THE SURFACE GEOLOGY OF WEXFORD COUNTY, MICHIGAN

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WEXFORD COUNTY, MICHIGAN

By

David Perry Stewart

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THE SURFACE GEOLOGY OF WEXFORD COUNTY, MICHIGAN

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INTRODUCTION

The Wexford County surface was deposited by an advance of the Lake Michigan lobe of the Labradorian ice sheet, during the Cary substage, late in the Wisconsin stage of Pleistocene glaciation. The glacial surface was deposited as the ice was withdrawing from its terminal position on the Kalamazoo moraine. The first halt in the Cary ice is marked by the position of the Valparaiso moraine. Because of the complex nature of the glacial deposits, the exact sequence of events following the deposition of the Valparaiso moraine has not been definitely established. It is apparent, however, that the ice movement probably fluctuated between interims of retreat and short readvances and was not a continuous retreatal consecution. However, the Lake Border moraine, the most prominent topographic feature in the county, was formed late in the interval during which the ice of the Lake Michigan lobe was retiring. The Cary marks the most recent ice invasion of Wexford County but it is certain that the area was glaciated during at least one earlier substage of the Wisconsin stage, the Tazwell. Pre-Wisconsin activity is evidenced by the compacted clay drift underlying the Cary surface.

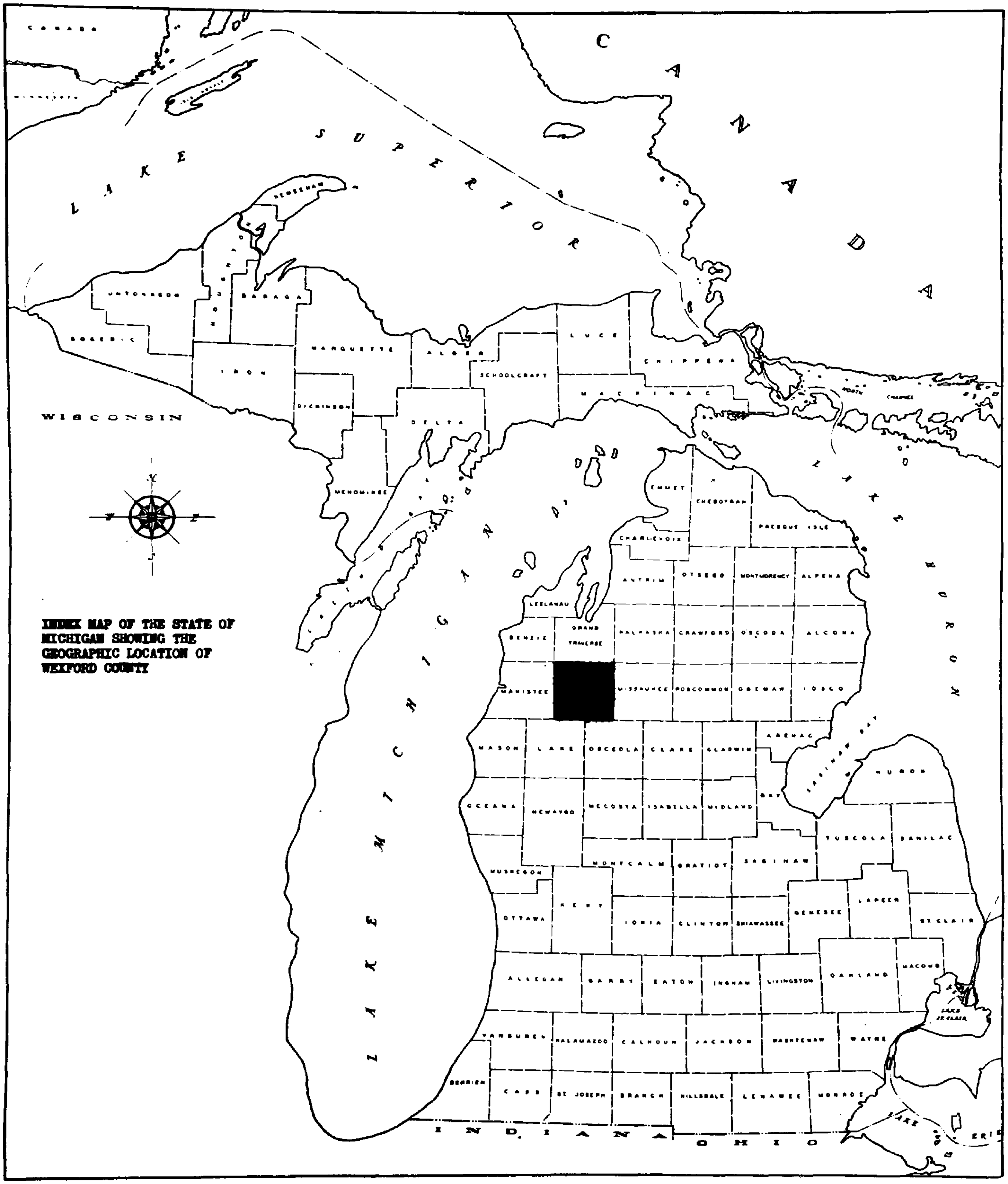

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Figure 1

Location

Wexford County is located in the northwest part of the Southern Peninsula near the geographic center of Michigan. The northwest corner of the county is fifteen miles south of the southern shore of Traverse Bay and twenty miles east of Lake Michigan (Figure 1).

Purpose of the Study

The purpose of the study on which this paper is based was to map and describe the details of the surface geology of Wexford County and to relate the topographic forms to the glacial activities that formed them. The most recent glacial map of this area is based on a general reconnaissance made by Leverett (1915, Plate VII) some forty years ago. The map constructed (Figure 2) from the data collected in this survey will be used as a part of the revision of the map of the Surface Geology of Michigan now in progress.

TOPOGRAPHIC REFLECTIONS OF A PRE-WISCONSIN SURFACE

Although the surface drift of Wexford County was deposited during the Cary substage late in the Wisconsin stage, it is obvious that the present topography is a reflection of a much older glacial surface, composed of

MAP OF SURFACE GEOLOGY
WEXFORD COUNTY, MICHIGAN

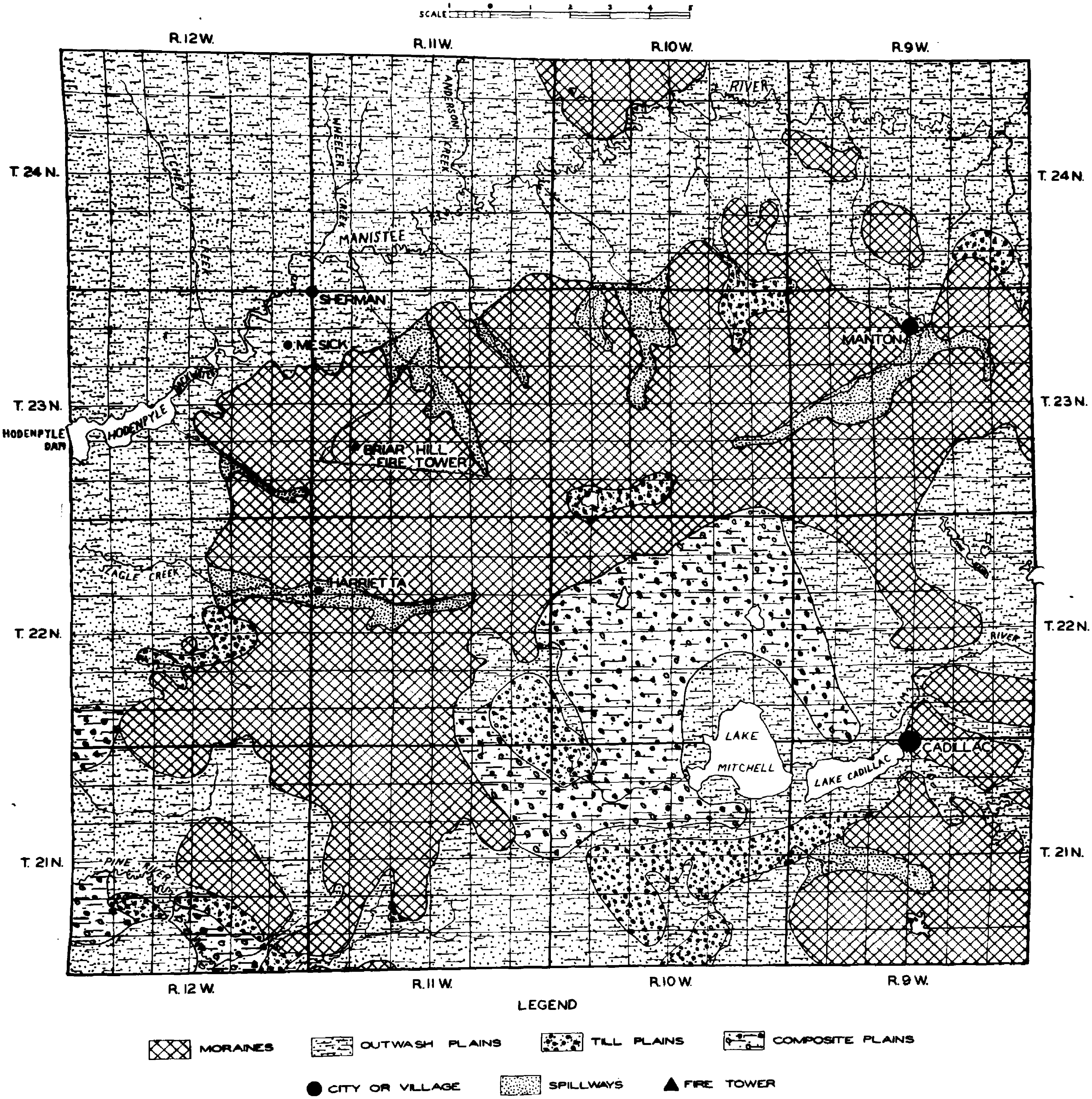

Figure 2

compacted clay, which may be referred to as pre-Wisconsin, probably Illinoian, in age. The Wisconsin surface deposit is apparently a relatively thin veneer covering the basal clay that makes up the cores of the moraines and underlies the glacial plains at varying depths.

In its unaltered state the basal clay is moderately calcareous, bluish gray in color, somewhat indurated and extremely well jointed. Upon initial weathering the color changes from bluish gray to chocolate brown with blue and gray mottling. The color change is the result of partial oxidation of the ferrous iron compounds to form hematite. According to Twenhofel (1932, p. 278), ferric oxides are produced only in moist, warm upland regions with good subsurface drainage. Since the temperature and moisture content do not vary greatly throughout the deposit, it is no doubt the difference in subsurface drainage that produces the mottling. Initial weathering is first apparent along the joint planes where better drainage is developed. Increased oxidation causes the mass to assume a reddish brown color while the leaching of calcium carbonate tends to produce a crumbly, loose and somewhat friable structure in the material. In general, the clay in the basal deposits contains small, well rounded, polished and often striated pebbles that vary greatly in size, shape and abundance from one locality to another. Some exposures of the clay, although pebble free, still exhibit all of the characteristics of ordinary till. In certain areas adjacent to Wexford County, however, varved deposits of alternate bands of clay and silt seem to suggest a lacustrine origin.

Exposures of the basal clay are widely distributed in the county (Table 1). The clay studied at numerous locations shows a definite correlation of physical properties which seems to indicate a fairly continuous deposit. In most cases the exact thickness of the clay could not be determined because neither the top nor the bottom of the deposit was exposed. Near Harrietta (S. ½ Sec. 7, T. 22 N., R. 11 W.) the exposed clay on the slope of the moraine exceeds a hundred feet in thickness as measured above the floor of Slagle Creek. How deep it extends below the creek could not be determined. Other localities where the exposures exceed twenty-five feet in thickness are indicated in Table 1 by an asterisk (*). It is probable that the clay in most localities would measure over a hundred feet if the total thickness could be determined.

It is apparent that prior to the Wisconsin invasion the older clay surface was exposed to erosive forces for an interval sufficiently long to produce the irregular surface upon which the later drift was deposited. The conclusion that the surface is very irregular is borne out by the differences in elevations taken at the top of the exposures by aneroid barometer (Table 1). The erosive activities that sculptured the older surface undoubtedly

TABLE I

LOCATION AND ELEVATION OF PRE-WISCONSIN
CLAY EXPOSURES MAPPED IN WEXFORD COUNTY

Location	Elevation (Aneroid Readings at top of exposure)	Exposures
N. E. ¼ Sec. 14, T. 24 N., R. 9 W.	910	In the Manistee River valley
*Secs. 25, 26 and 36, T. 24 N., R. 9 W.	1,060	Till plain surface
*Secs. 1 and 2, T. 23 N., R. 9 W.	1,100	Till plain surface
S. W. ¼ Sec. 13, T. 24 N., R. 10 W.	1,025	In the valley of Buttermilk Creek
*N. E. ¼ Sec. 34, T. 23 N., R. 10 W.	1,400	In a road cut on crest of moraine
S. E. ¼ Sec. 36, T. 23 N., R. 11 W.	1,000	Road cut
S. W. ¼ Sec. 33, T. 24 N., R. 10 W.	1,090	In the Fletcher Creek valley
S. W. ¼ Sec. 32, T. 24 N., R. 10 W.	1,100	Road cut
*S. W. ¼ Sec. 32, T. 24 N., R. 11 W.	925	In the valley of Cole Creek
*N. W. ¼ Sec. 12, T. 23 N., R. 12 W.	850	Reported in a water well in the town of Mesick
*N. E. ¼ Sec. 16, T. 23 N., R. 11 W.	1,075	In the Cole Creek valley
S. E. ¼ Sec. 18, T. 23 N., R. 11 W.	1,040	Road cut
S. E. ¼ Sec. 7, T. 22 N., R. 11 W.	1,120	In the valley of Slagle Creek

*Exposures measuring over 25 feet in thickness

Table I (Continued)

	Location	Elevation (Aneroid Readings at top of exposure)	Exposure
14	S. E. ¼ Sec. 15, T. 22 N., R. 12 W.	1,090	Till plain surface
15	N. W. ¼ Sec. 3, T. 21 N., R. 12 W.	1,200	Road cut
16	*N. W. ¼ Sec. 20, T. 21 N., R. 12 W.	875	In the valley of Pine River
17	N. E. ¼ Sec. 28, T. 21 N., R. 12 W.	870	In the valley of Pine River
18	*S. ½ Sec. 22, T. 21 N., R. 12 W.	1,010	Road cut
19	N. E. ¼ Sec. 31, T. 21 N., R. 11 W.	1,120	Road cut
20	Central Sec. 36, T. 21 N., R. 12 W.	1,025	Road cut
21	N. E. ¼ Sec. 33, T. 21 N., R. 11 W.	1,190	Road cut
22	N. E. ¼ Sec. 20, T. 21 N., R. 10 W.	1,300	Road cut
23	S. W. ¼ Sec. 16, T. 21 N., R. 10 W.	1,285	Road cut
24	S. E. ¼ Sec. 21, T. 21 N., R. 10 W.	1,250	Road cut
25	S. E. ¼ Sec. 13, T. 21 N., R. 10 W.	1,270	Clay pit
26	S. E. ¼ Sec. 34, T. 21 N., R. 10 W.	1,260	Road cut
27	S. E. ¼ Sec. 30, T. 21 N., R. 9 W.	1,315	Road cut
28	N. W. ¼ Sec. 32, T. 21 N., R. 9 W.	1,365	Road cut

*Exposures measuring over 25 feet in thickness

Table I (Continued)

	Location	Elevation (Aneroid Readings at top of exposure)	Exposures
29	N. W. ¼ Sec. 34, T. 21 N., R. 9 W.	1,340	Road cut
30	S. E. ¼ Sec. 22, T. 21 N., R. 9 W.	1,360	Road cut
31	N. W. ¼ Sec. 18, T. 22 N., R. 11 W.	1,220	Clay pit
32	N. W. ¼ Sec. 33, T. 23 N., R. 10 W.	1,390	Clay pit
33	N. W. ¼ Sec. 12, T. 23 N., R. 10 W.	1,125	Clay pit

*Exposures measuring over 25 feet in thickness

have been active during both glacial and interglacial stages since the deposition of the clay. Interglacial erosion was found by Powers and Ekblaw (1940) to be an important influence in the shaping of the present topography in the Gray Lake Quadrangle of Illinois. No doubt future studies in Michigan will reveal that Wisconsin and pre-Wisconsin interglacial erosion has carved significant features in the drift deposited in the path of earlier ice movements. In addition to interglacial action, scouring and cutting by Wisconsin ice prior to the Cary substage probably played an important role in the sculpturing of the older surface and may account for the absence of an old soil horizon at the top of the clay deposit such as is found in Ohio (White, 1939) and other regions.

The exact age of the basal clay has not been definitely determined. In fact, it is difficult to find supporting evidence in the literature that it is pre-Wisconsin. Geologists have noted similar clayey tills in various parts of Michigan for over forty years (Lane, 1907) and have described them as "probable pre-Wisconsin". However, no definite correlation has been attempted on a statewide basis. The only reference pertaining to the Wexford County clay is a description and an analysis of the exposure near Harrietta (Ries, 1900). This study is of little value because it is not stated how much of the exposure was studied at that time. Leverett (1915, pp. 66 and 289) believed that a till older than Wisconsin underlies the surface drift more or less continuously in Indiana and the Southern Peninsula of Michigan. He described the underlying till as being an indurated clay, bluish gray in color and oxidizing to brown near the surface.

The Wisconsin clayey drift is generally light brownish yellow to light brown in color, compacted but not indurated and exhibits no prominent structural features. Leverett (1915, p. 79) suggests that the underlying pre-Wisconsin drift has been cemented with calcareous and ferruginous material by percolating water to give it a tough, hard, indurated character. This, he states, is definite proof of age. The depth of weathering in the basal clay is much greater than it is in the Wisconsin drift.

According to White (1937 and 1939), the unaltered Illinoian till in eastern and north central Ohio is a bluish gray, moderately calcareous, tough, pebbly clay containing boulders. Five distinct horizons of weathering are described in his reports and although the Michigan clay has not been studied in such detail most horizons are recognizable in the thicker deposits. Leverett (1915, p. 72) noted the similarity between the pre-Wisconsin of Michigan and the Illinoian of Illinois and Indiana.

The Illinoian in the Salamanca re-entrant area in New York is described by MacClintock and Apfel (1944) as a compact, sticky, calcareous clay, gray in color with buff mottling and containing striated pebbles. The basis on which they classify the deposit as Illinoian is the "great lithologic difference", greater depth of weathering, and considerable amount of erosion of the older drift as compared to the overlying Wisconsin till.

Leggett (1946) studied and described a blue, compact, uniform, non-stratified clay containing pebbles in the Sarnia District of Ontario, Canada. According to his report, the Ontario clay has been referred to by former writers as being of deep water origin. Studies by Leggett, however, have led him to conclude that it was deposited by glacial ice, possibly before Wisconsin time.

Taylor (1939) and more recently Bergquist (1946) have recognized the blue clay as comprising the core of certain portions of the Port Huron Morainic System in Michigan. They describe it as having characteristics similar to the till referred to by Leverett as the pre-Wisconsin of the southern part of the Southern Peninsula.

EOLIAN MODIFICATIONS OF THE WISCONSIN SURFACE

Evidences of post glacial wind activities are everywhere present in Wexford County. No particular area, type of topography, or surface cover seems to have escaped modification by eolian forces. Sand blowouts and dunes are everywhere common on the slopes of the moraines and on the surface of the outwash and till plains (Plate 1, Figure 1).

PLATE I

FIGURE 1. SAND BLOW IN OUTWASH PLAIN (SEC. 31, T. 24 N., R. 12 N.).

FIGURE 2. LOOKING SOUTH ACROSS THE LAKE BORDER MORAINE (SEC. 31, T. 22 N., R. 10 W.).

Except for a few small isolated areas it is doubtful that any surface is entirely free of sand deposited by shifting winds.

The most serious result of the secondary surface veneer is its effect on the agricultural value of the land. The loose, unconsolidated sand cover invariably lessens the productivity of the soil. Vast areas that might have been adaptable to certain types of farming are now classified as marginal or submarginal waste lands.

The blowouts on the plains attest to the shallowness of the outwash deposit. In most cases, the lag material in the bottoms of the blow holes is largely cobbles and boulders revealing that the outwash covering the underlying till plain is merely a thin veneer.

Active dunes are present where conditions facilitate their formation. As in any other dune area, they are continually changing in size, shape and position. It is certain that the eolian features are of post-glacial origin. They should not be confused with wind deposits that, according to Hobbs (1911 and 1913), were formed by anticyclonic circulation and seasonal variation during the glacial stages.

MORAINES

Moraines are deposits of unsorted drift that were laid down during intervals in which the ice front remained stationary for a sufficiently long time to allow a sizable deposit to be formed. During the deposition of the moraine, the ice was in a state of balance between advance and retreat in that it melted along the margins as rapidly as it was supplied by the forward movement behind the ice front. The feature is characterized as a long, relatively narrow ridge that marks either the position of the most forward advance of the ice or the site on which the ice halted in its retreat. The moraines that bear witness to the outer limits of an ice advance are called terminal moraines in this report and those that connote cessation in retreat are termed recessional moraines.

Moraines cover more than two hundred square miles of the surface of Wexford County. Approximately three-fourths of this area lies in the Lake Border Morainic System. The remaining one-fourth is chiefly in a northern arm of the interlobate area of the Valparaiso and Charlotte systems that extends into the southeastern corner of the county. In this report, the interlobate area is designated the "Lake Michigan-Saginaw Interlobate Tract" after Leverett (1915, p. 184). A small area of moraine belonging to the Port Huron Morainic System extends as far south as the Manistee River in the extreme north central part of the county

(Figure 2).

Although the moraines are cored with compacted, indurated, pre-Wisconsin clay, the immediate surface is predominantly a loose, bouldery Wisconsin drift composed of medium to fine grained sand with variable contents of silt. The sandy matrix contains numerous cobbles and boulders ranging in size up to several feet. In most localities there is sufficient silt in the surface material of the moraines to produce a light loamy sand soil that is adaptable to general farming.

The morainic contacts are usually quite conspicuous being marked by slopes that rise abruptly above the plains. Erratics are numerous on the morainic surface.

Lake Border Moraine

The most prominent topographic feature in Wexford County is the Lake Border moraine. It is a recessional moraine that marks the position of the Cary ice during a halt in its retreat. It comprises a system of ridges that enters the state in the vicinity of New Buffalo in Berrien County and trends northward along the shore of Lake Michigan. Near Hart in Oceana County the moraine turns northeastward and bends around the northern limits of the Lake Michigan-Saginaw Interlobate Tract in Wexford County. The inner ridges of the moraine continue northeastwardly to Portage Lake in Crawford County and then trend almost due east to connect up with their correlative, the West Branch moraine, in Oscoda County. North and east of Wexford County three cross ridges trend southeastwardly to join the West Branch moraine. The first of the forms to thread out from the Lake Border moraine is named the Harrison-Lake City ridge. This feature angles off to the southeast just beyond the Wexford-Missaukee County line and joins the West Branch moraine near Harrison in Clare County. Two other ridges, the Houghton Lake and the Higgins Lake ridges thread out to the northeast.

The Lake Border moraine enters Wexford County as a single ridge about two miles wide near its southeast corner. It widens to eight miles where it incorporates both the inner and outer ridges a short distance north of the Wexford-Lake County boundary and maintains this width to the vicinity of Manton. Here the moraine again narrows and is only three miles wide at the Wexford-Missaukee County line.

The inner and outer ridges that are usually quite distinctive throughout most of the length of the Lake Border System are so closely interlocked in Wexford County that they can be differentiated only with difficulty. This part of the moraine is the most massive of the entire system.

The relief of the moraine above the surrounding plains varies from fifty to seven hundred feet. However, one to two miles inside the morainic boundary the average relief is merely a hundred feet. The summit of the outermost or southern ridge that swings around the Cadillac-Mitchell Lakes basin near the city of Cadillac tops the 1,400 foot contour for a distance of over twenty miles. Some of the crests exceed 1,500 feet in elevation. According to Leverett (1915, p. 16) this portion of the ridge is the highest of all the outer members. Elevations on the inner ridges immediately to the north are much more irregular. They generally range between 1,100 and 1,300 feet but rise to 1,630 feet at Briar Hill Fire Tower (Sec. 29, T. 23 N., R. 11 W.), the highest point in the county.

The topography on the broad summit of the combined inner and outer ridges of the moraine ranges from slightly undulating and rolling to rough and knobby with elevations changing abruptly over short distances (Plate I, Figure 2). Numerous kamic knobs, conspicuous along the slopes of the moraine (Plate II, Figures 1 and 2), are features of the type described by VerWiebe (1926) as kettle or moulin kames. According to Flint (1947, p. 147) kames were formed from bodies of sediment deposited in crevasses and other openings in the stagnant ice which later melted away leaving the accumulated material in the form of isolated or semi-isolated mounds. The stratified kamic deposits afford a supply of regular, well sorted gravel suitable for road construction.

PLATE II

FIGURE 1. KAMIC MORAINE (SEC. 8, T. 23 N., R. 11 W.).

FIGURE 2. SKI JUMP ON SLOPE OF LAKE BORDER MORAINE (SEC. 1, T. 21 N., R. 12 W.).

Lake Michigan-Saginaw Interlobate Tract

The corner township of southeastern Wexford County is covered by a ridged deposit that marks the northern limits of a morainic system trending north from the vicinity of Big Rapids in southern Mecosta County. The ridges mark the juncture of the Lake Michigan lobe that moved in from the northwest and the Saginaw lobe that deployed from the east. They are, therefore, correlative with the Valparaiso-Charlotte Morainic Systems of the Lake Michigan and Saginaw lobes respectively. As previously stated, Leverett (1915, p. 184) assigned the name Lake Michigan-Saginaw Interlobate Tract to these accumulations. In Wexford County the topography is generally of the knob and basin type with elevations on the moraine ranging from 1,350 to 1,550 feet. About three miles south of the southeast corner of Wexford County, the crest of the moraine rises to 1,710 feet, the highest point in the Southern Peninsula of Michigan.

Port Huron Moraine

In the extreme north central part of Wexford County, an elbow of the main ridge of the Port Huron moraine swings south as far as the Manistee River. The ridge turns immediately northward again to form an elbow that covers an area of only six square miles in the county. Because of its small extent in the county, the moraine is not a significant feature. It is important, however, in that its position marks the maximum readvance of a later ice invasion during the Valders substage.

The Lake Border Morainic System marks the close of the Cary substage. After its deposition, the Cary ice retreated to the north beyond the Straits of Mackinac and a short interval of no glacial activity, the Two Creeks subinterval, followed (Thwaites, 1946, p. 86). During this subinterval the climate was evidently similar to, but somewhat cooler than, the present. The area was invaded by plant life as evidenced by organic remains in the form of logs, stumps, peat and pollen incorporated in the later drift (Flint, 1947, p. 251).

At the close of the Two Creeks subinterval, the ice readvanced on all fronts to usher in the Valders (Antevs, 1945, p. 6), the fourth and final substage of the Wisconsin.*

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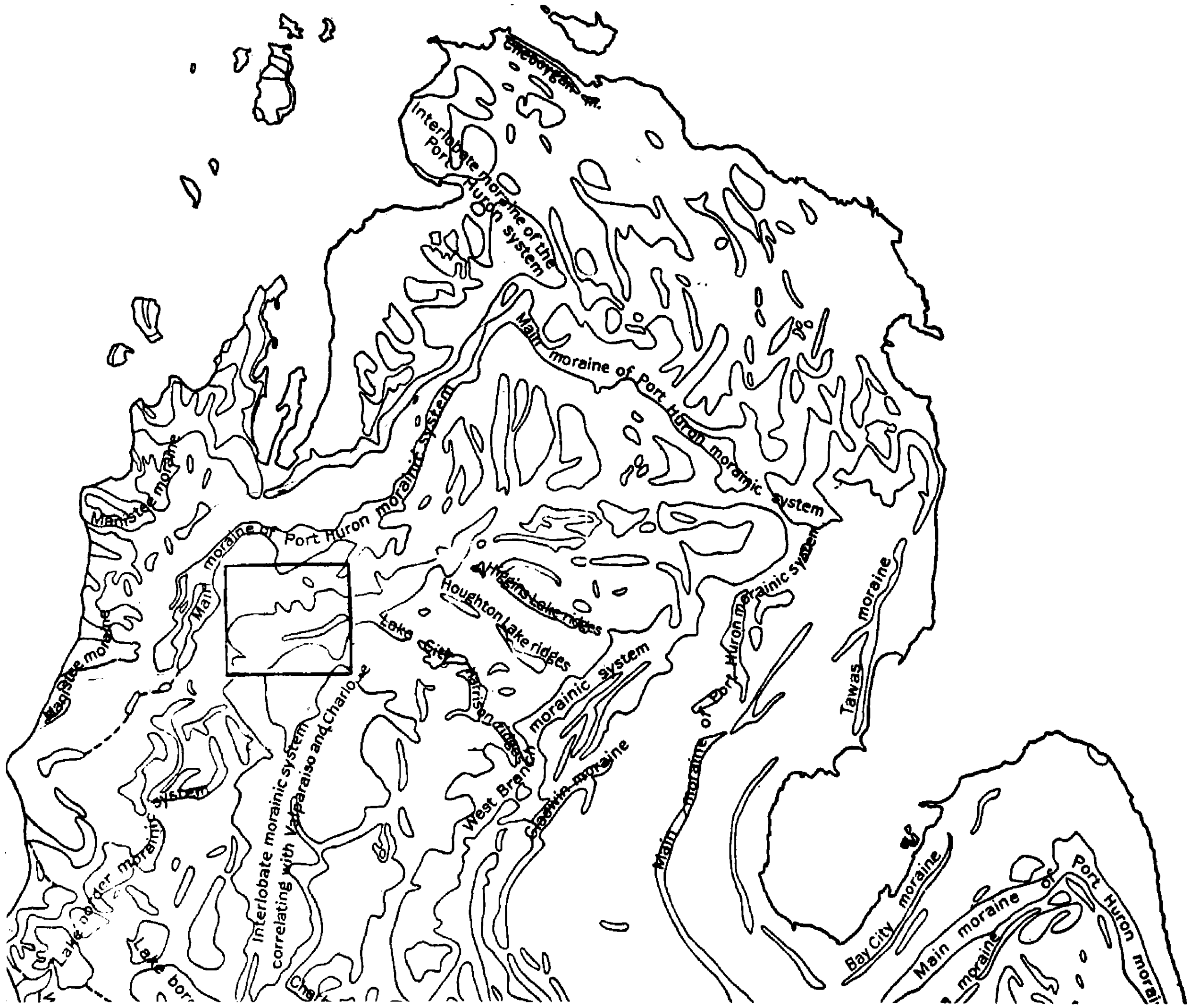
* The Valders is actually the third advance of the Labradorian ice in the Wisconsin stage. The Iowan which marks the base of the Wisconsin was an advance of the Keewatin ice sheet from the west and did not extend to the eastward beyond the Mississippi River. The Michigan lobe made its first advance across Michigan after the withdrawal of the Iowan. The Mankato, the final advance of the Keewatin ice sheet has been considered a fifth substage of the Wisconsin stage. However, it is now generally agreed that the Mankato of the West Cordillera area is correlative with the Valders of eastern North America (Antevs, 1945).

The Port Huron moraine which marks the outermost margin of this readvance has been mapped as a complex system extending from New York to the Dakotas. It may be considered as the backbone of the glacial features of the Southern Peninsula of Michigan.

North and west of the elbow of the Port Huron moraine the outer ridge trends northward for a short distance into Grand Traverse County. Here it makes a wide swing to the west before again turning south near the Grand Traverse-Benzie County boundary and then continuing south just west of the Wexford-Manistee County line. A large, almost semicircular arc is thus formed that has an enclosure of approximately one hundred square miles and extends southward across the northwest corner of Wexford County to the Manistee River (Figure 3).

OUTWASH APRONS

Outwash is stratified glacial drift deposited by meltwater streams during intervals of ice shrinkage. Since the streams that eventually build outwash start as far back as the upper limits of melting, an abundant supply of water and a steep gradient give them a transporting capacity sufficient to carry a large volume of sediment well beyond the ice margin. The texture of the material carried by running water is dependent upon the velocity of the stream and the volume and character of the available sediments. Inasmuch



DISTRIBUTION OF MORAINES IN THE NORTHERN PART OF THE SOUTHERN PENINSULA OF MICHIGAN (AFTER LEVERETT). SQUARE ENCLOSURE SHOWS THE LOCATION OF WEXFORD COUNTY.

Figure 3

as the outwash streams have access to an abundant supply of loose, unconsolidated detritus, they usually carry a capacity load of material ranging in size up to and including large cobbles. Beyond the ice margin, the stream velocity is checked and sorting begins. The coarser material is deposited near the glacier front while the finer material is transported far beyond. Depending upon the rate of melting and the distance of transport beyond the morainal border outwash plains are composed of material varying in texture from pure clay to very coarse gravel.

The surface of the outwash plains is not always flat. In addition to rock material, the streams commonly carry large blocks of ice as bergs that have broken off from the glacier. The bergs are deposited with the outwash material and often covered with detritus. When the ice blocks melt, depressions are formed which are called pits. If they are filled with water they are usually referred to as pit lakes. When the surface of the plain contains numerous pits, it is designated as a pitted outwash plain. The depressions are larger and more numerous near the morainic contact and gradually decrease in size and number away from it.

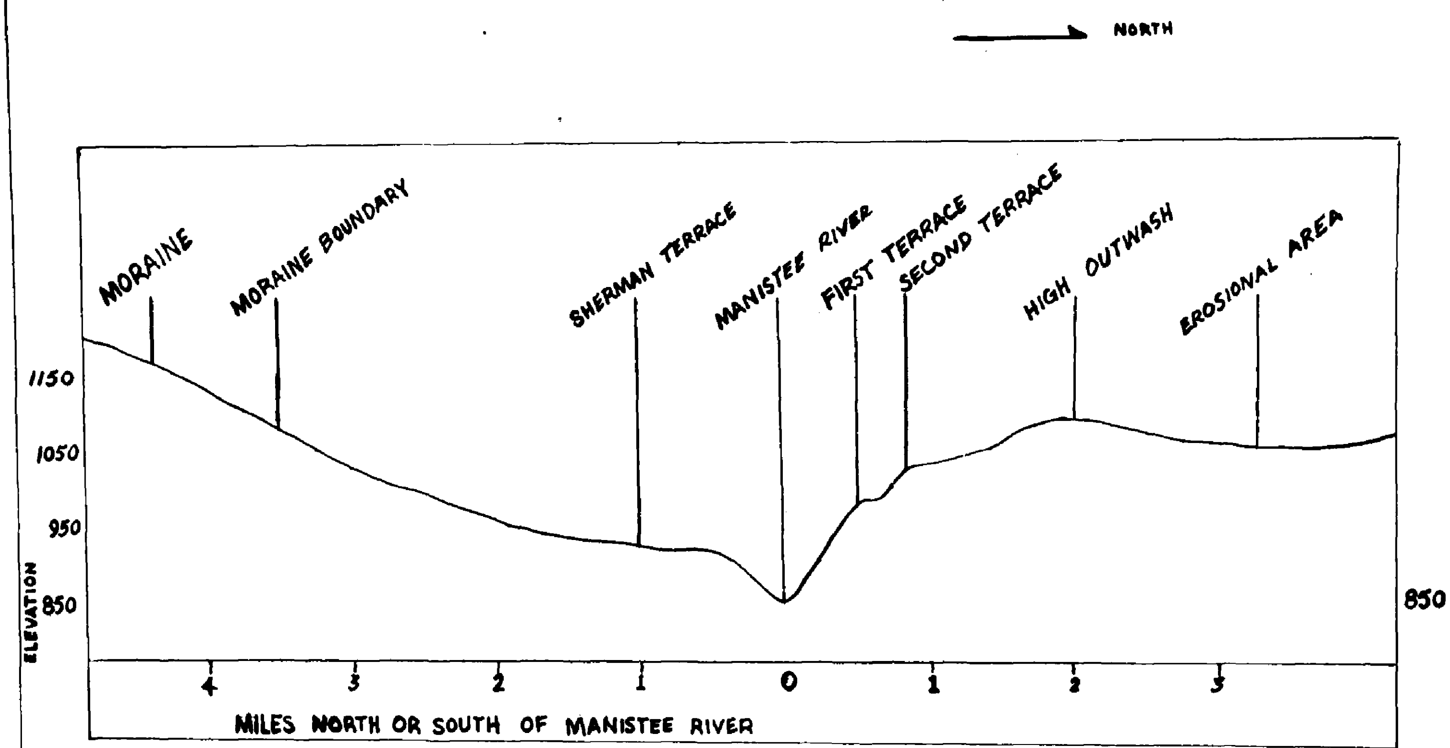
The outwash material in Wexford County is predominantly a mixture of silt, sand and gravel. The bulk of the gravel will pass through a two inch screen but a small amount is sufficiently large to be classed as cobbles. Because of the character of the material on the outwash plains, the surface has been modified to a great extent in many localities by recent activities of the wind. The finer material has been transported to other localities there to be deposited on the pre-existing surface. As a result of the removal of the finer material, the coarser fragments remain as lag concentrates in deflation hollows.

The soil of the outwash plains is relatively poor for agricultural purposes due in part to the eolian sand cover but more generally to the paucity of silt. It has been stated earlier in this report that the amount of silt present in the morainic material is usually sufficient to form a loamy sand soil. On the plains, however, the silt content in most places is too low to produce loamy characteristics in the soil. For this reason the vegetal growth on the plains is limited to plants such as scrub oak, jack pine, white birch, juneberry and elm, all of which are adapted to lighter soil types. The contrast between the morainic and outwash soil is so pronounced that it is often possible to trace the morainic borders by the abrupt change in vegetation.

The most extensive outwash plain in the county lies between the Lake Border and Port Huron moraines. The material forming the plains was laid down by meltwaters of the Valders ice at the time that the Port Huron moraine was being deposited. The portion of the plain west of the elbow of the outer ridge and north of the Manistee River forms an interesting topographic feature seldom found in outwash areas and unlike any other in Wexford County. The plain, situated on a high bluff overlooking the river, has a surface configuration that closely resembles a small plateau in the early stages of dissection. Its plateau-like surface was developed as the result of special circumstances which involve the environment of deposition, the course of the Manistee River and the activities of tributary streams of the river.

The outwash deposit forming this section of the plains was laid down in the embayment formed by the arc of the outer ridge of the Port Huron moraine described in the preceeding chapter (Figure 3). The embayment formed a large semicircular bowl that had a tendency to restrict the outflow of the meltwaters and thus facilitate the development of an unusually thick deposit. In addition to forming a thick deposit, the restricted water flow made possible the concentration of a large portion of fine material that normally would have been transported well beyond the ice margin. The presence of glacier flour on the high plains has produced a soil of much better quality than that developed on any other outwash plain in the county. Because of its good soil and gentle slopes, the high plain is the most productive agricultural area in the county.

At the time that the Port Huron moraine was in process of construction the Manistee River was initiating its



NORTH-SOUTH CROSS SECTION ALONG WESTERN BOUNDARY LINE OF R.11W. SHOWING MANISTEE RIVER TERRACES AND HIGH OUTWASH PLAIN NORTH OF RIVER.

Figure 4

course across Wexford County. Following the line of least resistance, the river made its way almost due west from northwestern Missaukee County to the Port Huron moraine and there turned southwest to flow through a gap in the ridge a few miles north of Wellston in Manistee County. Thus the river cut directly across the open end of the morainic embayment in northwestern Wexford County.

The river has carved a prominent lower terrace that rises abruptly to a height of 125 feet above its floor (Plate III, Figure 1). A mile or so farther north a second terrace rises fifty to seventy-five feet above the first level. Beyond the second terrace (average elevation 1,025) the high plain levels off and rises gently northward to gain an elevation of 1,090 feet at the county line (Figure 4). The present terraces were undoubtedly carved by the river as it trenched its valley in the outwash plain.

The surface of the high plain is relatively flat although gullies, produced by the erosive action of Fletcher, Wheeler and Anderson Creeks, tributaries of the Manistee River, have extended their heads northward into the high plains. The streams have begun a cycle of erosion on the high plains producing features closely resembling a plateau in the early stages of dissection. These features are so prominent that Leverett (1915, Plate VII), in his original survey, mapped parts of the area as moraine.

PLATE III

FIGURE 1. MANISTEE RIVER TERRACE. RELIEF OVER 100 FEET.

FIGURE 2. LOOKING SOUTH FROM CABERFAE FIRE TOWER THROUGH DRAINAGE GAP.

The degree of headward erosion of the tributary streams is exemplified by Fletcher Creek that flows into the Manistee River four miles up-stream from Hodenpyle Dam. The elevation at the confluence is 840 feet while three miles up-stream the elevation is 970 feet. This is equivalent to a gradient of forty feet per mile. In this distance, the stream has cut a steep sided valley over one hundred feet deep and about one-half mile wide (Plate IV, Figure 1). From this point to its head in a swampy area in the north-west corner of the county the gradient is only two feet per mile. Small tributaries of the creek are back-cutting into the valley walls to produce plateau-like features (Plate IV, Figure 2).

The remainder of the outwash plain south of the Port Huron moraine is a relatively flat surface that laps upon the Lake Border moraine to the south and slopes gently northward, away from the moraine, to the Manistee River.

Other outwash plains constitute a very small area of the county. The plain in the vicinity of Long Lake, along the eastern boundary of the county, is deeply pitted and is characterized by a rough topography. The plain, although quite limited in its extent in Wexford County, is the eastern extension of a large pitted outwash that extends westward from the Lake City area in Missaukee County. The outwash material laps high on the flanks of the bordering Lake Border moraine and, because of its rough

PLATE IV

FIGURE 1. FLETCHER CREEK TERRACE CUT IN OUTWASH (SEC. 27, T. 24 N., R. 12 W.).

FIGURE 2. OUTWASH DISSECTED BY TRIBUTARY OF FLETCHER CREEK (SEC. 21, T. 24 N., R. 12 W.).

surface, the boundary between moraine and plain is difficult to map.

Along the south edge of the county the surface expression of the outwash is undulating to rough owing in part to its pitted condition but more generally to the irregular surface of the pre-Wisconsin clay that underlies it at shallow depth.

TILL PLAINS

The till plain areas of Wexford County are so small that their chief significance is the fact that they are located where the pre-Wisconsin clay surface is exposed. This is especially true in the southern part of the county where the tributary streams of Pine River have eroded away a large part of the thin outwash cover. The topography in this area appears to have been definitely undulating before the Wisconsin drift was deposited.

COMPOSITE PLAINS

An area of approximately seventy-five square miles lying to the north and west of Lakes Cadillac and Mitchell has a surface cover with characteristics that are neither those of outwash plain nor of till plain. A similar surface is located in the Pine River drainage basin in the southwestern part of the county.

In these areas a till plain surface is partially covered with a thin veneer of sandy to gravelly outwash. The vegetative growth is characteristically the same as that found on outwash plains. However, boulders ranging in size up to four feet are distributed sparsely over a generally undulating surface. Gravel pits, sand blows, and road cuts reveal numerous boulders at and near the surface.

Hobbs (1939) believes that wastage of the ice during the summer season is great enough for glacial and extra glacial water flow to transport huge blocks of ice as bergs. The bergs transported from the glacial front by the braided streams may support large boulders which become partially or completely embedded in the outwash plain beyond the ice margin. It is conceivable that such action could produce an outwash surface that would appear much like that described above. However, the fact that the material exposed at and near the surface is characteristically till seems to indicate that the boulders scattered over the surface were deposited with the till and are exposed because of the thinness of the outwash. Because of the lack of criteria to definitely classify the feature as either till or outwash plain it is designated as composite plain.

DRAINAGE

The plain surrounding Lakes Cadillac and Mitchell slopes gently in all directions toward the basins with the result that the run-off of the area drains into them. Mitchell Creek, the only stream that feeds the lakes, heads three miles west and flows into Lake Mitchell near Sunset Point, the westernmost point on the lake. The waters of Lake Mitchell flow into Lake Cadillac which in turn is drained by Clam River. This river flows generally north from Cadillac for a distance of about two and one-half miles and then turns east to the county line. In Missaukee County, the river continues in an easterly course about half way across the county and then south to the Muskegon River in the northwest corner of Clare County.

Except for the small area described above, the county is drained by the Manistee River System (Plate V, Figure 2). The Manistee River enters the county one mile south of the northeast corner and follows a meandering course generally west for a distance of ten miles to the Port Huron moraine (Section 9, T. 24 N., R. 10 W.) and thence southwest to Hodenpyle Dam, where it leaves the county. The gradient of the river east of the moraine is approximately one and one-half feet per mile. From the moraine to Hodenpyle Dam, however, the river has an average gradient of about 6.5 feet per mile. This increase in gradient is probably influenced by the basal clay either because its surface

PLATE V

FIGURE I. PINE RIVER, STEEP BANK IN OUTWASH NEAR PETERSON BRIDGE (SEC. 20, T. 21 N., R. 12 W.).

FIGURE 2. MANISTEE RIVER (SEC. 12, T. 24 N., R. 9 W.).

slopes with the river or because it forms a ridge that holds the river at a higher level near the moraine. From Hodenpyle Dam the river continues generally southwestward across Manistee County to Lake Michigan.

Numerous tributaries provide good drainage for the plain through which the river flows. Many of these streams have eroded back into the slopes of the moraine to produce a more or less scalloped edge along the morainic boundary.

Pine River (Plate V, Figure 1), one of the tributaries of the Manistee, cuts across the southwest corner of the county. Together with its tributaries it is responsible for the drainage of the southern tier of townships of the county.

ECONOMICS OF SURFACE DEPOSITS

It has been stated earlier in this report that the kamic moraines in Wexford County provide an extensive source of gravel suitable for road construction. It is doubtful that the gravel could be utilized for a more profitable industry due to its high content of chert that prohibits its use for better grade cements and mortars.

Marl was mapped at only one locality in Wexford County. At this location (S. W. $\frac{1}{4}$ of the S. W. $\frac{1}{4}$ of Section 1 and the N. W. $\frac{1}{4}$ of the N. W. $\frac{1}{4}$ of Section 12, T. 23 N., R. 10 W.) marl is taken from two small pits in the floor of Silver Creek channel. The marl is used locally for agricultural purposes but the supply of this deposit is merely enough to supply the immediate demand of the surrounding area.

The possibilities for the commercial use of the clays in the county have not been explored to any great extent. Ries (1900, p. 53) in his report on the clays of Michigan states that the clay in the vicinity of Harrietta was being used for the manufacture of brick. However, a test made at that time revealed that the clay did not measure up to specifications required for the manufacture of good grade brick and tile. No brick yards are operating in the county at the present time. Ries also states that examination of the Harrietta clay by persons other than himself indicates it is probably best suited as slip clay for stoneware products. In the summer of 1946, the clay on the property of Mr. Louis Lieber, one-half mile east of Harrietta, was under lease to a company whose intentions are to utilize it for fuller's earth and related products. Hale (1903, p. 331), in his report on Michigan marl and the manufacture of cement, describes a clay which he calls "dean's clay" in the vicinity of Sherman. Although this designation is not familiar, it is assumed that he had reference to the extensive pre-Wisconsin deposit east of Sherman. This clay, he states, is "apparently a valuable clay for cement and other purposes."

CONCLUSIONS

The Wisconsin glacial deposits in Wexford County are composed largely of unconsolidated light brown drift that is predominantly sand and gravel. It is relatively thin and overlies a basal deposit of hard, blue, well jointed clay of pre-Wisconsin age. The irregular, eroded surface of the basal clay is definitely reflected in the present topography. Eolian activities have greatly modified the surface material by sorting out, transporting and redepositing the finer sand. This action is evidenced by small dunes in areas of redeposition and by boulder concentrations in blow holes where removal has been greatest.

The back bone of the topographic expression in Wexford County is the Lake Border moraine that marks the last halt of the retreating glacier during the Cary substage. The moraine includes both its inner and outer members in this area and is therefore most massive and attains the greatest height throughout its entire length.

At the time the Lake Border moraine was forming, meltwater streams were depositing an outwash plain immediately to the south. This deposit is quite thin and in some places so shallow that it does not mask completely the characteristics of the underlying till. It was deemed impracticable to differentiate between plains of till and outwash in these thinner areas and the feature was mapped as a composite plain. Till plains of the county are restricted to limited areas in which the sandy veneer has been removed to expose the pre-Wisconsin clay surface.

Upon completion of the Lake Border moraine, the Cary substage ended with the withdrawal of the ice from the Southern Peninsula of Michigan and the Two Creeks subinterval succeeded. In the Valders substage which followed, the ice again advanced to the site of the Port Huron moraine, an elbow of which extends southward into the extreme north central part of Wexford County. This elbow covers only six square miles in the county and is not an important topographic feature.

Manifestations of glacio-fluvial activities during the Valders substage are present in the form of the extensive outwash plain immediately to the north of the Lake Border moraine. The plain was laid down by meltwater streams from the ice front at the time the Port Huron moraine was forming. The erosional activities of the Manistee River and its tributaries have altered its surface configurations and in some localities have formed features resembling small plateaus in the early stages of dissection.

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