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CHAPTER IX. LAKES OF THE KALAMAZOO MORAINIC AND OUTWASH SYSTEM.

As stated in the Introduction, the work, the results of which are given in this chapter, was undertaken in order to include a much wider representation of the lakes in the various parts of the State but has been confined to the Southern Peninsula. It is possible that the distribution of these lakes would have been emphasized more had a county unit been used as a basis for their grouping. Such a unit, however, is not only artificial but difficult to adhere to and it was decided to group them according to their relation to the various positions of the border of the glacier during its retreat. Following this system the lakes may be referred to the three morainic systems shown in Fig. 3 with a fourth class of lakes bordering the Michigan-Huron shores.

The order of discussion is chronological in that the groups are taken up in the order in which they were uncovered by the ice but no attempt has been made to arrange the individual lakes in each group in the succession of their appearance. This grouping is used largely as a matter of convenience and emphasis should not be placed on the sequence for which no claim of accuracy is made.

GROUP I

In this group are included the lakes which lie in that portion of the State not covered by the ice at the time of formation of the Kalamazoo morainic system, see 2, Fig. 3, and also those within the moraine itself. They occur in Lenawee, Washtenaw, Jackson, Hillsdale, Branch, Cass, Kalamazoo, Calhoun, and Barry Counties, those of St. Joseph County having already been described. During this stage the reentrant between the Erie and Saginaw lobes of the glacier was located in northwestern Washtenaw County. The strong relief of the surface at the angle of the V formed by the junction of the two moraines presents a strong contrast to the greatly pitted outwash plain that .spreads out like a fan to the southwest into Jackson County. Numerous lakes are found both in the morainic basins and in the pits in the outwash. The greater number of morainic lakes is found within Washtenaw County and of these Sugar Loaf was selected as typical.

SUGAR LOAF LAKE

Sugar Loaf Lake is located somewhat more than five miles north of west of Chelsea and can be reached by conveyance from that city. The basin is larger and more irregular than the outline of the lake suggests and consists of several connected basins. A more flooded condition formerly existed and there is a probability that a much greater territory was covered by this lake at that time. The former shore line is well shown just east of the inlet at the north side. At this higher stage some of the smaller indentations were cut off by bars, a good example of which may be found a short distance east of the inlet mentioned. The material for the bars was carved from the bold cliffs which line this shore of the lake, but was limited in amount for bars were not thrown across the larger indentations and the exposed terrace is narrow. At the present level the slight development of the shores is consistent with the small expanse of the lake which is not conducive to strong wave action and vegetation is getting started at the shore. This lake is not so popular as some in the vicinity but cottages were in the course of construction at the time of the writers visit.

CAVANAUGH LAKE

This small lake lies four miles west of Chelsea and a mile and one-half north of the Sylvan Road stop on the interurban line. It is one of the most popular lakes in this section of the State. The many excellent locations for cottages have been used, especially on the south and east sides, and a number of excellent summer homes have been built. The lake lies in one of the numerous basins formed in this locality. Many are morainic basins but that of Cavanaugh is a fosse. Several of the lakes in this vicinity are separated by low sags which served as connections during a former flooded condition of drainage. Thus Doyle Lake to the east was once connected with Cavanaugh but a bar developed across the opening and may have separated the lakes during the later stages of the high water. This bar which swings around the southeast part of the lake may serve as a starting point for a study of the shores. Other features of the higher level are an exposed terrace at the foot of a cliff which rises locally to considerable height.

CROOKED LAKE

Crooked Lake is located a .short distance northwest of Cavanaugh and, although longer, is much narrower and more irregular in outline. The east shore of the lake for most of its extent is faced by steep cliffs consisting of the sand of the outwash plain west of Cavanaugh Lake. On the west, however, the land rises with more gentle slope to the moraine on the west. Such a trough-like depression between an outwash plain and a moraine has been termed a fosse and it seems logical, therefore, to call a lake situated in such a depression a fosse lake. The lake, however, is more true to type along the northern part than near the south end. The east side of the lake is used to some extent for resort purposes and affords good locations. This lake has also stood at a higher level but the shore features are not as pronounced as on Cavanaugh.

In the extreme southeastern part of the outwash, and also of Jackson County, are located two interesting lakes, Wamplers and Vineyard.

WAMPLERS LAKE

Wamplers Lake lies on the line of Jackson and Lenawee counties. It is not on a railroad but near the Chicago Pike and is reached by automobile over good roads. This pleasing body of water extends nearly two miles in an east-west direction but is less than one mile in width. The lake is much visited during the summer months and has a well appointed hotel in addition to numerous cottages. The greater number of buildings are located on the northeast shore and in particular on a split bar of a former level which stands several feet above the present level. This bar developed westward from the high cliff at the east end of the lake, splitting into two separate bars in the vicinity of The Farm. Soon after leaving the cliff it crosses a swale which formerly served as a connection with a small lake basin to the east. An exposed terrace may also be made out in places but this is rapidly being worn away by a revival of wave cutting due to damming of the outlet. A complete study of the drainage and shore conditions of this lake should prove interesting. The basin lies at the junction of the moraine to the south and outwash on the north but has the characteristics of a pit rather than those of a fosse.

VINEYARD LAKE

Vineyard Lake lies a mile or more west and north of Wamplers Lake and may be reached most conveniently from Brooklyn about three miles distant on the Ypsilanti, Hillsdale Branch of the New York Central Lines. The lake occupies a large, irregular pit in the outwash which has a length of more than two miles and a width in excess of one half mile. The principal irregularities are two long bays which extend to the north and to the northwestward. The lake is not as attractive as many in the vicinity because of the shallow water near the shore which is covered with a heavy growth of rushes and weeds. This condition is due to the partial exposure of a well-developed terrace, which was formed at a higher level. Steep and prominent cliffs face a large part of the shores, indicating strong wave action at the higher level, but most of the quarried material seems to have been carried out by the undertow to form the terrace, inasmuch as no bars were seen in the course of the rapid study made of this lake.

CLARK LAKE

Clark Lake, situated ten miles south of Jackson on the Cincinnati Northern R. R. which maintains a station stop at the west end of the lake, is another popular summer resort in southeastern Jackson County. This narrow basin—the lake measures less than one-half mile in width but more than two miles in length—appears to be part of an east-west drainage line which extends eastward from the lake to the Raisin River north of Brooklyn. In the immediate vicinity of the lake the channel is flanked on both sides by patches of moraine which rise above the till plain but to the east runs through outwash. The writer's information as to the depth of the lake is unsatisfactory but indicates relatively shallow water. It is evident, however, that the basin is not true to any one type. Inasmuch as it clearly is not a pit and also is not characteristic of morainic basins, a process of elimination leads to its classification tentatively as a sag in a till plain.

The long stretches of high ground along the sides due to the presence of moraine furnish excellent locations for summer cottages and the lake is well populated during the summer months.

The east-west orientation of the lake allows the stronger storm winds hill sweep of the lake and consequently considerable adjustment of the shores has taken place. This adjustment occurred during a level between two and three feet above the present and the shore features stand a short distance back from the water. These features include forms resulting from the action of waves, currents and ice, the latter two frequently combining in the formation of a single form. In particular, the rampart-bar at Pleasant View may be mentioned. Well-developed bars encircle the ends of the lake, that at the east end proving useful in damming the outlet. Among the more interesting features are the cuspate foreland and completely enclosed lagoon in the vicinity of Eagle Point.

DEVILS AND ROUND LAKES

The moraine which flanks the outwash just discussed on the east and south is of exceptionally high relief and includes the well known Irish Hills which lie south of Wamplers Lake. From one locality in these hills as many as seven lakes may be seen. These lakes are for the most part too small to be used extensively as summer resorts and were not studied. Many of the basins, however, are separated by very low land and, furthermore, show some alignment, suggesting the problem of former drainage conditions, the solution of which could not be undertaken at this time.

Among the larger lakes of this district are Devils and Round. These lakes are very popular with summer visitors as may be surmised from the extensive resort at Manitou Beach at the southwestern end of Devils Lake. Round Lake is less than a mile in diameter and is well named. Devils Lake is considerably larger than its neighbor, having a maximum length of more than two miles, but is much more irregular in shape, the outstanding feature being a narrow arm which extends nearly a mile and one-half to the northward. The lakes may be reached via the Cincinnati Northern R. R. but the greater number of visitors come in automobiles.

As regards origin these basins may be classed as morainic. That of Devils Lake appears large for basins of this type. Soundings may show, however, that the lake floods several basins. This was the case formerly with this lake and Round. The merging of the two lakes occurred when the water level stood about four feet higher than at present and the important adjustments of the shores took place at this stage. The most consistent feature is the partially exposed terrace which stands at the foot of the numerous cliffs. Currents also were active and deposited their loads at the indentations. A striking example of this may be seen at the narrow neck of land which now separates the two lakes. Currents in both lakes aided in building a strong bar which extended nearly across the opening and, with the lowering of the water level, divided the continuous sheet of water into the present Devils and Round Lakes. This locality serves as an excellent starting point for a physiographic study of these lakes.

BAWBEESE, COLDWATER AND MARBLE LAKES

The lakes visited in Hillsdale and Branch counties are discussed as a group because of the similarity of the origin of the basins. They all lie in channels through which the waters of the melting ice escaped to the south and southwestward. Within these channels tongues of ice of uneven thickness become stagnant and were covered by the deposits of the streams, forming narrow strips of out-wash of even surface below the general elevation of the surrounding country. The subsequent melting of the ice caused a settling or pitting of the surface which took the form of channels at a still lower elevation through which the present drainage flows. Due to uneven thickness of the ice tongues these lower channels are ungraded, the deeper parts being filled by the present lakes.

One of these channels runs in a southeasterly direction through Hillsdale and forms the setting for a string of five lakes the largest of which is Bawbeese on the outskirts of the town. This lake, named after an Indian chief, is very popular locally, the south shore being lined with cottages. For a lake of this size, one and one-half miles in length by less than one-half mile in width, the adjustments of the shore are strong. These adjustments all took place at a level five feet above the present level and may be accounted for by the sandy character of the material of the outwash which is easily worked. Cliffs are neither frequent nor prominent but, nevertheless, strong bars were built across indentations along the sides, the most prominent standing a short distance back from the present shore along the south side and that connecting Wolff Point on the north shore to the mainland. The outlet of the lake is now dammed and the rejuvenation may best be observed in the rapid cutting at Wolff Point.

About three miles west of Hillsdale a similar channel almost parallels that just discussed. Within this channel are numerous small lakes whose shores show little development but whose basins were formed in the same manner. A third channel runs nearly north-south about one mile east of the line between Hillsdale and Branch counties. Likewise in this channel are numerous lakes, the largest of which are Hamlin and Long, which are too small to show decided adjustments of the shores. The fourth and last of these channels lies in southeastern Branch County and is much wider and less defined as a channel than those just mentioned. The pits are correspondingly larger and less elongated in form but are arranged along the course of the channel. Our interest lies in the larger lakes at either end of the string, Marble and Coldwater, the intermediate ones, Long, Mud, Bartholemew and Middle being too small for special consideration.

COLDWATER LAKE

Coldwater Lake is the southern member and also the largest of the chain, having a length of three and a maximum width of one and one-half miles. The lake is triangular in shape and contains a large island in the southeastern part. A road skirts the east shore for most of its extent and forms an approach for the large number of cottages which have been built on this part of the lake. It is the only lake of the chain whose extensive marl deposits have not been tapped for the manufacture of cement and is therefore the most popular, although an eight mile drive from Coldwater is necessary to reach the lake. This lake probably stood at a higher level formerly but, if so, the drop in level has been not more than two feet, an amount so small that the present high water stage in the spring might well be confused with a definite higher level. The shore, features are relatively simple. Waves have been very active in forming the steep cliffs. Most of the material carved from the cliffs seems to have been distributed by the undertow rather than by long-shore currents, inasmuch as a well defined submerged terrace lines most of the shore and little evidence of the closing of indentations by bars was found.

MARBLE LAKE

Marble Lake extends three miles south from the edge of the town of Quincy on the Hillsdale-Adrian branch of the Michigan Central R. R. and is therefore easily accessible by rail. This lake, although of practically the same length as Coldwater Lake covers less area on account of its nearly uniform width of slightly more than one-half mile. It is essentially rectangular in shape except for the large embayments at either end. The lake has been of considerable economic importance in that its extensive marl deposits have been utilized in the manufacture of Portland cement at the Quincy mill. These deposits are now virtually exhausted in this lake but are being worked in the lakes to the south. The removal of the marl with steam shovels has caused an abrupt drop into deep water, a condition which makes the lake dangerous from the viewpoint of the resorter and has worked to the detriment of the lake. The workable deposits of marl appear to occur off the west shore mainly and consequently the east side of the lake has not suffered from artificial destruction of the shore. In addition, the east shore from Cedar Point southward is favored with one of the best locations for summer cottages the writer has seen, consisting of a flat well above the water and covered with a grove of beautiful oaks. This location has, of course, been "discovered" and numerous cottages line the shore. Here also is found the key to the shore adjustments of the lake. A well defined submerged terrace extends off-shore and slopes outward so gently that a zone of considerable width, is exposed during low water. Great quantities of small shells which have contributed to the formation of the marl may be found on the beach, thrown there by the waves. An almost continuous cliff lines the shore but breaks at an elevation of five feet above the present

level. This cliff with the occurrence of complete bars at the same elevation crossing the occasional indentations is sufficient to establish a former higher level of the lake. The action of currents is best shown at Cedar Point which extended out into the lake as a spit at the higher level.

GOGUAC LAKE

Goguac Lake is located just outside the southwestern limits of Battle Creek. The street car system of the city has extended its service to the lake which has become a recreational center. On this account and also the fact that a considerable part of the shore is utilized for a public amusement resort, Willard Park and a golf course and Country Club, the number of private cottages are not as numerous as might be expected.

This small lake lies in a pit which in outline is roughly like an hour glass and is nearly twenty-five feet below the general level of the outwash. The shore is faced by steep cliffs of sandy material broken occasionally by minor indentations. The adjustments of the shores, therefore, were largely confined to the attack of waves and the accompanying undertow which formed bold cliffs and a well defined submerged terrace. In places a part of the terrace is exposed at the foot of the cliff, indicating a former level between two and three feet above the present. This is further shown by the exposed bars and spits at the indentations and at the cuspate foreland at Willard Park. In addition to the shore features of the lake an interesting example of the extinction of a lake by vegetation may be seen on the Willard farm just east of the road leading to Willard Park.

GULL LAKE

Gull Lake is one of the best in the southern part of Michigan. It is nearly five miles in length and more than one mile in width for most of its extent. It is located about equidistant from Kalamazoo and Battle Creek but some three miles north of the main road between these cities. The popular means of transportation to the lake is by automobile but interurban service is maintained by the Michigan R. R. Co., connecting Grand Rapids as well as the cities mentioned. However, it must not be inferred that the appeal of this lake is limited to the locality for many of its visitors come from far without the State. Cottages are numerous, especially along the east shore, but, in addition, there are a number of imposing estates. The popularity of the lake, however, is not due entirely to its fortunate location and large size. Another reason is the excellence of the shores, due in large part to the physiographic developments that have taken place.

This basin is sunk below the surface of the extensive outwash plain which developed in the wide angle between the Michigan and Saginaw lobes when the ice border stood a few miles from the lake. The lake is large for a typical pit but may be included in this class until more detailed studies are made.

One of the first observations to be made at Yorkville which is situated on the outlet is that the lake has been dammed, causing what appears to be a serious flooding of the lake. The flooding of the outlet is clearly in excess of eight feet and it is, therefore, surprising to find the shores of the lake uniformly dry. The explanation is soon found in unmistakable evidence of an abandoned level more than six feet above the present lake at which stage the major adjustments of the shores took place.

The lake furnishes a wealth of material for physiographic study which could not be attempted at the time this work was done and, therefore a brief description of conditions near Midland Park is given as a key to other adjustments. At this locality the broad flat upon which the cottages are built is the exposed terrace of the higher level. It ends abruptly at the foot of a steep cliff, twenty or more feet in height, which marks the former shore line. On the terrace may be found two distinct sand bars which swing northward towards Bryant Point. The bar nearer the lake stands at the lower elevation, indicating a halt in the lowering of the lake level.

At present the adjustments are not important. Ice action is perhaps the most effective but prominent ramparts are not found on account of the sandy character of the material on the shore.

CROOKED LAKE, BARRY COUNTY

Of the numerous small lakes which lie in the outwash that developed in the reentrant angle between the Michigan and Saginaw lobes of the glacier only Crooked and Wall lakes were visited by the writer. Crooked Lake is located in southwestern Barry County and is reached most conveniently by automobile, although the Chicago, Kalamazoo and Saginaw R. R. passes the resort on the northeastern shore.

The lake lies near the apex of the elbow shaped outwash plain and occupies either a single pit of very irregular outline or a number of connected pits which have a striking northeast-southwest orientation. It has a length of more than four miles but consists of narrow parallel channels and bays separated by islands and peninsulas so that its area is relatively small. Lower Crooked is, in fact, an oblong channel which surrounds a large island and is not only narrow but shallow. Little adjustment of the shores has taken place and they are consequently muddy. The chief interest in this part of the lake lies in the heavy growth of vegetation which will eventually convert Lower Crooked into a marsh.

At the northeastern end, Upper Crooked, the lake expands to more than a mile in dimensions and some adjustment of the shores may be seen at a level nearly five feet above the present beach. One of the best localities to observe this higher level is at Stony Point which is a spur of the nearby moraine covered with a thin veneer of outwash material. The end of the point is a steep wave-cut cliff from which the material to form the spits on either side was carved. This locality indicates the adjustments that may be expected on other parts of

the shore of Upper Crooked. In addition to the development of the shores considerable filling by vegetation has been accomplished and is especially evident on the numerous shoals or "blind islands".

WALL LAKE

Wall Lake is located two miles northeast of Crooked in the very apex of the outwash plain which developed in the reentrant between the Michigan and Saginaw lobes. The north shore is bounded for the most of its extent by moraine but from the opposite side outwash stretches southward for miles. The basin was caused by the melting of buried ice and is, therefore, classed as a pit.

This small lake has a length of less than one and one-half miles and a width of somewhat more than one-half mile but is interesting nevertheless. In contrast to Crooked Lake its shores are broken by a single long peninsula and it is deep, so that the waves have an unobstructed sweep. Many adjustments of the shores, therefore, may be observed and those on the north shore are selected as typical.

The most striking adjustments in this locality are the steep cliffs at the headlands, the perfect bar which rises fully five feet above the present water level and is responsible for the name of the lake, and the decided off-shore terrace. In addition, strong ice ramparts were noted along the west side. This almost perfect adjustment means excellent shore conditions for resort purposes and the lake is deservedly popular during the summer months.

AUSTIN GROUP

AUSTIN, LONG, WEST (PIKE) AND GOURD NECK LAKES

This group of lakes lies some seven miles directly south of Kalamazoo on the Grand Rapids and Indiana R. R., trains of which stop at Austin Lake. The lakes are discussed as a group because they all occupy pits in the outwash plain first mentioned in the account of Gull Lake. Furthermore they all drain southward through the Portage River into the St. Joseph and were once connected, with the possible exception of Gourd Neck, during a former swollen condition of the drainage which appears to have been general in the State.

Austin Lake is the central member of the group and has a length of two and one-half miles and a maximum width of slightly more than one mile. It is very shallow a fact which evidently has effectively hindered wave action for there are few shore adjustments to be found. The lake has been artificially lowered and as a result a broad sand fiat is exposed along the shore. The flat is covered with reeds which with other water plants are encroaching on the shallow lake. The lake is popular as a fishing ground but the cottages are built on the neighboring lakes which have more attractive shores.

West, or Pike Lake, lies a few rods directly west of Austin and is nearly circular in form, the largest diameter being somewhat more than one mile. The sudden darkening in color of the water off shore gives the impression of a deep lake and a decided submerged terrace. Such is not the case, the effect being produced by the change from sand to mud which marks, nevertheless, the limit of effective wave action. The shallowness of the water has not interfered with the wave action as on Austin and decided adjustments of the shore are to be found. An excellent and convenient starting point for the study of these features is the resort at the east end where the land between this lake and Austin rises but slightly above lake level. The most decided feature is the strong-sand bar at an elevation of about four feet above the lake which crosses the flat between the lakes and shows that the lakes were connected during a higher stage and that later West Lake became an independent basin. This part of the lake is the most popular and the bar, although obscured somewhat by cottages, is, nevertheless, easily recognized. Similar adjustments are to be expected on other parts of the shore but probably are not as well developed inasmuch as the east shore is exposed to the strongest winds.

LONG LAKE

Long Lake is situated a short distance to the northeast of Austin into which it drains across a flat so low that it must have been flooded at the earlier stage indicated on West Lake. In this case no bar crossed the flat and the separation of the lakes must have been caused by the lowering of the water level. Elsewhere along the shore no evidence of current action was found but sharp cliffs indicate work by waves. This, however, was not great inasmuch as both bars and submerged terrace are lacking. The lack of these features has not proved a deterrent influence on its use as a summer resort as shown by the resorts on the south and southwest shores.

DIAMOND LAKE

The last lake in Group I to be considered is Diamond Lake. It is located just east of the limits of Cassopolis which is the junction point of the Grand Trunk and Air Line Division of the Michigan Central so that no difficulty need be encountered in reaching the lake. The lake is attractive and of good size for this section of the State, its dimensions being two and one-half miles in length and more than a mile in width. Many cottages and costly summer homes have been built along the shores near Cassopolis and on the island.

From the physiographic viewpoint the lake is of little interest except as to the type of basin which is one of the numerous pits which break the surface of the outwash plain. The level of the lake is high due to the obstruction of the outlet by a dam at Brownsville and, although the shores are not badly flooded, the waves are gradually wearing back the banks and undermining trees.

CHAPTER X. LAKES OF THE VALPARAISO-CHARLOTTE MORAINIC AND OUTWASH SYSTEM

In Group II are included the lakes which lie in the area between the Kalamazoo morainic system, 2, Fig. 3, and the Valparaiso-Charlotte morainic system of Southern Michigan, 3, Fig. 3. It will be noted from the figure that both the eastern and western interlobate areas became greatly accentuated as the ice shrank back to the position indicated by the Valparaiso-Charlotte moraine during which stage they existed as narrow valleys with ice walls. The western interlobate was much more pronounced, extending from the vicinity of Grand Rapids northward beyond Cadillac, a distance of nearly one hundred miles, as compared with less than half that distance for its eastern counterpart. Both, however, are made up of a patch-work of deposits which is characteristic of such locations. Between the two interlobates the formations are much more regular and have an east-west trend.

WALLED LAKE, OAKLAND COUNTY

This lake is roughly triangular in shape and has a length of one and one-half miles and a maximum width of somewhat more than one mile. Its shores are regular in outline with the exception of one long point on the northwest shore, thus the sweep of the waves is unobstructed. The lake lies for the most part in a morainic depression but at the south end overflows on the till plain which spreads southward from the lake. A road circles the lake and follows the shore on all but a part of the west side so that the shores are readily accessible. As to train service, the Jackson Branch of the Grand Trunk runs within one-half mile of the north end and the Detroit-Saginaw Line of the Pere Marquette has a stop at Wixom, three miles west of the lake.

For physiographic study the west shore is the best, although sharp cliffs and an exposed terrace are present on the east side. The sharp point on the west side is a spit which may be followed without difficulty southward for nearly a half mile. Soon after leaving the point one notes that the bar takes on the characteristics of an ice rampart or wall which is so distinctive as to give the lake its name. The absence of bars at other points on the shore where they might be expected leads to the conclusion that ice push has been the dominant force active on the shores. The lake is very popular as a summer resort and nearly all the available frontage on the west, east and southeast has been built upon.

WHITMORE LAKE

Whitmore is another of the popular lakes of this group. It is located ten miles north of Ann Arbor on the boundary between Washtenaw and Livingston counties. Trains of the Ann Arbor R. R. stop at the south end, but with the improvement of the roads the automobile is the more popular means of reaching the lake.

The lake lies in a region of complicated glacial deposits and many interesting features of this type as well as shore features may be seen. The high hills at the north end are kames. On the cast a strip of outwash borders the lake but gives way to ground moraine which extends to the south end of the lake. The south side consists of a flat outwash plain, on the west of which lies a narrow stretch of ground moraine followed by a moraine of low relief along the greater part of the west side. The lake has neither outlet nor inlets and for most of its extent the shore is bounded by banks which are of moderate height but steep for unconsolidated material. The basin appears to be a pit formed by a rather large block of ice of irregular thickness buried by outwash which developed from the southward. The outwash is a broad channel which carried the water escaping from the ice when the front of the glacier stood a short distance northwest of Ann Arbor.

As to the shore features, the chief interest lies in a higher level of the lake during which the water discharged through an outlet at the southeastern part. After leaving the lake the former outlet turns abruptly to the north and extends to the Huron valley. The development of the shores at the higher level was exceptional for a lake of this size and resulted not only from the activity of waves and currents but of ice as well. The best locality for study is along the northwestern shore where excellent examples of cliffs, spits, bars and ice ramparts may be found. At present the encroachment of vegetation is beginning in parts of the basin and is progressing rapidly on the spit-like form extending out from the south shore of the lake.

HURON RIVER GROUP

PORTAGE, BASE LINE, STRAWBERRY, ZUKEY, ETC.

The lakes included in this group are located in the valley of the Huron River southwest of Lakeland, situated at the junction of the Ann Arbor R. R. and the Jackson Branch of the Grand Trunk R. R. They all occupy parts of an elongated pit that extends in a northeast-southwest direction from Lakeland to Portage Lake. This pit was formed by the burial of an ice mass of very irregular outline and thickness in a former drainage channel through which the water from the glacier escaped in a northwesterly direction beyond Pinckney and thence to the southwest towards Jackson. The subsequent melting of the ice left a depression below the level of the outwash, which conformed in general outline to the ice mass and also contained a number of deeper basins which contain the present lakes.

The several lakes of the group are not discussed independently because the adjustment of the present shores is insignificant and also because a higher level was found at an elevation sufficient to have merged all into one large lake having numerous bays, peninsulas and islands. The principal indication of this stage is the

gently sloping flat which extends from the lake shores back to the sharp cliffs and is interpreted as an exposed terrace. In addition, bars which swing out from steep cliffs were found. Thus, the study of the former shore will give the best results. Some of the most interesting localities are the sand point on the east side of Portage Lake north of the cottages, the north shore of Base Lake near the outlet, and the great bar which swings south westward from the cliff on the southeast side of Bass Lake.

These lakes are used extensively as summer resorts, the most popular being the pairs, Portage-Base and Zukey-Strawberry, located at the ends of the chain.

DUCK LAKE

Duck Lake is located in northeast Calhoun County almost equidistant from Albion, Charlotte and Eaton Rapids, from which cities it draws many summer visitors. The nearest railroad stop is Springport on the Hillsdale-Lansing Branch of the New York Central, but good roads have made the automobile the principal means of reaching the lake. This small lake of one and one-half miles in length and somewhat more than one-half mile in width lies for the most of its extent on a till plain, the land rising to the moraine at the south end. The basin is, in general, shallow and has, furthermore, numerous shoals. Thus, it may be considered as one of the larger sags in the till plain modified by minor sags and swells.

The material of the shores is compact till except for the sandy morainic material on the south end; and consequently the attack of the waves has been slight. The adjustments have, taken place at a level four feet above the present stage and are found at either end and the east side. At the south end clean sand beaches indicate an assorting of the material by the waves; and a fairly well defined submerged terrace is the result of the accompanying undertow.

At Charlotte Resort a strong bar crosses the mouth of a former bay and at the north end there is the possibility of a similar form, obscured by the road. Waves and currents have had little force on the west shore as shown by the presence of marl beds. The ramparts on this shore, however, show a powerful shove by ice. A heavy growth of rushes on the offshore terrace indicates the beginning, at least, of the extinction process by vegetation.

CHIPPEWA LAKE

A number of small lakes are situated in the large morainic tract of north-central Mecosta County, and Chippewa Lake, which lies twelve miles east and north of Big Rapids, was selected as representative of these lakes. There are no rail connections but a good road from Big Rapids insures a comfortable trip by automobile or other conveyance.

Except for a narrow strip of outwash at the north end, the lake lies in a very sandy moraine of strong relief. The knobs and basins of the surrounding land have counterparts in the shoals and deep holes of the lake bottom so that the lake is typical of those which flood several adjacent morainic basins.

The slopes to the lake are a series of cliffs and flats, thus furnishing numerous possibilities for adjustments which were readily carried on in the sandy material but at a level nearly five feet above the present lake. In addition to the steep, wave-cut cliffs, the work of currents at the entrances to bays is noticeable. Many of the smaller indentations of the original lake were completely cut off by bars which have been remodeled into ice ramparts in some cases. However, at the larger bays spits are found. An interesting example of this was noted along the southwest end of the lake where the road follows the spits which developed from each side of the large bay, now nearly dry. Along the outwash at the north end the terrace of the higher level is well exposed and is from two hundred to three hundred feet wide. Another of the many interesting features is the land-tied island of the former level on the east shore. This lake has exceptionally interesting physiographic features which, together with the sinking of the water level, account for the present rather regular outline of the lake. It is becoming a very popular summer resort, the more favored locations being the village of Chippewa Lake, the north shore, and the land-tied island with connecting bar.

HESS LAKE

Hess Lake lies about two miles southwest of Newaygo, located on the Grand Rapids-Petoskey Branch of the Pere Marquette R. R. This lake has a length of nearly one and one-half miles and a rather consistent width of about three-fourths of a mile. The shores are regular in outline on all but the south side, which is broken by a number of bays and promontories. The lake is shallow —it probably does not exceed thirty-five feet in depth— and is surrounded by outwash except at the southwestern shore. It is, therefore, classed as a pit.

From the study of this lake it is apparent that the northerly and easterly winds have not been effective in the adjustment of the shores. The irregular south shore consists of headlands, which show few effects of wave action, and mucky bays, sparsely grown up to lily pads. The power of the westerly winds, however, is well shown on the north shore. As usual the adjustments were found between three or four feet above the present level and bars first appear near the middle of the north shore. The bars increase in strength towards the east end where former bays have been completely cut off. Ice action is also powerful and ramparts of sand, bound by the roots of trees, were noticed. The north shore of the lake is a popular summer resort and, due to the favorable shore conditions and its accessibility, is almost completely lined with cottages. The south shore is reached by a roundabout route over sand roads, and but one location, a camping ground, was found.

REED LAKE

The location of Reed Lake within the city limits of East Grand Rapids accounts for the great popularity of this small lake of but slightly more than a mile in length and less than a half mile in width. It lies in a morainic basin that is irregular both as to depth and outline. The shore is generally well drained except about the muddy bay at the east end. As a recreational center the lake is interesting but as an illustration of physiographic developments little can be said. The shore agents working in hard till accomplish little on a lake of this size and the adjustments of the shore are few and simple. Waves have succeeded in steepening the banks and forming a moderate off-shore terrace, a part of which is now exposed due to a drop of at least three feet in the water level. Bars are found only at the smaller indentations and stand back of the present shore. One example of a bar completely enclosing a small bay was found in the vicinity of Pierce's Landing. A heavy growth of vegetation both in the lake and on the shore indicates the initiation of the extinction process.

MINER LAKE

Miner Lake is a small lake one and one-half miles in length and less than a mile in width but is, nevertheless, one of the larger lakes of Allegan County. It is located about three miles northeast of Allegan and lies in an irregular depression of a till plain near its junction with the moraine. As is usually the case for small lakes whose banks are till, the adjustments of the shore are not far advanced. Inasmuch as there has been a lowering of the level of the lake, the adjustments are now beyond the reach of the waves and have virtually ceased to develop.

Furthermore, vegetation has taken hold and extinction appears to be the next step. Aside from wave cut cliffs and a partially exposed offshore terrace little of interest was noted. The lake is not popular as a summer resort but is frequented mainly by fishermen.

PAW PAW LAKE

Paw Paw Lake lies within two miles of the northern border of Berrien County, within a mile of the towns of Coloma and Watervliet and six miles west of Hartford. These towns are all located on the Chicago-Grand Rapids Branch of the Pere Marquette. The lake may also be reached directly by interurban from Benton Harbor. In addition, the main roads are excellent.

The total length of the lake is two and one-half miles but its width is but slightly more than a half mile, the elongation being nearly east-west. The chief irregularities are bays at the southwest and northeast ends, the latter being set off from the main lake by two distinct peninsulas. The peninsula on the east side and the east shore of the lake near the outlet are the favored locations for summer homes which line the shore even though the shore conditions are not uniformly good.

The lake lies on a till plain but is not typical of such lakes in that it is reported to be one hundred feet deep. The banks slope gently to the shore on the north side but on the south rise more abruptly from the lake, due possibly to a general rise in the till plain towards the moraine whose border stands about one mile to the south.

The lack of the adjustments of the shores is very noticeable considering the size of the lake and may be accounted for in part by the fineness and compactness of the till of which the shores are composed. The features found were all at a higher level and consisted mainly of sharp cliffs and an exposed terrace fronting the elevations. One small spit was noticed at the west end but none were seen at the other favorable localities, such as the peninsula at the east end which was an island at the higher level.

In recent times wave action has been renewed and is actively cutting back the shores wherever the vegetation has been removed. Such a condition suggests an obstruction in the outlet, in this case a dam four miles down the outlet.

This lake is a good example of the service of a lake as a reservoir for during the spring floods the Paw Paw River backs into the lake, causing exceptionally high water and the flooding of some of the low ground upon which cottages unwisely have been built.

CORA LAKE

That part of the surface of the outwash plain extending south-westward through Paw Paw in Van Buren County and drained by Dowagiac Creek which was not covered by glacial Lake Dowagiac is dotted with numerous small pits. A number of these pits hold water and are very typical of this kind of basin, having in many cases no outlets and insignificant inlets.

A group of lakes of this type is located some six miles southwest of Paw Paw and of these Cora, Three Mile, Little and Big Reynolds and Eagle lakes were visited. Conditions are so similar in these lakes that the brief description of Lake Cora will serve as a key to the many interesting examples of shore adjustments that may be found on all of them.

This lake may be reached via the Kalamazoo, Lake Shore and Chicago R. R. which stops at the summer resort on the north side, although the automobile is proving a more popular means of reaching Cora Lake on account of the excellent roads. The resort, consisting of a commodious hotel and a number of cottages, is an indication of the popularity this small lake has enjoyed. The basin of the lake consists of a main pit surrounded by numerous smaller connecting pits, making a rather irregular depression. Yet the shores are of exceptionally even contour, the greatest break being Paradise Point, and the disparity may be accounted for by the shore adjustments that have taken place. This lake which has no outlet has varied in level within recent times and now stands low. It has stood between three or four feet

higher and at this level the adjustment of the shore occurred. The change in color offshore indicates a well defined terrace, the upper part of which is now exposed as a sand flat. At the higher ground steep and prominent cliffs rise from the terrace, and at the indentations completed bars are found in virtually all cases. Paradise Point is of sufficient interest to warrant special mention for short bars have tied a former island to the mainland. As stated earlier, similar conditions hold for the other lakes of this group and their study should prove interesting.

SISTER LAKES

Another group of pit lakes in the outwash drained by Dowagiac Creek, including the Sister Lakes (Hound and Crooked), Dewey and Magician lakes, was visited by the writer. They are located five to six miles northwest of Dowagiac on the northern boundary of Cass County and have no direct railroad connections. These lakes, which are classed as pits, stand near the edge of the moraine to the west and are sunk well below the surface of the thin veneer of outwash, so that till is frequently exposed on the shores. Furthermore, the pits are so numerous that the outwash in places has a hill and depression topography very similar to the morainic knobs and basins. Since the moraine is very sandy, these two types of topography are best differentiated from the hill tops which rise to approximately the same elevation within the outwash but are of variable height in the moraine.

Considerable variation is found as to shore features on the different lakes of the group. Crooked, Round and Dewey are similar in development but Magician presents a decided contrast.

The latter is very irregular in form, having many bays and points and some islands. Strong wave action is possible only on the headlands and islands, and currents have little chance to develop on the irregular shores. Consequently the adjustments are limited to wave cutting in favorable localities and consist of sharp cliffs and an off-shore terrace. The outer edge of the terrace now appears as a flat at the foot of the cliffs, due to a lowering of the water level.

The lake is very attractive from the scenic viewpoint and numerous cottages line the shore.

The remaining lakes of the group, Crooked, Round and Dewey, are very similar, except in form, and present a contrast to Magician in that the adjustment of the shores by both waves and currents is very decided. They have all stood at a level four to five feet higher than at present and are, therefore, fringed by a broad sand flat. Improved roads lead to almost all parts of the lakes and they are, consequently, developing as summer resorts.

Among the more interesting features are the very noticeable cliffs fronting the high ground. Considerable recession of the cliffs has taken place, and a sharp off-shore terrace is of general occurrence. In addition, strong currents built bars across the mouths of indentations and spits at some of the points. Thus, on Crooked Lake a completely enclosed lagoon was found at the east end of the lake. Also the first point on the south side has been increased in length by a spit, and at the west end a bar may be made out, although very much obscured by the road, which indicates a probable connection between Round and Crooked lakes.

On Dewey Lake the most interesting developments have occurred, at the east end which leads into a marsh nearly as large as the lake. This marsh was formerly a shallow arm of the lake connected by a narrow but deep channel. Spits started at the higher level on each side of the channel and succeeded in closing about one-half of the gap. The marsh is a good example of almost complete extinction by vegetation which obtained an early start in this shallow part of the lake.

INDIAN LAKE

Indian Lake is located in the northwestern part of Cass County just off the western boundary line. It lies nearly six miles west of Dowagiac and the roads leading to it are improved. From the geological standpoint it is located on an outwash plain within a short distance of a moraine which skirts the west side of the lake. It is, thus, a pit but a large one for the lake is nearly two miles in length by almost a mile in width and is regular in outline. The regularity of the shore is due in large part to the adjustments of the shore which are numerous and interesting. They were accomplished at a level some three feet higher than the present and on the sides of the lake show a close correspondence to the strength and frequency of the winds.

On the east side the waves have formed bold cliffs and sand beaches, and currents have thrown complete bars across the embayments. On the opposite side, however, the cliffs are less steep, the beaches muddy and the bars with a single exception conspicuous by their absence. This is a spit which developed southward across the entrance to a large huckleberry swamp and probably did not rise above the former level for much of its extent. This contrast, which is emphasized by the encroachment of vegetation at the more protected places on the west side, shows clearly the greater effectiveness of the westerly winds.

At the ends of the lake the topography of the shores is very dissimilar, and the more pronounced effects have been produced at the north end under the drive of southerly winds, although the spit noted on the west side indicated stronger northerly winds. Thus, the land at the north end is low with the exception of the island-like hills at Highland from which complete bars swing in either direction around the head of the lake and cut off a broad swamp. At the south end, however, the land is higher and cliffs predominate.

With these general considerations the specific features may be left to those interested to work out. As a final consideration attention may be called to the geographic

relationship between the physiographic development of the shores and the settlement of all but the west shore of this very popular lake.

CHAPTER XI. LAKES OF THE PORT HURON MORAINIC AND OUTWASH SYSTEM

The lakes included in this group are located within the Port Huron morainic system, 4, Fig. 3, and in the area between this system (and the Valparaiso-Charlotte moraine, 3, Fig. 3. In general, the glacial deposits of this area are irregular in distribution with the exception of two areas: The lake plains of the southeastern part of the State and the regular series of formations which mark the retirement of the Saginaw lobe. In the latter of these areas the lakes are few in number and relatively unimportant and in the Erie plains they are almost entirely absent. The one lake of the Erie lowland (Ottawa) seen by the writer is little more than a mud hole, a large part of which dries up during the summer, and is interesting only as an example of a lake located in a sink. There are also no lakes of importance in this section of the eastern interlobate area, which extends well into the "Thumb" region. Therefore, the lakes in this group are located in the north central and western parts of the Southern Peninsula but do not include the lagoons along the west coast which are discussed in the following chapter.

CRYSTAL LAKE, MONTCALM COUNTY

Crystal Lake lies seven miles south of west of Stanton in eastern Montcalm County and may be reached by a drive of about ten miles over roads that were found in excellent condition. It is one of the few popular lakes which are located in the regular series of deposits of the Saginaw lobe.

The glacial formations have a north-south trend in this locality and the lake lies in an irregular morainic depression that originally consisted of several basins. This depression is situated on the edge of a sandy moraine which gives way to a till plain just east of the lake. The easily eroded material, the irregular outline of the lake, and the succession of hills and swales at the shore made favorable conditions for the numerous adjustments found on all the shores except the north, in which locality the lakeward slopes are uniformly gentle. At the uplands sharp cliffs show cutting by the waves, at the swales bars, usually complete, indicate the activity of currents, and on the gentle slopes, ramparts signify shove by the ice.

In addition, the shore adjustments enable one to decipher an interesting series of events in the physiographic history of this lake. The most favorable locality for this study is along the southwest shore where a former bay has been cut off by a series of bars and rampart-bars. The highest is a large sand bar which stands fully six feet above the present level of the lake. Between this bar and the lake are two distinct rampart bars at intermediate elevations which mark halts in the lowering of the lake to its present level. This locality requires careful study but, once solved, will (simplify further study of the shores.

The most significant adjustment was the dosing of the mouths of embayments by bars which, with the lowering of the water level, reduced the original area of the lake by at least one-half. In this connection the spit which developed along the northeast shore on the flat between Crystal and Mud lakes may be mentioned.

COLDWATER LAKE, ISABELLA COUNTY

Coldwater Lake is ten miles northwest of Mt. Pleasant in west central Isabella County; but a drive of fourteen miles from this, city is necessary to reach the lake. The lake rests in a pit in a narrow strip of outwash, which fronts a moraine to the eastward and was formed by border drainage, that is drainage running parallel to the ice front. The pit is located so close to the moraine that the southeastern shore is composed of the till of this formation. The relief along this shore, therefore, is great and presents a decided contrast to the surface of the outwash which rises barely more than ten feet above the level of the lake.

The adjustments are slight indeed along the shores bounded by outwash although many lakes similar in size—the length is approximately one mile and the width one-half mile—have decided shore features. The cliffs on the east shore show some wave action, but the southeastern shore, where the uneven morainic topography furnished more favorable conditions for adjustments, is the most interesting. In particular, may be mentioned the large amphitheatre which opens into the lake. Two well developed spits, which stand at elevations of three and five feet above the present level, swing out into the opening in parallel courses from the south shore and show that this indentation would have been cut off eventually, if their development had not been stopped by a lowering of the water level.

It is evident from the spits just mentioned that the lake has stood at two higher levels but the presence of an old dam on the outlet a few rods from the lake makes uncertain the relationship between at least one of the spits and a natural level of the lake. The level of the lake when the dam was operative and the length of time that this level was maintained was not learned, and it is possible, then, merely to make the suggestion that the lower and weaker spit was formed at this artificial stage.

Aside from the shore features at the southeast end, the lake furnishes an example of the partial filling by marl, formed in part of the minute shells that are abundant on the beach.

MISSAUKEE LAKE

Missaukee Lake is the largest of a group of ten or more lakes which are located in west central Missaukee County. It may be reached via the Lake City Branch of the Grand Rapids and Indiana R. R. which stops at Lake City on the east shore of the lake.

All of these lakes lie in pits in an outwash plain and of these the Missaukee Lake depression is by far the largest; it is nearly circular with a diameter of somewhat less than two and one-half miles. The lakes either have no outlets or drain eventually into Missaukee, the southeastern member of this group. Inasmuch as the drainage of the region in general is to the southeast, Missaukee Lake occupies the key position and it has no natural outlet, the artificial channel operating only at infrequent periods of exceptionally high water. The Missaukee Lake depression, although it contains the deep holes characteristic of pits, is nevertheless, very shallow. The writer's information is that the general depth of water is approximately fifteen feet, and, inasmuch as the surface of the lake stands about ten feet below the surface of the outwash, the total depth is twenty-five feet. The shallowness of the water must hinder the development of the larger waves but, nevertheless adjustments of the shore have taken place, due probably to the ease with which the outwash material is worked.

The adjustments are found above the present surface of the lake and indicate the usual higher level in past time. Along the south and east shores the depression has regular walls, and an almost unbroken, wave-steepened cliff faces the lake. At the foot of the cliffs there is now exposed a broad sand flat which continues beneath the water to a decided "drop-off" wherever the water is deep, as at the east end. The effects of current action are best seen along the very irregular north shore and are too numerous for specific mention in this brief report. Before leaving Lake City a well developed bar may be seen, and along the north shore examples of exposed spits, bars enclosing lagoons, and land-tied islands are numerous. The north shore bars are distinct but stand at a lower elevation than that at Lake City which is interpreted as an indication that these forms were in process of formation when the lake level subsided.

The extinction of former embayments by draining and vegetal accumulation is another interesting phase of a physiographic study of this lake, the details of which should prove to be well worth while.

The lake has not kept pace with many others as a summer resort but has qualifications which are superior to some of the more popular, including good fishing and favorable shore conditions on the south side.

MANISTEE LAKE

Manistee Lake is in northeastern Kalkaska County and may be reached from the town of Kalkaska on the Grand Rapids and Indiana and the Pere Marquette railroads. A drive of ten miles is necessary but the writer found the road good with the exception of the last mile.

This lake is located on the southwestern extension of the interlobate area between the Michigan and Huron lobes which joined at approximately right angles in the vicinity of Gaylord. The formations involved are a moraine, the Port Huron, and a rather broad strip of outwash lying to the southeast. The lake lies on the outwash at the junction of these two formations. It is the largest lake in the region, having a length of two miles and a width that averages nearly a mile. The basin is regular in contour but varies, most on the west side, due possibly to the influence of the moraine whose border runs not far from this shore. The basin forms a part of a broad drainage channel which is followed by the Manistee River to the southwest. Either the outwash is excessively pitted near the lake or the basin is not a pit, for the slopes quite generally rise gently from the lake. Whatever the origin of the basin may be, a small amount of material was furnished by wave action but this was distributed to such advantage that pronounced changes were effected. Thus, at a higher level the waves cut a broad terrace on the east shore and the material was worked southward into a strong sand bar which crosses the lowland at the south end as far as the outlet. On the opposite side of the outlet the material derived from the short stretch of low shore was carried in both directions and deposited in small spits near the outlet and on the south side of the entrance to an embayment to the northwest. Other adjustments were found on the west shore including well defined ice ramparts where conditions are favorable for their formation. The lake is not popular as a summer resort so far, as there are no cottages but it is visited by fishermen and campers who can get boats at the south end.

BIG STAR LAKE

Big Star Lake is located in the southwestern part of Lake County and has an area of about two square miles. Its length is more than two and one-half miles but its outline is so irregular that the width varies from less than one-fourth mile to more than one mile. It is not so popular as similar lakes nearer Lake Michigan but, nevertheless, is an attractive lake which should develop as a summer resort in the future. The nearest railroad stop is Baldwin on two lines of the Pere Marquette system, eight miles distant by road. The writer found the road from Baldwin to the lake in good condition and advises this route for those unfamiliar with the winding sand roads of the jack pine and grub oak plains.

The nature of the Star Lake depression is very easily recognized for one may almost fail from the edge of a

most monotonous sand plain to the lake shore, so sharp are the bluffs which surround the lake. It is clearly a pit but is large and much more irregular than the present crooked outline of the lake. This disparity between the outline of the pit and the lake is due to the adjustments of the shores at a higher level, the greatest changes having been, caused by the deposition of bars across the mouths of bays. Such, adjustments are best defined on the south side and are well illustrated along the southwest shore where a bar completely closes a narrow lagoon. Similar forms, but not complete at the larger, embayments, may be found on the south shore. The source of the material of these bars is the numerous sand cliffs which rise nearly twenty feet above the lake. Apparently a small amount of recession of the cliffs was sufficient to supply the material inasmuch as the off-shore terrace, although well defined, is narrow, and the strip exposed by the recession of the water has been removed from the foot of the cliffs.

The north shore consists of broad bays and headlands, and currents have developed along the shores of the bays rather than across the entrances, eventually dissipating in the lake off the ends of the points. Thus the changes in the outline on this shore are less striking than on the south side.

FREMONT LAKE

Fremont Lake is situated on the southern edge of Fremont in southwestern Newaygo County, the city limits extending to include a park on the north shore of the lake. The town is located on the Muskegon-Big Rapids Line of the Pere Marquette R. R., and the lake is not an unreasonably long walk from the station.

The basin lies at the border between outwash and till plain and is rather difficult to classify as to type. The till plain borders the north and east sides of the lake, the remainder of the shores consisting of the sands of the outwash. Also the eastern part of the basin is shallow, a characteristic of lakes in the sags of till plains, but the western part is deep. Thus, it appears that we have here a pit which is open to the east and that the water is sufficient in amount to fill not only this pit but also flood an adjoining depression of the till plain to the east.

The basin is very regular in outline and consequently very few adjustments by shore currents are to be found. The two bars noted stand at an elevation which denotes a former level of the lake about three feet above the present surface. One, a very indistinct spit, runs northwestward on the low flat at the southwestern part of the lake, and the second, also a spit but much better developed, extends from the bluff on the west side of the outlet to the stream channel. A much greater adjustment resulted from the action of waves and undertow and consists of numerous cliffs but more especially a decided submerged terrace. The terrace is uniformly present but varies in width, being greater along the shores bordered by outwash. The outer part of this terrace is exposed by the sinking of the water level, forming a sand flat which has a width of more than one hundred feet in places on the south shore. Ice shove is also effective as shown by the decided ramparts in the vicinity of the outlet. In some places as many as four ramparts were found, giving the impression of an ice-shove terrace although it is probable that such is not the case.

Another interesting feature is the delta which is the site of the park on the north shore. This delta consists of the silt deposited by the stream which enters at this point and was built at the higher level. The stream now carries a different type of load, consisting of the refuse of the canning factory and tannery which makes a very unpleasant condition of the shore.

BIG BLUE LAKE

Big Blue Lake is in the northeast corner of Muskegon County and may be best reached from Whitehall on the Pere Marquette R. R. One may go in from Twin Lakes or Holton, but, in any case, the roads are not good for automobile traffic at the present time. They are sand roads which offer difficulties even to those who are familiar with their peculiarities. A favorite description of such roads is parallel snake tracks through second growth woods, which means constant attention to the steering of the machine in order to avoid getting out of the tracks and striking trees or stumps. Also the sand becomes loose in dry weather and the traction is very heavy making it almost impossible for heavy machines to "plow through." Frequently, the familiar north-south, east-west system of roads is sadly lacking, and numerous branch roads offer opportunities to stray, none too pleasant an experience for most people in such thinly settled areas. The writer suggests the road from Whitehall.

It is obvious from the foregoing statements that Big Blue Lake, although within ten miles of a railroad, is not readily accessible at the present time. Yet it is a very attractive lake and is frequented by those who desire a complete change from the formalities of city life. The visitors come almost entirely from the vicinity of Chicago and have built a number of cottages which are grouped at the east end and at two localities on the north shore.

The lake measures nearly two miles in length by about three quarters of a mile in greatest width and lies in a deep pit in an outwash plain. In addition to the main depression, small pits are so numerous that the lake shores have a rolling topography, and the varied shore conditions made possible numerous adjustments which have been readily accomplished in the loose sand. These changes occurred at a level five feet above the present and are so numerous that mention of each feature would entail a description of almost the entire shore of the lake. The bluffs have been steepened by wave action and drop to a narrow exposed terrace which frequently continues under water to a "drop-off". At the embayments the bars, which rise well above the present level, are so well developed that it is possible to follow

the shore around the lake dry shod except at the small brook which drains the lake. In addition to the work of waves and currents evidence of strong ice push may be found. This is the only noticeable adjustment which is taking place under present conditions.

TWIN LAKES

Under this heading are four small lakes which are located about ten miles northeast of Muskegon on the Muskegon-Big Rapids Line of the Pere Marquette R. R. They are now known as East, Middle, North and West lakes. All of these lakes lie in shallow pits in the same outwash plain as Big Blue Lake, six miles to the north. None of the lakes has an area of one-half square mile but, inasmuch as they are connected, the group may be considered as one.

The water level now stands about ten feet only below the outwash surface. The lakes have no surface outlet and consequently the water level varies over periods of years, the highest level as recorded by the shore features having been three feet above the present or about seven feet below the plain. Thus, at that time the waves were able to accomplish much without the removal of am excessive amount of material and as a result there is present an off-shore terrace that appears out of proportion for a lake of this size. A part of the material quarried by the waves was distributed along the shores also and formed a number of distinct bars. One of the best localities to observe these is on the north shore at the connection between East and Middle lakes. The bars on Middle Lake are stronger than those on East, one in particular nearly crossing the lowland connecting the two lakes. Also in the same vicinity an island was tied to the mainland of Middle Lake. Two spits extend out from the south end of this island and show clearly the difference in activity of the currents in the two lakes at this point. The larger spit developed in Middle Lake, due to the greater power of the westerly winds. Another interesting example of the development of a spit occurs at the east end of North Lake where a broad arm of this lake was nearly isolated and has since become a marsh. Other similar features may be found on the shores of these lakes, and their discovery may be left to those interested.

The lakes are connected with Muskegon by an improved road in addition to the railroad and are popular summer resorts. A camping ground and boat livery are located at the east end of East Lake but the majority of the summer inhabitants own cottages many of which are much more pretentious than the usual summer resort cottage.

WOLF LAKE

Wolf Lake is six miles east of the city limits of Muskegon and within one-fourth mile of the main road between Muskegon and Grand Rapids. Auto bus service to the lake is maintained in summer so that no difficulty need be experienced in reaching it. The ride, however, is most monotonous for one travels over a sand plain so flat that even a slight variation in the surface claims the attention, and the variations are few indeed. Once there, the lake comes into view abruptly and is recognized at once as a pit for the sand plain near the lake is outwash and steep bluffs rise consistently from the water to a height of about twenty-five feet on all sides.

The regular outline of the lake as shown on the map is misleading as far as the original basin is concerned for there are small embayments on all but the south side. This change in outline is due to the natural development of shores which occurred when the lake stood nearly five feet higher than at present. The lowering of the water exposed the former shore and, thus, facilitated the study of its features. Inasmuch as the lake has no outlet, the drop in level is an indication of a climatic change, the significance of which is not as yet clear.

On a lake the size of Wolf,—less than one square mile in area and with a greatest diameter of less than a mile,—the waves and currents are comparatively feeble, but the high bluffs of loose sand were easily eroded, thus furnishing abundant material without seriously reducing the power of waves or currents. Consequently, the bluffs, although steepened, have not receded to any great extent and there is no decided off-shore terrace. The work of the shore currents, however, is much more noticeable in that a relatively small amount of material was deposited in such a way as to cause very decided changes in the outline of the lake. The reference here is to the bars which developed across the necks of embayments. These bars do not completely close the openings in all cases but are consistent in that their development shows a direct relationship to the prevailing winds. Thus, along the east shore which is exposed to the strongest winds one may follow the shore irrespective of cliff or swale because the bars are complete, but on the north and west shores only spits are found.

The lake has insignificant inlets and is fed mainly by springs, which accounts for the exceptionally clear water. This in combination with clean beaches, excellent locations for cottages along the bluffs, and good fishing has made this lake a favorite with the residents of the vicinity.

CHAPTER XII. BORDER LAKES AND LAKES OF DIVERSE ORIGIN OUTSIDE THE PORT HURON MORAINIC SYSTEM

The lakes described in this chapter constitute our fourth group and include those which lie outside the limits of the Port Huron Morainic system, 4, Fig. 3, as well as the border lakes which are within the area of the third group. The border lakes are so numerous that the fourth group may be conveniently subdivided into border lakes and those of diverse origin.

BORDER LAKES

The border lakes are all former coastal embayments which have been cut off by the development of great sand bars across the, openings and are, therefore, lagoons. The bars developed during higher stages of Lake Michigan—Algonquin or Nipissing—and were left well above the water level when the waters of these lakes subsided. Then there followed a period of eastward movement of the finely assorted sand of the bars caused by westerly winds and deposition of the sand in great rows of dunes which are unsurpassed, at least as regards size, so far as is known. Later the dunes became covered with vegetation which so effectually stopped their, movement, always to the east, that they have remained fixed in, position to the present time, except for occasional blow outs.

A blow out is merely the renewal of the movement of a fixed dune but apparently originates in a limited area and works up the front slope in a narrow zone to the very crest. This results in a great trough on the front slope, the transformation of the crest into a saddle, and a fresh deposit of sand on the back slope which is very steep. Often the blow outs encroach on the lagoon, causing a projection of the shore, and in this way contribute to the filling of the basin. It is recognized that the dunes are but indirectly related to the study of lakes, but they are most attractive and furnish such excellent locations for summer homes that this brief sketch, of their history seems warranted.

Even though the manner in which these embayments were isolated be known, there still remains the problem of the type of embayment, of which there are several. Some are easily recognized but others, for example Pine, Walloon, Torchlight, etc., which are described in an earlier chapter, present difficulties. Among the types of basins easily recognized are the numerous drowned mouths of streams. The causes of the drowning, or partial submergence, of the mouths of the streams entering the southern part of Lake Michigan is due to the uplift of the land in the northeastern part of North America following the retirement of the glacier. It is not necessary to go into the details of this complicated subject to realize that, if the lower part of Lake Michigan were not affected by the uplift while the northern part was being elevated, the water would pile up in the southern part of the lake and, thus, rise with reference to the land. Such was the case and in the tributaries of Lake Michigan as far north as the Betsie River at Frankfort the water backed into the mouths of the stream valleys.

The outline of such lakes is very irregular and, in a typical case, consists first of a main channel which may, or may not, be winding. Farther inland the main channel ramifies and each ramification may in turn divide so that the pattern resembles that of a deciduous tree. In all cases in Michigan the lakes branch to the east and, inasmuch as the strongest winds are from the west, the force of the waves is so largely dissipated in the diverging channels that the effects are insignificant. Conditions were unfavorable for adjustments by shore currents and the occurrence of features due to these agents are very exceptional. Waves and undertow were effective in forming cliffs and terraces which are found with monotonous regularity at levels above the present, In particular the level of Lake Nipissing which stood about fifteen feet above the present lake along this part of the shore. One other common characteristic of these lakes is the tendency for the heads of bays which have entering streams to be silted up, forming a delta-like flat which has pushed a singularly even front into the lake.

This degression, which possibly over-emphasizes the characteristics of the drowned-river lagoon, was made purposely in order to avoid the dull repetition which became very apparent when the attempt was made to discuss individually each lake of this type. Nine of these lakes were visited by the writer, as follows: Kalamazoo near Saugatuck, Black near Holland, Spring near Grand Haven, Muskegon, White near Whitehall, Pentwater, Pere Marquette near Ludington, Manistee, and Betsie at Frankfort. A number of these are well known ports which need no discussion here except that they are thereby made more accessible. Their use as summer resorts, however, is of interest. The exposed terrace of the higher level serves as an excellent site for cottages and their location just east of Lake Michigan assures at least a tempering of the summer heat. It is not surprising, therefore, to find some of them almost lined with summer homes many of which are costly estates. Of these mentioned Black, Spring and White are the most popular.

The lagoons of diverse origin, obviously, cannot be discussed as a group as were the drowned streams nor can the probability of shore adjustments be postulated in advance. Consequently they are discussed individually, although this method may give undue prominence to some of these lakes.

BASS LAKE

Bass Lake is located about five miles north of Pentwater and twice this distance south of Ludington, both on branches of the Pere Marquette R. R. Ludington is also accessible by boat, but in either case a drive is necessary to reach Bass Lake, which is situated near the excellent West Michigan Pike.

The most distinctive feature of this lake is that it parallels the Michigan shore instead of extending inland. The west shore consists of an exposed sand bar which is not wholly obscured by dunes and on the opposite side the land slopes gently upward to a sharp rise at the same elevation as the bar, this elevation being that of Lake Nipissing. Furthermore, the lake gradually increases in depth towards the west side and at most hardly exceeds twenty-five feet. The basin, therefore, is the deeper part of a shallow embayment which existed during Lake Nipissing and is masked by sand so that the surface indications are of little aid in the determination of its origin. It appears to be part of a narrow crescentic lagoon which was isolated during Nipissing time, the position of the bar having been determined by the then prominent headland a few miles north. This type of lake is rare in Michigan, the only other example seen by the writer being Devil's Lake near Alpena, an unattractive lagoon rapidly filling with vegetation.

The shore features of Bass Lake are very similar to the lagoons already discussed. The Nipissing shores are best developed and stand about fifteen feet above the lake. They consist of a broad terrace and cliff on the east side, and of a sand bar and flat on the west. Below the Nipissing terrace a lower exposed terrace is evident on the east shore but no deposits by shore currents were found. Aside from the terraces the most interesting physiographic development is the large delta formed by a stream entering the east side of the lake. This delta is triangular in shape but is exceptional in that it extends into the lake as an apex rather than one of the sides of the triangle, due to the fact that the stream did not form distributaries.

The lake is developing as a summer resort and cottages have been built on both sides. The west shore in the dune area is by far the better location and is also the more popular.

PORTAGE LAKE, MANISTEE COUNTY

Portage Lake is located eight miles north of Manistee and may be reached by the boats of the Michigan Transit Co., the Manistee and Northeastern R. R. from Manistee, and by automobile over excellent roads. The lake is three and one-fourth miles in length. Two broad points, one each on the north and south shores, break the otherwise regular shores but are offset in position so that they give the effect of a sinuous channel of about one mile in width. This is misleading, as may be determined from the very excellent Lake Survey Chart No. 777 which shows that the lake consists of two basin's separated by a narrow submerged ridge over which the water is but sixteen feet in depth. The greatest depth of the basins is sixty feet in each case but the eastern basin is much the larger in extent. The lake is separated from Lake Michigan by a narrow row of high dunes which is continuous except for two gaps, one across which the present channel has been dredged and another one mile north which was the natural outlet of the lake.

The basin resembles an elongated amphitheatre, the walls of which are moraine of high relief, the floor is till plain and the stage the dunes. Such a distribution of glacial formations is evidence that the depression was in existence at the time of the last advance of the glacier and that a small lobe flowed into the depression, the front of the ice halting for a time sufficient for the formation of the moraine. The bar which closed the open end was formed during Nipissing time and the dunes were formed subsequent to the subsidence of that lake.

The shore features of Portage Lake are very simple and require little more than brief mention. The specific features are all found at the Nipissing level and consist almost exclusively of a cliff, below which a broad terrace slopes to the lake. The only example of a bar seen on other than the west shore was at Onekama where a small stream is turned westward by it. Another physiographic form is the broad flat at the east end of the lake which is interpreted as a delta built during Nipissing time. The northern half of the submerged ridge which crosses the lake off North Point, as shown on the Lake Survey Chart, is at least, suggestive. The material is sand, and the form and location are characteristic of the beginnings of a shore current deposit.

This lake shares the popularity of the lagoons of the Lake Michigan coast but has not developed as a summer resort to the same extent as some of those farther south. Numerous cottages are scattered along the shores but the favorite location is on the dunes at the west end. Here is a large colony which includes a well appointed hotel, a recreation pavilion and a large number of private cottages. A water supply system is maintained so that a very comfortable vacation may be spent on this lake.

PLATTE LAKES

The Platte Lakes, Big and Little, are situated in western Benzie County on a triangular-shaped flat bounded on the east and south by moraine and on the west by Lake Michigan. The nearest railroad stop is Honor on the Manistee and Northeastern, but railroad connections from the south are not convenient. A drive of less than three miles brings one to the narrow strip of land which separates the two lakes. Another route is to drive from Frankfort which is the northern terminus of the Ann Arbor

R. R. and also a stop for the boats of the Michigan Transit Co. The latter route involves a ten mile drive the last half of which was found to be over heavy sand road. The more comfortable trip for automobiles is through Honor.

The writer attempts no explanation of the origin of the lake basins in this flat because the area was covered by one of the predecessors of Lake Michigan and is, therefore, masked by sand. Whatever the type of basin, it is known that this area was once flooded, with the exception of a group of high morainic hills on the north shore of Big Platte, and furthermore was connected with Crystal Lake through the Round Lake depression which is followed by the road. The narrow connection between the two lakes was closed by a bar along the Crystal Lake shore and the main depression at least partially separated from the main lake in a similar manner.

The shore of Lake Algonquin in this vicinity washed steep cliffs that stand well back of the present lake shores and furnish the chief source of interest in the study of the Platte Lakes, for the adjustment of the present shores is negligible. A complete study of this former lake involves an area of more than twenty square miles and a similar number of miles of shoreline. Time was not available for such a study but a hint of the possibilities was gleaned from the bars noted near the outlet of Big Platte. Near the lake the bars follow the outline of the shore and, therefore, are evidence that this lake was isolated from Lake Algonquin and that this level was maintained for some time. A study of these lakes might well begin in this locality and should by all means include the area along the outlet to Lake Michigan. Another locality that should prove interesting is that to the northwest of Little Platte.

The Platte Lakes are extensively fished but in other respects are not so well adapted to general summer resort purposes as many of our lakes. There are a number of excellent locations for cottages on Big Platte but a large part of the shore is low and, not desirable as a building site.

GLEN LAKE

Glen Lake and surroundings form one of the most attractive bits of scenery of its kind the writer has had the pleasure of seeing. We may pass over the details of its location in western Leelenau County and the routes to the lake very briefly. The trip by the Michigan Transit Company's boat is pleasant but the sailings are infrequent. The trip in from Empire, seven miles distant, must be tedious on account of poor railroad connections. The trip from Traverse City by automobile is long, although the roads are not bad. The inference that the lake is somewhat difficult to reach is correct, but the effort is well, worth while.

The Glen Lake depression may be likened to a great oval race track in the center of which is a large island, the present Glen Lake filling the entire eastern and the southwestern part of the oval course. The stands which surround all but the north side of the depression show an evolution, the originals consisting of a loop of high hills on the east and south. Later developments erected a west stand, the sands of the great Sleeping Bear. The best seats are located in the south and east stands for from here one may see below the cobalt blue water of the circular main basin of the lake with its fringe of maize, and off to the west is the narrow arm of the lake which bows to the Sleeping Bear.

The depression was very probably in existence previous to the final invasion by the glacier which slightly overran the depression, and persisted in its position. During this time earthy material was constantly beng brought forward and dropped as the ice melted. This material was piled higher and higher in hugh hummocks so that when the ice finally disappeared a high moraine or wall was left, which constitutes the south and east limits of the, basin. But this explanation does not account for the high land, (island) in the central part of the basin and, therefore, is qualified. This high land was once certainly an island for the waters of Lake Algonquin entered the basin through channels on the north and on the west sides isolating it. For a time the waves and currents of Algonquin coursed the track but eventually the western entrance was closed by a sand bar. Then followed a subsidence of the lake to the level called Nipissing and the west stand (the Sleeping Bear Point) was erected, the material being the sand of the bar and the builder the wind. The great Sleeping Bear is now a blow out, or better a moving dune. The colors of the lake are significant. The blue is due to a modification of the sun's rays as they pass through the water and the depth of color varies with the thickness, therefore the lake is deep. Similarly, the narrow but sharply defined fringe is the yellow of the sands seen through a thin layer of shallow water, signifying a submerged terrace. A final step was necessary for the complete isolation of the lake, namely the closing of the north entrance during Nipissing time by a series of bars which still retain the water at an elevation of seventeen feet above Lake Michigan.

Our interest in the lagoons lies primarily in deciphering their geologic history but Glen Lake also furnishes many examples of shore features so generally lacking on lakes of this type farther south. These features, formed to a large extent when one or both of the entrances were open, are naturally on a large scale. Thus, the cliffs are high and steep, the bars complete and large, and the offshore terrace wide and distinct. A final episode is due to the interference of man and is unfortunate. Reference is made to the damming of the outlet which has not seriously flooded the lake but has renewed the activity of the waves. The consequent recession of the cliffs is serious and will result in the destruction of portions of the newly graded boulevard, for effective preventive measures are too costly to be feasible.

This lake is beautiful, its physiography is most interesting, and the shore conditions are excellent, but, nevertheless, cottages are not numerous. It appears to

lag on account of its isolation but must develop rapidly as a summer resort once its qualifications are appreciated.

GRAND LAKE, PRESQUE ISLE COUNTY

A number of lakes that would naturally be discussed here, Elk, Torchlight, Pine, etc., have already been described in detail, so we must pass on to the Huron shore to complete this part of the group. Grand Lake is situated in western Presque Isle County within three miles of Lake Huron and a somewhat greater distance directly north of its neighbor Long Lake, which is described in detail in an earlier chapter. A long ride is necessary to reach the lake from Alpena, the most convenient railroad stop, but the road is excellent for most of the drive. Reference is made to Long Lake because of the great similarity of the two lakes in form, size, orientation, shore conditions and type of basin. With slight variations a single general description could be made to serve for both. Grand Lake varies in two respects: It has numerous islands and is a lagoon or at least an arm of the predecessor of Lake Huron.

The basin probably does not exceed thirty feet in depth and on the average is considered shallow. Its total length is more than eight miles and the maximum width not greater than two. A conclusion as to the origin of this elongated depression is a matter of considerable difficulty, inasmuch as a number of factors which cannot be accurately determined must be considered.

The lake is located in a region in which the bed rock is thinly covered with glacial deposits and in places outcrops at the surface. A logical inference, therefore, is that the basin is not due primarily to glacial action insofar as deposition is involved. However, the course of the lake is parallel to the movement of the glacier and the possibility of glacial scour suggests itself at once. In following this suggestion, the distribution of the underlying rocks is an important aid. They are all tilted sediments and, if not covered, would appear at the surface in belts which correspond quite closely with the orientation of the lake and the movement of the ice as well. The geological map of the region shows us that the lake stands on a narrow belt of shale on either side of which is limestone and also that the lake shores along the sides coincide fairly well with the boundaries of these formations. Inasmuch as shale is much more easily eroded than limestone, it is logical to conclude that a trough was eroded in the shale. The presence of the! numerous islands, however, is evidence that this was accomplished to a greater extent by running water than by ice for ice would have .swept the basin clean. The final isolation of the basin was accomplished by shore currents of Lake Nipissing which closed the ends of the trough. This conclusion, however, is too definitely drawn. The glacial cover is more complete on the east side than on the west, and the position of the boundaries of geological formations, where not actually exposed, are relative at best. Therefore, the manner of formation of this basin as given should be considered as a basis for future work which will furnish the facts necessary to the solution of the problem.

The study of the shore of this lake was a disappointment. The effects of ice shove were noted in several localities but aside from this little was found. The beaches are almost uniformly of coarse material and show little assortment, the one exception being the sand beach near Birch Hill. Such a condition is, however, not surprising if certain features of the lake are kept in mind. The shallow water and numerous islands greatly hinder the normal development of the waves, and the moderate waves that are formed are further reduced in crossing the off-shore shoals. Finally when they strike the beach they encounter a compact till, which is heavily laden with large rock slabs, and can accomplish little. Also the currents are of a like order with the additional deterrent factor of an irregular shoreline which, obviously, does not furnish any extended stretch of shore along which the currents may develop. The most conspicuous feature about the lake is the sheer rock cliff which follows the west side. The cliff stands above and back from the lake and is probably the shore of Lake Nipissing the waves of which were capable of a powerful attack.

The lake is especially attractive on account of the numerous bays, headlands and islands and is extensively visited during the summer months. Numerous cottages occur in groups at the more favorable locations on the east side and future development is to be looked for.

VAN ETTEN LAKE

Van Etten Lake is located within a mile of Lake Huron about two miles north of the village of Oscoda on the Detroit and Mackinaw R. R. The lake has a length of nearly four miles and a width of less than one. This narrow basin extends from Lake Huron in a northwesterly direction to an extensive swamp and apparently continues as the valley of the Pine River. It drops below the surface of a sand flat in bold cliffs and is exceptionally regular in outline. The sand flat is a long strip which lies between the Algonquin and Nipissing beaches and is, thus, the off-shore terrace of Lake Algonquin. Upon this eastward sloping terrace Nipissing bars developed hemming in several shallow lakes such as Tawas, which is little more than a marsh, and Cedar. Van Etten Lake is also located between the two shores, the Algonquin passing just west of the upper end of the lake and a Nipissing bar serving as a retaining wall at the lower end. The basin is much deeper than those of the other lakes on this plain and is clearly of different origin. Just what the origin may be is difficult to determine and one can do little more than conjecture until detailed studies are made. As a working hypothesis the writer suggests that, when the configuration of the basin is known, it may be apparent that the basin is a broad channel cut through the sand flat by the Pine River after the recession of the lake to the Nipissing level.

The shore features of Van Etten lake are relatively simple. Cliffs predominate and step down to the shore showing a former level about four feet above that at present, probably the Nipissing. Although the west shore is less regular than the east there are no decided embayments other than the valleys of entering streams, and bars are not found. Nevertheless, currents were active and left the shore at the points, forming poorly developed cuspate forelands, all at the higher level. The most decided physiographic feature, however, is the partially isolated basin at the upper end which is an excellent example of filling by vegetation.

The excellent East Michigan Pike parallels the west shore a few rods back from the lake and possibly accounts for the growing popularity of this side of the lake. This shore is rapidly being built up but the east side is apparently being deserted, although, skirted by a good road.

LAKES OF DIVERSE ORIGIN

The lakes described in this chapter, Group IV, which are not lagoons are located with one exception between the limits of Lake Algonquin and the Port Huron Moraine, 4, Fig. 3. The lakes visited occur in two groups with the exception of Carp Lake near Mackinaw City and Bear Lake on the west side of the State. One group is located along the boundary between Iosco and Ogemaw counties and the other a few miles southwest of Traverse City.

The lakes of the first group lie on a strip of moraine of very irregular shape and of great relief. The sharp slopes and sandy material of the moraine are not conducive to good roads, and a trip through this region by automobile is not an unalloyed pleasure. Ellake at the west end of Long Lake is a station stop on the Rose City Branch of the Detroit and Mackinaw R. R. but a visit to Sage Lake necessitates a drive.

LONG LAKE, IOSCO COUNTY

Long Lake appears more like a channel than a lake for its width barely exceeds one-fourth mile but its length is more than two and one-half miles, if its sinuous course is measured. The eastern part of the basin is a very irregular morainic depression which continues westward onto a till plain. Many of the irregularities of the basin do not appear on the map because their depths are not sufficient to bring them below the present level of the lake. In the past, however, a higher level was maintained which, although it stood only four feet higher than that at the present time, flooded several large embayments on the north side. From the study of the shores it is apparent that these indentations were abandoned because of the sinking of the water level rather than by their isolation by bars. A number of small bays were cut off by bars and some of the points lengthened by spits but, in general, the adjustments were still in an early stage of development when interrupted.

Among the specific localities where adjustments may be seen may be mentioned the sharp point on the southeastern shore. The greater part of this point is not a current deposit, but the distal end is clearly a spit which continues as a submerged bar across the narrow channel between it and the north shore. Another interesting locality is at Kokosen Resort. Currents were especially active on the west side of the point and, in addition to a straightening of this shore, have built a small hook which curves to the southeast from the tip of the point. East of the point several small indentations are completely isolated by bars and, at the large bay that runs north to a small circular lake, a long spit extends eastward part way across the depression. These forms are all at the higher level and may be readily observed.

The lake has a large group of excellent buildings at Kokosen Resort which apparently has declined in popularity in recent years.

SAGE LAKE, OGEMAW COUNTY

Sage Lake is not easily reached and a long drive is necessary whatever route is taken. The roads were not in good condition at the time of the writer's visit to the lake and the route taken was so roundabout that no directions as to roads are suggested.

The lake is more than two and one-half miles in length and has a maximum width of one mile. Perhaps the homely comparison of a meal bag tied near each end will serve to describe the shape of the lake. The main part of this lake lies in a depression consisting apparently of a number of morainic sags so placed as to form a large basin which completely trenches a strip of very sandy moraine, and the narrow ends are the extension of the basin onto the till plains which flank the moraine. The basin was not studied in sufficient detail, however, to venture a conclusion as to the cause of this peculiar grouping of the sags.

The moraine is one of very strong relief in this locality and the road which skirts the northeast shore is a succession of hills and swales. The swales are large and the shore, therefore, consists of an alternation of broad bays and prominent headlands. The southwest shore, however, is much more regular and is fronted by a cliff that is almost continuous. The adjustments of the shores of this lake all stand at an elevation between three or four feet above the present level and indicate an even earlier stage of development than those found on the shores of its neighbor, Long Lake. The headlands and high banks have been carved into steep cliffs but the off-shore terrace, where present, is poorly developed. Conditions are favorable along the northeast shore for deposition by currents but little had been accomplished when the sinking of the water level interrupted the work. No case of a complete bar was found but several spits were noted on the northeast shore. In all cases the spits are attached to the east sides of the headlands, indicating prevailing currents from the west. The best example is located just west of

the Lake View House and is a hook about one hundred feet in length.

Sage Lake has not been developed as a summer resort but a beginning has been made. The waiter is inclined to believe that this is due very largely to the difficulty encountered in reaching it. When the roads are improved this lake will be better known and should attract an enthusiastic summer colony.

CARP LAKE

Carp Lake is located on the boundary of Emmet and Cheboygan counties about seven miles south of Mackinaw City. The Dixie Highway and the Grand Rapids and Indiana R. R. both pass the west end of the lake. The lake is more than three miles in length and one and one-half miles in greatest width but is shallow. The basin lies within the limits of Lake Algonquin which flooded the region with the exception of a small patch of moraine which borders the northwestern shore of Carp Lake. The original characteristics of the basin are, thus, concealed by the sand which was distributed over this area by the waves and currents of Lake Algonquin. However, the presence of a moraine suggests the possibilities that the depression may be a large morainic basin which was partially filled by sand or a sag in a till plain with a small amount of filling.

The shores of the lake are rather uniform, and, therefore, no great changes in outline have resulted from the adjustment of the shores. Yet interesting shore features are to be found and among them a series of bars and ramparts along the shore at Carp Lake Village. These bars are spaced on the gentle slope which extends from the lake shore back to a low cliff and mark former levels of the lake. Two well defined sand bars skirt this shore but in places as many as four rampart-bars were seen. Inasmuch as the writer could not determine the elevation of these bars in this work, the relation of the lake levels represented by them to Lake Algonquin cannot be given. However, the very strong bar of cobbles which cuts off the marsh along the northeast shore must be an Algonquin beach because currents of sufficient power to move rock fragments of cobble size do not develop on lakes of the dimensions of Carp Lake. Another Algonquin bar swings part way around the east end of the lake and is located about two hundred and fifty paces back from the shore. The action on the present shores is limited very largely to ice shove and the main interest in the study of the lake lies in its relation to Lake Algonquin, a more extended study than could be made for this work.

The north shore of the lake is well adapted to summer resort purposes and is very easily reached from the main highway. As a result several groups of cottages have been built and future development may be expected.

GRAND TRAVERSE LAKES

DUCK, GREEN, LONG AND SILVER

Another group consisting of more than a dozen lakes, large and small, is located a few miles southwest of Traverse City and of these lakes Long, Silver, Duck and Green were visited. These lakes all occupy pits in an outwash plain and those seen by the writer have a north-south trend. Some of the lakes show similarities in other respects, which are well brought out from a study of Green and Duck lakes.

GREEN AND DUCK LAKES

These two lakes, which are separated by a strip of outwash of hardly more than one-fourth mile in width, might well have been named Twin Lakes. In addition to a like orientation and origin, their area and form are very similar. Furthermore each has a projection on the east side, that on Duck being the more prominent. Also the adjustments of the shores are alike in character, in both cases being in a very early stage. In fact, very little adjustment has taken place, although the lakes are approximately three miles in length and one mile in width, and they are not especially interesting from this viewpoint. The most prominent features are the steep cliffs, but apparently little recession has taken place. Currents have accomplished almost nothing except to remove the material from the cliffs, and depositional forms are rare. At the end of the peninsula on Green Lake, for instance, one might expect a large deposit but finds instead a relatively small submerged bar. Likewise on Duck Lake but one or two bars were found and they crossed very minor indentations.

The problem in connection with the study of these lakes is to account for the lack of adjustment of the shores. We may immediately eliminate the size and time elements in this consideration, for nearby lakes which are smaller and have been existent for a similar length of time show a much greater development of the shores, but farther than that the problem is as yet unsolved.

Long stretches of the shores are suitable for resort purposes and the fishing is considered good, so that the lakes are popular. Green Lake, however, appears to be the choice for those who build summer cottages but for the itinerant recreationist with camping outfit the State Park between the two lakes furnishes an excellent location on either. This park of eighty acres is almost unique for it is one of the few remaining tracts of Michigan's once famous pine forests. A trip to this region is well worth while and is easily made from Interlocken, the junction point of the Manistee and Northeastern and Pere Marquette R. R.

LONG LAKE, GRAND TRAVERSE COUNTY

Long Lake which is located some six miles southwest of Traverse City is one of the most attractive lakes in the vicinity. It is more than four miles long and nearly two miles in greatest width but is so irregular that its size is not appreciated on first sight. The view is also obstructed by several islands which add to the picture. One must drive to the lake but will surely encounter difficulties with sand roads to the south if the attempt to circle the lake is made by motor. Such a trip, however, will emphasize the sandy character of the outwash in which this lake lies for the basin is a pit, but a most irregular one. This irregularity in addition to the islands, which interfere with the full development of waves, may give rise to expectations of poorly adjusted shores; however adjustments have taken place.

At the north end one is in doubt as to whether the swamp was cut off from the main lake or not, for the bar, if such it be, is faint, but evidence may be found of a former level of the lake about three feet above the present level, at which stage the swamp was surely connected. Also the off-shore terrace is well developed here, and in places the part exposed by the sinking of the water is still intact. To the southward the bars increase in development and completely close the narrow openings of the embayments. One of these closed embayments on the shore extends some distance inland and is occupied by Mickey Lake.

It is not our purpose to cite all of the individual examples of adjustments. As a working basis, however, it may be assumed that the smaller embayments are cut off. The larger bays are open to the lake as would be expected from the exceptionally tortuous shoreline along which continuous currents could not develop, even though no islands obstructed the reach of the waves. The headlands have furnished the material for the deposits and have retreated somewhat under the attack of the waves. But the progress of the adjustment of the shores was interrupted at an early stage by subsidence of the water and little has been done since that time.

As a summer resort Long Lake has lagged in comparison to many others that are less attractive. This is due in part to its location near the beautiful Grand Traverse Bay but also to some extent to its inaccessability. Roads are being improved and people are using lakes more and more for recreation, so that this lake will surely share in summer resort development.

SILVER LAKE, GRAND TRAVERSE COUNTY

Another lake of the group under consideration is Silver, located about two miles east of Long Lake. It also lies in a pit in the same outwash plain but very near the margin of the moraine, so near in fact that the narrow basin continues northward from the north end of the lake as a stream valley in the moraine. The lake averages less than one-half mile in width but is mores than five times this figure in length. It actually appears much narrower on account of the numerous islands which obstruct the view across the lake. Furthermore, the lake is very deep and the black water comes close to the shore. This makes the lake very dangerous and is detrimental to its development as a summer resort.

It is, however, most interesting as a physiographic study. It has no outlet and varies greatly in level over a period of years. At present it stands nearly five feet below the highest water mark which has determined the elevation of the features formed by the adjustment of the shores. This higher level may be reached during exceptionally wet periods, but the higher levels which are almost universally found on other lakes make it more probable that this is a permanently abandoned higher level.

It is difficult to select a starting point for the discussion of the numerous shore features of Silver Lake unless one describes them all in detail. Waves have been very active but there has been little cliff recession. Of the material derived from the cliffs some has undoubtedly been carried out by the undertow but it was not sufficient in quantity to build a wide off-shore terrace, which would require an excessive amount of material in this deep lake. The material which was worked along the shore by currents, however, although possibly not greater in amount, has produced more noticeable effects. All of the indentations except two are small and have been cut off by bars. And of the two larger embayments one only, the large bay on the southeast side, is open. The other is at the north end and is completely bridged by a strong bar which separates the small Mud Lake from the main basin. In this connection the islands are interesting. The original islands were nine in number most of which are distributed off the east shore opposite Silver Lake Resort, but this number is now reduced by at least three by the development of bars which either tied islands to each other or the mainland. The details of these bars were not worked out and should prove an interesting part of the study of the numerous physiographic features on the shore of Silver Lake which offers such a decided contrast to the nearby Duck and Green lakes.

BEAR LAKE

Bear Lake is located in northwestern Manistee County about midway between Manistee and Beulah, eighteen to twenty miles distant. Such distances seem rather long but the road in each case is the West Michigan Pike which was found to be in excellent condition. An automobile ride of this distance is preferable to the trip of seven miles from Norwalk which has a one-train-a-day service on the Manistee and Northeastern R. R.

The lake is an open expanse of water of very regular outline and has dimensions of two and one-fourth by one and one-fourth miles, the longer axis having an east-west direction. The western part of the basin hardly exceeds fifteen feet in depth but depths of fifty to sixty feet are reported for the eastern part. The glacial formations may be readily made out as one approaches the lake on the Pike from the south. At first the route is

through a rugged moraine from the crest of which a broad outwash plain may be seen below in the distance, extending northward to another moraine some six miles away. Beyond the crest the moraine slopes sharply to the north and the entire lake appears in view, extending from the foot of the slope onto the outwash. The basin is limited on the east side by upland but stretches eastward as a low, heavily-wooded swamp to Bear Creek, several miles away. Briefly stated the lake basin is part of a depression in the outwash at its junction with the moraine. This depression has some of the characteristics of a fosse but is in part a pit, as shown by the deep basin which forms the eastern part of the lake.

The shore features of Bear Lake are very simple because the shore conditions are singularly uniform. The shore is lined by wave-cut cliffs except at the east end. Where the depression continues eastward conditions were favorable for deposition by currents, and, in spite of the presence of a road around this shore, a well defined bar may be traced across the flat to the higher ground on the north side. Also a similar form developed eastward in front of the swamp at the northeastern part of the lake but was never completed. These forms stand well above the present level and mark a higher stage of the lake. At present the shore agents are rejuvenated and the recession of the cliffs is very evident. The reason for this revival of activity is high water but the cause of the high water is uncertain. The natural conditions of the outlet which flows from the east end have been altered by the building of a road, and, in particular, the position of the outlet has been shifted south of its normal position. This may account for the filling of the artificial outlet which functions only at high water and has no definite channel for some distance east of the bar.

The lake has not yet developed as a summer resort, although it is well suited for such use. This seems to be due to the fact that it was formerly isolated, for, since the construction of the West Michigan Pike and the thereby more convenient access to the lake, it is becoming popular.