limestone used for ornamental building construction (faces of structures and fireplaces) and for road aggregates.

PENNSYLVANIAN

The Pennsylvanian Seas were the final waters whose sediments completed filling up the basin and received its nourishment from the south - southwest. These were 125 miles in diameter. This occurred during extremely hot tropical weather accompanied by much precipitation. Unusual growth of vegatation persisted which built up peat swamps and peat bags. These were compressed under later sedimentary deposits and became metamorphized and turned into bituminous coal and cannel coal. Michigan had many shallow coal mines in the vicinity of Flint, Saginaw Bay City and Unionville. These were abandoned after World War No. 1.

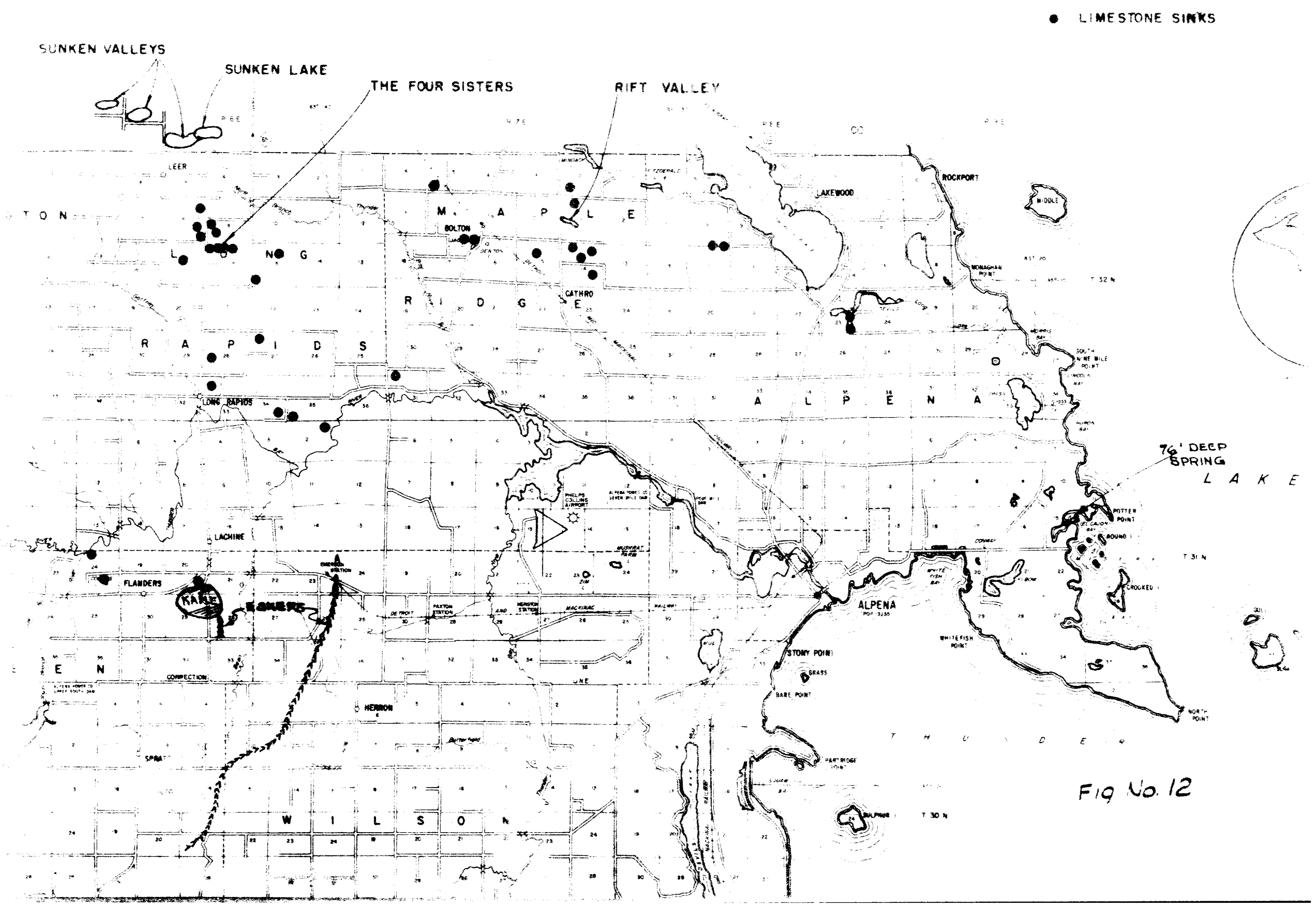
LIMESTONE SINKS
SUNKEN VALLEYS
SUNKEN LAKE
THE FOUR SISTERS
RIFT VALLEY
76' DEEP SPRING
LAKE
M A P L E
R I D G E
L O N G
R A P I D S
A L P E N A
W I L S O N
ROCKPORT
LAKEWOOD
BOLTON
CATHRO
LEER
LONG RAPIDS
LACHINE
FLANDERS
HERRON
ALPENA
STONY POINT
NORTH POINT
WHITEFISH POINT
T 32 N
T 31 N
T 30 N

Fig No. 12

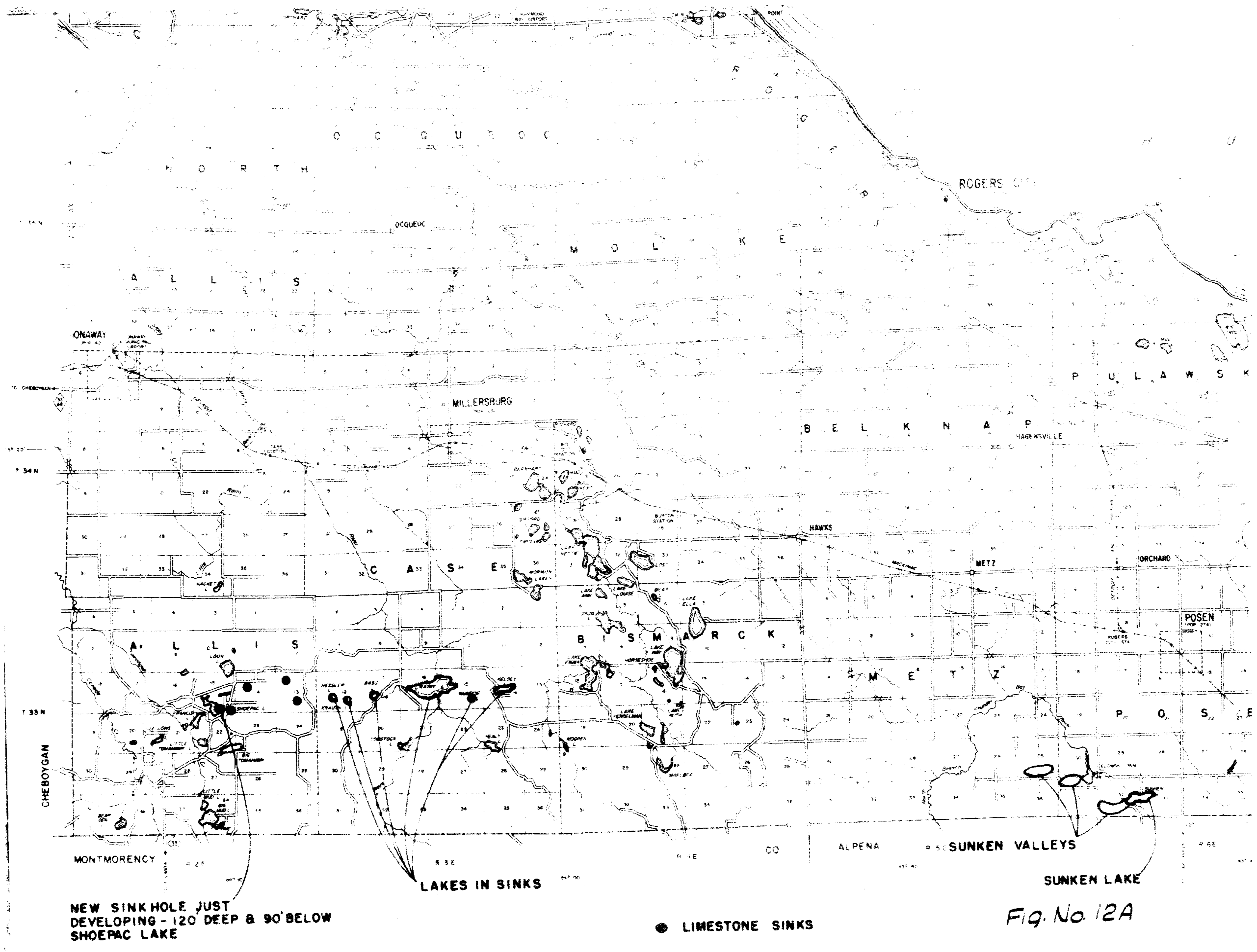
ROGERS CITY
OCQUEOC
NORTH ALLIS
MOLTKE
ONAWAY
MILLERSBURG
PULAWSKI
BELKNAP
HAGENSVILLE
HAWKS
METZ
ORCHARD
CASE
POSEN
ALLIS
BISMARCK
METZ
POSEN
CHEBOYGAN
MONTMORENCY
ALPENA
SUNKEN VALLEYS
SUNKEN LAKE
LAKES IN SINKS
NEW SINKHOLE JUST DEVELOPING - 120' DEEP & 90' BELOW SHOEPAC LAKE
LIMESTONE SINKS

Fig. No. 12A

A sandstone of this sea used a great deal in ornamental stone work is mined at Ionia. This stone is soft and easily cut but after exposure to the air for a short time hardens up and develops sufficient strength to use. It is colored light yellow and has dark reddish veins of oxdized iron giving it a delightful bright color pattern.

This completes the history of the development and the formation of the colorful sedimentary beds of the warm tropical ocean seas in Michigan; or the filling in of the Michigan Basin converting it from a lake to a penninsula. Another contributing factor was a general continental uplift, this raised the basin some 700' above its elevation when fed by ocean waters. This continental uplift is not to be confused with that which later resulted from the retreat of a huge continental glacier.

KARST REGION - ALPENA AND PRESQUE ISLE COUNTIES

32 - Major Limestone Sinks, Three Rift Valleys and Several Sunken Lakes, See Maps

This is a special type of Geological formation found only in a few places in the world eg. Karst Region in Vgoslavia, Limestone Caves in France and Mommoth Cave in Kentucky.

It occures where the limestone beds which were originally formed in water have been uplifted so that they are now elevated above any generally established water table.

The limestone beds now crack into huge rectangular blocks with parallelogram faces.

Atmospheric precipitated rains accumulate on the surface of the bed rock and by gravitational forces flow vertically down the cracks until they meet a horizontal impervious bed of shale. They then move horizontally along the top of this bed.

These streams of water are highly impregnated with Carbon Dioxide from the atmosphere which converts them into a weak acid called Carbonic Acid - not to be confused with carbolic acid, a very strong base (Phenol).

Limestone, Calcite, or Calcium Carbonate is almost insoluble in water. However the carbonic acid converts the limestone into Calcium Bi-Carbonate which is thirty times more soluble and therefore the limestone is very readily dissolved. This creates tunnels, in the limestone immediately above the shale or other impervious horizontal barrier.

When the cavern reaches a certain magnitude regarding shape and diameter, its roof not being a perfect dome or arch and not being reinforced with steel as most other domes and arches are, collapses and the rock immediately above it shears off vertically and falls.

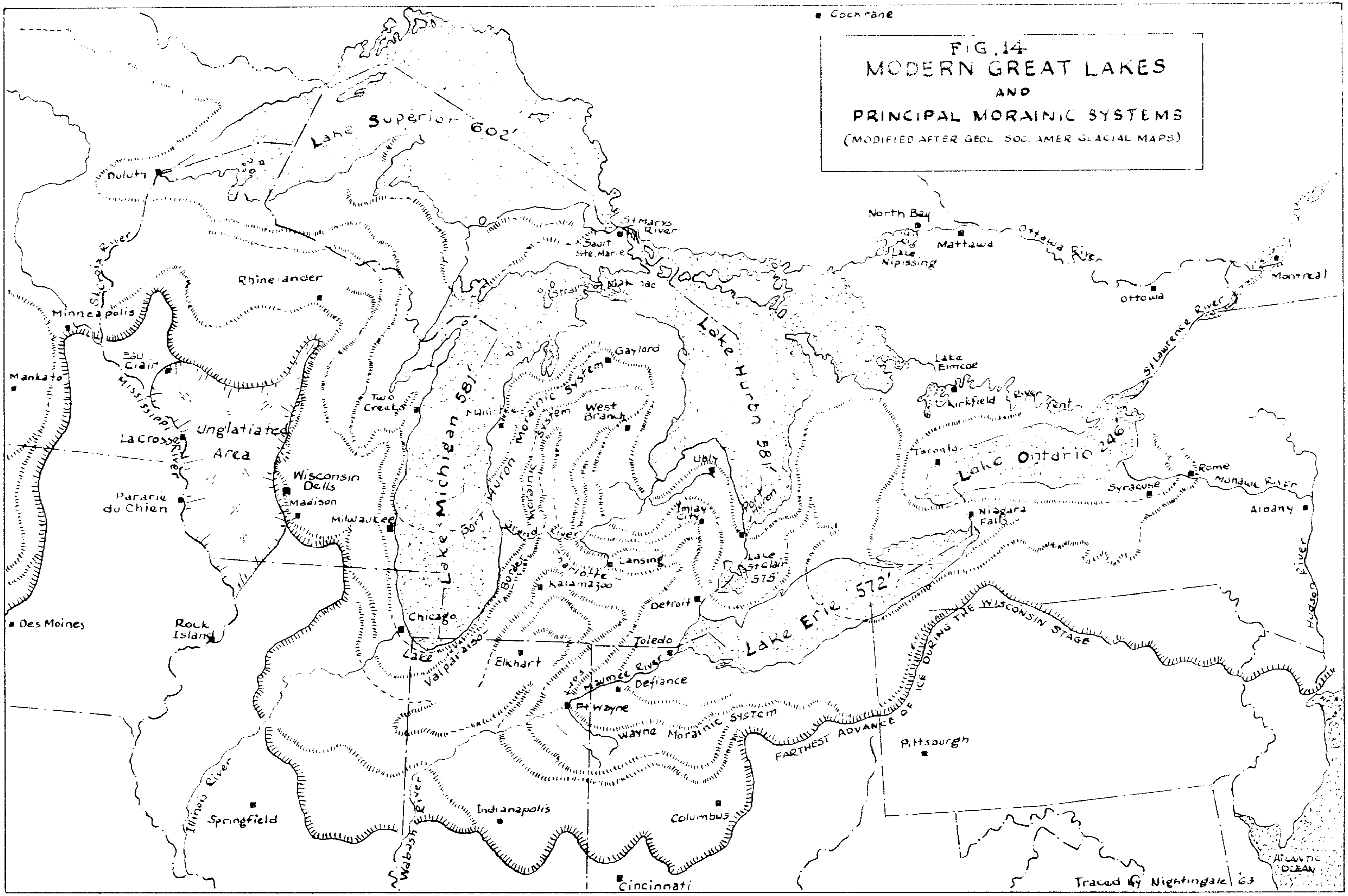

FIG. 14
MODERN GREAT LAKES
AND
PRINCIPAL MORAINIC SYSTEMS
(MODIFIED AFTER GEOL. SOC. AMER. GLACIAL MAPS)

If this occures at a joint in the limestone, a limestone sink, circular in cross-section and with vertical walls will form. Sometimes there is much glacial drift superimposed upon the surface of the bed rock. During the creation of the sink, the glacial drift also falls into the sink giving it an inverted conical shape.

If it occures along a crack, a rift valley will be formed such as at Sunken Lake at Fletchers Park and two valleys to the west of it. A small rift valley occures 2.1 miles north of Cathro and on the east side of the road. Devils Lake, a three armed lake, on Long Lake Creek outlet immediately after it leaves Long Lake is another example of three bed rock cracks forming rift valleys.

Another interesting sink is found in El Cajon Bay (Misery Bay). This occures in very shallow water and is 76 feet deep with water flowing up through it.

Circular sinks vary in size from 50 feet in diameter with or without shear walls depending upon whether or not glacial drift has sluffed into them) and are from 10 feet in diameter to 80 feet deep to the larger ones 500 feet in diameter and 100 feet deep.

The rift valleys vary from 1000 feet in length to one and one half miles in length.

Ten of the most interesting and spectacular sinks are to be found between Long Rapids and Leer. Four very represenative sinks are found by following a small foot trail into a forest. These are about 50 feet in diameter and 80 feet in depth with shear vertical walls of beautiful limestone. These are located about 4 miles north of Long Rapids and on the east side of the road.

Six miles north of Long Rapids is Fletchers Park. The two sinks are at the west end of this long rift valley. A dam has been constructed across the valley cutting it into two parts. An artifical lake is permanently formed in the east end. The west end with the sinks is still an open valley.

Devil's Lake on the outlet to Long Lake has two sinks on its south arm. In the summer of 1938 the writer observed these two inverted conical sinks obsorbing a 1' x 2' outlet stream from Long Lake. Devil's Lake that summer had completely dried up. Ordinarily the outlet is easterly into Lake Huron via Long Lake Creek.

Great cracks, some 20 feet in depth, have formed at Misery Bay, Firzgerald Lake and Sunken Lake. Please refer to maps.

PLEISTOCENE GLACIATION

Down from the north swept a series of glacial ice invasions. The first ice sheets removed most of the unconsolidated mud beds from the Michigan Basin and deposited them as heavy glacial till in the states south of us. The later ice sheets picked up glacial drift from the disintegration of the granite and basalts of the igneous mountains of the Canadian Shield. These were brought down and plastered over the Michigan Basin, building it high above its sedimentary lake bed elevation.

This radical change in conditions from tropical to frigid weather isn't too hard to visulize inasmuch as a mean change in temperature of 9 degrees here in Michigan would cause a state of refrigeration. This is what would happen:

An accumulation of presumably ten feet of snow would fall during the winter. Nine feet and eleven inches would melt during the following summer. No vegetation or crops would grow and we would immediately have a state of starvation. There would be a mass migration of people to the south who might meet with resistance from southern people and a war would result. The next year ten feet of snow would fall and only nine feet and eleven inches of it would again melt. We would then have a minimum accumulation of 2" of snow at the end of the year. This accumulation would first fill the valleys forming valley glaciers. The valley glaciers would merge together to constitute a continental ice sheet. When the ice became between six hundred feet to two miles in height it would begin to squeeze out like the batter of a pan cake mix or the tar from a leaking barrel.

LABRADOR GLACIER Fig. 14

The most plausable theory advanced so far for the creation and extinction of the four continental ice sheets, (Nebraskan, Kansan, Illinoin and the Wisconsin) is as follows:

The ice sheet flowing across Michigan had its source of accumulation east of the Hudson Bay Region. This accumulation center had to have a source of nourishment. This came from an open sea from the Bearing Straits on the west between Russia and Alaska, easterly through the Davis Strait between Greenland and Baffin Island of Canada.

The warm Japanese current flowing up from the tropics in the Pacific Ocean past Japan, the Aleutian Island, through the Bearing Strait, across the Polar Seas and out into the Atlantic Ocean via the Davis Strait, kept this Polar Sea open as long as the drainage course was continous and allowed the Japanese current to flow.

Prevailing westerly and northerly winds passing over the open Polar Sea picked up moisture and carried it southerly. When these moisture ladened winds began crossing the northern part of Continental Canada, they were met by winds of sub-zero temperatures and precipitated their moisture as snow.

This continued and eventually great concentrations of snow were deposited. The weight of the snow compressed the underlying snow into ice. The ice was brittle and fractionable and solid at first but as the accumulation became higher and higher the pressure on the lowest portion became greater and greater until this tremendous pressure changed the physical charactor of this Basel Ice from a solid into a plastic, flowing state. The ice sheet then began to move southerly.

When this one to two mile in height sheet of ice had moved southerly to the margins of the Ohio and Missouri Rivers, over half the continent of North America had ice two to three miles in thickness covering it. Consider that this was also happening in South America, Europe and Asia.

These large ice sheets had removed large volumes of water from the oceans, therefore their level fell about two hundred feet.

A sill of rock between Iceland and Europe normally lies at two hundred feet below the ocean's level. This was the lowest sort of weir over which the warm Japanese current could escape from the Polar Sea.

When the ocean's level dropped to the level of this sill, the Japanese current was trapped in the Polar Sea. It couldn't flow; became stagnant; froze over; and therefore cut off the moisture necessary to nourish the ice sheets.

The ice sheet was starved for lack of snow and began to retreat northerly.

This moving front (if it is two miles in height) would have a bearing pressure of 260 tons per square foot. Considering that the best of soils will fail and start to flow at 10 tons per square foot, -- we now have an unbalanced condition in which something would have to give. The ice itself has a strength of 144 tons per square foot before fracturing or becoming plastic. Therefore, the lower ice being under a stress of 260 tons per square foot is plastic and amorphous and resembles axle grease, soap or candle wax. Therefore, this state of plasticity must not be thought of as being soft like a sponge rubber ball but very hard and rock like similar to glass under pressure.

The ice front acts like a huge giant bulldozer kicking up much of the loose weathered rock in front of it, displacing it like the surcharged sand nose of a fill displaces peat as it moves across a swamp.

Now this varying front is less than 2 miles in ehight. Instead of maintaining a sharp cutting vertical edge like a grader blade, it is curved up to some extent. Although it pushes soil in front of it, yet its sleigh like runner or shoe rides over part of the soil which is later either quarried and picked up as basel drift or it acts as a lubricant for the ice, rolling along to some extent with the glacier.

The upper part of the sedimentary filled ocean lake beds were seas of mud and soft while their lower depths had turned to stone because of the above pressure. The Wisconsin Ice Sheet used this mud as a lubricant, greasing its skidway. Some of this material moved along under the glacier as basel till and did not move but relatively short distance - something like under 50 miles. This to be true for Devonian fossels from Petoskey region. There are very concentrated in the till south of Petoskey up to a distance of some 50 miles and then they die out almost entirely.

A few of the Petoskey stones are found up to several hundred miles away from their source. This is due to the fact that some basel drift is literally jetted up through fishers and vertical cracks in the ice up into the upper region of the ice by the tremendous hydrostatic pressure and there they become super-glacial till.

Because of the excessive pressures of the ice sheet, something like 150 to 260 tons per square foot, some of this basel till became quite indurated and almost like rock before the ice sheet left it.

With the complete disappearance of the ice, the super glacial till rested upon the basel till creating a heavy till that had moved some 50 miles with a capping of superglacial till that has moved several hundred miles.

The Wisconsin Ice Sheet followed the Illinoian Ice Sheet and pounded, packed and compressed the original Illinoian Till in place and made it a little more dense. It seems to me that the Illinoian Till was rolled out like pastry under a big rolling pin above the original Nebraskan Ice Sheet, and beneath the Wisconsin Ice Sheet.

The ice sheets built up their concentrations of glacial drift principally during their northern retreat. The sandy moraines and the till plains were constructed from the same basel and superglacial drift or material that they had gathered up north and accumulated during their passage south.

The difference in the materials in the various formations is due to the amount of sorting action by water and this depends entirely upon the amount of water used. The water was in direct relationship to the amount of ice melted. The formation of a moraine can be best illustrated by an elevated belt conveyor which moves backwards toward its source of supply. If it moves slowly, the stockpile formed will be high and large; if it moves rapidly it will just dribble material in a thin path behind it.

MORAINE

It works the same way with a glacier. If the front stands almost stationary and retreats very slowly, the ice front is almost in a state of equilibrium. This means that forward movement of the front actuated by the pressure at the ice center up in the Hudson Bay Region is almost equal to the eating off of this face by melting. Therefore, a tremendous amount of drift is deposited in front of its face and a large amount of ice is melted, creating a great volume of water.

This water will separate the granular material from the clays, carrying away the clays in a suspended condition. Some of the granular material will be deposited in front of the moraine in the form of an outwash plains. This granular material will be segregated and deposited according to the velocity of the outwash flood waters. Heavy boulders will first be dropped as the velocity decreases, next to be dropped will be the gravels, then the sands.

The clays supported in colloidal suspension will be the last part of the load to be released and they will be deposited in a lake where the water's velocity is zero.

Let us get back to the block of ice moving up to the ice face, there to be melted off. The face, in retreating two or three miles, may melt up a block of ice a thousand miles in longitudinal depth that has moved up to it. This may take an interval of sereral hundred years. This was the way the huge Kalamazoo and West Branch moraines were formed.

TILL PLAIN OR GROUND MORAINE

When the climate next changes and there is more heat present, the ice face may melt off an area ten miles in width in its backward retreat in just a few years. The block of ice in this area may be completely stagnate or nourished by only a slowly moving ice mass. In either case the ice block melts vertically down and becomes like honeycombed ice upon a lake in the spring. Its small load is also dropped vertically and since there is very little water action or sorting, this drift remains a heavy clay or sandy clay. This land form is low in relief in comparison to the big sandy moraines; is gently rolling; is called a till plain (farming country) or a ground moraine.

MORAINE

Let us again return to the Big Granular Moraine. This was formed from a discharge from the face of the glacier similar to the discharge from a conveyor belt. The materials are not segregated and they are piled up promiscuously. The great volume of water removed much of the clay with the outwash waters. However, large clay boulders 50' to 100' in diameter are dropped off this belt into the mass of debris being built up. These clay boulders are frozen, and before they can be completely melted, they become buried in granular material. This is the reason why moraines, although typically granular, will have pockets of clay in them.

We have seen the development of the large sandy moraines when the ice front was in a state of equilibrium and the ice face melted off as fast as it advanced, and the Ground Moraines or Till Plains when the retreat was so rapid that it left large blocks of stagnate ice to literally melt and die in their own footsteps.

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off as fast as it advanced, and the Ground Moraines or Till Plains when the retreat was so rapid that it left large blocks of stagnate ice to literally melt and die in their own footsteps.

OUTWASH PLAINS

The retreat of the ice sheet was a series of stops or hesitations followed by backward movements; building up massive walls and fortifications of granular soils with low lying, gently rolling clay plains between them. Sometimes the ice front would remain so long constructing a moraine that the discharge waters from it would carry enough sandy outwash over the adjacent Till Plain tq completely submerge it in sand, filling in the small depressions, and plastering sandy material over the whole clay foundation structure; creating an outwash plain.

Outwash plains with thin smears of sand over a clay till cause a Soils Engineer a great amount of anxiety while the thick granular outwash plains are a pleasure to work with because of their freedom from knobs of clay, wilt pockets and seepage.

DISCHARGE GLACIAL RIVERS

The outwash water usually collected in the trough of till or outwash (or combination of these two) between two majestic moraines flowed longitudinally along them until it found an opening in the outside moraine and a change to escape. The glacial rivers literally were flooded Amazon rivers during glaciation, particularly those emptying into the Lake Michigan Area. If you examine those drainage courses of the Kalamazoo, Grand, Muskegon, Pere Marquette, Manistee, and the Betsie you will see where torrents of water cut passageways 50' to 100' deep and one half to one mile wide through the existing drift to carry their billions of cubic acres of glacial melt waters to Chicago and to the Mississippi River.

The sight of these old spillways demands awe and respect of the writer. Just imagine the volume of roaring, seething water, and the billions of unharnessed horsepower. It gives one an idea of the magnitude of Noah's problems.

OUTWASH PLAINS

Returning to the outwash plains it can be said that deep outwash plains are a joy to the road builder. These plains are sometimes the source of large deposites of gravel.

A good example of an excellent outwash plain is located along US-131 between Kalkaska and the Elmira Hill. This narrow plain containing thick beds of Rubicon, Kalkaska and Mancelona Series Sands lies between a very, high, formidable moraine on the east called the Outer Ridge of the Port Huron Moraine and a much lower appearing ridge on the left called the Inner Ridge of the Port Huron Moraine.

This latter morainic structure although of low relief when approaching it from the east is actually supporting the outwash or holding it well above the adjacient lake plain country to the west. The west slope of this moraine is very rough, and stands out in relief much as does the west slope of the outer ridge. It actually rises some 500 or more feet above the Algonquin Lake Plain at its base.

Another beautiful outwash plain lies adjacent to US-10 and on both sides of the Muskegon River from Evart West to Reed City with a huge gravel deposite at Hersey.

A very interesting outwash plain is the commerce-Drayton Plains-Oxford Plain with a Northeast-Southwest Axis.

This plain is in an interlobate morainic area. The Huron Ice Lobe constructed the wall on the Northeast, (Hadley-Metamora-Romeo Moraine). The Saginaw Ice Lobe constructed the Morainic wall on the Northwest, (The Portland-Lansing Ortonville Moraine). The Erie Ice Lobe constructed the Moranic Wall on the Southeast (Outer ridge of the Defiance Moraine).

This was the site of the collection of tremendous volumes of melt water which sorted out the drift and left only the sands, gravels, cobbles and boulders. This is a good source of gravel products.

This outwash plain can be divided into three major areas each of which secured it's drift from one of the ice lobes.

The Southern most area is in the vicinity of commerce and has a definite downward slope in a Northwesterly direction indicating that it was hourished by melt waters flowing off the defiance moraine.

The intermediate area is in the vicinity of Drayton Plains and has a negative grade in a southeasterly direction indicating that it received its nourishment from melt waters flowing off the Portland-Lansing-Ortonville Moraine.

The Northern area is in the vicinity and south of oxford and tilts downward to the southwest indicating that it received its nourishment from melt waters flowing off the Hadley-Metamora-Romeo Moraine.

VALLEY TRAINS

Valley trains are usually narrow, glacial river drainage courses hemmed in my very high, steep, sloped moraines. All the melt waters are confined in this narrow flume or channel. The small cross section creates swift velocities in the melt waters and this results again in great sorting action or segregation of the various particle sizes. This action almost elliminates altogether the clays and silts leaving a braided valley train composed of sands, gravels, cobbles and and boulders. These valleys are good sources of base gravel for manufacturing aggregates.

Such a valley lies between the inner and outer ridges of the deviance moraine. Large lobes of gravel are located in this valley just south of Northville and two miles Northeast of Bloomfield Hills.

RIVER TERRACES

All existing rivers that lie in outwash plains between two morainic walls and which during glaciation carried away melt waters, today occupy drainage channels which are only a fraction of the size of the original drainage ways.

Many of these now smaller rivers have by erosion or down-cutting knifed deeply into the original river basin.

A good example of this stream retrenchment is to be found in the Glacial Outwash Plain and Glacial Manistee River Basin located between five and six miles North of Manton on US-131.

North of the present river are four river terraces that step upward to the north. These indicate the various stages of the river from a width of over a mile during glaciation activity down to only a hundred feet in width and occupied by the river today.

As the nourishment for the river decreased, the river became smaller and cut down in the older, wider, river basin a channel only large enough to accommodate its volume at that particular time. There are four older channels visible above the present river making a total of five river stages.

Another good example of this stream retrenchment can be seen in traveling Northeast on US-131 between Kalkaska and Mancelona.

In this case we are crossing the Glacial River on a long diagonal and dropping at the same time down over three escarpments. Each escarpment is an Easterly retaining wall or bank of the Glacial River which flowed Southwest down this Outwash Plain.

Immediately after crossing the third escarpment look over to the West and one can see the final river basin which is less than two hundred feet wide and is dry today. This is a stream retrenchment of four stages.

A dry Glacial River Channel of only 200 feet in width crosses M-88 North of the Cemetary at the West Village Limits of Mancelona.

FROZEN RIVERS AND ICE RAFTS

Five hundred feet East of US-131 at the South Village Limits of Mancelona lies a valley which is cut 100 feet deep in this Outwash Plain and 300 feet wide, and which runs South for a half mile. It also runs Northeast toward the Village water tower in a series of pot holds. From the water tower it can be traced by small, deep valleys, small, lime lakes and pot holes for a distance of twelve miles Northeast almost to Elmira.

This outlines or traces an extinct glacial river which actually froze solid during an exceptionally cold weather cycle. When there was a resumption of glacial activity and melt waters again collected on the outwash plain, they formed another river channel for their discharge. The old frozen river eventually melted and left these traces of its existance.

KAMES

Kames are generally formed of very granular materials eg. sands, gravels, cobbles and boulders. They are excellent sources of base gravel for the manufacture of aggregates; for subbase, for backfill for peat marshes and for grade raises through high watertable soils.

They take two Geometric Forms; a cone and a semi-sphere kamic cones are formed on either the outer or frontal face or on the inner or retreating face of a moraine. They appear to be formed by streams flowing off the top surface of the ice sheet at an indented "V"-s in its vertical face and look like the cones in the borrom section of hour glasses.

Good examples of these are located North of Old M-72 between one and two miles East of the railroad crossing at Barker Creek; along the inner face of the Port Huron Moraine at its contact with the Algonquin Lake Plain, East and South of Rapid City; and along the North face of the Port Huron Out-lyer Moraine along M-75 from Boyne Falls West to Boyne City.

Kamic Semi-spheres are formed on till plains, and are also formed by streams flowing along the top of the glacier. These streams find a vertical passage-way in the ice at the intersection of two vertical cracks. The movement of the melt waters downward takes a rotating or whirl-pool motion and constructs a half sphere as it deposites its thoroughly water washed and sorted materials. As the central mass is deposited and built up more ice is melted and worn away by the streams action between this mass and the adjacent ice, thereby making more room available for the enlarging of the half sphere.

A good example of this is the Kame just South of the junction of M-32 and M-65 at Lachine between Hillman and Alpena.

ESKERS

Another structural formation closely related to the Kame is the Esker and it is also formed on a Till Plain in the shape of a long, winding hill. This is formed in two ways and both from granular drift carried and deposited by melt waters of a stagnant block of ice. The ridges are parallel to the direction of the ice movement but opposite in activity and in direction to its retreat.

1. Melt waters from the surface of the stagnant block of ice flow vertically downward along cracks in the ice and deposite their load on the till plain floor being formed.

2. Melt waters from the surface of the ice find a vertical funnel in the ice and flow vertically down to the till floor. They then flow foreward under the ice towards the recently formed moraine. They wash and melt away the ice above and about them and deposite drift in this tunnel under the ice. This creates a snake or serpentine shaped hill sometimes called a hogs-back.

The material is predominately granular and can vary from gravels to coarse sands to silts and will sometimes have mud flows of sandy clays and clays.

Good examples can be found principally South of Old US-16 between Lansing and Howell on the till plain between the Lansing and the Charlotte Moraines.

DRUMLINS

Drumlins are long cigar shaped hills formed from till plains by the re-advance of the ice sheet over the recently deposited glacial till. The till plain or ground moraine is plowed up into longitudinal hills with their axis all parallel to each other and in the direction of the movement of the ice. They vary from 1000 feet to two miles in length. They generally have smooth barrel shaped sides.

Excellent examples of drumlins can be seen along a band 4 to ten miles wide along the Lake Michigan shore in Antrim and Charlevoix Counties and West of Leelanau Lake and North of Suttons Bay in Leelanau County. They are full of crushed rock which is embedded in a Matrix of pink sandy loam. This Matrix will sometimes vary from loamy sand to sandy loam to sandy clay.

Another location is along Old US-2 between Kinross and the Soo. This drumlin field is almost totally submerged or drowned in a 40 feet to 85 feet bed of Lacustrian Lake Clay of post glacial lake Algonquin when Lakes, Michigan, Huron and Superior were confluent.

The drumlins in this field have only their backs protruding above the sea of clay. They look like submarines that are surfacing or fish that are swimming in too shallow water with backs and dorsel fin exposed. Incidently this lacustrian clay is 6-% to 70% moisture and similar in fluidty or viscosity to toothpaste. Ordinary clay found on till plains has a natural moisture content of 15% to 18%.

Another very interesting drumlin is located on M-204, 0.7 mile East of the Bridge at Lake Leelanau Village.

A four hundred foot long face is exposed along its left side or flank.

From the floor of the valley up to a height of approximately twenty feet the texture is a pink, loamy sandy till suturated with crushed limestone cobbles from 1/2" to 4" in diameter. This core would fit the "C" horizon for an Onaway Series Soil.

This indicates that this part of the drumlin was formed from a ground moraine.

Resting upon the till plain is a four to five foot thick bed of nested cobbles and boulders embedded in a matrix of gravel. The cobbles and boulders vary from 6" to 18" in diameter.

This indicates that there was a resumption of very great glacial activity; that outwash waters were traveling at great vellocities, that only the heaviest and largest sized drift particles were deposited at this location; and that there was a great amount of sorting action.

Resting upon this boulder bed is a seven foot bed of intermittant minor beds of varved silts and varved clays.

This now indicates that there was an ice block across the neck of the valley to the south which took the form of a dam and ponded the melt waters in this area above the plain. This was a lake stage.

The varving of the silts and clays is the deposition of alternate thin layers of different sized and colored particles in lenses. These thin layers are similar to the annual growth on a tree. Spring freshets will bring more silts and large particles of clay than quieter flowing streams will transport in the winter. Varved lacustrian clay has no grittyness and if placed between ones teeth, feels like wax. These flows with different velocities carry clays and silts in suspension of variable size and color and as stated above, deposite them in thin lenses. The composite section of these lenses is said to be varved.

A one to three foot bed of gravel surmounts the bed of varved clay and silt indicating that glacial activity had started again.

The final twenty to thirty foot top layer is composed of outwash sands placed in more or less a braided pattern. This also indicates great glacial activity but again with reduced velocities.

The final act was the surging foreward of the recently received ice sheet plowing up this heterogenious drift into a geometrically shaped drumlin.

GLACIAL AND POST LAKE BEDS

Glacial and post glacial lake beds are to be found all around the perimiter of the Lower Penninsula in the form of small and large embayments eg., a twelve mile embayment exists inland between South Haven and Muskegon; an embayment between Ludington and Manistee extends inland as far as Scottville, Free Soil and Filer City in these areas; an embayment from Petoskey to Rogers City sweeps northward to Mackinaw City and Northeasterly to Lake Michigan.

The larger embayments include, Saginaw Bay which extends to National City-West Branch-Gladwin-Mount Pleasant-Ithaca-Elsie-Pine Run and Vassar. Lake Maumee extended South and Westerly from Port Huron-Romeo-Rochester-Birmingham-Plymouth-Ypsilanti-Adrain to Fort Wayne, Indiana.

BEACH RIDGES

These Lake Plains are very flat and broad without any relief except Beach Ridges of gravel and sand perched upon them. Various lakes invaded these plains and established their shore-lines in the form of these Beach Ridges.

These Beach Ridges are sometimes the only source of granular material for road building that can be found in the larger embayments for many miles. They are also good sources of base material for the manufactor of aggregates.

Post glacial Lakes Algonquin and Nipissing have built strong Beach Ridges along the Northern shore of Leelanau County and the Lake Michigan shore of Antrim, Charlevoix and Emmet Counties.

These beaches are almost 90% round particles that vary from the size of golf balls to base balls and which are almost entirely limestone and which belong to the Alpena series soils.

These Beach Ridges vary from 5 feet to 10 feet in height and are between 100 feet and 300 feet in width. They look like huge contour lines curving back and forth upon the lake beds.

STORM BEACHES

Storm Beaches are constructed similar to Beach Ridges but usually occur on points of land jutting out into the lake in a Northerly and Northwesterly direction facing the predominate winds across a large expanse of water. This Northerly exposure and wide lake area are conditions which create very extensive and strong wave action.

These beaches are composed of a small amount of sand and large quantities or rounded particles of limestone varying in size from golf balls to base balls to foot balls. The soil series is either Alpena, Mancelona or Rodman.

These beaches are from 1000 feet to 2000 feet in width and from 10 feet to 20 feet high.

Good examples are located at Levering in Emmet County and between Northport Point and Lighthouse Point in Leelanau County.

ICE RAMPARTS

Ice ramparts are usually formed along existing shorelines of the Great Lakes where the lake floor is a outcrop of limestone bedrock.

The upper two or three feet of the bedrock becomes cracked and jointed in rectangular geometric patterns; becomes weathered and breaks up into smaller angular fragments. These smaller particles on the sea floor in shallow waters become frozen in the bottom of the ice. The one eleventh volumetric expansion of the water is being converted to ice moves the ice sheet shoreward. These fragmets of limestone which are figurativelly quarried from the bed rock are moved shoreward year after year.

This sliding action grinds the fragments against the bed rock and makes them flat like slate or shingles. Eventually they reach the beach where they are pushed together and pilled up in wind rows 10 feet to 25 feet wide and 3 feet to 6 feet high in sort of small beach ridges.

These fragments are now quite small and flat eg., 1/2" to 2" long on an oval face and 1/4" to 1/2" thick. There is no sand matrix to speak of.

Good examples of ice ramparts exist at Light House Point park on the far Northerly point of Leelanau County; along the Lake Michigan shore South of the City of Charlevoix; along the North beach at Mackinaw City, and on the North shore of Mackinaw Island.

CLIFF-CUT SHORELINES AND LAKE TERRACES

Another very interesting glacial and post glacial structure closely associated with melt waters of ice sheets are cliff-cut shore-lines and lake terraces cut into existing moraines, till plains and drumlin fields by wave action.

Excellent examples of these features were created by post glacial lakes Algonquin and Nipissing. These lakes existed when Lakes Michigan, Huron and Superior were confluent or all one giant inland lake. They carved and etched their shore lines in the form of contact beaches and broad, flat lake terraces in the drift structures boardering today's great lakes.

These two lake terraces are parallel to each other and are 25 feet and 15 feet respectivelly above the present elevation of Lake Michigan from Arcadia South to Chicago and thence North to Sturgeon Bay. They are in the same relationship to each other and at these same elevations above Lake Huron from Forestville North to Port Huron South to Algonac and thence North along the Canadian Shore to Grand Bend North of Kettle Point.

These are beautiful terraces and resemble giant steps ascending up from the present great lakes. These terraces are wide and strong on points of land jutting Northerly into the existing great lakes due to exposure to severe wave action whipped up by prevailing Northerly winds. In these areas these points of land have profiles resembling alligators floating on the waters.

A beautiful Nipissing Lake terrace is cut into limestone from Mackinaw City South two miles to its shoreline at the base of a steep escarpment. The Algonquin Lake terrace cut in limestone works inland from the top of this scarp as far as two miles South of Carp Lake. It is a beautiful Lake Plain.

Excellent examples of both lake terraces can be seen along both shores of Old Mission Penninsula above Traverse City.

M-22 rests upon a 200 feet to 300 feet wide Nipissing terrace with an escarpment to the West and an Algonquin Sea Floor perched above it from Traverse City North to Suttons Bay. Both terraces exist from Norwood North Charlevoix and thence East to Petoskey.

M-66 from the Loeb Farm North to Charlevoix rides along a narrow Algonquin terrace from a very wide Nipissing terrace .

The City of Charlevoix rests upon both these very broad definite terraces. Part of the City of Petoskey also rests upon these two terraces. Also these shorelines and terraces in much of this area are cut into coral reefs of the Little Traverse Limestone bed of the Devonian Paleozoic Sea. This is very perceptible from the business section North to Bayview.

Incidently this same limestone coral reef outcrops also at Alpena and in the Detroit River Bed.

US-31 from Bayshore East to Petoskey rides along a beautiful 200 foot to 500 foot wide algonquin terrace notched into a drumlin field to the south 125 feet above and overlooking beautiful Little Traverse Bay. The high plain in the City of Charlevoix on both sides of Pine River and Pine Lake is also 125 feet above the elevation of Lake Michigan. Bear in mind that this same lake terrace is only 25 feet above the elevation of Lake Michigan at Arcadia. This brings us to another geological wonder and fact-continental-uplift.

CONTINENTAL UP-LIFT

A Continental ice sheet or granular two miles in Height creats a load at its base of 250-tons per square foot. This amount to 11,000,000 tons per acre of countryside.

This tremendous pressure acts upon the surface of the continent in the same way that an earth surcharge placed during the construction of a road above the surface of a swamp. The underlying earth is compressed or displaced resulting in down-warping. This down warped surface becomes greater as the center of the ice accumulation is approached. In our case this ice center was in Labrador.

The ice sheet eventually melted or retreated to its center with the removal of this huge ice load the areas that were depressed began to slowly rise to their former elevations. This quality of elasticity or resilience is usually thought of as applying only to certain metals. However, in this case it also applies also to our underlying beds of rock.

HINGE LINE

Down warped areas are always in contact with areas that are not depressed. The line of contact between two such areas is called a hinge line when the depressed area begins to rebound upward to its original elevation.

We have had several minor hinge lines across Michigan. However, the most important one is diagonally across the state from Arcadia South of Frankfort to Forestville in the Thumb Area North to Port Huron.

POST GLACIAL LAKE ALGONQUIN

As has been previously stated, Post Glacial Lake Algonquin occured about 10,000 years ago and has an established shore line elevation 25 feet above Lakes Michigan and Huron, South of this line. However due to continental up-lift this same shoreline is now 125 feet above the elevation of Lake Michigan at Petoskey and Charlevoix showing an up-lift of 100 feet.

This same shore line has an up-lift of 200 feet at Cheboygan and Mackinaw Island; 290 feet at Grand Marais; 335 feet at Munising and 417 feet on Manitoulin Island. This continental up-lift is fantastic.

Post glacial Lake Nipissing occurred about 3000 years ago after much of the continental up-lift had taken place, therefore, even though its established shore line elevation south of the hinge line is 15 feet above Lake Michigan as compared with that of Post Glacial Lake Algonquin at 25 feet above Lake Michigan, yet its up-lift of Lake Algonquin. eg. up-lift at Petoskey is 20 feet; at Mackinaw Island 33 feet; at Grand Marais 30 feet; at Munising 45 feet.

Continental uplift also sealed off the south flowing AuTrain White Fish drainage way which was transporting Lake Superior waters into Lake Michigan, this drainage way then separated into two rivers flowing in opposite directions.

Continental uplift also blocked off the southwesterly flowing Tahquamenon Manistique drainage way which carried Lake Superior waters into Lake Michigan, this drainage way likewise separated into two rivers in opposite directions.

Continental uplift increased the length and gradient of south flowing rivers in the Upper Penninsula increasing their velocities, vivaciousness and activity. It shortened the length and decreased the gradient of north flowing streams making them slow and sluggish in activity.

SAND DUNES

Sand dunes are very recently developed land forms. It will be noted that these occure in their greatest relief on the easterly shores of the Great Lakes and on the southeast shore of Saginaw Bay.

The reason for this is that the prevailing winds are from the west and northwest and that they received sand nourishment from dry sand bars existant at that particular time in great lake basins which had water-tables 350 feet or more lower than they are today. These sand ladened winds transported the sand shoreward and eventually deposited them on what is today dryland.

These dunes vary in thickness of from 25 feet to 200 feet and are perched upon post glacial lake beds, outwash plains, till plains and moraines.

Sleeping Bear Dunes are 200 feet of dune resting upon a 150 foot ground moraine.

The dunes that circle the east end of Little Traverse Bay at Petoskey and that sealed off the west end of the Cheboygan-Mullett Lake-Burt Lake-Crooked Lake-Petoskey Glacial and Post Glacial Drainage course are between 100 and 150 feet high.

High sand dunes occure between Ludington and Manistee. North of both of these cities are dunes that are sources of core sand used in the foundaries in Detroit and Chicago. Train loads are removed from North of Ludington and ship loads from Manistee.

Large dune areas exist from Muskegon North 15 miles, Muskegon South 10 miles, Macatawa North 10 miles, South Haven South 15 miles, and from St. Joseph through Gary, Indiana and almost to Chicago.

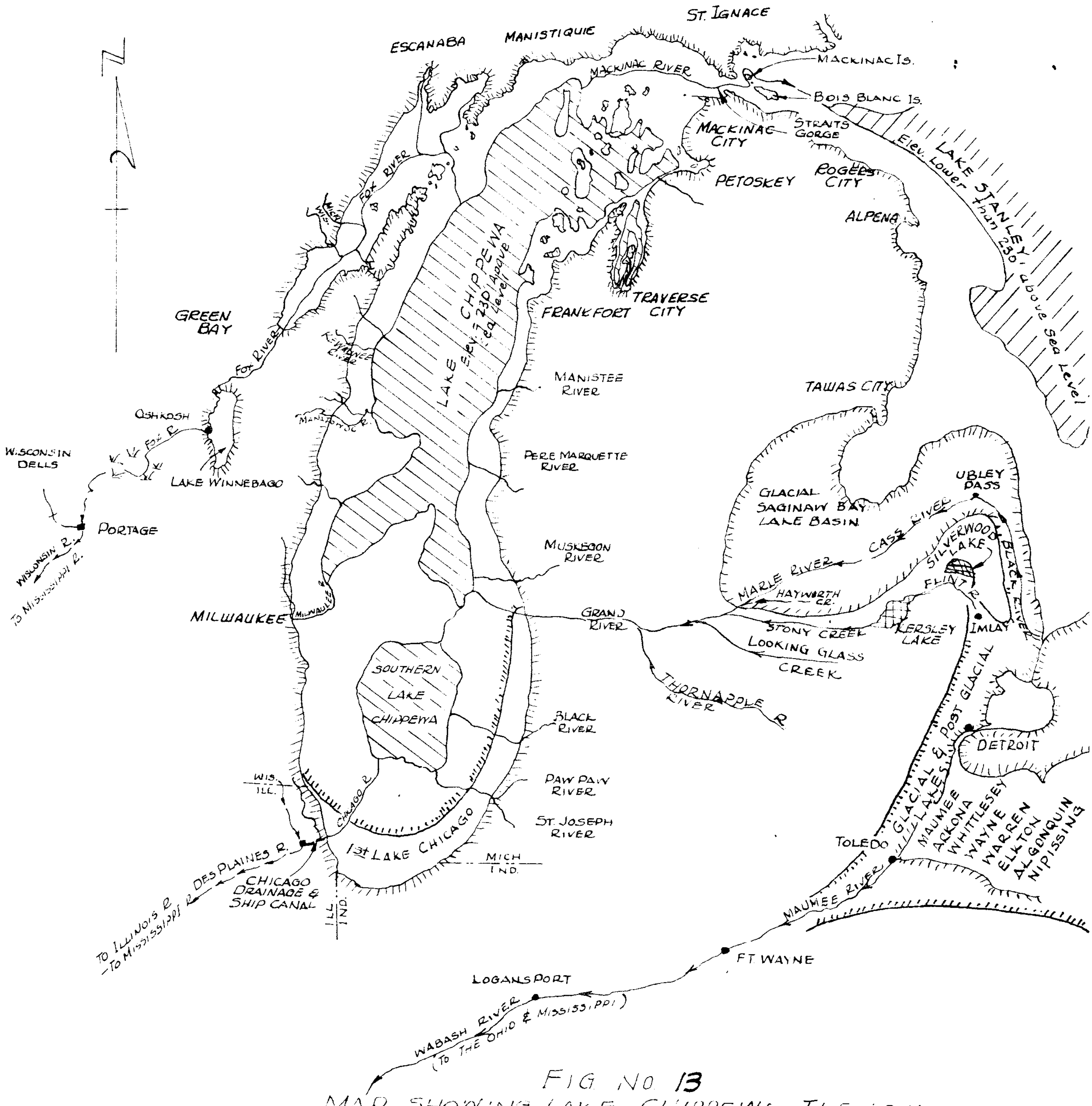


FIG. NO. 13
MAP SHOWING LAKE CHIPPEWA, THE LOW STAGE IN THE LAKE MICHIGAN BASIN BETWEEN THE ALGONQUIN AND NIPISSING STAGES ALSO VARIOUS GLACIAL DRAINAGE COURSES.

They also occure from Port Austin southwesterly to Sevewaing on the south shore of Saginaw Bay.

These sands are clean, of uniform size, with rounded surfaces and are classified as Bridgman and Wallace Series Soils. They are excellent for use in road construction as backfill for peat marshes, for grade riases, for subbase and for backfill in frost heave excavation.

LAKES CHIPPEWA AND STANLEY

The period of low lake levels when lakes Chippewa and Stanley occuppied only the deepest portions and just a fraction of the existing lake basins of Michigan and Huron occurred about 6,000 years ago.

This came about when the ice melted back exposing an unknown outlet south of the Georgian Bay orth Bay-Ottawa River drainage course.

This whole area up to the east side of Lake Huron in the vicinity of Georgian Bay had been down warped almost 500 feet or almost to the elevation of the Atlantic Ocean.

Almost immediately Lake Huron dropped over 400 feet. (Algonquin Beach on Manitoulin Island has an uplift of 417 feet). This drained much of Lake Huron and left Lake Michigan high with a sort of dam or low weir between Lake Michigan and Lake Huron. The spilling out of Lake Michigan into Lake Huron eroded a gorge in the straits about fifty miles long called the Mackinac River.

MACKINAC STRAITS RIVER

During this time the elevation of Lake Michigan dropped and its outlet waters down-cut the Mackinaw Straits river bed 350 feet to an elevation of 230 feet Atlantic Table.

This drop in elevation of both Lake Chippewa and Stanley exposed large areas of sand in the form of sand bars and river deltas. He stated before these volumes of sand dried out and were transported landward by west and northwesterly prevailing winds. They were the source of the sand in these dunes today.

This low elevation of Lake Chippewa increased the length of such rivers as the Betsie, Manistee, Peermarquette, Grand, Kalamazoo and St. Joseph Rivers and also increased their gradient.

They down-cut their channels by the erosional effect of swift currents. Continental uplift of the region east of Georgian Bay and the opening up of the Georgian Bay-Lake Nipissing-North Bay-Ottawa River drainage course restored the elevation of the waters in the Lake Michigan basin to about 595 feet Atlantic Table.

This new highwater table drownded or stagnated the deeply eroded channels of many rivers at the new shore line. This state of stagnation created thick beds of peat and alluvial material and in some cases burried old, deep channels. In the St. Joseph River lie two such channels, one at 180 feet depth and the other at 220 feet depth from the elevation of Lake Michigan. At Arcadia the channel bottom lies at

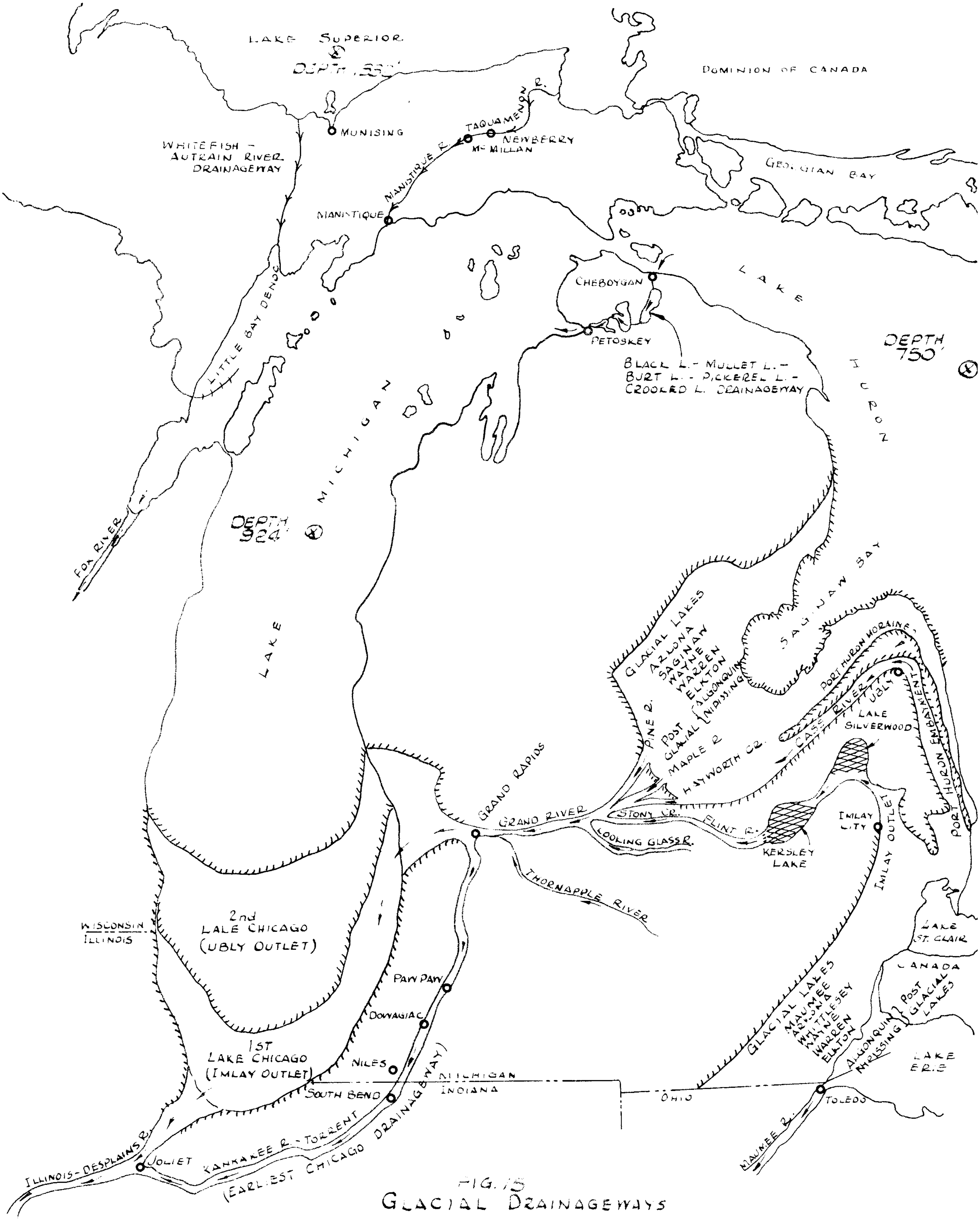


FIG. 15
GLACIAL DRAINAGEWAYS

MICHIGAN
REFERENCE ROOM
GEOLOGICAL SURVEY
DIVISION
Dept. of Natural Resources

50 feet depth and at Elberta at 65 feet depth below todays surface elevation of Lake Michigan.

GLACIAL AND POST GLACIAL DRAINAGE COURSES

Some of the most fascinating and often appearing paradoxial drainage-ways were creations by glacial melt waters escaping to the ocean. These exist today as dry abandoned drainage courses; reversed drainage courses; and ship, barge and sanitary canals.

The dry drainageways often have huge water falls, gorges, cataracts, plunge basins and gravelly delta plains.

Some of the old drainage courses which flowed entirely in one direction have been separated into two streams flowing in opposite directions.

All are utilizing drainage basins today that are only fractions of the original glacial stream.

CHICAGO SANITARY AND SHIP CANAL

One of the "naturals" for the engineer to construct with very little effort into an active canal is the Chicago Sanitary and Ship Canal Drainage Canal.

The Chicago River with its discharge and Lake Michigan water is now directed into this canal which flows southwesterly to Lockport where it drops some forty feet into the Des Plaines River. This portion of the system is a reversal of todays existing drainage. However, at one period in glacial history this drainage was southwesterly and required only deepening and cleaning out to re-activate it.

After the discharge cuts over the divide at Lockport it follows the Des Plaines River westerly to the Illinois River which flows south to the Mississippi, which in turn flows south to the Gulf of Mexico.

This is exactly the way the first glacial waters discharged that were ponded in what is called Lake Chicago at the south end of the Lake Michigan trough.

This outlet not only carried melt waters from the Lake Michigan Ice Lobe but discharged melt waters collected on the west end of Lake Erie and Saginaw Bay and carried to it vai Imlay-Maple River-Grand River cross country drainage course and also vai Port Huron-Black River-Ubly-Cass River-Maple River-Grand River cross country drainage course and others.

It is one of the first glacial outlets to be formed. Glacial Lake Maumee discharged its waters via this route when the Imlay Outlet was uncovered and available to use.

Glacial Lakes Arkona, Whittlesey, Warren, Saginaw, Elkton and Algonquin in turn, also shared the use of this outlet.

In recapitulation this should be notes: The discharge from Lake Chicago was Southwest through the Valparaiso Moraine which boardered it; thence South to Joliet via Des Plaines River; thence Southwest to the junction with the Kankakee River at Channahon to form the Illinois River; thence West to Depue; thence South to Peoria.

This was the drainageway that cut through the Valparasio Moraine and seven other minor morainic structures and was 150 miles long. Glenwood Stage of Lake Chicago outletted through the Valparasio Moraine 60 feet above Lake Michigan. This outlet was eroded down to only 25 feet above Lake Michigan when Lake Algonquin discharged through it.

ERIE BARGE CANAL

Another "Natural" for the engineers to construct with very little effort into a ship and barge canal is the valley north from Buffalo, New York to Tonawanda and Lockport and thence East through Rochester and Syracuse to Utica to the Mohawk River.

The Mohawk River flows east to the Hudson River at Albany. The Hudson flows south to the Atlantic Ocean. A splendid dry water falls plunge basin and gravelly delta exists at Syracuse.

This canal was easy to construct because during the glacial period, Lakes Warren, Elkton and Algonquin discharged part or all their melt waters through this valley carving it out for future use.

CHAMPLAIN* HUDSON RIVER DRAINAGE COURSE

At one time during glaciation ice in the St. Lawrence River to the east of Sorel (Northeast of Montreal) blocked drainage in this direction and forced it to flow southerly down the Richelieu River into Lake Champlain; thence south via Lake George River; through the valley which contains the Champlain Canal to the Hudson River. This also was a "natural" for canal construction.

Continental uplift has sealed off this drainage course. It then became separated into a north flowing Richelieu River and a south flowing Hudson River.

ST. CROIX DRAINAGE COURSE

Glacial Lake Deluth formed in the west end of the Superior Basin. The St. Croix River valley became its outlet to the southwest where it entered the Mississippi River south of Minneapolis and St. Paul. Lake Duluth which occuppied the west half of the Superior Basin found a lower outlet to the south to Lake Michigan as soon as it had melted easterly enough to expose the Au Train-White Fish channel cut into bed rock.

WISCONSIN AND ROCK DRAINAGE VALLEYS

The Green Bay ice lobe ponded water in front of it as it retreated. Two glacial drainage ways removed melt waters from its accumulation basin. The Wisconsin River Valley discharged southwest to the Mississippi and the Rock River Valley discharged southerly to the Mississippi.

The ice lobe retreated opening up the Lake Winnebago ponded area and eventually the southern end of Green Bay.

At this time the Rock River ceased to be a glacial outlet and melt waters poured southwesterly out of Green Bay through the Little Fox River into Lake Winnebago; thence southwest via the Fox River to the Wisconsin River at Portage; thence via the Wisconsin River to the Mississippi at Prairie Du Chen.

MAUMEE WABASH DRAINAGEWAY

We have prewiousely discussed the Chicago outlet via Des Plaines-Illinois River system. Let us now go the Detroit-Toledo-Cleveland area where melt waters first began to accumulate in front of the Erie and Huron Lobes.

Water accumulated in a sort of triangular area between Port Huron, Cleveland and Fort Wayne, Indiana with the outlet through a cut in the Fort Wayne Moraine into the Wabash River.

This huge ponded area in the Maumee River, Basin was called Lake Maumee and stood at an elevation of 812 feet above Atlantic Table when it discharged into the Wabash; thence into the Ohio; thence into the Mississippi.

This is 240 feet above Lake Erie today. It is amazing to know that Metropolitan Detroit would be submerged in over two hundred feet of water if this stage of Lake Maumee existed today.

This lake is one of the bodies of water which contributed to the disposition of so much Lacustrian clay in this area. Some of this clay is 60% water; has the consistancy of toothpaste; has shear values of less than 100 pounds per square foot; is quite unstable and flows under pressure; and is a real challenge to the designer.

AU TRAIN WHITEFISH DRAINAGEWAY (LAKE DULUTH HINGE LINE AND CONTINENTAL UPLIFT)

The Green Bay ice retreated northerly exposing the Au Train-Whitefish channel cut into bed rock from Little Bay De Noc north to Autrain Bay.

The Lake Superior ice retreated easterly from Duluth forming Lake Duluth with its drainage southwesterly vai St. Croix River to the Mississippi River.

Eventually the Superior ice exposed the Au Train Valley which was lower than the St. Croix outlet. Therefore the St. Croix course dried up and the Au Train took full charge of the discharge. Eventually all the ice melted in the Superior Basin and Lakes Michigan, Huron and Superior became confluent.

With the removal of this heavy surcharge of ice, the continent in this region began to spring back to its original elevation. This is called continental uplift.

The region south of a line between Arcadia (south of Frankfort) and Forestville (north of Port Huron) had not been perceptibly depressed, therefore it remained unchanged in elevation after the ice was removed.

This Arcadia-Forestville line is called a hinge line. The region north of this line began to rise like a trap-door and its rise is called continental up-lift.

Continental up-lift eventually raised the Upper Penninsula out of Post Glacial Lake Algonquin.

It was at this time that the Au Train-Whitefish drainage course began to carry melt waters from the Lake Superior Basin south to the Lake Michigan Basin.

This drainage course was narrow, steep and soon eroded and carved out a channel in the bed rocks of the Silurian, Ordovician and Cambrian formations of the Ancient Paleozoic Seas.

Continental up-lift is 93 feet in just the 14 miles between Trenary and Chatham or 6.6 feet per mile.

Continental up-lift eventually chocked off the inlet at Lake Superior. A divide occurred at Trout Lake 3 miles east and 3 miles south of the Village of Limestone.

North of this the waters move into the long and narrow Cleveland Cliffs Power Basin and down through the Penstocks of the Electric Power Company or over the Au Train Falls located just south of the Village of Forest Lake.

The Au Train Falls is 100 feet from crest to base and is sort of broken in the middle with a step and is eroded into Siliceous, Hermansville Dolomite of the Ordovician formation.

At the base of the falls is the contact between the overlying Ordovician-Dolomite and the top of the underlying Cambrian-Lake Superior Sandstone. This sandstone forms the walls of the gorge leading to Au Train and to Lake Superior at Au Train Bay west of Munising. This is a beautiful sight.

Returning to the divide at Front Lake, we find that the south flowing Whitefish River also has its head-waters here. The Whitefish River flows swiftly south through this narrow valley cut into bed rock down to the City of Rapid River on Little Bay De Noc on Lake Michigan.

At the sametime that Lake Superior discharged south through the Au Train-Whitefish drainage course to Lake Michigan another similar drainage course opened up on Whitefish Bay on Lake Superior and flowed southwesterly via Tahquamenon-Manistique River Basins and outletted on Lake Michigan at the City of Manistique.

This system had a narrow channel hemmed in by 300 feet high walls of the Newberry Moraine on the south and the Munising Moraine on the north, two to three miles wide and ten miles long with an east-west axis between Dollarville near Newberry and Danaher. This gorge is called McMillan Pass and through it poured torrental currents from the Tahquamenon River to the Manistique River.

This mad rush of water stood 1.50 feet deep during the highest stage of Lake Algonquin.

This discharged waters of the late stage of Post Glacial Lake Algonquin or early Lake Chippewa stage and functioned until continental up-lift blocked off the inlet on Whitefish Bay.

A divide was created in the Newberry swamp near Danaher separating the system into a northeast flowing Tahquamenon River Basin and a southwest flowing Manistique River Basin.

From Danaher easterly and northeasterly the present Tahquaenon River drops approximately 0.4 foot per mile for 49 miles to a point one mile south of the Upper Tahquamenon Falls or a total drop of 18 feet. It then down-cuts through 8 feet of bed rock of the Hermansville Dolomite Formation to the crest of the falls.

The first 40 miles of this drainageway is slow and sluggish and through flat swampy country. This sluggish action is due to continental up-lift raising the river's bed up to a more horizontal attitude.

From crest to base of the Upper Falls the River cuts through 40 feet of Cambrian sandstone. At the crest of this falls is a thin layer of bed rock of silicocalcareous dolomite of the hermansville formation of the Ordovician Paleozoic Sea. This is a very hard dolomite tough capping and protects the more easily eroded cambrian sandstone directly beneath it.

From the plunge basin at the foot of the falls, the river rushes through a narrow gorge cut out of this same paleozoic rock cascading with a sort of cataract effect for another four miles to the crest of the lower falls.

This new gradient is approximately seven feet per mile and the total down cutting amounts to about 28 feet.

The drop in elevation between the crest and base of the lower falls is 20 feet and is also cut down through Cambrian Sandstone. The base of this falls is only four feet above the watertable of Lake Superior.

PETOSKEY CHEBOYGAN DRAINAGEWAY

During the last stages of Post Glacial Lake Algonquin and the early stages of the Lake Chippewa and Lake Stanley, shallow lakes which occupied the Lake Michigan and Lake Huron throughs, the drainage from west to east split and discharged through the Straits of Mackinac and from Petoskey to Cheboygan by the inland route.

This route passed from Petoskey on Little Traverse Bay eastward to Mullet Lake via Route Lake, Crooked Lake, Crooked River, Burt Lake and Indian River.

The drainage course turned north at Mullet Lake and flowed up the lake and into Lake Huron via Cheboygan River.

This drainage course was eventually blocked off at Petoskey by a huge circle of sand dunes which ringed the east end of Little Traverse Bay at Petoskey.

These sand dunes were nourished by dry sand from deltas and sand bars which were exposed to the prevailing westerly winds when the watertable of Lake Algonquin fell some 350 feet to an elevation of 230 feet atlantic table.

This old drainage system could be easily converted into a beautiful cross country inland waterway between Lakes Michigan and Huron by means of locks at Cheboygan and Petoskey and with a little dredging. At present pleasure boats can sail all the way from Cheboygan to Conway just outside of Petoskey.

IMLAY OUTLET FOR LAKE MAUMEE

Now we must return to Glacial Lake Maumee which stretched in a sort of triangular shape with its baseline between Port Huron and Cleveland and with its apex southwesterly from here at Fort Wayne, Indiana where the ponded waters broke through a col or low sag in the Fort Wayne Moraine and reached the Wabash Ohio and Mississippi Rivers and traveled to the Gulf of Mexico.

This was the highest stage of Lake Maumee and its shore lines stand between 800 and 805 feet atlantic table at Birmingham on the Defiance Moraine.

As has been mentioned previously, this elevation at shoreline is about 225 feet above present Lake Erie and represents the stage when the outlet was at Fort Wayne and the melt waters stood about 200 feet deep at Port Huron and along the inner face of the inner ridge of the Defiance Moraine from Romeo-Birmingham-Plymouth-Ypsilanti-Saline to Macon. From Adrian southwest these shorelines are banked against or notched into the inner face of the outer ridge of the Fort Wayne-Defiance Moraine.

These foregoing paragraphs attempt to establish the existance of Maumee Lake, its highest shoreline elevation and the Wabash Outlet at Fort Wayne, Indiana, the first outlet of three for this lake.

Two other consecutive outlets let the melt waters of Lake Maumee escape to the north through the Imlay Outlet. The first outlet lowered Lake Maumee to an elevation of between 755 and 765 feet above atlantic table, (lowest Lake Maumee).

FIRST IMLAY OUTLET 755'-765' A.T. LOWEST STAGE LAKE MAUMEE

It is believed that the first so-called Imlay Outlet brought melt waters to a point near Brown City through three channels:

1. Waters flowing north across the broad lake plain east and west of Emmet turn and funnel westerly in narrow lake plain three miles north of Yale.

2. Waters ponding south between Capac and Imlay City flow northerly through a channel three miles east of Imlay City.

3. Waters ponding south of Imlay City flow northerly through a narrow valley one of three miles wide directly north of Imlay City.

From the vicinity of Brown City these collected waters flowed westerly to North Branch where they entered the Flint River Valley. A little west of North Branch and adjacent to the Flint River Valley lay Lake Silverwood, to the north a Reservoir Lake. Maumee waters flowed southwesterly along the Flint River Valley through Columbiaville to Kersley Lake at Flint, another Reservoir along the route.

They left Kersley Lake at Swartz Creek and flowed westerly through Durand, Corunna and Owasso to Ovid where they divided into two drainageways respectivelly: Stony and Hayworth Creeks.

Hayworth Creek flowed into the Maple River at Maple Rapids. The Maple River and Stony Creek united near Lyons to form the Grand River.

Drainage was now west in the Grand River Valley past Ionia, Lowell and Belmont, and thence south to Grand Rapids.

From here it traveled southerly all the way south to Lake Chicago just inside the Lake Boarder Moraine or just outside the Lake Boarder Moraine and confined between it and the receeding face of the Michigan Ice Lobe.

At Chicago it drained to the Gulf of Mexico via Chicago Sanitary and Ship Canal-Des Plains River-Illinois River and the Mississippi River.

SECOND IMLAY OUTLET MEDIUM STAGE LAKE MAUMEE 775'-785' A.T.

As mentioned before, a re-advancement of the ice in the neighborhood of Brown City or south of there constructed a morainic structure which blocked off the free gravitational flow of melt waters to the north and therefore closed off this section of the Imlay Drainageway.

Lake Maumees Shore stood at about the same boarder between Port Huron and Imlay City and moved northward through the same three channels as they did for the previous drainageway. However, this time they collected about nine miles directly north of Imlay City.

From here they moved northwesterly to the Flint River Valley at North Branch via Madison Drain and Cedar Creek.

From here on glacial drainageway was the same as for the first stage.

The elevation of the Glenwood stage of Lake Chicago was 640 feet atlantic table or approximately 120 feet below the elevation of the first stage of the Imlay Outlet and 140 feet below the elevation of the second stage. Most of this change in elevation occurred in the drainageway across Michigan or in about 150 miles. This was the first of the drainage courses that crossed Michigan from east to west.

The waters of Glacial Lake Shittlesey from a point seven miles west of Port Huron, ponded in an estuary one to six miles wide and fifty miles long, north of Ubly. This is the Black River Basin and today drains south.

At the time of Lake Whittlesey melt waters moved north to Ubly in this quiet, lake, like pond; turned a right angles at Ubly; dropped into the southwesterly trending Cass River Valley; and began a very rapid decent for the next fifty miles into Lake Saginaw. They flowed past Cass City, Caro and Vassar and entered Lake Saginaw between Pine Run and Frankenmuth.

This valley also is between one and six miles wide. The waters were of torrenal magnitude. They left a gravel delta at Ubly where they poured out of Lake Whittlesey and rolled boulders along the floor of the Cass Valley.

They moved slowly westerly for fifty miles in Lake Saginaw and entered Stony Creek, Hayworth Creek and the Maple River at its west edge.

These creeks and river formed the Grand River which flowed westerly to an embayment of Lake Chicago at Grand Rapids.

These was the calumet stage of Lake Chicago and the Chicago outlet had eroded its floor down some twenth feet to an elevation of 620 feet atlantic table.

Lake Whittlesey stood at an elevation of 740 feet in flowing through the Cass River and the Grand River Valleys. This amounts to 120 feet in 100 miles of one foot per mile.

PETOSKEY INDIAN RIVER ROGERS CITY DRAINAGEWAY

There is much merit in the conjecture that an unknown glacial drainage course lies close to the contact line between the Algonquin Lake Plain and the Morainic Structures that arize above it in the northern part of the Lower Penninsula.

This Lake Plain sweeps southerly from Lake Huron with its shoreline in the vicinity of a line between Petoskey-Indian River and Rogers City.

KIRKFIELD TRENT RIVER VALLEY DRAINAGEWAY

Post Glacial Lake Algonquin in which Lakes Superior, Huron and Michigan were confluent, had four outlets: Chicago, Port Huron, Kirkfield and North Bsy.

Melting of the ice sheet north of Lake Ontario flooded the lake Ontario basin and created Lake Iroquois and also uncovered the country north of it to the southern end of Georgian Bay.

This also exposed a drainageway traversing a southeasterly course between Georgian Bay and Lake Iroquois that was lower than the Chicago and Port Huron Outlets thereby drying them up.

This outlet was from Victoria Harbor to Lake Simcoe to Kirkfield to

Fenelon Falls to Trenton via Trent River Valley.

This was another one of those "Natural" drainage courses that the Engineers with very little dredging and some small locks were able to convert into a veautiful inland waterway by which small pleasure craft could cross the Penninsula between Victoria Harbor on Georgian Bay and Trenton on Lake Ontario through a series of beautiful lakes, streams and canals.

NEW UNKNOWN OUTLET EAST OF GEORGIAN BAY EXPOSED

The Kirkfield Outlet continued to drain Lake Algonquin until the ice receeded and exposed the Ottawa River Basin. The north end of Georgian Bay was depressed between 600 and 700 feet and lay at an elevation close to that of the Atlantic Ocean. In other words the Atlantic Ocean shore was brought westerly next to Georgian Bay.

LAKE STANLEY

This immediately emptied much of the water out of Lake Huron creating a muck smaller lake called Lake Stanley.

This created a sort of dam or weir at the Straits of Mackinac which held back Lake Michigan.

MACKINAC STRAITS RIVER

It wasn't long before Lake Michigan waters pouring through the Straits of Mackinac began to erode or cut out a deep channel 3,600 feet wide out of the weakly cemented breceiated limestone in its floor.

LAKE CHIPPEWA

This narrow channel soon became a gorge as the waters of Lake Michigan dropped to an elevation of 230 feet, atlantic table and became Lake Chippewa.

CONTINENTAL UPLIFT AND LAKE NIPISSING

Continental uplift raised the Ottawa River basin and Post Glacial Lake Nipissing took the place of Lake Algonquin at an elevation of 595 feet atlantic table.

NORTH BAY OUTLET

Lake Nipissing found an outlet easterly through Georgian Bay to present Lake Nipissing via French River; thence from City of North Bay to the Ottawa and on to the St. Lawrence at Montreal. This is a noble river.

CONTINENTAL UP LIFT

Lake Nipissing continued to flow in this outlet until continued Continental Uplift raised the North Bay Outlet too high. This sealed off the inlet for Georgian Bay waters entering the Ottawa River Drainage; raised lake level and the Port Huron Outlet began to operate again.

GLACIAL LAKES AND POST GLACIAL LAKES

So far we have discussed the many glacial and post glacial drainageways for melt waters that accumulated in the form of lakes south of the several ice lobes that retreated from great lakes region. Now let us turn to study these lakes in chronological order.

LAKE MAUMEE

This lake formed of melt waters at the west end of the Erie Ice Lobe and extended graphically in the form of a triangle with its base line extending between Port Huron and Cleveland and with its apex at Fort Wayne, Indiana.

800-812± FEET — The initial outlet was past Fort Wayne into the Wabash River Basin and on to the Ohio and the Mississippi and south to the Gulf of Mexico. The water level of Lake Maumee stood at an elevation of between 800 and 812 feet, atlantic table or about 235± feet above existing Lake Erie. The Maumee River flows into Lake Erie at Toledo today.

755-765 feet A.T.; 775-780 feet A.T. — The second and third outlets for this lake were through the Imlay Outlet to the Flint-Maple-Grand River Drainage course to Lake Chicago and thence through the Chicago-Sanitary and Ship Canal to the Des Plaines, Illinois and Mississippi Rivers and south to the Gulf of Mexico. The elevations of these stages were respectivelly: 755 to 765 feet, Atlantic table and 775 to 780 feet, Atlantic table. Lake Glenwood stage of Lake Chicago stood at 640 feet, Atlantic table or between 120 and 140 feet lower than Lake Maumee.

LAKE ARKONA 694 to 710' A.T. — The ice completely retired from the Erie Basin extending Lake Maumee easterly to Buffalo. The ice retreated completely off the thumb region allowing Lake Maumee to become confluent with Lake Saginaw which had started to form from ponded waters in front of the Saginaw Ice Lobe.

This new Lake was called Arkona and established three beaches indicating three stages between 710 and 694 feet, atlantic table. These stages represented the erosion and down cutting of the Maple River Outlet.

The Maple River flowed into the Grand River and into Claumet stage of Lake Chicago at 620 feet, atlantic table. The drop in elevation between Lake Arkona and the Chicago outlet varied between 75 and 90 feet.

LAKE WHITTLESEY 735 to 740 feet, A.T. — There was an impulse given to the Huron Lobe of ice and it moved foreward covering the thumb region inland to Athins, Jeddo, Croswell, Applegate, Carsonville, Mc Gregor, Deckerville, Palms, North of Ubly, Greenleaf, Cass City, Ellington, Caro, Wahjamego, Vassar, Tuscola and Frankenmuth.

This is the east boarder of the Black River Estuary from Port Huron north to Ubly and the northwest boarder of the Cass River Valley.

This movement of the ice separated Lakes Saginaw and Arkona and removed the short-circuited drainage around the thumb causing Lake Arkona to rise and to seek another drainageway.

The new lake was Lake Shittesey which occupied the Erie Basin and the Black River embayment with an outlet at its north end at Ubly.

The Cass River carried its discharge southwesterly to Lake Saginaw. It left Lake Saginaw via Maple-Grand River drainage course and entered the Calumet stage of Lake Chicago and left this body through the Chicago Outlet. Lake Shittlesey stood at an elevation of 735 to 740 feet, atlantic table or 120± feet above the Chicago Outlet.

LAKE WAYNE
6 to 665'AT.

The northerly retreat of the ice of the Ontario Lobe began to uncover the Lake Ontario Basin and to flood the area to form Lake Iroquois.

The withdrawal of this ice also exposed the lowlands in which the Erie Canal was later constructed.

Melt waters from Lake Shittlesey now found an outlet in these lowlands 80 feet lower than the Cass River drainage course.

Lake Whittlesey dropped to an elevation on 660 to 665 feet, atlantic table and became Lake Wayne.

The drainage was via Erie Canal Valley to Syracuse where it dropped into the Mohawk River and continued eastward to the Hudson; thence south to the Atlantic Ocean.

LAKE WARREN
660 to 685'
A.T.

The Ontario Ice Lobe surged foreward sufficiently to block the Syracuse Outlet.

The ice in the thumb region retreated into the Huron Basin and the Saginaw Sag enough to allow Lakes Wayne and Saginaw to connect up again as they did during the Arkona Lake Stage.

Blockage of the Syracuse Outlet caused Lake Wayne-Saginaw to rise. The next lowest outlet was via Maple-Grand River Valley to Calumet stage of Lake Chicago at 620 feet, atlantic table.

LAKE ELKTON
GRASSMERE
640' A.T.
ELKTON 620'
A.T.

The Ontario Ice Lobe again retreated exposing the Erie Canal Valley and re-opened the syracuse outlet into the Mohawk Valley.

The elevation of Lake Warren fell to 640 feet, atlantic table, the level of Lake Grassmere. A later opening in a col or pass in the mountains at Troy, New York lowered the watertable to 620 feet, atlantic table, the level of Lake Elkton.

EARLY LAKE
ALGONQUIN
605' A.T.
PORT HURON
OUTLET

With continued lowering of the Lake Erie-Erie Barge Canal Valley-Mohawk River Outlet, Lake Elkton dropped from 620 feet, atlantic table to 605 feet, atlantic table, by the Port Huron River.

The waters collecting in the lower reaches of Lake Huron were called early Lake Algonquin and the initial outlet was through the Port Huron Channel, through Lake Erie, Erie Valley, Mohawk Valley and down the Hudson to the Atlantic Ocean.

Eventually all the ice retreated from the basins of Lakes Michigan, Huron and Superior and these lakes became confluent to form a huge post glacial lake called Algonquin.

SECOND STAGE KIRKFIELD OUTLET The ice margin of the Ontario Lobe retreated uncovering a lower outlet than that at Port Huron. This outlet extended from Victoria Harbor on the Southeast end of Georgian Bay to Lake Simcoe to Kirkfield to Fenelon Falls and on to Trenton via Trent River Valley. This discharge continued across Lake Iroquois to the Mohawk Valley and on to the Hudson and South to the Atlantic Ocean.

THIRD STAGE PORT HURON AND CHICAGO OUTLETS Continental uplift in the Trent Valley Region slowly closed the Kirkfield Outlet and forced the Port Huron and Chicago Outlets to carry this discharge.

The Chicago Outlet was at an elevation of 600 to 605 feet, atlantic table and was called the Toleston Stage.

PORT HURON OUTLET The Chicago Outlet was seated in Bed Rock and eroded very slowly. The Port Huron River Channel traversed a plain of glacial till which eroded more easily, therefore this channel eventually cut down deep enough to carry all the discharge and the Chicago Outlet dried up.

The Ontario Ice Lobe continued to withdraw north and soon uncovered the Ottawa River Valley. This region was depressed by the weight of a two mile height of ice sheet to between 600 and 700 feet, or almost to the elevation of the Atlantic Ocean.

This brought the shore of the Atlantic Ocean adjacent to Georgian Bay.

LAKE STANLEY Lake Huron spilled out of its basin to the east into this sort of an embayment of the Atlantic Ocean and shrunk to only a fraction of the Huron Basin and became Lake Stanley.

MACKINAC STRAITS RIVER AND LAKE STANLEY 230 FEET A.T. This created a weir of the Straits of Mackinac which held back the waters of Lake Michigan.

These waters plowed through this sag and cut a gorge 3,600 feet wide and 250 feet deep with almost vertical walls in the weak brecciated limestone of the Mackinac formation of the Devonian Paleozoic Sea. Lake Michigan became Lake Chippewa at an elevation of 230 feet, atlantic table.

CONTINENTAL UPLIFT Continental Uplift raised the Ottawa Valley about 600 feet. This raised the elevation of Lakes Stanley and Chippewa up to 595 feet, atlantic table and inaugurated Lake Nipissing, this Lake included Lakes Huron, Superior and Michigan and drained to the St. Lawrence River via Georgian Bay, French River, Little Lake Nipissing, City of North Bay, Mattawa River and Ottawa the river.

This outlet was eventually closed by further continental uplift and drainage since that time has been through the Port Huron River, Lake Erie, Lake Ontario and the St. Lawrence River.

RADIO-CARBON DATING This discussion should begin with an understanding of the basic principles of all matter in whatever form it is found: Gaseous, Liquid or Solid.

ATOM An atom is the smallest division of an element without destroying its structures. Atoms unite with each other to form molecules.

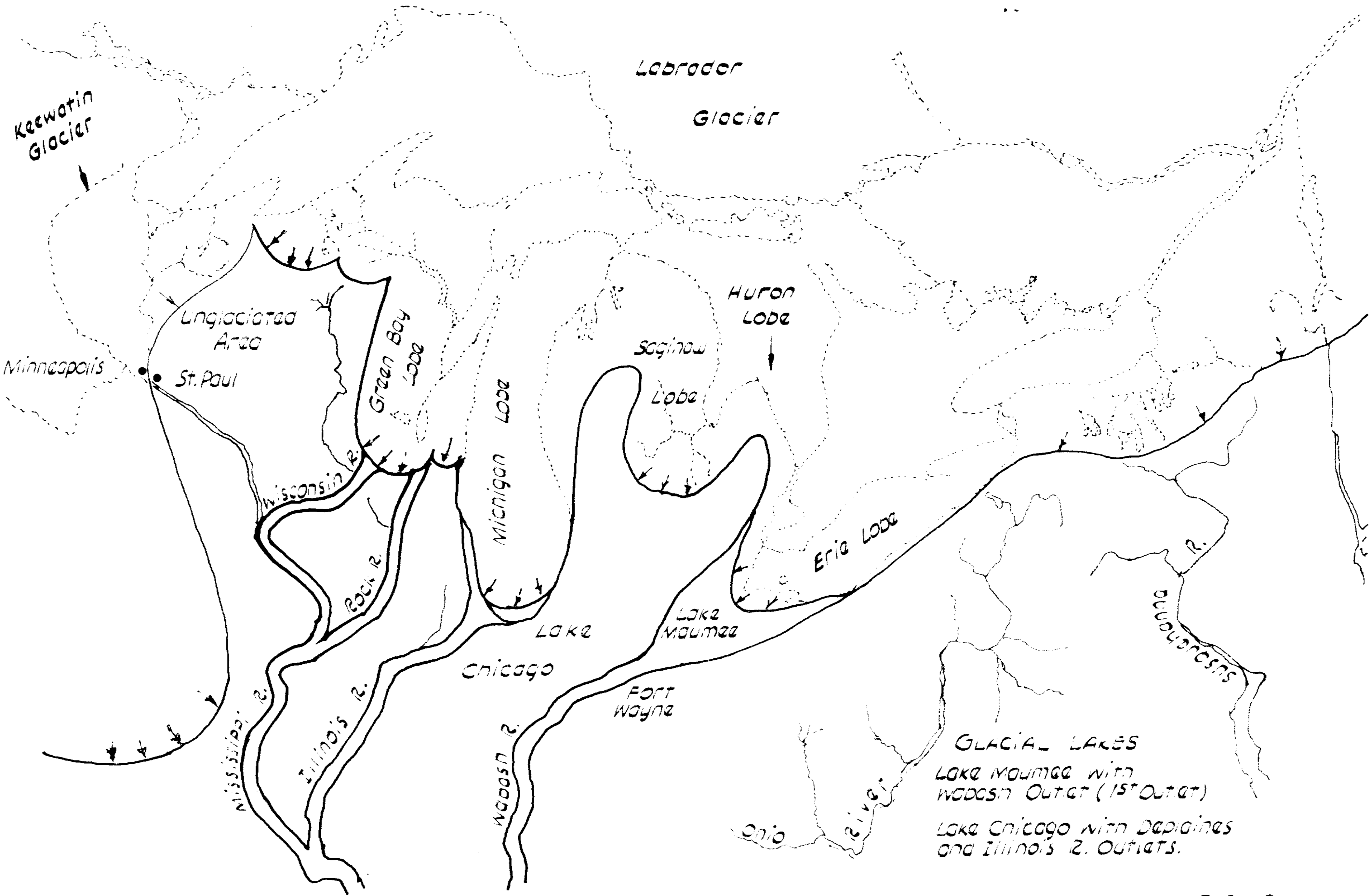
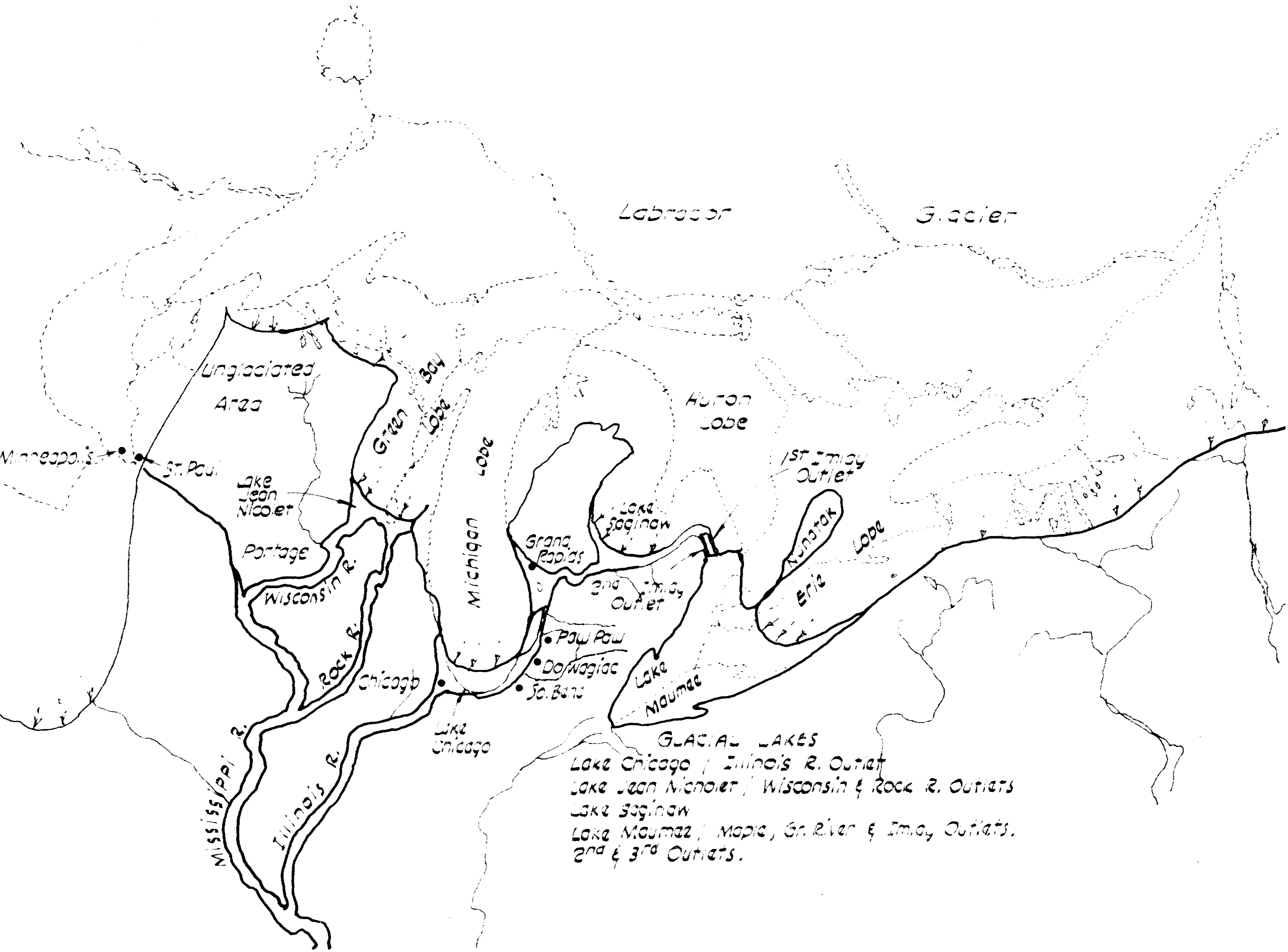

Labrador
Glacier
Keewatin
Glacier
Unglaciated
Area
Minneapolis
St. Paul
Green Bay
Lobe
Michigan Lobe
Saginaw
Lobe
Huron
Lobe
Erie Lobe
Wisconsin R.
Rock R.
Mississippi R.
Illinois R.
Lake
Chicago
Lake
Maumee
Fort
Wayne
Wabash R.
Ohio
River
Susquehanna
R.
GLACIAL LAKES
Lake Maumee with
Wabash Outlet (1st Outlet)
Lake Chicago with Desplaines
and Illinois R. Outlets.

FIG. 16



Labrador Glacier
Unglaciated Area
Green Bay Lobe
Michigan Lobe
Huron Lobe
Minneapolis
St. Paul
Lake Jean Nicolet
Portage
Wisconsin R.
Rock R.
Chicago
Mississippi R.
Illinois R.
Lake Chicago
Grand Rapids
Lake Saginaw
2nd Imlay Outlet
1st Imlay Outlet
Nunatak
Erie Lobe
Paw Paw
Do/wagiac
So. Bend
Lake Maumee
GLACIAL LAKES
Lake Chicago / Illinois R. Outlet
Lake Jean Nicholet / Wisconsin & Rock R. Outlets
Lake Saginaw
Lake Maumee, Maple, Gr. River & Imlay Outlets.
2nd & 3rd Outlets.

FIG. 17

Michigan Lobe
Gladwin
Saginaw
Port Huron
Lake Arkona
Buffalo
Toledo
Cleveland
Chicago
Glacial Lakes
Lake Arkona
Lake Chicago

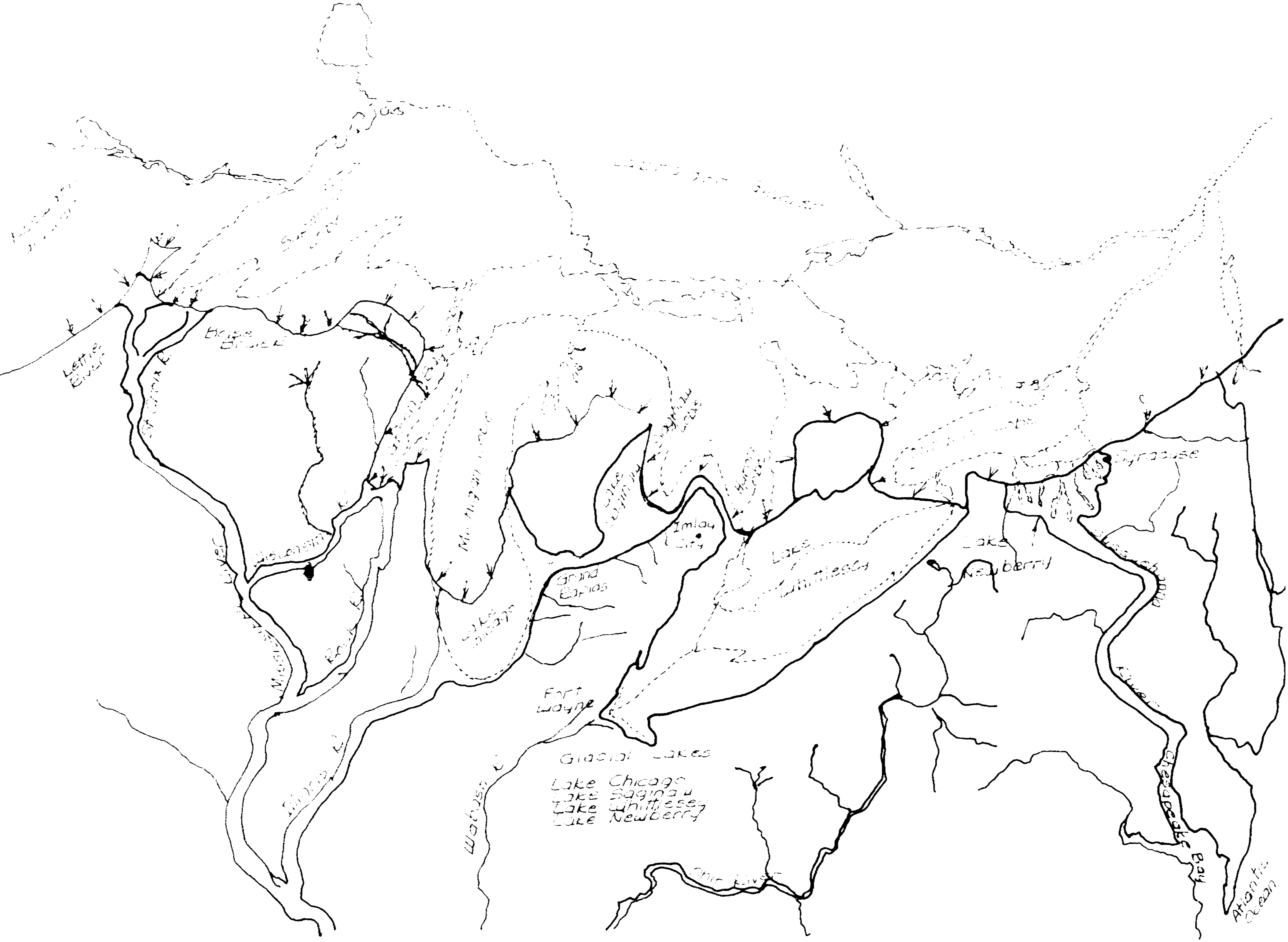

Wisconsin
Rock R.
Illinois R.
Lake Chicago
Grand Rapids
Imlay City
Lake Whittlesey
Lake Newberry
Syracuse
Fort Wayne
Wabash R.
Glacial Lakes
Lake Chicago
Lake Saginaw
Lake Whittlesey
Lake Newberry
Ohio River
Chesapeake Bay
Atlantic Ocean

Fig. 19

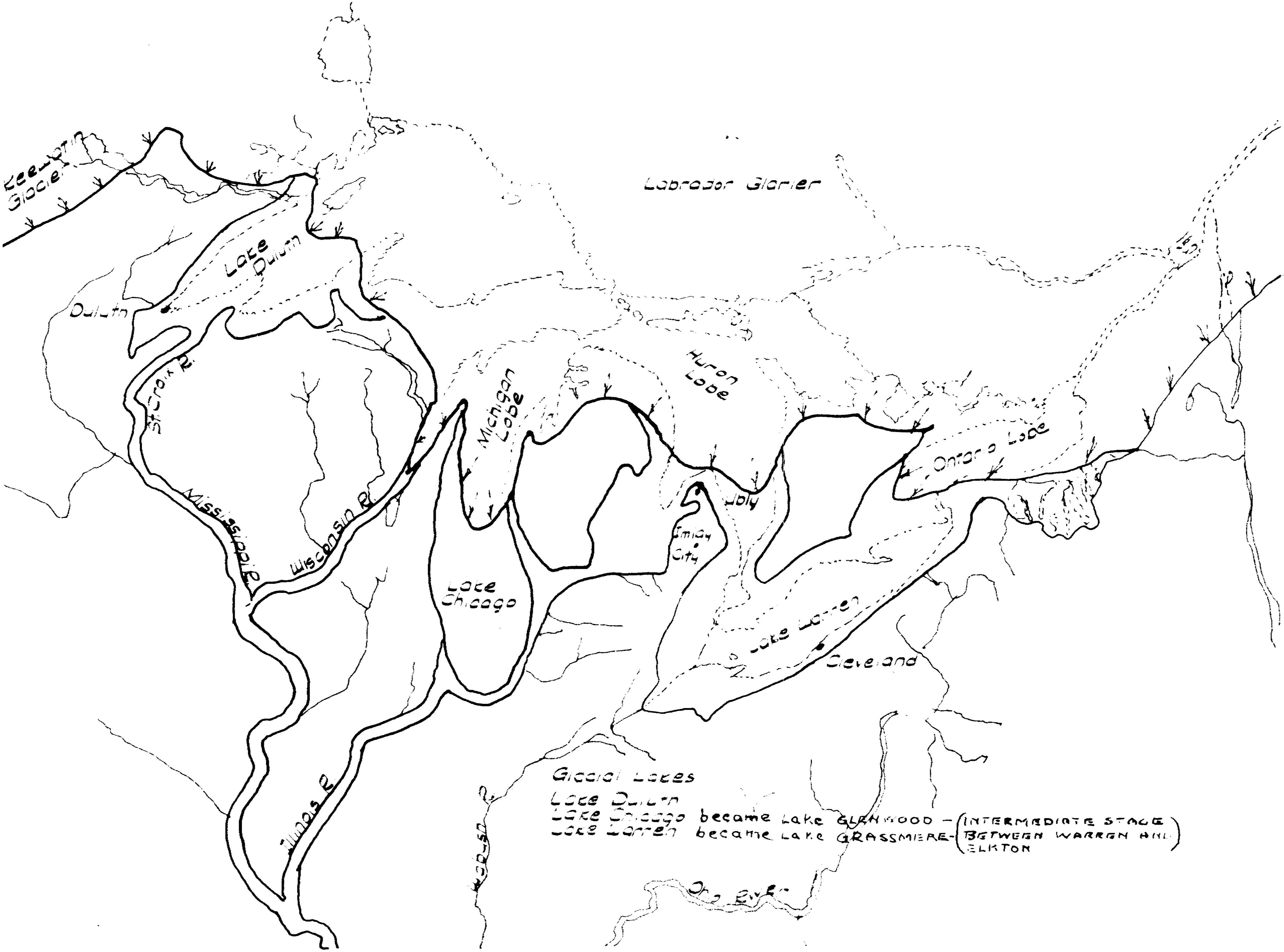

Keewatin Glacier
Labrador Glacier
Lake Duluth
Duluth
St. Croix R.
Mississippi R.
Wisconsin R.
Michigan Lobe
Huron Lobe
Ontario Lobe
Lake Chicago
Ubly
Imlay City
Lake Warren
Cleveland
Illinois R.
Ohio River
Glacial Lakes
Lake Duluth
Lake Chicago became Lake GLENWOOD — (INTERMEDIATE STAGE
Lake Warren became Lake GRASSMERE — BETWEEN WARREN AND
ELKTON)

Fig. 20

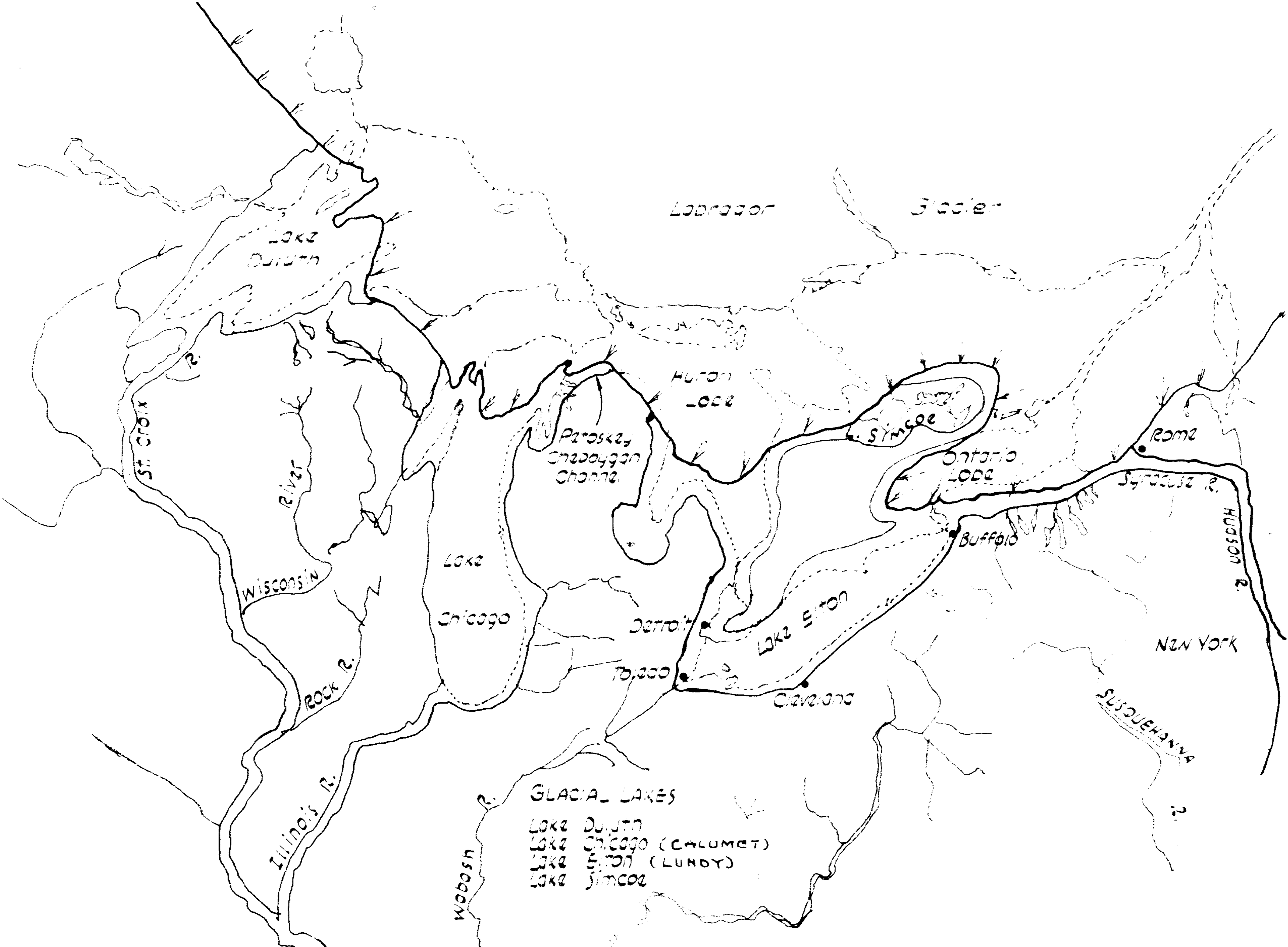

Labrador Glacier
Lake Duluth
St. Croix R.
River
Wisconsin
Rock R.
Illinois R.
Wabash R.
Lake Chicago
Petoskey Cheboygan Channel
Huron Lobe
Simcoe
Ontario Lobe
Rome
Syracuse R.
Hudson R.
Buffalo
Detroit
Toledo
Cleveland
Lake Elton
New York
Susquehanna R.
GLACIAL LAKES
Lake Duluth
Lake Chicago (CALUMET)
Lake Elton (LUNDY)
Lake Simcoe

FIG. 21

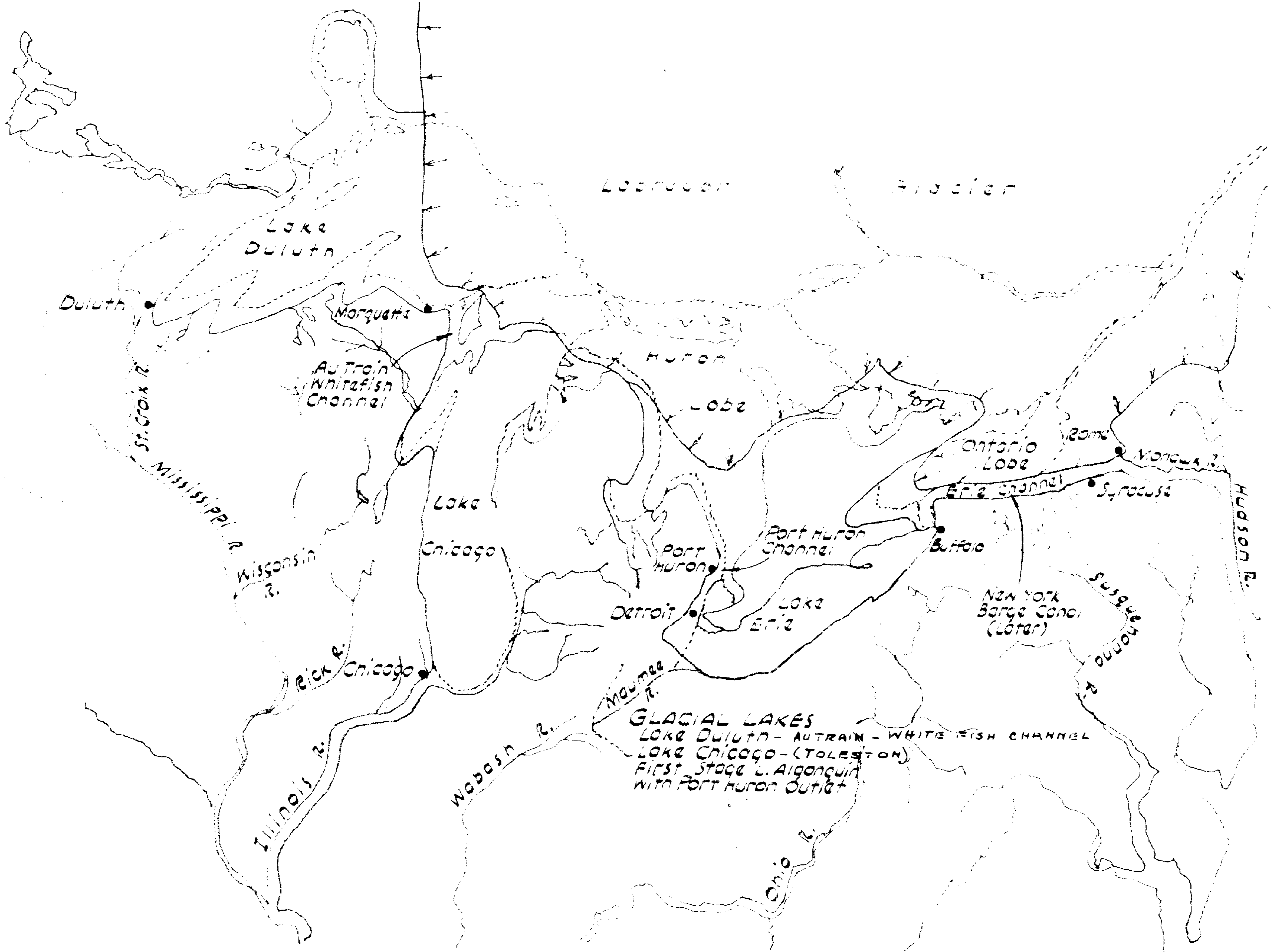

Labrador Glacier
Lake Duluth
Duluth
Marquette
Au Train Whitefish Channel
St. Croix R.
Mississippi R.
Wisconsin R.
Rock R.
Chicago
Lake Chicago
Illinois R.
Wabash R.
Maumee R.
Huron Lobe
Port Huron
Port Huron Channel
Detroit
Lake Erie
Buffalo
Ontario Lobe
Erie Channel
Rome
Mohawk R.
Syracuse
Hudson R.
New York Barge Canal (Later)
Susquehanna R.
Ohio R.
GLACIAL LAKES
Lake Duluth - AUTRAIN - WHITE FISH CHANNEL
Lake Chicago - (TOLESTON)
First Stage L. Algonquin
With Port Huron Outlet

FIG. 22

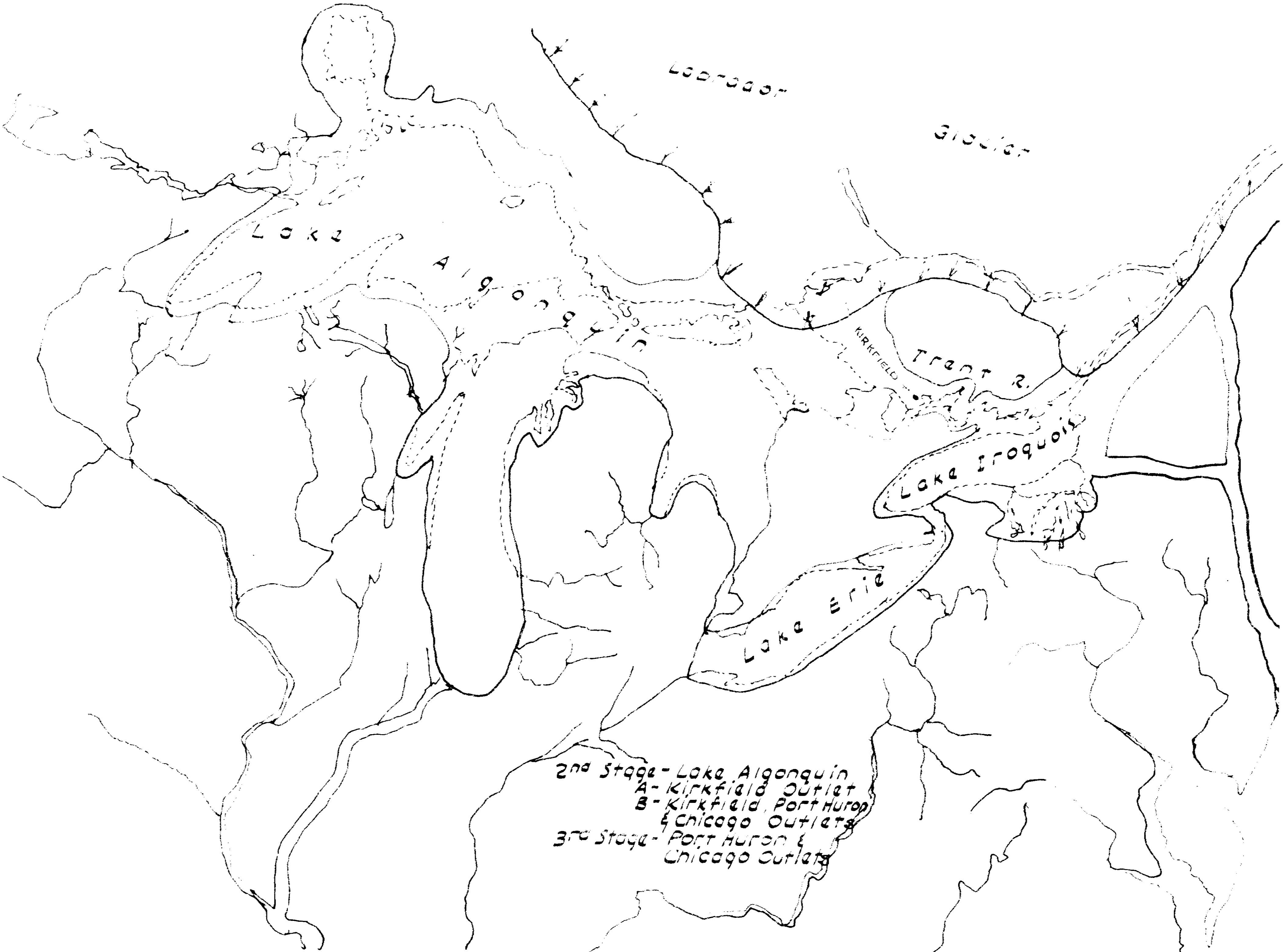

Labrador
Glacier
Lake Algonquin
KIRKFIELD
Trent R.
Lake Iroquois
Lake Erie
2nd Stage - Lake Algonquin
A - Kirkfield Outlet
B - Kirkfield, Port Huron & Chicago Outlets
3rd Stage - Port Huron & Chicago Outlets

FIG. 23

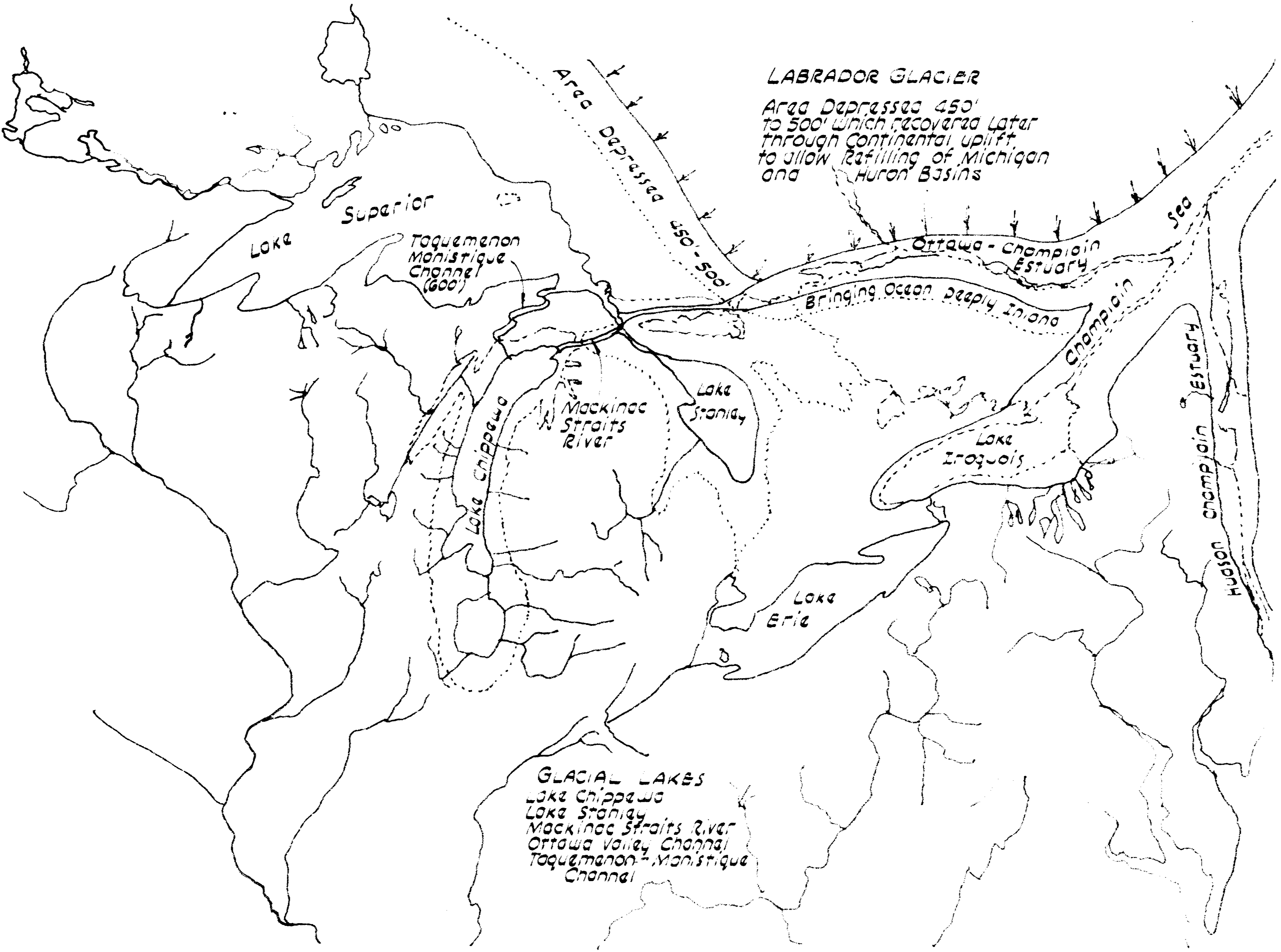

LABRADOR GLACIER
Area Depressed 450' to 500' which recovered later through Continental uplift to allow Refilling of Michigan and Huron Basins
Area Depressed 450'-500'
Lake Superior
Toquemenon Monistique Channel (600')
Ottawa - Champlain Sea
Ottawa - Champlain Estuary
Bringing Ocean Deeply Inland
Champlain
Mackinac Straits River
Lake Stanley
Lake Chippewa
Lake Iroquois
Champlain Estuary
Hudson Champlain
Lake Erie
GLACIAL LAKES
Lake Chippewa
Lake Stanley
Mackinac Straits River
Ottawa Valley Channal
Toquemenon - Monistique Channel

FIG. 24

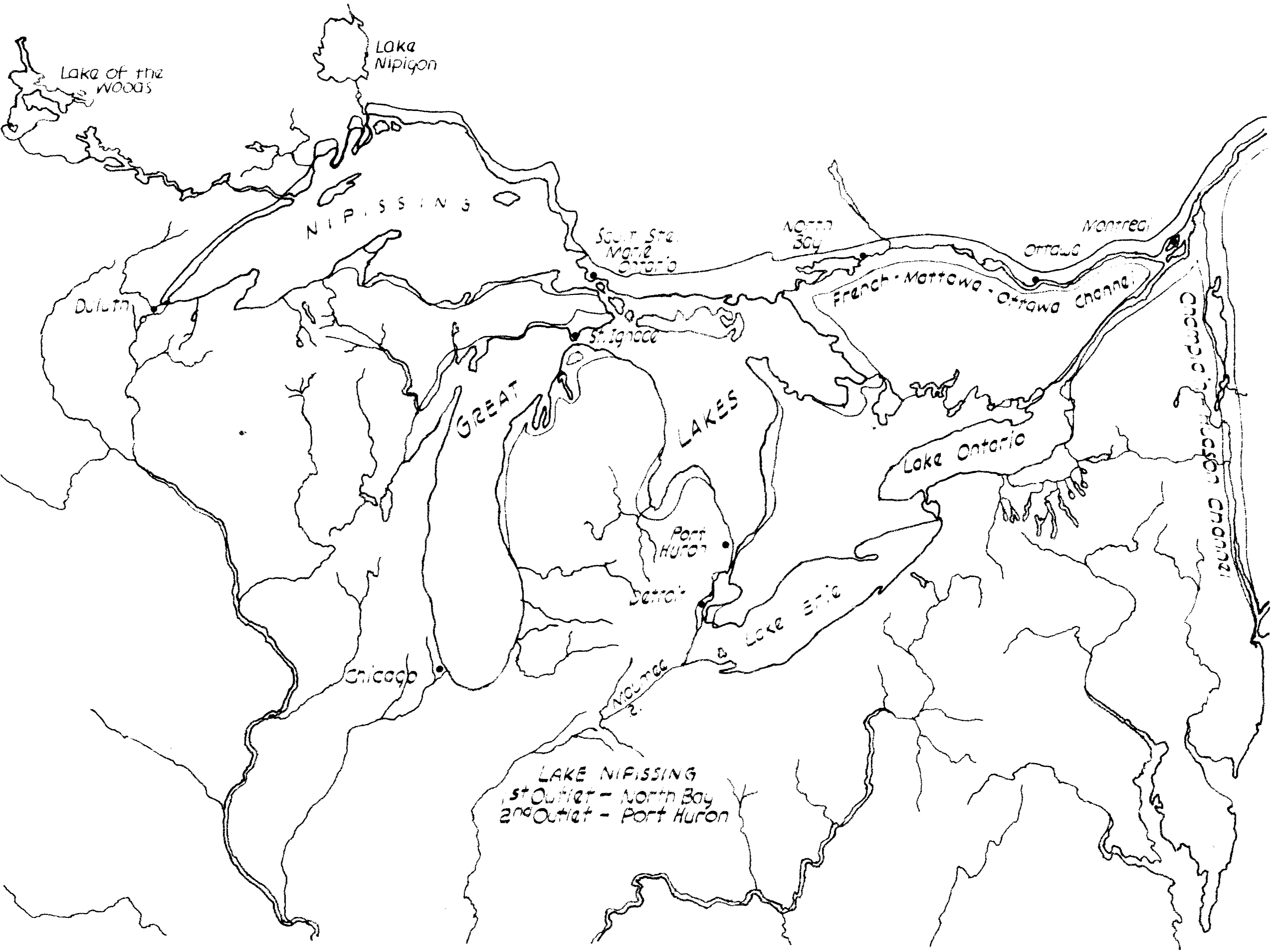

Lake of the Woods
Lake Nipigon
NIPISSING
Duluth
Sault Ste. Marie Ontario
North Bay
Ottawa
Montreal
French - Mattawa - Ottawa Channel
St. Ignace
GREAT
LAKES
Lake Ontario
Champlain Hudson Channel
Port Huron
Detroit
Lake Erie
Maumee R.
Chicago
LAKE NIPISSING
1st Outlet – North Bay
2nd Outlet – Port Huron

FIG 25

ALGONQUIN (HIGHEST SHORE)

Frankfort	609	Port Huron	606	
Traverse City	648	Port Sanilac	605	
Northport	674	Grindstone City	615	
Harbor Springs	709	Port Austin	615	
Cross Village	746	Sebawaing	605	
		Bayport	607	
		Kawkawlin	610	
		Omer	610	
		Tawas	617	
		Greenbush	642	
		Harrisville	653	
		Ossineke	663	
		Alpena	688	
		Posen	741	
		Rogers City	741	
		Mackinaw City	804	
		Glenwood	640	Correlative of Arkona (Highest)
		Calumet	615	
		Toleston	600	Probably correlative of Algonquin

NIPISSING

Frankfort	595	Port Huron	595
Traverse City	609	Grindstone City	598
Northport	606	Bayport	596
Charlevoix	601	Sebawaing	597
Harbor Springs	615	Kawkawlin	595
St. Ignace	628	Alabaster	599
North Bay	698	Oscoda	601
		Greenbush	603
		Harrisville	604
		Alpena	613
		Rogers City	621
		Cheboygan	626

Location	Lake Nipissing *	Lake Algonquin
Arcadia	595'	605'
Frankfort	599'	605'
Northport	606'	658'
Suttons Bay	607'	654' approx.
Traverse City	602'	648'
Elk Rapids	606'	635'
Torch Lake	608'	655'
Charlevoix	611'	690'
Petoskey	615'	709'
Mackinaw City	628'	804'
Cheboygan	626'	800'
Rogers City	621'	741'
Alpena	613'	688'
Ossineke	613'	663'
Harrisville	604'	653'
Greenbush	603'	642'
Oscoda	601'	630' approx.
Tawas City	599'	617'
Alabaster	599'	617'
Pine Run	506' approx.	610'
Bay City	595'	610'
Sebewaing	597'	605'
Bay Port	596'	607'
Point Au Barques	598'	615'
Grind Stone City	598'	615'
Port Sanilac	595'	605'
Port Huron	595'	606'

Years B.P. Before Present	Lake Stage	Elevation above Sea Level
	Lakes Michigan & Huron	581'
3,500 - 2,500	Algoma	595'
5,000 - 3,500	Nipissing	605'
8,000 - 5,000	Chippewa-Michigan Trough Stanley-Huron Trough	230'
11,000 - 8,500	Algonquin	605'

* Someday this shore line will be called Lake Algoma as noted above.

LAKE STAGES

STAGE	ELEVATION	ICE BARRIER	OUTLET
Maumee	805-800	Defiance - Birmingham	Wabash
	785-775	Imlay - Yale	Imlay
	760	?	
Arkona	710-694	North of Thumb	Maple R.
Saginaw	710		
Whittlesey	740-735	Port Huron	Ubly
Wayne	650		Mohawk
Warren	680	W. of Alpena	Maple R.
Elkton	640	Grassmere	Mohawk
	620	Dane	
Algonquin	607		Kirkfield
Nipissing	595		North Bay
Chicago	640	Glenwood	Arkona Correlative
	620	Calumet	
	607	Toleston	Algonquin Correlative

HINGE LINES

Whittlesey	-	Near Birmingham
Warren	-	Near Richmond
Elkton	-	Near Lexington
Algonquin-Nipissing	-	Near Forestville

SHORE LINES

Warren	685-675	
Ann Arbor	680	
Goodells	707	
Atkins	709	
Amadore	725	
Charleston	750	N. part Sanilac County
Ruth	748	
Verona Mills	775 ?	
Bad Axe	765	
Popple	754	
Gagetown	744	
Vassar	709	Spit of Warren Beach at water tower.
	808	AuSable sand plain.

MO~~ECULE

A molecule is the smallest division of a substance without destroying its structure of atoms.

ELEMENTS

There are approximately one hundred elements which in combination with each other form all the inorganic and organic compounds and substances in this universe.

These vary from simple metalic elements such as iron, copper and silver to simple salts such as sodium chloride (table salt), calcium chloride, calcium carbonate (limestone), silicon dioxide (sand) to very complex minerals such as the orthoclases (clays).

These also include such simple compounds as the hydro-carbon series, (gases, fuel oils and lubricants); more complex molecular structures of carbohydrates; and the miracle drugs such as streptomycin.

The amazing thing about all this is that it just takes these one hundred elements or atoms re-arranged and connected to each other in different ways and quantities to make up all the multitude of molecules or substances in our material world.

For instance just the three elements of carbon, hydrogen and oxygen are required to form the molecules of the big family of hydrocarbons and the family of carbohydrates.

Add the element of nitrogen to the above elements and we can build up the big family of complex molecules of the amino acids and the proteins.

LAW OF IN-DUSTRUCTABI-LITY OF MASS AND ENERGY

One law of chemistry is that matter cannot be destroyed or created nor is there any change in the total amount of energy involved. In other words in a chemical reaction, there is no change in the total number of atoms involved. One starts out with a total number of atoms of x, of y and of z, and no matter how they are re-arranged the sum total of each will remain the same at the end of the action or re-arrangement as at the biginning of the action. If heat is involved, either absorbed or released, it would require this same energy in reversing the reaction.

To recapitulate the above, it can be said that in the final analysis of a chemical action involving the rearrangement of atoms that atoms are neither created nor destroyed and that energy has not been created nor destroyed.

The Alchemists tried for centuries to create gold out of lead and always failed.

FISSION AND FUSION

This now brings us to an apparent violation of the above low. However the above low still holds good for chemical reactions but does not apply to fission and fusion in which the element's atom is internally disturbed resulting in the alteration of this particular atom; sometimes destroying it altogether; up-grading it into a heavier atom; or down-grading it into a lighter atom.

TRANSMUTATION This creation of one element from another is called transmutation and was discovered in 1919 by Sir E. Rutherford in the transformation of nitrogen into oxygen.

A discussion of the internal structures of an atom, (smallest integral of an element) is now in order.

All atoms are small models of our solar system. The unstable atoms of thorium, radium, vranium and plutonium could be compared to stars that are burning up.

Stars such as our sun are constantly under going atomic action called fission.

FISSION Fission is the disintegration of a heavy or high type, very complex, unstable atom into smaller, more simple stable, atoms.

FUSION Fusion is the construction of higher type larger atoms from smaller atoms by a reconstruction of them.

TRANSMUTATION Transmutation of atoms is either up-grading an atom into a higher type or down grading it into a lower type atom.

PROTONS
NEUTRONS
ELECTRONS
POSITRONS

As mentioned before, atoms are similar to our sun and planitary system. The heavy mucleus center resembling our sun is made up of positivelly charged protons and neutrally charged neutrons around which orbit negatively charged electrons and positivelly charged positrons which are much lighter in mass then the mucleus and resemble our planets.

MASS The relationship between the masses of the protons and the electrons is 1830 to 1. The electron is relativelly small and is the body in orbital motion.

The electrons in any atom are identical with those in any other atom. This holds true for the positrons, protons and neutrons. In other words, all matter can be resolved into these four types of bodies. Also all matter or atoms can be formed from these four basic bodies. Scientists may add to these someday.

At present the relationship follows that for every proton in the mucleus there is one electron to balance its charge and to encircle the nucleus.

eg. Hydrogen has one proton and one electron. Helium has two protons and two electrons. Lithium has three protons and three electrons.

ATOMIC NUMBER The atomic number of an element represents the number of electrons in the atom and likewide represents an equal number of protons.

ATOMIC WEIGHT The atomic weight of an element is the weight or mass of an element relative to that of one element given as a standard. Carbon is that standard and 12 was assigned to it.

Below is a table which gives the atomic numbers and weights of a few of the elements that seem more interesting to the writer:

ATOMIC TABLE

ELEMENT	SYMBOL	ATOMIC NUMBER	ATOMIC WEIGHT
Hydrogen	H	1	1.008
Helium	He	2	4.003
Lithium	Li	3	6.939
Beryllium	Be	4	9.012
Boron	B	5	10.811
Carbon	C	6	12.011
Nitrogen	N	7	14.007
Oxygen	O	8	15.999
Iron	Fe	26	55.847
Cobalt	Co	27	58.933
Nickel	Ni	28	58.710
Copper	Cu	29	63.540
Zinc	Zn	30	65.370
Strontium	Sr	38	87.620
Silver	Ag	47	107.870
Barium	Ba	56	137.340
Platinum	Pt	78	195.090
Gold	Au	79	196.967
Mercury	Hg	80	200.590
Thallium	Tl	81	204.37
Lead	Pb	82	207.19
Bismuth	Bi	83	208.98
Radium	Ra	88	....
Thorium	Th	90	232.038
Uranium	U	92	233-234-235-238
Neptunium	Np	93	....
Plutonium	Pu	94	....

It will be noted that the atomic weight is almost twice the atomic number. This holds true for the first twenty elements. Beyond this point the elements gain weight above the factor two. This increase in weight is due to added neutrons and not to additional protons eg.

Lead has an atomic number of 82 and an atomic weight of 207.
2 x 82 = 164 - protons and 164 electrons.
207 - 164 = 43 - neutrons.
Total: 164 protons and 43 neutrons make up the nucleus or sun while 164 electrons encircle it as planets or satellites.

TRANSMUTATION Now let us return to the study of the transmutation of elements.

Ir'ene Curie and F. Joliot in 1932 discovered that if they bombarded Baron (5) with alpha rays (double protons released during the disintegration of radium), that radio-active nitrogen (7) would be formed along with the release of a positron and a neutron. This was the transmutation of boron into nitorgen.

Sir E. Rutherford bombarded gaseous nitrogen (7) in 1919 with these same type alpha rays and found that oxygen (8) was formed with the release of one proton (nucleus of hydrogen atom). Alpha rays are double protons and the nucleus of helium, this was the transmutation of nitrogen into oxygen.

Atmospheric nitrogen bombarded by protons from the inner band of the Van Allen Radiation Belts, located 600 to 800 miles above the earth, produces radio-active carbon (6).

These bombarding protons are in the form of primary cosmic rays, are sub-microscopic electrically charged particles that travel in space with almost the speed of light. When they collide with nitrogen atoms in the air, they also give off part of their energy to electro-magnetic radiation called photons.

ISOTOPES Six carbon isotopes are formed when the cosmic rays (protons) drive their way into the nitrogen atoms and down-grade them into the next lower series atoms.

These new carbon isotopes have the same atomic weight of 12.011 but they all differ slightly from each other until their radio activity energy is dissipated. Following is a table of these isotopes, their given numbers and their half-lives:

Carbon^{10}, 20-sec.; carbon^{11}, 20.5 min.; carbon^{12}, stable; carbon^{13}, stable; carbon^{14}, 5568 years; carbon^{15}, 2.4 sec.;

Note: These numbers must not be confused with atomic weights because they have no bearing upon mass but are used to separate and identify each individual isotope.

Most of these isotopes revert or change into carbon 12 or 13 in a relativelly short time. However carbon 14 has a relativelly long half-life and is used in dating archeological and geological times quite accurately up to a range of 50,000 years.

Constant bombarding of atmospheric nitrogen by cosmic rays maintains carbon 14 at a level of radio-activity of 15.3 ± 0.1 disintegrations per minute per gram of contained carbon (14) at all times in the atmosphere.

The nitrogen atom in the form of a gas immediately upon transmutation into carbon becomes a solid. This is the form of very fine dust which settles to the carth and becomes food for plant life forming the complex molecules in the plants and trees such as cellulose structures, starches and sugars

Mammals eat the plants and use them for fuel. Carbon dioxide exhaled by the animals returns the carbon (14) to the atmosphere where plant life again lives upon it.

There is also a possibility that at the time of transmutation there is enough heat energy released and oxygen gas present to form carbon dioxide directly through simple chemical action.

PHOTOSYN-THESIS

This would make carbon (14) available for photosynthesis action in plant life in which carbon dioxide from the atmosphere and water is converted into carbohydrates (sugars and starches) by the action of the sun's radiation and the green chlorophyll of the plant.

All plant and animal life maintains a level of 15.3 disintegrations per minute per gram of contained carbon while living.

As soon as the plant or animal ceases to take in atmospheric carbon into its system, either directly through carbon dioxide as in plants or indirectly through eating the plants as in animals, the radio active carbon (14) begins to decay and change into the stable carbon (12).

DISINTEGRATION CURVE

This rate of decay or disintegration of carbon (14) follows a logarithmical scale and is not a straight line function. It also has a half life of 5568±30 years.

These means that at the end of 5568 years it will be emitting 7.65 disintegration per minute or half of the original strength of 15.3 disintegrations per minute.

At the end of 11,136 years it will be radiating 3.825 disintegrations per minute instead of 7.65.

At the end of 16,704 years it will be radiating 1.9125 disintegrations per minute instead of 3.825.

This logarithmical scale as stated is good for acurately dating archeological artifacts, and skeletons of mammals and plants up to 50,000 years ago.

RADIO-ACTIVE CARBON DATING USES

The logarithmical curve for carbon (14) for the first half life of its activity or 5568 ± 30 years has been very accurately checked with wood from funural ships found in the phramids in Egypt; from wood in the toombs of Vezier Hemaka, 3000 B.C., Snefru, 2600 B.C., Sesotris III, 1800 B.C., deep sea SC rolls 100 ± 100 B.C.; and tree rings 100 B.C. and 600 A.D., from the giant redwoods (Sequoia-Gigantea) in California.

Radio active carbon has been useful in dating glacial and post glacial lakes from wood burried in beach formations and in setting the dates for certain glacial stages such as the two creeks interstadial period in which an inter-glacial forest was burried later by till upon resumption of glacial activity.

RADIATION

Now that we are in an atomic age, the writer would like to submit some information relative to radio-activity or radiation. This is also associated or related to what has been immediately said.

ATOMIC DECAY OF RADIUM, THORIUM URANIUM AND PLUTONIUM

Atomic discharge, activity, radiation, disintegration or decay is measured in curies (1-curie equals 3.7×10^{10} disintegrations/second) or in Rutherfords (1-Rutherford equals 10^6 disintegrations/second).

X RAYS OR ROENTGEN RAYS RADIATION

The unit of radiation energy absorbed in by tissue in x-ray work is called the roentgen (4) and is equivalent to between 84 and 93 ergs of work depending upon whether long wave lengths under low voltage is used or short wave lengths under high voltage.

NON PHOTON RADIATION ALPHA RAYS, BETHA RAYS AND NEUTRONS

1-Rad equals the release of 100-ergs of energy per gram of matter.

1-Rem equals the dosage of radiation which has the same biological effect as one rad of x-ray radiation.

1-Erg is the amount of energy required to lift $\frac{1}{981}$ gram vertically through one centimeter.

One foot pound of energy equals 1.356×10^7 ergs.

I hope this dissertation has been of interest and informative to the reader.

CHESTER H. FINSTER