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PAPERS OF THE MICHIGAN ACADEMY OF SCIENCE ARTS AND LETTERS

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SPIRIT STONES

WILBERT B. HINSDALE

NO WRITER has better described the mysticism of the Indian and his simple philosophy than Addison in the *Spectator* two hundred and twenty years ago. He says: "The Americans believe that all creatures have souls, not only men and women, but brutes, vegetables, nay, even the most inanimate things, as stocks and stones. They believe the same of all works of art, as knives, boats, looking-glasses; and that as many of these things perish, their souls go into another world, which is inhabited by the ghosts of men and women. For this reason they also place by the corpse of their dead, food, a bow and arrows, that he may make use of the souls of them in the other world, as he did of their wooden bodies in this. How absurd soever such an opinion may appear, our European philosophers have maintained several notions altogether as improbable."[1]

Although the Indian's religion did not have a personal god, or a pantheon of divinities, he recognized what has been variously described as "the supernatural," "a mystic potency," "the more than human," "cosmic reality," "determiner of destiny," "a mystery of purpose," or an "X" which possesses some "transcendent power concretely divine."

Nowhere in the world did men reverence "stocks and stones" as such. Everything in nature possessed a " power " and it was the power, usually referred to as spirit, that evoked awe and occasionally ceremony.[2] Whatever was unusual in shape, color, movement or situation caused the Indian, as he passed by, to hesitate and perform acts that may not have been worshipful, but they were reverentially respectful, and his ceremonies, upon such occasions, may well be described as religious.

With this introduction, I will proceed to locate and describe briefly numerous natural stone or mineral objects in Michigan that, for want of a better term, may well be characterized as spirit stones. Perhaps the better way will be to observe some order of geographical situation. We shall follow around the lake shore, beginning at Detroit, and then note some inland objects.

In 1669 the Sulpitian priests, Galinée and Dollier, passed through the Detroit River and Lake St. Clair. They arrived at Detroit in the spring of 1670. In his journal Galinée says that six leagues from Lake Erie he found a "stone idol" which the Indians regarded as influencing navigation of Lake Erie, and to which they made sacrifices of skins and food whenever they were about to embark upon the lake. "They broke one of their hatchets, in breaking the idol to pieces, and then threw it into the river, adding 'God rewarded us for the pious deed, for we killed during the same day a deer and a bear.'"

In referring to this incident, Mr. Bela Hubbard remarks: "Sacred stones were not uncommon in these parts. I have seen several such altars, sometimes in the most wild and lonely situations, invariably covered with bits of tobacco and other petty gifts."[3]

Mr. Hubbard gives the following description of a situation he visited at the mouth of the Kawkawlin River, Saginaw Bay, in 1837: "Upon a swelling knoll, overlooking the bay, in the midst of a tract of country from which all timber had been burned, was a spot which seemed to have been dedicated to the evil Manitou. Here an altar was erected, composed of two large stones, several feet in height, with a flat top and broad base. About were several small stones which were covered with propitiatory offerings, — bits of tobacco, pieces of tin, flints, and such articles, of little value to the Indians, as, with religious philosophy, he dedicates to his Manitou."[4]

Mystery stones were common along the Lake Huron shore. Through the southern part of Alpena County flows Devil River, originally called Rivière Au Diable by those who spoke the French language, a name significant either of swampy lands in the vicinity, or of the peculiar behavior supposed to reside in the stones to be described. The account is taken mostly from the Centennial History of Alpena County, Michigan, by Mr. David D. Oliver.[5]

When Mr. Oliver, a surveyor, first visited Devil River in 1839, he saw near its mouth two large stones standing together. One was a gneiss rock with bands of quartz, which had been much worn by wind and water and weighed about three hundred pounds. The other stone was in the shape of the human body, but without head, arms or legs. Near arid around the stones were large numbers of pipes, tobacco, beads, ear jewels, silver brooches, buttons and various kinds of trinkets.

There was a story that Shin-gaw-ba, a divine chief, lived there a long time ago. He told his people he would come back to the stones for the presents that they might leave for him. The Indians called the place Shin-gaw-ba-waw-sin-eke-go-ba-wat-waw-sin-eke, signifying "image stones." Out of the long Indian phrase Mr. Oliver made the name Waw-sin-eke for the township, the whole Indian name being too long to retain. It was misspelled and Os-sineke, the name of a small hamlet that stands there now, is the outcome of it.

There is an interesting legend about the two stones, which is as follows: Some Iroquois captured two Chippewa near the river and put them and their images into a canoe and started across Thunder Bay with them. When they were in the middle of the bay, the stones were thrown into the water. Suddenly the water boiled and spouted up; the canoe capsized and the Iroquois drowned, but the Chippewa escaped and rescued the canoe. When they returned to the place whence they started, they found the stones had preceded them and were standing in their places as they had done before being removed. These valuable relics were finally broken up by fishermen and used for net anchors. Mr. Oliver states that "These stones are found throughout the country of the Chippewa."

The Lake Huron shore, Presque Isle County, from the Waw-waugh-waugh-gue-oc River, which is now called Ocqueoc, to the Swan River, a distance of twenty miles, seems to have been held by the Indians of long ago as "sacred ground." There is an interesting legend connected with the Sacred Rock, situated six miles up the shore from Rogers City. The rock is a huge, conglomerate boulder, 20 feet long, 6 feet high and 8 feet in transverse dimension. It was quite regularly rectangular, but its angles have been rounded by wave and weather action. It stands at the edge of the water when the lake is low, but at high level of the lake it is a hundred or more yards from the beach. The Indians coming down the shore offered sacrifices of dogs and left other offerings upon the rock. In August, 1926, when it was visited by a member of the University of Michigan Museum staff, two or three small piles of tobacco were observed, indicating that the Indians living in the locality still observe some of the sacred rites.

The late Frederick Denny Larke wrote, in 1909, the following: "The history of the Sacred Rock is this: Ages ago, where the rock now stands, was the boundary line between the hunting grounds of two Indian tribes; the chief of the one was exceedingly aggressive and frequently trespassed upon the preserves of the neighboring tribe, and, in so doing, had caused much trouble and bloodshed to follow these excursions. At last the chiefs of the two tribes met, when the one as usual was trespassing over the border, and an altercation ensued which would probably have again resulted in a bloody war between the conflicting tribes, but Kitchie Manitou, the Great Spirit, who was up Lake

Superior at the time, became disgusted with both of them, seized hold of the Sacred Rock and hurled it down, crushing both the chiefs beneath its immense weight, which was so great, that the banks above the beach have been sliding and trembling ever since. Hence the Rock became an object of worship to the Indian races."[6]

Mr. Larke also relates the following story: "The mouth of Swan River, southeast of Rogers City, was also considered a sacred spot, probably because a tide sets in at intervals every day, and logs or boats launched upon or thrown into the stream will float against the current of the river. In the writer's time, Indians brought down an old squaw who was aged and crippled, and drowned her in the mouth of Swan River. She appeared to be perfectly contented to be immolated in this manner, it being, as the writer was led to understand, the usual custom in such cases."

There was found, in 1820, on Thunder Bay Island, toward which point, according to the story by Oliver, the Iroquois had started with the Ossineke stones, a stone with a circular flat base and a long slender arm, which had been set up under a tree and "in its solitary, desolate aspect furnished a place eminently appropriate, according to the Indian's superstition, for the residence of a Manitou or spirit."[7]

Four miles north of St. Ignace is Rabbit's Rock. From a distance it has the outline of a sitting rabbit and is a legendary spot. It is an immense, high rock, and on account of its shape was supposed by the Indians to be inhabited by a manitou. When they paddled by, they would stop and make offerings of tobacco, supposing it to be a great spirit that once presided over their ancestors, and they always treated it with reverential respect.[8]

Father Gagnieur states that the Pictured Rocks off the shore of Alger County were famous in Indian legend. In one of the coves was an "altar" which the Indians used for ceremonial purposes.

No doubt Mackinaw Island, which is almost entirely of rock, was regarded as a prodigious and powerful manitou. Manitou Islands, in Lake Michigan, belonging to Leelanau County, have thrilling legends connected with them. On account of the belief that they were the abodes of spirits that would work evil, they were usually avoided by Indian canoemen or approached with the greatest circumspection and propitiatory offerings.[9]

Of Hubbard Lake, the largest lake in Alcona County, much has come down in legend about its sacredness to Indian tribes who frequented its shores. Even in more recent times there remained on the southern end of the lake, on an elevation commanding a bird's-eye view of the great stretch of water, a weird monument of stone called "Indian Worship," a sacred relic of early aboriginal days. The story is that this stone was erected to mark the burial-place of Se-don-i-ka-to, a great Chippewa chief, and that Indian hunters and trappers, and even some white men of earlier days often brought offerings of beads and tobacco and left them at the monument as an act of worship. "Old-timers" remember this stone image as having a hollow head, or an opening in the natural stone formation of the head, and recall that the votive offerings were placed in this cavity. Some Alcona County residents of today tell of having seen, in their younger days, some of these votive offerings at the "Indian Worship" stone. This historical spot has been desecrated, the grave dug up, and report has it that the stone was taken away by some Pittsburg people in 1880.[10]

"Between Grand Blanc and Flint the Indian trail passed over a beautiful rise of ground, which the Indians had cleared and surrounded with plum trees, which bore a large amount of wild plums, red and yellow, the finest I ever saw. This spot was, perhaps, forty or fifty feet in diameter, the trail passing through nearly in the center of this beautiful, green grass spot, where all travelers, both white and Indian, stopped. The Indians always stopped, as it was a place of Indian worship. Beside the trail, nearly in the center of this spot, stood a very peculiarly shaped stone, perhaps four feet high, erected by the Indians as one of their idols or gods. They called it Bab-o-quah." This manitou was taken away by Captain Jacob Stevens, in 1823-24, but the Indians forced him to return it.[11]

Mr. Williams, at an early date, visited a sacred rock on the Pine River "not far above the present St. Louis, in Gratiot County. We examined the boulder and found it was worn quite smooth by the Indians. It was a sacred Indian god which they all stopped and worshiped by a speech or a smoke. They also left other articles in addition to pieces of tobacco, and among them were pieces of copper which we afterward learned were cut from the copper boulder on the Ontonagon River, Lake Superior. . . ."

"Nearly every Indian has discovered such an object in which he places special confidence, of which he most frequently thinks, and to which he sacrifices more zealously than to the Great Spirit. They call these things their 'Manitou personnel' but the proper Ojibbeway word is said to be 'Nigouimes,' which means 'my hope/ One calls a tree, another a stone or block, 'his hope.' Thus, for instance, on the mainland, opposite La Pointe, there is an isolated boulder and huge erratic block, which the Voyageurs call 'le rocher' or 'la pose de Otamigan.' . . . This rocher de Otamigan is in a swamp close to one of these *poses* [resting places]." There is also quoted here the legend of Otamigan, and how he selected this rock for his manitou: ". . . he (the Indian) never goes past it without laying some tobacco on the rock as a sacrifice, and often goes expressly to pay worship to it."[12]

There was quite an eminence back of the cantonment at the Sault Ste. Marie, called by the French La Butte de Terre, and Wudjuwong ("Place of the Mountain") by the Indians. Not far from this eminence stood a hollow mountain ash of unusual size. Tradition says a drumlike sound, upon pleasant days, was emitted from the tree. From year to year the offerings of the Chippewa had accumulated in large quantity at this place. The vicinity had been considered the haunt of a spirit. Hence the propitiatory offerings.[13]

An image of black bronze is described in the Journal of Father Claude Allouez's Voyage into the Outaouac Country, 1666-67. "There is observed in those regions (of the Ottawas) a kind of idolatry which is rather unusual. They have a grotesque image of black bronze, one foot in height, which was found in the country, and to which they give a beard like a European's, although the savages themselves are beardless. There are certain fixed days for honoring this statue with feasts, games, dances and even with prayers, which are addressed to it with divers ceremonies. Among them is one which, although ridiculous in itself, is yet remarkable in that it embraces a kind of sacrifice. All the men, one after another, approach the statue and, in order to pay it homage with tobacco, offer it their pipes, that it may smoke; but, as the idol cannot avail itself of the offer, they smoke in its stead, blowing into its face the tobacco-smoke, which they have in their mouths,—which may be regarded as a mode of offering incense, and performing sacrifice." By "black bronze" the father means of course copper.[14]

A farmer living in Houghton County unearthed a piece of float copper which presents a striking resemblance to a human profile. It was an accidental find. There is no positive evidence for thinking so, but it had probably been an object of veneration. The greatest diameter of the specimen is forty inches, the weight four hundred and eighty-four pounds. There is no legend connected with it, and the reason for calling it a "spirit" object is conjectural. Its story is short. It is now placed in the Museum of Mineralogy of the University of Michigan.

Kohl says in *Kitchi-Gami*, pp. 60-61: "Among the dead stuffs in nature, the dwellers on Lake Superior seem to feel the most superstitious reverence for copper, which is so often found on the surface soil in a remarkable state of purity. . . . Large masses of metallic copper are found at times in their forests. . . . Admiration leads the savage to adoration, and thus these masses of copper began to be regarded by nearly all the Ojibbeways as something highly mysterious, and were raised to the dignity of idols." An Indian friend whom Kohl asked for a certain lump of copper which was in the forest replied: ". . . it is a great treasure to me. It was so to my father and grandfather. It is our hope and our protection. Through it I have caught many beavers, killed many bears. Through its magic assistance, I have been victorious in all my battles, and with it I have killed our foes. Through it, too, I have always remained healthy, and reached that great age in which thou now findest me." After Kohl had secured the piece of copper, the Indian placed a quantity of tobacco in the hole in the ground from whence it had been lifted.

The Ontonagon copper boulder, weighing three tons, which finally found a resting place in the National Museum after many vicissitudes in transit, is declared to have been "worshiped as a manitou by superstitious Indians during uncounted years."[15]

The descriptions that have been given are confined to natural objects that evoked the suspicion and veneration of the Indians as they found them in place. It is said that occasionally the objects had been bedaubed with paint, probably to "bring out the features" more distinctly. Some of them have been referred to as "idols," but idols are usually man-made effigies to represent deities and belong to a different, if not a higher, grade of worship than the mere abiding place of *orenda* or *mana* in a natural object.

At certain places the Indians had made stone piles, built up one stone at a time by passers-by. These heaps, no doubt, were located at certain spots where some event had occurred, or where previously a "spirit tree" had stood. There are not many records of Indian stone piles in Michigan. Some very symmetrical stone mounds stood in Macomb County, but they had been built up with care and contained human skeletons.

Both isolated stones of veneration and the heaps had a very wide distribution, and were not distinctive of Indian culture. Tobacco pipes, especially those of peculiar material like catlinite, were nothing more or less than transportable spirit stones or diminutive altars. Catlinite was considered sacred, and before breaking off pieces for pipes, one asked permission from the presiding spirit. Although it is going far afield for an illustration, Lot's wife cannot be better described than by calling her, after she became a "pillar of salt," a spirit stone. If there was a "pillar of salt" at all by the Dead Sea, it stood there ages before the legend of "looking back" was associated with it.

No mention can be made of lakes, springs, streams, waterfalls, caves, hills, mountains or trees that were the depository of votive offerings, although they would classify under the general term "spirit objects."

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[1] *The Spectator in Miniature*, from the second London edition (A. Sherman, Phila., 1826), 1: 65.

[2] Brinton, Daniel G., *Religions of Primitive Peoples*, p. 131.

[3] *Michigan Pioneer Collections*, 3: 649.

[4] Hubbard, B., *Memorials of a Half-Century* (G. P. Putnam's Sons, New York, 1887), pp. 85-86.

[5] Oliver, D. D., *Centennial History of Alpena County*, Michigan (Argus Printing House, Alpena, Michigan, 1913), p. 25.

[6] Unpublished manuscript.

[7] Squier, E. G., *Antiquities of the State of New York* (Geo. H. Derby & Co., 1851), p. 171.

[8] Gagnieur, Rev. Wm. F., S. J., "Indian Place Names in the Upper Peninsula, and Their Interpretation," *Michigan History Magazine*, 2 (1918): 532.

[9] Blois, John T., *Gazetteer of the State of Michigan* (Sydney L. Rood & Co., Detroit, 1838), pp. 317-318.

[10] Stannard, Mae E., and Hunzicker, Beatrice Plum, "Glimpses of Huron Shore in Early Days and the Story of Harrisville," *Alcona County Review*, 1926, p. 4.

[11] Williams, Ephraim S., *Michigan Pioneer and Historical Collections*, 10: 139-140.

[12] Kohl, J. G., *Kitchi-Gami* (London, 1860), p. 58.

[13] Schoolcraft, H. R., *Personal Memoirs of a Residence of Thirty Years with the Indian Tribes on the American Frontiers*, A.D. *1812 to* A.D. *1842* (Lippincott, Grambo & Co., Phila., 1851), p. 99.

[14] Kenton, Edna, *The Indians of North America*, 2: 164, quoting Le Mercier's Relation, 1664-65, xlix, Doc. CXVII, pp. 241, 243.

[15] Moore, Charles, *Report of U. S. National Museum*, Washington (Government Printing Office, Washington, 1897), p. 1023.

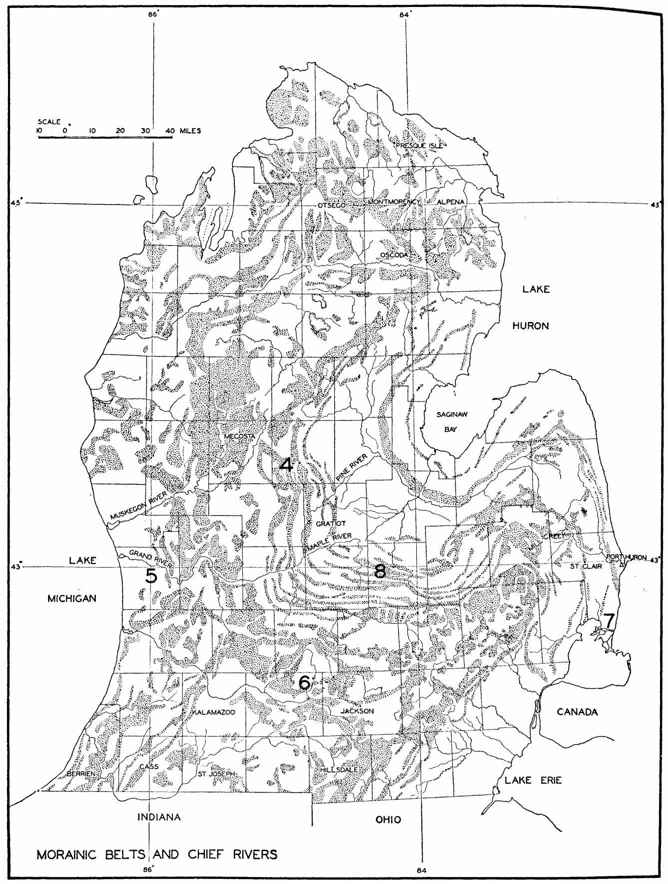
ROAD PATTERNS OF THE SOUTHERN PENINSULA OF MICHIGAN*

ARTHUR FIELD

IN GENERAL, two major types of road patterns may be recognized. The first is the natural type, developed naively by man or animals as a compromise between the most direct route from one place to another and the most expedient route. The second is the artificial type, created and applied by man irrespective of conditions of the fundament. The natural pattern developed in an area may be interrupted by a superimposed artificial pattern, as, for example, the rectangular pattern of the Middle West of the United States. In the long run, however, except in urban areas, the natural patterns tend to dominate the artificial ones. In hilly or mountainous lands, also, the artificial plans have less chance for development. Whatever the pattern may be, it cannot be fully understood unless it is considered in relation to the character of the terrain on which it lies.

GENERAL PATTERN OF SURFACE FEATURES OF SOUTHERN MICHIGAN

The surface features of the state of Michigan owe their origin primarily to the fluctuating movements of the ice cover in glacial times. In the Southern Peninsula of Michigan and in northern Indiana there were three main directions of ice movement, as evidenced in the southward lobate extensions of the continental ice-sheet (Map 6). The names of these lobes correspond to the present names of the penetrating arms of the Great Lakes, which occupy the same depressions as did the ice-lobes in their southward migration.[1] The focus of these lobes was in northwest Indiana; the Lake Michigan, the Saginaw and the Huron-Erie lobes have movements in southward, southwestward and westward directions, respectively. Since, however, the whole of the state of Michigan is an area of glacial deposition, it was the retreat of the ice-sheet which was the great surface-molding agent. The Saginaw lobe was the first to melt back and it retreated along its axis of general movement. A recess was thus formed between the Michigan and the Huron-Erie lobes; the Saginaw section retained its essentially lobate contour through the formation of reentrant angles. Frequent pauses in the retreat of the ice along this line led to the forming of morainic belts in harmony with the configurations of the three lobes. The distance between the concentric moraines varies from less than a mile to ten miles, the intervening plains being composed chiefly of sand and gravel outwash material. Periodic oscillations in the general retrogression caused the emphasis of some of the morainic belts and the weakening of others.



MAP 6. Moraines and chief rivers of the Southern Peninsula; also locations of type maps 8-12 (numbered 4-8 on this map)

The retreat of the ice cover north of the southern water-parting of the Great Lakes drainage basin occasioned the formation of ice-dammed lakes, small at first, but later increasing in size. Lake Chicago, at the end of the Michigan lobe, Lake Saginaw at the end of the Saginaw lobe, and Lake Whittlesey at the end of the Huron-Erie lobe were formed in this manner; the last two united to form Lake Warren at a later stage. The drainage from Lake Warren to Lake Chicago by the Imlay Outlet accounts for the present-day channel of the Grand and Maple rivers.

The continued northward recession of the ice front resulted in different levels of the surface of the glacial lakes. Therefore, the margins of the Southern Peninsula at the present time have a series of well-defined glacial lake plains. The best examples are in the southeast portion of the state and around Saginaw Bay. The lakes finally dropped to their present levels when their eastward outlets through Niagara and the St. Lawrence were uncovered.

The depth and continuity of the deposits have given a uniformity to the landscape of the state. Conspicuous elevations and rugged profiles are notably absent. Rock outcrops at a few places along the present lake shores and in Hillsdale, Jackson, Presque Isle and Alpena counties, but nowhere has it any marked effects on the land forms. Five main areas of plain may be distinguished. The old lake plain in the southeast is formed in a series of steps representing the different levels of the successive glacial lakes. This plain tapers from about thirty miles in width in the south to a few miles in width in the neighborhood of Port Huron. The second plain was formed by glacial Lake Saginaw and its successors. It is separated from the previous plain by a rather complex morainic system formed in the reentrant between the Saginaw and the Huron-Erie lobes. The subparallel moraines, which border the Saginaw glacial lake plain in the northwest, provide the southeastern boundary for an extensive area of ground moraine and glacial outwash plains which extend as far north as Otsego, Montmorency and Oscoda counties. The moraines formed at the reentrant between the Saginaw and the Michigan lobes in Mecosta County separate the interior till and outwash plains from the fourth plain, which is composed of sandy lake deposits and has its maximum width of twenty miles where the Muskegon River flows across it to Lake Michigan. The fifth plain includes Kalamazoo, Cass and St. Joseph counties and was the outwash apron formed by the premature retreat of the Saginaw lobe.

Proving no exception to the general rule of recently glaciated areas, the surface drainage of the state varies greatly in its efficiency from one location to another. The majority of the surface streams are in the stage of early mature development in the normal erosion cycle, but with the irregular pattern typical of glaciated areas. Lakes occupying basins in the morainic belts or pits in some of the lowland areas of glacial outwash are present in every county except the three at the head of Saginaw Bay. Most of the shores of these lakes are marshy and bordered by belts of reeds, revealing the rapidity with which such depressions are filled by side-wash in a region of rainy climate and deep frosts (Dfb). Marshes occupy lake beds which have been partially filled and cover extensive areas of the old glacial lake plains and of the inter-morainic belts.

The primitive cover was dominantly forest. A line from Mill Creek in St. Clair County to the water-parting between Pine and Maple rivers in Gratiot County and thence to the southwest corner of Berrien County forms approximately the northern boundary between the southern hardwood forests, chiefly oak and hickory, and the northern forests of mixed hardwoods and conifers, and pure stands of pine. The areas of these pure pine stands coincided, for the greater part, with the north-central sand and gravel plains. The distribution of cedar, balsam, tamarack and other swamp vegetation corresponded to that of the marshy tracts. Patches of prairie, nowhere of any great extent, obtained prominence in the southwestern part of the state. At the present day, owing to the destructive exploitation of its virgin stands during the latter part of the last century, the greater part of Michigan has a second-growth timber. In the southern half of the state the percentage of cleared land is higher than in the northern.

INDIAN TRAILS

The first marks of human travel to be engraved on the primitive landscape were the Indian trails. The arrangement of these trails resulted from the interplay of three factors: first, the desire for communication; second, modes of transportation; and, third, the character of the fundament, chiefly land forms, soil and natural cover. The latter set of factors has been discussed in the previous section.

The activities of the Indians fell into two main divisions, agriculture and hunting. The pursuit of the former resulted in the tendency to become sedentary, to form permanent villages. Settlements were formed near spots most favorable to agriculture, where a suitable combination of level land, fertile soil and abundant water might be had. The morainic ridges were unfavorable because of their infertility, the marshes because of their unhealthiness. Mouths of rivers were most commonly chosen as village sites. There was a village at the mouth of practically every river on the western shore of the state. There were also concentrations of villages around the sites of the present cities of Mackinaw, Saginaw, Detroit and Niles. Scattered villages were found in favorable locations throughout the rest of the state. Maize cultivation was the dominant factor in the agricultural economy of the Indians, although there were other occupations. Better situation or greater industry might give to a village an increased ability to satisfy its needs. This created in neighbors a desire to raise their standard of living, either by barter or by the primitive but infinitely easier and simpler method, usurpation.

In hunting the Indian was necessarily governed by the habits of his prey. In their migratory movements deer and other wild animals tended to keep to definite routes. They avoided swamps, since their hoofs were unsuited for passage over soft ground. They traveled the lines of least resistance, as indicated by the river valleys and ridge crests. The hunter followed.

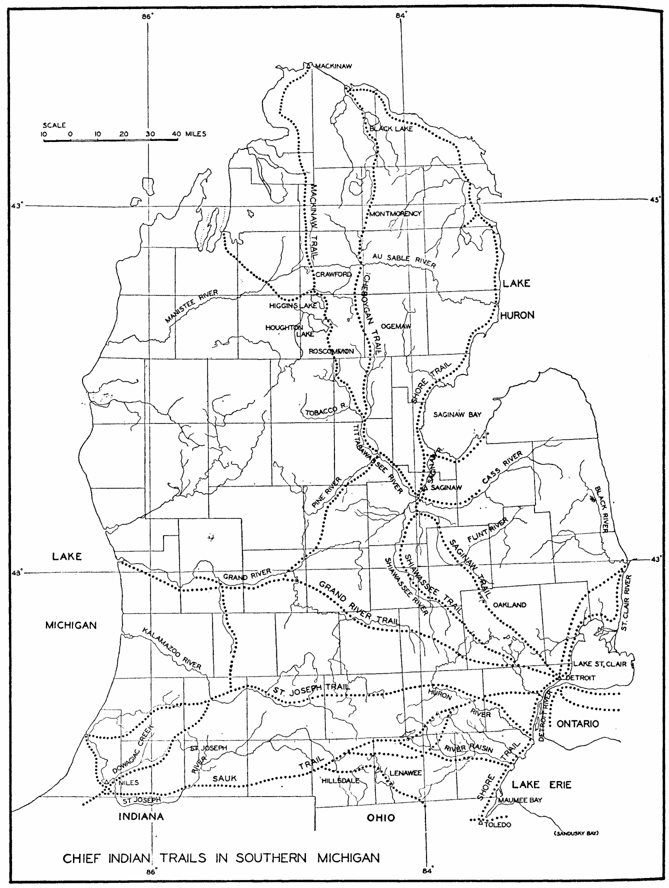
Tracks were developed, therefore, by the hunter pursuing his quarry and by the man seeking the products of his neighbor. These two agencies worked together; the same path frequently suited the needs of both and the casual trail became the recognized line of travel.

After the immediate needs of the group had been satisfied, the Indian, like other primitive beings, turned his attention to personal adornment. In the course of his wanderings, contact was made with neighboring groups, some new article was seen and immediately coveted, such as the copper of the Lake Superior district or sea shells from the tribes to the south. The elements of foreign trade became evident, and sometimes a medium of exchange was introduced, which usually had an apparent rather than a real value. The shells which came from the Gulf of Mexico probably are examples. Thus a system was evolved which was based on intercourse.

As regards means of travel, the Indian had but two, by foot and by canoe. Travel by land was the more important; even when he started by water, the Indian often had to go part of the way by land. In the months when the streams and lakes were ice-free long journeys were made by canoe, stream divides were crossed by portage, but the carrying of a light birch bark canoe imposed no great physical strain. In some months frozen streams necessitated recourse to land travel, thus accounting, in many places, for the faithful adherence of some trails to river valleys, which at times provided water transport. Domestic animals as means of transport were introduced only after the spread of the white man's culture, which brought with it the horse and the wheel.

The interpretation of the Indian trail pattern rests on the distribution in the state of the nodal points of settlement, which were connected by the chief trails. In detail the trail pattern is modified by surface features. Thus in order to find main trend lines of travel it is necessary to determine first the major points of settlement, which were also points of external contact. There were three of these nodal points (Map 7), the districts around Detroit, Mackinaw and Niles. First is the Detroit location, at the westward apex of a triangular piece of land formed by Lakes Huron and Erie, which had a marked nodality, since trails from the St. Lawrence Valley and southern Lake Ontario converged at the northern end of the Detroit River. The second point, Mackinaw, is situated where the Straits of Mackinac are narrowest and facilitate passage to the copper region of the Upper Peninsula. The third point, Niles, is just to the northeast of the place where all lines of travel from north and east would converge in order to pass around the southern end of Lake Michigan. The concentration of routes at Niles on the St. Joseph River seems to be due to a favorable ford. Thus one would expect to find in the Southern Peninsula of Michigan an approximately triangular pattern of travel trend lines in Indian times, with modifications due to surface features.

The Southern Peninsula of Michigan was only a link in the great chain of travel which stretched westward across the nation from the Delaware and Chesapeake bays for over a thousand miles. This was the Great Trail. It joined the southern Shore Trail of Lake Erie at Sandusky Bay, from which, owing to the shifting boundary of the Black Swamp near Maumee Bay, it varied somewhat from one year to another, but eventually reached the site of Toledo. A trail which continued along the shore of Lake Erie, the Detroit River and the western shore of Lake St. Clair, led to a village at the junction of the St. Clair and Black rivers. From the Detroit junction an important route extended in a southwesterly direction, first over the flat lake plain and then as far as the northeastern part of Hillsdale County along the southern slopes of the dissected morainic ridge which forms the main water-parting between the rivers of western Lake Erie and the Kalamazoo and Grand River systems. From there, the southwest trend was preserved; the trail went across morainic country, interspersed with small outwash plains, as far as the southwestern part of St. Joseph County, where the St. Joseph River was encountered and used as a guide. This trail continued around the southern shore of Lake Michigan to the site of Chicago. It is called the Sauk Trail and formed part of the Great Trail system by means of a connecting route from north-central Lenawee County along the right bank of the River Raisin.



MAP 7. Chief Indian trails of the Southern Peninsula

From the Detroit junction two trails branched in a northwesterly direction — the more westerly of the two being the Shiawassee Trail, which avoided the marshy interlobate reentrant area of the northwestern part of Oakland County by keeping to the higher ground in the southwest of that county until the headwaters of the Shiawassee River were reached. Thence it became a valley trail, linking at Flint River with the more easterly of the two trails, called the Saginaw Trail. Crossing this river by the most convenient ford a single trail ran northwestward along the banks of the Saginaw River to its junction with the Cass River. From this point a trail ran northwestward along the Tittabawassee River, the direction of which is determined by the western edge of one of the later moraines of the retreating Saginaw lobe of the ice-sheet.

At the confluence of the Tobacco and Tittabawassee rivers the trail branched. The western arm, the Mackinaw Trail, followed the former river, then skirting the eastern shores of Houghton and Higgins lakes, continued in an almost straight line along the water divide of the Au Sable and Manistee rivers, making the Indian settlements on the Straits of Mackinac its objective. The eastern or Cheboygan Trail made great use of river valleys, following the Tittabawassee to its source in Ogemaw County, whence it continued across the outwash plains of the northeastern part of Roscommon County and the southeastern part of Crawford County to the confluence of the North and South branches of the Au Sable River Since it utilized a small left bank tributary of the North Branch to its source in the southwestern part of Montmorency County only about ten miles of undulating country had to be traversed before a tributary of the Black River was encountered. This valley the trail followed to the Black Lake and thence to the Indian settlements at the mouth of the Cheboygan River. At this point connection was established with the Shore Trail which had conformed in its pattern to the outline of the eastern shore of the state from Saginaw Bay.

From the junction of the Pine and Tittabawassee rivers easy communication could be made with the western shore by means of the Imlay Outlet. The Pine River flows east in the eastern part of this trough and is separated in its upper course from the Maple River only by a low divide in the valley of the glacial drainage line. The Maple River is a right-bank tributary of the Grand River, which was followed throughout its lower and middle course by a trail of similar name, which had for its objective the district now occupied by Detroit. Although there was a marked converging of routes at the northern end of the Detroit River, this was not the area in which there was the greatest concentration of Indian villages. This occurred at the meeting place of the St. Joseph River and Dowagiac Creek. Communications were maintained with the head of the Detroit River by the Sauk and St. Joseph trails. The latter ran in a northeasterly direction up the valley of Dowagiac Creek, then along a section of land-laid moraine to the Kalamazoo River, which it followed with a due easterly orientation to a right bank tributary of the Huron River; the valley of this stream facilitated the linking up with the eastern end of the Sauk and the Shore trails.

It is unfortunate that data are lacking for the completion of a western trail from Mackinaw to Niles; otherwise the triangular pattern would be strikingly illustrated. Traces of a trail down the west coast have been discovered, but not enough to warrant the inclusion of a western trail in this study. The two other sides are shown by the Sauk and St. Joseph trails on the southern side of the triangle and the Shiawassee, Saginaw, Cheboygan and Mackinaw trails on the eastern side. That there is a correlation between the pattern of the surface features and the pattern of direct lines between the points of external contact is shown by variations of these trails from the straight line. In every case the variation is capable of explanation by some surface feature.

Whether the east-west routes in Indian times were of more importance than the north-south routes is difficult to determine. The line of the Great Trail, the convergence of travel lines in the southeast of the state, the village grouping at both ends of the Sauk Trail, all point to an emphasis on east-west routes, yet a widespread distribution of copper from the Upper Peninsula must have occasioned frequent travel north and south. Probably the Mackinaw, Cheboygan, Saginaw and Shiawassee trails were of equal importance with those of the Sauk, St. Joseph and Grand River.

The entrance of the white man upon the scene introduced another phase in the road pattern.

THE COMING OF THE WHITE MAN

The state of Michigan was for some time sheltered from the feet of white intruders during the early part of Colonial history. At the end of the sixteenth century and the beginning of the seventeenth, the English were making a footing on the New England coastal plain, while the French were pressing up the St. Lawrence. The presence of the haughty and powerful Iroquois nation in the region stretching from the eastern end of Lake Erie to Lake Champlain kept the adventurous French, to whom the Indians were hostile, to the north. The English at this time were bent on consolidating their agricultural settlements east of the Appalachians and so they had no great call to test their rather nominal friendship with the Iroquois. The French settlements began with traders' huts, fortified posts and missionary stations; their objects were fur-trading, dominion and evangelization. The English settlements began with outlying villages and farms; their object was agriculture.

In 1634 Jean Nicolet, following the paths of Le Caron, a Récollet friar, and at a later date Champlain, traveled up the Ottawa and Mattawa rivers, made the short portage to Lake Nipissing and thence by the French River and Georgian Bay to the "Mer Douce" (Lake Huron), eventually going on to Green Bay. It is significant that the first and most important French posts were at Sault Ste. Marie and Saint-Esprit (near the head of Lake Superior); these were settled in 1668. The southern parts of Lake Huron and Lake Erie were neglected. In 1669 a mission post was founded on the Island of Michilimackinac, in the Straits of Mackinac; the settlement was subsequently moved to the mainland. This was the first French recognition, although it was probably unconscious, of one of the main points in the Indian trail pattern. The Indian settlement through its strategic position attracted priests, traders and soldiers. Some ten years later La Salle ascended the St. Joseph River and founded Fort Miami; this settlement persisted through many vicissitudes, until it was eventually superseded by the building farther up the stream of Fort St. Joseph. But it was not until 1701 that a French settlement was formed at Detroit and even then its founder, Cadillac, came by the Georgian Bay and St. Clair River route. Detroit was not founded by the French primarily because it was on their east-west line of travel, but chiefly for other reasons. The "Thumb" of Michigan provided some of |he best known beaver grounds; the poorly drained morainic country was particularly suitable to the beavers as a habitat. There was also great danger that the English, by virtue of their friendly relations with the Iroquois, would travel along Lake Erie and up the Detroit River, and so exploit these beaver grounds, of which Detroit was then a guardian. It was also a center for the evangelization of the neighboring villages as well as an excellent port for the shipping of skins.

Although the French preferred to travel by way of the Lakes, it must not be supposed that they confined themselves to them. The following extract shows how much the settlers were dependent upon the Indians: "Detroit habitants also cultivated the soil, but that settlement drew large quantities of supplies from the Illinois."[2] It is hardly likely that a long journey was made when a much shorter one by land would serve the same purpose. It is beyond doubt that considerable use must have been made of the Sauk and St. Joseph trails by the traders and *coureurs des bois* in their journeys to the western side of the state. Although in 1749 French reports stated that English traders were swarming into the Maumee Valley, and although in 1763, when Canada was ceded to England, more traders came into this region, yet no new centers were developed and the early pattern remained unchanged except for a somewhat greater emphasis on the east-west routes and the growing importance of Detroit, owing to the opening up of Lake Erie as a line of travel.

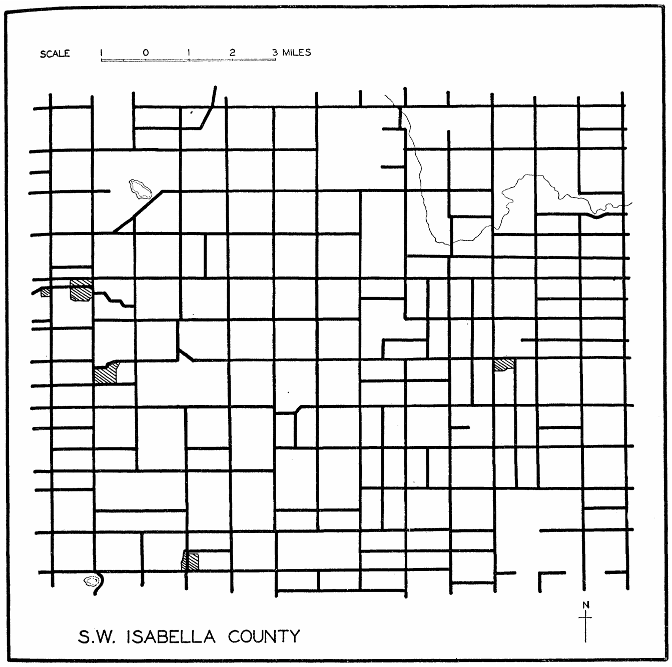
THE INTRODUCTION AND APPLICATION OF THE RECTANGULAR SURVEY

The year 1783 saw the end of the American War of Independence and the beginning of disputes about the extent of the territories of the several states. Between 1780 and 1802 the problem was solved by creating in the west, under the federal government, a vast territory which was to be called the "public domain" and which was later to be split into new states. Numerous and frequently large tracts of this territory were sold to potential settlers and these purchasers naturally had their land surveyed, with the result that overlaps or narrow strips between the various purchases were frequently noted and were a source of constant dissension. Great need was felt for the systematic survey of the area. In 1785 an ordinance was passed establishing the subdivision of the "public domain" by means of rectangular surveys. Since the township plan had previously been used in New England, the rectangular survey was by no means new, but it was recognized that this kind of survey afforded a security of title which provided an orderly settlement of new lands. The novelty of this system as it was applied to the "public domain" lay in the determination to make "careful surveys of the townships six miles square and of the thirty-six internal sections in each, before disposing of the public lands."[3]

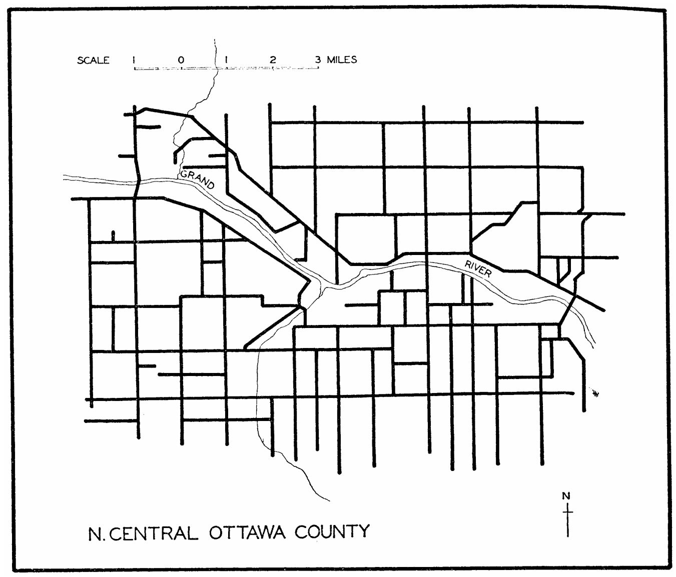
As late as 1805 the inhabitants were very much backwoodsmen and the total number in the Michigan area was only some eight thousand. Detroit was the nominal head of this area and it owed this status to its previous position as an important fur-trading center and a fortress. A series of events took place soon after this which greatly stimulated interest in Michigan and led to its subsequent development. In 1817 the first steamboat Walk in the Water appeared on Lake Erie; in the same year the Erie Canal was begun and it is significant that in 1819 Congress, in anticipation of the boom, organized the lower tier of counties in the Michigan area. The opening of the Erie Canal in 1825 greatly aided the outpouring of settlers from New England and New York, as is shown by the following figures. The population of the Michigan area in 1820 was 8,000; in 1830, 31,000; in 1840, 212,000.

The division of the land into rectangles, oriented to true north and south, necessarily involved the construction of roads the pattern of which would conform to the plan of land divisions. There were, however, several obstacles which were not to be overcome; they may be classed as "natural" and "cultural," although this division is purely arbitrary. Lakes, swamps and rivers may be classed as "natural obstacles"; previous settlements, such as Detroit, and established routes of travel may be classed as "cultural obstacles." There is a well-founded principle that a thing established tends to persist.

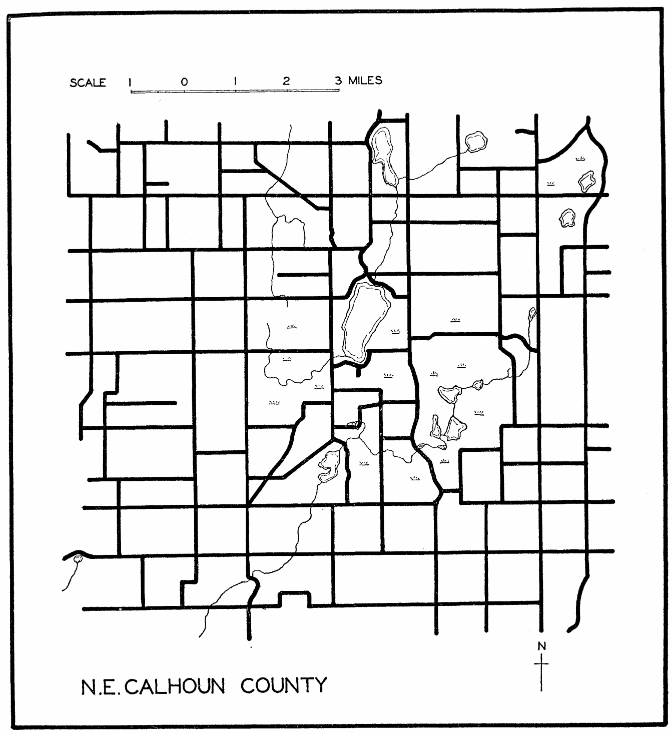
In an area of glacial deposition like the Southern Peninsula of Michigan lakes and marshy tracts are scattered over the surface in great abundance, so that it is extremely difficult to select a type area of rectangular pattern which does not have some modifications because of lakes and marshes. (See Map 8,[4] in which there is shown a minimum of modification in the pattern by lakes and marshes, as opposed to Map 10, in which the marshes and lakes cause great alterations in the pattern.) Since the whole area, is one of low relief, there are no modifications on account of gradients which might prove too severe to be practicable. The presence of rivers, although not necessarily a modifying factor, frequently was one, since to avoid unnecessary duplication of bridges on the little-used routes there would tend to be a concentration at bridgeheads; numerous examples can be found on the topographic map of roads following the bank of a stream some way before crossing it. (See Map 9, in which roads run along the bank of the Grand River and tie in the ends of the rectangular roads to the bridgeheads.)



MAP 8. Typical rectangular road pattern in the state of Michigan



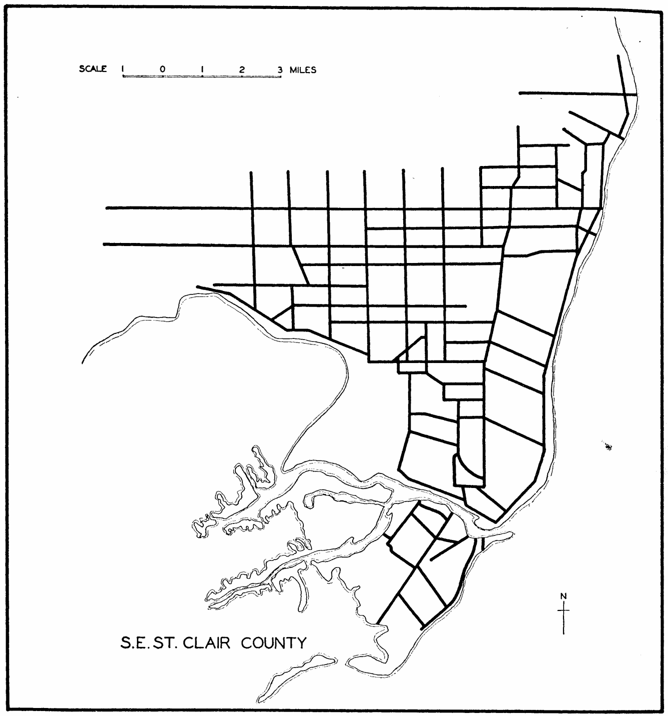
MAP 9. Modification of rectangular pattern by river



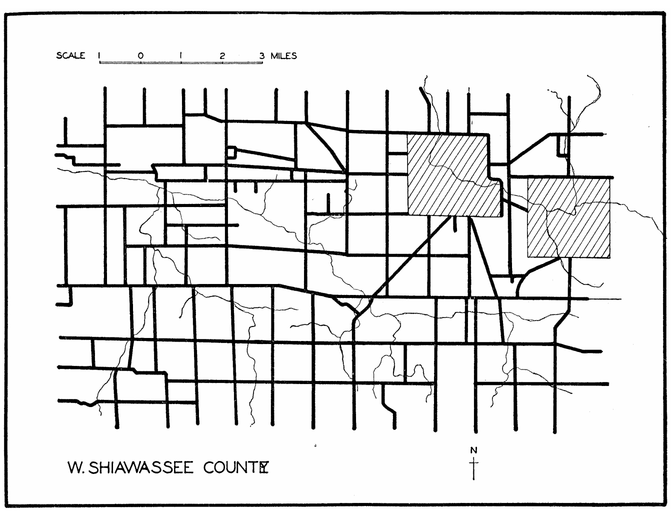
MAP 10. Modification of rectangular pattern by lakes and marshes

The cultural influences had their greatest effect in the southern part of the area. Mackinaw had not grown at a rate in any way commensurate with the growth of Detroit; the Erie Canal was responsible for this. Detroit had become a center, and had a focal, and, conversely, a radial road pattern; the Indian trails had formed the nucleus of this, but the increasing importance of connections east and west as compared with those north and south had accentuated this. The point of concentration had moved from southwest Michigan into northeast Illinois, at Chicago, and there was a growing interest in the lands west and southwest of Lake Michigan-all of which tended to emphasize the function of the routes west from Detroit to such an extent that no arbitrary route was able to disturb those already established. Moreover, in the disturbances at the beginning of the nineteenth century the old St. Joseph Trail was used by the military and it survived for a long time as the Territorial Trail. On the other hand, the routes in the northern part of the area, owing to the fact that their functions as routes were for a time in a decline as compared with those of the south, took on a decidedly angular appearance as a result of the rectangular survey. In southeast St. Clair County (see Map 11) the roads show a distinct tendency to be oriented at right angles to the River St. Clair. A pattern like that formed by the roads of the old "shoe-string" farm settlements of the French along the St. Lawrence River, where every original land grant had some river frontage, points to an influence before 1785. Minor modifications are also noticeable, owing to the inability of surveyors to tie the section lines in accurately. This caused a slight offset in an otherwise straight road (see Map 12).

It may be seen that the creation of roads according to the rectangular pattern means the creation of "nominal" roads that may be functional roads, but are not necessarily such; in fact the pattern may be called an artificial one. The mere laying out of a strip of land and surfacing it with the necessary material to mate it appear like a road does not mean that it will be utilized as a road. It has to have a definite function as a route of travel. The rectangular survey, with its accompanying road pattern, is an extremely efficient method of dividing up land of low relief, at an early stage in development. But as soon as the favorable sites are developed at the expense of those less favorable, urban formations spring up and the need for direct communications is immediately felt. Moreover, the urban centers are rarely so accommodating as to situate themselves at the ends of corresponding due east, west, north and south lines. In any case, as soon as there are more than two centers, the problem of diagonal communication has to be faced, and at the expense of modifying the rectangular pattern.



MAP 11. Modification of rectangular pattern by earlier settlement



MAP 12. Modification of rectangular pattern by surveying errors

FURTHER MODIFICATIONS OF THE RECTANGULAR PATTERN

During the present century there has been an enormous increase in the urban population of the state, while the rural population has shown a decrease. In the ten-year period 1900-10 the urban population increased from 952,000 to 2,241,000, but the rural population decreased from 1,468,000 to 1,426,000. The meteoric growth of Detroit incidental to the popularity of the automobile has been largely responsible for this. Moreover, the introduction of the automobile itself has caused a concentration of markets; the large town has further increased its size at the expense of the smaller town. To take a local illustration, the journey from Dexter to Detroit and back (some 80 odd miles) would have been a very good two-day trip previous to 1900, but with a modern automobile three hours is ample time. Although formerly the rural dweller around Dexter had to buy and sell in the small town or waste an enormous amount of time, he now transacts his business in a larger city where there is a more comprehensive market for both buying and selling. The outcome of this is the desire to travel rather long distances in a short time. Therefore, in its capacity of guardian of the public weal, the state has to see that roads are in such condition as to be able to meet the new demands which are made of them. In a state like Michigan there are two ways in which a road may be adapted for fast traffic: first, by improving the surface, which, of course, leads to no change in the pattern and, therefore, will not be considered here; second, by straightening the route and obviating all unnecessary turns. On the rectangular pattern, any travel which was not in a due north-south or east-west direction involved frequent right-angled turns, an oblique direction only being achieved by a series of steps. The flattening out of these steps resulted in a considerable shortening of distances. Examples of this type of road improvement are too numerous to mention specifically. They are to be found half a dozen times along U. S. Highway 16 between Ann Arbor and Grand Rapids and this situation is typical for the state (see Fig. 9). It is noticeable that the greater the function of the route the sooner it tends to lose its rectangular characteristics. For instance, the main roads from Detroit to the southwest have lost what little of the rectangular pattern they ever acquired; route U. S. 16, although still retaining some rectangular features, is rapidly becoming straightened, but many cut-off corners are noticeable on route U. S. 27 from Lansing to Cheboygan, although there are still right-angled bends on the latter route. The secondary roads are, as yet, practically unmodified from their original pattern. It is significant that the sections of the state remote from the urban centers and their connecting links tend very markedly to retain their rectangular pattern; the "Thumb" of Michigan provides an excellent example of this (Map 13).

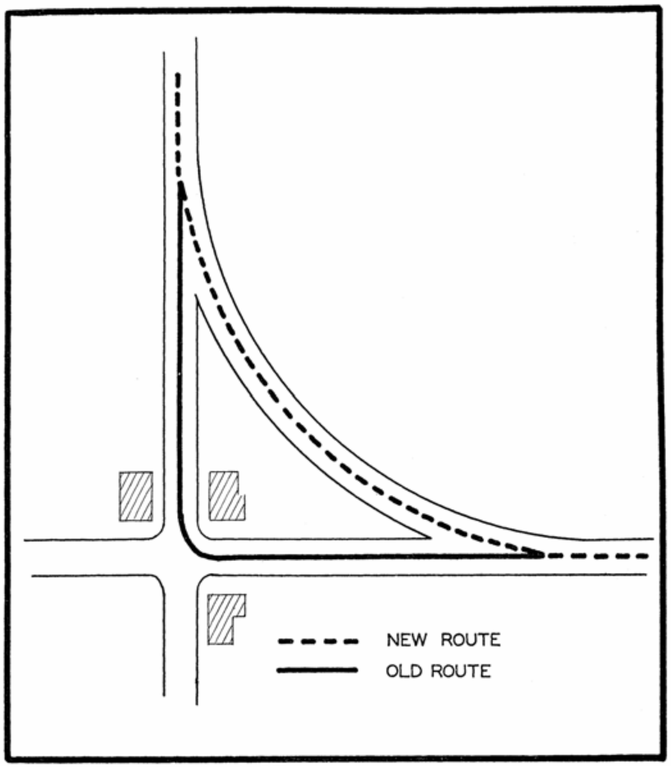
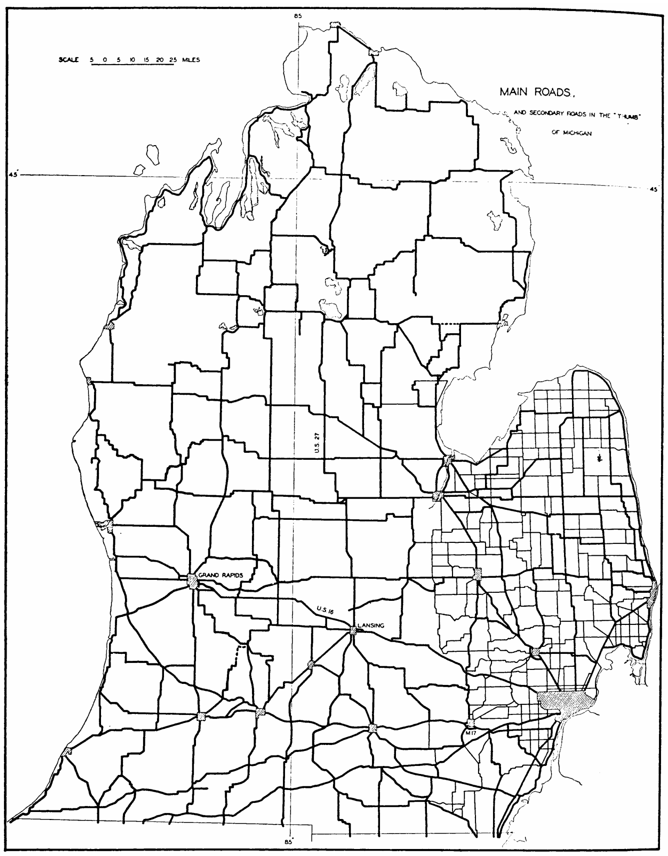


FIG. 9. Modification of the rectangular pattern by typical "cut-off"



MAP 13. Road map of the Southern Peninsula, showing secondary roads in the "Thumb" and main roads in the rest of the Peninsula

In the urban centers, which are essentially artificial in their setting, there is a tendency to use the rectangular pattern, for it admits of an orderly arrangement of lots and a consequent saving in space. There is, however, one modification which has come with the increase in the function of the urban center as a point of concentration; that is the development of a marked radial road pattern. On the other hand it may be only an accentuation of this radial pattern by the filling in of the space between the arms of the roads, as in the case of Detroit, which had such a pattern in the days of the Indians and French settlers. There is a tendency, which is more marked in the pattern of some English roads, for "by-pass" roads to be constructed to enable traffic to miss the centers of the smaller towns; such a road now exists on the outskirts of Ann Arbor (route M-17). This again is the direct result of the growth of "through routes" incidental to the development of high speed traffic, the concentration of markets and consequent congestion of towns.

The uniform surfaces of the old lake plains surrounding the Southern Peninsula were recognized as possible routes, even in Indian times, but with improved drainage and a general lowering of the water-table of the whole state, it has been made possible to encircle almost the entire Southern Peninsula with a road.

CONCLUSION

The road pattern of the Southern Peninsula may be said to have passed through two phases and to be now well advanced in the third. In the first phase, which may be called one of natural pattern, a road or trail was developed only as the necessity for it arose and its importance was in direct proportion to its function or use as a route of travel. The second phase was an artificial one; roads were created which had no justification for existence; many of these were purely "nominal" roads and had no functional significance. A journey along one of the modern state highways will show "nominal" roads, a strip of land inclosed by parallel fences and exhibiting few signs of use. The rectangular road pattern could not cope with the complex distribution of centers of population, since by it the principle of the road as the easiest and shortest route of travel between two points was neglected. The third or contemporary phase is a return to a natural pattern, but with many modifications inherited from the intervening artificial phase.

UNIVERSITY OF MICHIGAN

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* Paper from the Department of Geography of the University of Michigan, prepared under the direction of Professor Preston E. James. For information regarding the Indian trails, the author is indebted to Dr. W. B. Hinsdale of the University of Michigan.

[1] Leverett, F., and Taylor, F. B., *The Pleistocene of Indiana and Michigan, and the History of the Great Lakes, U. S. Geol. Surv*., 1915.

[2] B. A. Hinsdale, *The Old Northwest* (New York, 1888), p. 50.

[3] From the Ordinance of May 20, 1785.

[4] Maps 8-13 are taken from the road maps of the State Highway Department, Lansing.

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COVER MAPPING IN SOUTHERN MICHIGAN

OTTO E. GUTHE AND KENNETH C. McMURRY

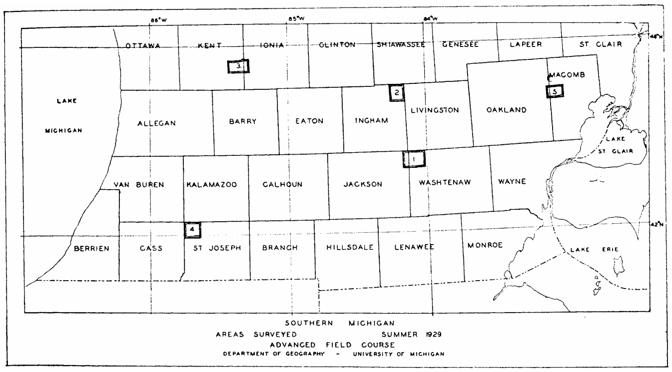
THE land inventory as practiced by the Land Economic Survey has become the fundamental basis for the planning of land use in northern Michigan for many conservation purposes. This inventory, with its precise presentation of the facts of soil, cover and economic condition, forms the background of scientific determination of assignment of lands to such purposes as game refuges, public hunting grounds, state forests, wilderness parks and the like. It is true that the inventory includes wild life only incidentally, but the relationships between wild life, cover and distribution of land types and uses are very close. Only the broader phases of this series of relationships are clear at present, but enough is known to make procedure much more definite than at any time in the past.

The counties mapped by the Land Economic Survey all lie in the north, and in the less settled parts, so that "wild land" is the principle type involved. The areal relationships of wild and agricultural lands are important, but granted an area of sufficient size, the characteristics of wild land are of chief importance. The game species of the north, deer, bear and partridge, are essentially associated with wild lands, with few close relationships to settlement. The results of the Survey, therefore, are of value in only a part of the state.

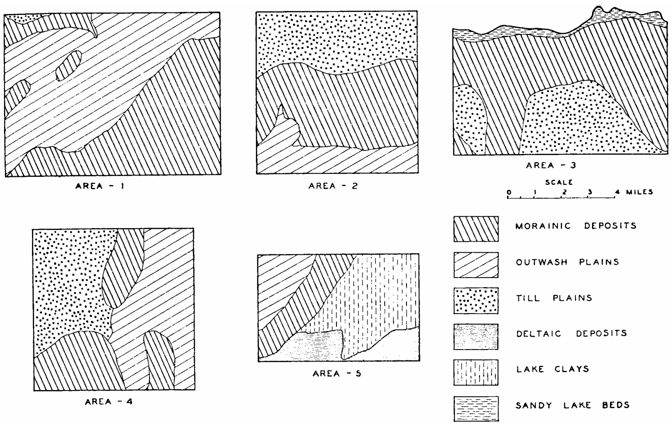
Southern Michigan presents a different picture. South of the latitude of Saginaw Bay, wild land in terms of the north disappears, and crop land assumes the dominant position. This southern half of lower Michigan ranks with the best agricultural sections of the country in terms of productive farm land, with 50 to 75 per cent of all farm land classed as improved. The problems of land use in this section differ entirely from those of the north. Instead of the problem of putting idle land into some form of use of recreational character, intensification and improvement of farm practice are of chief importance. Large-scale ownership of residual lumbering lands is replaced by individual farm ownership of small farms. Recreational use of land is a minor matter, rather than a major item.

In another sense recreational land is of greater importance in the south than in the north. Of 400,000 small game hunting licenses sold in 1929, about three fourths were for use in this southern agricultural section of the state. To be sure, this is but one of several types of recreational use of land, but it is sufficiently important to merit close study. Three hundred thousand hunters evenly distributed over 10,000,000 acres would mean less than forty acres per hunter, and the fact that some areas are far superior to others in stocking of game actually means a high degree of congestion in some sections during the hunting season. The large expenditure over several years for propagation of pheasants and their release in this southern country illustrates the appreciation of the problem by the state authorities. The demand for hunting facilities of good quality far exceeds the supply in this part of the state, a situation which is not duplicated in the major farm products of the area.

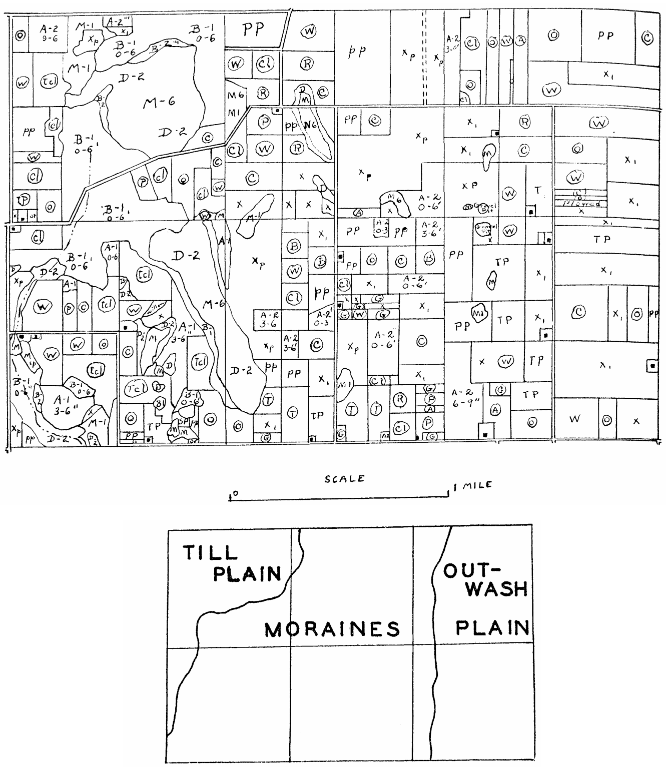
Farming methods, organization and procedure have received a large amount of attention over a long period. Millions of dollars have been spent in experiments, investigations and surveys. All classes of farmers are serviced in terms of their various types of production by extensive organizations, and by a background of fifty years of experimentation. The game crop has received but little attention. Legislation, attempting to limit seasons and bags, has been the major experiment in regard to this crop, with the addition of occasional planting of such exotic species as the pheasant in more or less haphazard manner. Lately, with the growing demand for the game crop, it has seemed probable that great improvement is possible. "Game management" has become a rather common idea among sportsmen. A field for investigation has been opened in which it seems possible that in time methods of improvement analogous to those of scientific farming may be applied.



MAP 18



MAP 19. Surficial geology



MAP 20. Cover map of a part of Flowerfield Township, St. Joseph County, Michigan

LEGEND FOR MAP 20

Timber sizes, 0-3", 3-6", 6-9", 9-12", 12-15", 15" plus at breast height
Timber stocking, ' = poor, '' = medium, ''' = good

Upland timber associations

A1 — Oak, hickory, elm, basswood, white ash, cherry
A2 — Sugar maple, beech, oak, elm, hickory, white ash, cherry
A3 — Oak, hickory, beech, maple, ironwood

Swamp and semiswamp timber associations

B1 — Elm, ash, silver maple, swamp white oak, aspen, tamarack, willow
B2 — Tamarack, aspen, maple, elm, willow
B3 — Elm, ash, oak, silver maple, sycamore, beech, basswood, walnut, butternut, aspen, cherry, cottonwood, tulip
B4 — Pin oak, white oak, elm, red maple

Shrub brush associations

C — Brush and small second growth following lumbering
D1 — Willow, aspen, birch, sedges
D2 — Osier, huckleberry, ilex, tamarack, aspen, birch

Marsh associations

M1 — Sedge, bluejoint, shrub willow, aspen, birch, tamarack
M2 — Cat-tail, sedges, sagittaria
M3 — Water-lily, sagittaria
M4 — Lake bulrush
M5 — Buttonwood ponds
M6 — Leatherleaf sphagnum, blueberry

Non-cropped cleared lands

X — Apparently idle or abandoned land
PP — Permanent pasture
SP — Swamp pasture

Cropped lands

These lands are indicated by circles, with the following letters designating their use: A, alfalfa; B, beans; Be, beets; Br, barley; Bw, buckwheat; C, corn; Cl, clover; Fl, farm lot; Gr, garden; O, oats; R, rye; Rt, redtop; Sw, sweet clover; T, timothy; W, wheat. Any special crop may be written in.

A possible first step in the development of scientific method to the game crop problem is the application of the land inventory method, which has proved so successful in the wild lands of the north. Since agriculture is well and permanently established in the southern part of the state, and since the game crop is of minor importance in comparison with farming, the state probably is not justified in undertaking any such operations as those of the north. If the inventory is essential, some more simple and economical procedure is necessary. A method of sampling has been devised for this purpose. Map 18 illustrates the application of the sampling principle. Several townships were chosen, widely distributed through the southern part of the state. To judge from topographic maps of the U. S. Geological Survey, soil maps, and maps of surficial geology, each of these townships is fairly representative of a much larger section of the state. A major difficulty arises from the fact that the structure of southern Michigan is extremely complicated, with wide variety of soil, surface and drainage within small compass. There are no broad expanses of land of simple and similar structure, like those of the till plains farther south and west. Therefore townships are chosen which represent each of the major land types of the region in considerable area (Map 19). Moraine, outwash plain and till plain appear on the various maps, with an area of lake plain in one of the maps, and the relative areas represented are roughly the same as in their relationships over much broader extent. It is believed that these five townships, representing but a tiny fraction of the area of this southern part of the state, are fair samples or cross-sections of a considerable part of the whole area. If this is true, the results obtained from the sample or type area may be applied with a considerable degree of accuracy over a much broader area.

As the term is commonly used in the north, there are no "wild lands" in southern Michigan. On the other hand, there are various types of essentially non-agricultural lands. These are classified into various types: (*a*) upland forest, (*b*) swamp forest, (*c*) brush swamps, (*d*) marshes (see Map 20 for details of legend). In the small part of the total area mapped, which has been analysed to date, the combined total of these non-agricultural lands is 24 per cent of the total area. Such wild lands are of importance in providing cover for protection, food, nesting places, etc., for the various forms of wild life.

The fields of various crops are significant in relation to different birds and animals. They provide food, shelter and nesting places for various species. With this fact in view each field has been mapped and the particular crop of the year noted. The percentage of actual crop land in the area presented on Map 20 is 38 per cent.

For twenty years at least the actual amount of crop land in most of southern Michigan has been shrinking steadily. This gives rise to the third category or classification, permanent pasture and abandoned land, 34 per cent of the area mapped. The term "abandonment" indicates merely cessation of regular use for either crop or pasture, a common situation in this area, but not necessarily permanent. The growth of weeds, brush and the like on such fields gives food and cover of a desirable character.

It has been shown by analysis that the details of the land use (Map 20) vary considerably with the character of the surficial geology, which to a considerable degree causes differences in soil and in land surface. Of the area under discussion, the extreme eastern portion, 27 per cent of the total area, is outwash plain. The central and southwestern portion, comprising 59 per cent of the area, consists of morainic deposits, while the northwestern portion, or 14 per cent, consists of till plain, much of which is poorly drained.

On the outwash plain, the major part of the acreage is devoted to crops. The almost level land surface, together with the calcareous sandy loam soil, undoubtedly accounts largely for this predominance of crop land. Wheat has by far the largest acreage, followed by oats and corn. During the year 1929 considerable acreage was left idle, but there was clearly no permanently abandoned land.

Much uncleared land is found in the portion underlain by morainic deposits and in the poorly drained till plain in the northwest. This uncleared land consists chiefly of swamp timber and scattered areas of other swamp types of vegetation; on the better drained lands several stands of upland timber are noted. The dominant crop is clover or timothy, with corn next in importance. Large areas of uncleared land remain abandoned or in permanent pasture. The character of land use in this portion of the area results largely from the fact that the surface as a whole is rough and rolling, with a coarse-textured, sandy loam soil. As is characteristic of morainic deposits, areas of poorly drained land are prevalent.

On the till plain in the northwest the proportion of the acreage in crops increases, except in the poorly drained parts. Here the land surface is gently undulating, with a soil similar to that of the outwash plain, but with crop associations closely allied to those of the moraines rather than to those of the outwash plain.

As outlined in part above, the inventory gives the actual areal extent of the cover types of all kinds which may be measured accurately. It shows decided differences from place to place and between variations in soil and surface. The actual classification of cover types used is, of course, merely tentative. It seems quite probable that experience may show the value of further refinement. In addition, the maps reveal clearly the patterns of cover types, that is, the areal relationships between the various classes. Some sections are composed almost wholly of crop lands; in others the crop lands are distributed irregularly among wild land types. Such pattern is of major importance, especially to the wild life species which do not range widely.

The cover mapping, as carried out during the summer of 1929, makes no effort to appraise the wild life itself, either actual or potential. Such mapping is but the first step in the inventory. The next step is the inventory of wild life itself, in terms of the various cover characteristics and patterns which are illustrated here. Naturally this must, in turn, lead to the study of the relationships between the wild life forms and the environment, and between the forms themselves. The project, of course, is experimental in character. The cooperative efforts of various scientists are necessary to bring it to a logical conclusion. The scientific development of game management and the development of the game crop to a maximum appear to require such basic data as result from the completion of the inventory.

UNIVERSITY OF MICHIGAN

AGRICULTURAL REGIONS IN MICHIGAN

ELTON B. HILL

MICHIGAN is a large state. It is a distance of about 400 miles from the northern tip of Keewenaw County to the southern edge of the state; from the extreme eastern to the western part of the state it is about 385 miles. Within this large area is found a wide variation in soil type and surface and climatic conditions. Largely because of these things, together with factors of an economic nature, Michigan farmers have found it advantageous to follow types of farming which vary quite widely within rather short distances. An understanding of the nature and extent of these variations should be of interest and value to geographers and others who desire to know more about the basic nature of the resources of the state.

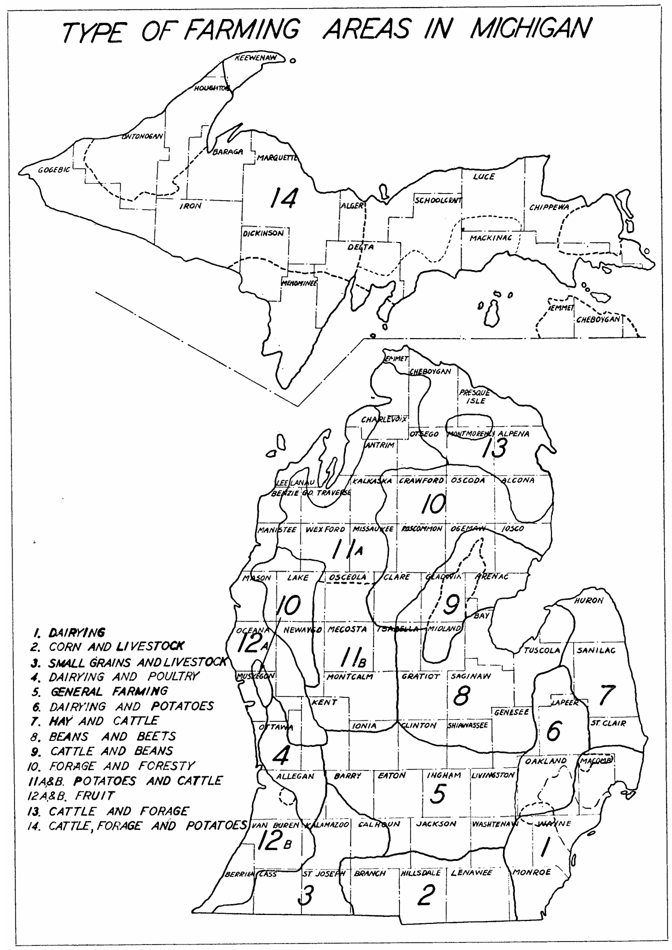
The great diversity of crop and livestock production in Michigan has long been recognized. In 1914 Shaw[1] pointed out that Michigan was practically a self-supporting state with the exception of cotton, citrus fruits and rubber. The distribution of the different agricultural enterprises was shown by Church[2] in 1922. The grouping of these different enterprises into regions in which a homogeneous type of agriculture prevails is in accord with established geographical practice. In this study we have attempted to locate and delineate different agricultural regions in Michigan within which there are similar crop and livestock organizations and similar physical and economic conditions with respect to climate, soil type, topography, markets and price of land.

That a knowledge of the agricultural regions of the state is quite essential in the application of certain economic principles to farming is evidenced by the work of this nature which is being done in other states and by the Bureau of Agricultural Economics of the United States Department of Agriculture. Spillman[3] has prepared an excellent treatise for the different types of farming areas of the United States. In 1928 bulletins relating to the agricultural regions of their states were published by North Dakota[4] and Massachusetts.[5] In 1929, similar publications were issued by Iowa[6] and by South Dakota.[7] Many other states have work under way leading to publications for the purpose of delineating and describing the different types of farming areas or agricultural regions within their borders.

METHODS AND SOURCES OF INFORMATION

This study by the Michigan Agricultural Experiment Station was in cooperation with the Bureau of Agricultural Economics, United States Department of Agriculture. Through the use of the 1925 census the counties which had a similar type of agriculture were grouped together. Then the 1922 Supervisor's Census made township data available which enabled us to cut through political boundaries. This rough outline map was then checked carefully with agricultural specialists at the Michigan State College and with farmers and county agricultural agents throughout the state. Either F. T. Riddell, co-worker on the project, or the author carried it for the purpose of checking in practically all the different regions. The result is the accompanying map (Map 24).

The line of separation between many of the regions is relatively quite distinct in that there is a significant change in the kind and amounts of crop and livestock enterprises within the range of a few miles. In other places the change from region to region was more gradual and less distinct. Some lines of demarcation are still subject to debate and change, depending upon the emphasis placed on the individual farm enterprise.



MAP 24. The outlines of the fourteen major agricultural regions of Michigan

THE REGIONS

For practical purposes it is not desirable to account for the occasional small sections to be found in many regions which, owing to extreme variations in soil types, have a somewhat different type of agriculture. It is desirable to keep the number of regions as low as is consistent with the major types of farming areas within the state.

In Michigan's agriculture there are three basic crop enterprises, namely, dairy, hay and oats. These are found generally throughout the state, and the other enterprises are for the most part superimposed upon them. Thus the different regions were delineated on the basis of the variation from the average. Quite often the predominance of certain crops or livestock and physical conditions was the determining factor. At other times it was a matter of degree of intensity.

The causal factors of major importance in determining the different agricultural regions are considered to be: (1) physical, relating to climate, soil and topography; (2) economic, relating to transportation, distance to markets, kind of markets, market demand and price of land; (3) biological, relating to insect pests and the plant and animal diseases.

In this study the state was divided into fourteen major agricultural regions. The type of farming practiced was the main criterion in determining the outline for the different areas. A name was selected to represent the major agricultural enterprises found on the farms in each section.

REGION 1: DAIRYING AND TRUCK CROPS

This is the specialized dairy and truck crop region of southwestern Michigan and is comprised of Monroe, Wayne and parts of the adjoining counties. In these counties the trend of both these enterprises has been upward for the past twenty years to a greater extent than it has in adjoining areas. Dairy cows and poultry are of major importance. Sheep and swine are not numerous except in Monroe County. Corn, wheat and oats are the major field crops. Fruit is found in the northwest corners of Macomb and Wayne.

The predominance of this intensive type of agriculture is due to near-by markets and favorable soil conditions. In addition, the price of land and taxes are relatively high, which tend to force more intensive types of farming. The surface is level for the most part.

REGION 2: CORN AND LIVESTOCK

This region is composed of Lenawee, Hillsdale, Branch and portions of adjoining counties. The soil and climate more nearly approach "corn belt" conditions than in any other region in the state; thus we find corn an important crop with its usual complement of hogs, cattle and sheep. All grain crops do well, and wheat is the most important cash crop. Sugar beets are grown in the eastern part of Lenawee County. The steer-feeding sections center around Blissfield and the lamb-feeding sections around Clinton in Lenawee. Dairying has been increasing rapidly, especially in Branch and Hillsdale. Lenawee is one of the poultry centers of the state. About 90 per cent of the land was in farms in 1925.

REGION 3: SMALL GRAINS AND LIVESTOCK

This region comprises the counties of Cass, St. Joseph, most of Kalamazoo and Calhoun and the southwest corner of Barry. It is a small grain and general livestock section somewhat similar to Region 2, but with about one third less cattle and swine and one half less sheep per 100 acres of improved farm land. The major cash crops are wheat, rye and potatoes. Mint, onions and celery are minor crops. From 80 to 85 per cent of the land area was in farms in 1925.

The soils and topography are the major factors determining the type of farming. The soils are, for the most part, sands and sandy loams low in humus and medium to low in fertility and acid in reaction.

REGION 4: DAIRYING AND POULTRY

This region is comprised mostly of Ottawa and Allegan and parts of Kent and Muskegon counties. It is one of the most intensive dairy and poultry sections of the state. Swine and sheep are not numerous. In 1925, corn occupied about 15 per cent of the crop area, wheat and rye about 13 per cent and oats 10 per cent. Truck crops, namely, celery and onions, are also of importance. There is much variation in soil types, from sands to clay loams. About 82 per cent of the land area was in farms in 1920.

REGION 5: GENERAL FARMING

This general farming region is based primarily on dairying, wheat and beans. It comprises all of Livingston, Ingham, Eaton and most of Jackson, Barry, Clinton and Ionia counties. It is one of the largest areas in the state in which a similar type of farming predominates. The swine and sheep enterprises are also of much importance. Somewhat less corn is produced than is produced in Region 2 to the south. The topography varies from gently rolling to hilly. Thus on many farms will be found untillable pasture land which favors the dairy and sheep enterprises. From 80 to 85 per cent of the land area was in farms in 1925.

A combination of climate, soil, topography and marketing conditions determines the type of farming.

REGION 6: DAIRYING AND POTATOES

This region comprises part of Tuscola and most of Lapeer and Oakland counties. Potatoes are the leading crop. The major livestock enterprise is the dairy. Sheep, formerly of importance, have been decreasing since 1910. The number of hogs has been decreasing since 1920. Much tree fruit is found in the southern part of Oakland; beans are common in Lapeer and Tuscola. The topography is for the most part gently rolling to hilly.

In general, the soils are somewhat lighter than in the surrounding regions. The chief factors determining the type of agriculture are soils, topography and nearness to market.

REGION 7: HAY AND CATTLE

This region, commonly known as the "Thumb," comprises the northern portion of St. Clair, all of Sanilac County and the eastern part of Huron. Beef and dairy cattle, with hay and oats, predominate. Beans, wheat and chicory are of importance in Huron and in parts of Sanilac counties.

This region is well adapted to the production of hay and pasture Hay has long been one of the main cash crops. Beef cattle production, which has been the major livestock enterprise, is now being replaced in some degree by dairy cows for the production of whole milk for Detroit. There are very few sheep and hogs, owing quite largely to the small acreage of corn. In 1925, about 85 to 90 per cent of the land area was in farms.

For the most part the topography is level. Heavy soils predominate and thousands of acres are seeded late in the spring because of inadequate means of carrying away the heavy rainfall. The major factors determining the type of farming are the soils, climate and markets.

REGION 8: BEANS AND SUGAR BEETS

This region, commonly known as the "Saginaw Valley," includes Saginaw, Gratiot and most of Bay counties, together with portions of all adjoining counties. The agriculture is dominated by beans, sugar beets, wheat and dairy cows. Other important crops are corn, hay and small acreages of rye, chicory, fruit and truck crops. Poultry and swine are important minor enterprises. In 1925 about 85 per cent of the land area was in farms

This section in general is one of the better farming areas in the state. The climate, type of soil and markets are the major factors determining the type of farming.

REGION 9: CATTLE, SHEEP AND FORAGE

Gladwin, Arenac, most of Midland and part of Clare, Ogemaw and Iosco counties make up this region. Hay, cattle and sheep are the predominating agricultural enterprises. Corn and hogs are beginning to be of less importance as we go north in the state. The number of dairy cattle has been increasing for quite a number of years. More extensive types of farming are found in these counties. Farm land constituted about 40 to 55 per cent of the total land area in 1925.

The topography is level to rolling, and the soils are mostly sands to sandy loams. The climate and the soil are the major factors determining the type of farming.

REGION 10: FORAGE AND FORESTRY

Crawford, Roscommon, Oscoda and portions of adjoining counties are included in this area. This region has the lowest percentage of land in farms of any area in the Lower Peninsula. It is characterized by its light soils of relatively low fertility. Agriculture is limited, but what there is is based primarily upon cattle, mostly dairy and forage crops, hay and pasture. A number of sheep ranches are found in the better sections.

The lighter soils and short growing season are the major factors determining the type of farming. From 10 to 13 per cent of the land was in farms in 1925.

REGIONS 11*a* AND 11*b*: POTATOES AND CATTLE

This region is best known as the "potato region" of the state. It includes the west-central counties of the northern part of the Lower Peninsula. The extent of the area may be observed by a study of the map.

The enterprises which predominate are potatoes, hay, pasture and cattle. About one half of the cattle are dairy cows. Hogs and sheep are of minor importance. Dairy products are marketed mostly in the form of cream and sold on a butter fat basis.

Region 11*b*, with a somewhat longer growing season, has a greater proportion of its land in farms, 65 to 85 per cent, than has 11*a* with 40 to 50 per cent in farms.

The climate, soils and topography are the major factors determining the type of farming.

REGIONS 12*a* AND 12*b*: FRUIT

This area, long known as the "fruit belt," borders Lake Michigan. It includes a strip of land varying in width from one half to thirty-five miles, extending from the southern boundary of the state to the north line of Charlevoix County, a distance of approximately 300 miles.

In the southern portion, or in 12*b*, the production of the following fruits is of importance: apples, pears, grapes, peaches, small fruits (raspberries, blackberries, dewberries and strawberries) and truck crops. Considerable acreages of cantaloupes and tomatoes are grown in Berrien County. Apples are found quite generally throughout the entire region. An intensive peach section is found in a strip 5 to 15 miles wide bordering Lake Michigan. Grapes are found mostly in Van Buren, Kalamazoo and Berrien counties. Much general farming supplements the fruit end of the business.

In 12*a*, or the northern portion of the "fruit belt," cherries are of major importance, in addition to apples, peaches and raspberries.

In both these areas the major factors determining the type of farming are climate, soils and topography.

REGION 13: CATTLE AND FORAGE

This section is the tip of northeastern Michigan. It contains most of Cheboygan, Presque Isle, Montmorency and Alcona counties and all of Alpena County.

The predominating features of the farming are hay and forage combined with cattle, of which about one half are dairy cows. Owing to the short growing season, very little corn is grown. Potatoes are an important cash crop, although not to the same extent as in Region 11 to the west. Swine and poultry are of little importance. About 22 to 39 per cent of the land area was in farms in 1925, of which about 35 per cent was classed as crop land.

The climate, soils and lack of good markets largely determine the type of farming.

REGION 14: UPPER PENINSULA OF MICHIGAN

This region includes nearly one third of the land area of the entire state. Such a large section should normally be divided into several regions, but, owing to the limited agricultural development in some districts, the type of farming areas has not become so well established as in the Lower Peninsula. For this reason subregions have been designated on the map by dotted lines. In this section there are large tracts of timber and cut-over land.

Counties showing the greatest agricultural development are Menominee, Houghton, Chippewa and Delta, which have from 20 to 35 per cent of their land area in farms. In the other counties the amount of land in farms occupies from 4 to 10 per cent of the total land area.

Dairying and poultry are important livestock enterprises; hay, pasture, oats and potatoes are the major crop enterprises. Potatoes are the main cash crop. Sheep and hogs are handled only on a minor scale.

The factors determining the type of farming are climate, type of soil, topography and the distance from markets.

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[1] Shaw, R. S., *Michigan Agriculture, Its Present Status and Wonderful Possibilities, Michigan Exper. Sta. Special Bulletin No. 70.*

[2] Church, V. H., *Statistical Analysis of Michigan Agriculture*, Michigan Department of Agriculture, 1922.

[3] Spillman, W. J., *Distribution of Types of Farming in the United States. U. S. D. A. Farmers' Bulletin No. 1289*, 1923.

[4] Willard, R. E., et al., *Types of Farming in North Dakota. Technical Bulletin No. 102.*

[5] Mighall and Brown, *Types of Farming Areas in Massachusetts. Bulletin No. 244*.

[6] Holmes, C. L., *Types of Farming in Iowa. Bulletin No. 256*.

[7] Rogers, H. R., *Types of Farming in South Dakota. Bulletin No. 238*.

NATURAL GEOGRAPHIC DIVISIONS OF LAND

JETHRO OTTO VEATCH

THE word "land," like most words which have been in universal use for a long period of time, has acquired a multitude of meanings. Taken from its context it does not mean anything definite. It may be given a most comprehensive and all-inclusive meaning, as in the ponderous definition given by Blackstone,[1] or may have a more restricted and specialized meaning according to its use by the agriculturist, the economist, the geographer and the geologist.

In its broadest scientific meaning it comprises the solid part of the earth (the lithosphere), in contradistinction to the hydrosphere and to the atmosphere. To be a little more specific, it comprises the surface part of the lithosphere. But since it was observed that the physiognomy of the land was not everywhere the same, it became necessary to distinguish the different aspects; therefore, such broad divisions as mountains, plains and plateaus were made; and with the division carried still farther, secondary and minor features of a topographic nature, such as hills, valleys, lakes, scarps, mesas and similar features, were recognized.

Again, it was found that certain areas could be isolated which possessed a common geologic history and the same general surface aspect — physiographic divisions. This in brief constitutes a basic scientific conception of land, but it is properly a classification of land forms and is purely geologic or physiographic in nature.

Then man enters, and subdivisions of the earth's surface are made purely in relation to his material needs. Such classifications have not been scientific in a stricter sense of the word, and are not natural, but generally have been purely utilitarian, artificial or local in their application.

However, it may be possible to construct a plan for the classification of land which would include the environmental factors of soil and vegetation as well as topography, and which would still be a part of a natural classification. The divisions of this classification could be considered properly geographic. The broadest divisions of land, according to this conception, are essentially climatic: arctic, temperate and tropic. Subdivisions of the next order or rank would be based upon peculiar combinations of the criteria of the geographic classification: homogeneity in soil, vegetation and drainage. Such subdivisions would be nearly equivalent in their boundaries to the major soil families of the world. The boundaries of these divisions might transcend those of the major physiographic divisions; or, on the other hand, a single physiographic division might include two or more major geographic land divisions. For example, in the eastern part of the United States the major land divisions have a rough zonal arrangement north and south, while the major physiographic divisions have a general east-west parallel arrangement. For an additional illustration, the Great Plains may include two or more major geographic land divisions.

The next lower rank comprises subdivisions based upon a narrower range in altitude, soil and vegetation. The delineation of these geographic areas may be accomplished in this manner: on the basis of accumulated facts from detailed surveys of the topography, vegetation and soil, by trial and error, a single area may be finally isolated which is different in aspect from any other area in the same general region. The geographic divisions so outlined can perhaps be best designated by compound names, a place name and terms signifying some outstanding character in soil, vegetation, topography and geology, for example, Chippewa Clay Plains, Grayling Pine Plains, Yazoo Bottom Lands and Miami Limestone Region.

Smaller geographic units may be recognized on the basis of differences in degree, that is, the range permitted in slope, drainage and vegetation is still more restricted than in the preceding divisions. These smaller units might be the equivalent in distribution to soil types (the unit of the detailed soil map); or, they might represent associations of soil types. A uniform clay soil dotted with small bodies of sand, or a network of dry sandy soil and small bodies of muck and water surface, would constitute peculiar types of land of local significance.

So far as the writer is aware, there have been but few conscious attempts to map natural land divisions.[2] Probably most land maps are purely use maps. These are open to the criticism that they tell nothing directly about the intrinsic nature of the land — the chemical and physical nature, and durability of the soil and the nature of the topography and the vegetation. In addition, these maps may have no more than a temporary value since use of the land is quite likely to change with political and economic conditions.

Land divisions have been made on a climatic basis also and such comprehensive classes as "arid land" and "humid land" are natural divisions. However, in areas of small extent, especially where a single element of climate, as precipitation or temperature, is employed as the basis of classification, inferences concerning the character of the land may be greatly in error.

Physiographic and geologic maps are perhaps most frequently substituted for land maps. It may happen that the physiographic unit as drawn by the physiographer is also a land unit, but also it may be that the physiographic division has such a wide range in climate, soil and vegetation that it possesses no homogeneity as land. A physiographic division may be a function of geologic agencies and may be inherited from a past geologic period. The land (in the geographic meaning) is a function of present climate, soil and vegetation.

Descriptions of land on a vegetational basis, such as "grass lands," "pine lands," "prairie," "savannah," are generally inadequate, since other elements of land, as surface configuration and soil, cannot always be inferred with assurance of correctness.

It follows that some kind of classification of land on a natural basis would serve a useful purpose in facilitating and clarifying geographic description. It would also constitute basic knowledge for the economic classification.

The ideas on land classification presented in this paper are embraced in the accompanying map and schematic table. The classification in its present form is perhaps no more than a suggestion for the need of one and is not offered with any pretensions to scientific completeness.

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[1] "Land comprehends all things of a permanent and substantial nature; being a word of very extensive signification." — *Commentaries*, Book II, Chap. 16.

[2] In this connection, however, the county maps made by the Michigan Land Economic Survey constitute an exception. The work of R. M. Harper in subdividing Florida and Alabama into geographic regions should also be mentioned. A much stronger emphasis is placed by him upon vegetation and geology than on soil in determining the separate divisions. (See *Florida Geological Survey, Sixth Ann. Rep., 1914; Eighteenth Ann. Rep., 1927;* and *Alabama Geological Survey, Monograph 8, 1913*.)

OUTLINE SCHEME OF LAND CLASSIFICATION

- Lithosphere
  - Land forms (Geologic and physiographic)
    - Continents
      - Plains, Plateaus, Mountains
        - Physiographic divisions: Piedmont plateau, Atlantic coastal plain, Great basin, Etc.
          - Topographic forms: Hills, Valleys, Lakes, Scarps, Etc.
  - Natural land divisions Geographic
    - Land Regions
      - Arctic: Ice, Tundra
      - Temperate: Pedalferic, Pedocalic
      - Tropic: Pedalferic, Pedocalic
        - Major divisions: Steppe black lands, Gray lands, north forest, Brown earth lands, Desert lands, Etc.
          - Land types
            - Criteria: Soil, Topography, Vegetation
            - Example: Coastal flatwoods, Grayling pine plains, Chippewa clay plains
              - Minor unit: Equivalent to soil type
  - Use divisions (Economic or commercial)
    - Agriculture
      - Farming
        - Types and kinds according to crops
          - Classes according to value
      - Grazing
        - Grass, Brush, Swamps
          - Classes according to value
      - Forestry
        - Types according to species, pine lands, oak-hickory, etc.
          - Classes according to timber value; Productivity of soil
    - Mining
      - According to mineral and kind of mining
        - Classes according to value
    - Urban
      - Residential, Business, Etc.
        - Classes according to value

MAP 41. Natural land divisions of Michigan

LEGEND FOR MAP OF LAND DIVISIONS OF MICHIGAN

Name	No. on map	Soil	Topography	Vegetation
Monroe lowland clay plains	1	Dark-colored fertile loams underlain by clay	Flat, level, in large part poorly drained; low, narrow sand and gravel ridges	Hardwood forest; elm, soft maple, ash, hickory and swamp white oak; locally tulip, cottonwood, walnut, chestnut
Washtenaw high clay land	2	Loam soils underlain by clay; medium to high fertility	Rolling plains	Hardwood forest; beech, maple and oak, hickory
Hillsdale-Lapeer sandy highland	3	Light-colored sandy loams and sands; medium to low fertility; in part stony; large aggregate of muck	Rolling and hilly highland with included level and pitted dry sand plains; lakes and swamps characteristic	Hardwood forest; mainly oak, hickory; scattered white pine in northern part
Branch plains	4	Complex of dark- and light-colored loams; medium to high fertility; dry sandy loams	Undulating plains of clay land, and level dry sand plains; lakes and swamp	Hardwood forest; beech, maple, oak, hickory
Kalamazoo sandy plains	5	Sandy loams and sands; medium to low fertility; large aggregate of muck	Level plains, in part pitted with lakes; and locally choppy with steep slopes	Hardwood forest; mainly oaks, hickory, partly prairie and oak openings
Cass sandy hill land	6	Sandy loams and sands; medium fertility	Hilly, ridges inclosing dry sandy valleys; slopes generally smooth, but locally knob and basin topography	Hardwood forest; oaks, hickory
Paw Paw sandy plains	7	Sandy loams and sands; medium to low fertility	Level plains, including a large aggregate of swamps and lakes	Hardwood forest; oaks, hickory; oak openings and patches of prairie
Allegan clay upland	8	Loams underlain by clay; medium to high fertility; sandy loams underlain by coarse, sandy drift	Undulating to rolling clay plains; rolling to hilly sandy ridges; slopes generally moderate	Hardwood forest; beech, maple, oaks, hickory

Name	No. on map	Soil	Topography	Vegetation
Lake Michigan lowland plain	9	Complex of wet and dry sands; loams underlain by heavy clay; sands of low fertility; clays medium to high fertility	Smooth land, low ridges and gentle swells; large aggregate of wet land; dunes along the lake shore	Forest; oaks on the drier sands; elm, soft maple, aspen, ash, oaks on the wetter sands; beech, maple, elm, basswood, hickory on the clays; pine abundant in the more northern areas
Clinton rolling plains	10	Loams over compact clays; medium to high fertility; not excessively stony; large percentage muck	Level to rolling clay plains with hilly and rolling ridges at broad intervals; swamps generally in long, shallow valleys	Hardwood forest; sugar maple, beech, oaks, hickory
Mecosta-Wexford sandy highland	11	Mainly deep sandy loams; locally sandy loams and loams underlain by red clay; mostly medium and low fertility	Rolling and hilly, locally slopes excessively steep; lakes and swamps comprise large aggregate acreage	Hardwood forest; sugar maple-beech; mixed hardwoods, hemlock, and white pine; swamps of cedar, tamarack, fir and spruce
Saginaw lowland plains	12	Complex of wet and dry sands and dark-colored clay and loams; heavy soils, high fertility; sands of low fertility	Level land; low swells and low narrow sand ridges; large proportion poorly drained	Forest; elm, ash, maple, basswood; white pine on sands and wet land
Sanilac rolling clay plains	13	Light- and dark-colored loams over clay; locally stony	Level plains and gently rolling upland; less swamp, more rolling than 1 and 12	Forest; elm, ash, soft maple, basswood, beech, maple, white pine
Newaygo-Manistee sandy plains	14	Mainly sands and light sandy loams; dry, and low fertility	Level dry sand plains; also hills and ridges with smooth slopes	Forest; white, Norway and jack pine; oaks
Oceana hill land	15	Mainly sandy loams; locally loams and sandy loams underlain by red clay; medium fertility	Hills with moderate slopes; level plains underlain by clay and cut by streams; dunes along the lake shore	Forest; mainly hardwoods, maple, beech, hemlock; locally white pine mixed with hardwoods; jack and Norway pine on drier sands

Name	No. on map	Soil	Topography	Vegetation
Missaukee clay plains	16	Mainly sandy loams and dark-colored loams over impervious reddish clay; medium to high fertility	Flat or wet and swampy with low swells	Forest mixed hardwoods, maple, beech, elm, basswood, white pine, hemlock, fir, cedar and spruce
Grayling pine plains	17	Sands, dry, acid, low fertility and productiveness; large aggregate acreage of peat soil included	Level and pitted dry plains; smaller areas of sandy hill land; swamps and lakes included	Forest; Norway and jack pines; smaller growth blueberry, sweet fern, grasses, lichen; oaks and aspen second growth
Ogemaw pine hills	18	Sands, dry, acid, low fertility; smaller aggregate of light sandy loams and sands underlain by sandy and impervious clays	High broadly rolling hills and plateau-like upland forming a drainage divide	Forest; Norway pine characteristic; in part white pine and mixed hardwoods, pine and hemlock
Gladwin clay upland	19	Sandy loams and light loams over red clay; medium fertility and productiveness	Moderately rolling and nearly level; small aggregate of wet land	Forest; mainly hardwoods, maple, beech, birch, basswood; local areas of mixed white pine; fir and spruce on wet land
Iosco sand plains	20	Mainly dry, acid sands of low fertility; small aggregate of wet infertile sands, and moderately productive sand over clay	Nearly level; low sand ridges on the lake shore	Forest; mainly Norway, jack and white pines
Montmorency hill land	21	Sandy loams underlain by sandy clay; moderate fertility; dry acid sands of low fertility included	Broadly rolling hills and both wet and dry sandy valleys and plains; high plateau-like upland	Forest; part pine and part hardwood hills, Norway, white and jack pines on the dry valleys and plains

Name	No. on map	Soil	Topography	Vegetation
Alpena stony clay land	22	Loams and sandy loams underlain by reddish limy clay or by limestone bed rock; stony but fertile soils; much peat; also dry sands, gravelly and cobbly soils	Nearly level or gently rolling clay plains including swamps and lakes; low sand and gravel ridges and stony knobs; level plains underlain by limestone bed rock	Forest; hardwoods and mixed fir and spruce on the clay lands; cedar, fir and spruce, white and Norway pine on wet stony land, and dry sands and gravel
Cheboygan lake region	23	Complex of infertile dry and wet sands, peats and stony gravelly soils; with some productive red clay and stony limy sandy loams	Level lake bed plains of both clay and sand; low dunes or beach ridges; isolated hills, lakes and swamps	Forest; complex of hardwoods on the hills; hardwoods, fir and white pine and spruce on the clay and wet mineral soils, cedar, fir, spruce in the swamps
Emmet sandy upland	24	Dry sands and sandy loams underlain by moderately limy gravel or by sandy clay; medium fertility	Smooth upland-level valleys and plains; in smaller part, hills with excessively steep slopes	Forest; mainly hardwoods, maple, beech, birch and hemlock
Muskegon sand plains	25	Sands, acid and of low fertility; mostly deep, but locally underlain by clay at shallow depths	Smooth plains, locally interspersed with dry depressions and by lakes	Forest; mainly white pine, but in part mixed pines and hardwoods
Antrim hardwood highland	26	Sandy loams and sands underlain by moderately limy sandy loams, clay or sand; moderate fertility; much peat	Hilly, and locally broken with steep slopes, but with even sky-line; bold westward front with deep valleys, which are in large part occupied by peat swamps	Forest; mainly hardwood, maple, beech, birch, hemlock
Traverse clay land	27	Loams and sandy loams underlain by pale reddish limy friable clays; fertile, productive soil, in part stony	Rolling plains, parallel ridges, the valleys occupied by lakes or swamps; large area of lake surface	Forest; hardwoods, beech, maple, birch, elm, ash, basswood
Leelanau hills	28	Sandy loams and loams underlain by limy clays and limestone gravel; moderate fertility; in part very stony	Hilly; in part bold steep slopes, in part broadly rolling; sandy plains and dunes included	Forest; mainly hardwoods

Name	No. on map	Soil	Topography	Vegetation
Benzie upland	29	Sandy loams and sands; locally small patches of loam underlain by heavy limy clay; soils of moderate fertility and productiveness	Higher land an even-topped plateau, broadly rolling, locally chopped and deeply dissected by stream valleys; dunes near lake shore; large aggregate of swamps and lakes	Forest; mainly beech, maple, birch, hemlock
Mancelona hardwood plains	30	Brown sands and sandy loams underlain by dry gravel and sands; limestone and shale influence; locally excessively cobbly; soils moderately productive, but poor infertile sands included	Dry plains, cut by dry valleys bordered by low scarps; numerous dry depressions; lakes and swamps interspersed	Forest; mainly maple, beech, yellow birch, hemlock; locally white and Norway pines
Kalkaska hill land	31	Sands and sandy loams underlain by sandy clays and locally by heavy red clays; intermediate limestone influence; medium fertility and productiveness	Plateau-ridge; broadly undulating to rolling	Forest; sugar maple, beech, yellow birch, hemlock; locally white pine
Manistee valley plains	32	Sands and sandy loams underlain by dry sands and gravel; acid, low fertility; large aggregate of sands over red plastic clays at shallow depths	Mixed dry and wet sandy plains, with large percentage of swamp	Forest; white and Norway pines; swamp conifers and hardwoods on the wet land
Crawford plateau highland	33	Loamy sand, sandy loam and loam underlain by sand and gravel; intermediate limestone influence	Nearly level or gently rolling high land, having bold slopes on the borders of the dry sandy valleys and plains	Forest; sugar maple, beech, birch, hemlock

Name	No. on map	Soil	Topography	Vegetation
Isabella red clay lands	34	Sandy loams and loams underlain by red clay; relatively medium to high productivity; less extensive acreage of sandy loams and sands of medium to low productivity	Rolling clay plains, with ridges at broad intervals, which have rolling to hilly topography	Forest; sugar maple, beech, elm, basswood, on the clay lands; mixed white pine and hardwoods on the hills
Chippewa clay plains	35	Gray, blackish and reddish soils, underlain by reddish limy clay; no or relatively little stone; high fertility	Low-lying level plains, in part poorly drained	Original forest mixed hardwoods, white pine, hemlock, fir and spruce
Mackinac stony land	36	Loams underlain by clay, fertile but excessively stony; dry acid sands; limy gravelly soils; large aggregate of peat and muck	Level plains both dry and wet; gravelly ridges; plateau-like ridges and hills of limestone	Hardwoods on the higher land; mixed hardwoods, pine, spruce and fir on the wet land and dry sand and gravelly ridges
Gilchrist sandy plains	37	Brown loamy sands, in part stony, in part stone-free; dry yellow sands, stony loams and peat	Level or gently rolling sandy plains, stony hills and limestone plateaus	Beech, maple, birch, hemlock on the better sands and stony lands; pine on the drier sands
McMillan hardwood upland	38	Brown loams and sandy loams underlain by clay and sand; stony in places; moderate to strong limestone influence; medium fertility	Level, gently rolling to moderately hilly	Mainly beech, maple, yellow birch and hemlock
Taquamenon swamp region	39	Peats and mucks; small areas of silts, fine sands and clay; wet but fertile	Swamps; low-lying wet clay plains; low hills and ridges of sand	Mainly spruce and fir; in part mixed hardwoods and swamp conifers
Luce sandy hardwood uplands	40	Brown, loamy sands and sandy loams, very strongly acid, little or no limestone influence; medium to low fertility	Level to rolling sandy plains and plateau-like ridges; small areas of hilly highland	Mainly beech, maple, birch and hemlock

Name	No. on map	Soil	Topography	Vegetation
Whitefish sandy pine lands	41	Dry acid sands and peats low in fertility; small bodies of brown loamy sands, sandy loams, and wet clay land	Level plains, swamps, low sand ridges and dunes	Mainly Norway, jack and white pine; swamp conifers, small areas of hardwoods
White Rat pine plains	42	Dry acid sands, low fertility	Level and pitted dry sand plains	Mainly pine
Seney swamp region	43	Mainly acid peats; dry and wet sands, low fertility; small areas of iron hard-pan soils; small areas underlain by limestone bed rock, and coarse limy drift	Swamp containing flat islands and ridges of loose sand; swampy low-lying level plains; a few hills	Mainly black spruce, tamarack and cedar; Norway, jack and white pine on the sandy soils
Munising hardwood upland	44	Loamy sands and sandy loams, medium fertility; locally stony; locally, slopes are excessively steep	Mainly rolling and moderately hilly; locally slopes excessively steep	Mainly hardwood forest; beech, maple, birch and hemlock
Wetmore sand plains	45	Dry sands, low in fertility	Level and pitted sand plains, a few lakes and considerable swamp included	Mainly pines; in part hardwoods and hemlocks
Manistique stony lowland	46	Brown loamy sands, stony and large blocks and bed rock of limestone; dry and wet sands of low fertility; small bodies of stony loams and sandy loams of high fertility	Level and rolling stony plains; large aggregate of swamp	Mainly hardwoods; pines on drier sands; conifers in swamps
Delta sandy lowland	47	Dry acid sands of low fertility; small spots of wet clay soil, moderate fertility; spots of stony limy soil	Dry sandy plains and swamps; low sandy ridges	Mainly pines; hardwoods on stony and clay lands
Steuben hills	48	Sands and sandy loams of low fertility; small limestone influence	Upland; hills, basins, dry valleys, plains; lakes numerous	Maple, beech, birch, hemlock; also in large part Norway and white pine and mixed pine-hardwoods
Trenary hardwood plains	49	Brown and reddish loams underlain by clayey subsoils; in large part stony and underlain by limestone bed rock; fertile soils; also stony sandy loams underlain by limy sands and clays	Rolling to level highland, includes low ridges and a large aggregate of swamp; hill land in the western part	Mainly maple, beech, birch forest; mixed hardwoods, white pine, spruce, fir on wet land
Menominee hardwood upland	50	Mainly loams and sandy loams underlain by clayey, limy subsoils; fertile productive soils	Oval ridges and hills alternating with swampy valleys; gravelly stony plains	Hardwood hills, maple, beech, birch, basswood, asn, elm; pine, fir, spruce, hardwoods on wet soils; spruce, fir, cedar in peat swamps
Escanaba sandy lowland	51	Dry sands and peats of low fertility; stony and gravelly moist loams of fair fertility	Sandy, swampy and wet stony plains; dry sandy plains, and low sandy ridges	Mainly cedar, spruce, fir, white pine, aspen, birch, on wet land; Norway pine on dry land
Onota stony highland	52	Reddish, sandy soils, excessively stony and in part underlain by sandstone bed rock at shallow depths	Plains and plateaus trenched by streams and bordered by bluffs along Lake Superior	Mixed forests, maple, birch, beech, hemlock, fir, cedar, and white pine
Swanzy sand plains	53	Dry sands, poorly productive; some stony soil included	Plains; level or slightly undulating	Mainly pines
Dickinson sandy hill region	54	Sandy loams on hills, showing influence of limestone; productive soil; dry sand hills; dry sand plains; thin stony, sandy loams and loams on bed rock	Hills; knob and basins; swells and sags; rock hills and plateaus with steep slopes; large aggregate of lakes and swamps	Hardwoods; maple, birch on sandy loams; conifers on thin soil of rock knobs; pines on dry sand hills and sandy valleys
Marquette stony highland	55	Thin stony soils on bed rock; coarse deep, dry sandy soils in valleys; local patches of productive red loams	Mountains, hills and rock knobs with steep slopes; valleys with rough pitted uneven surfaces; lakes and swamps numerous	Hardwoods, maple, birch on the deeper, heavier soils; conifers in swamps; pines on the drier sands and the thin rock soils
Iron River stony loam highland	56	Reddish stony loams and silts; medium to high fertility; generally moist; generally stony throughout the whole thickness	Smooth plains; locally choppy and undulating; local stony hills and ridges; lakes, swamps and poorly drained mineral soils	Hardwoods, maple, birch, elm, basswood; fir and spruce local or intermixed with the hardwoods
Baraga stony highland	57	Grayish and yellowish stony silts, and loams; cold, acid soils; in part wet at shallow depths and resting on bed rock at three feet or less	High table-land, locally ledges and cliffs of rock; large aggregate of wet land; small aggregate of dry sandy plains	Hardwoods; maple, birch forest; mixed maple, birch, cedar, fir, hemlock, spruce and wnite pine
Watersmeet hardwood hills region	58	Mainly sandy loams, locally reddish loams; in part dry, in part moderately fertile; locally stony, but deep penetrable soils	Hilly plateau region; sags and swells; high plateau ridges and irregular dry valleys; lakes numerous; elevations: 1200 to 1700 feet; slopes locally very steep	Mainly hardwood forest; maple, birch dominant
Bessemer stony highland	59	Thin, stony soils, mostly loams and sandy loams; moderately productive; locally patches of red clayey soils, productive but stony	Ridges and parallel lines of hills or knobs; level stony plains in part; elevations 1300 to 1700 feet above sea-level	Mixed hardwoods and conifers
Gogebic stony plain	60	Soils wet and moist; thick forest mold or thin muck cover, over stones on bed rock or over stony, sandy clay; productive	Semi-wet and swampy; undulating and level plain; small aggregate of hills and ridges included	Coniferous; fir, cedar, spruce, hemlock, white pine; locally maple, birch, hardwood forest
Porcupine rock knob region	61	Thin stony soils on bed rock; valleys have reddish loams and sandy soils; productive, but excessively stony	High rock knobs and ridges 1200 to 2000 feet above sea-level; rough uneven surface and steep slopes	Hardwoods on the deeper stony loams — maple, birch, elm, basswood; white pine, fir, spruce, cedar on the thinner and on the wetter soils
Ontonagon lake plains	62	Silts, clays and fine sands underlain by limy silt, clay and fine sand; locally dry and wet acid hard-pan sands	Level or gently sloping terraced plains, trenched by streams	Mixed hardwood-conifer forest; maple, birch, basswood, white pine, fir, cedar and spruce
Ontonagon high clay plains	63	Silts, clays and blackish wet loams underlain by red, impervious limy clay; productive, durable soils	Nearly level plains trenched by streams; locally wet, elevation 1200 to 1400 feet above sea-level	Mixed maple, elm, birch, basswood, white pine, fir, spruce and cedar
L'Anse lowland plains	64	Soils generally moist or not excessively dry; moderate fertility; sandy loams, loams and silts; not generally excessively stony	Smooth land and rolling land; elevation 600 to 900 feet	Mixed hardwoods; fir, spruce, cedar, white pine
Keweenaw stony highland	65	Thin stony soils on bed rock; rock outcrop and barren cliffs and ledges; valleys of stony loams and sandy loams; swamps, peat and muck and wet sandy soil	High rock ridges, steep slopes; stony, rough, pitted valleys; valley swamps	Mixed hardwood-conifer forest
Rexford pine plains	66	Loose yellowish sands; dry, acid, low in productiveness	Plains, level to moderately undulating; pitted	Norway, jack and white pines
Isle Royale	67	Soils probably fairly fertile, but thin or excessively stony; local bodies of sands and peat	Stony rock ridges and knobs; complementary and parallel sandy valleys; lakes	Mixed conifers with admixture of hardwoods

ON THE DISTRIBUTION OF VOLCANOES IN JAPAN *

AKIRA WATANABE

THE investigations that have been taking place in Japan for the last fifty years have made possible a fairly exact study of the distribution of volcanoes. The present study is an attempt to learn their general distribution, chiefly from the geomorphological point of view. The method used is first to classify the volcanoes according to their form and then to locate them areally, with symbols indicating their character.

The classification is done by keeping the three important geomorphic factors in mind: initial form, stages of dissection and size.

I. CLASSIFICATION

A. Initial forms. — Because of the ways of formation and consequently because of their visible forms, the following classification is adopted in this study:

1. Strato volcano (Konide);
2. Massive volcano (Tholoide and Belonite);
3. Shield volcano (Aspite);
4. Lava plateau (Pedionite);
5. Maar and Homate.

Although caldera represent not the constructional forms of volcanoes, but merely the destructional form through explosion or depression, they are considered here. This form is so conspicuous that it should not be neglected. Perfect kettle depressions that have no direct relation to volcanic bodies are frequently found in volcanic regions. These have been considered caldera in this study because they are sure negative expressions of volcanism.

B. Stages of dissection. — These are divided as follows:

1. Young volcano which has wide initial surface;
2. Dissected volcano of early maturity, which, although it has lost some parts of the initial surface, still retains some;
3. Maturely dissected volcano, which has lost the greater part of the initial surface.

In addition to these types, there is the old volcano, but it is hardly recognizable geomorphologically.

Many varieties of sequential (erosional) forms of volcanoes are found because of the differences of their initial forms and sizes. For example, the top of a gigantic volcano shows a more advanced stage of dissection than the flank. This is due chiefly to the hard weathering in the high altitude and to the steep slopes. The dissection of a flat volcano is caused chiefly by insequent streams. Thus the top or the central part of the volcano is better preserved than the flanks.

C. Sizes. — The size of a volcano is determined by its mean basal diameter. There are six groups of volcanoes classified according to the size of the basal diameter: (1) less than 2 km.; (2) between 2 and 5 km.; (3) between 5 and 10 km.; (4) between 10 and 20km.; (5) between 20 and 35 km.; (6) more than 35 km.

II. THE FACTS OF DISTRIBUTION

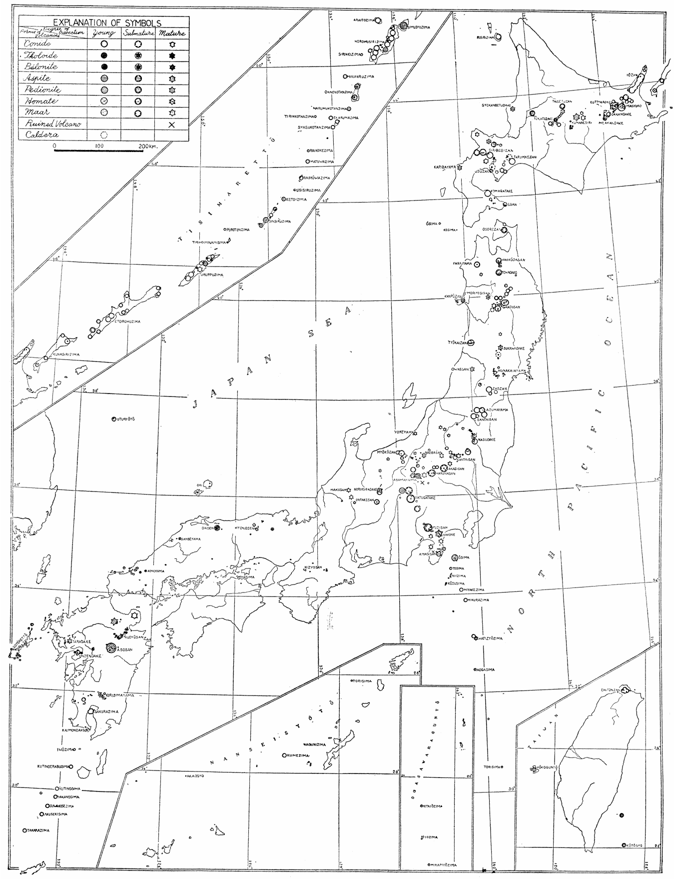
Without counting parasitic and central cones, well over five hundred volcanoes are found in this insular empire. There are records of historic eruptions for just sixty of them. Most of the famous ones are strato volcanoes. The typical shield volcano is very rare and a massive volcano occurs chiefly as a parasitic cone.

A mere glance at the distribution map (Map 42) is enough to show the general accordance of the arrangement of the volcanoes with the major trends of the insular arc. Five salient lineaments of volcanic arrangement are apparent.

A. Chishima and eastern Hokkaido. — This district applies to that lineament which enters into Chishima (Kurile Islands) from the volcanic region of Kamchatka at Alaido Island, stretches over 1400 km. and terminates in the central part of Hokkaido Island. This stretch of volcanoes makes an arc with the convex side toward the Pacific Ocean. It is suggested by the sea charts that they are resting upon the submarine range. A closer analysis of their distribution will show that they are grouped into many minute lineaments that are arranged in *en échelon* pattern. This pattern becomes clearer as we go southwestward. Most of the volcanoes are of the strato type, and, in spite of the lack of historical records, thirteen active ones are known in this region. Some of them are always smoking. Caldera characterize some of the volcanic bodies, giving them picturesque lakes or sheltered harbors.

B. Western Hokkaido and the northeastern part of Honshu. — Stretching from the volcanic group of the southwestern Hokkaido south to the central part of Honshu is another important volcanic region. At its southwestern part it intersects another row of volcanoes making a clear cusp. The characteristic pattern of the distribution within this region is the separation into small compact agglomerations, occurring at more or less equal distances.

Most of the volcanoes in this area are in Tertiary deposits. The mountain lands of Abukuma and Kitakami are chiefly composed of ancient rocks and the volcanoes are rather small. With the exception of a row of volcanoes upon the central range of northeastern Honshu, most of the volcanoes are in depressed areas. Caldera are found in the northern part. Eighteen of them are active and their density of distribution is as great as those in the Chishima district.



MAP 42. Distribution of volcanoes in Japan

C. The central part of Honshu and the southern islands. — A row of volcanoes stretches along the lowlands of Fossa Magna southward far into the southern Pacific. The celebrated volcano, Fuji, is in this region. Compact groups of volcanoes are also found here. Of the fifteen which have historic records of eruption, three are in Honshu and twelve in the southern islands. Submarine eruptions are sometimes reported in this area.

D. Southwestern Honshu and Shikoku. — Fewer volcanoes are found in this region than in the others. All of them are confined to the inner zone, and no volcano is reported from the outer zone or the "Kumakii Bergland." Even these few volcanoes are, in large part, small and massive; none is active in this region.

E. Kyushu and Lu-Chu islands. — Stretching from the vast volcanic region of northern Kyushu southward into the Daiton volcanic group in Taiwan, many fresh volcanoes are found. Fourteen of these are active. There is no volcano in this part of the outer zone. Compact groups of the same initial form are characteristic of the distribution pattern.

Lastly, it may be added that all the known volcanoes of Japan that are still recognized as such from the present form have accomplished their latest constructional processes in the Quarternary age. None of the volcanoes has ever been reported as covered by Tertiary deposits. Even some of the large ruined volcanoes are resting in unconformity upon the youngest Tertiary formations.

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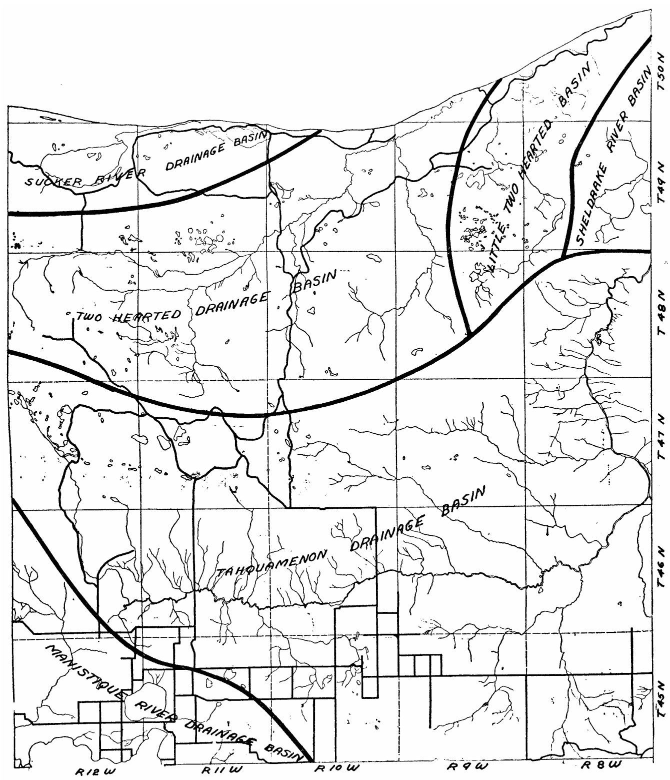
SURFACE GEOLOGY OF LUCE COUNTY, MICHIGAN

STANARD G. BERGQUIST

THE geological work in Luce County was carried on during the summer of 1929, in connection with the activities of the Land Economic Survey of the state of Michigan. Luce County lies within the region which was covered by a re-advance of the Superior lobe of the Labrador ice-sheet, late in the Wisconsin stage of Pleistocene glaciation. The lobation of this ice-sheet, which moved down from the northeast, was induced by the basin of Lake Superior.



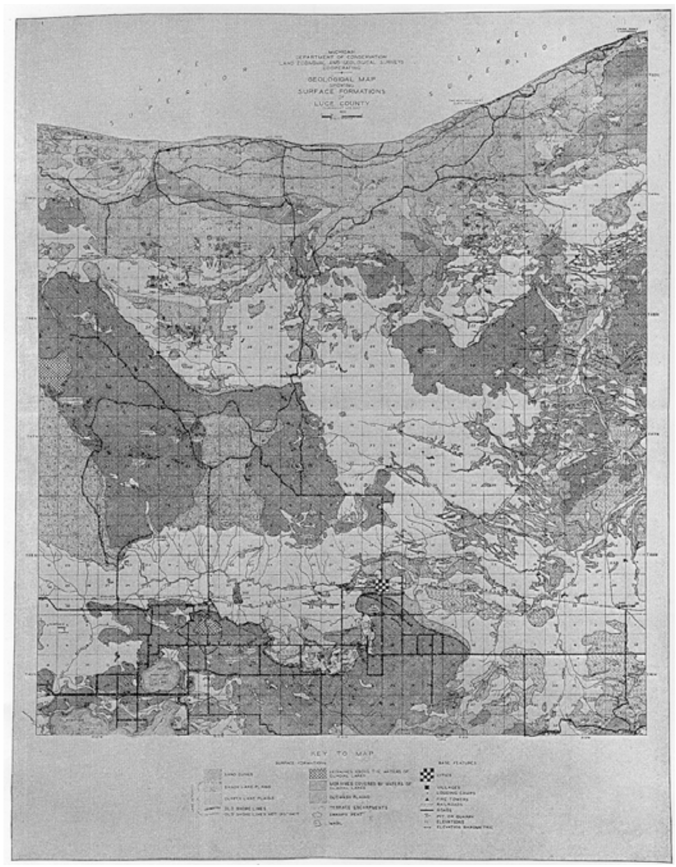
MAP 43. Drainage basins in Luce County

The glacial surface, deposited in the retreat of the ice from the area, was subsequently invaded by the waters of Lake Algonquin which, at its highest stage, spread out over practically the entire county. Some of the older surface features were thus reworked by the waters of this glacial lake, with the result that in places the relief was modified and greatly subdued.

The differential uplift, which occurred north of the hinge-line during Algonquin times, caused the Lake Superior region to be raised several hundred feet above its normal plane. This change in elevation was responsible for extensive modifications in drainage, which are now reflected in the broad, swampy and poorly drained tracts bordering the principal rivers in the area. (See Map 43.)

DRAINAGE

The most extensive single feature in the county is represented in the numerous swamps and lowland tracts which have developed along the drainage ways of the main rivers and streams. (See drainage map, 44.)



MAP 44

The Tahquamenon River

Of the 934 square miles included in the county, 480 square miles, or slightly more than 50 per cent of the total area, are drained by the Tahquamenon River.

This river headwaters in a group of glacial lakes in T. 47 N., R. 12 W., and, from a point 10 miles south of its source, flows eastwardly across the county, thence north and out of the area, in the northeast corner of T. 48 N., R. 8 W. Its waters are finally discharged into Whitefish Bay, near Emerson, in Chippewa County.

For the greater portion of its course, the river leads through an extensive swampy lowland, poorly drained, and with a floor made up of areas of sand, silt, clay and muck of variable depth and surface extent (Pl. LIX, Fig. 1).

In a distance of 50 miles above the Upper Falls the river has a total fall of 26 feet, or a gradient of practically six inches to the mile. Its flow is sluggish and the discharge is irregular, depending upon the season. The confining walls of the channel are low and in flood stages the overflow is extremely great. The channels of most of the tributaries are likewise poorly confined and ramify through swampy tracts for considerable distances upstream, spreading the waters out into broad, shallow sheets during the rainfall periods.

At the Upper Falls, Section 11, T. 48 N., R. 8 W., the Tahquamenon River flows over a ledge of Cambrian sandstone (Pl. LIX, Fig. 2) and for some distance below passes through a gorge of similar material (Pl. LIX, Fig. 3). The elevation at the falls, as determined by Wisler by means of levels, is 694 feet. This area of bed rock, one of the few which are exposed, is the most extensive outcrop in the county.

The divide between the Tahquamenon and Manistique drainage basins lies near the line of Luce and Delta counties, just to the north of the station of Danaher, on the Duluth South Shore and Atlantic Railroad. The watershed here stands at an altitude of 720 feet, or approximately 120 feet above the level of Lake Superior. During Algonquin times, in the development of the Great Lakes, the narrow strait to the north of McMillan connected the Tahquamenon and Manistique drainage systems across this divide, and provided a southward passage from the Lake Superior to the Lake Michigan basins. This outlet was abandoned when the level of Lake Algonquin receded to a plane below that of the divide.

The Tahquamenon Valley and much of its swampy border occupy an old preglacial channel, which apparently had been scoured quite deeply before it was invaded by Pleistocene glaciation. The southern margin of the swamp in Luce County is confined by the northward facing Niagaran escarpment, the steep face of which no doubt was here at least partially cut by the preglacial river which flowed through the basin. There seems to be a definite alignment between this escarpment and basin and that of Green Bay Peninsula, which is a continuation of the escarpment and the Green Bay depression, farther south in Wisconsin (Pl. LX, Fig. 1).

The differential movement, which was in progress during the latter portion of Algonquin times, caused the northeastern part of the lake to be strongly uplifted. This activity raised the ledge of Cambrian sandstone at the Upper Falls of the Tahquamenon River, causing the upstream gradient to be greatly decreased and the velocity of the river to be lowered. The waters of the river were thus forced to spread out over the bordering lowland tracts and produced the swampy condition which now exists over such a large portion of the region.

This same uplift movement had a counter-effect upon the Manistique drainage, which is carried southward down the gentle back slope of the Niagaran cuesta. The headwater area of this basin was somewhat rejuvenated and the velocity and erosive power were decidedly increased, with the result that the postglacial channel has become more deeply scored, and swampy tracts are less extensively developed than in the Tahquamenon basin.

In many places a narrow sandy plain extends along the south border of the Tahquamenon swamp with morainic features setting in at 750 to 800 feet above sea-level. McMillan and Newberry each stand on such a plain.

The Tahquamenon swamp, as well as the majority of the other lowland areas in the county, is studded with an unusually large number of sandy ridges. These range in size from merely a score of feet to several miles in length, and from a few feet to twenty feet and more in height. They seem to run in somewhat definite trends through the swamp, and occasionally are to be found rather high up on the slopes of moraines along the borders of the lowland tracts (Pl. LX, Fig. 2).

In general, the ridges are made up of a very fine textured quartz sand, with grains which are slightly subangular. In many areas they are superimposed upon a gravelly floor and may even contain coarse material throughout. The fine sandy ridges appear as though they may be of aeolian origin and possibly represent marginal dunes. Many of them have the characteristic crescent shape so common to dunes. The gravelly areas, however, apparently represent deposits formed under water and laid down as offshore bars along the margins of the retreating waters of Lake Algonquin. It seems probable that a combined lacustrine and aeolian activity may explain the origin of the ridges, but nothing definite can be ventured until more detailed studies are made of them.

The pine-covered sandy ridges are of importance from the fact that they afford more or less connected routes for travel through an otherwise almost impenetrable tangle of swamp vegetation, and at the same time furnish suitable sites for temporary camps.

The Two Hearted River

This river heads in a series of swamps to the north of the middle morainic system in T. 48 N., Rs. 11 and 12 W.; it flows in a northeasterly direction through swamps and sandy plains and enters Lake Superior in T. 50 N., R. 9 W. It drains an area of 230 square miles and for much of its upper course leads through an extensive swampy lowland. This drainage system, like that of the Tahquamenon River, suffered a reduction of gradient and a retardation of velocity during the differential uplifts which affected the region. There was, however, no rock barrier to hold the waters back and to prevent a lowering of the channel; consequently, the swampy tracts are confined principally to the headwater area. In the lower half of its course the river flows through a level sandy lake plain, and for a distance of about five miles back from its mouth follows parallel with the shore of Lake Superior, where it is held back by a row of low sand dunes. In much of its course through the old lake plain the river has cut its channel quite deep into the loose sand and is lined with steep-cut banks, the slopes of which are controlled by the angle of repose of the material.

The Manistique River drainage basin

In the southwest corner of the county, in the district of the Manistique lakes, is an area of about 80 square miles which is drained into the southward-flowing Manistique River. The East Branch of Fox River, one of the headwater streams of the Manistique drainage system, taps the region and leads through an extensive swampy tract. The watershed of this drainage system stands at an altitude of 720 feet and is separated from the headwaters of the Tahquamenon River by a very low divide (Pl. LX, Fig. 3).

The Little Two Hearted River

This river has its headwaters in the group of Two Hearted lakes in T. 48 N., R. 9 W., and drains an area of approximately 75 square miles in the northeast portion of the county. It flows generally north, across a sandy lake plain, and enters Lake Superior in T. 50 N., R. 9 W., a few miles to the east of the outlet of the Two Hearted River.

From near its source, the river swings with a broad sweeping curve in a northeasterly direction around a group of lakes located in the SE. ¼ of T. 49 N., R. 9 W. It is very probable that this part of its course was at an earlier date controlled by the border of a moraine, which has since been cut down by the combined erosional activity of the Two Hearted and Little Two Hearted rivers. The numerous water-filled basins in the region between the two rivers, together with the small scattered morainic fragments, would suggest that this area was at one time a portion of the inner morainic system.

The Sucker basin

In the northwest corner of the county, there is a deep basin which serves to hold the waters of the Blind and Dead Sucker rivers, which drain an area of 45 square miles (Pl. LXI, Fig. 1). The basin rim is confined on the south by a steep wave-cut escarpment, the crest of which has an altitude of 730 to 750 feet (Pl. LXI, Fig. 2). The north edge of the depression is bordered by a series of sand ridges and dunes which rise to a height of 75 to 100 feet above the level of the lake.

The two rivers, which occupy the basin, have little or no gradient and are practically stagnant the year around. They are lined with broad swampy borders, but are separated from each other by a low, sandy interfluve, which stands at an elevation sufficiently high to have held in the waters of Lake Nipissing. No definite shoreline development is presented here, however (Pl. LXI, Fig. 3).

The Shettdrake drainage system

In the region of Betsy Lake, in the northeast corner of the county, there is an area of approximately 24 square miles which is drained into the northwest-flowing Shelldrake River. The greater portion of this drainage basin in Luce County borders Betsy Lake in a broad swampy lowland, the south side of which is cut by a series of low, parallel, disconnected sand ridges.

MARGINAL MORAINES

Three distinct marginal moraines cross the county from west to east as separate systems, but merge somewhat brokenly into a more or less single unit in the vicinity of Strongs Station, to the south of Whitefish Bay, in Chippewa County.

The outer moraine

The oldest of these systems follows along to the south of the Tahquamenon swamp and for most of its distance in Luce County lies within the basin to the north of the Niagaran cuesta. Here it has been built up to and above the level of the escarpment, and in places is superimposed upon it. This moraine may be traced from near the axis of the Green Bay lobe about six miles west of the county line in Schoolcraft, and eastward across the south edge of Luce County, as a mass of rolling drift not definitely separated into ridges. Its average width on the west end, where it extends south into Mackinac County, is 8 to 10 miles. It gradually narrows toward the east and where it enters Chippewa County is quite fragmentary and broken (Pl. LXII, Fig. 1).

Throughout much of its course the moraine stands at an altitude between 800 and 900 feet and has a rather strong expression. Along the borders of the big swamp, however, it may in places be as low as 720 feet. The topography of its surface is somewhat irregular, except in the outer borders, and is typically of the knob-basin development. The knobs, for the most part, are not high, and the basins are not especially deep. In the region to the south of McMillan, however, a series of knolls rises to an altitude of over 1000 feet (Pl. LXII, Fig. 2). These high knobs were well above the highest level of Lake Algonquin, which in this region was about 900 feet above sea-level. Some of the basins are fairly large; the one occupied by Manistique Lake has an area of approximately 15 square miles.

The material which makes up the drift of the outer moraine is largely sandy in character, but is locally admixed with heavier clay. In general, the drift is loose-textured and well drained, the heavier phases being found in the vicinity of Manistique Lake. In the more strongly developed portions of the inner border of the moraine, erratics are very numerous and limestone slabs of local origin are abundantly scattered through the drift. The shaly limestone contains numerous fragments of trilobites of the genus Ogygites, which Ehlers[1] has ascribed to the Collingwood formation. In the more subdued and weaker outer border, the moraine contains a sandy to gravelly drift and erratics are exceedingly scarce upon the surface. These areas have been subjected to modification by the Algonquin waters and the true morainic character has been partially masked by a thin sheet of fine sediment, which was carried down from the higher inner slopes. In places where postglacial streams have been actively engaged in cutting down their channels, the thin veneer of surface sediment has been removed and the underlying glacial drift exposed.

This feature is well illustrated in the morainic area to the south of Newberry. On the strong inner border of the moraine in the vicinity of the state hospital, much bouldery material and many erratics are inclosed in the drift. To the southward, the boulders become scarce, but cobbly and gravelly material sets in. On the outer border, near the county line, cobbles disappear and give way to a sandy-gravelly drift and the relief is smoothed down to that of a low, even morainic plain.

The drift varies in thickness according to the character of the bed rock topography upon which it lies. Where the rock floor is high and ridged, as it is to the north of Hendricks quarry in the southeast corner of the county, the drift is very thin and the relief is more or less directly controlled by the bed rock surface. In areas where the rock floor has been deeply channeled by water or by glacial activity, the drift is invariably much thicker.

Two recesses occur in the north border of the moraine; one between McMillan and Newberry, and the other four to ten miles east of Newberry. In each of these areas there is a thick deposit of red lacustrine clay. An artesian well recently drilled in the SE. ¼ of the NE. ¼ Section 8, T. 45 N., R. 10 W, penetrated 80 feet of red clay above 50 feet of sand over 2 feet of gravel before entering bed rock. In the SW. ¼ of SW. ¼ Section 12, T. 45 N., R. 8 W., artesian water was encountered in a well sunk into 53 feet of lake clay (Pl. LXII, Fig. 3).

The middle moraine

Another morainic system composed of a rolling mass of drift is situated to the north of the Tahquamenon Swamp in Luce County. It represents the eastern end of the high moraine which swings along the shore a few miles south of Lake Superior from Munising to Grand Marais. In Luce County the moraine is somewhat broken in trend, being interrupted in places by swamps and lowland tracts.

This morainic system is similar to the one south of the swamp in that it cannot be separated into distinct ridges. The drift is predominantly loose-textured and sandy, but is locally intermixed with small amounts of clay.

The inner border of this moraine stands at an altitude of between 750 and 800 feet and is quite strongly developed. It is composed largely of a sandy drift interspersed with small amounts of gravel. The surface is quite rolling and in places irregular, owing to the numerous basins which are inclosed among the knolls. Some of the larger basins contain lakes and swamps, but the smaller depressions are generally dry for the reason that they stand above the water-table. Erratics and boulders are scattered widely through the drift. Limestone slabs and fragments are present in certain areas, but constitute a relatively small proportion of the composition of the deposit. Limestone blocks are conspicuous in the shore bluff to the south of Cold Spring in Section 6, T. 47 N., R. 10 W., but no calcareous material was found to the north of this belt.

The outer border of the moraine is relatively low and exceedingly weak. It breaks into the Tahquamenon swamp at altitudes ranging from 700 to 720 feet. The drift is largely a mixture of sand and gravel, with only occasional erratics exposed at the surface. The relief is generally smooth and unbroken, except where the surface has been seared with drainage creases, which have been cut down into the unmodified drift below.

Like its counterpart to the south of the swamp, this moraine was practically inundated by the waters of the highest Lake Algonquin. A small area, covering merely a few square miles in the SW. ¼, T. 48 N., R. 12 W., and the NW. ¼ T. 47 N., R. 12 W., in Luce County and extending over into the southeast corner of T. 48 N., R. 13 W., in Alger County, stands at an altitude of approximately 1000 feet and was well above the level of the Lake Algonquin waters.

The inner moraine

The latest moraine, developed by the withdrawal of the ice-sheet from the eastern end of the Northern Peninsula, stands in the sandy lake plain a few miles to the south of Lake Superior. It is rather fragmentary and in much of its distance is difficult to trace, being broken by low areas of swamp and sandy lake bed. The westernmost fragment of this sytem lies to the south and west of the Sucker River basin in the western portion of T. 49 N., R. 12 W., where it extends for a few miles west into Alger County. Another fragment continues eastwardly from the east end of the Sucker River basin through T. 49 N., R. 11 W., and into R. 10 W.

In most of this latter section, the inner border of the moraine is quite distinct, being marked by a fairly conspicuous shoreline, and rises to an elevation of 730 to 750 feet (Pl. LXIII, Fig. 1). The weak outer border, on the other hand, is not so well defined and merges more or less indefinitely into the sandy plain to the south. The topography of this morainic fragment is generally weak and quite subdued, but is broken by occasional low knobs and shallow depressions. The drift is very sandy, light and loose-textured, with scattered patches of gravel and cobble.

East of the Little Two Hearted River, in the northeast corner of the county, is another fragment of this moraine. Here the feature is made up of an undulating mass of drift with no ridge development. The till is sandy to clayey in texture with numerous boulders and erratics scattered through it. This portion of the moraine has a very strong relief and is marked by a characteristic swell and sag topography. It stands at an elevation much higher than its counterparts to the west, and has an altitude ranging up to 800 feet (Pl. LXIII, Fig. 2).

The general trend of this innermost morainic system would suggest a north-northwest recession of the ice border from the southeast end of Lake Superior. It is the youngest glacial deposit in this portion of the peninsula.

OUTWASH PLAINS

Outwash plains constitute a relatively small portion of the surface area in Luce County. They are confined entirely to the south border of the moraine, which lies to the north of the Tahquamenon swamp.

An outwash apron of sandy-gravelly material occupies a reentrant of the moraine in Townships N. 46 and 47, R. 11 W., or directly across the swamp north from McMillan. Near its inner edge the plain is smooth and generally unbroken and presents the typical outwash surface character. It consists of coarse, cobbly and gravelly material, which apparently was washed down from the slopes of the bordering moraine to the north (Pl. LXIII, Fig. 3).

The south half of the apron is rough and in places deeply trenched and pitted. Except for the character of the material and the absence of erratics, the outer border does not differ materially from the surrounding morainic areas. It is quite probable that the apron was formed upon a more rugged morainic topography during a recession of the ice border, which was marked by successive halts of short duration. The apron did not receive a sufficient amount of sediment to fill in completely the depressions and smooth out the irregularities, but was built up in a series of steps from south to north as the ice retreated.

To the west of the morainic spur which borders this outwash apron, in the western half of T. 47 N., R. 12 W., and extending southward into T. 46 N., R. 12 W., is another outwash plain. This is merely the east end of the extensive outwash area which fronts the Munising-Grand Marais moraine in Alger County and borders the north edge of the Manistique-Tahquamenon swamp in Schoolcraft County. It stands at an altitude of about 800 feet above sea-level or 80 feet above the level of the Tahquamenon swamp.

This outwash plain is composed of material of very loose structure and of a sandy to gravelly texture. It is very well drained and contains but few areas of swamps and undrained depressions. The relief is smooth and regular except at its outer borders, where it is trenched by streams flowing down the slopes into the Tahquamenon drainage basin.

OLD SHORE-LINES

The highest Algonquin shore feature

With the exception of two rather widely separated areas, covering a total of about three and one-half square miles, Luce County was completely inundated during the highest stage of Lake Algonquin. The waters of this lake stood at an altitude of slightly more than 900 feet and only those morainic knobs which rise above this level were exposed as small islands. Many of the higher moraines, and portions of bordering outwash plains as well, standing at an elevation slightly less than 900, were merely covered by shallow water of the lake.

The highest shore work in Luce County is to be found in the morainic region to the south of the village of McMillan, where it is evident up to an altitude of 870 feet. This places the highest Algonquin level about 30 feet too low to fit the plane at Rexton to the southeast, as determined by Leverett.[2] It is also more than 30 feet below the Algonquin level south of Grand Marais, to the northwest, as determined by aneroid leveling.

Leverett[3] suggests that this discrepancy may be accounted for if the ice persisted as a stagnant mass in the low places to the north and covered the district around McMillan to a later time than at Rexton, so that the highest beach at Rexton is not represented here.

The highest Algonquin shore may be followed somewhat interruptedly along the north edge of the outer moraine, which borders the south side of the Tahquamenon swamp, all the way from. McMillan to Newberry. It maintains its elevation fairly well for much of this distance, but the features are not sharply defined. It loses elevation a mile south of Newberry and cannot be definitely traced beyond Section 6 in T. 45 N., R. 9 W.

Lower Algonquin shore-lines

The drainage changes, which were initiated by the withdrawal of the ice-sheet from the Lake Superior basin and were further influenced by the differential uplift in this region, caused the waters of Lake Algonquin to recede. Four successive changes in level are evidenced by the wave-cut terraces which stand between the highest Algonquin and the non-glacial Nipissing shores.

A rather poorly defined shore standing at an altitude between 795 and 805 feet marks the boundary between the moraine and the sandy lake plain to the south of the village of Newberry. It extends from the northwest corner of Section 35 in T. 46 N., R. 10 W., for a distance of about six miles to the SW. ¼ of Section 10 in T. 45 N., R. 9 W., where it seems to disappear. To the south of

Newberry it is marked by a strongly developed wave-cut terrace with a gravelly strand, but this feature becomes more obscure to the south and east.

Another shore feature, with an altitude between 795 and 810 feet, borders the north edge of the middle moraine. It may be traced as a wave-worn cliff for a distance of 16 or more miles, from the northwest corner of Section 7 in T. 48 N., R. 12 W., south-eastwardly to the southwest corner of Section 5 in T. 47 N., R. 10 W., where it breaks off into the swamp and loses its identity. The strongly developed shore cliff, together with the presence of numerous small, sandy to gravelly bars perched rather high up on the slopes of the moraine, would indicate that the waters of the receding Lake Algonquin lingered at this level for quite a long time.

Both these shore features are too high to be correlated with the Battlefield beaches, which stand at an altitude of 720 feet at Mackinac and 765 to 790 feet at Grand Marais, Michigan. They are probably the records of one of the lower members of the upper Algonquin group, which stands slightly above the plane of the Battlefield beaches.

A third level of lower Lake Algonquin is marked by the shoreline, at 715 feet, which follows along on the inner edge of the morainic fragment in the northeast portion of the county. From the southwest corner of this moraine and extending westwardly for about twelve miles, the feature becomes obscure and difficult to follow except by level readings. In Section 18 of T. 49 N., R. 10 W., it continues again as a definite escarpment along the north border of the moraine to the Sucker basin. Here it drops down to its level on the south escarpment wall and goes out of the county in the west-central portion of Section 7 in T. 49 N., R. 12 W.

The lowest level of Lake Algonquin which can be identified in the county more or less parallels the shore of Lake Superior at a distance of from one to two miles south of it. The wave-cut feature of this shore is fairly well developed to the west of the west side of T. 49 N., R. 9 W., and may be followed as a definite ridge to the Sucker basin, where it runs along the south escarpment. To the east of this line, however, it is fragmentary and difficult to trace. The plane of this shore feature stands at an altitude of 670 feet and may possibly correlate with the Fort Brady beach, which at Grand Marais has an altitude of 674 feet.

The Nipissing shore

The Nipissing shore in Luce County has an altitude of 640 to 650 feet, or approximately 40 to 50 feet above the level of Lake Superior. In general, it follows rather closely the shore of the present lake, and in much of its extent is marked by a pronounced escarpment. The shore features of Lake Nipissing are more continuous and more strongly developed than are those of the Algonquin group. This is probably due to the fact that the waters remained at the Nipissing level for a much longer period. Sandy and gravelly bars are found scattered along this shore and in places where the slopes were steep, wave-cut terraces and cliffs are prominent (Pl. LXIV, Fig. 1).

SANDY LAKE PLAINS

Sandy stretches of old lake beds are scattered quite widely in the swamps of the county. The most extensive area of lake plain is to be found north of the parallel crossing the north edge of T. 48 N. This plain stands at an altitude ranging from 640 feet on the crest of the Nipissing beach to about 800 feet in some of the more highly elevated sections. Its surface is generally smooth and regular except where it has been pitted with lakes and other depressions or where rivers have cut channels into the unconsolidated sand (Pl. LXIV, Fig. 2).

This plain was formed as a result of wave action in the receding waters of Lake Algonquin. Much of the sandy and gravelly material which constitutes the area was contributed by the inner moraine and no doubt has been spread out over the low-lying inner extension of this same feature.

SAND DUNES

Most of the sand dunes of the county are confined to the Lake Superior shore in Townships 49 and 50 N., R. 12 W., and T. 50 N., Rs. 8 and 9 W. Those in Ranges 9 and 12 W. have been built up as a series of tenuous ridges in post-Nipissing times. They are fairly well covered with vegetation and for the most part stationary (Pl. LXIV, Fig. 3). The dunes in R. 8 W. stand upon the Nipissing shore and in all probability were blown up by wind action from the Nipissing beaches. These dunes are likewise mostly grown over with vegetation and quite definitely fixed. Small isolated patches of drifting sand are found widely scattered along the present shore of the lake, a short distance back from the strand. This material is being whipped up from the present beaches and will in time develop into definite dune areas.

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EAST LANSING, MICHIGAN

[1] Ruedemann, R., and Ehlers, G. M., "Occurrence of the Collingwood Formation in Michigan," *Contributions from the Museum of Geology, University of Michigan*, Vol. 2, No. 2.

[2] Leverett, Frank, *Moraines and Shore Lines of the Lake Superior Region, U. S. Geol Surv. Professional Paper 154—A,* 1929, p. 67.

[3] *Ibid*.

PLATE LIX

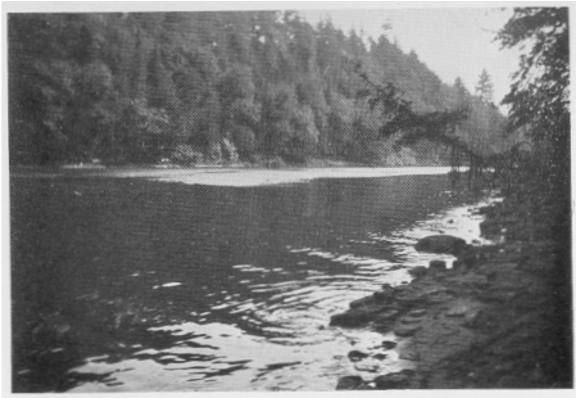


FIG. 1. Tahquamenon River above the Upper Falls

FIG. 2. The Upper Falls of the Tahquamenon River

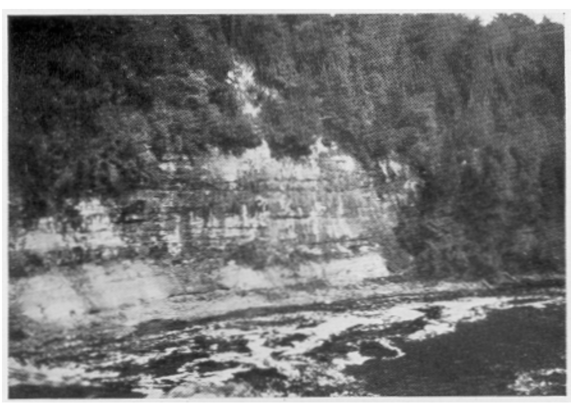


FIG. 3. Wall of Cambrian sandstone in the gorge below the Upper Falls

PLATE LX

FIG. 1. Looking north across the Tahquamenon swamp from the crest of the moraine, Section 31, T. 45 N., R. 8 W.

FIG. 2. Sandy ridge bordering swamp in Section 33, T. 45 N., R. 10 W.

FIG. 3. Swampy lowland bordering the East Branch of the Fox River, west of Danaher

PLATE LXI

FIG. 1. Looking north across the Sucker basin

FIG. 2. Shore cliff and escarpment, south rim of the Sucker basin

FIG. 3. The Blind Sucker drainage basin

PLATE LXII

FIG. 1. Morainic hills one mile east of Danaher (in the background)

FIG. 2. Morainic topography south of McMillan

FIG. 3. Clayey lake plain in recess east of McMillan

PLATE LXIII

FIG. 1. Shore-line escarpment south of Whorls Camp in Section 9, T. 46 N., R. 11 W.

FIG. 2. Kettle basin in water-worked inner moraine, south of Perch Lake

FIG. 3. Sandy outwash plain, east of Murray Lake, T. 47 N., R. 11 W.

PLATE LXIV

FIG. 1. East end of the Blind Sucker basin, showing the Nipissing shore to the right

FIG. 2. Sandy lake plain south of Muscalonge Lake. Note the deer in the background

FIG. 3. Sand dunes north of the Sucker basin in the northwest portion of the county

A REVIEW OF THE STRATIGRAPHY OF THE SAGINAW FORMATION*

WILLIAM A. KELLY

CONTENTS

INTRODUCTION

THIS paper is intended as a review of present knowledge of the stratigraphy of the Saginaw formation of Michigan. Brief summaries of those portions of publications which deal with the stratigraphy of the coal-bearing beds are included; they show the varying views held by different workers from the time of Douglass Houghton to the present. An attempt is made to define the upper and lower limits of the Saginaw formation. The varying lithology of the beds between these limits is described, and emphasis is laid upon what seem to be salient characters which may prove of value in correlation. The evidence bearing upon the age of these beds is very meager. An outline to guide future efforts is suggested.

PREVIOUS WORK

The first explorations for coal were made in 1835 west of Jackson, but it was not until a few years later that geological investigation was started.

1838. — Douglass Houghton, in his first report[1] as state geologist, mentions some of the outcrops of the Coal Measures within the state of Michigan. He noted the presence of fossil plants in beds exposed in the quarries at Jacksonburgh (Jackson) and associated these with the coal. He also mentions the occurrence of a stratum of limestone near Shiawassee town (Corunna), which was similar to limestone outcropping near Jacksonburgh. This latter occurrence of limestone is not mentioned, however, by later writers. It was Houghton's belief at this early date that the Coal Measures underlay an area extending to the northern part of the Lower Peninsula.

1839. — A second report[2] includes brief descriptions by D. Houghton and C. C. Douglass of the occurrence of sandstone and coal outcrops in Ingham, Eaton and Jackson counties. No attempt is made to subdivide the Coal Measures into smaller groups.

1840. — The work on the Coal Measures had been largely assigned to C. C. Douglass; it is included in a third annual report by Houghton.[3] Douglass grouped the rocks observed in the counties of Jackson, Calhoun, Kalamazoo, Eaton, Ionia and Kent under two divisions, the rocks that overlie the coal, or are associated with it, and those that are below the lowest coal beds. The upper division was composed as follows:

1. Upper coal strata — layers of coal, shale and sandstone
2. Limestone — limited and irregular beds
3. Sandstone — light gray and red
4. Lower coal strata — layers of coal, etc,

The lithologic characters of Douglass' four divisions are described in stratigraphical order. Though he mentions the plant fossils of the sandstone above the lower coal as a criterion of its age, he mistakes the limestones exposed at Bellevue as a part of his "coal-bearing rocks." The sandstones exposed near Ionia, which are now thought to be equivalent to Woodville, Douglass assigned to a position" intermediate between the upper and lower coal-bearing rocks."

1841. — The work on the Coal Measures was transferred from Douglass to B. Hubbard, who gives a "geological section" for the then organized counties of the state. In the section of the fourth report[4] dealing with the Coal Measures, Hubbard changed Douglass' subdivision so that the limestone stratum, number two of Douglass' order, is stratigraphically below all the coal beds and the associated sandstones and shales. The limestone, however, is still included under the term "Coal Measures." His division reads as follows:

Upper coals and shales
Included sandstones
Lower coals and shales
Limestone stratum

The areas underlain by the Lower Coal are described by Hubbard. He believed that the coal beds near the edge of the basin were stratigraphically below the beds exposed near the center, for example, those of Eaton County. The two coal-bearing formations are overlain by red or variegated sandstones. Hubbard estimated the area underlain by the Coal Measures to be about 11,000 square miles.

1861. — Under the reorganized State Geological Survey, Alexander Winchell gives a general sketch of the geology of Michigan in the *First Biennial Report*.[5] The Coal Measures of the earlier workers is subdivided into three divisions, the Parma Sandstone at the base, the Coal Measures (restricted), and the Woodville Sandstone at the top. Descriptions of these divisions are given. The area underlain by the rocks of the middle division is estimated at 6,700 square miles. The location and character of natural rock sections throughout the state are described. Descriptions of the sections exposed in several mine shafts are included. The part dealing with the Coal Measures, or middle division, is concluded with a generalized tabular list of the beds which Winchell thought to be typical of the stratigraphy. It was his belief that one persistent coal seam ran through the entire Coal Measures. His estimate of their thickness is low.

1876. — The three divisions proposed by Winchell were not used by C. Rominger.[6] The latter took exception to the use of "Parma Sandstone," since he did not believe in regularity of sequence of the strata of the Coal Measures. Under the term "Coal Measures," he included all strata above the Bayport limestone. He estimated the thickness of the coal-bearing series to be 300 feet. The outcrops near Jackson, Grand Ledge, Owosso, Rifle River, as well as several localities, are described in detail. Descriptions of natural sections, or sections exposed in mine shafts close to outcrops, are tabulated and illustrate the variable succession of strata from one locality to another. The presence of *Lingula* shales are noted, but no effort is made to use that brachiopod for correlation purposes. A geological map of lower Michigan accompanies the report.

1882. — A short, but comprehensive, report on the Coal Measures appears in one of the reports on the mineral statistics of Michigan.[7] In it C. D. Lawton describes the lithology and attributes a maximum thickness of 300 feet to the formation. The presence of sandstone channels is noted and described. The region underlain by the measures, Lawton says, is a circular area about 50 miles in diameter with very few exposures. Lawton was familiar only with the area south of Corunna, and believed that there was but a single workable seam. He did not believe, however, in the current notion that the presence of sandstone at the surface precluded the finding of coal below.

The later reports of Lawton are concerned chiefly with descriptions of individual mines and the progress of the coal-mining industry.

1895. — A. C. Lane gives a brief description of the formations of the Lower Peninsula.[8] He describes the rocks associated with the coal beds as the Jackson Coal Group. The Woodville and Parma are recognized as a part of the Coal Measures, but from the log of a well at Ithaca, Gratiot County, one might infer that Lane restricted the name "Jackson Coal Group" to the beds between the Parma and the Woodville.[9]

1900. — The small Sebewaing Coal Basin is described by Lane.[10] An explanation is put forward to account for sandstone channels known from this district. The presence of faulting on a small scale is noted.

In his discussion of clays and shales of Michigan, H. Ries[11] treats of some of the beds of the Coal Measures. He notes that the shales vary greatly at different mines, but distinguishes three common types, one of which is a so-called fire-clay. Brief descriptions of sections exposed in quarries and mine shafts are given.

1902. — The most comprehensive work on the Coal Measures of Michigan was prepared by A. C. Lane.[12] He states that the report is a compilation of several smaller ones that were published in issues of the *Michigan Miner*. This report, though dealing principally with the subject of coal, contains important information on the stratigraphy of the Coal Measures. The lithology, thickness and probable origin are given. The Michigan Coal Measures are correlated with the Pottsville on the basis of their plant remains, which were identified by David White.[13] Lane Lower Rider, Saginaw Coal, Middle Rider, Lower Verne Coal, proposes a subdivision of the Coal Measures into Lower Coal, Upper Verne Coal and Upper Rider, to assist in correlating coal seams in various mines throughout the state. He notes the presence of two marine invertebrate faunas which he is inclined to believe come from the zone of the Verne coals. From the relation of the depth of the base of the Coal Measures to the top of the underlying Napoleon sandstone, Lane inferred that the coal seams and associated sandstones and shales were essentially horizontal and that they did not share in the basinward dip of the older formations.

A report, shorter than that contained in the second part of Volume 8 of the Michigan Geological Survey, was prepared by Lane for the United States Geological Survey.[14] The coal-bearing beds are referred to as the Saginaw formation. The chemical character of the upper and lower coals is contrasted, and the probable significance of fossiliferous marine beds is stressed.

A preliminary report on Arenac County by W. M. Gregory[15] gives a short account of the lithology and the distribution of coal and associated strata in that county.

1904. — Grimsley[16] includes a map showing outcrops of the Saginaw formation in the area northwest of Saginaw Bay. The report, however, does not deal with the Saginaw formation.

1906. —- In this year W. F. Cooper's report on Bay County[17] appeared. The stratigraphic division of the Saginaw formation as represented in Bay County is described. An average thickness of 350 feet is given. Cooper follows the example of Lane by subdividing the Saginaw formation on the basis of the coal seams, but adds five new horizons, making twelve in all. The list from the bottom upward is as follows: Bangor Coal, Bangor Rider, Lower Coal, Lower Rider, Saginaw Coal, Middle Rider, Lower Verne Coal, Lower Verne Rider, Upper Verne Coal, Upper Verne Rider, Salzburg Coal, Salzburg Rider. The correlation of the coal seams encountered in drill-holes is apparently carried on in part by their elevations above mean tide-level, chemical and mineralogical characters of the coals or the beds above or below, and also on the relation of some of the coals to marine fossiliferous strata carrying *Lingula* or *Productus* faunas. Descriptions in detail of washouts or preglacial drainage channels are given. Several geological sections are included. The bulk of the latter half of the report is made up of the logs of numerous drill-holes.

In the report of the state geologist for 1905, Lane[18] states that he believes that the Verne coals are the most widespread.

1908. — The report for 1907 contains a brief description by David White[19] of a collection of fossil plants sent to him. White classes the plants as Upper Pottsville. In the latter part of his letter to the state geologist, he says: "I presume it [a specimen at the University Museum from Jackson] is older than coal at Bay City."

1909. — The report of C. A. Davis on Tuscola County contains a description by W. F. Cooper of the Saginaw formation.[20] The boundaries of the formation are given. The average thickness of the formation is stated to be 126 feet. The Parma is not recognized in Tuscola County, although it may be represented by a basal conglomerate. Cooper adds two coal horizons to the list of twelve given in his Bay County report. These two seams are stated to occur above the Salzburg Rider. Cooper says the lower four coal horizons of Bay County occur at higher elevations in Tuscola County.

A summary of the stratigraphy of the Saginaw formation is included in a paper by Lane on the geological section of Michigan.[21] It is a summary of the views expressed by him in the report contained in Volume 8 of the reports of the Geological Survey of Michigan. Lane does not lay much stress on the fourteen coal horizons proposed by himself and Cooper, but emphasizes the importance of the Verne horizons, which he thinks are associated with fossiliferous beds of shale and limestone. The thickness of the Saginaw is given as 400 feet.

1912. — R. A. Smith,[22] in a report on Michigan coal, summarizes the views of previous workers. He stresses the variable character of the beds of the Saginaw formation and discounts the value of Cooper's subdivisions. Smith gives a probable maximum thickness of more than 600 feet for this formation in the center of the coal basin.

The work of W. M. Gregory[23] on Arenac County describes the distribution of outcrops of the Saginaw formation and the area underlain by it. An outcrop map which accompanies the report shows that most of the exposures are along Rifle River. The thickness of the formation in this county is less than 100 feet.

A very brief summary of the stratigraphy of the Saginaw formation is given by R. A. Smith[24] in a report on oil and gas. Mention is also made of the occurrence of oil in a sandstone lens of this formation at a depth of only 157 feet in a well near Fowlerville.[25]

1915 and following years. — The reports on the mineral resources of Michigan for 1914 and the years following all contain brief references on the subject of coal. Most of the information is of a statistical nature bearing on production and makes no contribution to the stratigraphy of the Saginaw. The sections of the reports which do pertain to stratigraphy are brief and are, as a rule, rewritten parts of former reports. In one of these reports R. A. Smith[26] points out that some wells which penetrate the Saginaw formation near the center of the basin indicate the absence of both coal and black shales there. This is interpreted as a further proof of the variability of the beds of the Saginaw formation.

A report on the shales within the state by G. G. Brown[27] includes a map showing exposures of shales of the Saginaw formation.

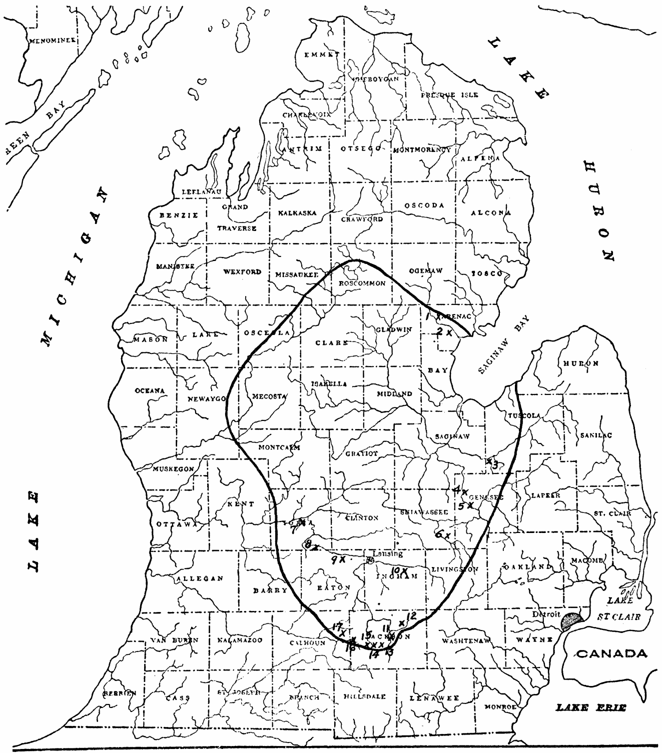
ORIGIN OF THE NAME "SAGINAW FORMATION"

The Saginaw formation has also been referred to as the "Coal Measures," the "Coal-bearing Measures," the "Jackson Coal Group," the "Jackson Series," and even as the "Pottsville." In most cases these terms have been quite loosely used. Thus C. C. Douglass, in his report to the state geologist,[28] included in "Coal Measures" rocks now recognized as Mississippian, and, later on, C. Rominger[29] used the same term to apply only to rocks younger than the Bayport limestone, which today is considered to be the youngest formation of the Mississippian represented in Michigan. On the other hand, Winchell,[30] in a report antedating Rominger's, restricted the name "Coal Measures" to the beds between the Parma and the Woodville, groups which Rominger did not recognize. The name "Coal Measures" itself had been and is still used, with an entirely different significance.[31] It was probably for such a reason that Lane[32] used the name "Jackson." This name in turn, however, was replaced because it was preoccupied by a Tertiary formation in Mississippi.[33] Accordingly, Lane[34] suggested applying the name "Saginaw" to the coal series, because it was a characteristic Michigan name. It has come into general used since 1901, when Lane employed it in connection with his report on the Northern Interior coal field for the United States Geological Survey.

The name is still subject to some discussion. According to Mr. R. Newcombe[35] of the State Geological Survey, the well-drillers in the Saginaw oil field apply the term "Saginaw Sand" to a petroliferous horizon in the Traverse formation. This usage, however, yields in priority to Lane's.

AREAL DISTRIBUTION

The area underlain by the Saginaw formation is practically coextensive with the Michigan coal basin. Lane[36] briefly describes the extent of the coal field as being from "Jackson County on the south to Roscommon County on the north, and from Tuscola County on the east to Kent County on the west. It embraces an area of 7500 square miles." This area is entirely separated from the Pennsylvanian areas in the states to the south. It is probable that there were only brief periods of communication between the Michigan and adjoining basins.



MAP 45. Michigan coal basin, showing location of outcrops (see next page for legend)

LEGEND FOR MAP 45

Data compiled principally from publications of the Michigan Geological Survey. References are to authors mentioned in the text.

No.	Locations	References
1	Rifle River, above Omer	Gregory, 1911
2	Rifle River, below Omer	Gregory, 1911
3	Cass River, near Tuscola	Winchell, 1861
4	Flint River, 1½ miles below Flushing	Ries, 1900
5	NE. ¼, Section 35, Flushing Township	Winchell, 1861
6	Two miles northeast of Corunna	Brown, 1926
7	Grand River, Section 23, Ionia Township	Rominger, 1876
8	Grand River, below Grand Ledge	Rominger, 1876
9	Near Grand Ledge	Rominger, 1876
10	Near Williamston	Brown, 1926
11	Highway M–127, Section 10, T. 2 S., R. 1 W.	Unpublished
12	Portage River, east of confluence with Grand River	Rominger, 1876
13	Near Woodville mine, Section 25 (?), T. 2 S., R. 2 W.	Winchell, 1861
14	Roadside, SW. ¼, Section 27, T. 2 S., R. 2 W.	Unpublished
15	NW. ¼ of NW. ¼, Section 29, T. 2 S., R. 2 W.	Winchell, 1861
16	NE. ¼, Section 19, T. 2 S., R. 3 W.	Winchell, 1861
17	NW. ¼, Section 12, T. 2 S., R. 4 W.	Unpublished

The formation outcrops in isolated localities, principally within the counties of Arenac, Tuscola, Genesee, Shiawassee, Eaton, Ingham and Jackson. The outcrop localities mentioned in reports of the Michigan Geological Survey are indicated on the accompanying map (Map 45). The scarcity of outcrops is due to the thick accumulation of drift material, which has an extensive distribution in the state of Michigan. This drift is only rarely trenched through by streams.

The lack of outcrops is partially compensated for by the large number of mine-shafts and drill-holes which have been put down in the state. Many of the old mine-shafts and workings have caved in or are flooded today, however, and as a consequence the information they might have yielded has been lost. The data contained in the logs of numerous drill-holes are ordinarily of an incomplete character and of little value from a stratigraphical point of view.

STRATIGRAPHIC POSITION

The Parma sandstone, which has a conglomeratic facies at times, lies beneath the Saginaw formation. From a study of well-sections showing both the Parma and Saginaw, it appears to one that the boundary is at the contact between the lower shales of the Saginaw and the upper white sandstone of the Parma. Cooper[37] doubts the presence of the Parma in Tuscola County. In cases such as this the lower boundary of the Saginaw formation is the erosional unconformity at the top of the Bayport, or the underlying Michigan formation. In several instances the Saginaw formation may rest directly upon the Napoleon sandstone.[38] The formation rests, therefore, upon an uneven surface which probably resulted from the differential erosion of Mississippian and early Pennsylvanian strata. The irregularities of this pre-Saginaw surface are reflected in the beds above, giving them an undulatory structure.

LITHOLOGIC CHARACTERS

The Saginaw formation is composed of material of both marine and terrestrial origin. Undoubted marine rocks are subordinate in amount and consist of thin beds of argillaceous limestone and blue and black shales. *Lingula* faunules occur in the shales, and richer faunules are known from the calcareous beds. Terrestrial sediments, which make up the greater part of the formation, are represented by several types of sandstones, shales and coal. Many of the beds contain recognizable plant fragments which throw light on the age of sections of the Saginaw. In addition to these there are beds of as yet undeterminate origin which make up a considerable part of the formation.

A review of the literature on the Saginaw formation shows that several attempts have been made to subdivide it. The last and most elaborate of the subdivisions, in which fourteen coal horizons are recognized, was made by Cooper.[39] This classification is not supported by Smith,[40] who holds that "none of the coal beds extend continuously over the whole basin and few are continuous over any considerable part of it." A critical study of some of the numerous test holes and drill records which form a great part of Cooper's Bay County report leads one to believe that the subjective element would enter into correlation carried on by means of superposition of seams. The log of test hole No. 362[41] shows three riders between the Lower Verne Coal and Salzburg Coal, and the omission of the Upper Verne Coal, when the normal succession should be Lower Verne Coal, Lower Verne Rider, Upper Verne Coal, Upper Verne Rider, Salzburg Coal. A test hole near Wolverine Shaft No. 2 in the north part of Bay County shows two riders between the Upper Verne and Salzburg coals,[42] whereas one only is supposed to occur. Test hole No. 238 does not show the Saginaw Coal, although the Middle Rider is identified.[43] Several other examples might be cited to illustrate the fact that the logs are capable of at least two interpretations. One must believe correlations of the foregoing kind would have to be substantiated by careful analyses of not only the coals, but the rocks above and below the seams. Cooper does not give the criteria he uses in making his correlations. The elevations above sea-level cannot be used, for there is evidence in mine workings that pronounced rolls to the individual seams are by no means uncommon. R. A. Smith[44] cites an example from the Bliss mine of Saginaw County.

Some method of subdividing the Saginaw formation must be used other than those employed in Cooper's classification. In this respect one might return to the later views of Lane[45] which emphasize the importance of the Verne horizons because they are associated with marine fossiliferous strata.

It is generally agreed that marine deposits are accumulated under more uniform conditions than terrestrial deposits, and it might be inferred from this statement that marine members would be more constant in composition and thickness than coal seams would be. Several sections of the Saginaw formation show at least two fossiliferous marine members. Together with other criteria, such as the flora, a consideration of the lithology of the overlying and underlying strata and unconformities, the marine members may prove to be critical beds in the division of the Saginaw.

Sections of the beds of the Saginaw formation that are exposed from the southern to the northern limit of the coal basin frequently show the presence of a shale member containing an abundance of brachiopoda which belong apparently to the species *Lingula carbonaria* Shumard. This is the zone which Lane[46] considered occurred above the Upper Verne Coal. A section in the vicinity of Grand Ledge, Michigan, shows two *Lingula* horizons separated by shales, sandstones and a seam of coal. A study of the Pennsylvanian faunas which is now being carried on leads the writer to believe that there are possibly more than two *Lingula* horizons. Because of their present undecided stratigraphic location and the need of future study of their faunules, the *Lingula* members will not be further treated in this paper.

Another fossiliferous marine member has been referred to by Lane[47] and Cooper.[48] Lane does not state which fossil is the most characteristic of the member, but Cooper considers *Marginifera* (*Productus*) *muricata* (N. & P.) to be one of the four most commonly occurring forms. Several mine shafts in the Saginaw Valley seem to indicate that this member is present over a wide area. Outside the Saginaw Valley a fauna characterized by Productidae has been found at Grand Ledge.[49] This fauna differs in detail from those listed by Lane. Moreover, it occurs stratigraphically above beds containing *Lingula*, whereas the reverse order of occurrence applies to all other listings of *Lingula* and *Productus* in Michigan.[50] There is a possibility that more than one *Productus* horizon exists.

The literature on the Saginaw formation contains frequent references to nodular seams of black iron ore, without indicating whether these beds are extensive or very local in distribution. At the present time the rank of member cannot be applied to any of these readily recognizable beds.

Preliminary investigation of a few sandstone samples by means of elutriation indicates some notable differences in the mineral contents and the textures of different beds. Any further work along this line may serve to either group or separate the imposing array of sandstones that are mentioned in almost any section or well-log of the Saginaw. Similarly, the varying types of shales might lend themselves to a serviceable grouping.

Coal seams may be grouped on the basis of whether they are coking or non-coking, or high or low in sulphur. The coking coals of Michigan which have a high sulphur content are stated to be younger than the non-coking and low sulphur varieties.[51] This statement may require further substantiation. If this is proved true, it will be of aid in the subdivision of the Saginaw into members.

STRIKE, DIP AND THICKNESS

The beds of the Saginaw formation are essentially horizontal, all dips which have been observed being local and of an undulatory character. This is exemplified in several parts of the state. Lane[52] figures a section from a mine in Sebewaing and Smith[53] describes an example observed in the Bliss mine at Swan Creek, Saginaw County. Another line of evidence is furnished by a well drilled near Saginaw on a Pennsylvanian structure. No production was obtained from the beds which are petroliferous in the adjacent Saginaw field. According to R. B. Newcombe[54] of the State Geological Survey, these results do not indicate a similar pre-Pennsylvanian structure. Apparently the local structures reflect the topography of pre-Pennsylvanian time, and the upward arching was produced by the settling of the strata along the flanks of preexisting hills.

The thickness of the Saginaw formation varies. In Arenac County it is said to be less than 100 feet.[55] The maximum thickness for this formation is more than 600 feet.[56]

PHYSIOGRAPHIC EXPRESSION

The Saginaw formation throughout the greater part of its areal extent is concealed by drift. It occupies a low, flat country surrounded by a rim of higher land that partially reflects buried escarpments. These were produced by heavy sandstones and limestones belonging to the Mississippian period, during the cycle of erosion preceding the age of glaciation. The rough and irregular preglacial topography accounts in some measure for the few outcrops and for the varying depths at which bed rock is struck in well drilling. A rock contour map of lower Michigan indicates a well-developed drainage system.

PALEONTOLOGICAL CHARACTERS AND CORRELATION

Many of the sandstones and shales contain recognizable plant remains from two or three horizons. Small collections have been made in the past and sent to David White for identification. Lists of the plants identified by him are contained in reports written by Lane.[57] White referred the collections to an age corresponding to the upper part of the Pottsville.

Some invertebrate fossils which were collected from shale and limestone members encountered in mine shafts of the Saginaw Valley and associated with the Verne Coals were identified by G. H. Girty. The collections reveal two faunules, one represented by *Lingula* and the other characterized by several species of *Productus* and other invertebrates. Girty's lists appear in Lane's report.[58] There is a general similarity between the faunas collected from the mine shafts and those from Six-Mile Creek[59] and at Grand Ledge.[60] Girty, after a study of the Saginaw Valley collections, could see no reason for disagreeing with White's conclusions concerning the age of the Saginaw formation. He considered the fauna to have a long range and to be indicative of no particular part of the Pennsylvanian period, since there was nothing distinctive characterizing it. This statement might be used in referring to the Six-Mile Creek and Grand Ledge faunules also.

However, regardless of the value of these faunules in interregional correlation, their importance in the correlation of Michigan strata may be admitted. If there is but one horizon at which the Productidae occur, it will be an easily recognizable zone and make possible at least a twofold division of the Saginaw. It has not been proved, however, that there is but one horizon at which the Productidae occur. From analogy with Ohio, on the contrary, we have reason to expect several such horizons. Our chief dependence in correlation will then be on the sequence of beds above and below the fossiliferous horizons.

MICHIGAN STATE COLLEGE
EAST LANSING, MICHIGAN

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HEAVY MINERALS FROM SOME PENNSYLVANIAN SANDSTONES OF MICHIGAN

WILLIAM A. KELLY AND EDWARD L. BEUTNER

OBJECT OF INVESTIGATION

THIS paper is a preliminary report upon an investigation the object of which was to determine whether heavy minerals, if present in the Pennsylvanian sandstones, occurred in sufficient quantities to be of any value in correlation work. It was hoped also that, by means of mechanical analyses and the separation of heavy minerals, some light might be thrown upon the origin of the sandstones.

LOCATION OF SAMPLES STUDIED

Twenty-five sandstone samples were examined. They were collected from the type locality of the Parma sandstone, or lowest formation of the Pennsylvanian system in Michigan, and from other outcrops believed to be of Parma sandstone. A few samples were collected from the type locality of the Ionia sandstone, the youngest formation of the Pennsylvanian system in Michigan, or, at least, the youngest formation exclusive of the drift and alluvial deposits, in Michigan. Many samples were also collected from the Saginaw formation, which is intermediate in age between the Parma and Ionia. These came from outcrops, quarries and mine dumps in Jackson, Calhoun, Ingham, Eaton, Clinton, Shiawassee, Genesee, Saginaw and Arenac counties, Michigan.

METHOD OF PROCEDURE

A series of nine specimens which were considered to be representative of known sections of the Pennsylvanian system were examined by means of a mechanical analysis. This examination was accomplished by generally following a scheme outlined by Wanless.[1] The results obtained are represented graphically by means of a triangular diagram (Fig. 12), which shows the relative proportions of sand, silt, mud and carbonate making up any sandstone.

The sand content of the samples was first examined qualitatively for its mineral content. Most of the sandstones contained some feldspar, micas and heavy minerals in addition to quartz particles, but some from the horizons thought to be Parma were remarkably clean.

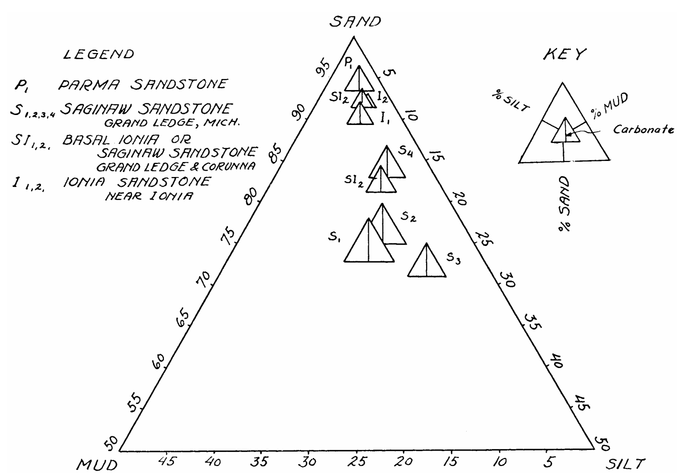

FIGURE 12

For a determination of heavy minerals the sand residue was treated in a separatory funnel with acetylene tetrabromide, a heavy liquid having a specific gravity of

2.97. This liquid was supplied by the Dow Chemical Company and was found to be quite satisfactory. Since available apparatus was limited, we used a very simple separatory funnel consisting of an ordinary glass funnel, to the stem of which was attached a rubber tube and pinch-cock. The mineral powder and heavy liquid were thoroughly mixed, and the sands allowed to settle for twenty minutes before the heavy concentrate was drawn off. The concentrate was then mounted in Canada balsam for microscopic study. In addition to the nine specimens already mentioned, sixteen other samples were examined for their mineral content. Heavy minerals were determined by the method already outlined.

RESULTS OF INVESTIGATION

The investigation shows that several heavy characteristic minerals are present and may be determined with comparative ease. Of these, zircon is the most common and occurs in greater or lesser quantities in nearly all the specimens examined. Tourmaline, garnet, zoisite, hornblende, muscovite, biotite, and possibly phlogopite, are other minerals which have been identified. The last three are not proportionately represented among the heavy concentrates, partly because the flaky cleavage does not permit easy settling in the heavy liquid and partly because the gravity range of the micas is between 2.8 and 3.2, and thus on either side of acetylene tetrabromide. There is a marked absence of apatite and magnetite, heavy minerals often found in sandstones.

THE PARMA SANDSTONE

This is a clean, highly siliceous sandstone ordinarily composed of 90 to 95 per cent sand grains. The hand specimen is white to light gray, friable and moderately coarse in texture. The chief mineral is quartz, and there is practically no feldspar present. Heavy minerals are not so abundant in the samples of this sandstone which were examined as in the Ionia sandstone and in the sandstone members of the Saginaw formation. Tourmaline is the most common heavy mineral determined. It is usually found in excellent crystals showing marked absorption. Zircon is much less common. Hornblende was also determined.

SANDSTONE MEMBERS OF THE SAGINAW FORMATION

These sandstones contain 70 to 75 per cent of sand, the rest being silt, mud and carbonates. The terrestrial character of some of the sandstones is shown by the presence of fossil plants and the occasional inclusion of thin coal seams. The micas, muscovite and biotite, form a large portion of the constituents of some of the sandstones. Several heavy minerals are present. Tourmaline crystals are common in the samples examined, although not so abundant as in the Parma samples. Zircon is more common than in the Parma. Garnet is sparingly found in irregular grains; it is far less common than the first two minerals mentioned. Uvarovite, the green variety of garnet, was determined in a specimen which came from Flushing, Michigan. Zoisite was also identified in the Flushing sandstone.

IONIA SANDSTONE

Undoubted examples of this sandstone are found in abandoned quarries near the Grand River between Lyons and Ionia. Sandstone from that locality contains about 85 per cent of sand grains and is much cleaner than sandstones from the Saginaw formation. Among the heavy minerals there is an abundance of zircon, a mineral which seems to be especially characteristic of these sandstones. In one specimen the crystal outlines were not observable. Garnet is relatively rare and tourmaline is sparingly found.

CONCLUSIONS

The preliminary work has shown that heavy minerals are present in the Pennsylvanian sandstones in sufficient quantities to be determined in a small sample.

The preliminary work also shows that further investigation along this line is promising, for while the limited amount of material already examined is not sufficient to permit drawing any definite conclusions, the samples appear to indicate that:

1. Tourmaline and zircon are the common heavy minerals;

2. The ratio of tourmaline to zircon is greater in the Parma sandstone than it is in the Ionia;

3. The feldspar content of the Parma and Ionia sandstones is low, but comparatively high in the Saginaw;

4. The sandstones of the Saginaw formation have relatively high contents of silt and mud.

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[1] Wanless, H. R., "Lithology of the White River Sediments," *Proc. Am. Philosoph. Soc*., Vol. 61 (1922).

THE DUNES OF THE MANISTIQUE AREA

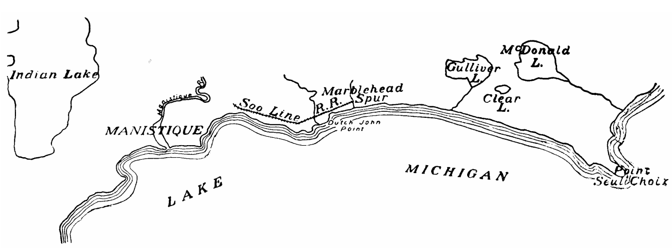
ELLEN B. STEVENSON

THIS study of dunes was made in the Manistique section on the north shore of Lake Michigan covering the area from the city of Manistique on the west to McDonald Lake and Seul Choix Point on the east. The area between Gulliver Lake and Seul Choix Point was only briefly surveyed; the major portion of the time was spent on the western section. Several reconnoitering surveys were made at first and later two detailed topographic maps were constructed to determine the elevations of the dunes and possibly their alignment and relation to former lake levels (Map 46).

This is the first comprehensive survey of the dunes of this region, although a brief mention of those between Manistique and Brevort Lake was made by Lane[1] in 1904. Cressey[2] has studied the dunes along the Indiana shore of Lake Michigan and as a result of this he was able to correlate the dune ridges with the Glenwood, Calumet and Tolleston-Hammond (Algonquin) stages. The remaining dunes are considered as having been formed by present Lake Michigan.

The reason for selecting the Manistique area is because it is north of the hinge-line and the dunes are spread over a wider zone, and also because the dunes formed are subsequent to Lake Algonquin. This study supplements, therefore, the work done by Cressey and may be used as one of the type locations to be compared with sections studied south of the hinge.

Limestone is exposed on the shore at Seul Choix Point, Dutch John's Point, and westward at Manistique and Thompson. The Indian Lake and the Manistique River embayments are deep, but farther east between Dutch John's Point and Seul Choix there is a shallow, broad one. At an earlier lake stage all these embayments were cut off from Lake Michigan by bars forming Indian Lake in one depression, and Gulliver, McDonald and Clear lakes in the other; a spit in the Manistique River depression caused the Manistique River to turn westward before entering Lake Michigan.



MAP 46. Place map of the Michigan shore from Manistique to Seul Choix Point

On the present shore of Lake Michigan, a short distance back from the water's edge, the sand which comes from the offshore terrace piles up on the shore as a result of wave action and the alongshore currents, and forms a storm beach, which, after drying out, is blown landward by the wind and deposited in a low fore-dune ridge. The ridge varies from six to ten feet in height and is continuous with a somewhat uneven front and crest. The back slope, which is much more irregular than the front, is slightly steeper but does riot represent the natural angle of repose of sand.

A second fore-dune ridge inland from the first is about twenty-five feet high and varies from fifty to one hundred and fifty feet from the first. Owing to "blow-outs" its crest is irregular in height and sinuous in character. The back slope of these blown dunes is steeper and approaches more nearly the angle of repose of sand.

Behind these dunes the ridges are lower and less regular and are separated by swamps. These lagoon-swamps are crossed by long, narrow, low-curving sand ridges offering a means of traversing the marshes.

Inland from these low ridges and swamps is a series of ridges, irregular in elevation and continuity, but roughly parallel to the lake shore and transverse to the wind. Some of the high spots in this area indicate a “blow" type, but there are no very conspicuous variations from the ridge type.

Landward from these high ridge-like hills is a zone of low ridges, irregular in direction, shape and relationships, and interrupted with low peaks where the sand has been blown higher. Some of these join to the northward long, sinuous side ridges of parabola dunes whose apices lie one quarter to one third of a mile to the northward and sometimes stand seventy to seventy-five feet in elevation. Some of these side ridges have hummocks which probably mark halts of the main dune area between blow-outs. Often extensive swamps occur between these high peaks.

This significant cross-section may, therefore, be definitely separated into three distinct provinces or types. The older and higher parabolic dunes lie well back from Lake Michigan and stand above the forty-foot level. The middle belt of high dunes belongs to a later lake stage and the lesser deformed dunes and dune ridges along the shore belong to the present.

There are two possibilities in regard to the formation of this complex dune topography. One is that they were formed near their present location and the second that they have migrated and thus may represent waves of sand moving to the leeward across the country. The reason for believing that they formed at the shore and migrated landward are: first, the fore-dune ridge at the shore is relatively smooth in contour; second, the dune ridges inland show deformation of both surface and continuity. The parabola dune is formed at the head of the blow-out and blowout is the chief means of migration. Thus, the greater the height of the dunes the greater the sinuosity until the dune ridge loses its identity entirely. Further deformation of the blow-out may lead to a wind rift and longitudinal dunes which may be separated by swamps also longitudinal in character.

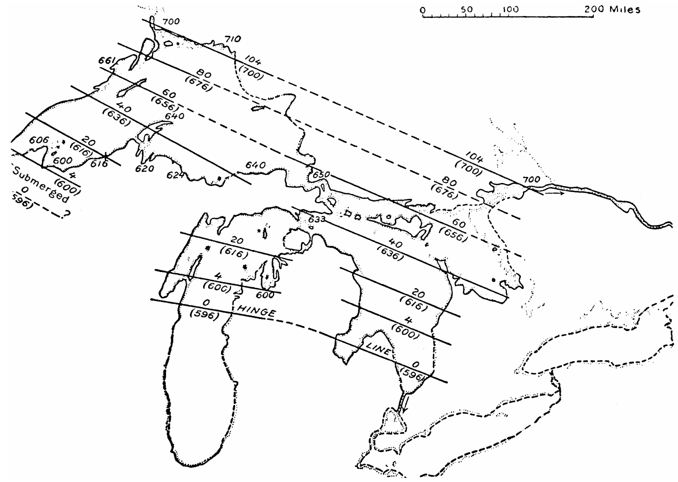
The dune ridges may be traced for one hundred yards into the dune area, where they become deformed by blow-outs and can no longer be traced. This would favor the ideas that dune ridges advance irregularly by the blow-out method and, conversely, that a smooth dune ridge is indicative of formation at or near its present location.

The other possibility as to the formation of the dune ridges is that they were formed *in situ* and blown by the wind, but have never migrated enough to become detached from their source of supply, the beach. Then the lake level lowered and additional sand areas were exposed to the wind, with subsequent formation of dune ridges in front of the old ones.

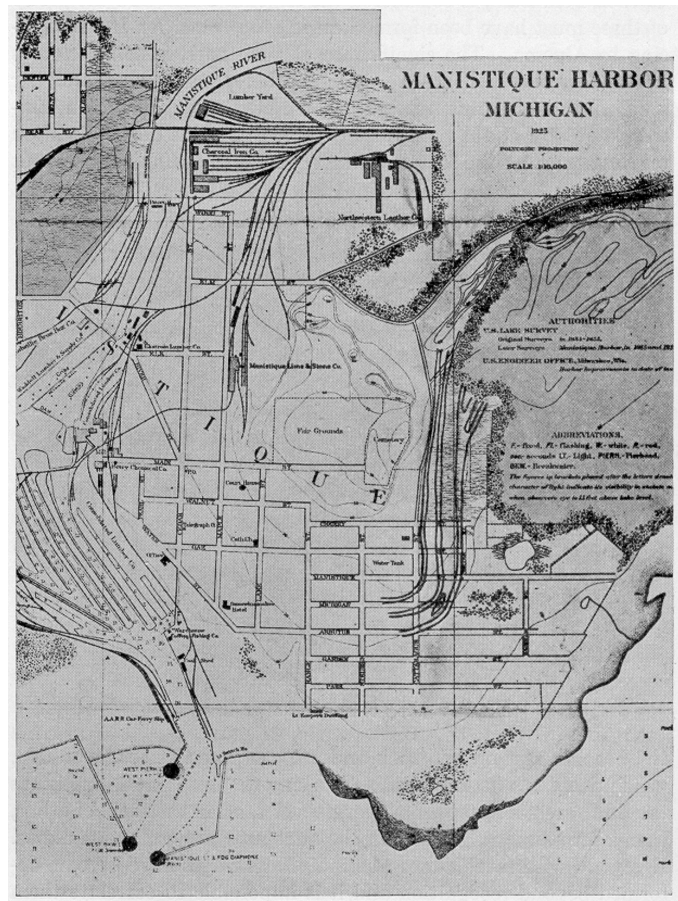
The cross-sections studied this past summer (1929), maps of which are shown in figures, as well as the map indicating beaches near the city of Manistique, substantiate the theory that migration from a shore-line approximating the present one has not been a dominant factor in the formation of the big dune ridges far inland from Lake Michigan shore.

The city of Manistique is for the most part located on a wave-cut terrace which slopes gently upward from the lake. This terrace within the city limits is unbroken save for the hill on which the cemetery is located at the eastern outskirts. The foot of this hill is a well-defined shore-line which stands between forty and forty-five feet above Lake Michigan, 620-625 A.T. According to an interpolation of the elevations shown in Leverett's map[3] of the isobases of Lake Nipissing (Map 47), this has been called the Nipissing terrace.

On Manistique Point wave action was strong in the past, and is at the present time, as evidenced by the rubble beaches (Map 48), which are well exposed within the city along Cattaragus Street between Manistique and Michigan streets. There are four of these beaches; they consist, first, of a group of three moderately developed bars of coarse rubble at successively lower elevations, and, finally, a strongly developed bar of rubble at an elevation of twenty to twenty-one feet above Lake Michigan, 601-602 A.T. This bar, from the elevations of the beaches given by Hobbs[4] on the Garden Peninsula, is considered the Algoma beach and the group of three must have been formed during the transition from Nipissing to Algoma. The significance of such bars, which is not as yet understood, will not be discussed here, inasmuch as further study of them is contemplated. These beaches turn from an east-west direction at the point and continue in a due north direction on the terrace at the foot of Cemetery Hill. At Manistique Point the beaches rest on bed rock and are composed of coarse rubble, which decreases in size northward along the beach and, finally, as the dune area is approached, consists of sand in the form of a bar, then a fore-dune ridge, and, in the dune area proper, blown dunes. Eastward within the dunes, the individual ridges have become deformed beyond recognition and it is impossible to correlate them with any stage.



MAP 47. Map of isobases after Leverett



MAP 48

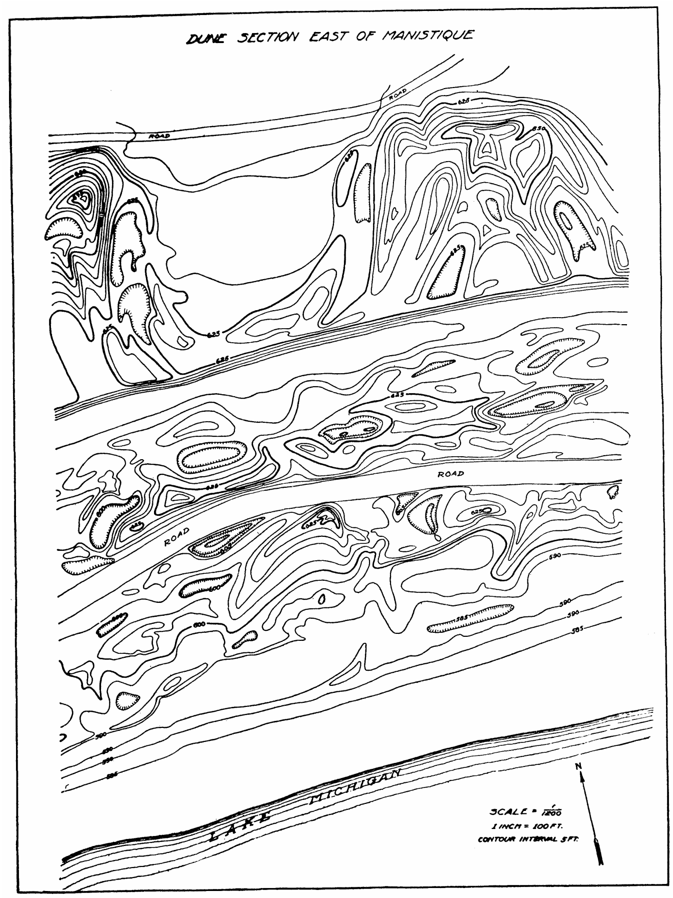
At the opposite end of the dune area, however, approximately three miles east of Manistique, conditions are less complex, and again the history of the dune ridges can be interpreted. An upland east of the junction of Highway 2 and the Soo Line tracks has been the locus of wave action at higher lake levels. The resulting cliff, the foot of which is twenty-one feet above the lake level, has, therefore, been cut by the waves of the Algoma stage. However, two terrace remnants at forty-five feet above the level of Lake Michigan indicate that this headland was attacked during Nipissing time also. The Nipissing shore continues west from the upland as a spit which extends nearly to the outskirts of Manistique and has turned the Manistique River westward.

On this spit a row of dunes has been piled to a height approximately one hundred feet above the present level of Lake Michigan. They consist of an almost continuous row of adjacent parabolic dunes extending from near the cliffs on the east to the outskirts of Manistique nearly two miles distant. The front slopes of these abruptly terminate at a very definite cliff of variable height (Map 49). This cliff, with its front slope representing the angle of repose of sand, is of varying elevation, but remarkably continuous, extending from the Algoma headland westward along the spit and dunes just described for about one third of a mile. The cliff forms the northern boundary of a depression which has for a southern boundary a slope lower and much more variable in contour, continuity and elevation. Just below the north wall the bed of this depression shows for most of its length a low ridge which is interpreted as a storm beach. This depression with the north wall is definitely of Algoma age, both because of its junction with the upland and because of its elevation, which is approximately twenty feet above the present level of Lake Michigan.

The zone between the Algoma cliff and the lake is occupied by a number of low, transverse dune ridges which, although linear in arrangement, are all somewhat deformed, except the almost perfectly linear low fore-dunes of the present shore. The entire dune topography from the Algoma cliff lakeward is thus opposed in topographic expression to those ridges occurring between the twenty-one- and the forty-foot levels. The former series approximately parallels the present lake shore; the series north of the cliff is nearly at right angles to it.

The dunes of this older series reveal almost uniformly four episodes of formation. Each of these stages seems to be a distinct wave of sand due to the deformation of the fore-dune ridges formed during a slowly sinking lake level. In this section these episodes, although they cannot be traced through, appear to correspond with the stages in the Manistique cemetery area where, as stated above, three distinct rubble beaches, in addition to the Nipissing beach, were found. The greater the deformation the greater the variation in elevation and sinuosity of the ridges. These were blown sufficiently to form large parabolic dunes upon the front slopes of which are three waves or ruffs.

There are several breaks in this row of large Nipissing dunes. One occurs near the junction of the upland and Highway 2, and another in front of the swamp in a portion of the basin of the Manistique River just north of the highway. There are two possible explanations for the breaks; first, that dunes never formed, and, second, that they formed and were subsequently blown out and the material carried into the Manistique River. That the latter explanation is not valid in this area is evidenced by the fact that fore-dune ridges, intact, connect the upland with the row of large dunes, whereas the break farther west, as shown on the map, is bridged by an unbroken fore-dune ridge. These dune ridges were formed during the late stage of Nipissing when the lake level was dropping, owing to the down-cutting of the Port Huron outlet and uplift of the land. The termination of the Nipissing sand dunes in the Algoma cliff represents the time when the down-cutting of the outlet, the uplift, or both, were halted and erosion by the waves became dominant in this area. Since Algoma time deposition has been more important here than erosion, and has resulted in the formation of the transverse dune ridges between the Algoma cliff and the present lake.



MAP 49

In the Gulliver section a somewhat different condition exists. The width of the area of deposition of sand is about a mile and a half. Here three rows of high dunes occur, one along and parallel to the Michigan shore, a second intermediate zone half a mile landward and roughly parallel to the first row, and the third and highest along the shores of Gulliver Lake (Map 50).

The middle row was traced west and northward across the Soo Line tracks to the vicinity of Marblehead spur, where it drops to low, blown, fore-dune ridges of sand. Farther westward these soon change to sand beaches and then chiefly to rubbly material. The elevation of the highest and most definite of these beaches east of

Marblehead spur was determined by plane table as six hundred feet, which is the elevation of the base of the Algoma cliff in the Manistique area. This has been designated, therefore, as the Algoma beach, and the intermediate row of dunes in this section was formed during Algoma time. This is in decided contrast to the cliff of the Manistique area.

The series of high dunes along the shore of Gulliver Lake, which are between seventy-five and one hundred feet in elevation, are of parabolic type and correspond in development to those of the back row in the Manistique area. These dunes decrease somewhat as they progress westward until at their crossing with the Soo Line tracks between mileposts 395 and 396 they are only forty feet in elevation. From there on westward they assume the characteristics of rather high, winding ridges of sand, blown in places and sinuous in character, until about one hundred yards from Marblehead spur they drop quite suddenly and become a series of three dune ridges. These sand bars change to definite well-defined rubble beaches, which in turn join the Nipissing cliff. Therefore this high row of dunes which has resulted from the blowing of these beaches is of Nipissing age.

The dunes formed since Algoma time are less complex and correspond in general characteristics to those of the Manistique area south of the Algoma cliff. The dunes of Nipissing age, however, are relatively complex, apparently representing large quantities of sand blown into dune ridges which subsequently became deformed. These piled one on the other, so that the three episodes, distinct in the Manistique area, cannot be identified. The high dunes with their irregular front slopes seem to have long sinuous ridges resembling arms which run southward to the intermediate row. This row of Nipissing dunes is not continuous eastward, but is broken where the sand has been blown into Gulliver Lake. This is indicated by the fact that no intact fore-dune ridges cross the gaps, as occurred in the Manistique region.

Southward from the high Algoma dunes, which, though blown, have not lost their ridge-like character, deformation has been decidedly less and the low fore-dune ridges do not afford evidences of having been extensively blown. They consist rather of definite ridges transverse to the shore, winding but with relatively even crests. These zones of low sand ridges between the high dunes in this Gulliver area indicate a gradually sinking lake level combined with an uplift of the land. The sand thus exposed is subsequently blown by the wind into fore-dune ridges, each dune ridge representing a more advanced position of the shore-line. When the lake level becomes consistent for a relatively long period, these are cut into by the waves and deformed into horseshoe or high parabolic dunes. A consistent lake stage is one similar to the present stage of Lake Michigan, in which only minor fluctuations of the water level occur over a relatively long time. The period of consistency was less in Algoma time than in Nipissing, as indicated by the lesser degree of deformation of the ridges.

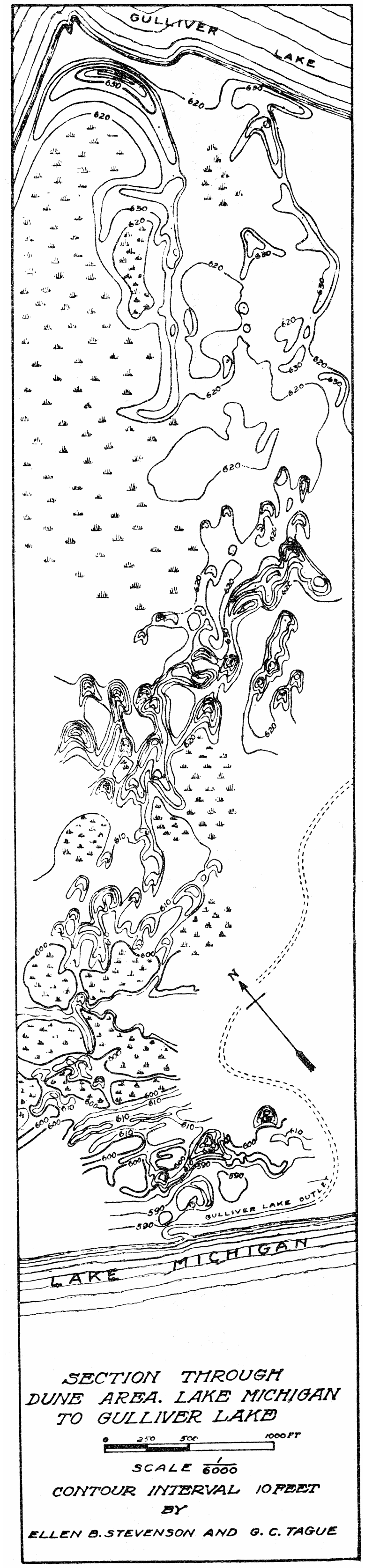


FIGURE 50

SUMMARY

In conclusion, then, it may be said that a study of the dunes in the vicinity of Manistique has revealed for this area:

First, that this series of dune ridges spread over a broad zone is the result of a sinking lake level combined with an uplift of the land;

Secondly, that the series of undeformed fore-dune ridges indicates a continuance of these factors;

Thirdly, that deformation of these fore-dune ridges takes place during relatively stationary periods, that is, during consistent lake levels;

Fourthly, that there have been three such periods, namely, Nipissing, Algoma and the present;

Fifthly, that the Nipissing has been the greatest stage of dune formation and has been productive of the largest dunes;

Sixthly, that these results supplement the correlations of Cressey in the Indiana dune area.

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[1] Lane, A. C., *Northern Michigan Geological Survey, Ann. Rep*., 1904-06, pp. 96-97.

[2] Cressey, G. B., *The Indiana Sand Dunes and Shore Lines of the Lake Michigan Basin*, University of Chicago Press, May, 1928.

[3] Leverett, Frank, and Taylor, Frank, *The Pleistocene of Indiana and Michigan and the History of Great Lakes, U. S. Geol. Survey, Monog*. 53, p. 461.

[4] Hobbs, W. H., "The Late Glacial and Post Glacial Uplift of the Michigan Basin," *Mich. Geol. and Biol. Surv., Publ*. 5, Geol. Ser. 3, pp. 45-68.

A STUDY OF THE MARSHALL FORMATION IN MICHIGAN

WILLIAM A. THOMAS

THE Marshall formation was named from its numerous outcrops around the town of Marshall in Calhoun County; the upper phase of this formation has been called "Napoleon" from its typical section, which outcrops near Napoleon in Jackson County. According to Smith,[1] the Marshall should correlate with the Logan and Blackhand of Ohio and the Kinderhook of Illinois, formations which are Mississippian in age.

Glaciation and deposition have concealed the Marshall in almost all parts of Michigan, but there are good exposures in Cass River in northeastern Tuscola County, and also at Point Au Barques at the northern tip of Huron County. From these outcrops a meager amount of information about its character has been obtained. Rominger[2] merely mentions the fossils, but Winchell studied them extensively and showed that the Marshall was not correlative to the Chemung age,[3] as had been thought by Hall. This particular paper will be confined to the information we have obtained through well drilling and core testing.

In the summer of 1927 the Pure Oil Company saw the need of geological data on some shallow formation which could be used as a key horizon above the oil pay sands. Lane's description of geological structures was confirmed by intensive core testing in Huron and Tuscola counties.[4] In this paper Lane recognized faulting or folding which had disturbed the Marshall sandstone and caused it to lie in two parallel folds, striking west, northwest and east, southeast. This old information was obtained from water wells which had been drilled in Huron County.

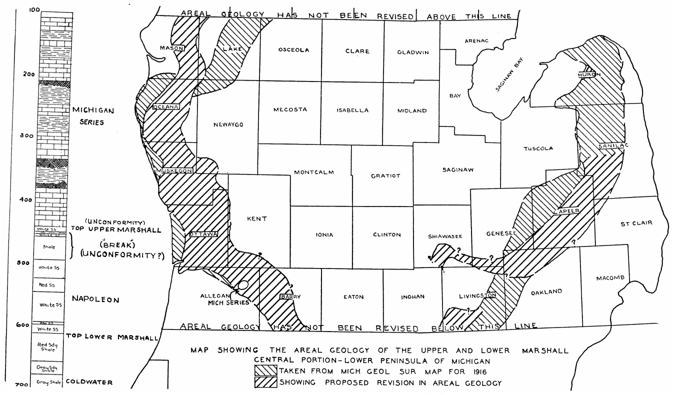
Along with the Pure Oil Company, the Dixie, the Shell, the Sun, the Muskegon Oil, the Phillips Petroleum and other concerns started coring the state by use of the hollow-rod drill, rotary and cable tools. The data which have been obtained from this program bring out some unusual and interesting stratigraphic information.

A revision in areal geology has been attempted, as illustrated on the map of the Lower Peninsula of Michigan (Map 51). The greatest change in the map is in Livingston County, where we show the Marshall to extend much farther out in the basin than previously mapped on the geological map of Michigan as compiled by R. C. Allen, R. A. Smith and L. P. Barrett in 1916. The exact boundary of the Marshall has not yet been determined in the whole area and the question marks on the map indicate the need of more detailed information. Another point that looks abnormal, but which is based on a recent test now drilling in southern Kent County, is the Upper Marshall sandstone extending into the southeastern part of Kent.

In Hopkins Township, Allegan County (T. 3 N., R. 12 E.), a recent test shows the formation immediately under the drift to be Michigan Series, so that we have attempted to show a small outlier of Michigan Series, since this is one of the few tests drilled in this general area.

Another important change in the position of the Marshall sandstone is in Mason and Oceana counties, where we show the Marshall to be nearer the rim of the basin than it has previously been mapped.

The boundary lines of the Upper Marshall are more or less arbitrarily drawn, since glaciation has left such an irregular surface floor, causing the formations to be gouged out in some places and left as outliers in others. The revision is based on data obtained through recent core testing; and when Marshall has been logged, or a good set of samples saved on deep-well cuttings, this information also has been used. Corrections of the revised boundary line of the Marshall will undoubtedly be made in the future, but at the present time this map seems to be more accurate than the old map based on the meager information available at that time.



Map 51

In the eastern part of the state the Marshall sandstone, Mississippian in age, is our first key horizon penetrated. This lies almost conformably over the Berea, Traverse and Dundee formations. The data concerning the detailed structural conditions of the Marshall are more or less confidential, but we have plotted as nearly as possible the true picture of the Marshall section from about one hundred core tests which have penetrated the entire thickness of the formation. A large proportion of these wells show conclusively that the Marshall is not so uniform a sand body as had been thought originally.

From the information obtained on a few of our core tests and deep-well logs a graph (Fig. 13) has been constructed. In places erosion has been so pronounced on the top of the Upper Marshall that it has cut into the Napoleon proper, as is shown by the absence of the upper part of the Marshall section. The Napoleon sand in local areas retains an almost uniform thickness below the "break" or unconformity, though wells drilled in Huron County prove the Napoleon sandstone to be thicker on the Kilmanagh structure than on the structure passing through the town of Pigeon.

In a typical section there is a very thin veneer of greenish shale at the contact of the Michigan Series and the Upper Marshall. This shale is usually so fine that it passes through an 80-mesh-to-an-inch screen and the drillers made note on their samples that green water was present, but they were unable to catch any of the shale. This grades into a clear yellowish-white sandstone, of which there is from 5 to 25 feet. The drill then penetrates an unconformity, or disconformity, within the Upper Marshall. This is termed the "break," and is well marked in most places, except where erosion on the top of the Upper Marshall has cut into the massive sand of the Napoleon proper.

The "break" (by which we mean an interruption in the normal sandstone deposition of the Marshall formation) consists of a green shale, a coal, or a limestone from 1 inch to 35 feet in thickness. The green shale is perhaps more characteristic and Dr. Slawson examined one of these samples, giving the following description: "This sample was essentially quartz, but there were a number of globular green masses. These masses consisted of many minute crystalline scales of chloritic material. The scales are so small that it is impossible to designate any member of the chlorite group. The aggregate index of refraction is approximately 1.59, which would be characteristic of any of the chlorites. All of the material appeared to me to be derived from a sandstone because of the preponderance of quartz. There is good deal of clay present and you may have washed out still more." As suggested, shale was present in these samples and, with the chlorite, it indicates an hiatus, differing greatly from the sand above and below.

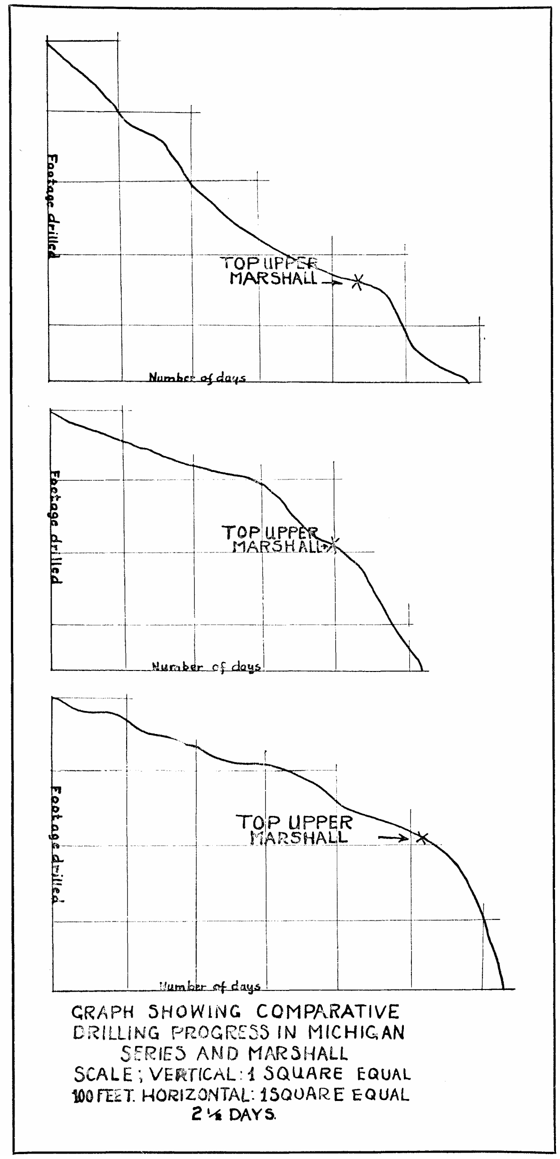


Figure 13

The question may now arise whether this break should not be used as the contact between the Marshall and the Michigan Series. Further examination shows, however, that the sand above it closely resembles the sand below it, and the absence of gypsum from the sandstone also helps to identify it with the Marshall group in preference to the Michigan Series. Another point in favor of correlating this sand above the break with the Marshall is the similarity of the oil found above the break to that taken from the unquestioned Marshall. Both oils have an asphaltic base and register gravity of 24½ degrees Baumé. This oil is of such a heavy texture that it is practically impossible to pump, and its low gasoline content makes it of very little commercial importance at the present time. The oil of the Michigan Series is usually of a greenish color and lighter in texture than oil from the Marshall formation. Both oils examined were from the Midland-Isabella Oil Pool.

Below the shale, coal or limestone break, the section again becomes a white-yellowish sandstone, which grades into a peanut conglomerate near the base. Very often a band of marcasite is encountered at the top of this sand from one-half inch to two inches in thickness. The matrix binding the sandstone grains is a very soft Kaolin-like material; according to an analysis furnished by the Department of Mineralogy of the University of Michigan, this substance is gibbsite (AlO_3H_3), an aluminium hydroxide. There are from 45 to 110 feet of this sand.

The Lower Marshall contact is very definite. The sand of the Lower Marshall is a very fine gray micaceous sandstone alternating with gray shales, and red shales and sandstones. Where the red sandstones and shales are absent, the gray sand is extremely micaceous, often carrying muscovite, biotite and occasionally phlogopite in the same sample.

We have tried to describe the Marshall section in detail, as brought out by the drilling program, and we should like to suggest definite limits for the terms already in use for this formation. To date "Napoleon" has been used interchangeably with "Upper Marshall" to describe the section from the Michigan Series to the fine gray sand and red rock of the Lower Marshall. As the U. S. Geology Survey does not encourage the naming of a new formation unless it outcrops, no new name can be attempted at this time. Since we have this definite break or disconformity within the section formerly termed "Napoleon," it would seem best to limit the terms "Upper Marshall" and "Napoleon," and to give to each a specific meaning. "Upper Marshall" could be used to describe the sand from the base of the Michigan Series to the base of the shale, limestone or coal which indicates the disconformity. The name "Napoleon" would then be applied to the sand between the break and the Lower Marshall. The term "Lower Marshall" would still be used for the section from the base of the Napoleon to the blue-gray shale of the Coldwater formation. This is illustrated in the following section:

Michigan Series	Gray limestone, dolomite, calcareous shale, shale and gypsum
Upper Marshall	White to gray sandstone, gibbsite. Unconformity ("break")—green and gray shales, limestone and coal
Napoleon	Massive yellow-white sandstone, rather coarse grained, often peanut conglomerate at base, gibbsite
Lower Marshall	Fine-grained gray sandstones and shales, red sands and shales, very micaceous

Dr. Alfred C. Lane suggested the terms "Neo-Marshall," "Meso-Marshall" and "Eo-Marshall," instead of "Upper Marshall," "Napoleon" and "Lower Marshall," as used above.

In general the Marshall is thinner on structure than in the synclines. Near the center of the Lower Peninsula it is usually thicker than around the rim of the basin. Near the rim the rate of dip is somewhat variable, but in general the beds dip 17 feet to the mile from the rim of the basin to the center, a short distance northwest of Mt. Pleasant, Isabella County.

On the western side of the state the Upper Marshall, Napoleon and Lower Marshall together attain a thickness of approximately 200 feet; in the Huron County area the thickness is between 450 feet and 500 feet. The color of the Marshall section on the western side is more red to pinkish; on the eastern side of the state the reds occur only in the Lower Marshall.

The color of the Upper Marshall suggests that the waters containing iron came from the old pre-Cambrian land mass of the Upper Peninsula. The iron material carried by the waters draining into the sea, which covered the Lower Peninsula, was precipitated in greatest quantities on the western side during the entire Marshall period. On the eastern side of the state there were alternations of the western waters and possibly the eastern waters, which contained very little iron material. This accounts for the gray shales of the Lower Marshall with only an occasional fingering of red. The distance from the source beds of the iron content may also be used to account for the depositing of lesser amounts of the heavier minerals on the eastern and southern sides of the state, when compared with the amount deposited on the western side of Michigan.

It would seem that the eastern waters free from iron sediments predominate throughout the Upper Marshall and Napoleon; in places we find no reds whatever in these formations on the southeastern side of the state. The center of the basin was evidently more influenced by the western drainage throughout the Lower Marshall period, since 80 to 90 feet of red sand and shales are common immediately below the Napoleon. During the Upper Marshall and Napoleon deposition, however, there seems to have been less iron content in the waters, since the reds are found only on the western side of the state, but the Upper Marshall and Napoleon of the center of the basin consist of a white sandstone with only an occasional streak of red sandstone.

The Marshall sandstone contains a brine from which the Dow Chemical Company of Midland has been producing for over thirty-five years. The constant drain on the Marshall water has lowered its static head, so that the wells on structure have a head of only 300 feet, but those off the axis have about 800 to 1200 feet, with an occasional flowing well. There is also a very noticeable demarcation in the sandstones in wells where the static head is low; the upper portion of the sand from which the brine has been exhausted shows considerable oxidation, though the lower 20 feet of the sand has the characteristic white of the Napoleon without any apparent change in color.

The bromine content of wells on structure is much less than that of wells drilled in the synclines, as shown by the following table:

	Percentage of bromine
Laura Root Number 1, Section 18, Greendale, Midland (T. 14 N., R. 2 W.)	0.0059
G. West Number 1, Section 25, Isabella, Isabella (T. 15 N., R. 4 W.)	0.0425
Shepherd Number 1, Section 23, Chippewa, Isabella (T. 14 N., R. 3 W.)	0.1777
Buck Number 1, Section 19, Geneva, Midland (T. 15 N., R. 2 W.)	0.1349
Isabella State Bank Number 1, Section 8, Denver, Isabella, (T. 15 N., R. 3 W.)	0.1536

The Root Number 1 and West Number 1 are on structure, the others are off.

The Marshall water is, in general, strongly saturated with chlorine compounds, and much might be accomplished from the analysis of waters throughout the state for correlation purposes were it not for the fact that the bittern seems to have a mixed source; it is usable, however, in most local areas. Undoubtedly there are fractures or faults between the Marshall and lower-lying beds which allow the waters to migrate from one formation to another.

The following is an analysis of the water from the Shepherd well (Section 23, T. 14 N., R. 3 W.) made by the Dow Chemical Company and shows a typical Marshall brine for the center of the basin.

Specific gravity	1.236
Bromine	0.1777
Calcium chloride	12.50
Magnesium chloride	2.77
Sodium chloride	10.50
Potassium chloride	0.76

The drilling through the Marshall has brought out some very interesting information which could be used by anyone planning to drill in the future. The Michigan Series contains an abundance of gypsum, limestone, dolomite and marcasite streaks which are very difficult to drill. To illustrate this, we have plotted the number of days required for drilling the Michigan Series as compared with the time it takes for drilling the Marshall formation. In doing this a record of the footage made each day was plotted on the vertical scale, the number of days drilling being represented by the horizontal scale (see Fig. 14). As the wells are drilled deeper, this curve in reality should begin to flatten out instead of becoming accentuated, or tending toward the perpendicular; the reason is that with depth more time is required for raising and lowering the tools in the hole and for replacing bits than is consumed for the same purposes when drilling near the surface.

Despite the rapidity of drilling in the Marshall, it is frequently a hazardous undertaking in fields where drillers are not accustomed to the formation. The following conditions are usually found: If the drillers' bit is not dressed out to gage, a "fishing" job often results when a new bit is run into the hole. Furthermore, the Marshall sandstone is very abrasive on the sides of the bit and at no time is it possible to run over a five-foot screw with safety unless the driller knows his bit is out to full gage. Near the base of the Napoleon the sand is so loosely cemented that the bailer is likely to become frozen. In spite of these difficulties, however, core testing in Michigan is successful on the whole, and much important information has resulted from the use of the diamond drill and the hollow rod.

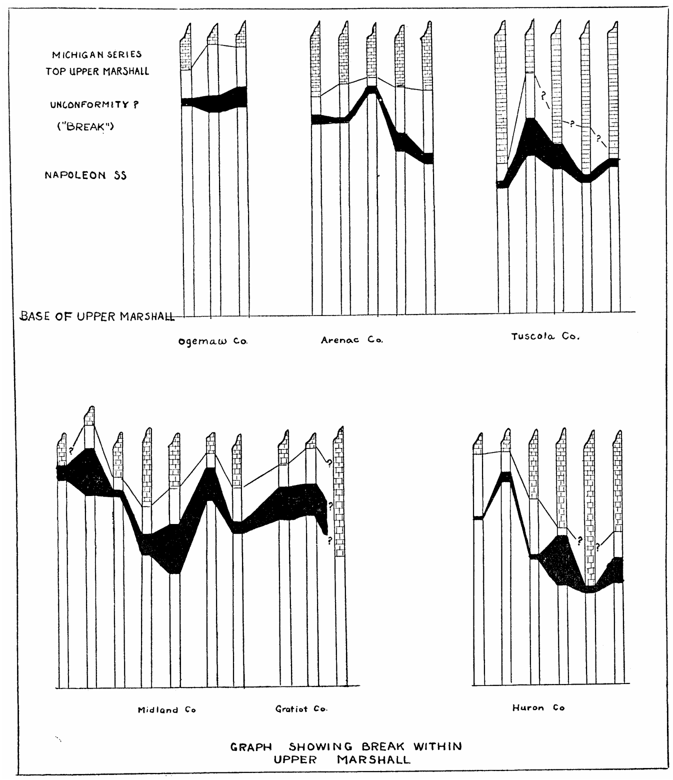


FIGURE 14

In conclusion, the following summary seems to bring out the most important results of core testing in Michigan:

1. A slight unconformity or hiatus is found to be very persistent in the section between the base of the Michigan Series and the Lower Marshall.

2. Because of the persistence of the break in the section formerly designated as "Upper Marshall" or "Napoleon," this section should be separated, and this paper has suggested calling "Upper Marshall" the part from the base of the break upward to the base of the Michigan Series. The lower massive uniform sand, or the section below the break, we would call "Napoleon."

3. In some places the erosion on top of the Upper Marshall has completely cut out the Upper Marshall, the break and about 20 feet of Napoleon.

4. The Marshall on the eastern side of the state is conformable over the lower formations, but on the

western side there seems to be a pronounced unconformity between the Upper Marshall and the underlying beds.

5. The source of the red color must have been from the northwest.

6. The use of brine analysis for correlation purposes is, in general, diagnostic over small areas.

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PURE OIL COMPANY
SAGINAW, MICHIGAN

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